Towards Digital Quality Infrastructure Workshop
Model-driven measurement information infrastructure

6 March 2024, 15:00 – 15:30 (CET)

NCSL International Committee Week

NCSL INTERNATIONAL
Serving the World of Measurement

Model-driven measurement information infrastructure

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NCSL International 141 MII and Automation Committee

The CIPM *Towards Digital Quality Infrastructure Workshop*

Section 1

Introduction

Overview

Suggestion

As our various organizations embark on DX initiatives, ...
keep conceptualization and modeling at the forefront.

- Lessons from an eleven-year public journey
- March 22, 2013 recommendation: "Standardize and automate!"
- March 6, 2024: Conceptualize, model and implement!

Today's Topics

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1. Introduction
2. Principles for DX initiatives

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4. NCSLI MII—a journey from elementary models to ...

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4. NCSLI MII—a journey from elementary models to ...
5. Conclusion

Section 2

Principles for DX initiatives

Principles

- FAIR use: (not expounded on herein)
- Customer use cases
  - What problems do we solve?
  - What value do we add?
- Conceptualization
  - Step back from current practice.
  - Return to concepts and rethink implementation.
  - Ask why, why, why; don't emulate.
- Models
  - Focus on abstractions (integrated essentials)
  - that unite concrete differences (pressure as against voltage).

Rethinking processes

- Expose pragmatic assumptions underlying manual practices.
- Look for shortcuts, avoided work, sub optimum quality.
- Examples: Why
  - buy from familiar equipment and service vendors?
  - round off measurement results and uncertainties?
  - choose simple uncertainty distributions (rectangular)?
  - interpret specs simply (all 95 % confidence)?
  - ignore correlation and degrees of freedom?
  - generate "conservative" uncertainties?
  - test and report only at minimal points?
  - curtail information on calibration certificates?
  - apply tolerances (MPEs) and decision risk?

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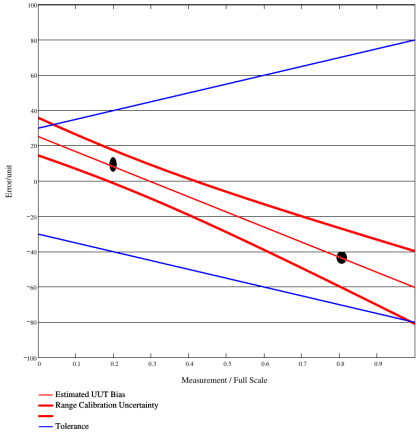
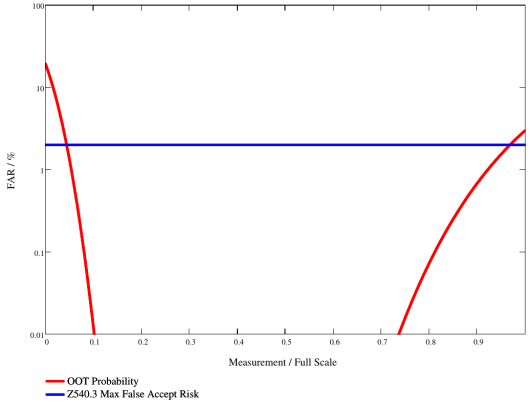
to save resources: time, manual labor, brain cells, ...

Range Calibration Example

Rethink: Calibration points only sample the instrument state—a shortcut. Use a model!





Section 3

Conceptual modeling

Modeling concretes

- Rutherford: "Science is either Physics or stamp collecting."
  - Science (ideally) reconciles theoretical modeling and empirical data.
  - Principles and abstract concept hierarchies to encompass the concretes
  - Models to back up the stamps (tags, taxons, endorsements)
- Models: structured frameworks for expressing and understanding DX requirements
  - shared requirements language
  - accurate process and information description
  - explicit concepts that go beyond labels and tags
- Realizations
  - Mathematical models: equations for clarity, language independence
  - Data models: UML, Structured Analysis (entity-relationship diagrams et al.), IDEF
  - A modular approach helps prevent scope bloat. Start small.

Model examples

- Mathematical models
  - The GUM offers an uncertainty-propagation (traceability) model.
    - GUM advice: Err on the side of providing too much rather than too little information.
    - Digitalize the model rather than current shortcuts.
  - Math expressions would robustly generalize and optimize MPEs, measurement functions, bias corrections, instrument behavior models, CMC uncertainties, et al.
- Data models
  - We might model an instrument as [manufacturer, model number, serial number, . . .] with each data element appropriately related to other models.
  - The VIM offers a nice (implicit) metrology model, even diagrams (VIM3).

Requirements Engineering

Synergy, best practices: engage professionals to work with metrology SMEs.

Requirements analysis (iterative):

Assess:	business objectives, boundaries, stakeholders, decision makers
Elicit:	use cases, events & responses, data concepts & relationships, quality attributes
Analyze:	origin and rationale, inconsistencies, models, prototypes, priorities
Specify:	consistent structured requirements, business rules, terminology
Validate:	independent reviews, tests against models, verifications
Manage:	baseline & as-built requirements, change control

A long-standing mature field with much valuable experience.

IQI modeling scope

The range of JSI Signatories exemplifies the breadth of modeling required.
The depth of modeling extends from high-level processes & data to low-level fundamentals.

Processes

- mutual recognition
- assessment and accreditation
- conformance acceptance

Quality documents

- certificates
- accreditation scopes
- instrument specifications

Information

- traceability & uncertainty
- CMCs
- measurement functions
- measurement results
- requirements (e.g., MPEs)
- quantities & properties
- units & scales

Section 4

NCSLI MII—a journey from elementary models to . . .

A problem to solve

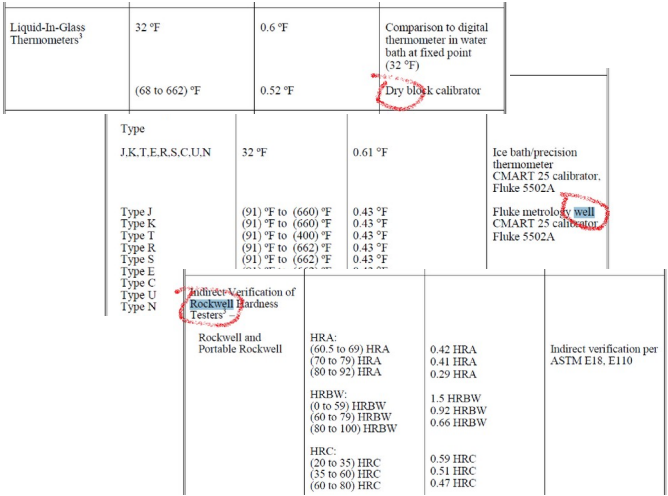
Key word “dry well” CMC search

No model

No metadata

No taxonomy

Who might calibrate my dry-well temperature bath? No clue



Liquid-In-Glass Thermometers[3]	32 °F (68 to 662) °F	0.6 °F 0.52 °F	Comparison to digital thermometer in water bath at fixed point (32 °F) Dry block calibrator

Type			
J,K,T,E,R,S,C,U,N	32 °F	0.61 °F	Ice bath/precision thermometer CMART 25 calibrator, Fluke 5502A
Type J	(91) °F to (660) °F	0.43 °F	Fluke metrology well CMART 25 calibrator Fluke 5502A
Type K	(91) °F to (660) °F	0.43 °F	
Type T	(91) °F to (400) °F	0.43 °F	
Type R	(91) °F to (662) °F	0.43 °F	
Type S	(91) °F to (662) °F	0.43 °F	
Type E			
Type C			
Type U			
Type N			

Indirect Verification of Rockwell Hardness Testers[3]			
Rockwell and Portable Rockwell	HRA: (60.5 to 69) HRA (70 to 79) HRA (80 to 92) HRA	0.42 HRA 0.41 HRA 0.29 HRA	Indirect verification per ASTM E18, E110
	HRBW: (0 to 59) HRBW (60 to 79) HRBW (80 to 100) HRBW	1.5 HRBW 0.92 HRBW 0.66 HRBW	
	HRC: (20 to 35) HRC (35 to 60) HRC (60 to 80) HRC	0.59 HRC 0.51 HRC 0.47 HRC	

A model solution, added value

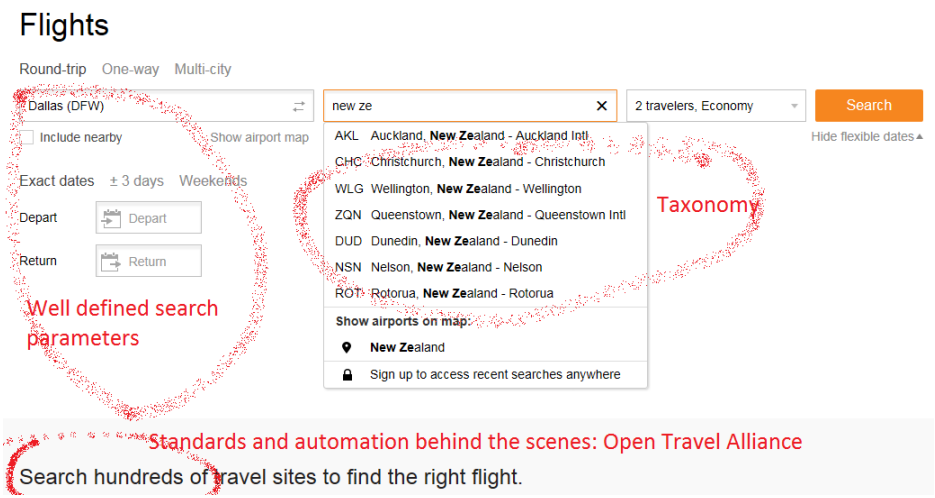
Smart search

Models

Metadata

Taxonomies

Standardization



Solution process

1. Elementary document models
   - Format agnostic
   - Common modular measurand conception
2. CMC model, accreditation-scope schema
3. Software for scope creation
4. Taxonomy of metadata
5. Software for taxon creation
6. Soon. . . GitHub for collaboration and FAIR use
7. Less soon: KCDB coverage

Taxon hierarchy

From chaos. . .

"Mass Flow", "Liquid Flow", "Gas Flow", "Flow - Air", "Flow - Gas", "Flow - Liquid", "Flow - Gas (Air)", "Air/Nitrogen Flow", "Flow Rate by Volume", "Air Volume Flow", "Flow Hydraulic", "Fuel Flow", "Flow Rate by Volume for Compressible Gas", "Volumetric Flow Rate (Water)", "Liquid Flow Rate Inline", "Liquid Flow Rate Non-Intrusive", "Gas Flow - Leak", "Gas Leak", "Gas Flow Rate Into Vacuum", "mole-flow-rate", . . .

. . . to standardization for machines.

- `Source.MassFlowRate.Gas`
- `Measure.MassFlowRate.Gas.Inline`
- `Measure.MassFlowRate.Gas.NonIntrusive`
- `...MassFlowRate.Liquid...`
- `Source.VolumeFlowRate.Gas`
- `Measure.VolumeFlowRate.Gas.Inline`
- `Measure.VolumeFlowRate.Gas.NonIntrusive`
- `...VolumeFlowRate.Liquid...`
- `Source.Ratio.MassFlowRate.Gas.MeterFactor`
- `Source.Coefficient.Voltage.MassFlowRate.DC.Gas`

Solution: abstract model to instantiate a CMC for any context

Source.Coefficient.Voltage.Luminance

Definition: `https://cie.co.at/eilvterm/17-25-061`, `https://cie.co.at/eilvterm/17-21-050`

- **Required Parameters (instantiated with ranges)**
  - Luminance
  - SourceType {CIEA, CIED65, ..., Tungsten, TungstenDiffuser, Halogen, ...}
    - Alternatively perhaps: Temperature.Color.Correlated, e.g. CCT = 2856 K for Tungsten
  - Angle.Solid
- **Optional Parameters (instantiated with ranges)**
  - LuminanceResponsivity
  - Voltage[.Output]

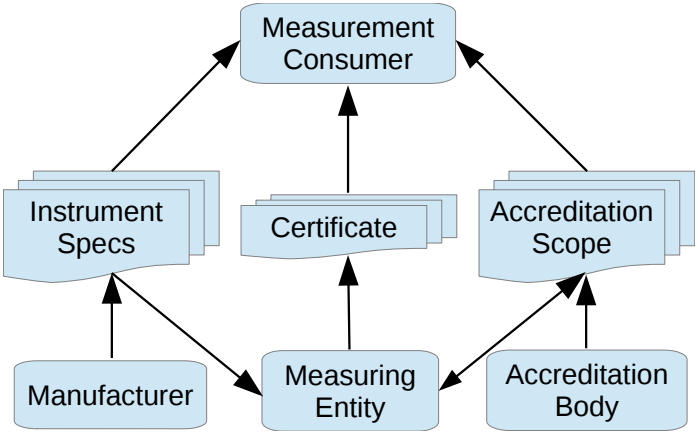
MII metadata for measurands

1. Data modeling principles
2. Standardized metrology metadata
3. Digital measurement data and services offerings identified.

Spec: `Source.Voltage.DC`

SoA: `Measure.Voltage.DC`

Cert: `Source.Voltage.DC`



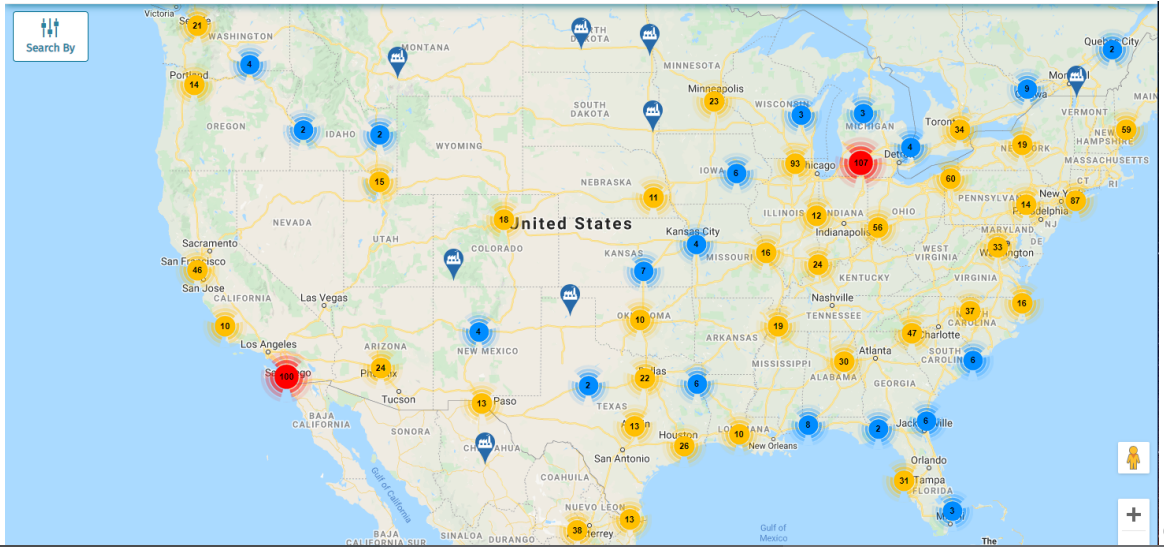
KCDB CMC links

Taxon	**kcdbCode**
. . .	. . .
Measure.Coefficient.Voltage.Illuminance Measure.Coefficient.Current.Illuminance	EURAMET-PR-TR-000006KM-2
Measure.Coefficient.Voltage.Luminance Measure.Coefficient.Current.Luminance	SIM-PR-MX-00000GER-1
Measure.LuminousExposure	APMP-PR-CN-00000K9V-1
Measure.LuminousIntensity	AFRIMETS-PR-ZA-000006FO-1
Measure.LuminousFlux	SIM-PR-BR-0000053M-2
Measure.Illuminance	COOMET-PR-RU-00000DMG-1
. . .	. . .

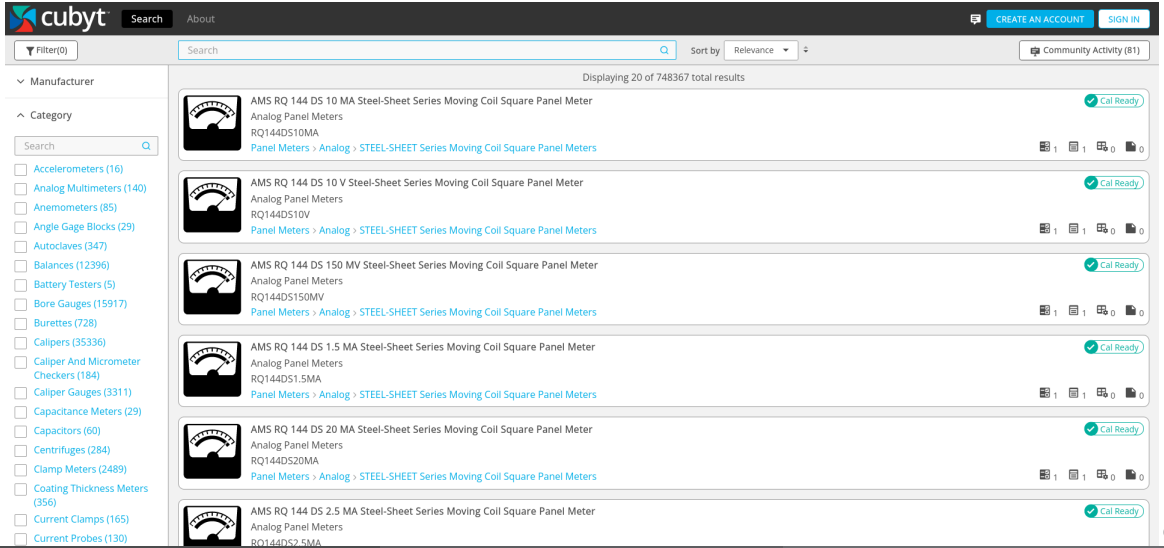
Currently covered: 351 of 25868 KCDB CMCs, $\approx$ 1.4 %

Next: EM measurement area (4609 CMCs), reporting results at the NCSLI 2024 Conference

Demonstrated value



A universal measurement model easing implementation.



More intentional modeling: M-Layer development

- Facilitates quantities and units handling in digital systems
- Aspects and scales reconceptualize quantity kinds and units.
- Generalizes and extends to all unit systems, scales, quantities
- PIDs, conversions as expressions ($\pi/180$)
- Allows consistent transformations and alternate expressions

Quantity Kind(s)	Aspect(s)
one temperature	multiple (thermodynamic temperature, Δ temperature)
one dimensionless quantity	multiple (voltage gain, reflectance, . . .)
multiple log-level quantities	one aspect (e.g., log voltage gain)

Separate but integrated: the MII taxonomy and the M-Layer

Taxons link to the aspect ID that governs the quantity values.

Quantity Value	Aspect ID	Taxon (`Measure...` or `Source...`)
		`Length.Circumference`
		`Length.Diameter`
		`Length.Form.Flatness`
1 ft		`Length.Form.Parallelism`
12 in		`Length.Form.Perpendicularity`
0.3048 m	$\Leftrightarrow \langle \text{length} \rangle \Leftrightarrow$	`Length.Form.Roughness`
30.48 cm		`Length.Form.Roundness`
304.8 mm		`Length.Form.Sphericity`
		`Length.Form.Straightness.Axis`
		`Length.Form.Straightness.Surface`
		`Length.Radius`

Section 5

Conclusion

Critical success factors

True fit-for-purpose DX requires rethinking our processes to leverage digital technology.

For true DX we should:

- Rethink our processes from the ground up.
- Discard pragmatic shortcuts for extensible replacements.
- Champion adoption within top-level authorities—the JSIS spirit.
  - Leaders provide top-level support,
  - understand the big picture,
  - direct digitization from a scientific viewpoint,
  - delegate expert metrologists to liaison with other groups.

Solutions

Joint efforts between

- Leadership and expertise
- Modelers and metrologists (domain experts) together

Appropriate strategies

- Data models and mathematical models
- Semantics and standardized resources
- Metadata and PIDs

Activity Proposal

1. Model processes and the associated informational components across the IQI, from the lowest to the highest abstraction level.
2. Document technologically agnostic models to facilitate different implementations and information exchange independent of data formats.
3. Encourage Forum-MD members to develop, support, and implement digital processes and data derived from standardized models.
4. Create and populate FAIR reference-data systems with the metadata, taxonomies, and entities required to support IQI processes.

Acknowledgments

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- Presentation contributions by Mike Schwartz, Blair Hall, Ryan White
- Cherine-Marie Kuster

And Thank You for your time!

Collaboration opportunities? Please bring your expertise!

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Upcoming Events

SAVE THE DATE!

JULY 6–10 2024

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Proposed for Thursday, July 11, 2024