A Measurement Information Infrastructure (MII)

Inception, Vision and Progress

Abstract

Imagine a set of normative standards that define data structures, taxonomies, service protocols and security for locating, communicating and sharing measurement information. Those standards comprise what we call a measurement information infrastructure, or MII. What if your organization's measurement, analysis and management computing systems spoke this MII language with other world-wide measurement-related systems? How would that affect your business? This session discusses the real-world benefits such an MII will create, the efforts underway to realize them, and how you may participate.

Topics

Inception and Motivation

World-wide, people have created many puzzle pieces for decades.
A hundred scattered conversations began to coalesce ca. 2011-12.
Enter Linda Stone, NCSLI Media Coordinator

NCSLI *Metrologist* started a conversation in 2013:

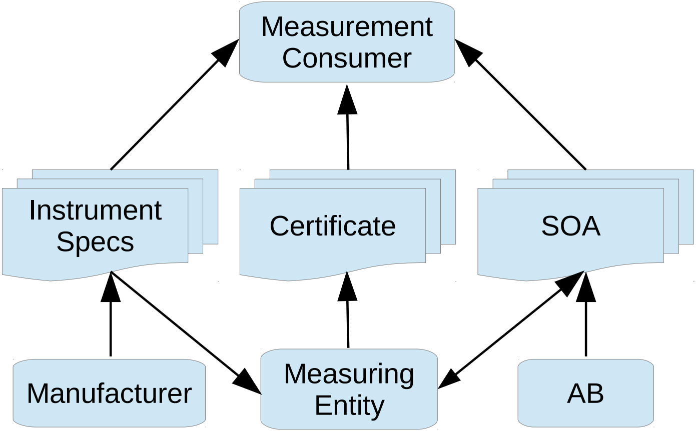
- The measurement world automates test & calibration.
- Much other metrology software exists
  - Lab management systems
  - Enterprise management sytems
  - Analytical software for uncertainty, etc.
- Many local benefits
- . . . but the systems by and large do not communicate.

Why haven't we automated the bigger picture?

Measurement Information Vehicles

- Instrument data sheets (specifications)
  - Designed and warranted performance
  - Manufacturers → potential customers & instrument users
  - Manufacturers, re-specifiers, vendors, specifiers, users
- Statements of accreditation (SOAs)
  - A measuring entity's (ME) accredited services
  - CIPM MRA, unaccredited "scopes of capability"
  - MEs → accreditation body (AB) → MEs, instrument users
- Certificates (test, calibration, etc.)
  - Measured performance
  - MEs → instrument users
- Measurement information circulates through these documents.

Measurement Information Flow



Small excerpt from a vast network

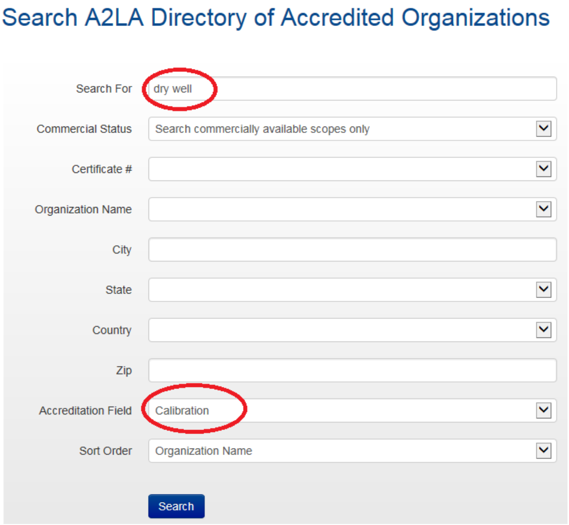
Typical Manual Information Processing Tasks

- Search for information
  - Acquire candidate spec sheets from vendors
  - Analyze specifications to select instruments
  - Search AB web sites to obtain SOAs
  - Examine CMCs to find suitable MEs
- Validate information
  - Validate certificates against SOAs
  - Reconcile certificate content against requisitions
  - Verify measurement results vs. specifications
  - Initiate non-conformance notices

Typical Manual Information Processing Tasks

- Maintain information
  - Augment SOAs as they expire
  - Copy calibration results to measurement software
  - Update data files and uncertainty budgets
  - Summarize measurement results on certificates
  - Send certificates to customers
  - Transfer test results to software systems
  - Archive and retrieve documents
- Analyze information
  - Determine calibration or verification points
  - Transform uncertainty analyses into SOA CMCs
  - Apply measurement quality metrics to results

Accredited Lab Search Example



Accredited Lab Search Example

Your query returned 24 records

Certificate#	Organization	Contact	City, State	Country	Phone	Comm Code	Field	Standard	Expiration
1009.01	Accu-Check Instrument Service, Inc.	Robert Vaughan	Lancaster, OH	United States	740 654 0500	C1	Calibration	ISO/IEC 17025:2005	07/31/2016
2171.01	ACR Technical Services, Inc.	Richard Hogan	Newport News, VA	United States	757 890 0460	C1	Calibration	ISO/IEC 17025:2005	10/31/2016
3467.01	Al Hoty Calibration Services - A Branch of Al Hoty Co. Ltd.	Wendell Arevalo	Al Khobar 31952,	Saudi Arabia	00966 3 864 4150	C1	Calibration	ISO/IEC 17025:2005	08/31/2017
2260.01	Alpha Controls & Instrumentation Inc.	Slava Peciurov	Markham, Ontario L3R 3V8,	Canada	905 477 2133 x228	C1	Calibration	ISO/IEC 17025:2005	01/31/2017
71.05	Bowser-Morner, Inc.	Robin Wolfe	Dayton, OH	United States	937 236 8805 x 226	C1	Calibration	ISO/IEC 17025:2005	01/31/2016
3781.01	Cal-Tec, Inc.	Chris Grevemberg	Broussard, LA	United States	337 839 0450	C1	Calibration	ISO/IEC 17025:2005	05/31/2017
2147.01	ENI Labs	Andrew Burd	Fort Wayne, IN	United States	260 471 6775	C1	Calibration	ISO/IEC 17025:2005	03/31/2016
2496.01	Eustis Co., Inc./Pyrocom Calibration Lab	Bill LeMesurier	Lynnwood, WA	United States	425 423 9996	C1	Calibration	ISO/IEC 17025:2005	10/31/2016

Accredited Lab Search Example

Searching for "Dry well"

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

Accredited Lab Search Example

Searching for “Dry well”

Calibration of Thermocouple Wires[3] –			
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
Type K	(91) °F to (660) °F	0.43 °F	CMART 25 calibrator
Type T	(91) °F to (400) °F	0.43 °F	Fluke 5502A
Type R	(91) °F to (662) °F	0.43 °F	
Type S	(91) °F to (662) °F	0.43 °F	
Type E	(91) °F to (662) °F	0.43 °F	
Type C	(91) °F to (662) °F	0.43 °F	
Type U	(91) °F to (662) °F	0.43 °F	
Type N	(91) °F to (662) °F	0.43 °F	

Accredited Lab Search Example

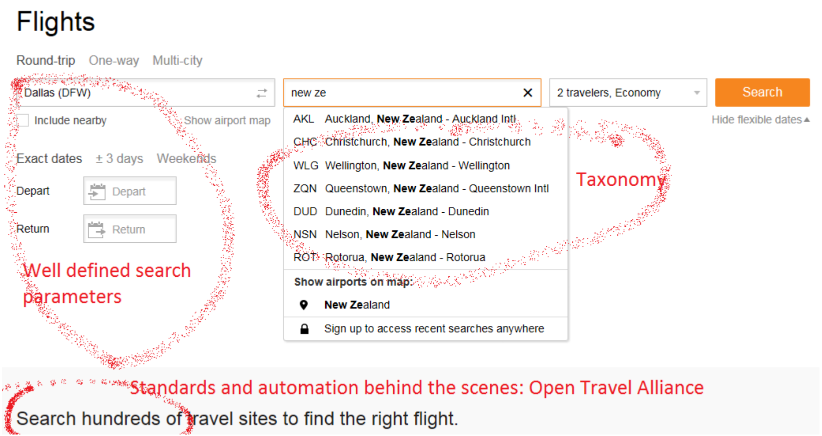
Searching for "Dry well"

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	

Accredited Lab Search Example

- 24 scopes to search
- Too often fruitless
- Many other possible search terms
- With several ABs, the USA multiplies the difficulty.
- International operations also use multiple ABs.
- Makes your lab a needle in the haystack
- Similar problem for instrument searches
- No fun!

An Easier Way



MII

Why not apply similar technology to accredited lab searches? What about instrument specs? Certificates with embedded traceability, uncertainty, error corrections, . . . ?

Definition

Measurement Information Infrastructure–a set of normative standards that define data structures, taxonomies, service protocols and security for locating, communicating and sharing measurement information

Motivation

An MII realization would empower developers to incorporate MII features into measurement-related software, streamlining many tedious and error-prone tasks, improving traceability, engendering new service opportunities, and generally increasing the value and quality of testing, calibration and measurement.

Automated Possibilities

- Publish machine-readable information
  - OEM software creates spec sheets for vendors to post.
  - Lab software writes and posts CMCs
  - AB software generates and posts SOAs.
- Find information
  - A user enters measurement requirements into MII SW.
  - User software locates suitable instruments and labs.
  - The user selects the instrument and lab.
  - Software writes purchase orders and transmits requirements.

Automated Possibilities

- Validate and use information
  - Lab software creates test points from the requirements and MII certs for its equipment.
  - Lab software generates an automated measurement procedure.
  - Lab software tests the instrument and issues a calibration cert.
  - User software validates the certificate.
  - User software initiates any non-conformance actions.
  - User software updates systems with corrections & uncertainty.
  - Software validates data at every step.

Measurement Information Vehicles

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Centered on Measurement Data

Absolute Uncertainty Specifications

± 5 °C of Calibration Temperature

Voltage Range	Frequency Range	Absolute Uncertainty			
		AC/DC Transfer Mode ± ppm 2 Years	Measurement Mode ± (ppm of Reading + µV)		
			90 Days	1 Year	2 Years
2.2 mV	10 Hz - 20 Hz		1700 + 1.3	1700 + 1.3	1700 + 1.3
	20 Hz- 40 Hz		740 + 1.3	740 + 1.3	740 + 1.3
	40 Hz - 20 kHz		420 + 1.3	420 + 1.3	420 + 1.3
	20 kHz - 50 kHz		810 + 2.0	810 + 2.0	820 + 2.0
	50 kHz - 100 kHz		1200 + 2.5	1200 + 2.5	1200 + 2.5
	100 kHz - 300 kHz		2300 + 4.0	2300 + 4.0	2300 + 4.0
	300 kHz - 500 kHz		2400 + 6.0	2400 + 8.0	2600 + 8.0
	500 kHz - 1 MHz		3200 + 6.0	3500 + 8.0	5000 + 8.0

Similar information

- Measured quantity (electric potential difference)
- Influence quantities (frequency)
- Quantity values (ranges, MPE, results, uncertainty)

Centered on Measurement Data

Parameter/Range	Frequency	CMC[2, 4, 5, 6, 7] (±)	Comments
AC Voltage – Generate, Fixed Points			
2 mV	10 Hz, 20 Hz, 100 Hz, 1 kHz, 10 kHz, 20 kHz, 50 kHz	0.02 %	Fluke 792 AC/DC Transfer Standard with AC Divider
	100 kHz	0.022 %	

Similar information

- Measured quantity (electric potential difference)
- Influence quantities (frequency)
- Quantity values (ranges, MPE, results, uncertainty)

Centered on Measurement Data

Calibration Data					
			Limits of Error		
Parameter	Nominal Value	Measurement Result	Lower Limit	Upper Limit	Expanded Uncertainty
INPUT 1 ABSOLUTE AC ERROR					
2.2mV Range, 2mV Applied					
1 Year Specification Limits shown					
0.0 µV/V @ 10 Hz	0.00	XXX.X	-2350.0	2350.0	200 µV/V
0.0 µV/V @ 20 Hz	0.00	XXX.X	-1390.0	1390.0	200 µV/V
0.0 µV/V @ 100 Hz	0.00	XXX.X	-1070.0	1070.0	200 µV/V

Similar information

- Measured quantity (electric potential difference)
- Influence quantities (frequency)
- Quantity values (ranges, MPE, results, uncertainty)

Human- vs. Machine-Readable

Human-Readable

Mterogoly rqures accrcy, presishn and stndrdztn.

Machine-Readable

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Metrology requires accuracy, precision and standardization.

Human- vs. Machine-Readable

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ZER0S D0N'T EQUAL Os.

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Human- vs. Machine-Readable

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ZER0S D0N'T EQUAL Os.

voltage, electric potential, electric tension, emf?

Machine-Readable

Metrology requires accuracy, precision and standardization.

ZEROS DON'T EQUAL Os.

Use only one in data! Allow aliases for humans.

Human- vs. Machine-Readable

Human-Readable	Machine-Readable
Mterogoly rqures accrcy, presishn and stndrdztn.	Metrology requires accuracy, precision and standardization.
ZER0S D0N'T EQUAL Os.	ZEROS DON'T EQUAL Os.
voltage, electric potential, electric tension, emf?	Use only one in data! Allow aliases for humans.
$\pm(0.01\,\% + 2\,\mu\text{V})$ Percent of what?	$\pm(0.01\,\% \cdot Q + 2\,\mu\text{V})$ $Q = FS = 100\,\text{mV}$

Human- vs. Machine-Readable

Human-Readable

Mterogoly rqures accrcy, presishn and stndrdztn.

ZER0S D0N'T EQUAL Os.

voltage, electric potential, electric tension, emf?

$\pm(0.01\,\% + 2\,\mu V)$
Percent of what?

$\pm(0.01\,\%$ of value $+ 2\,\mu V)$
setting, output, nominal, stimulus, indication?

Machine-Readable

Metrology requires accuracy, precision and standardization.

ZEROS DON'T EQUAL Os.

Use only one in data! Allow aliases for humans.

$\pm(0.01\,\% \cdot Q + 2\,\mu V)$
$Q = FS = 100\,mV$

$\pm(0.01\,\% \cdot Q + 2\,\mu V)$
parameter Q [reference value]

Semantic Data Structure–Old Hat

- *VIM*, *ISO 80000-x*: ontological foundation & taxonomies
- *IEEE 1671.x*: automatic test markup language (ATML)
- SysML: systems modeling language–*ISO 80000-1* quantity kinds, measurement units
- NASA: automatic ATML generation from LabVIEW code and SysML equipment descriptions
- NI: Translator from ATML test descriptions to executable code
- MIMOSA: infrastructure for process industries to exchange operations and maintenance data

Other MII Elements

- File formats
  - XML (eXtensible Markup Language) for one for one
  - Many others: JSON, YAML, etc.
- Communications Protocols
  - SOAP (Simple Object Access Protocol)
  - REST (Representational State Transfer)
- Security
  - Public certificates to verify signatures & logos
  - Encryption for confidentiality if required
  - Blockchain (BitCoin)
- Norms (Standards)
  - Metrology & commerce revolve around them.
  - Up front consensus or defacto development

Research & Development

- MII-aware software
  - Create, manipulate and process MII documents
  - Standard calculation libraries for interfacing any software
  - Automation changes the economics, creates opportunities
  - Makes manually impractical refinements practical
- Metrology itself
  - Extended traceabililty schemes
  - Instrument modeling
  - Libraries of measurement models

MII Forward Action

Plenty of MII work proper . . .

- Identify and involve stakeholders
- Identify useful ISO, IEEE, etc. standards
- Research metrology taxonomies
- Refine and implement MII document models
  - Instrument specifications
  - Accreditation scopes
  - Test and calibration certificates
  - Available on the MII Community page at ncsli.org
- Research web services options
- Design web service protocols for MII documents
- Draft MII-specific standards, recommended practices

MII Support Work

. . . and plenty of enabling development work.

- Software development
  - Demo MII document editors
  - Demo MII-aware applications
  - Demo MII web site(s)
  - Standard APIs for interfacing any software to the MII
- Metrology enhancements–more accurate data to practitioners
  - Automation changes the economics, creates opportunities
  - Makes manually impractical refinements practical
  - METAS: traceability structure with upstream correlations
  - GTC: GUM Tree Calculator–propagates *uncertain numbers* via scripting
  - METBENCH: arbitrary equations for instrument specs, parameters bound to measurement quantities at cal time
  - Instrument modeling, measurement model libraries

Conclusion

The requisite systems and technology already exist.
We only lack applying them within a consensus framework.

Motivation

An MII definition would empower developers to incorporate MII data processing features into future versions of already ubiquitous measurement-related software, which in turn would raise opportunities to simplify and streamline many tedious and error-prone tasks, improve traceability and generally increase the value and quality of testing, calibration and measurement.

Questions

<u>Volunteers? Contact us!</u>

MII community page at ncsli.org
Colin Walker, colin@qualer.com
Mike Schwartz, mschwartz@callabsolutions.com
Mark Kuster, mjk@ieee.org

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Thank You for your time!

Demos

Project Demonstration