Toward a Measurement Information Infrastructure

Mark Kuster, Pantex Metrology

Motivation

- The measurement world automates test & calibration . . .
- and other metrology software exists
  - Lab management systems
  - 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?

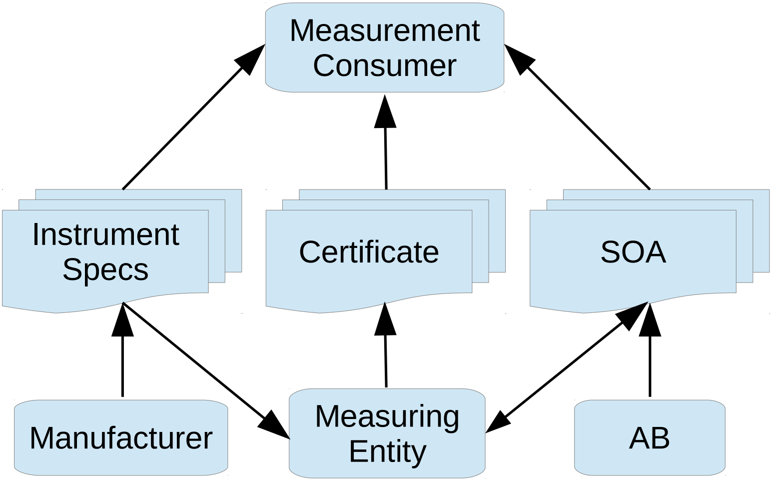
NCSLI *Metrologist* started a conversation.

Metrologist MII Column

Measurement Information Vehicles

- Instrument data sheets (specifications)
  - Designed and warranted performance
  - Manufacturers $\rightarrow$ 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 $\rightarrow$ accreditation body (AB) $\rightarrow$ MEs, instrument users
- Certificates (test, calibration, etc.)
  - Measured performance
  - MEs $\rightarrow$ instrument users
- Measurement information circulates through these documents.

Measurement Information Flow



Small excerpt from a vast network

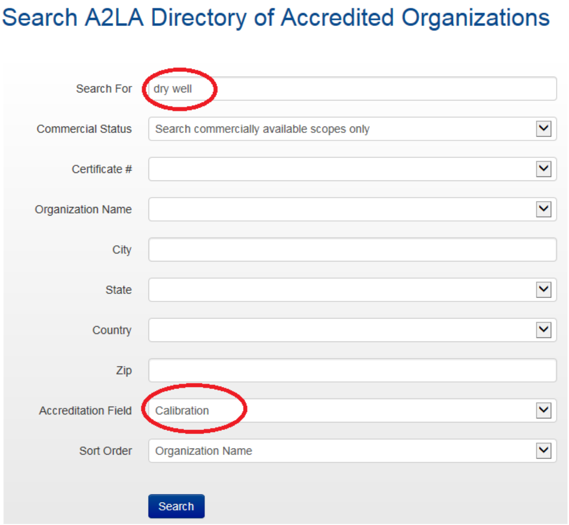
Typical Manual Information Processing Tasks

- 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

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 °F	0.6 °F	Comparison to digital thermometer in water bath at fixed point (32 °F)
	(68 to 662) °F	0.52 °F	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

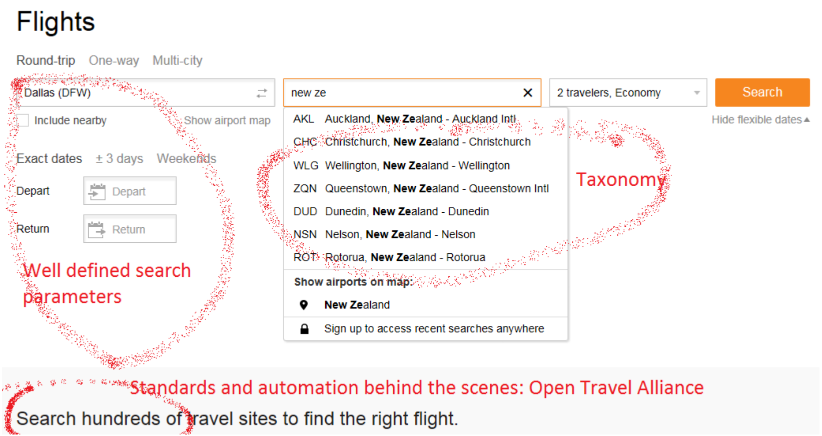
Searching for "Dry well"

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
- International Accreditation New Zealand (IANZ)
- 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

What if we applied similar technology to instrument and accredited lab searches?

What about 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

Automated Possibilities

- Publish information
  - OEM software creates spec sheets for vendors to post.
  - Lab software writes and posts CMCs
  - AB SW generates and posts SOAs.
- Find information
  - A user enters measurement requirements into MII SW.
  - User SW 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.

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 100 kHz	0.02 % 0.022 %	Fluke 792 AC/DC Transfer Standard with AC Divider

Similar information

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

Centered on Measurement Data

Parameter	Nominal Value	Measurement Result	Limits of Error Lower Limit	Limits of Error Upper Limit	Expanded Uncertainty
Calibration Data					
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)

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
- METBENCH: arbitrary equations for instrument specs, parameters bound to measurement quantities at cal time
- METAS: traceability structure with upstream correlations
- GTC: GUM Tree Calculator–*uncertain numbers* to propagate uncertainty via scripting

Other MII Elements

- File formats
  - XML (eXtensible Markup Language) for one, many others
- Communications Protocols
  - SOAP (Simple Object Access Protocol)
  - REST (Representational State Transfer)
- Security
  - Public certificates to verify signatures & logos
  - Encryption for confidentiality if required
- Norms (Standards)
  - Metrology & commerce revolve around them.

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

Current Status–Fragmented

- Conceptual MII document models
  - Instrument specifications
  - Accreditation scopes
  - Test and calibration certificates
  - Availabe on the MII Community page at ncsli.org
- Some exploratory software development
- Independent efforts on many puzzle pieces

MII Forward Action

Plenty of MII work proper . . .

- Identify and involve stakeholders
- Identify useful ISO, IEEE, etc. standards
- Research data formats for MII documents
- Research metrology taxonomies
- Refine and implement data models
- 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.

- Involve existing developers
- Develop software
  - Demo document editors
  - Demo applications
  - Demo web site(s)
  - Software libraries, APIs for developers
- Metrology research–more accurate data in practitioners' hands

Conclusion

- The requisite systems and technology already exist.
- We lack a consensus

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

Acknowledgments

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Volunteers? Contact us at ncsli.org, mjk@ieee.org.

Thank You for your time! Questions?