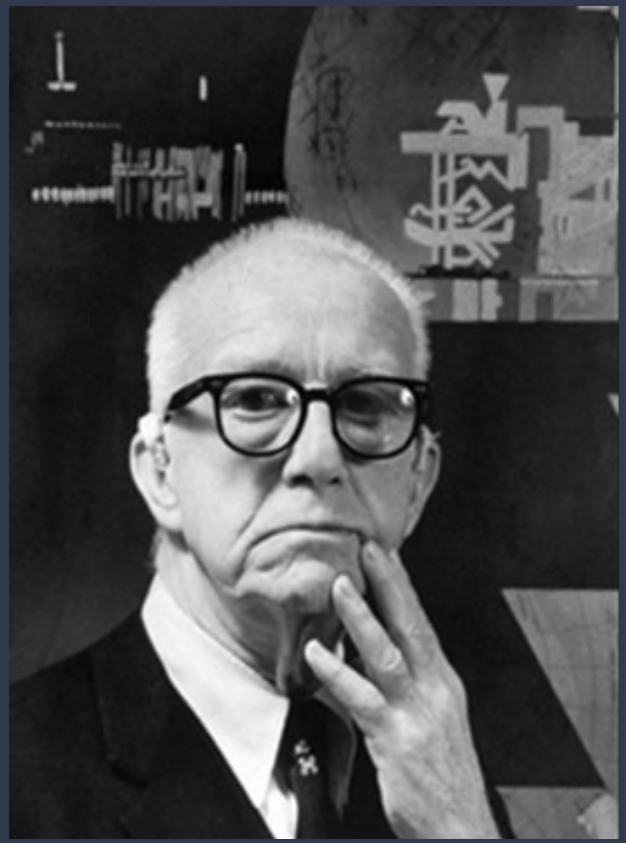
Metrology.NET

Metrology Driven Software Engineering

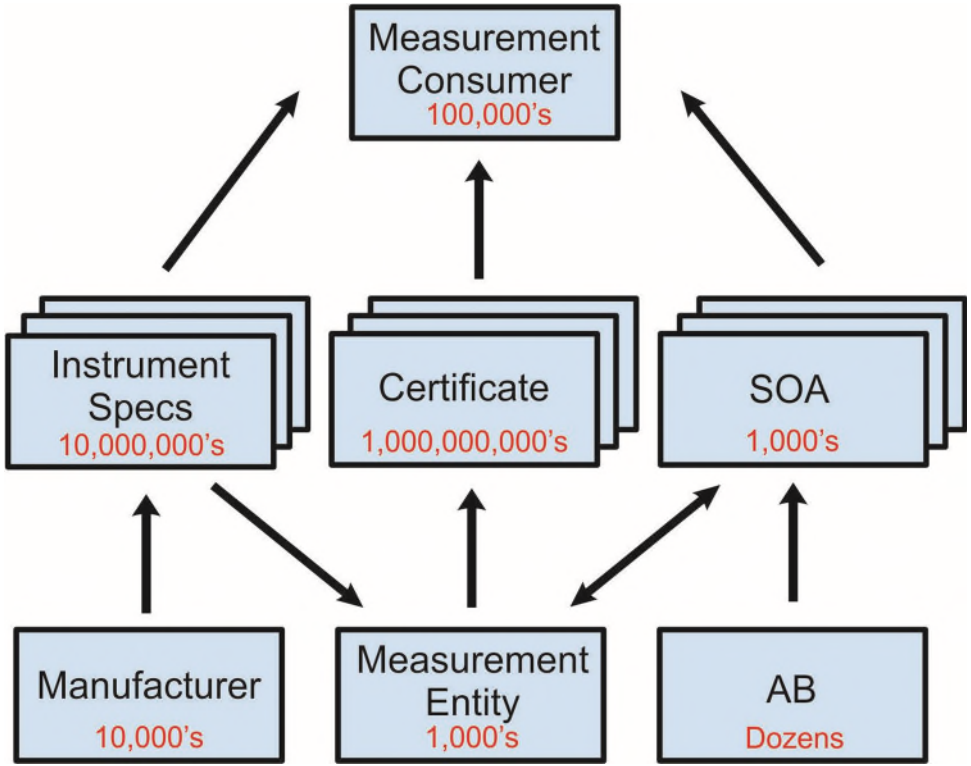
Michael L Schwartz - Cal Lab Solutions



You never change things by fighting the existing reality. To change something, build a new model that makes the **existing model obsolete**.

R. BUCKMINSTER FULLER

Metrology Information Infrastructure (MII)
NCSI 141 Committee

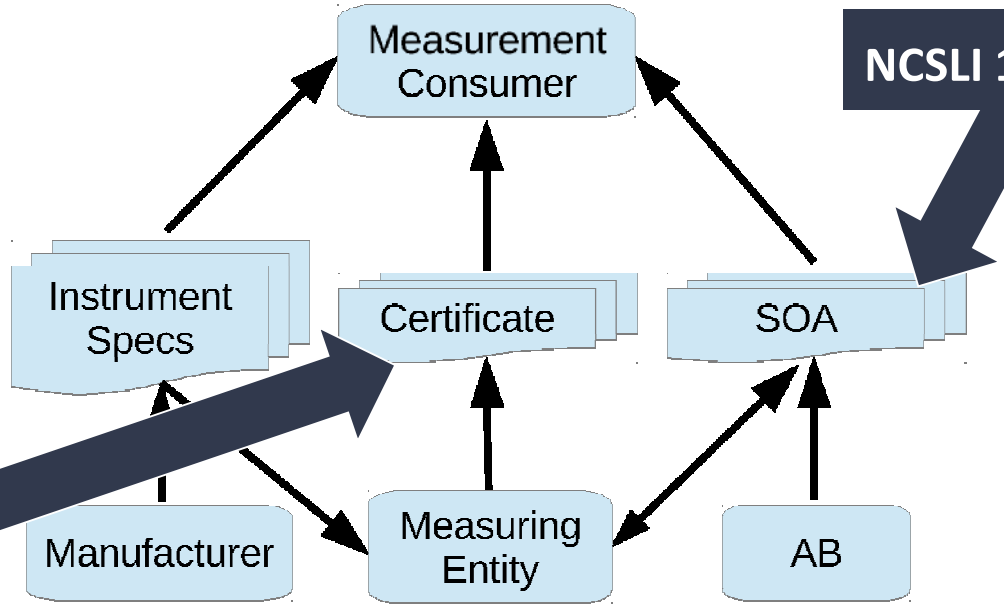


Standardized Certificates of Calibration
- Measurement Entities
  - Create Calibration Certificates for Measurement Customers

Equipment Specifications
- Manufacturers
  - Create Instrument Specs that Measurement Customers buy

Accredited Calibrations
- Accreditation Bodies
  - Create Scopes of Accreditation that Measurement Customers view

Metrology Information Infrastructure (MII)



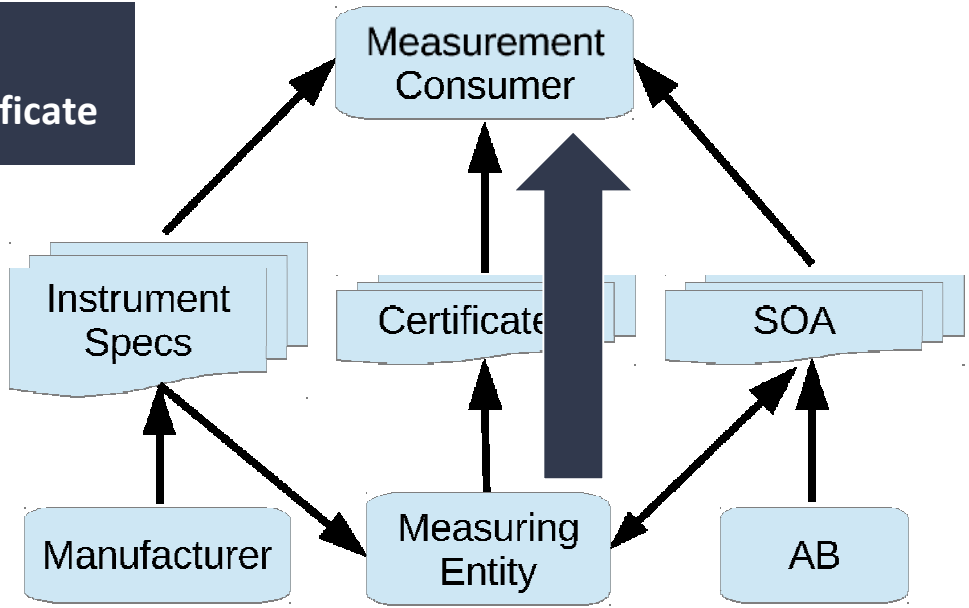
NCSLI 141 - MII

- **EMPIR SmartCom D-SI and DCC**
- **Digital Certificates (DOE PSL, PTB, NPL, Fluke, others)**

- **BIPM's KCDB, M-Layer**
- **European Metrology Cloud**
- **PTB's Digitization Strategy**
- **MSL, APMP, others**

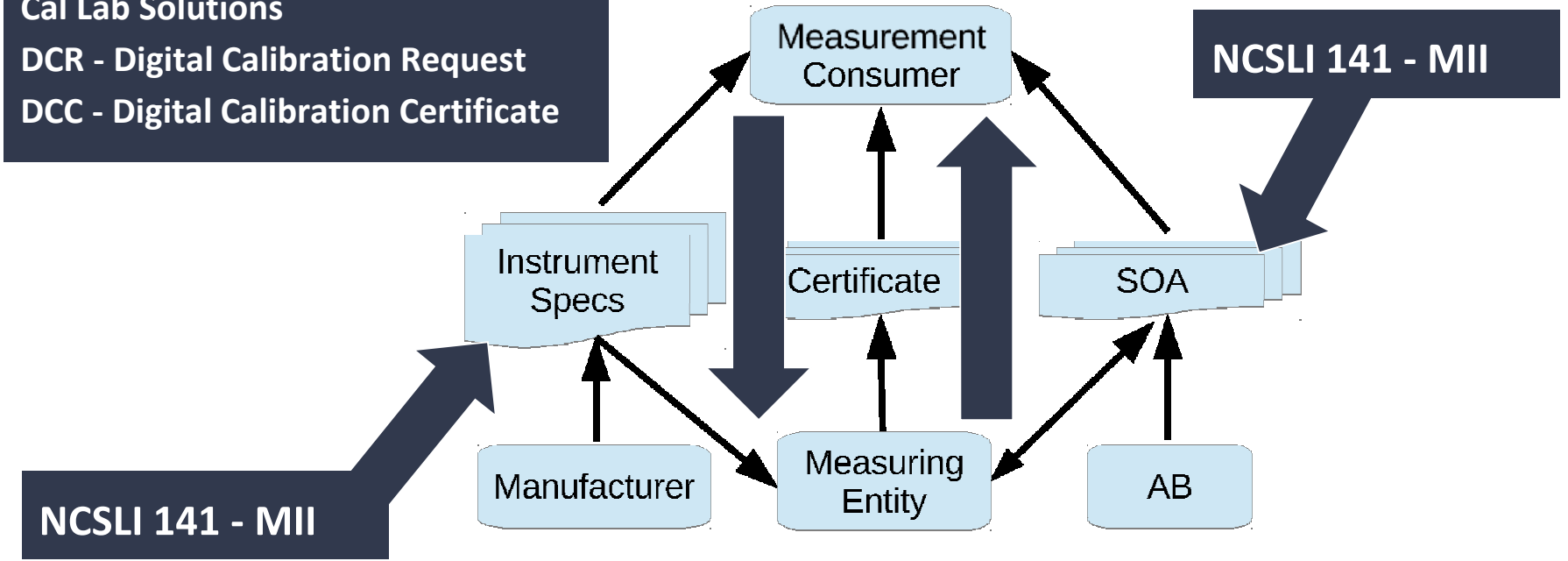
Metrology Information Infrastructure (MII)

- **PTB / DCC**
- **Digital Calibration Certificate**



Metrology Information Infrastructure (MII)

Cal Lab Solutions
DCR - Digital Calibration Request
DCC - Digital Calibration Certificate



What is Metrology Driven Software Engineering

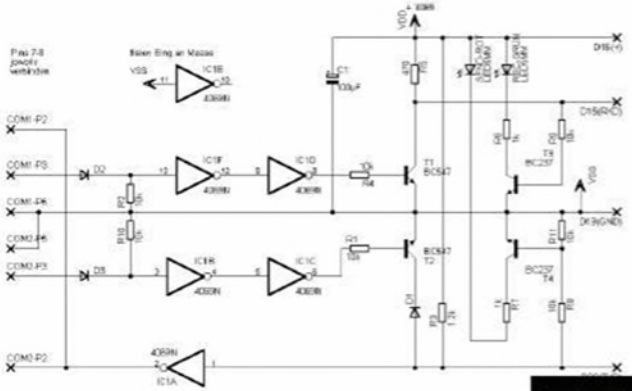
- It's a **metrology based language**
- It's a method of describing **test requirements in detail**
- **Generic description** /detailed enough to function
- It's a metrology based version of Model Driven Engineering

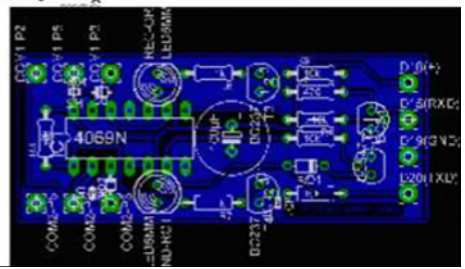
Model Driven Engineering

Is nothing new!

We have been using them for years

Electrical Schematics is a model driven language





Model Driven Software Engineering

Precise & Unambiguous

Efficiency of Expression

Universal & Abstract

Language of Math

A α	alpha	N ν	nu
B β	beta	Ξ ξ	ksi
Γ γ	gamma	O ο	omicron
Δ δ	deta	Π π	pi
E ε	epsilon	P ρ	rho
Z ζ	zeta	Σ σ	sigma
H η	eta	T τ	tau
Θ θ	theta	Y υ	upsilon
I ι	iota	Φ φ	phi
K κ	kappa	X χ	chi
Λ λ	lambda	Ψ ψ	psi
M μ	mu	Ω ω	omega

mass	=	[M]
lemght	=	[L]
time	=	[T]
velocity	=	$\frac{[L]}{[T]}$
momentum	=	$\frac{[M][L]}{[T]}$
force	=	$\frac{[M][L]}{[T][T]}$
acceleration	=	$\frac{[L]}{[T][T]}$
work	=	$\frac{[M][L][L]}{[T][T]}$
energy	=	$\frac{[M][L][L]}{[T][T]}$
pressure	=	$\frac{[M]}{[L][T][T]}$

$$\frac{d}{dx}a = 0 \qquad \frac{d}{dx}u^n = au^{n-1}\frac{du}{dx}$$

$$\frac{d}{dx}(au) = a\frac{du}{dx} \qquad \frac{d}{dx}(uv) = u'v + uv'$$

$$\frac{d}{dx}(u+v) = \frac{du}{dx} + \frac{dv}{dx} \qquad \frac{d}{dx}\left(\frac{u}{v}\right) = \frac{(u'v - uv')}{v^2}$$

$$\frac{d}{dx}(u-v) = \frac{du}{dx} - \frac{dv}{dx} \qquad \frac{d}{dx}\left(\frac{1}{v}\right) = -\frac{v'}{v^2}$$

$$\frac{d}{dx}f(g(x)) = f'(g(x))g'(x) = \frac{dv}{du}\frac{du}{dx} = (v(u))'u' \text{ where } v = f(u) \text{ and } u = g(x)$$

$$\frac{d}{dx}(e^u) = e^u\frac{du}{dx} \qquad \frac{d}{dx}(a^u) = a^u(ln\ a)\frac{du}{dx}$$

$$\frac{d}{dx}(ln\ u) = \frac{1}{u}\frac{du}{dx} \qquad \frac{d}{dx}(log_a\ u) = \frac{1}{(ln\ a)u}\frac{du}{dx}$$

$$\frac{d}{dx}f^{-1}(x) = \frac{1}{f'(f^{-1}(x))}$$

$$\frac{d}{dx}\sin u = \cos u\frac{du}{dx} \qquad \frac{d}{dx}\cos u = -\sin u\frac{du}{dx}$$

$$\frac{d}{dx}\tan u = \sec^2 u\frac{du}{dx} \qquad \frac{d}{dx}\cot u = -\csc^2 u\frac{du}{dx}$$

$$\frac{d}{dx}\sec u = \sec u\tan u\frac{du}{dx} \qquad \frac{d}{dx}\csc u = -\csc u\cot u\frac{du}{dx}$$

$$\frac{d}{dx}\sin^{-1}u = \frac{1}{\sqrt{1-u^2}}\frac{du}{dx} \qquad \frac{d}{dx}\cos^{-1}u = -\frac{1}{\sqrt{1-u^2}}\frac{du}{dx}$$

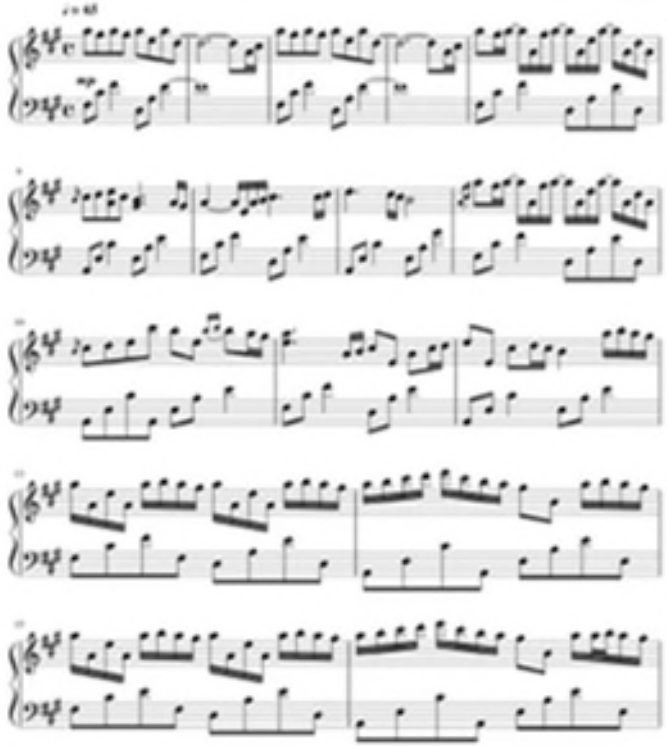
$$\frac{d}{dx}\tan^{-1}u = \frac{1}{1+u^2}\frac{du}{dx} \qquad \frac{d}{dx}\cot^{-1}u = -\frac{1}{1+u^2}\frac{du}{dx}$$

$$\frac{d}{dx}\sec^{-1}u = \frac{1}{|u|\sqrt{u^2-1}}\frac{du}{dx} \qquad \frac{d}{dx}\csc^{-1}u = -\frac{1}{|u|\sqrt{u^2-1}}\frac{du}{dx}$$

Model Driven Engineering

Is nothing new!

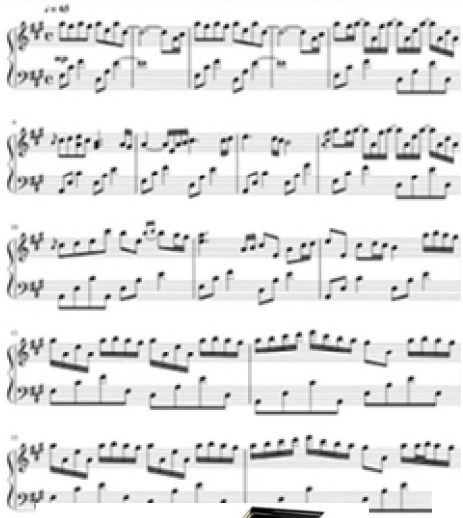
Music
is a model driven language



What is a model based language

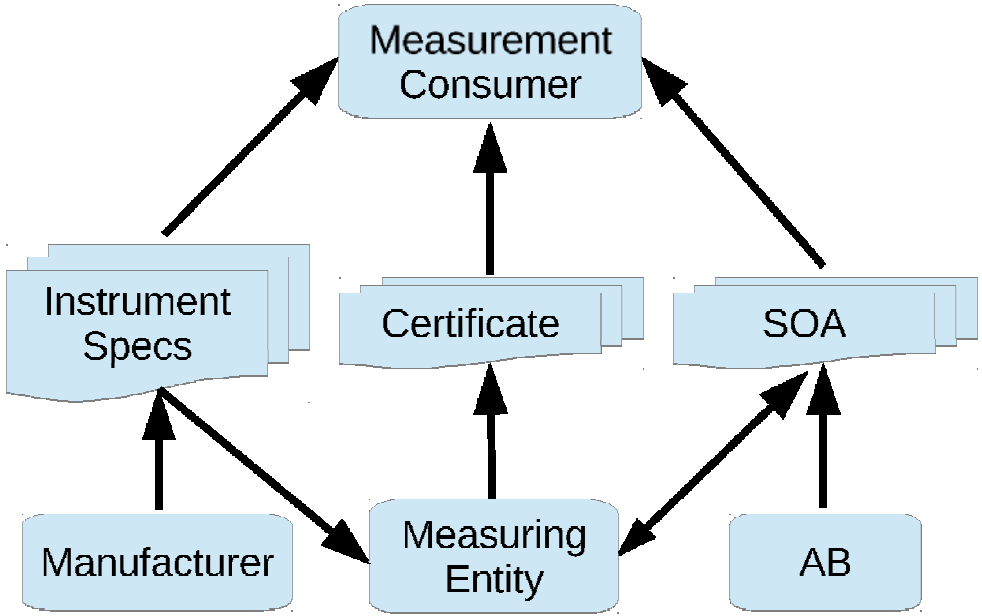
It defines the requirements not the implementation

Music defines the notes
Not the instrument

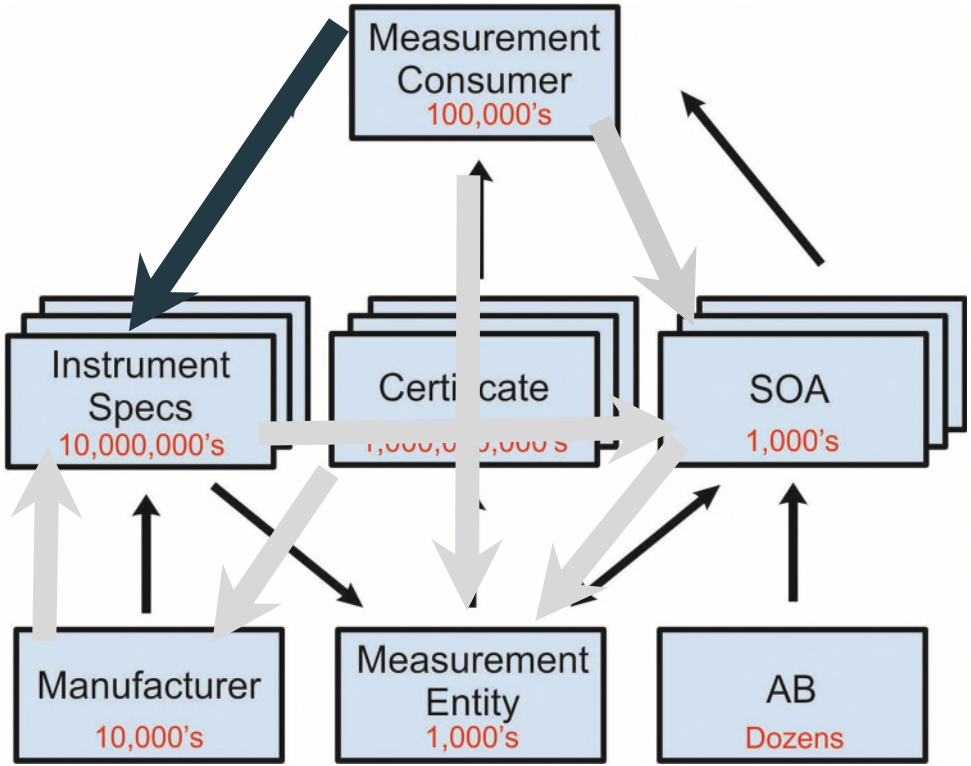


Metrology Information Infrastructure (MII)

Well Defined
Taxon Tagged Data
is
Easier to Move from
system to system



Model Driven Software Engineering Metrology Taxonomy



Customer can select the right / best equipment for their needs.

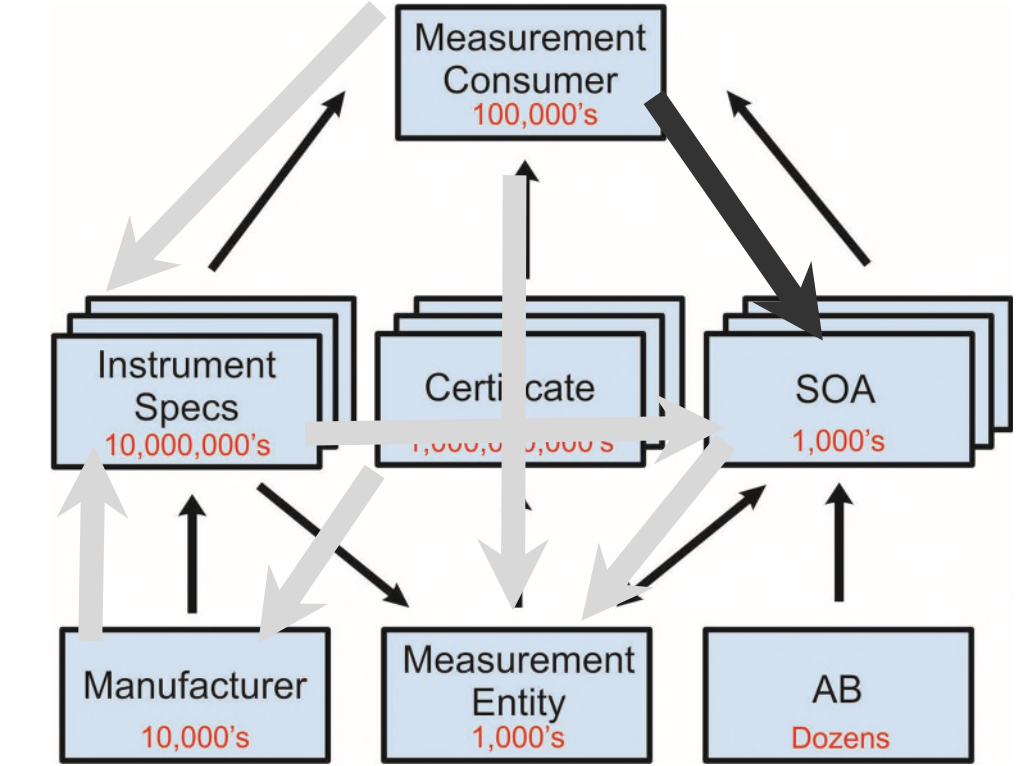
Customers can find a calibration lab

Specs can be used to simplify SoA uncertainties.

DCR to define exact Cal Requirements!

Calibration data can be used to update instrument specs

Model Driven Software Engineering Metrology Taxonomy



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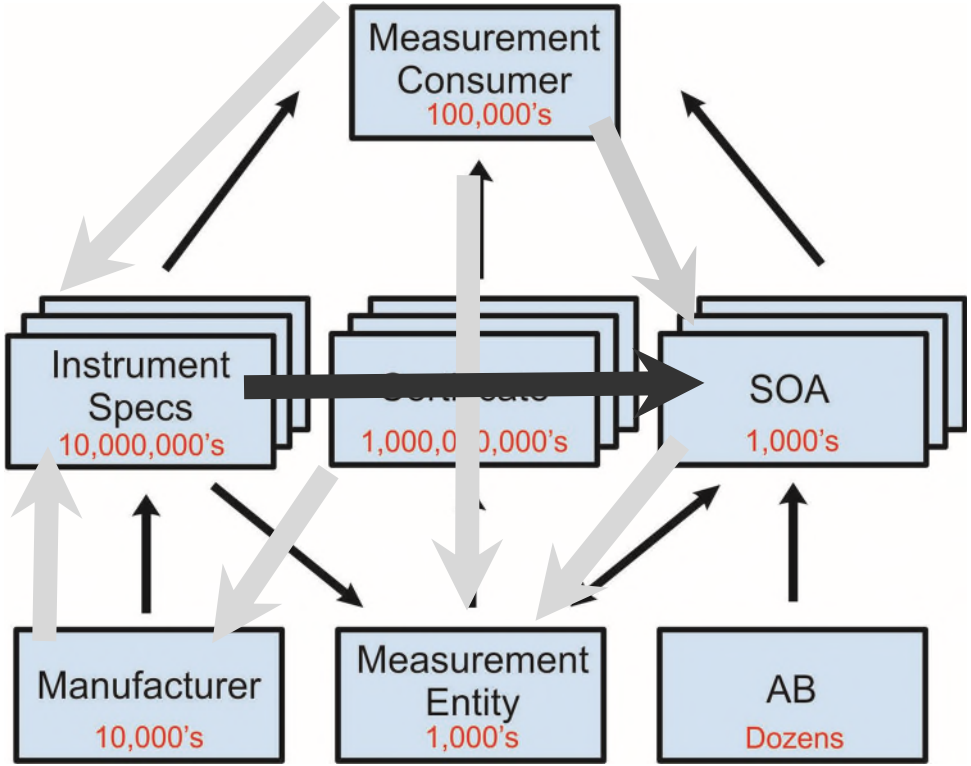

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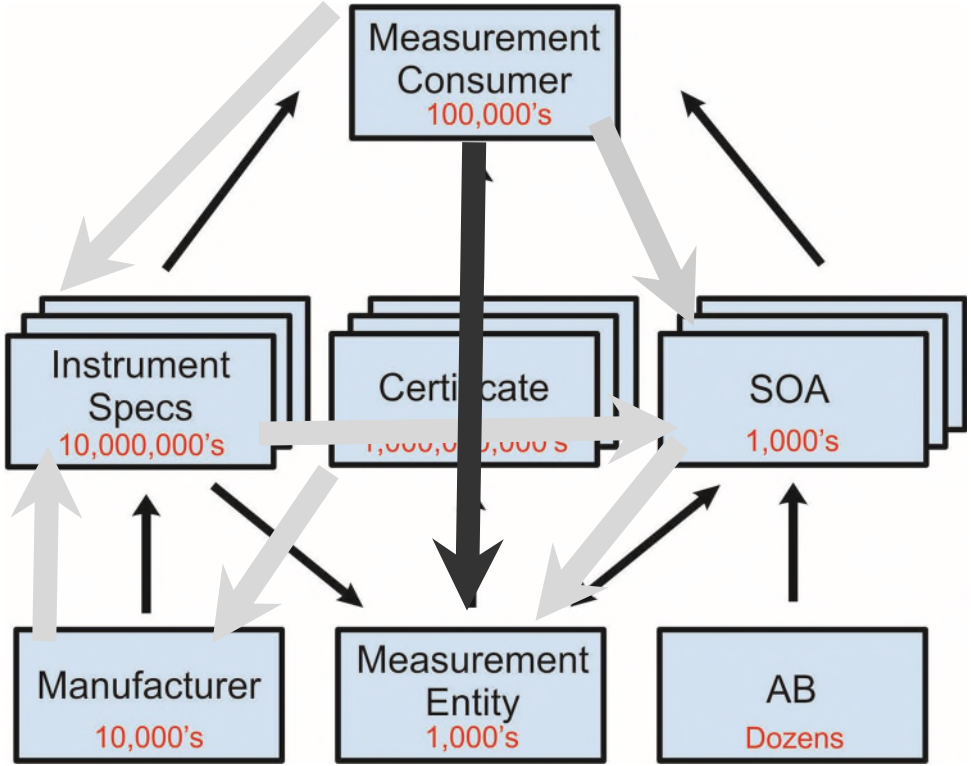

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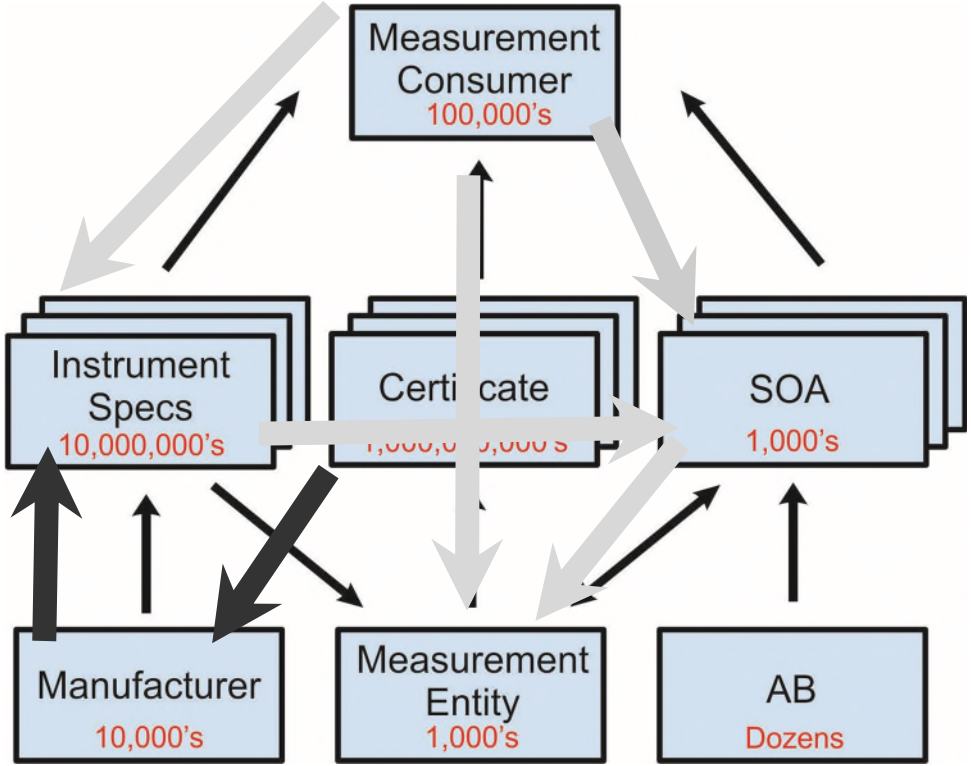

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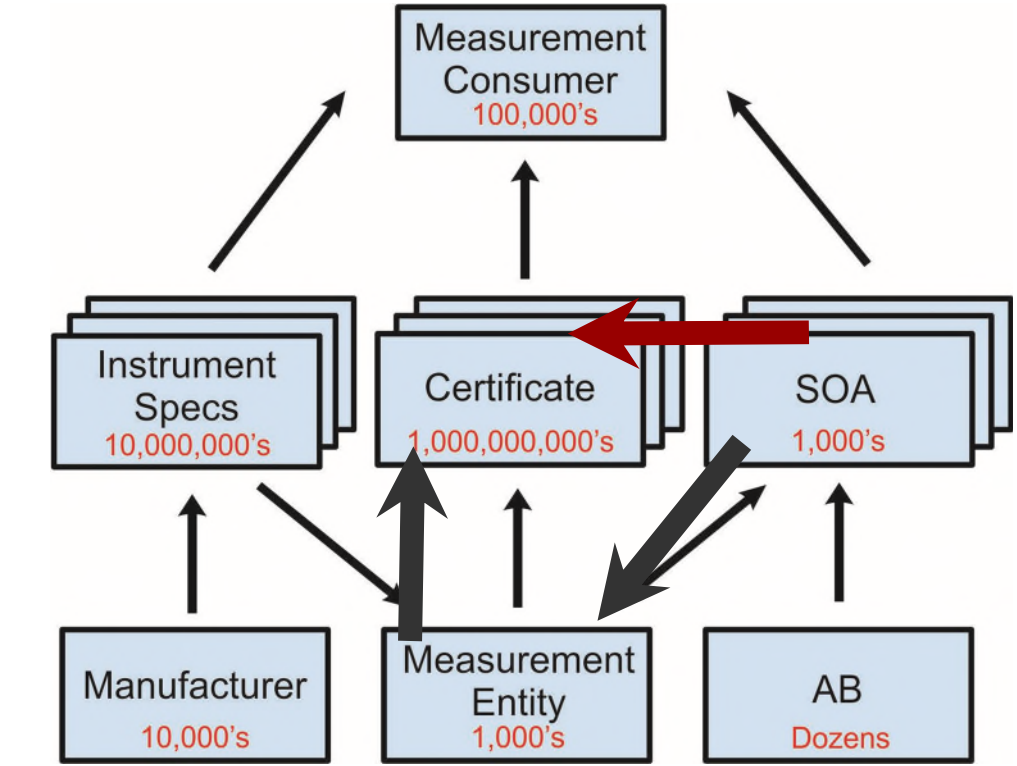
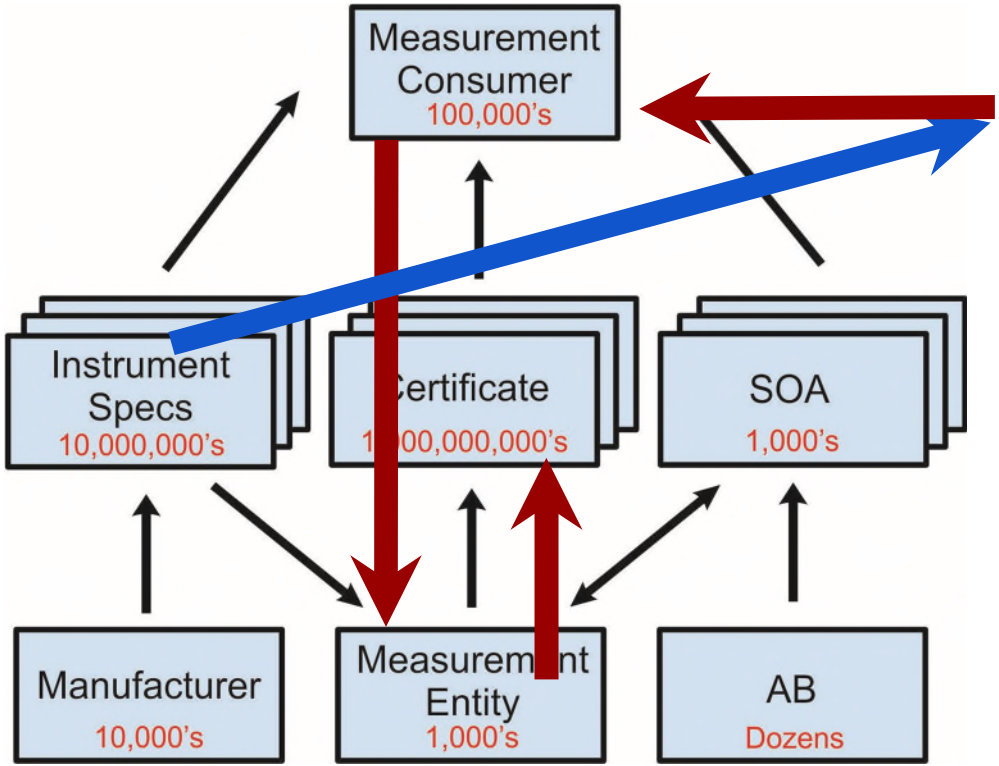


Automated ISO/IEC 17025 Uncertainty Verification for each and every test point

Already developed and running.

Model Driven Software Engineering Metrology Taxonomy



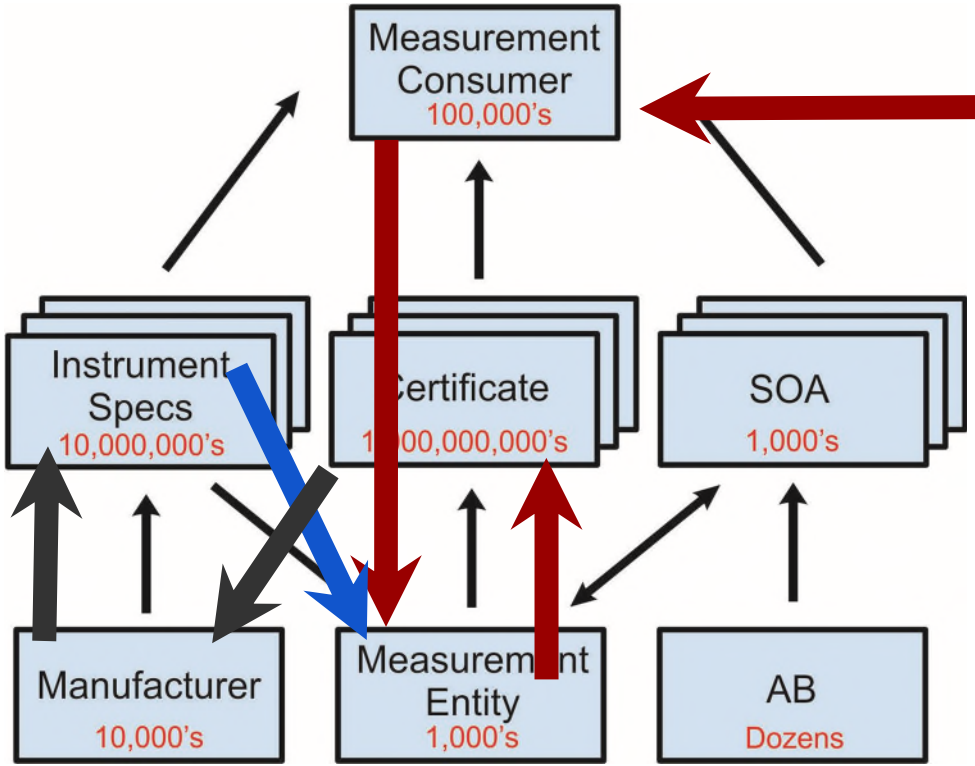
Customer's Requirements

Pass those needs digitally to the lab
Based on the Model

The Lab can perform the exact calibration
Because Details are in the Model
Custom Test Points
Manufacturer's Test Points
Military Spec / Test Points
Custom Spec / Test Points

All Automatic
Low-Code to **No-Code**

Model Driven Software Engineering Metrology Taxonomy



95% Confidence Calibration w/ Minimal Test Points

High Failure vs Low Failure Test Points

All Data is used to update Specs

Individual Test Points w/ Intervals

High Failure Points have shorter intervals

Low Failure Test Points tested less often

All Automatic

Low-Code to **No-Code**

Making Sense of Chaos - For Data Exchange

Units of Measure
- Not Definitive

Ontology
- Needs a Domain

Artificial Intelligence
- Need Structured Data

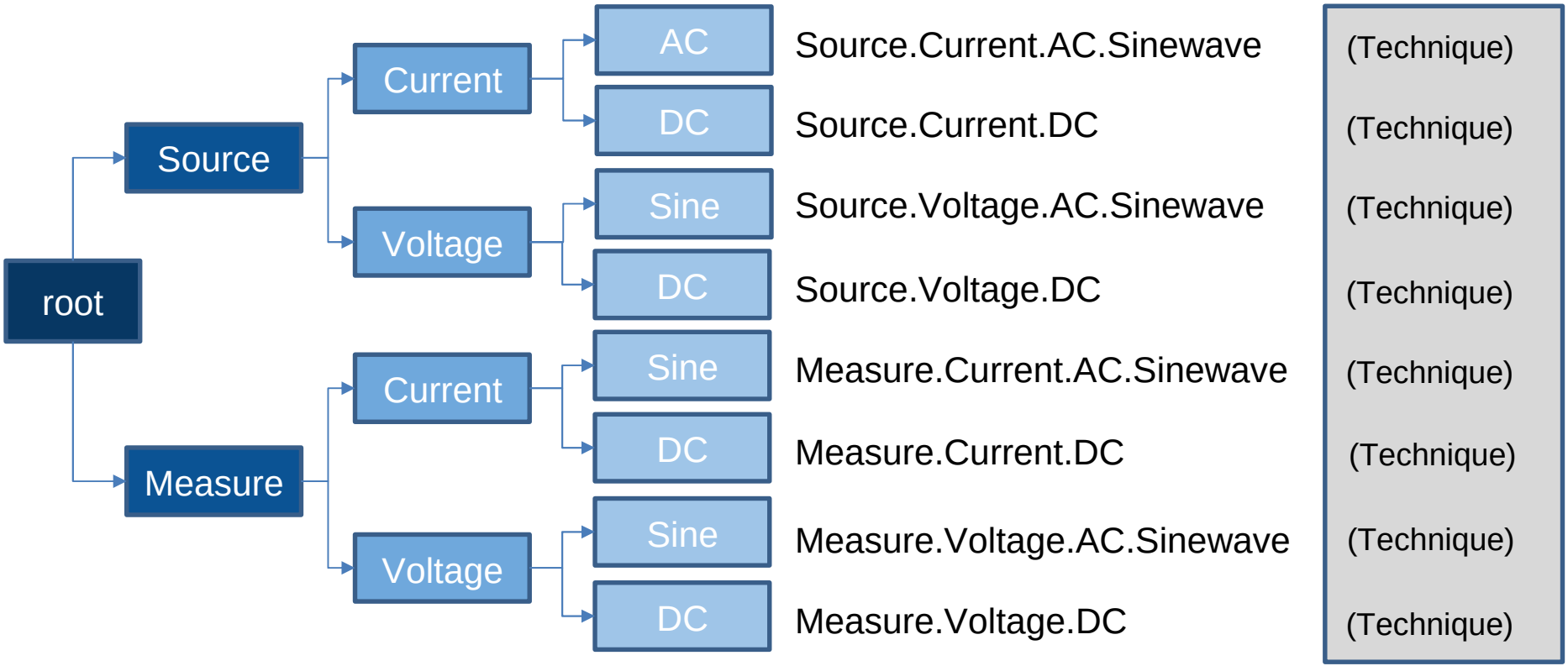
Data Format

- 30 fpm
- 1.2 g
- 10°
- XML / json
- PDF - Signed

Metrology Taxonomy

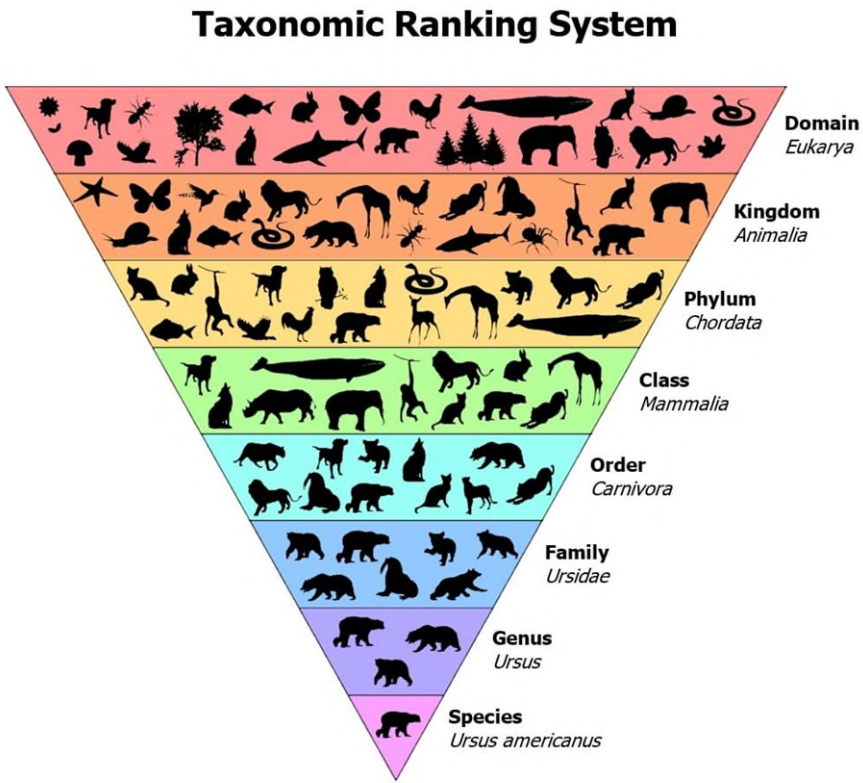
DCC RefType = ?? Taxonomy ??

https://www.metrology.net/home/metrology-taxonomy/



Metrology Taxonomy

Based on the natural worlds Taxonomy



Metrology Driven Software Engineering

Long Calibration Script versus Metrology Driven Software Engineering

Let's assume we have 5,000 UUTs
And 6 different Calibrators

Long Calibration Script
5000 * 6 = 30,000 scripts

Model Driven Software
5000 + 6 = 5,006

- **30,000 *Avg * $100 /hr**
- **5,006 *Avg * $100 /hr**
- **+ 80% of software is in Support & Maint**

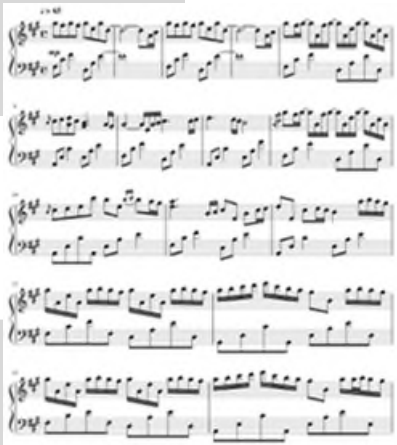
Source.Voltage.AC.Sinewave as Metrology Taxon

https://www.metrology.net/home/metrology-

Standardized Test Definition

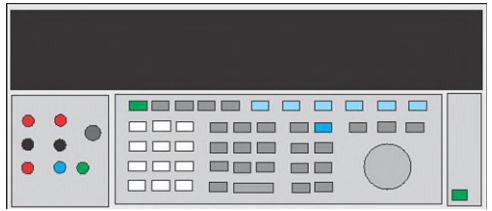
REQUIRED Settings

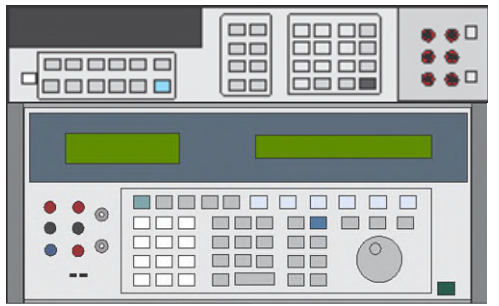
- **Volts = ??**
- **Frequency = ??**



Optional Settings

- **Impedance = ??**
- **UUT.Range = ??**
- **UUT.Input = ??**





Metrology Taxonomy -> Test Point

https://www.metrology.net/home/metrology-taxonomy/

Voltage.AC.Sinewave **(Fluke 5720A)**
Voltage.AC.Sinewave **(Fluke 5520A)**
-- **(Fluke 5520A - Char)**
-- **(Fluke 5520A - Drift)**
Voltage.AC.Sinewave **(Meatest 9010)**
-- **(Meatest 9010 - Char)**
-- **(Meatest 9010 - Drift)**
Voltage.AC.Sinewave **(New Calibrator 1)**
Voltage.AC.Sinewave **(New Calibrator 2)**

Test Point

Nominal = 10 V
Upper Limit= 10.02 V
Lower Limit= 9.98V
Format= #0.000
Type= WithIn-Limits

Taxonomy=
Source.Voltage.AC.Signwave

Metrology Taxonomy -> Settings

https://www.metrology.net/home/metrology-taxonomy/

Voltage.AC.Sinewave	**(Fluke 5720A)**
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Voltage.AC.Sinewave	**(New Calibrator 2)**

Settings

REQUIRED Parameters

Volts = 10

Frequency = 1e3

Optional Parameters

Impedance = 1e6

UUT.Input = 2 Wire Front

UUT.Range = 10

Metrology Taxonomy -> Command Script

https://www.metrology.net/home/metrology-taxonomy/

Voltage.AC.Sinewave	**(Fluke 5720A)**
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Commands

Command Script

- **Reset**
- **Setup**
- **Measure**
- Output On
- Output Off

Metrology Taxonomy -> Command Script

https://www.metrology.net/home/metrology-taxonomy/

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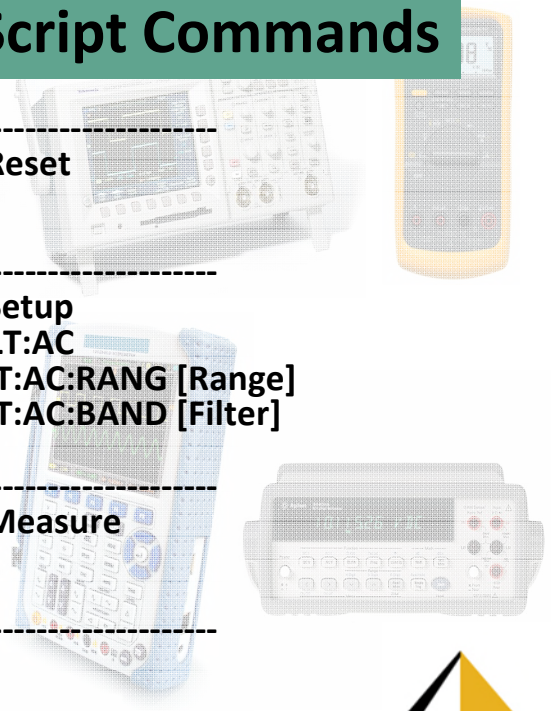
VISA Script Commands



```
--------------------------------
Section= Reset
*RST
*OPC?
--------------------------------
Section= Setup
CONF:VOLT:AC
SENS:VOLT:AC:RANG [Range]
SENS:VOLT:AC:BAND [Filter]
*OPC?
--------------------------------
Section= Measure
READ?
READ?
--------------------------------
```

Metrology Taxonomy -> How it Works

https://www.metrology.net/home/metrology-taxonomy/

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Metrology Taxonomy -> Implementation

https://www.metrology.net/home/metrology-taxonomy/

Voltage.AC.Sinewave (Fluke 572[illegible]

Voltage.AC.Sinewave (Fl[illegible]

-- [illegible]ar)

-- [illegible]A - Drift)

Voltag[illegible]atest 9010)

-- (Meatest 9010 - Char)

-- (Meatest 9010 - Drift)

Voltage.AC.Sinewave (Fluke 5560A)

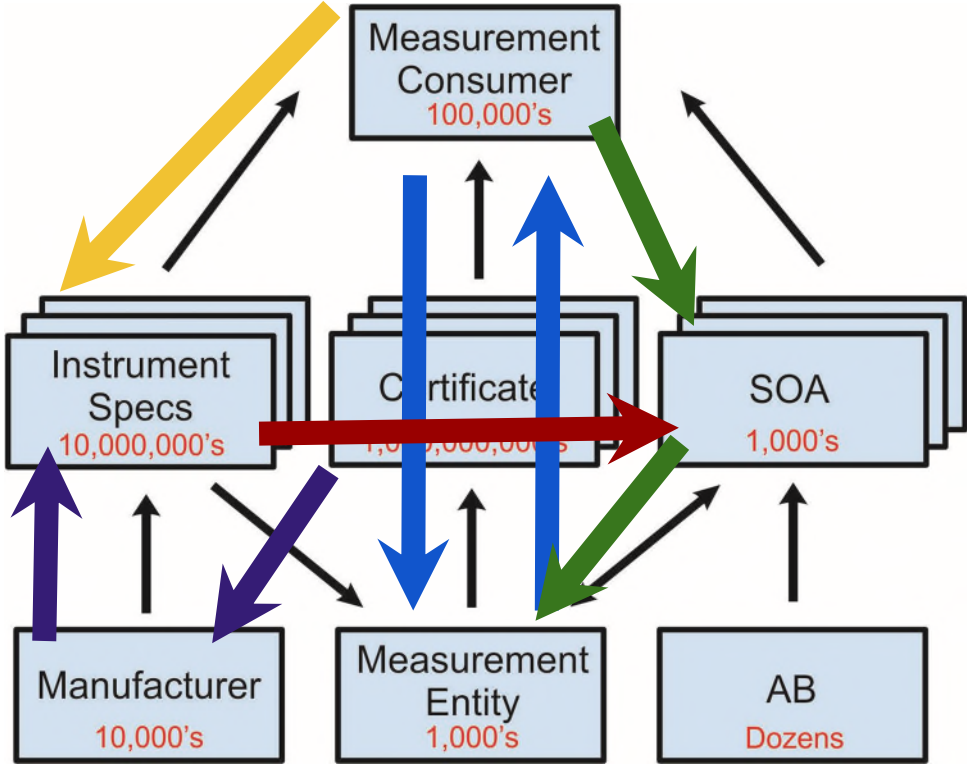
Voltage.AC.Sinewave (Meatest 9010+)

Future Proof

MEATEST 9010+

Fluke 5560A

The Digitalization of Metrology will depend on Model Driven Software Engineering



DCC & DCR is about getting the customer a digital copy of their calibration data!

Customers can find a calibration lab

Calibration data can be used to update instrument specs

Customer can select the right / best equipment for their needs.

Specs can be used to simplify SoA uncertainties.

Questions

Michael L. Schwartz

Cal Lab Solutions

mschwartz@callabsolutions.com

Source.Voltage.AC.Sinewave as Metrology Taxon

https://www.metrology.net/home/metrology-

Future Proof

Standardized Test Definition

REQUIRED Settings

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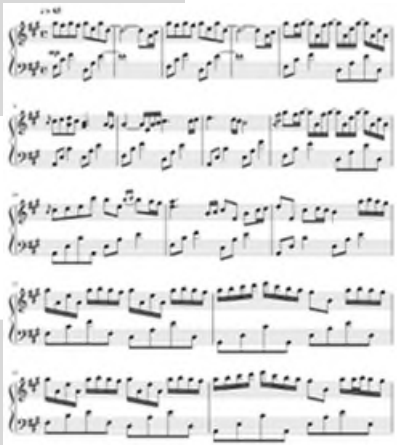
- Frequency = ??



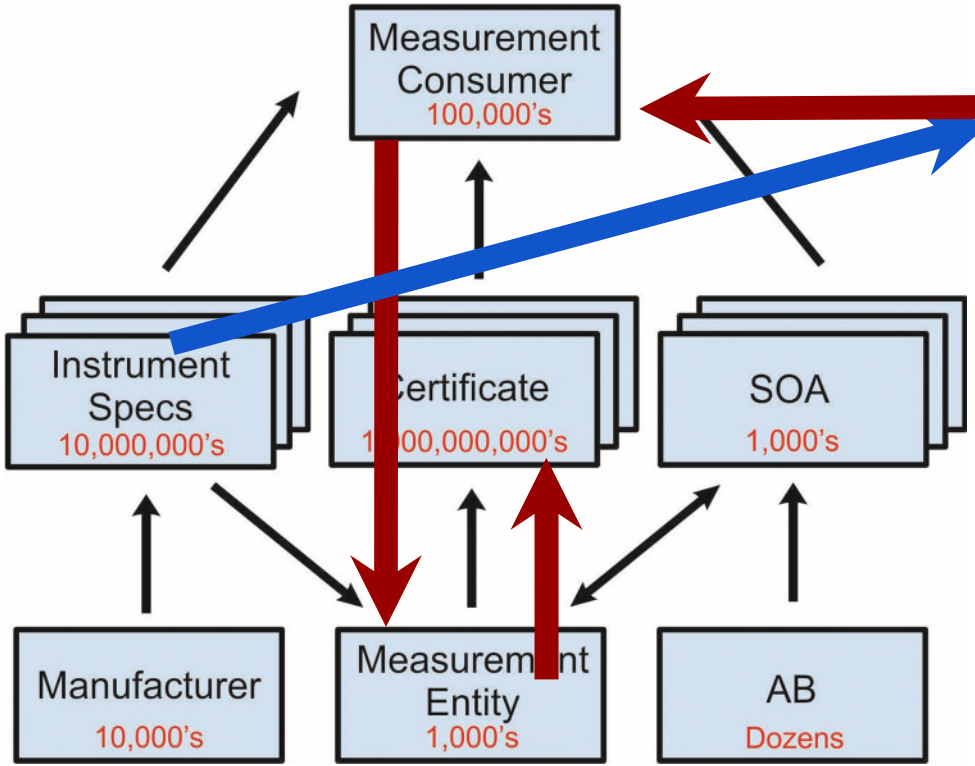
Optional Settings

- Impedance = ??
- UUT.Range = ??
- UUT.Input = ??

MEATEST 9010+

Fluke 5560A

Model Driven Software Engineering
Cal Lab Solutions MET/CAL Development



Building a MET/CAL a Procedure

Metrology.NET
Build Test Points & Driver

Code Generator
Build 85% of the MET/CAL Procedure

All Automatic
Low-Code to **No-Code**

Programmer
Create Connection Messages
Link to specific Reference Standard

Why Metroly Driven Software Engineering?

Metrology Centric
Supplier Independent
Future Proof

We can write ***One Sheet of Music*** and play it on any ***musical instrument.***

So why do we write a ***different scripts*** for every ***reference standard*** to calibrate the same UUT?

The model is the center.
- **Write using the model**
- **User implements the model**

It’s a be a better way!

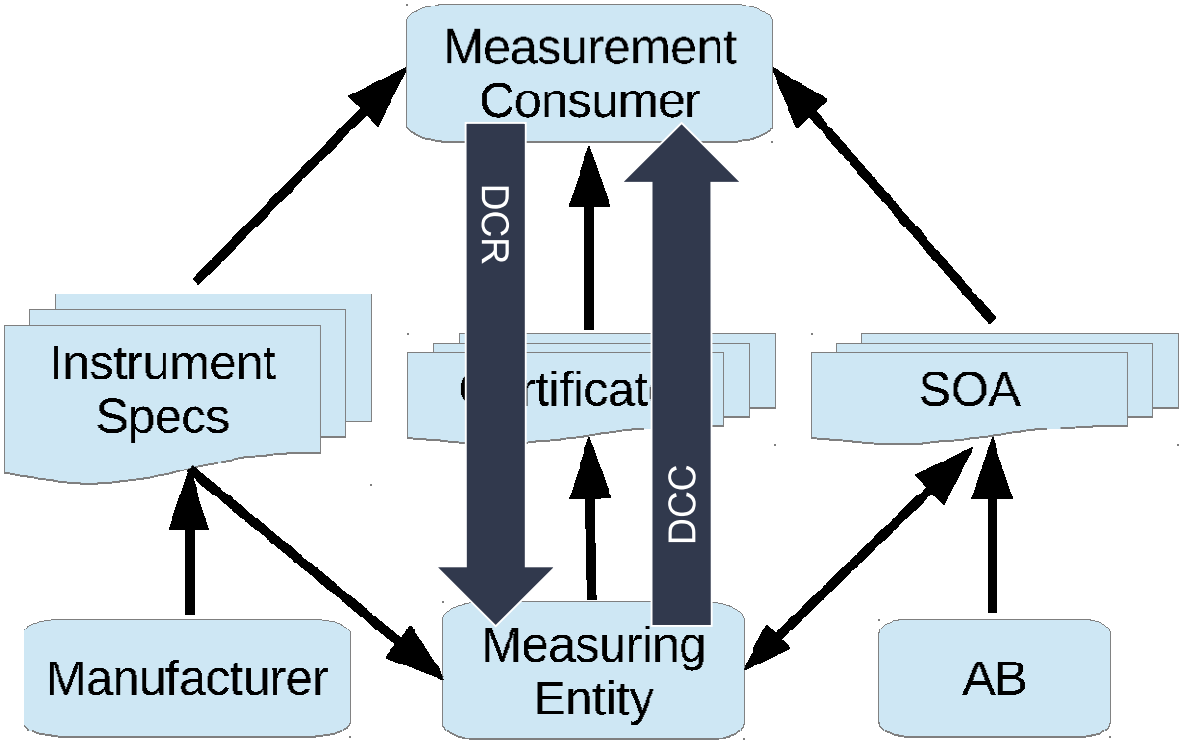
Metrology Driven Software Engineering

Why change the software development model?

What are the **Advantages**?

- **Writing and supporting big long calibration scripts become a thing of the past!**
  - 80% of the cost is in Support & Maint
- We can move to a **Low-Code** or **No-Code** Software development model
  - Saving Time and Money!
- Models & Data are **Easily Transported**
  - **Any Database Any Software**

Metrology.NET Focused on DCR & DCC



2013 -

How to calibrate signal generators

Different Standards

HP 8902A / 8903B Stack
Agilent N5531S
Agilent N9030A
R&S FSMR

Metrology.NET was born

Customers could define requirements
Labs calibrate exact requirements
Data exchange is simple

Metrology Taxonomy -> Implementation

DEMO

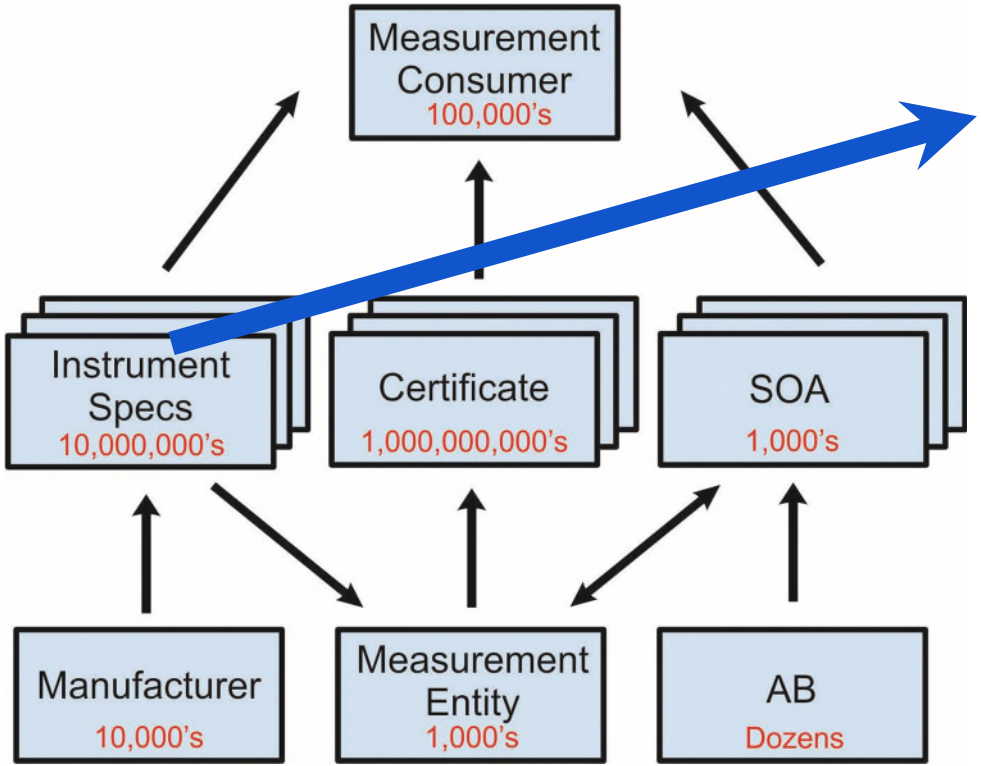
Calibration Certificate Data Standard

- NCSLI 141 MII & Automation
- Germany & New Zealand's NMI
- Fluke Calibration
- Cal Lab Solutions
- INEGI - Portugal
- Sandia - New Mexico

Data Format

- 30 fpm
- 1.2 g
- 10 deg
- XML / json
- PDF - Signed

Model Driven Software Engineering



Auto Create Test Procedure

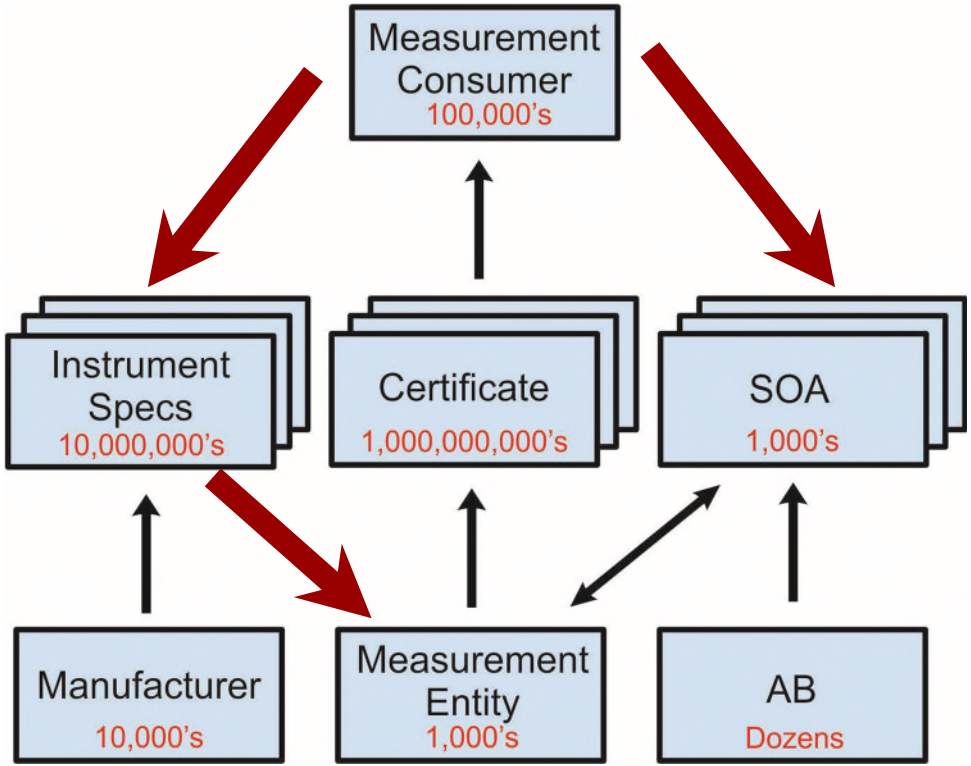
Abstract Model needed for Spec
Based on Metrology Taxonomy

Fully automated
All data driven

All Automatic
Low-Code to **No-Code**

Any Language
Currently ~80% of a MET/CAL procedure is auto code gen

Model Driven Software Engineering



Data Empowerment!

Find 17025 Capable Labs

Search based on Measurement Requirements

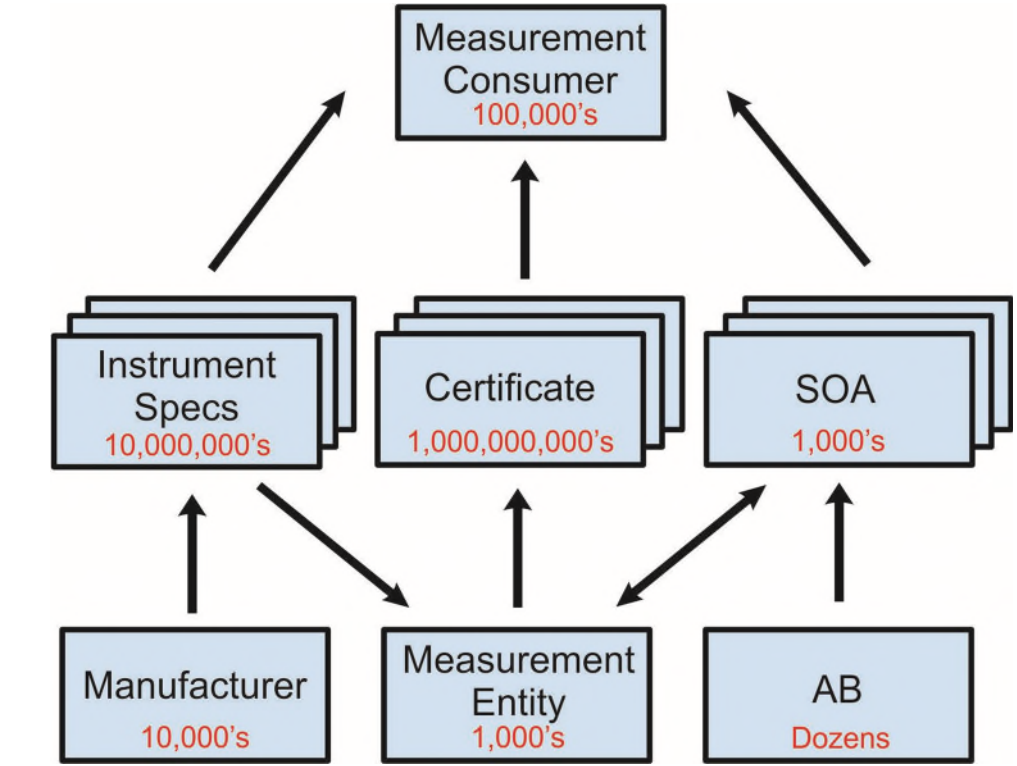
Define Instrument Test Requirements

What needs to be tested only
Saving time and Money

Easily Pass that data to the Lab

The Model contains all the test requirements

Metrology Information Infrastructure (MII)



Standardized Certificates of Calibration
- Measurement Entities
  - Create Calibration Certificates for Measurement Customers

Equipment Specifications
- Manufacturers
  - Create Instrument Specs that Measurement Customers buy

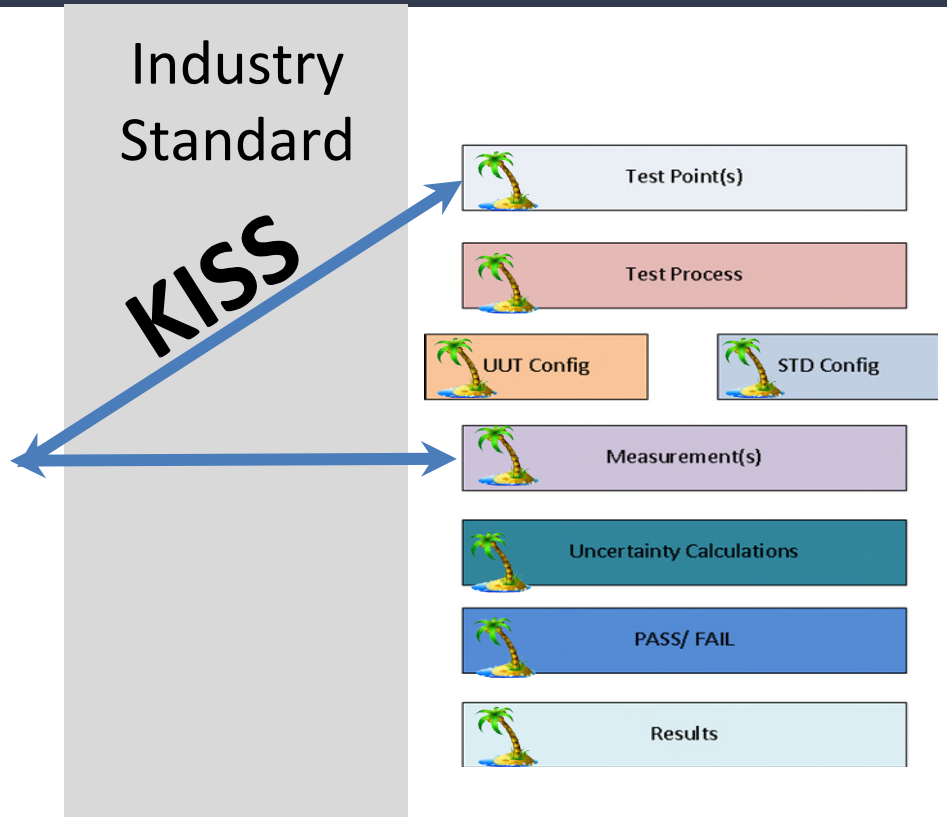
Accredited Calibrations
- Accreditation Bodies
  - Create Scopes of Accreditation that Measurement Customers view

Model Driven Software Engineering Overview

Any Software Platform that can

- **Authenticate with the Server**
- **Download Test Points**
- **Make the Measurements**
- **Upload Test Results**

…is Model Compliant!



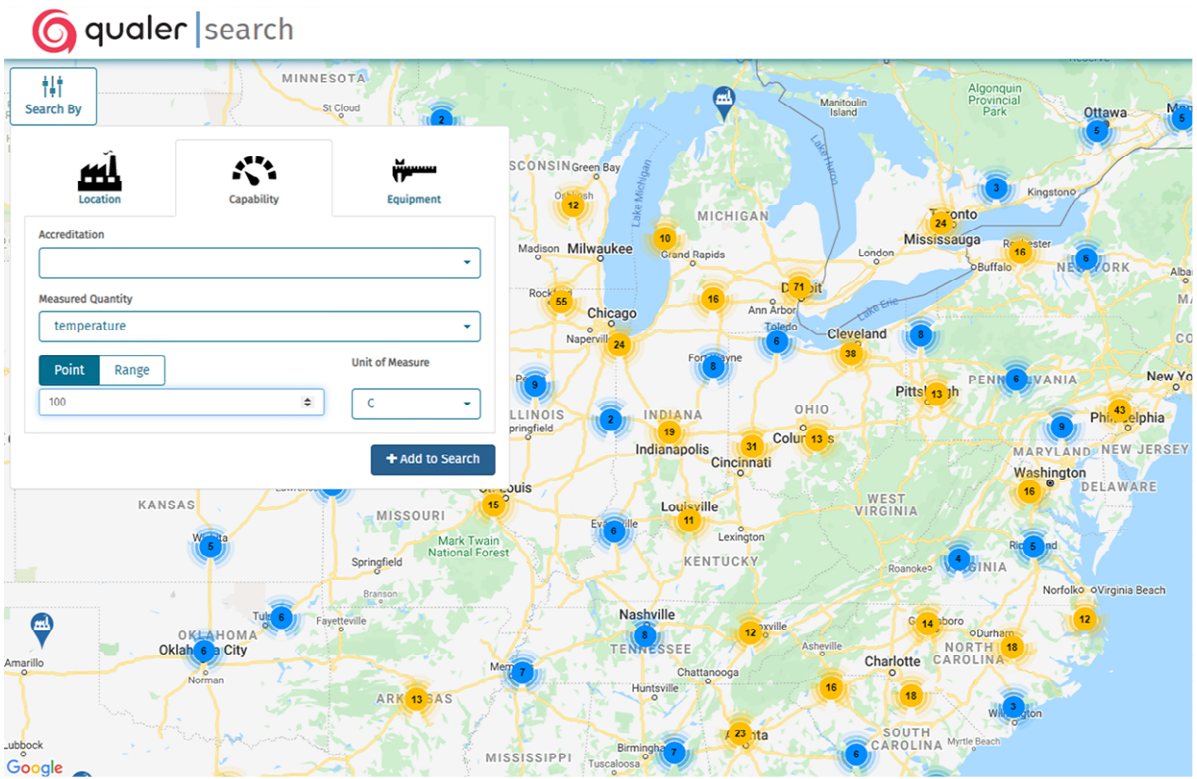
Qualer Search & the Search of the Future

TODAY!

- **Search Accredited Labs**
  - Using Unit of Measure

In the Future!

- **Find a Calibration Lab**
  - Based on measurement points
- **Check Uncertainties**
  - Auto Calculate
- **Custom Pricing by test point**
  - Send the Calibration Lab your measurement points



Metrology.NET® Overview

Data Sync is Easy

- **Find the Asset**
- **Select TestPackage**
- **Create Work Order**
- **Cal the UUT**
- **Pull Results**

4 Easy / Well Defined REST Calls