Method for Verifying Measurement Uncertainties for Every Test Point Against Your Lab's ISO/IEC 17025 Scope of Accreditation

By

Michael L Schwartz
David Wolfe

Abstract:
Digitalization of business processes is essential for future metrology, and all stakeholders, such as calibration labs, customers, and Accreditation Bodies (ABs), will need to move into the 21st century. A critical use-case for digitization is the process of verifying measurement uncertainties on an accredited certificate of calibration.

To accomplish this, we need digital representations of a Scope of Accreditation (SoA) containing a calibration lab's calibration measurement capabilities (CMC). But digitization is more than just a lab's PDF copy of their SOA found on the Accreditation Body's (AB) website.

Using the NCSLI 141 MII Committee's beta version of a "Metrology Taxonomy" database used for creating a digital version of a Scope of Accreditation, it is now possible for a computer to verify every test point's measurement uncertainty against the Lab's SoA. This paper will demonstrate the steps required (with sample code) to modify a Digital Calibration Certificate (DCC) by adding taxonomy tags, using those tags to compare the uncertainties in the DCC against the measurement uncertainties in the lab's SoA, and then show the user what, if any, measurement uncertainties are not in accordance with the lab's SoA.

Problem:
Calibration labs using automation often find that automation software is generating measurement uncertainties below the calibration lab's accredited calibration measurement capabilities (CMCs). This can result in a finding by the auditor and a huge undertaking updating the automation software, if that is even possible.

Simple Solution:
Well, there is no simple solution! In the majority of cases, the solution is either rewriting the software or creating some manual process where a technician can verify and edit each and every test point on an accredited calibration!

The Digital Metrology Solution:
This start with the Metrology Taxonomy work the 141 Committee with NCSLI, the National Council of Standards Laboratories International, has been working on for the last several years.

The MII (Measurement Information Infrastructure) 141 Committee's charter is to create a set of normative standards that unambiguously define data structures, taxonomies, service protocols, and security for locating, communicating, and sharing measurement information. At the heart of

this technology is the creation of a catalog containing all of the unique "Metrology Taxon" definitions for every known measurement and then use that catalog of metrology taxonomies to link data from different systems, formats, and technologies.

The examples covered in this paper will show how the Metrology Taxonomy can be used to verify the measurement uncertainties generated from inside an automated calibration against a calibration lab's Scope of Accreditation. And to keep things simple, we will be using the Source.Voltage.AC.SineWave taxon.

Source.Voltage.AC.SineWave Taxon:
Source Voltage AC Sinewave as a taxon is a generic description or tag for anything that can generate a known sine wave voltage. "Source" means it is created or generated as opposed to being measured. The second element, "Voltage," is the quantity kind of metrological interest. Lastly, the "AC.SineWave" is a brief further description of the "Voltage" element.

Along with the unique name "Source.Voltage.AC.SineWave," the taxon definition also requires us to provide two additional elements: Voltage and Frequency. These two elements are required because, without them, it would be impossible to create an AC Sine wave signal. Additionally, the taxon definition allows for additional elements like Impedance or anything else the user may want to include.

This is a high level of abstraction that breaks the measurement requirements down into the root data elements independent of the hardware required to source AC voltage at a given voltage and frequency.

	Voltage	Frequency
Source.Voltage.AC.SineWave	120 V	60 Hz
Source.Voltage.AC.SineWave	10 V	1 MHz
Source.Voltage.AC.SineWave	100 kV	60 Hz

Table 1.

More information on creating and understanding Metrology Taxonomies can be found http://miiknowledge.wikidot.com/start.

Technique:
Measurement Techniques implement Metrology Taxons! This is where the HOW of metrology comes into play. How does the lab source a known "Voltage" of an AC Sinewave signal?

Looking at the three examples above (Table 1), a typical multi-function calibrator could generate a known 120V @60 Hz. But only a few could generate 10 V @ 1 MHz; hardware to generate 100 kV @ 60 Hz is not as common.

Techniques and implementations can vary. How a lab generates a known voltage is independent from the Source.Voltage.AC.SineWave's generic definition. For example, a lab could use a long-scale multimeter with a variac to get a known 120.000 V from the AC power outlet. If the lab could prove proficient in using a variac with a DMM to generate "a known" AC Voltage, it could be added to a lab's scope of accreditation.

Digitizing the Scope of Accreditation:
Part of the 141 Committee's efforts have focused on creating a digital version of a calibration lab's Scope of Accreditations. The short history is back in 2015, a group of us tried to digitize a lab's SoA as a proof of concept and discovered much of the details needed were unstructured and found in the notes column of a typical SoA. This made searching an SoA for a set of relieving CMCs impossible, let alone calculating measurement uncertainty.

This challenge was quickly adopted into the mission statement of the 141 Measurement and Information Infrastructure Committee (MII). In 2016, at NCSLI, David Zajac presented the first XML schema to represent a calibration lab's SoA in a digital format. The group continued evaluating CMCs from over 1300 accredited labs across the US. In 2017, Qualer loaded all of the CMC into https://search.qualter.com, allowing users to search CMCs by the unit of measure and quantity type.

What we learned was that searching by the unit of measure, quantity types, and or keywords was insufficient to aggregate data from different CMC, SoA, or accreditation bodies. Even after collecting over 250k CMC and putting them into a single format, the data was still far from machine-actionable.

Here are some of the problems we discovered:
1) **1.2 g** as a unit of measure. One would think this is grams, but it was a vibration measurement.
2) **30 fpm** as a unit of measure. We had to call the lab; it was frequency flashes per minute.
3) **10 °** What is a degree? Temperature, plane angle, magnitude phase….
4) **3000 °C** Does the lab really have a furnace that goes that high?

These are just a few examples of where simply using the unit of measure is unreliable. Even using quantity type identifier, the data want machine-actionable. The problems still remain; First was the lab sourcing or measuring the value.   And second, as in temperature, does the lab really source a know 3000 °C?

So the committee zeroed in on Metrology Taxons to identify better what an individual CMC was doing metrologically. Using the problems posed above:
1) **1.2 g** gets extended with **Measure.Acceleration.Vibration**
2) **30 fpm** gets extended with **Source.Frequency**
3) **10 °** gets extended to **Measure.Phase.TransmissionFactor**

4) **3000 °C** gets extended to **Measure.Temperature.Simulated.Thermocouple**
The 141 Committee is working weekly, and on occasion with other organizations around the world, to further define taxons in additional measurement areas. We are in the process of setting up a public GitHub site where we can maintain all of the official taxons.

Scope of Accreditation Editor:
In 2022, Cal Lab Solutions, Inc. released beta version 1.0 of the Taxonomy Editor and the Scope of Accreditation Editor. These two tools are open-source and maintained on GitHub: https://github.com/CalLabSolutions/Metrology.NET_Public.
You don't have to be a developer; simply download the files, then navigate to /Source/Executables/SoA_Editor. You can start digitizing your SoA today. NOTE: This software is still in beta, so feedback is appreciated.

Another important thing to note is the SoA Editor is not just text; the formulas and calculations are functional as well. Users can define fixed values or more complex calculations, then pass in values like
Nominal = 10
Range = 10,
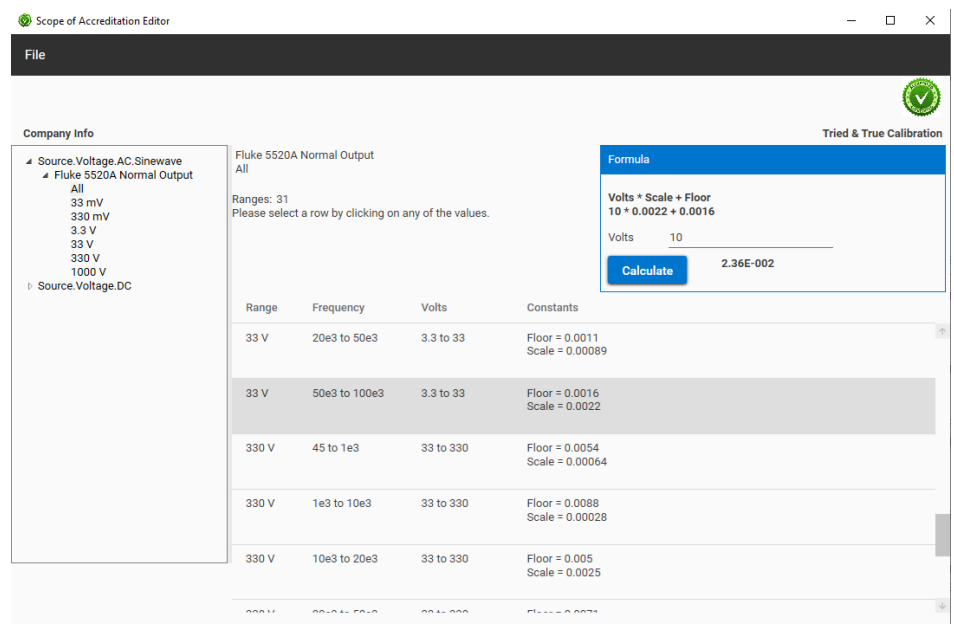and the SoA Editor will calculate the uncertainty!

Figure 1.

The SoA Editor is open-sourced, so other organizations and accreditation bodies could use it freely and with few restrictions. Our motive is to move metrology into the digital age by promoting solutions for stakeholders, not profits to shareholders.

SoA Calculation Service:
The SoA tool is great for checking calculations, communicating, and coordinating with an accreditation body. But it was never designed to integrate with other applications. This is where a RESTful application programming interface or API comes into play.

This was the majority of our work in 2023 and the highlight of this paper. Now that we have a digitized version of our SoA in an XML format, we need a simple and easy way to connect it to all of our automated calibration software. Service-oriented architectures allow us to make a

decoupled call to a server requesting some data, and the server will securely return the resulting data to my application.

The way this works is by sending an encrypted data package in a JSON format to an https server on port 443 using a REST call. It may sound strange, but this is how the whole internet works!

The UseCase, illustrated in Figure 2, is fairly simple. After the technician in green on the left has uploaded the XML file, the technician in blue on the right is able to run a calibration where the software can check each and every test result's measurement uncertainties against the SoA.
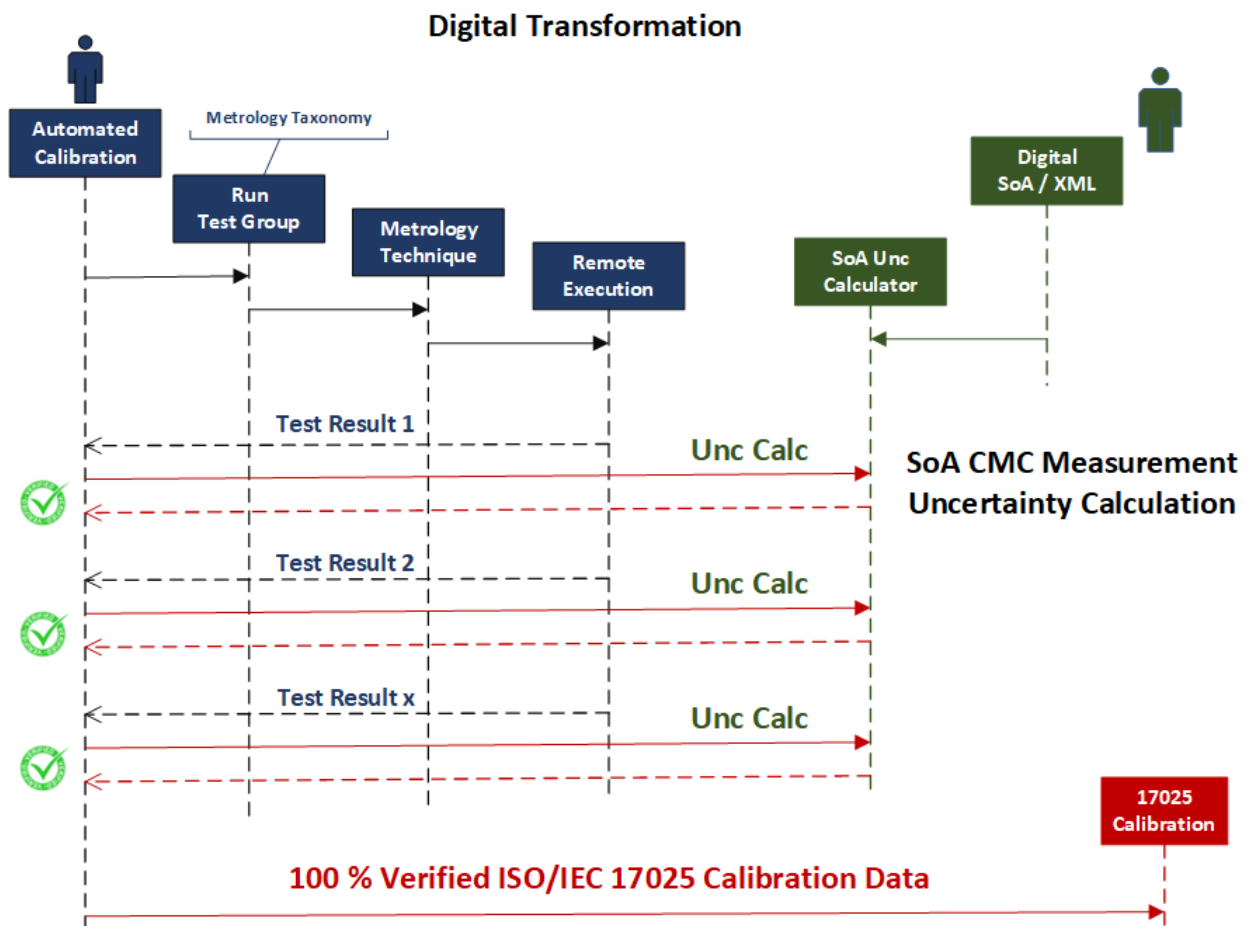

Figure 2.

As each test result is saved back to the server, a REST call to the Unc Calc will be executed, passing the specifics of the test result to the SoA Uncertainty Calculation Service. The JSON data package will contain the exact requirements for the uncertainty calculation requested from the lab's SoA, generically, meaning it will contain the metrological specifications, not the specific CMC line in the SoA. The JSON formatted data look like this inside:

Taxonomy= Source.Voltage.AC.SineWave
Voltage= 3.5
Frequency= 100e3

The data will be sent using a POST to an API URL like this:
https://metrologymanager.com/data/UncCalc/SoA_FileID. Where the API would return a list of
CMCs-based measurement uncertainty calculations matching the request parameters.

Item1
Uncertainty = 6.2e-4
Technique = Fluke 5720A
Range = 2.2 to 22
Volts = 3.5
Frequency = 50e3 to 100e3

Item2
Uncertainty = 1.8e-3
Technique = Fluke 5720A
Range = 2.2 to 22
Volts = 3.5
Frequency = 100e3 to 300e3

Item3
Uncertainty = 9.3e-3
Technique = Fluke 5520A Normal
Range = 3.3 to 33
Volts = 3.5
Frequency = 50e3 to 100e3

From the list of Items returned, the software can now select the best matching CMC or the
lowest CMC, depending on the requirements.

When the application receives the uncertainty calculations from the SoA Calculation Service, it
can then determine the uncertainties to report on the accredited calibration. If the user has
selected an alternate uncertainty calculator overriding the in-app calculation, it will then compare
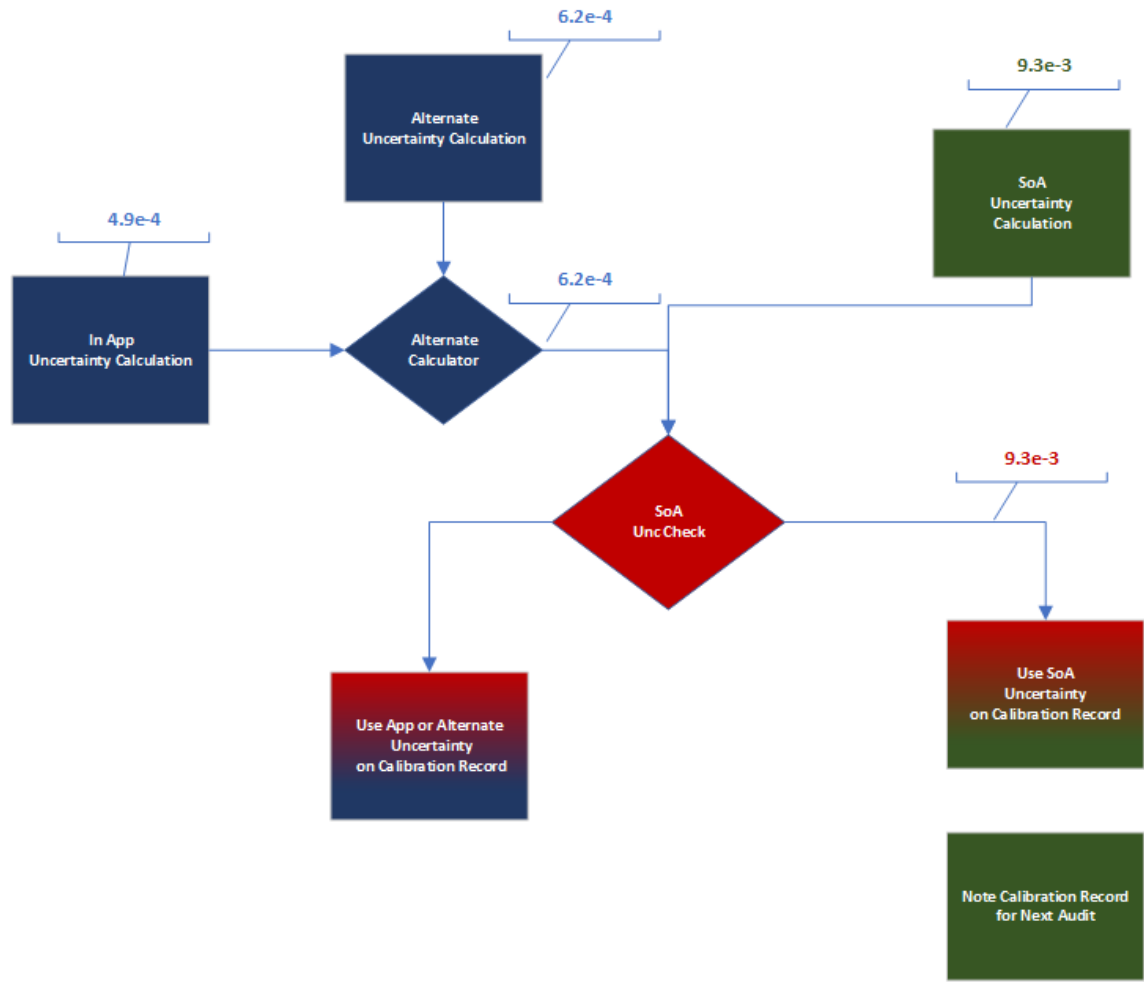the result to the SoA uncertainties.

Figure 3.

If the SoA's uncertainty calculation is greater than the software's uncertainty calculation, it will report the SoA's uncertainty and note this test point for future audits. Otherwise, it will use the uncertainties produced by the software in the calibration results.

MOCK Example:
For our test case, we wanted to do a mock accredited calibration on an HP 34401A using a Fluke 5730A calibrator. In the example, the calibration lab is accredited with their Fluke 5520A. They just received a new 5730A with a 5725A Boost amplifier with an accredited calibration, but they have yet to update their accredited uncertainties with their accreditation body.

They can perform accredited calibrations with their Fluke 5730A; they just can't overstate their uncertainties.

Here we see the software will place a light green check mark on all the test points the lab is accredited for, but the software used the best uncertainties from the SoA in place of the 5730A's

in-app calculated uncertainties. It will place a dark green check mark everywhere the in-app or alternate uncertainty calculations are equal to or greater than the SoA's uncertainty. If the lab was not accredited at that test point, the check marks in the accredited column were all left blank.

Referring to Figure 3, the application software calculated an uncertainty of ±4.9e-4 V using only the Type B 95% specifications of the Fluke 5730A. Then by calling an alternate calculator, where the calibration lab added additional contributors like traceability, repeatability, and reproducibility resulting in an expanded uncertainty of ±6.2e-4 V. Then, the software is able to check against the SoA uncertainties. Because the lab is only currently accredited to ±9.3e-3 V using their Fluke 5520A, they cannot report an uncertainty below that value. So the software replaces the 6.2e-4 V uncertainty with 9.3e-3 V and reports that value on the certificate of calibration.

Each test point and test result is checked. The difference in uncertainty between a 5730A and a 5520A is huge. The software will be able to check and verify small values just as well. If the application using a 5520A generated an uncertainty of ±9.2e-3 V, just the same, it would have replaced it with ±9.3e-3 V.

Conclusion:
Moving metrology into the digital age, there is still a lot of work that needs to be done!

This paper and software example is the first attempt at creating an architecture to allow a software application to verify each and every test point against a calibration lab's Scope of Accreditation. Over time, the systems will become more polished as technologies advance.

As the NCSLI MII 141 committee continues to push technology forward, we're learning what works and what doesn't, innovating at the leading edge of technology.