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5th International DCC-Conference

2025-02-25 to 2025-02-27
Proceedings

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DOI: https://doi.org/10.7795/810.20250619

Table of contents

Chairs of the Program Committee

- Carlos Galván, Centro Nacional de Metrologia CENAM, Mexico
- Shanna Schönhals, PTB - Physikalisch-Technische Bundesanstalt; Germany (Vice-Chair)

Members of the International Programme Committee

The preparation of the scientific programme and review of submitted abstracts was carried out by the International Programme Committee (IPC). The IPC combines a broad knowledge and commitment in digitalisation to ensure a high-quality event. Members of the IPC are:

- David Balslev-Harder, Team Leader at Danish Fundamental Metrology (DFM), Denmark
- Jariya Buajarem, Head of Digital Centre and Materials Metrology, Quality System and International Cooperation Office, NIMT, Thailand
- Carlos Galván, Dirección Metrología Dimensional, CENAM, Mexico
- Hugo Gasca Aragon, Co-Chair of IMEKO TC6 Digitalization
- Blair Hall, Distinguished Scientist at Measurement Standards Laboratory of New Zealand (MSL)
- Robert Hanisch, Director of the Office of Data and Informatics (NIST), USA
- Brett Hyland, Project lead at UN/CEFACT and NATA Australia
- Martin Koval, Chair of the FORUM-MD ad hoc Task Group on Harmonizing DCC and DRMC, Czech Metrology Institute (CMI), Czech Republic
- Thomas Krah, CEO of German Calibration Service DKD, Germany
- Mark Kuster, Chair of "Metrology Practices" and "MII & Automation Committees" at NCSLI, USA
- Hector Laiz, Director of Metrology and Quality, INTI, Argentina
- Kim Nguyen, Assessor of the Board of D-Trust GmbH, Germany
- Anjali Sharma, Senior Principal Scientist and Head, NPLI, India
- Shanna Schönhals, Group Lead and Head of DCC Development Team at PTB, Germany
- Alexis Valqui, Digital Transformation Consultant, Peru

Agenda and Chairpersons

2025-02-25 (Tuesday)

UTC	2025-02-25 (Tuesday) Plenary Session (Chair: Martin Koval)
12:00	Welcome and Key Notes (Martin Koval, Cornelia Denz, Cui Shan)
12:30	#P01 Brett Hyland - Interoperable conformity data exchange in a digital quality infrastructure - update from UNECE
13:00	#P02 Ciro Alberto Sánchez - Advancing Digital Calibration Certificates: The INM's Role in Modernizing Metrological Services in Latin America

13:30	Break	
	Key Aspects of DCC I (Chair: Shanna Schönhals)	**Applications NMI I** (Chair: Brett Hyland)
14:00	#001 Thomas Krah Harmonisation of DCCs in DKD – an update	#006 Rodolfo Manuel Gomez Rodriguez Concepts and frameworks fostering interoperability within a digital quality infrastructure: DCC development in Colombia and QI infrastructure interoperability under an Enterprise Architecture Framework
14:20	#002 Julian Haller Harmonisation of DCCs for non-automatic weighing instruments (NAWIs) through a DKD expert report to ensure full interoperability	#007 Ryu Dong-Hun Calibration support system development of KTL (Korea Testing Laboratory) using certificate database established by OCR
14:40	#003 Shanna Schönhals Implementation of Digital Calibration Certificates for Force Calibration According to ISO 376	#008 Praiya Thongluang The Web-Based Digital Calibration Certificate Generation Platform developed by NIMT
15:00	#004 Mark Kuster A Taxonomy of Radiometric-Measurand Metadata	#009 Itzel Dominguez Generating Mass DCC based on DKD expert report using a spreadsheet
15:20	#005 Andrew Freund A Matter of Trust.	#010 Yoshitha Weerasinghe Real-World Applications of Digital Calibration Certificates (DCC): Use Cases and Implementation Stories

2025-02-26 (Wednesday)

UTC	2025-02-26 (Wednesday) Plenary Session (Chair: Hugo Gasca)		
12:00	#P03 Tuukka Mustapää - Advances in the DCC enablement at Beamex		
12:30	#P04 Gean Marcos Geronymo - Python-based DCC Tools Development and Implementation		
13:00	#P05 Thomas Engel - DCC in production mode		
13:30	Break		
	Tools & Software (Chair: Anjali Sharma)	**Industry Applications** (Chair: Carlos Galvan)	**Applications NMI II** (Chair: Jariya Buajarern)
14:00	#011 David Balslev-Harder Getting Started with Digital Calibration Exchange (DCX): Software Tools, Interfaces, and Workflow Integration	#016 Christian Sander Instructions for using the DCC scheme to create a digital calibration certificate for gauge blocks	#021 Henrike Fleischhack Digital Calibration Certificates for Radioactivity and FAIR Data Exchange
14:20	#012 Alexander Reissert GEMIMEG 2.0: Evolution of the concept and implementation of the GEMIMEG Tool	#017 Aldo Adrián García González Automation in calibration process using DCC, primary to secondary labs.	#022 Diego Coppa Transport of DCC with cryptographic signature in PDF/A
14:40	#013 Justin Jagieniak Formula Evaluation and MathML Processing in Python: A High-Precision Framework for XML documents like the DCC	#018 Tomasz Sołtysiński Semantic registration of DCC and DCoC onto Information Model of International Data Spaces	#023 Blair Hall A service to authenticate documents issued by MSL

| 15:00 | #014 Benedikt Seeger
Consistent Representation and Usage of Tabulated Data in the DCC. Enable Easy-To-Use Computer-Aided Processing and Visualization of Your Data | #019 Lisa Busser
DCC in a Mass-Calibration Software | #024 Beste Korutlu
Progressive Shift towards Digitalization in TUBITAK UME Mass Laboratory |
| 15:20 | #015 Arif Sanjid
A framework for digitising dimensional metrology | #020 Jens Leinhos
Progress Towards Producing DCC with Standard Structured Measurand Information | #025 Søren Kynde
Practical Applications of Digital Calibration Exchange (DCX) covering Certificates, Requests, and Templates |

2025-02-27 (Thursday)

UTC	2025-02-27 (Thursday) Plenary Session (Chair: Hektor Laiz)		
12:00	#P06 Martin Koval - Motivation for using DCC		
12:30	#P07 Anjali Sharma - Modelling Digital Calibration Certificates Using Object-Oriented Technologies to Address Heterogeneity and Harness FAIR Principles		
13:00	#P08 Sajiv Perera - DCC Sharing within a Government Agency		
13:30	Break		
	Schema & Semantics (Chair: Robert Hanisch)	Key Aspects of DCC II (Chair: Mark Kuster)	DCR & DRMC (Chair: Alexis Valqui)
14:00	#026 Moritz Jordan Augmenting the DCC Framework with the DSI Ontology: Enabling Semantic Web Integration in Calibration Data Management	#030 Blair Hall Calibration and metrological traceability	#035 Heidi Foldal Implementation of Digital Calibration Request, DCR
14:20	#027 Muhammed-Ali Demir The latest version of the DCC	#031 Christian Müller-Schöll Traceability chains using the DCC	#036 Martin Cradock Østerlund Benefits of developing DCR with a focus on machine readability and automation.
14:40	#028 David Balslev-Harder An In-Depth Look at the DCX Schema	#032 Ulrich Harmes-Liedtke Applying FAIR Principles to Quality Infrastructure Data for Economic Analysis - Approaching Challenges in Data Availability, Accessibility, and Interoperability	#037Michael Melzer The Digital Reference Material Document Derived from the DCC
15:00	#029 Muhammed-Ali Demir Compatible sub schemata of the DCC Schema	#033 Jon Gabirondo-López A new data structure for improved scientific data reporting a FAIR compliant manner	#038 Dinis Camara The Digital NIST: Update on the Digital Transformation of Reference Materials
15:20	**Open Exchange on Schema and Semantics**		**Open Exchange on DCR and DRMC**
15:40	Closing Session		

Day 1 2025-02-25 (Tuesday)
Plenary Session (Chair: Martin Koval)

Welcome address of the president of PTB,
Prof. Dr. Cornelia Denz, Germany

Dear representatives of the National Metrology Institutions, dear speakers of the 5th DCC conference, dear attendees, it is a great pleasure welcoming you to the 5th International Conference on the Digital Calibration Certificates - DCC number 5. I am happy that you have followed the call to the digital DCC conference in such a large number.

In previous years, I have referred to the corresponding number of our DCC conference series in my welcome speech. On the occasion the 3rd DCC conference, I referred to the German saying *Aller guten Dinge sind Drei* or *All great things come in three*. On the occasion of the 4th DCC conference, I referred to a compass with its four celestial directions.

And I would like to continue this today. With the 5th edition of the DCC conference, we celebrate a special birthday.

For most children, reaching the age of five means starting school and increasing their independence. This is why the 5th birthday is often considered a milestone.

This is without any doubt also true for the 5th DCC conference, especially with respect to the number of participants and their world-wide representation.

The number five is often accompanied – saying it in metrological terms – by the prefix Big.

In Africa, the Big Five represent royal animals as the lion, the leopard, the rhinoceros, the elephant, and the buffalo. The term was originally coined by hunters to refer to the five most difficult animals in Africa to hunt. Nowadays it is widely used by safari tourists for spotting these animals. The Big Five animals of Africa are also famous since they appear on South African Rand banknotes.

Trait theory is another field referring to the role of number five. The Big Five model describes human personality in five core dimensions:

openness, conscientiousness, extraversion, agreeableness and neuroticism.

The model is often referred to as the OCEAN model due to the initial letters of the English names of the five trait dimensions.

Extraversion is sociability, being bold and energetic; agreeableness is kindness, being sympathetic or cooperative; openness to experience, intellect, or imagination includes creativity and intrigue; conscientiousness is thoughtfulness in the sense of efficiency and being organized; neuroticism refers to emotional stress.

The rational of the model is the assumption that a personality is made up of varying degrees of the five core elements. Specific personality profiles are then created from the individual distributions.

Is it possible to transfer the idea of the Big Five traits to the DCC? To do so, I'd like to take a closer look at the successes, challenges and developments of DCC since the last conference and compare them to the five personality profiles.

First, considering the challenges of the DCC in the near future, one definitely finds the trait of openness. A high degree of openness shows a thirst for knowledge, a willingness to experiment and to tackle new aspects with imagination, interest, and joy of abstract thinking.

The harmonization as well as the variability of DCC schemas require precisely these aspects of openness. Openness to different formats for example that can be exchanged or transferred from one to another in a variable way is important for the future of the DCC.

This includes openness to harmonization of various metrological disciplines as well as harmonization of certificates for different purposes. For example, harmonization will be important between DCC and DCR, the digital calibration request, between DCC and DPP, the digital product pass, or between DCC and DRMC, the digital reference material certificate. The challenging future question is, if these certificates can be directly derived or adapted from the DCC schema, or if it needs to be schematically different.

I am absolutely confident that there is world-wide a very high level of openness and many ideas how to face this challenge. Let me name some examples.

In September 2024, the metrological community was meeting at the premier event in measurement science and applications in Hamburg. The IMEKO World Congress brought together more than 1.000 metrological minds, and digitalization in metrology and the DCC played a prominent role in many sessions and workshops.

A timely workshop was held in conjunction with the Conference International de Poids et Measure, CIPM, and its newly founded horizontal structure Metrology and Digitalization. It was focused on basics of metrological traceability in the digital era, especially traceability in today's digital measurement infrastructure, and subsequently addressed applications such as digital twins, virtual data spaces, sensor networks and the DCC, all with respect to traceability *and also* provenance of data.

Furthermore, due to the fact that digital calibration certificates are developed both by national metrology institutes and calibration laboratories worldwide, a workshop dedicated solely to the DCC took also place at the conference.

It provided a deep insight into the international status of the DCC development. It combined short pitches with news from different Regional Metrology Organizations, and project results of the EURAMET Technical Committee TC-IM 1448. The newly established CIPM Task Group on Harmonization of DCC and DRMC, one of seven task and working groups of the Forum Metrology and Digitalization of CIPM, was also introduced and contributed user success stories.

These examples show that the DCC is also a social animal, that loves to gain energy by cooperation - a strong characteristic of extraversion. I assume that the DCC is highly scoring in extraversion as it is likely to start more and more effective interactions, allowing the DCC to attract a wider circle of interested stakeholders.

Furthermore, the DCC is highly scoring in agreeableness because it tends to be cooperative and includes attributes such as FAIRness. Being findable, accessible, interoperable and reusable can be interpreted as features for common understanding, contributing to the harmonization – and with it the satisfaction of different stakeholders with the DCC.

This can also be associated with the dissemination of the DCC. In the digital transformation era, new opportunities emerge almost every day in trade and industry through digital data traffic. This upheaval is challenging for the quality infrastructure, consisting of metrology, standardisation, accreditation, conformity assessment and market surveillance.

Here, the DCC can contribute digital traceability, provenance as well as FAIR data quality as a highly relevant profile for quality infrastructure and industry: it enables the seamless integration of calibration data into industrial processes and ensures a greater transparency - for more quality, productivity and lower costs.

One of the companies that collaborates with PTB on this avenue, is Testo Industrial Services, which relies on the digital calibration certificate and encourages its customers to digitize. For this purpose, a best practice example for a caliper gauge was established together with PTB. Also, the implementation of the DCC by large pharma industry companies as Boehringer Ingelheim shows, how important the DCC is for different industrial sectors.

In order to establish secure and robust calibrated measurement systems for the digital transformation, it is also important to develop internationally agreed basic standards to ensure reliable communication of digital information and certificates in the world-wide quality infrastructure processes.

An important standard is the International System of units in the digital version - the SI digital reference point. It has now been fully established by the international Metrology at BIPM. It is a tremendous enabler of the digital transformation in metrology and gives the DCC the right base for traceability of the measurements behind the certificates.

At the same time, digitalization has implications for development cooperation. For example, digital transformation can lead to a mitigation of existing economic or social disparities for developing countries and allows them to connect to the digital services of the quality infrastructure as DCC.

The fourth of the five personality traits I like to connect to the DCC is the way in which negative emotions are dealt with. And that is Neuroticism.

In such a dynamic and at the same time protracted process as digitalization and the necessary interaction of different stakeholders, with different interests, priorities and sensitivities, it would be perfectly understandable that worries about different aspects of digitalization are appearing. However, I experience that neuroticism is nearly not existing in the community around the DCC. This is on the one hand because it actually leads to many advantages, to efficiency, stability, and resilience, but also because the community is discussing together important developments of the DCC in conferences like today and come quickly to common grounds.

This is also true within today's conference program: Advances in machine-actionable format, data tailored to the quality infrastructure, industrial implementations and convincing use cases and success stories of digital certificates, and solutions enabling uptake of FAIR data across systems and processes, fostering interoperability within a digital quality infrastructure are all hot topics that will be will be presented and discussed in different sessions throughout the three days of the conference.

Last but not least there is conscientiousness as the fifth personality trait. It is defined by high levels of thoughtfulness, and goal-directed behaviors. This is not only fully true for the DCC but also for this conference.

In this spirit, I would like to take the opportunity to express my sincere gratitude to the DCC team at PTB, head by the powerful trio of Wiebke Heeren, Franziska Decker and Shanna Schönhals, who did a tremendous job organizing this large conference, together with the 15 active and engaged members of the International Program Committee. Please give them a very warm digital applause.

I want to close by wishing you a great conference with the big five: inspiring talks, intensive discussions, many interactions, expanding networks, and innovative, forward-looking ideas – all for versatile digital certificates of tomorrow.

Thank you.

Presentation of Martin Koval

14 Members of the International Programme Committee (IPC)

David Balslev-Harder, Team Leader at Dansk Fundamental Metrologi (DFM), Denmark

Jariya Buajarern, Head of Digital Center and Materials Metrology, Quality System and International Cooperation Office, NIMT, Thailand

Carlos Galván, Dirección Metrología Dimensional, CENAM, Mexico

Hugo Gasca Aragon, Co-Chair of IMEKO TC6 Digitalization

Blair Hall, Distinguished Scientist at Measurement Standards Laboratory of New Zealand (MSL)

Robert Hanisch, Director of the Office of Data and Informatics (NIST), USA

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Shanna Schönhals, Group Lead and Head of DCC Development Team at PTB, Germany

Alexis Valqui, Digital Transformation Consultant, Peru

5TH INTERNATIONAL DCC CONFERENCE

Chair and Co-Chair of the International Programme Committee (IPC)

- Chair: Martin Koval, CMI

- Co-Chair: Shanna Schönhals, PTB

5TH INTERNATIONAL DCC CONFERENCE

Key Notes

Cornelia Denz, President of PTB and Chair of FORUM-MD

Cui Shan, NMC A*Star, Chair of APMP Focus Group on Digital Transformation

5TH INTERNATIONAL DCC CONFERENCE
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Plenary sessions

Plenary Session	DAY 1	DAY 2	DAY 3
12:00	**Welcome and Key Notes** (Martin Koval, Cornelia Denz, Cui Shan)	**#P03 Tuukka Mustapää** Advances in the DCC enablement at Beamex	**#P06 Martin Koval** Motivation for using DCC
12:30	**#P01 Brett Hyland** Interoperable conformity data exchange in a digital quality infrastructure - update from UNECE	**#P04 Gean Marcos Geronymo** Python-based DCC Tools Development and Implementation	**#P07 Anjali Sharma** Modeling Digital Calibration Certificates Using Object-Oriented Technologies to Address Heterogeneity and Harness FAIR Principles
13:00	**#P02 Ciro Alberto Sánchez** Advancing Digital Calibration Certificates: The INM's Role in Modernizing Metrological Services in Latin America	**#P05 Thomas Engel** DCC in production mode	**#P08 Sajiv Perera** DCC Sharing within a Government Agency
13:30 - 14:00	**Break**		

5ᵀᴴ INTERNATIONAL DCC CONFERENCE
DCC FOR FAIR PRINCIPLES IN THE QUALITY INFRASTRUCTURE

DAY 1

Parallel Sessions	Key Aspects of DCC I	Applications NMI I
14:00	**#001 Thomas Krah** *Harmonisation of DCCs in DKD – an update*	**#006 Rodolfo Manuel Gomez Rodriguez** *Concepts and frameworks fostering interoperability within a digital quality infrastructure: DCC development in Colombia and QI infrastructure interoperability under an Enterprise Architecture Framework*
14:20	**#002 Julian Haller** *Harmonisation of DCCs for non-automatic weighing instruments (NAWIs) through a DKD expert report to ensure full interoperability*	**#007 Ryu Dong -Hun** *Calibration support system development of KTL(Korea Testing Laboratory) using certificate database established by OCR*
14:40	**#003 Shanna Schönhals** *Implementation of Digital Calibration Certificates for Force Calibration According to ISO 376*	**#008 Praiya Thongluang** *The Web-Based Digital Calibration Certificate Generation Platform developed by NIMT*
15:00	**#004 Mark Kuster** *A Taxonomy of Radiometric -Measurand Metadata*	**#009 Itzel Dominguez** *Generating Mass DCC based on DKD expert report using a spreadsheet*
15:20	**#005 Andrew Freund** *A Matter of Trust.*	**#010 Yoshitha Weerasinghe** *Real-World Applications of Digital Calibration Certificates (DCC): Use Cases and Implementation Stories*

5ᵀᴴ INTERNATIONAL DCC CONFERENCE
DCC FOR FAIR PRINCIPLES IN THE QUALITY INFRASTRUCTURE

DAY 2

Parallel Sessions	Tools & Sofware	Industry Applications	Applications NMI II
14:00	**#011 David Balslev-Harder** *Getting Started with Digital Calibration Exchange (DCX): Software Tools, Interfaces, and Workflow Integration*	**#016 Christian Sander** *Instructions for using the DCC scheme to create a digital calibration certificate for gauge blocks*	**#021 Henrike Fleischhack** *Digital Calibration Certificates for Radioactivity and FAIR Data Exchange*
14:20	**#012 Alexander Reissert** GEMIMEG 2.0: Evolution of the concept and implementation of the GEMIMEG Tool	**#017 Aldo Adrián García González** *Automation in calibration process using DCC , primary to secondary labs.*	**#022 Diego Coppa** *Transport of DCC with cryptographic signature in PDF/A*
14:40	**#013 Justin Jagieniak** *Formula Evaluation and MathML Processing in Python: A High-Precision Framework for XML documents like the DCC*	**#018 Tomasz Sołtysiński** *Semantic registration of DCC and DCoC onto Information Model of International Data Spaces*	**#023 Blair Hall** *A service to authenticate documents issued by MSL*
15:00	**#014 Benedikt Seeger** *Consistent Representation and Usage of Tabulated Data in the DCC. Enable Easy-To-Use Computer-Aided Processing and Visualization of Your Data*	**#019 Lisa Busser** *DCC in a Mass-Calibration Software*	**#024 Beste Korutlu** *Progressive Shift towards Digitalization in TUBITAK UME Mass Laboratory*
15:20	**#015 Arif Sanjid** A framework for digitising dimensional metrology	**#020 Jens Leinhos** *Progress Towards Producing DCC with Standard Structured Measurand Information*	**#025 Soeren Kynde** *Practical Applications of Digital Calibration Exchange (DCX) covering Certificates, Requests, and Templates*

5ᵀʰ INTERNATIONAL DCC CONFERENCE
DCC FOR FAIR PRINCIPLES IN THE QUALITY INFRASTRUCTURE

DAY 3

Parallel Sessions	Schema & Semantics	Key Aspects of DCC II	DCR & DRMC
14:00	**#026 Moritz Jordan** *Augmenting the DCC Framework with the DSI Ontology: Enabling Semantic Web Integration in Calibration Data Management*	**#030 Blair Hall** *Calibration and metrological traceability*	**#035 Heidi Foldal** *Implementation of Digital Calibration Request, DCR*
14:20	**#027 Muhammed-Ali Demir** *The latest version of the DCC schema V3.3.0*	**#031 Christian Müller-Schöll** *Traceability chains using the DCC*	**#036 Martin Cradock Østerlund** *Benefits of developing DCR with a focus on machine readability and automation.*
14:40	**#028 David Balslev-Harder** *An In-Depth Look at the DCX Schema*	**#032 Ulrich Harmes-Liedtke** *Applying FAIR Principles to Quality Infrastructure Data for Economic Analysis - Approaching Challenges in Data Availability, Accessibility, and Interoperability*	**#037Michael Melzer** *The Digital Reference Material Document Derived from the DCC*
15:00	**#029 Muhammed-Ali Demir** *Compatible sub schemata of the DCC Schema*	**#033 Jon Gabirondo-López** *A new data structure for improved scientific data reporting in a FAIR compliant manner*	**#038 Dinis Camara** *The Digital NIST: Update on the Digital Transformation of Reference Materials*
15:20	Open Exchange on Schema and Semantics		Open Exchange on DCR and DRMC

5ᵀʰ INTERNATIONAL DCC CONFERENCE
DCC FOR FAIR PRINCIPLES IN THE QUALITY INFRASTRUCTURE

Conference Chairs

Session	Chairs
DAY 1	
Plenary Session	Martin Koval
Key Aspects of DCC I	Shanna Schönhals
Applications NMI I	Brett Hyland
DAY 2	
Plenary Session	Hugo Gasca
Tools & Sofware	Anjali Sharma
Industry Applications	Carlos Galvan
Applications NMI II	Jariya Buajarern
DAY 3	
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Schema & Semantics	Robert Hanisch
Key Aspects of DCC II	Mark Kuster
DCR & DRMC	Alexis Valqui

5TH INTERNATIONAL DCC CONFERENCE
DCC FOR FAIR PRINCIPLES IN THE QUALITY INFRASTRUCTURE

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In case of technical questions or issues please contact the team at dcc-conference-2025@ptb.de

5TH INTERNATIONAL DCC CONFERENCE

Conference Agenda

UTC	Tuesday		Wednesday			Thursday		
12:00 – 12:15	**Welcome and Key Notes** *(Martin Koval, Cornelia Denz, Cui Shan)*		**#P03 Tuukka Mustapää** - *Advances in the DCC enablement at Beamex*			**#P06 Martin Koval** - *Motivation for using DCC*		
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13:30 – 13:45	**Break**		**Break**			**Break**		
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15:40 - 16:00	-		-			**Closing Session**		

5ᴛʜ INTERNATIONAL DCC CONFERENCE
DCC FOR FAIR PRINCIPLES IN THE QUALITY INFRASTRUCTURE

P01 Interoperable conformity data exchange in a digital quality infrastructure - update from UNECE

Presenting author: Brett Hyland, Project Lead at UN/CEFACT, NATA Australia
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Additional authors: Nil

Abstract

Conformity data related to traded goods differs in quite fundamental ways compared with calibration and other equipment assurance data, yet there are potential payoffs if a degree of interoperability could be achieved. The United Nations Economic Commission for Europe (UNECE) has presented for public review a draft policy recommendation for governments, UNECE Recommendation 49 - Transparency at Scale, which outlines the need for interoperable and platform-independent streams of information for substantiating claims about product sustainability attributes. A central element of this recommendation is a conformity credential, designed to digitally capture basic product conformity information within a hosted file that also links to the underlying conformity certificate (which may be in analogue, digital or hybrid form and may also be encrypted). Numerous implementations of this general approach are proceeding under a specification known as the United Nations Transparency Protocol, in which the credential file is cryptographically verifiable back to its issuing body in a tamper-evident manner and includes provision for referencing relevant endorsement credentials (such as those issued by accreditation bodies) in either digital or analogue form. It is hoped that increased awareness of these developments may facilitate discussion regarding digitalisation matters between the scientific and trade measurement community and the wider conformity community.

Presentation of Brett Hyland

Interoperable conformity data exchange in a digital quality infrastructure

Update from UNECE

25 February 2025

Brett Hyland
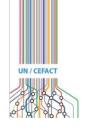NATA Australia
& UN/CEFACT Project Lead

UNECE Recommendation 49 Public Review

A new **United Nations Economic Commission for Europe (UNECE)** Recommendation is now **OPEN** for Public Review:

Recommendation No. 49
Transparency at Scale

- This a draft recommendation to member states, promoting the value of transparent supply chain data exchange using international and interoperable standards and based on an open architecture
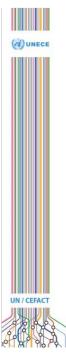- To be considered for adoption at the July 2025 UN/CEFACT Plenary

Reducing costs, increasing participation

To encourage maximum inclusion, digital trade systems cannot favour rich countries or create unjustified barriers for small businesses.

This means:

- adopting internationally accepted approaches, emphasising open development and free resources

- adopting an open architecture, so that stand-alone technology platforms do not add friction to data exchange or be leveraged to disadvantage certain participants

- providing a backbone of trust to supply chain data and making the trust anchors verifiable by any participant - but leaving decisions regarding the acceptability of specific trust anchors up to the buyers.

Perhaps we should start at the beginning

- why is the UN interested in supply chain transparency?

The problem of greenwashing

United Nations Sustainable Development Goals depend on the reliability of claims being made about product sustainability.

A race to the top:

It's hard to fake claims!

Consumer confidence improves

Higher prices are justified

Business is motivated to make provable claims

A race to the bottom:

It's easy to fake claims!

Even well-intentioned businesses must fake claims to survive.

Low confidence means no price differential

Consumer confidence drops

Digitalisation can help shift the balance, favouring a race to the top

Transparency at Scale

UNECE Recommendation 49 'Transparency at Scale' is about finding equitable and scalable ways for discovering and verifying information that supports a claim made about a product.

But does it have anything to do with Metrology? *Potentially 'yes'* if product claims are based on measurement and where access to a testing laboratory's certificates (DCC/DRMC/…) may become relevant. Or if a certified cargo quantity is included in the trade data.

Transparency at scale for metrology?

A completely different question (but possibly still interesting) is whether entire chains of measurement traceability might be constructed using a similar architecture, noting some common ground with trade data:

- A common need to **link data with physical objects** and a potential role for **product passports** (for instrument/artefact/material as well as for traded goods)
- A common need for **verifiable access** to certificates/reports
- Both involve certificates/reports that are **subject to revision/withdrawal**
- Common **assessment/accreditation** frameworks exist
- Data confidentiality may not suit **publicly accessible registers**

UN/CEFACT

The **United Nations Centre for Trade Facilitation and eBusiness (UN/CEFACT)** is an intergovernmental body, established in 1966, which aims to deliver simple, transparent and effective processes for global commerce.

In particular, UN/CEFACT facilitates national and international transactions, through the simplification/harmonization of processes and information flows.

One major area of focus:
Digital exchange of trade data that supports product sustainability claims.

Some data challenges to be addressed

Making data trustworthy!

Some suppliers exploit non-verifiable data points to give non-compliant products the appearance of compliance.

Interoperablility!

Closed (non-interoperable) data exchange systems mean that many participants adopt a 'wait and see' approach to digitalisation, due to the dependency on other supply chain actors for enabling data flow.

Accessibility vs confidentiality!

There is tension between requirements for disclosure and protection of commercially sensitive data.
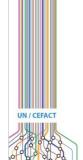
Some milestones

June 2022 – a workstream was created for the development of a standard for conformity data exchange/access

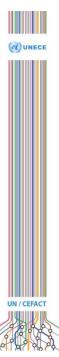July 2024 - a Business Requirements Specification was published titled: Digital Product Conformity Certificate Exchange – High Level Process

October 2024 – The United Nations Transparency Protocol (UNTP) released as a specification for testing

February 2025 - Public review version of UNECE Rec#49 lists UNTP as a representation of relevant principles uncefact.unece.org/display/uncefactpublicreview
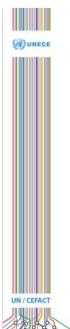
Let's take a quick dive into UNTP

A framework for certificate discovery and verification
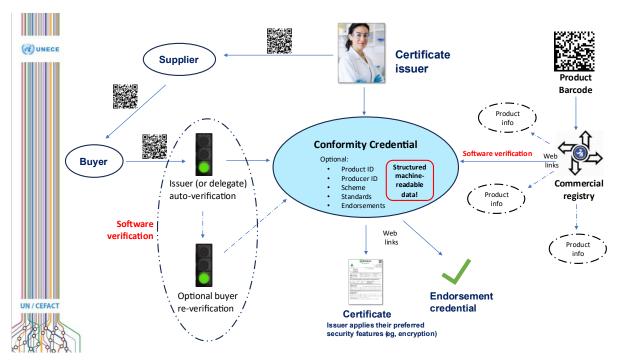
Support for issued certificates within UNTP
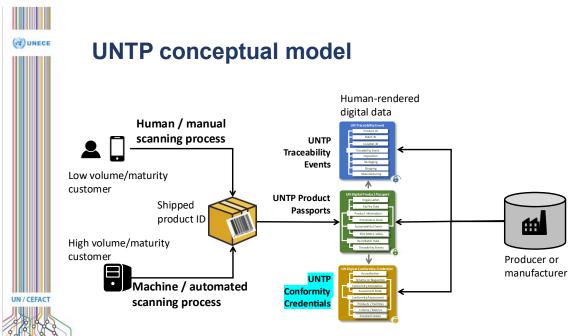
Digitalisation of certificates is not within the scope of this work

The certificate - whether analogue, digital or hybrid - remains the key reference for conformity data and so the focus is providing a surrounding framework offering:
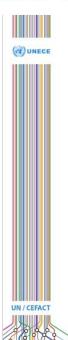
1. A means of discovering relevant certificates from products of interest in a tamper-evident & machine-readable manner.

2. Verifiable connections between data points, including any trust anchors like testing/certification bodies, accreditation bodies and regulators.

3. Compatibility with confidentiality requirements of supply chain actors (including third party selective redaction).

UNTP conceptual model
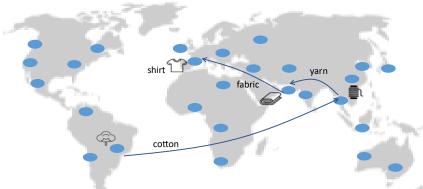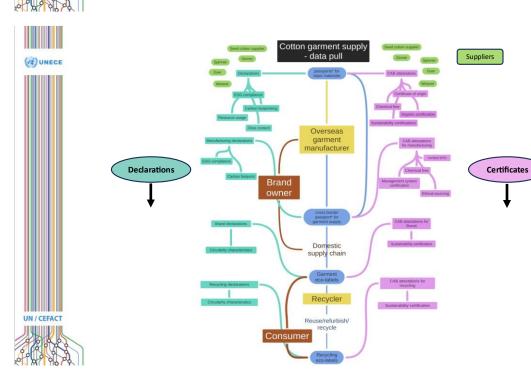
Interoperability protocol - not a platform

Leave data where it is - but link it together when needed
Use any software you like – so long as it conforms to UNTP

shirt
yarn
fabric
cotton

Thousands of platforms, millions of value-chains, billions of transactions

Cotton garment supply - data pull

Suppliers

Declarations

Certificates
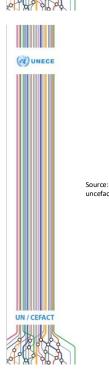
Resources
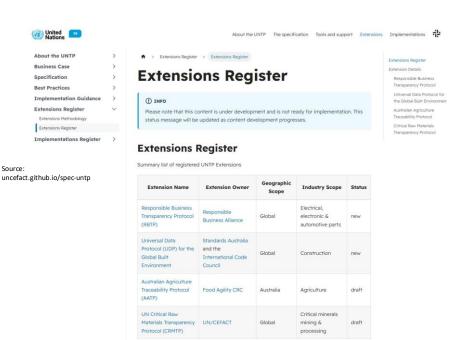
All UNTP resources are available without charge and are royalty free
https://uncefact.github.io

- UNTP embraces relevant international protocols, including the open source and free World Wide Web Consortium (W3C) protocols for Decentralised Identifiers (DID), Verifiable Credentials and compatible alternatives
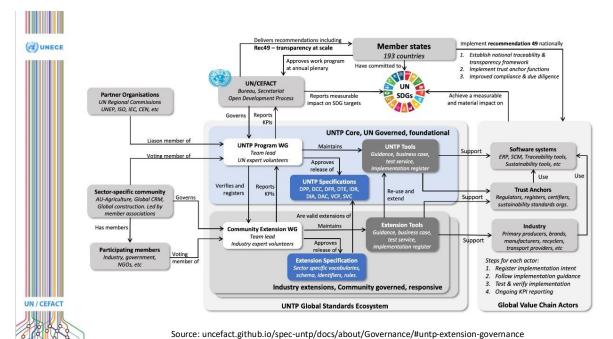
Industry adoptions of UNTP can be registered, either as an 'implementation' (for selected UNTP elements) or as an 'extension' (with extensions owned and managed by the party undertaking the extension).
https://uncefact.github.io/spec-untp/docs/implementations
https://uncefact.github.io/spec-untp/docs/extensions

Source:
uncefact.github.io/spec-untp

Extensions Register

⊙ INFO

Please note that this content is under development and is not ready for implementation. This status message will be updated as content development progresses.

Extensions Register

Summary list of registered UNTP Extensions

Extension Name	Extension Owner	Geographic Scope	Industry Scope	Status
Responsible Business Transparency Protocol (RBTP)	Responsible Business Alliance	Global	Electrical, electronic & automotive parts	new
Universal Data Protocol (UDP) for the Global Built Environment	Standards Australia and the International Code Council	Global	Construction	new
Australian Agriculture Traceability Protocol (AATP)	Food Agility CRC	Australia	Agriculture	draft
UN Critical Raw Materials Transparency Protocol (CRMTP)	UN/CEFACT	Global	Critical minerals mining & processing	draft

Source: uncefact.github.io/spec-untp/docs/about/Governance/#untp-extension-governance

Exchange of ideas

It would be very nice to leverage existing communication channels (formal and informal) to exchange ideas between the trade data world and the world of metrology, noting that:

- Some laboratories are involved in providing test results for traded goods while also undertaking metrology activities and, similarly, most accreditation bodies work across both testing and calibration (often certification as well)

- Exchanging ideas across different domains might enhance compatibility and assist in planning for future directions

On a personal note, I would like to express my deep gratitude to the International DCC Conference for doing exactly this!!

Thank you!

For more information
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P02　Advancing Digital Calibration Certificates: The INM's Role in Modernizing Metrological Services in Latin America

Presenting author: Giro Alberto Sanchez, Instituto Nacional de Metrologia de Colombia (INM)
Email: csanchez@inm.gov.co

Abstract

The digital transformation of quality infrastructure has become a key driver for enhancing efficiency, traceability, and interoperability in metrological processes. Digital Calibration Certificates (DCC) are central to this transformation, offering machine-actionable information that supports seamless data exchange among laboratories, accreditation bodies, and stakeholders. This abstract focuses on the pivotal role played by the National Metrology Institute (INM) in promoting the adoption and development of DCCs, highlighting its efforts in preparation, standardization, and socialization.

The INM has been actively involved in initiatives under the Inter-American Metrology System (SIM) to promote the digitalization of metrological services. Its general experience in this field includes the production of reference materials via a timestamped environment and participation in various seminars organized by the PTB of Germany, BIPM, and SIM, which provided key guidelines on the development of digital infrastructures. These efforts have laid the groundwork for future DCC implementation.

A real-world use case from the INM's Temperature and Humidity Laboratory illustrates the early stages of a project aimed at integrating DCCs into routine calibration processes. Supported by standards for digital languages provided by PTB, this initiative anticipates national industry needs and enhances compliance with ISO/IEC 17025 requirements regarding traceability and reporting. The adoption of DCCs not only enhances data integrity and reduces errors but also supports the modernization of metrological services.

Key challenges encountered during the implementation include ensuring interoperability with existing quality management systems, meeting stakeholder expectations for usability, and aligning with international frameworks for digital quality infrastructure. By addressing these challenges, this project contributes to the development of a harmonized approach to DCC adoption across the region.

This work concludes by outlining recommendations for future developments, including the creation of regional guidelines for DCC implementation, further stakeholder engagement, and the exploration of software solutions that facilitate integration. These efforts aim to foster greater consistency in the application of DCCs, ultimately supporting the modernization of metrological services in Latin America.

Keywords: Digital Calibration Certificates, ISO/IEC 17025, quality infrastructure, metrology, interoperability, Latin America.

Presentation of Giro Alberto Sanchez

Instituto Nacional de
Metrología de Colombia

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Advancing Digital Calibration Certificates: The INM's Role in Modernizing Metrological Services in Latin America

Ciro A. Sánchez, Jeyson A. Monroy and Adrian L. Blandón

Instituto Nacional de Metrología de Colombia – INM

February 25th, 2025

Introduction and Context

Introduction
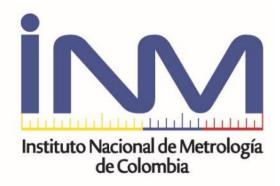
- Overview of Digital Calibration Certificates (DCC) and their impact on metrological traceability.

- Strategic importance of digital transformation in metrology.

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INM's Role in Digital Transformation

- Leading the implementation of DCC in Latin America.

- Enhancing interoperability and data integrity in metrological processes.

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Inter-American Metrology System - SIM

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Introduction to SIM

- **Inter-American Metrology System (SIM)**

    - A regional organization promoting metrology cooperation across the Americas.

    - Enhances the quality infrastructure by fostering collaboration among National Metrology Institutes (NMIs).

    - Aims to support trade, health, safety, and environmental protection through reliable measurements.

Digital Transformation in Metrology at SIM

- **Driving Digital Quality Infrastructure**: Enhancing reliability and efficiency in calibration and testing.

- **Promoting Digital Metrological Traceability**: Ensuring accurate and consistent measurements across member countries.

- **Collaboration and Innovation**: Facilitating cooperation between NMIs to develop digital solutions for metrology.

- **Strategic Vision**: Leading the region in adopting international standards for digitalization in metrology.

SIM's Working Group on Digital Transformation (SIM-MWG14-M4DT)

- **Objective and Focus Areas**
    - Leads digital transformation initiatives within the SIM community.
    - Focuses on:
        - Digital Quality Infrastructure
        - Digital Metrological Traceability
        - Metrology for AI

Achievements and Plans

- **Barothermohygrometer Prototype (2023 – 2024):** A prototype was developed to measure environmental conditions, enhancing digital metrological infrastructure.

- **2025 Goal:** To share the measurements obtained with the prototype across different countries, promoting digital transformation in the region.

- **Calibration and DCC Issuance:** Plans include calibrating the barothermohygrometer and issuing DCCs, ensuring interoperability and traceability in the digital environment.

Implementation in the Temperature and Humidity Laboratory

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Progress Report
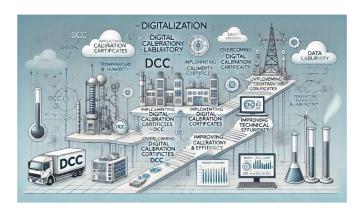
• Project 2404076, undertaken by the Measurement Automation Group, titled 'Digital Calibration Certificate in the INM Temperature and Humidity Laboratory', was an initiative within the framework of the digital transformation of the services offered by the National Institute of Metrology (INM).

• The main objective of this project was to adapt the Digital Calibration Certificate (DCC) prototype, which was previously developed for the Time and Frequency Laboratory in 2023, specifically for the Premium Legal Time service. This adaptation aims to enable the issuance of digital calibration certificates for the thermometer calibration service in the Temperature and Humidity Laboratory.

• By implementing this digitalization process, the project seeks to enhance calibration and certification procedures, improving the efficiency and traceability of the services provided by INM.

System Architecture and Integration

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- **Framework:** Django with Python, leveraging flexibility and scalability for digital certificates.

- **Database Adaptation:**

  - Modified the existing database to support thermometer calibration data.

  - Ensured data integrity and traceability through a structured storage system.

- **Script Development and Automation:**

  - Customized scripts to automate certificate generation, reducing manual intervention.

  - Enhanced efficiency and minimized errors in the calibration documentation process.

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Digitalization Workflow

- **Certificate Generation Process:**

  - Input: Calibration data collected from thermometers.

  - Processing: Data validation, calculation of measurement uncertainty, and certificate formatting.

  - Output: Digital Calibration Certificate (DCC) in XML format, ensuring compatibility and interoperability.

- **Integration in Existing Infrastructure:**

  - Seamless connection with laboratory management systems.

  - Ensured compliance with ISO/IEC 17025 requirements for calibration traceability.

Technical Challenges and Solutions

- **Interoperability Issues:**

  - Challenge: Integrating DCC into the existing technological infrastructure and ensuring data exchange.

  - Solution: Utilized XML schema standards to enable seamless communication between systems.

- **User Adoption and Training:**

  - Challenge: Transition from traditional to digital calibration certificates.

  - Solution: Conducted training sessions and developed user guides for laboratory personnel: digital certificates.

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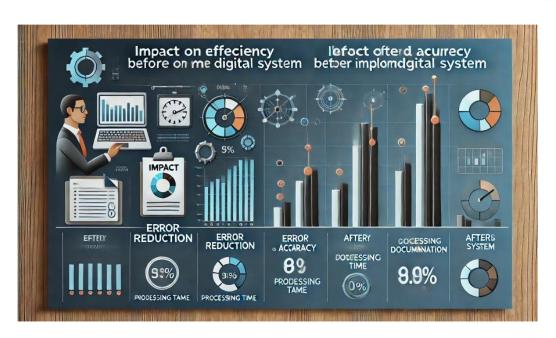
- **Data Security and Integrity:**

  - Challenge: Ensuring the authenticity and protection of digital certificates

  - Solution: Implemented encryption protocols and digital signatures.

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Results and Impact

- **Efficiency Gains:**

  - Certificate issuance times are expected to decrease, minimizing manual errors.

  - Calibration workflows will be streamlined, enhancing overall productivity.

- **Accuracy and Traceability:**

  - Accuracy in data processing and measurement uncertainty calculations will improve.

  - Digital record-keeping and data integrity will strengthen traceability.

- **Operational Improvements:**

  - Resource allocation will be optimized, enabling staff to focus on core metrological tasks.

  - Client satisfaction is anticipated to rise with faster certificate delivery times.

Next Steps and Strategic Vision

- **Expansion of DCC Implementation:**

  - Extend the digital certificate system to other calibration services in the laboratory.

  - Collaborate with international metrology institutes for standardization and best practices.

- **2025 Objectives:**

  - Full integration of DCC in the Temperature and Humidity Laboratory.

  - Participation in international intercomparisons and validation of DCCs.

  - Contribution to the Digital Transformation Group at SIM, promoting regional standardization.

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Impact on Metrological Services

- Enhanced efficiency and accuracy in calibration processes.

- Improved traceability and data integrity.

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Strategic Vision

- Proactive approach to digital transformation

- Anticipating future industry demands

- Aligning with international best practices

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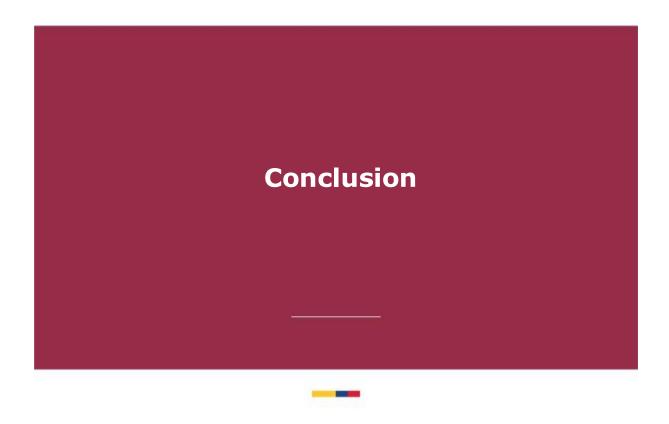
Challenges and Solutions

- Resistance to change and adoption barriers

- Solutions: Training, collaboration with stakeholders, and technical support

Conclusion

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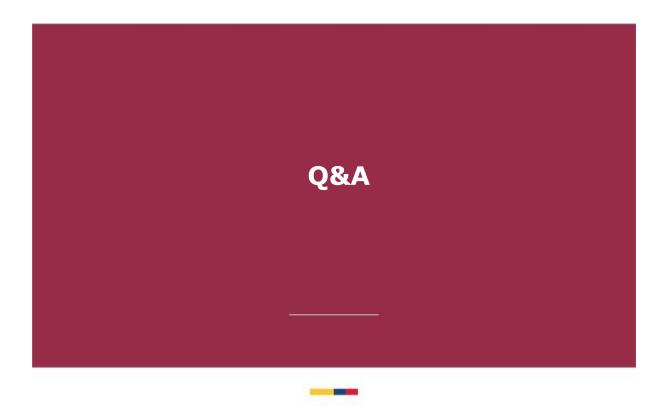
- DCC as a key enabler of digital transformation in metrology

- INM's leadership in modernizing metrological services in Latin America

- Strategic anticipation of industry needs

Q&A

- Thank you!
- Questions?

Instituto Nacional de
Metrología de Colombia

Contact information

csanchez@inm.gov.co

Physical Metrology

INM

www.inm.gov.co

Day 1 (2025-02-25 Tuesday)
        Parallel Session "Key Aspects of DCC I"
        (Chair: Shanna Schönhals)

001   Harmonisation of DCCs in DKD - an update

Presenting author: Thomas Krah, PTB Germany
Email: thomas.krah@ptb.de
Additional authors: Martin Czaske, Muhammed-Ali Demir, Gisa Foyer, Julian Haller, Wolfgang Schmid

Abstract

Harmonisation is one of the key elements for the DCC to become the common exchange format for calibration data. One aspect of the harmonisation is that the calibration laboratories creating DCCs need to know which information should be written in each element of the DCC. Another aspect is that the users who process the calibration data, especially when dealing with multiple measurands, need to be able to read all the different DCCs in a simple way, without having to adapt their software to each measurand or calibration supplier. One way of harmonising the DCC could be to create a specification within a standard. This would probably be the most simple and effective way. However, it usually takes many years for a standard to become established.

In Germany, we chose the German Calibration Service (Deutscher Kalibrierdienst, DKD) with its well-established structures and the extensive knowledge of its members to speed up the process of harmonising the DCC. In all 13 technical committees, the members of the DKD are working on standardising the DCC.

Several committees have already published some of their work. There are community specific DCC examples available, expert reports which describe the DCC examples and give additional explanations, and a machine interpretable dictionary for the used refTypes is accessible for everybody worldwide. Currently is an interoperability challenge from the sub-committee mass in preparation to validate if their DCC example together with their expert report covers all relevant aspects and thus leads to an unambiguous content of the DCCs the participants of this challenge created.

Furthermore, DKD experts developed an easy-to-use tool which shows if all mandatory and if applicable optional requirements of the ISO 17025 are covered in any given DCC.

Presentation of Thomas Krah

Harmonisation of **DCC**s in **DKD** – an Update

5th International **D**CC Conference 2025

T. Krah, M. Czaske, W. Schmid,	Section 9.1
Gisa Foyer,	WG 1.14
M.-A. Demir,	WG 1.24
J. Haller,	Sartorius Lab Instruments

Introduction

What is the DKD?

What is the DKD?

Abbreviation for **D**eutscher **K**alibrier**d**ienst (German Calibration Service)

The DKD ...

… consists of a network of **experts** from **PTB** and around 500 accredited **calibration laboratories**.

… is **networking** with other organisations in the field of calibration and accreditation.

… **supports** calibration laboratories to obtain / maintain their **accreditation**.

DKD's mission is to achieve high quality in calibration laboratories

What is the DKD?

Technical committees

1. Direct Current and Low Frequency
2. High Frequency and Optics
3. Force, Acceleration and Acoustics
4. Length
5. Temperature and Humidity
6. Pressure and Vacuum
7. Mass and Weighing Instruments
8. Metrology in Chemical and Material Properties
9. Materials Testing Machines
10. Torque
11. Flow Quantities
12. Metrology in Laboratory Medicine
13. Measurement Uncertainty

Annual Meetings

Experts from PTB and calibration laboratories

Sub-Committees and Projects

The Technical Committees are the panels for the scientific / technical cooperation between the members of DKD:

- Develop calibration guidelines: standardised procedures accepted for accreditation.
- Organise inter-laboratory comparisons and discusses results.
- Inform members about relevant developments in the field of calibration and accreditation.
- Network with experts from PTB and other calibration laboratories.
- **Develop a standardised format for digital calibration certificates (DCC).**

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Harmonisation of DCCs in DKD

Harmonisation of DCCs in DKD

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Harmonisation of DCCs in DKD

Technical committees

1. Direct Current and Low Frequency
2. High Frequency and Optics
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4. Length
5. Temperature and Humidity
6. Pressure and Vacuum
7. Mass and Weighing Instruments
8. Metrology in Chemical and Material Properties
9. Materials Testing Machines
10. Torque
11. Flow Quantities
12. Metrology in Laboratory Medicine
13. Measurement Uncertainty

How is the harmonisation of DCC done?

- 1 DCC sub-committee for each technical committee.
- 12 sub-committees for measurand specific questions: SC_{meas}.
- 1 sub-committee for overarching questions: $SC_{general}$.

SC_{meas}

$SC_{general}$

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6

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Harmonisation of DCCs in DKD

Composition of the members in $SC_{general}$

- All TCs represented.
- From each TC:
  - the TC chair.
  - If applicable the sub-committee chair.
  - Further representatives
- Area of operations of members:
  - Laboratories
  - Software manufacturers
  - Device manufacturers
  - NMIs

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Output of the TCs

Output of the **TCs**

Output of the TCs: expected

- Development of **D**CCs for selected important measurands and measurement equipment types (Good practices / templates).

- Harmonised wording.

- Expert reports.

Output of the TCs: delivered

- Development of **D**CCs for selected important measurands and measurement equipment types (Good practices / templates).
  - **D**CC mass available.
  - **D**CC length.
  - Code extracts available.

- Harmonised wording.
  - Thesaurus created. RefTypes machine-interpretable and with persistent IDs
    https://digilab.ptb.de/dkd/refType/vocab/

- Expert reports.
  - Expert report mass available
    https://www.ptb.de/cms/fileadmin/internet/dienstleistungen/dkd/archiv/Publikationen/Expertenberichte/DKD-E_7-2_rev1_en.pdf
  - Report length available.
    https://www.ptb.de/cms/fileadmin/internet/dienstleistungen/dkd/archiv/Publikationen/Expertenberichte/DKD -E_4-3_2024-12.pdf
  - Report admin. block in draft version for members downloadable.

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Output of the TCs: delivered

TC	Example DCC	Expert report
Mass	**Mass**	**Available** https://www.ptb.de/cms/fileadmin/internet/dienstleistungen/dkd/ archiv/Publikationen/Expertenberichte/DKD -E_7-2_rev1_en.pdf
Length	**Gauge Block**	**Available** https://www.ptb.de/cms/fileadmin/internet/dienstleistungen/dkd/ archiv/Publikationen/Expertenberichte/DKD -E_4-3_2024-12.pdf
Scales/weighing instruments	Scales	In progress
Metrology in Laboratory Medicine	Amount of substance concentration/fraction	In progress
Temperature and Humidity	Resistance thermometer	In progress
Force, Acceleration and Acoustics	Force transducer Acceleration-sinusoidal and acceleration-shock	In progress -
Material Testing Machines	Tensile testing machine	-
Pressure & Vacuum	Digital pressure measuring device, acc. DKDR 6-1 (de, en, es) Vacuum measuring device, acc. DKDR 6-2 (only in de)	In progress
Torque	Calibration of static torque measuring devices, acc. to DIN 51309	-
Metrology in Chemical and Material Properties	Pipettes	-
DC & LF	Multifunction calibrator	-
Flow Quantities	Fluid flow	-
Measurement Uncertainty	**Various code snippets**	In progress

Status of work:
Ready & available
Ready, to be released soon
First results
In progress

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Output of the TCs: **delivered**

DKD ISO 17025 Checker

- Idea behind it:
  - Provide an easy tool to check if a given **D**CC fullfills all requirements of the ISO/IEC 17025 towards calibration reports.
  - Simplify the work of laboratory stuff, customers and auditors.

- Realisation:
  - Usage of a XSLT file to check and process the content of a given **D**CC.
  - Provide a web application for checking the **D**CCs.
    The web application is running locally on a computer without connection to any server.

- Publication:
  - The Expert report general conventions and recommendations for a harmonised issueing of digital calibration certificates (**D**CCs)
  - The XSLT file for checking **D**CCs against the ISO/IEC 17025
  - The corresponding web app

  Will be released in a bundle in April.

XSLT + DCC = YES / NO

DKD/DCC web

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25.02.2024
12

DKD Nationales Metrologieinstitut
5th International DCC Conference 2025

DKD ISO 17025 Checker
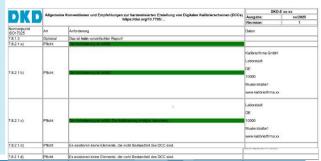
- Functionality:
  - The XSLT file transforms a given **D**CC (XML) into a HTML file which displays the result of the check in human readable form.
  - The XSLT file contains xpath expressions to find the right data and routines for checking against the ISO/IEC 17025 requirements.

- Output:
  - If everything is ok, green entries are shown.
  - In column Data is the content of the **D**CC elements for the requirements shown.
  - If a requirement is violated, red entries are shown.
  - If possible, it is stated what is the cause of the violation.

Human Readable Stylesheet + DCC = Protokoll YES / NO

Normenpunkt ISO17025	Art	Anforderung	Daten
7.8.1.3	Optional	Das ist **kein** vereinfachter Report!	
7.8.2.1 a)	Pflicht	Die Aktivierung ist erfüllt	
7.8.2.1 b)	Pflicht	Die Aktivierung ist erfüllt.	Kalibrierfirma GmbH Laborstadt DE 10000 Musterstraße1 www.kalibrierfirma.xx
7.8.2.1 c)	Pflicht	Die Aktivierung ist erfüllt Die Kalibrierung erfolgte laboratory	Laborstadt DE 10000 Musterstraße1 www.kalibrierfirma.xx
7.8.2.1 d)	Pflicht	Es existieren keine Elemente, die nicht Bestandteil des DCC sind.	
7.8.2.1 d)	Pflicht	Es existieren keine Elemente, die nicht Bestandteil des DCC sind.	

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25.02.2024
13

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Interoperability challenge DCC mass

- Idea:
    - Can we create a **D**CC which everyone can read just with the help of the DKD expert report mass and the DKD good practice example mass.
    - Assessing interoperability of mass **D**CCs through comparison of test **D**CCs issued by different parties.
- Output:
    - For manually created **D**CCs: Prove that you correctly understood the PTB **D**CC schema and DKD-E 7-2.
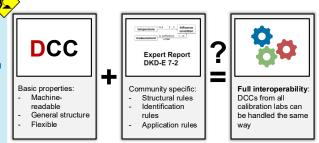   - For **D**CCs created by dedicated software: Prove that you correctly understood and implemented the PTB **D**CC schema and DKD-E 7-2.
    - Update the expert report and the good practice example if necessary.

DCC

Basic properties:
- Machine-readable
- General structure
- Flexible

+

Expert Report DKD-E 7-2

Community specific:
- Structural rules
- Identification rules
- Application rules

?
=

Full interoperability: DCCs from all calibration labs can be handled the same way

Interoperability challenge DCC mass

- Information for interested participants:
    - Contacts:
        - Gisa.foyer@ptb.de
        - Julian.haller@sartorius.com
- For participation, it will be necessary that you :
    - Can create a **D**CC for a weight set either with a dedicated software (plus possible manual modifications) or manually.
    - Follow the PTB **D**CC Schema in version 3.2.1 (or 3.3.0).
    - Follow the DKD expert report DKD -E 7-2, Revision 1 (01/2024) - DOI: 10.7795/550.20240119B .

Task	When?
Provide examples	02/25
Create DCCs and submit them	03-05/25
Develop queries for the scenarios	
Apply queries and provide first analysis	06-07/25
Discuss and analyse results	08-10/25

DCC development is about to start. You can still join!

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www.ptb.de

Stand: 02/25

002   Harmonisation of DCCs for non-automatic weighing instruments (NAWIs) through a DKD expert report to ensure full interoperability

Presenting author: Dr. Julian Haller, Sartorius Lab Instruments GmbH & Co. KG,
Email: julian.haller@sartorius.com
Additional authors: Nil

Abstract:

The benefits of digital calibration certificates (DCC) for efficient and modern test equipment management and the sensible use of calibration data are well known. The PTB has created a very flexible DCC scheme that makes it possible to provide content in different ways. This carries the risk that implementations from different labs may differ from each other and that there will be non- interoperable realizations.

For this reason, so-called expert reports are currently being prepared in expert groups of the German Calibration Service (DKD) to ensure the harmonized use of the DCC scheme for the respective subject areas.

While such an expert report for the harmonized creation of DCCs for weights was already published in 2022 and revised in 2024, the publication of such an expert report for the harmonized creation of DCCs for non-automatic weighing instruments (NAWIs) in accordance with the calibration guideline EURAMET cg-18 is imminent.

The aim of this presentation is to present the current status of the expert report and to give an overview of its contents.

Presentation of Julian Haller

Harmonisation of DCCs for non-automatic weighing instruments (NAWIs) through a DKD expert report to ensure full interoperability

Dr. Julian Haller, Sartorius Lab Instruments GmbH & Co. KG, 25.02.2025

DKD Working Groups

- DKD: Deutscher Kalibrierdienst (German Calibration Service)

- A panel to promote the uniformity in metrology and with the aim to offer complementary technical assistance, in which PTB and accredited calibration laboratories work closely together.

- The panel's objective is to develop metrological foundations for calibrations.

- 13 Technical committees:
    - 1. Direct Current and Low Frequency
    - 2. High Frequency and Optics
    - 3. Force and Acceleration
    - 4. Length
    - 5. Temperature and Humidity
    - 6. Pressure and Vacuum
    - **7. Mass and Weighing Instruments**
    - 8. Chemical Measurands and Material Properties
    - 9. Materials Testing Machines
    - 10. Torque
    - 11. Flow Measurands
    - 12. Measurands in Laboratory Medicine
    - 13. Measurement Uncertainty

Working group „DCC Mass"

Working group „DCC Weighing Instruments"

For cross-sectional harmonisation among the technical committees, see

Parallel Sessions	Key Aspects of DCC I
14:00	#001 Thomas Krah *Harmonisation of DCCs in DKD – an update*

2

DKD Working Group „DCC NAWIs"

D. Knopf, G. Foyer, A. Scheibner, S. Hackel (PTB)

K. Fritsch (Mettler-Toledo)

M. Häfner (Häfner)

H. Lauer (Bizerba)

S. Osang (Minebea, DKD-FA)

M. Turino (Kern)

Z. Zelenka (BEV, EURAMET TCM)

J. Haller (Sartorius)

- Define conventions concerning structure, identification and use cases

- Final target: A guide that, if followed, ensures that any import algorithm can read in a DCC issued by any lab.

- Everything based on PTB's DCC schema!

3

Julian Haller: Harmonisation of DCCs for non-automatic weighing instruments (NAWIs) through a DKD expert report to ensure full interoperability

It's all about being FAIR….

Measurement results | Measurement uncertainties

Repeatability	
Test load (nominal): 100 g	
1	100.0001 g
2	99.9999 g
3	100.0002 g
4	99.9999 g
5	99.9998 g

Eccentricity	
Test load (nominal):	100 g
Center	99.9999 g
Front left	100.0002 g
Back left	99.9997 g
Back right	100.0000 g
Front right	99.9999 g

```xml
<dcc:result>
    <dcc:data>
        <dcc:quantity>
            <si:realListXMLList>
                <si:valueXMLList>0.001000001 0.000999999 0.001000002 0.000999999 0.000999998</si:valueXMLList>
                <si:unitXMLList>\kilogram</si:unitXMLList>
            </si:realListXMLList>
        </dcc:quantity>
    </dcc:data>
</dcc:result>
<dcc:result>
    <dcc:data>
        <dcc:quantity>
            <si:realListXMLList>
                <si:valueXMLList>0.000999999 0.001000002 0.000999997 0.001000000 0.000999999</si:valueXMLList>
                <si:unitXMLList>\kilogram</si:unitXMLList>
            </si:realListXMLList>
        </dcc:quantity>
    </dcc:data>
</dcc:result>
```

Not Findable : Which values are for repeatability and which are for eccentricity?

4

Julian Haller: Harmonisation of DCCs for non-automatic weighing instruments (NAWIs) through a DKD expert report to ensure full interoperability

It's all about being FAIR….

Measurement results | Measurement uncertainties

Repeatability	
Test load (nominal): 100 g	
1	100.0001 g
2	99.9999 g
3	100.0002 g
4	99.9999 g
5	99.9998 g

Eccentricity	
Test load (nominal):	100 g
Center	99.9999 g
Front left	100.0002 g
Back left	99.9997 g
Back right	100.0000 g
Front right	99.9999 g

```xml
<dcc:result>
    <dcc:name>
        <dcc:content>Repeatability</dcc:content>
    </dcc:name>
    <dcc:data>
        <dcc:quantity>
            <si:realListXMLList>
                <si:valueXMLList>0.001000001 0.000999999 0.001000002 0.000999999 0.000999998</si:valueXMLList>
                <si:unitXMLList>\kilogram</si:unitXMLList>
            </si:realListXMLList>
        </dcc:quantity>
    </dcc:data>
</dcc:result>
<dcc:result>
    <dcc:name>
        <dcc:content>Eccentricity</dcc:content>
    </dcc:name>
    <dcc:data>
        <dcc:quantity>
            <si:realListXMLList>
                <si:valueXMLList>0.000999999 0.001000002 0.000999997 0.001000000 0.000999999</si:valueXMLList>
                <si:unitXMLList>\kilogram</si:unitXMLList>
            </si:realListXMLList>
        </dcc:quantity>
    </dcc:data>
</dcc:result>
```

Not Interoperable: What if other languages/other terms are used?

4

It's all about being FAIR….

Measurement results | Measurement uncertainties

Repeatability	
Test load (nominal): 100 g	
1	100.0001 g
2	99.9999 g
3	100.0002 g
4	99.9999 g
5	99.9998 g

Eccentricity	
Test load (nominal):	100 g
Center	99.9999 g
Front left	100.0002 g
Back left	99.9997 g
Back right	100.0000 g
Front right	99.9999 g

```
<dcc:result refType="NAWI_repeatabilityMeasurement">
    <dcc:data>
        <dcc:quantity>
            <si:realListXMLList>
                <si:valueXMLList>0.1000001 0.0999999 0.1000002 0.0999999 0.0999998</si:valueXMLList>
                <si:unitXMLList>\kilogram</si:unitXMLList>
            </si:realListXMLList>
        </dcc:quantity>
    </dcc:data>
</dcc:result>
<dcc:result refType="NAWI_eccentricityMeasurement">
    </dcc:data>
        <dcc:quantity>
            <si:realListXMLList>
                <si:valueXMLList>0.0999999 0.1000002 0.0999997 0.1000000 0.0999999</si:valueXMLList>
                <si:unitXMLList>\kilogram</si:unitXMLList>
            </si:realListXMLList>
        </dcc:quantity>
    </dcc:data>
</dcc:result>
```

Findable
(Search for refType=„NAWI_repeatability")

Accessible

Interoperable
(Search will work for every issuer that follows this convention)

Reusable

4

FAIRness of DCCs via DKD expert reports

Overarching expert report with general rules and conventions:
In progress, to be published soon

Expertenbericht DKD-E 0-3	Allgemeine Konventionen und Empfehlungen zur harmonisierten Erstellung von Digitalen Kalibrierscheinen (DCCs)	#001 Thomas Krah — Harmonisation of DCCs in DKD – an update

Mass/Weights:
Published 2022, revised 2024
In use

Expert Report DKD-E 7-2	Instructions on how to use the DCC schema to create a digital calibration certificate for weights and weight sets

#009 Itzel Dominguez
Generating Mass DCC based on DKD expert report using a spreadsheet

#019 Lisa Busser
DCC in a Mass-Calibration Software

NAWIs(Balances):
To be published soon

Expert Report DKD-E 7-3	Instructions on how to use the DCC schema to create a digital calibration certificate for non-automatic weighing instruments

#002 Julian Haller
Harmonisation of DCCs for non-automatic weighing instruments (NAWIs) through a DKD expert report to ensure full interoperability

Length:
To be published soon

#016 Christian Sander
Instructions for using the DCC scheme to create a digital calibration certificate for gauge blocks

Force:
To be published soon

#003 Shanna Schönhals
Implementation of Digital Calibration Certificates for Force Calibration According to ISO 376

Other communities:
In progress

Temperature
Humidity
Lab Medicine
Flow
Pressure
Electrical Quantities
…..

5

Julian Haller: Harmonisation of DCCs for non-automatic weighing instruments (NAWIs) through a DKD expert report to ensure full interoperability

Current status of the „DCC NAWI" expert report

- Final draft has been agreed

- Report will be submitted to DKD for publication in March

- Expected publication in Q2/2025

Physikalisch-
Technische
Bundesanstalt

DKD

Expert Report DKD-E 7-3 — Instructions on how to use the DCC schema to create a digital calibration certificate for non-automatic weighing instruments

Edition 02/2025

https://doi.org/10.7795/...

6

Julian Haller: Harmonisation of DCCs for non-automatic weighing instruments (NAWIs) through a DKD expert report to ensure full interoperability

Content of the expert report

Table of contents

- Basic information about DCCs and D-SI

- Chapters 1 and 2 have been taken over almost unchanged from the expert report "DCC Mass"

- Editorial note that chapters 1 and 2 will be included in an expert report "DCC cross-sectional topics" in the medium term and can then disappear from the subject-specific expert reports

7

Julian Haller: Harmonisation of DCCs for non-automatic weighing instruments (NAWIs) through a DKD expert report to ensure full interoperability

Content of the expert report

Table of contents

Chapter 3: describes NAWI-specific aspects for each DCC element

- e.g. in dcc:items:
  - How do I denote/identify MR and MI instruments?
  - How do I denote/identify modular instruments?

8

Julian Haller: Harmonisation of DCCs for non-automatic weighing instruments (NAWIs) through a DKD expert report to ensure full interoperability

Content of the expert report

Table of contents

Chapter 4: Specific Application Rules for NAWIs:

- Multiple calibrations (before/after adjustment)
- Indication of adjustment and repair status
- Results for MR and MI instruments

9

Julian Haller: Harmonisation of DCCs for non-automatic weighing instruments (NAWIs) through a DKD expert report to ensure full interoperability

Content of the expert report

Table of contents

Chapter 5: NAWI-specific refType attributes:
- NAWI_repeatabilityMeasurement
- NAWI_eccentricityMeasurement
- NAWI_errorOfIndicationMeasurement
- NAWI_auxiliaryMeasurement
- NAWI_range1, NAWI_range2, NAWI_range3, NAWI_range4
- NAWI_resolutionOfDisplayingDevice
- NAWI_verificationScaleInterval
- NAWI_initialMeasurement
- NAWI_finalMeasurement

Proper definition/reference for each refType:

5.3.21 repeatabilityMeasurement

Definition note - Deutsch: Messung der Wiederholpräzision

Definition note - English: Measurement of the measurement repeatability

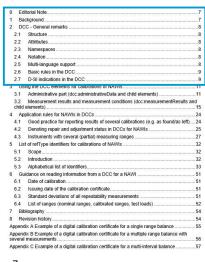| Element	Element in TemaTres	Beschreibung deutsch	Beschreibung englisch
PRÄFIX:	Broader Term	NAWI_	NAWI_
Quelle:	Bibliographic note	EURAMET Calibration Guide No. 18 Version 4.0 (11/2015) 5.1	EURAMET Calibration Guide No. 18 Version 4.0 (11/2015) 5.1
HINWEIS:	Scope note	für mehr Informationen zur Verwendung siehe Beispiele	for more information on use see Example note
ELEMENT:	Related Term	dcc:result	dcc:result

BEISPIEL:	Example note	`<dcc:result refType="NAWI_repeatabilityMeasurement">`
		`<dcc:name>`
		`<dcc:content lang="en">Repeatability measurement</dcc:content>`
		`</dcc:name>`
		`<dcc:data>`
		`<!--Content omitted for clarity-->`
		`</dcc:data>`
		`</dcc:result>`	

10

Julian Haller: Harmonisation of DCCs for non-automatic weighing instruments (NAWIs) through a DKD expert report to ensure full interoperability

Content of the expert report

Table of contents

Chapter 6: Examples how to find specific information in a NAWI DCC

- e.g. Standard deviations of all repeatability measurements:

```xsl
<xsl:for-each select="//dcc:result [@refType='NAWI_repeatabilityMeasurement']" >
  <xsl:for-each select="//dcc:quantity [@refType='math_standardDeviationSample']" >
    <p>
      <xsl:value-of select="dcc:data /dcc:list /dcc:quantity [@refType='math_standardDeviationSample']"/>
    </p>
  </xsl:for-each >
</xsl:for-each>
```

11

Julian Haller: Harmonisation of DCCs for non-automatic weighing instruments (NAWIs) through a DKD expert report to ensure full interoperability

Content of the expert report

Table of contents

Appendices with example DCCs

- single range balance
- multiple range balance with several measurements
- modular multi-interval balance

12

Julian Haller: Harmonisation of DCCs for non-automatic weighing instruments (NAWIs) through a DKD expert report to ensure full interoperability

Next steps

- Publish expert report

- Apply expert report to issue interoperable DCCs for NAWIs

- Collect experiences, feedback,.....

- Revise expert report to implement
  - Corrections
  - Overarching changes/updates
  - Missing parts (uncertainty in use, minimum net weight)

13

Thank you.

Connect with me on LinkedIn to stay updated:

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003 Implementation of Digital Calibration Certificates for Force According to ISO 376

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Abstract

Machine-readable and, ideally, interpretable digital transfer documents present a promising approach to automating processes that require smooth digital data transfer. To ensure interoperability between the issuing and receiving parties, as well as between different stakeholders in the calibration chain, it is crucial to provide standardized solutions when transforming from paper-based to fully digital calibration certificates. This requires the metrological community to reach a consensus on good practices and guidelines for their use. The German Calibration Service (Deutscher Kalibrierdienst, DKD) has established a coordinated process to develop the required solutions, and the work presented here is the result of the work done by the expert group formed by the force and torque community that is contributing to this effort.

In the field of force and torque calibration, specific issues relevant to the community have been identified, and proposed solutions will be introduced and explored in this presentation.

Most force calibrations, particularly in the industrial sector, follow the ISO 376 standard, so the expert group focused on good practices for this calibration process. ISO 376 not only outlines the measurement process and data handling for calibration results but also specifies requirements for calibration reports. As a result, ISO 376 calibration certificates are generally consistent in format, even across different laboratories, including descriptions of processes, raw data, processed results, and final classifications for different measurement ranges based on clear technical criteria. These standardized formats facilitate the transition to machine-readable data structures by limiting the number of variations.

However, machine-interpretable solutions had to be developed for various aspects and issues specific to the community. These included the structuring and reorganisation of tables, while allowing individual series of measurements made in different mounting positions and loading sequences to be addressed in a machine-interpretable way. The group developed solutions for expressing classifications according to the standard and the machine-interpretable interpolation function.

The presentation reflects the current state of the work. The final results of the expert group's activities will be published by the DKD in a special open-access expert report both in German and in English languages.

Presentation of Shanna Schönhals

Implementation of Digital Calibration Certificate for Force Calibrations according to ISO 376

2025-02-25

5th International DCC Conference
Shanna Schönhals on behalf of DCC Task Force of DKD TCs 3 and 10

Task: develop a good practice certificate for force calibrations according to ISO 376

- ISO 376 standard defines:
  - Measurement process
  - Data handling of calibration results
  - And also requirements for calibration reports
    - ▶ CC already quite consistent
    - ▶ Facilitates transition to DCC
- Machine-actionable solutions sought for:
  - Structuring and re-organizing tables
  - Addressing individual series in different mounting positions
  - Expressing classifications
  - Interpolation function

DCC Working Group on Force and Torque   by DKD Technical Committees 3 and 10

DKD

outside DKD

Founding
DCC Task Force comprising DKD-TC 3 and 10

Selection
Agree on simple and significant measurement task (ISO 376 cal. Cert.)

Documentation
Creating pre-normative documents (Expert Reports) Publish open-access with examples

Roll-out
Send DCC to customer

Members
Voluntary participants representing calibration labs and PTB members 19 persons, 13 labs

Harmonisation
Creating harmonised DCC examples

Issuing
Issuing DCCs based on agreed examples

Starting Point: Analogue Calibration Certificate

Source: Calibration Certificate Sample PTB Dep. 1.2

- PTB sample calibration certificate for force transducers according to ISO 376
- First draft DCC created with the Excel Tool (Dirk Röske/PTB):
  - Mapping of calibration data → DCC
  - Output: XML DCC

- Discussion resulted in extending the XML example to cover use cases relevant to accredited laboratories, e.g.
  - Additional components of calibration item
  - Additional measuring equipment
  - Influence condition (Transducer zero signal)

Shanna Schönhals | Implementation of Digital Calibration Certificate for Force Calibrations according to ISO 376   25.02.2025   4
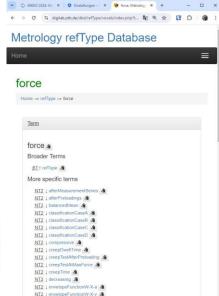
Some words about refTypes

- refTypes are special attributes in DCCs ensuring association of meaning to data and providing context → machine-interpretability
- Essential: harmonised and FAIR
- DKD involved in definition and filling the database
- Combination of
  - basic refTypes (e.g. basic_temperature)
  - community-specific refTypes (e.g. force_compressive)

All used refTypes entered to Tematres DB:
https://digilab.ptb.de/dkd/refType

  - Currently, 56 refTypes for force identified and described

Shanna Schönhals | Implementation of Digital Calibration Certificate for Force Calibrations according to ISO 376   25.02.2025   5

Achieving Machine Interpretability

Addressing measurement series using a combination of refTypes and metadata

Tabelle 4: Nullkorrigierte Anzeigewerte der Messreihen
Table 4: Zero-reduced values indicated for all series

Kraftrichtung: Druckkraft
Force application: compressive

F	X_1	X_2	X_3	X_4'	X_5	X_6'
Kraft *Force*	Messreihe 1 *Meas. series 1* 0 °	Messreihe 2 *Meas. series 2* 0 °	Messreihe 3 *Meas. series 3* 120 ° auf / up	Messreihe 4' *Meas. series 4'* 120 ° ab / down	Messreihe 5 *Meas. series 5* 240 ° auf / up	Messreihe 6' *Meas. series 6'* 240 ° ab / down
in kN	in mV/V	in mV/V	in mV/V	in mV/V	in mV/V	in mV/V
0	0,000000	0,000000	0,000000	0,000166	0,000000	0,000188
100	0,199962	0,199972	0,199982	0,200146	0,199992	0,200201
200	0,399929	0,399949	0,399969	0,400183	0,399989	0,400243
300	0,599901	0,599931	0,599961	0,600211	0,599991	0,600276
400	0,799878	0,799918	0,799958	0,800230	0,799998	0,800300
500	0,999862	0,999913	0,999963	1,000238	1,000013	1,000312
600	1,199854	1,199914	1,199974	1,200234	1,200034	1,200314
800	1,599859	1,599939	1,600019	1,600193	1,600099	1,600283
1000	1,999900	2,000000	2,000100		2,000200	
0	0,000122	0,000133				

Source: Calibration Certificate Sample PTB Dep. 1.2

Shanna Schönhals | Implementation of Digital Calibration Certificate for Force Calibrations according to ISO 376   25.02.2025   6

Achieving Machine Interpretability

Addressing measurement series using a combination of refTypes and metadata

Tabelle 4: Nullkorrigierte Anzeigewerte der Messreihen
Table 4: Zero-reduced values indicated for all series

F	X_1	X_2	X_3	X_4'
Kraft *Force*	Messreihe 1 *Meas. series 1* 0 °	Messreihe 2 *Meas. series 2* 0 °	Messreihe 3 *Meas. series 3* 120 ° auf / up	Messreihe 4' *Meas. series 4'* 120 ° ab / down
in kN	in mV/V	in mV/V	in mV/V	in mV/V
0	0,000000	0,000000	0,000000	0,000166
100	0,199962	0,199972	0,199982	0,200146
200	0,399929	0,399949	0,399969	0,400183
300	0,599901	0,599931	0,599961	0,600211
400	0,799878	0,799918	0,799958	0,800230
500	0,999862	0,999913	0,999963	1,000238
600	1,199854	1,199914	1,199974	1,200234
800	1,599859	1,599939	1,600019	1,600193
1000	1,999900	2,000000	2,000100	
0	0,000122	0,000133		

Source: Calibration Certificate Sample PTB Dep. 1.2

Shanna Schönhals | Implementation of Digital Calibration Certificate for Force Calibrations according to ISO 376   25.02.2025   7

Achieving Machine Interpretability

Addressing measurement series using a combination of refTypes and metadata

Tabelle 4: Nullkorrigierte Anzeigewerte der Messreihen
Table 4: Zero-reduced values indicated for all series

F	X_1	X_2	X_3	$X_4{}'$
Kraft *Force*	Messreihe 1 *Meas. series 1* 0 °	Messreihe 2 *Meas. series 2* 0 °		
in kN	in mV/V	in mV/V		
0	0,000000	0,000000		
100	0,199962	0,199972		
200	0,399929	0,399949		
300	0,599901	0,599931		
400	0,799878	0,799918		
500	0,999862	0,999913		
600	1,199854	1,199914		
800	1,599859	1,599939		
1000	1,999900	2,000000	2,000100	
0	0,000122	0,000133		

Source: Calibration Certificate Sample PTB Dep. 1.2

Combining tables for loading directions

- Analogue: separate tables on separate pages for human readability

- DCC: combined tables into one single table for each loading direction (tension and compression for the force, clockwise and anti-clockwise for the torque)

- Improve machine interpretability and simplify the data structure

Empty cells in tables: numerical values

Empty cells indicate values that were not measured

F	X$_1$	X$_2$	X$_3$	X$_4$'	X$_5$	X$_6$'
Kraft *Force*	Messreihe 1 *Meas. series 1* 0 °	Messreihe 2 *Meas. series 2* 0 °	Messreihe 3 *Meas. series 3* 120 ° auf / *up*	Messreihe 4' *Meas. series 4'* 120 ° ab / *down*	Messreihe 5 *Meas. series 5* 240 ° auf / *up*	Messreihe 6' *Meas. series 6'* 240 ° ab / *down*
in kN	in mV/V	in mV/V	in mV/V	in mV/V	in mV/V	in mV/V
0	0,000000	0,000000	0,000000	0,000166	0,000000	0,000188
100	0,199962	0,199972	0,199982	0,200146	0,199992	0,200201
200	0,399929	0,399949	0,399969	0,400183	0,399989	0,400243
300	0,599901	0,599931	0,599961	0,600211	0,599991	0,600276
400	0,799878	0,799918	0,799958	0,800230	0,799998	0,800300
500	0,999862	0,999913	0,999963	1,000238	1,000013	1,000312
600	1,199854	1,199914	1,199974	1,200234	1,200034	1,200314
800	1,599859	1,599939	1,600019	1,600193	1,600099	1,600283
1000	1,999900	2,000000	2,000100	___	2,000200	___
0	0,000122	0,000133	___	___	___	___

Tabelle 4: Nullkorrigierte Anzeigewerte der Messreihen
Table 4: Zero-reduced values indicated for all series

Kraftrichtung: Druckkraft
Force application: compressive

Solution: representation as NaN, available with D-SI schema v2.2.0, DCC schema 3.3.0

Empty cells in tables: string-based classification

Tabelle 6: Klassifizierungen
Table 6: Classifications

Kraftbereich / *Force range*		Geräteklasse / *Instrument class*			
Von / *From*	Bis / *To*	Fall A / *Case A*	Fall B / *Case B*	Fall C / *Case C*	Fall D / *Case D*
100 kN	1000 kN	00	0,5	00	0,5
200 kN	**1000 kN**	**00**	**00**	**00**	**00**
300 kN	1000 kN	00	00	00	00
400 kN	1000 kN	00	00	00	00
500 kN	1000 kN	00	00	00	00

Source: Calibration Certificate Sample PTB Dep. 1.2

Table restructured to match measured values table

Use of NaN not appropriate and could lead to misinterpretation

Undefined if a class cannot be determined

noClass if class requirements are not met

Kraft *Force* \kilo\newton	Fall A *Case A*	Fall B *Case B*	Fall C *Case C*	Fall D *Case D*
0	undefined	undefined	undefined	undefined
100	noClass	0,5	00	0,5
200	00	00	00	00
300	00	00	00	00
400	00	00	00	00
500	00	00	00	00
600	00	00	00	00
800	00	00	00	00
1000	00	00	00	00
0	undefined	undefined	undefined	undefined

Source: Human Readable generated by the GEMIMEG Tool from XML

Empty cells in tables: string-based classification

```
<dcc:list>
    <dcc:quantity refType="basic_referenceValue">
        <dcc:name>
            <dcc:content lang="de">Kraft</dcc:content>
            <dcc:content lang="en">Force</dcc:content>
        </dcc:name>
        <si:realListXMLList>
            <si:valueXMLList>0 100 200 300 400 500 600 800 1000
                0</si:valueXMLList>
            <si:unitXMLList>\kilo\newton</si:unitXMLList>
        </si:realListXMLList>
    </dcc:quantity>
    . . .
    <dcc:quantity refType="force_classificationCaseA">
        <dcc:name>
            <dcc:content lang="de">Fall A</dcc:content>
            <dcc:content lang="en">Case A</dcc:content>
        </dcc:name>
        <dcc:charsXMLList>undefined 00 00 00 00 00 00 00 00 undefined</dcc:charsXMLList>
    </dcc:quantity>
    <dcc:quantity refType="force_classificationCaseB">
        <dcc:name>
            <dcc:content lang="de">Fall B</dcc:content>
            <dcc:content lang="en">Case B</dcc:content>
        </dcc:name>
        <dcc:charsXMLList>undefined 0,5 00 00 00 00 00 00 00 undefined</dcc:charsXMLList>
    </dcc:quantity>
    <dcc:quantity refType="force_classificationCaseC">
        <dcc:name>
            <dcc:content lang="de">Fall C</dcc:content>
            <dcc:content lang="en">Case C</dcc:content>
        </dcc:name>
        <dcc:charsXMLList>undefined 00 00 00 00 00 00 00 00 undefined</dcc:charsXMLList>
    </dcc:quantity>
    <dcc:quantity refType="force_classificationCaseD">
        <dcc:name>
            <dcc:content lang="de">Fall D</dcc:content>
```
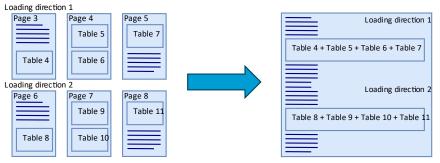
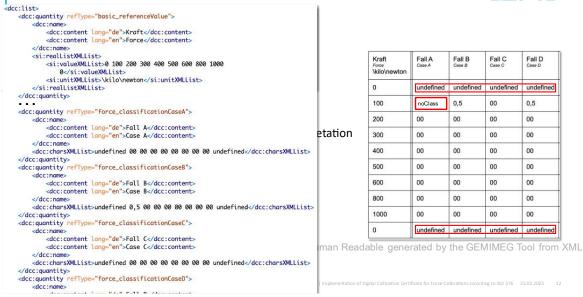| Kraft *Force* \kilo\newton	Fall A *Case A*	Fall B *Case B*	Fall C *Case C*	Fall D *Case D*
0	undefined	undefined	undefined	undefined
100	noClass	0,5	00	0,5
200	00	00	00	00
300	00	00	00	00
400	00	00	00	00
500	00	00	00	00
600	00	00	00	00
800	00	00	00	00
1000	00	00	00	00
0	undefined	undefined	undefined	undefined

...etation

...man Readable generated by the GEMIMEG Tool from XML

...l Implementation of Digital Calibration Certificate for Force Calibrations according to ISO 376   25.02.2025   12

Example for fitting function of the balanced mean

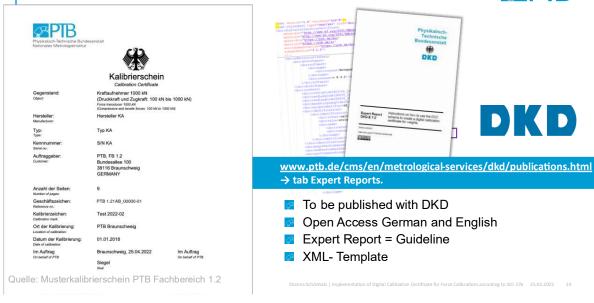**Ausgleichsfunktionen / Fitting functions $X = X(F)$**

Die in der Tabelle oben aufgeführten ausgeglichenen Mittelwerte X_a sind mit folgender Funktion berechnet:
The balanced mean X_a values stated in the table above have been calculated with the following function:

$$X_a = [\ + 0{,}001999767 \cdot F/\mathrm{kN} + 1{,}99 \cdot 10^{-10} \cdot (F/\mathrm{kN})^2 + 1 \cdot 10^{-13} \cdot (F/\mathrm{kN})^3\ ]\ \mathrm{mV/V}$$

Unter Berücksichtigung der Umkehrspanne v ergibt sich folgende Funktion für abnehmende Kraftbeträge:
Considering the reversibility v the following function results for decremental forces:

$$X_f = [\ + 0{,}002000139 \cdot F/\mathrm{kN} - 1{,}91 \cdot 10^{-10} \cdot (F/\mathrm{kN})^2 - 4{,}33 \cdot 10^{-13} \cdot (F/\mathrm{kN})^3 + 1{,}67 \cdot 10^{-4}\ ]\ \mathrm{mV/V}$$

- force_fittingFunction
- force_balancedMean
- force_functionParameters force_increasing
- force_functionParameters force_decreasing

- Reported in dcc:result
- refType force_fittingFunction
- Equation represented by dcc:formula using dcc:mathml (Content MathML)
- Coefficients of each variable is given using the element dcc:list with the child element dcc:quantity
- Each quantity receive a refType force_functionParameters.

Shanna Schönhals | Implementation of Digital Calibration Certificate for Force Calibrations according to ISO 376   25.02.2025   13

Page 70 of 487

Report on Good Practice for Force (ISO 376)

Quelle: Musterkalibrierschein PTB Fachbereich 1.2

www.ptb.de/cms/en/metrological-services/dkd/publications.html
→ tab Expert Reports.

- To be published with DKD
- Open Access German and English
- Expert Report = Guideline
- XML- Template

Shanna Schönhals | Implementation of Digital Calibration Certificate for Force Calibrations according to ISO 376   25.02.2025   14

Conclusions and next steps

- Producing an additional, minimal example for simplicity

- Presenting and discussing results at DKD TC 3 and TC 10 meeting in May 2025

- Finalising and releasing the expert report

- Transferring solutions to torque - very similar structures
  - E.g. DIN 51309

- Using force good practice as template for comparison

Shanna Schönhals | Implementation of Digital Calibration Certificate for Force Calibrations according to ISO 376   25.02.2025   15

Acknowledgement to members of the DCC Task Force of DKD TCs 3 and 10

- Moritz Jordan, Shan Lin, Dirk Röske, Christian Schlegel, Shanna Schönhals (PTB)
- Alex Cocev, Daniel Reissiger (SCS Concept)
- Axel Grönboldt (Atlas Copco)
- Torsten Wallner (HBK GmbH)
- Siegfried Herbold (STAHLWILLE)
- Michael Melzer (BAM)
- Peter Weyrich (CEH Messtechnik)

- Roland Klinke (MG Sensor)
- Siegfried Gerber (MPA Uni Stuttgart)
- Stefan Baus (Gedore)
- Saher Hassan (Kessler-QMP)
- Torsten Hahn (GTM)
- Robert Bausch, Stephan Posch (Kistler Instrumente GmbH)

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004   A Taxonomy of Radiometric-Measurand Metadata

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NCSL International 141 Mil and Automation Committee

Abstract:

The NCSL International 141 MII and Automation Committee and collaborators continue to develop a taxonomy to uniquely identify and distinguish measurands in machine- actionable digital metrology documents such as calibration certificates, accreditation scopes, and instrument specifications. The committee intends to link one or more measurand taxa to each calibration and measurement capability (CMC) contained in the key-comparison database (KCDB) managed at the International Bureau of Weights and Measures. Further extensions would cover national metrology institutes and accredited laboratories CMCs not directly mapped to KCDB service codes. As a FAIR reference data set, such metadata will contribute to the interoperability critical for metrology's digital transformation and the DCC in particular.

This presentation outlines the taxonomy structure and presents progress toward covering the KCDB CMCs in general and efforts at New Zealand's Measurement Standards Laboratory to extend coverage to radiometry in particular. We report current KCDB coverage, new radiometric taxa, and describe the relations between the taxa and the KCDB's services, sub services, individual services and quantity designations.

the authentication of digital assets by end-users. This demonstrator shows that data spaces, as federated network, are inherently suited to these complex tasks. Implementing self-sovereign identities, digital wallets, and using the Eclipse Data Space Components controlled data sharing via beforehand agreed policies, Quality-X facilitates the secure creation, collection, distribution, and verification of credentials, digital assets, and meta data.

Furthermore, we discuss the potential of semantic models and semantic hubs in achieving interoperability across diverse digital assets. This interoperability is paramount for the seamless and automated interaction of various actors within the QI ecosystem, such as standardization institutes, conformity assessment bodies, and market surveillance authorities. We outline other QI processes that can be simulated in our Testbed: digital issuance and signing of certificates, tamper-proof metadata publication to neutral registries, and dynamic digital asset versioning from inception to lifecycle conclusion.

Presentation of Neil Swift

A Taxonomy of Radiometric-Measurand Metadata

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NCSL International 141 MII and Automation Committee

Measurement-Information Infrastructure

Introduction

Section 1

Introduction

Today's Topics

1. Introduction

2. Motivation and Strategy

3. Tools and Process

4. Conclusion

Acronyms

- BIPM—International Bureau of Weights and Measures
- CMC—calibration and measurement capability
- DCC—digital calibration certificate
- DCR—digital calibration request
- DX—digital transformation
- FAIR—findable, accessible, interoperable, reusable
- KCDB—key comparison database

- M-layer—metrology information layer to support measurement systems
- NCSLI—NCSL International
- NMI—national metrology institute
- PID—persistent identifier
- PR—photometry-radiometry
- SIRP—SI reference point
- SoA—scope of accreditation

MII (measurement information infrastructure)

set of normative standards that unambiguously define data structures, taxonomies, service protocols and security for locating, communicating and sharing measurement information

Section 2

Motivation and Strategy

Motivation

- We want interoperability and reusability for machine-actionable measurement data.
    - Time and labor savings
    - Automatic data validation and verification
    - New productivity, services, data value and insight
    - Digital documents such as DCCs won't realize their potential otherwise.
- This requires standardized metrology metadata.
- One of least standardized data elements: measurand descriptions
    - Various DCC and other DX projects currently seek a measurand identifier.
    - Wanted: unique measurand PIDs
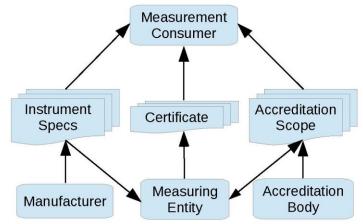
MII Proposal for Measurand Metadata

1. Standardize a measurand taxonomy.
2. Link taxa to KCDB CMC IDs.
3. Tag digital document data and service offerings with the taxa as metadata.

Spec: `Source.Voltage.DC`

SoA: `Measure.Voltage.DC`

Cert: `Source.Voltage.DC`
Cert: `Measure.Voltage.DC`

Solution: abstract taxon definitions customized for any context

Measure.Coefficient.Current.SpectralIrradiance

Definition: `https://cie.co.at/eilvterm/17-25-063`, `https://cie.co.at/eilvterm/17-21-053`

- **Required Parameters (instantiated with ranges)**
  - SpectralIrradiance
  - DetectorType {SiliconSingleElement, SiliconTrap, InGaAs, GaN, Ge, Photomultiplier, Pyroelectric, Thermopile, CryogenicRadiometer, Photocell, ...}
  - Wavelength
  - SpectralBandwidth
- **Optional Parameters (instantiated with ranges)**
  - Irradiance
  - OpticalPower
  - Current[.Output]

Uptake and Interest

Known interest in the MII Measurand Taxonomy

- Metrology companies: Cal Lab Solutions, IndySoft, Keysight
- "Enhancing the interoperability of Calibration Certificates", Diego Nahuel Coppa, Marcos Bierzychudek, Andrés Torn, Héctor Laiz, FORUM-MD Workshop 2025
- "Proposal to improve the interoperability of the DCC", Diego Coppa, DCCC 2024
- "Toward standardized language and structure for machine interpretable DCCs", David Balslev-Harder, DCCC 2024
- "Digital workflows and e-services in metrology for small and medium NMIs", Søren Kynde, DTI's DCC Theme Day 2023
- "Machine Readability—Automating the Extraction of Data from DCCs", David Balslev-Harder, DCCC 2023

Uptake requires a wide-ranging taxonomy.

Current Project

We would like to link the taxonomy to KCDB CMCs.

- Started with one service category (photometry) to test the process
- Extend coverage across the KCDB: electrical-RF, radiometry, ...
- Extend coverage for additional measurand demand down the traceability chain.
  - Derived NMI measurement services
  - Lower laboratories' accredited CMCs
  - Unaccredited CMCs

The MII taxonomy will point to the KCDB since it already exists but future digital documents and enterprise systems may use the taxonomy as a FAIR standardized metadata resource.

Differences in Approach

BIPM proceeds with its own digital transformation, which includes PIDs and digitalized CMCs.

So what does the MII Measurand Taxonomy add?

- Coverage for all CMCs: NMI services, accreditation scopes, unaccredited services
- Interoperability for all measurement data: CMCs, DCCs, instrument specs, DCRs
- Comprehensive M-layer coverage
  - All quantity and unit systems (e.g., Dobson units)
  - All scale types (e.g, ordinal scales for hardness)
  - Aspects that disambiguate traditional quantity systems
  - Machine-targeted unit conversions and scale transformations

All MII metadata systems will point back to BIPM CMCs, SIRP, etc., whereever relevant.

Section 3

Tools and Process

Tools and Process

Tools

- Open-source taxonomy editor at
  `https://github.com/CalLabSolutions/Metrology.NET_Public`
- Project hosted on GitHub at `https://github.com/NCSLI-MII/measurand-taxonomy`
- Provides the taxonomy as a combined XML file and as separate XML taxa
- In process: a repository to integrate quantities, units, measurands, CMCs
  - Pull data from the M-layer and KCDB APIs
  - Link taxa to M-layer quantities (aspects) and units (scales)
  - Link taxa to KCDB CMCs and service categories
  - Monitor coverage, find orphans, expose gaps, facilitate development

Tools and Process

Process

Third effort: radiometry branch of the PR area. Steps:

1. Review documentation: "Classification of Services In Photometry And Radiometry".
2. Draft initial taxa to match the services, sub services or individual services.
3. Focus on taxon names first, though parameter sets influence the names
4. Pull all the relevant KCDB CMC-entry data.
5. Sort and filter on service, subservice, individual service, quantity and instrument.
6. Analyze the method, units, uncertainty, comments and parameter data.
7. Supplement the data from other sources—experts, literature, standards, etc.—as required.
8. Draft a taxon set to represent the unique measurands and their parameters.

The information assembled at BIPM through CIPM and its Consultative Committees greatly facilitates taxon creation. The BIPM's KCDB digitalization should speed the process considerably.

Tools and Process

Example KCDB CMC Data

KCDB Field(s)	Data
metrologyAreaLabel	PR
branchValue, serviceValue	Properties of detectors and sources, (2) Properties of detectors
subServiceValue	(2.2) Responsivity, spectral, irradiance
individualServiceValue	(2.2.2) Broad band detector
quantityValue	Responsivity, spectral, irradiance
instrument	Broad band detector
instrumentMethod	Substitution with spectral responsivity standards
cmc	unit: $A/(W/m^2)$, $V/(W/m^2)$, reading$/(W/m^2)$
traceabilitySource	—
comments	Other type of detector could be measured
internationalStandard	—
parameters	Wavelength: 400 nm to 500 nm; Bandwidth: 4 nm to 50 nm; Irradiance: 1 µW to 50 µW

Tools and Process

Branch: Properties of detectors and sources, Service: Detectors

Sub Service	Individual Service	Quantity	Taxon(s)—PRELIMINARY
Responsivity, spectral, power	Broad band detector	Responsivity, spectral, power	Measure.Ratio*.OpticalPower
Responsivity, spectral, irradiance	Broad band detector	Responsivity, spectral, irradiance	Measure.Ratio*.SpectralIrradiance*
|	Spectroradiometer	|	Measure.Ratio*.SpectralIrradiance*
Responsivity, spectral, radiance	Broad band detector	Responsivity, spectral, radiance	Measure.Ratio*.SpectralRadiance*
Responsivity, laser, power	General detector	Responsivity, laser, power	Measure.Ratio*.OpticalPower.CW.Laser
Responsivity, laser, energy	General detector	Responsivity, laser, energy	Measure.Ratio*.Energy.Pulse.Laser
Responsivity, solar, irradiance	General detector	Responsivity, solar, irradiance	Measure.Ratio*.Irradiance.Solar
|	|	|	Measure.Current.DC.DSR
|	Broadband detector	|	Measure.Ratio*.Irradiance.Solar
Resp., UV, BB irradiance	UV radiometer	Resp., UV, BB irradiance	Measure.Ratio*.Irradiance.UV
Resp., UV, BB rad. exposure	UV radiometer	Resp., UV, BB radiant exposure	Measure.Ratio*.RadiantExposure.UV
Resp, solar, spectral, irradiance	Solar spectroradiometer	Resp., solar, spectral, irradiance	Measure.Ratio*.SpectralIrradiance.Solar*

*These sub services also include ...Coefficient.Voltage... and ...Coefficient.Current... taxa (omitted for space).

Tools and Process

Branch: Properties of detectors and sources, Service: Sources

Sub Service	Individual Service	Quantity	Taxon(s)—PRELIMINARY
Irradiance, spectral	Tungsten lamp	Irradiance, spectral	Measure.SpectralIrradiance*
|	Deuterium lamp	|	|
Radiance, spectral	Tungsten lamp	Radiance, spectral	Measure.SpectralRadiance*
|	Deuterium lamp	|	|
|	General source	|	|
Power, spectral total radiant	Laser	Power, spectral total radiant	Measure.OpticalPower.CW.Laser
|	|	|	Measure.OpticalPower.Pulse.Laser
Radiant intensity, spectral	Tungsten lamp	Radiant intensity, spectral	Measure.SpectralRadiantIntensity*
|	Deuterium lamp	|	|
Radiant flux, spectral	General source	Radiant flux, spectral	Measure.SpectralRadiantFlux*
|	Tungsten lamp	|	|

* Tokens including "Spectral" indicate spectral-density quantities, e.g., per nm.
Some KCDB CMC entries inevitably contradict themselves. Digitalization and input validation will help.

Tools and Process

Example KCDB-Linkage Results

Taxon	kcdbCode
. . .	. . .
Measure.Coefficient.Voltage.SpectralIrradiance Measure.Coefficient.Current.SpectralIrradiance Measure.Ratio.SpectralIrradiance	AFRIMETS-PR-ZA-000006G1-1
Measure.Coefficient.Current.OpticalPower	APMP-PR-JP-000005T7-2
Measure.Coefficient.Voltage.Irradiance.Solar	EURAMET-PR-CH-00000DR2-1
Measure.Energy.Pulse.Laser	SIM-PR-US-00000A2B-2
Measure.SpectralRadiance	SIM-PR-CA-000009MC-1
. . .	. . .

Section 4

Conclusion

Photometry and Radiometry Service Coverage as of Feb 22nd, 2025

PR Services

1. Photometry ✓
2. Properties of detectors ✓
3. Spectral emission properties of sources ✓
4. Spectral properties of materials—taxa drafted
5. Spectrally-integrated measurements for sources and detectors—taxa drafted
6. Colour and other spectrally-integrated measurements of materials—taxa drafted
7. Fibre optics

Some PR sub services have no CMC entries in the KCDB.

KCDB CMC Coverage as of Feb 22nd, 2025

Area Code	CMC Count	Metrology Area	Taxon Coverage
AUV	Acoustics, Ultrasound, Vibration	1260	scattered
EM	Electricity and Magnetism	4640	≈ 79 %*
L	Length	1696	scattered
M	Mass and related quantities	2973	scattered
PR	Photometry and Radiometry	1551	≈ 56 %*
QM	Chemistry and Biology	6455	none
RI	Ionizing Radiation	3708	none
T	Thermometry	3001	scattered
TF	Time and Frequency	825	scattered
	Total	**26109**	**17 % to 29 %**

* Reported at NCSLI 2024 Conference
* Reported at DCC 2024, 2025 Conferences

Recommendations

Establish and use a measurand taxonomy

- Unique measurand PIDs with unlimited human-readable aliases
- Fully qualifies measurands for interoperable digital documents
- (DCCs, instrument specs-DCRs, SoAs, . . .)
- Provenance to BIPM: KCDB, SIRP, etc.

Collaboration

- Available for metrologists to augment, review and critique
- Current information
  - GitHub for configuration management (submission, review, approval):
    https://github.com/NCSLI-MII
  - Open-source taxonomy and SoA editors:
    https://github.com/CalLabSolutions/Metrology.NET_Public
  - Further info: http://miiknowledge.wikidot.com/

Conclusion

Acknowledgments

Many thanks go to

- Neil Swift, MSL, New Zealand for subject-matter expertise
- PTB and the DCC conference organizers for the kind invitation
- NCSL International for its MII support
- NCSL International 141 MII and Automation Committee members for their MII development work
- Cherine-Marie Kuster

And Thank You for your time!

Collaboration opportunities? Please bring your expertise!

Questions?

| NCSLI 141 (MII&AC) | DCC 2025 | Tuesday, February 25, 2025 | 23 / 23 |

005   A Matter of Trust

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Abstract

It is not hard to argue that in the digital world we trust too much and take a lot of things for granted. For example, we assume that our paying for things with our smart watches and phones is completely secure despite the presence of NFC Scanners that can rob us and defraud us in seconds. We like the convenience of solutions like our Banking Apps and Google Pay and the speed and effectiveness of these solutions and quickly jump over possible security problems with "oh, it can't happen to me. I'm careful". In the corporate world, nobody looks at digital security with a critical eye unless it's necessary. When it's necessary, it's usually due to pain. That pain usually has large monetary consequences.

By passing the eIDAS Regulations, the EU have created means to anchor and support the trust the world puts into digital products. In the regulation are prescribed digital certificates to confirm website origins or secure connections, and digital signatures and seals that have the same legal standing as ink and stamps are but a few examples. All of which firmly hold up our quickly given trust in digital solutions.

In our presentation we will show that Qualified Electronic Seals confirm the origin of digital documents and protect against unnoticed changes. We will explain how a digital calibration

certificate wrapped in a qualified electronic seal anchors and supports the baked in quality of a digital calibration certificate. A Qualified Digital Seal is a foundation for the trust the consumers of Digital Calibration Certificates have in those certificates.

Presentation of Andrew Freund

Convienience or easy to steal?
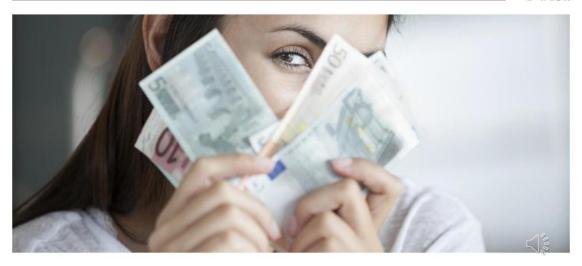
d-trust.

Teil der Bundesdruckerei-Gruppe 3

The Pain

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Teil der Bundesdruckerei-Gruppe 4

The Trust Anchor

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eIDAS Trust Services

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The trust services of the eIDAS Regulation ensure security and transparency in the digital world

Electronic Signatures
The individual's digital signature

Delivery Services
Secure digital messaging as with the post office or bailiff

Electronic Seals
The trustworthy digital mark of Government and industry

Verification Service
The automatic independent verifier

Time Stamp
The official Time like on an electronic photo

Archive Service
The forever digital archive

Website Certificates (QWAC)
The secure identification of a website owner
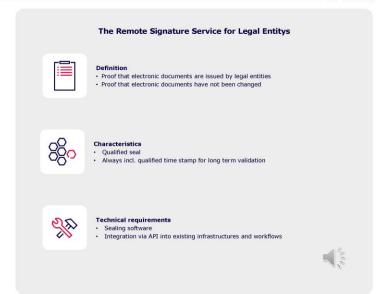
seal-me: D-Trust Qualified Remote Sealing Service

d-trust.

The Remote Signature Service for Legal Entitys

Definition
- Proof that electronic documents are issued by legal entities
- Proof that electronic documents have not been changed

Characteristics
- Qualified seal
- Always incl. qualified time stamp for long term validation

Technical requirements
- Sealing software
- Integration via API into existing infrastructures and workflows

seal-me: Qualified Remote Sealing Service

Remote Sealing Service
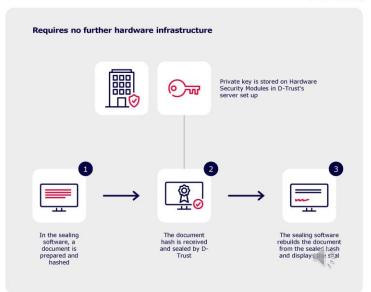
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Qseal-as-a-service

Requires no further hardware infrastructure

Private key is stored on Hardware Security Modules in D-Trust's server set up

With the qualified remote sealing service, you can handle your sealing processes electronically from start to finish.

Simple and uncomplicated.

1 In the sealing software, a document is prepared and hashed

2 The document hash is received and sealed by D-Trust

3 The sealing software rebuilds the document from the sealed hash and displays the seal

Securing and Anchoring our Trust in DCCs with QESeals

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• Sealing a DCC XML

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Challenges
- **DCC is an stable XML with instable content with many types and attributes being optional**
    - This can make the XADES Signature Type inpractible for the QTSP and can lead to errors in the signature process
- **Guaranteeing that the DCC XML has not in any way been changed since issuance**
    - All elements of an XML can be changed in a simple text editor by an intercepting party
- **Guaranteeing the issuer of the DCC XML, the source of the document**
    - In an age where Hackers route through multiple IP Adresses, determining the source of an XML document can be tricky

There is a solution already being used multiple D-Trust Customers in Health Care and Goverment for non-PDF Documents

- The Solution: Remote Sealing using Enveloping Specified in RFC 5652 - Interworking

d-trust.

Customer IT

Customer-Application → seal-me API → seal-me Enveloping-Proxy → sign-me API → **D-TRUST IT** seal-me Remote Seal

Customer application uses seal-me API and addresses an enveloping proxy with it

Data protection: the request from the customer application to the enveloping proxy contains plain text documents. This does not create a data protection problem, as the proxy lies within the customer's IT!

Customer application receives a seal with the embedded, unchanged plain text document back from the enveloping proxy

Enveloping-Proxy calls D-TRUST

The plain text document is hashed in the Proxy on the way to D-TRUST

D-TRUST only recieves the document hash

The document is enveloped in the CADES Signature on the return path to the Customer Application

Enveloping is performed as specified in RFC 5652 Section-5.2 "EncapsulatedContentInfo"

- Enveloping according to RFC 5652 – Principles and Advantages

d-trust.

Enveloping according to RFC 5652 Section-5.2

The eContent field is empty in the seal-me signature as seal-me only recives hashes

The eContent field will be addressed in the Enveloping Proxy and filled with the original unchanged plain text document on return path to the customer application.

Can be implented with standard libraries such as Bouncy-Castle

ASN.1 Struktur aus RFC 5652

```
EncapsulatedContentInfo ::= SEQUENCE {
    eContentType ContentType,
    eContent [0] EXPLICIT OCTET STRING OPTIONAL
}
```

- **Advantages**

  - Data protection of highly sensitive documents is easy to ensure despite remote signatures
  - Signature and document can be processed and archived together in a compact form (as with PDF), which is an advantage over remote CADES signatures
  - The process is independent of the data format of the plain text document to be signed
  - Plain text documents can be binary content of any size

A Secured DCC

d-trust.

d-trust.

Andrew Freund
Senior Product Manager

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Teil der
Bundesdruckerei-
Gruppe

14

Day 1 (2025-02-25 Tuesday)
Parallel Session "Applications NMI I"
(Chair: Brett Hyland)

006 Concepts and frameworks fostering interoperability within a digital quality infrastructure: DCC development in Colombia and QI infrastructure interoperability under an Enterprise Architecture Framework

Presenting author: Rodolfo Manuel Gomez Rodriguez
Email: jefeoidt@inm.gov.co
Additional authors: Jose Eduin Culma Caviedes jeculma@inm.gov.co
National Metrology Institute of Colombia

Abstract

For the DCC adoption, development, and implementation in the INM Colombia, we are working decisively in identifying, structuring, and generating a data governance model for all the processes we have, including data generated during measurements. So, it has been recognized that it's necessary to employ a reference framework that allows us to define our main objectives, scopes, capabilities and maturity levels.

In this regard, some activities have been carried out to recognize the different data and variables used in the laboratories, with the objective of achieving a data collection and visualization that in the future be in accordance with standards that are useful for presenting measurement data in a format that aligns with the consensus in the metrological world, thus allowing its reading and interoperability.

To govern the data, we must identify the data we have. In this context, activities have been undertaken to review all management processes at the INM, allowing the identification of data flows for each process and enabling the initial characterization of these data.

Furthermore, according to the criteria adopted in the country to leverage data, the INM is designing and implementing actions and guidelines aimed at ensuring data quality, security, and privacy. So, while we are working on identifying tasks to do in the future, we are also advancing in structuring guidelines and procedures that will guide the future creation of data and consequently, their utilization. This allows us to perform in data quality, becoming Findable, Accessible, Interoperable and Reusable (FAIR).

Now we have an opportunity to achieve progress on another fundamental aspect of Enterprise Architecture: the identification of artifacts that are reusable across many tasks, referred to solutions building blocks (SBB). The reusability of SBB must be seen as an opportunity for being more effective, because some tasks that were solved by someone (area, laboratory or researcher), can be analysed by another regarding its viability of use and appropriation in another process and in the future by another institution, specially from the Quality Infrastructure.

This is a key element for moving forward under a structured framework to the digitalization of data, and therefore the construction of the DCC in the different NMI Colombia laboratories, as well as in the mechanisms for data interoperability with other stakeholders, especially with our partners.

The integration of Quality Infrastructure will allow us to advance collectively towards solutions that are useful and transversal for industries, where our new building has walls made by SBB as bricks and data as glue.

Presentation of Rodolfo Manuel Gomez Rodriguez

Instituto Nacional de
Metrología de Colombia

Theme 4 –Concepts and frameworks fostering interoperability within a digital quality infrastructure

DCC development in Colombia and QI infrastructure interoperability under an Enterprise Architecture Framework

National Metrology Institute
Colombia

February 2025

5TH INTERNATIONAL DCC CONFERENCE
DCC FOR FAIR PRINCIPLES IN THE QUALITY INFRASTRUCTURE

Departamento
Nacional de Planeación

Instituto Nacional de
Metrología de Colombia

Agenda

1. Policies and regulatory framework related to Digital Transformation in Metrology.
2. Enterprise Architecture Framework

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**Departamento
Nacional de Planeación**

**Instituto Nacional de
Metrología de Colombia**

1. Policies and regulatory framework related to Digital Transformation in Metrology

www.inm.gov.co

National Digital strategy 2023 - 2026

Main objective: unleash the potential of the digital transformation to overcome the economic, social and environmental challenges through the strengthening of its enablers and a strong and a decisive boost to **the use and appropriation of data and digital technologies**.

This strategy focuses on eight axes are:
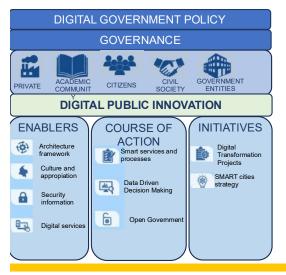
1. Digital connectivity to change lives:
2. **Access, use and exploitation of data to drive social transformation**;
3. Digital security and trust to guarantee people's freedoms and integral development;
4. Digital skills and talent as a driver of opportunities;
5. Artificial Intelligence and other emerging technologies to generate economic and social value;
6. Public digital transformation to strengthen the State - Citizenship link;
7. **Digital economy** for productive transformation;
8. Digital society for inclusive, equitable, and sustainable development.

**Departamento
Nacional de Planeación**

www.dnp.gov.co

Colombian Digital Government Policy (Decree 767 – 2022) and Digital Transformation Guidelines

DIGITAL GOVERNMENT POLICY

GOVERNANCE

PRIVATE | ACADEMIC COMMUNITY | CITIZENS | CIVIL SOCIETY | GOVERNMENT ENTITIES

DIGITAL PUBLIC INNOVATION

ENABLERS	COURSE OF ACTION	INITIATIVES
Architecture framework	Smart services and processes	Digital Transformation Projects
Culture and appropiation	Data Driven Decision Making	SMART cities strategy
Security information	Open Government	
Digital services		

Departamento
Nacional de Planeación

www.dnp.gov.co

Guidelines and standards applicable to public digital transformation (Decree 1263 of 2022)

1. **Use and exploitation of data**
2. **Interoperability**
3. **digitization and automation of procedures, services and processes**
4. Use of demand aggregation mechanisms
5. **Cloud services**
6. **Strategic Plan for TI**
7. Exploration for new regulations
8. **Artificial Intelligence**
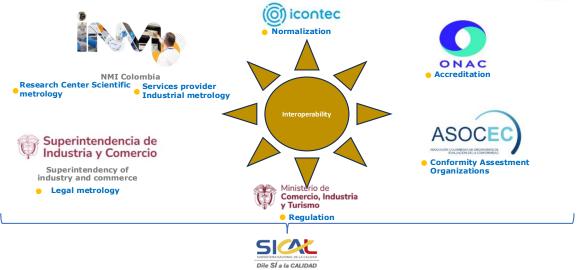
2. Entreprise architecture framework

www.dnp.gov.co
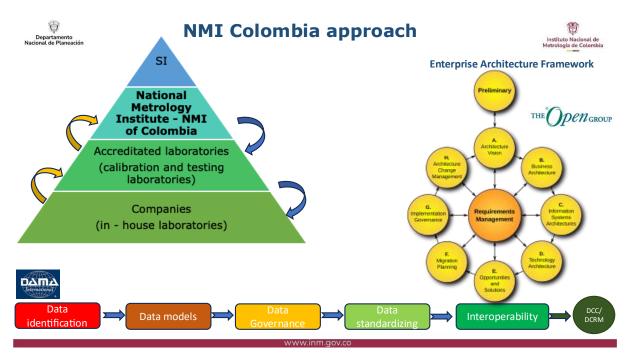
Stakeholders in Digital Transformation – Colombian QI

Normalization

NMI Colombia
Research Center Scientific metrology
Services provider Industrial metrology

Accreditation

Superintendency of industry and commerce
Legal metrology

Conformity Assessment Organizations

Interoperability

Regulation

Quality Infrastructure Sub-System
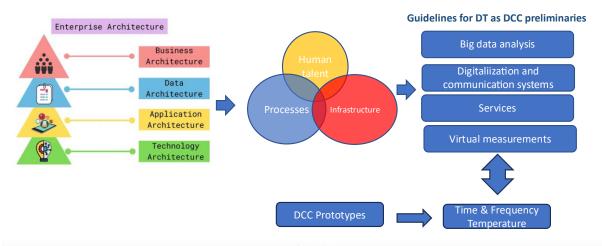
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NMI Colombia approach

SI

National Metrology Institute - NMI of Colombia

Accreditated laboratories (calibration and testing laboratories)

Companies (in - house laboratories)

Enterprise Architecture Framework

| Data identification | Data models | Data Governance | Data standardizing | Interoperability | DCC/ DCRM |

www.inm.gov.co
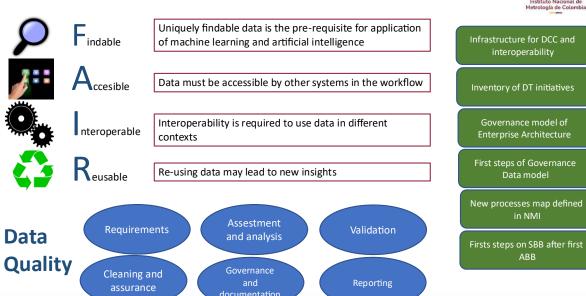
Digital Transformation in metrology through Enterprise Architecture

Guidelines for DT as DCC preliminaries

Enterprise Architecture

- Business Architecture
- Data Architecture
- Application Architecture
- Technology Architecture

Human talent

Processes

Infrastructure

- Big data analysis
- Digitaliization and communication systems
- Services
- Virtual measurements

DCC Prototypes → Time & Frequency Temperature

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NMI Colombia Advances

Instituto Nacional de Metrología de Colombia

Findable — Uniquely findable data is the pre-requisite for application of machine learning and artificial intelligence

Accesible — Data must be accessible by other systems in the workflow

Interoperable — Interoperability is required to use data in different contexts

Reusable — Re-using data may lead to new insights

- Infrastructure for DCC and interoperability
- Inventory of DT initiatives
- Governance model of Enterprise Architecture
- First steps of Governance Data model
- New processes map defined in NMI
- Firsts steps on SBB after first ABB

Data Quality

- Requirements
- Assesment and analysis
- Validation
- Cleaning and assurance
- Governance and documentation
- Reporting

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Thank you!

Rodolfo Gómez – jefeoidt@inm.gov.co

007 Calibration support system development of KTL (Korea Testing Laboratory) using certificate database established by OCR

Presenting author: Ryu Dong-Hun
Email: dhryu@ktl.re.kr
Additional authors: None

Abstract

KTL (Korea Testing Laboratory) has developed a data-driven calibration certificate management system, KArgos, for the digital transformation of calibration certificates. This system utilizes AI-based OCR (Optical Character Recognition) technology to convert calibration certificates, which exist in various document formats such as PDF, Excel, Word, and images, into a database (DB). KArgos provides statistical data based on the accumulated calibration results, such as general performance level of test equipment and fault possibility in calibration data. This was achieved by extracting data from various unstructured documents and standardizing it for storage. Additionally, KArgos oﬀers a function to correct the equipment's identification information (e.g., manufacturer, model name, serial number). As part of its future plans, KArgos will implement an online service for technical managers that automatically verify data, identify any anomalies, and notifies the technical manager during the digital sign stage of the calibration process. KArgos is expected to significantly enhance the digitization and data utilization of calibration certificates, contributing to the improvement of the eﬀiciency and reliability of the calibration process.

Presentation of Ryu Dong-Hun

Summary

- Certificates Database accumulation and analysis example
- Future plan

Example
1. DB accumulation using OCR
2. Grouping similar results I   : manufacturer correction
3. Grouping similar results II   : nominal value estimation
4. Analysis using the past results

Future Plan
1. Making a certificate check agent to enhance the quality.
2. Making a client service to digitized certificates.
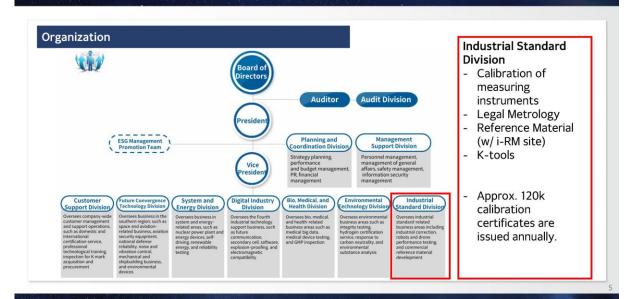
3

1. Introduction : KTL

KTL (Korea Testing Laboratory)

Public Institute
Under the ministry of trade, industry and energy

Main Objective
Test and Certification For industry

4

1. Introduction : KTL

Organization

Industrial Standard Division
- Calibration of measuring instruments
- Legal Metrology
- Reference Material (w/ i-RM site)
- K-tools

- Approx. 120k calibration certificates are issued annually.

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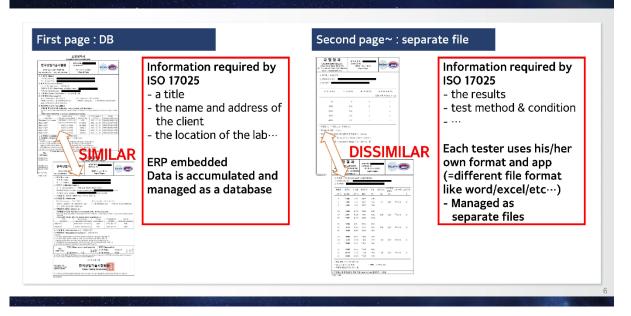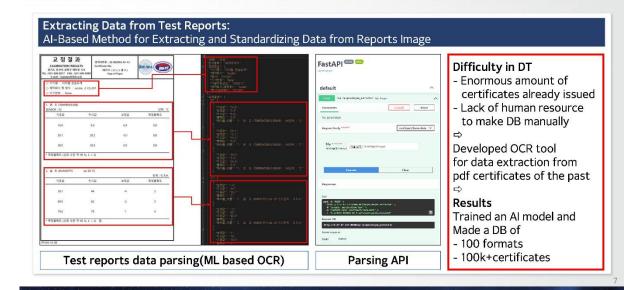
1. Introduction : Certificates and database

First page : DB

SIMILAR

Information required by ISO 17025
- a title
- the name and address of the client
- the location of the lab…

ERP embedded
Data is accumulated and managed as a database

Second page~ : separate file

DISSIMILAR

Information required by ISO 17025
- the results
- test method & condition
- …

Each tester uses his/her own format and app (=different file format like word/excel/etc…)
- Managed as separate files

2. Research field : Calibration Certificate OCR

Extracting Data from Test Reports:
AI-Based Method for Extracting and Standardizing Data from Reports Image

Test reports data parsing(ML based OCR)

Parsing API

Difficulty in DT
- Enormous amount of certificates already issued
- Lack of human resource to make DB manually
⇨
Developed OCR tool for data extraction from pdf certificates of the past
⇨
Results
Trained an AI model and Made a DB of
- 100 formats
- 100k+certificates

7

2. Research field : AI-Based Similarity Search

Data Search System :
Extracting Search Results Containing User-Input Keywords (*LIKE* search system)

Grouping the results I

- Manufacturer & Model & SN data are enough to identify the instrument.
- Have to make a group similar instruments, but…

Ex :   BROOKFEILD
        Brookfield
        brook-field
        QL200–MK
        QL200 MK
        QL200MK
        …

BROOKFIELD = BROOKFIELD

2. Research field : AI-Based Similarity Search

Data Search System :
Similarity Search When No Exact Matches Are Found (Similarity search system)

2. Research field : AI-Based Similarity Search

Data Search System :
Similarity Search When No Exact Matches Are Found (Similarity search system)

2. Research field : AI-Based Similarity Search

Data Search System :
Similarity Search When No Exact Matches Are Found (Similarity search system)

2. Research field : Digitalization of Certificate

Grouping the results II

- Reference value may vary slightly and making a group could be difficult

- In some cases, nominal value estimation is required. Could be a source of error.

Cert. #1	Cert. #2	
100.0	100.1	SAME?
100.0	101.1	SAME??
100.0	104.5	??
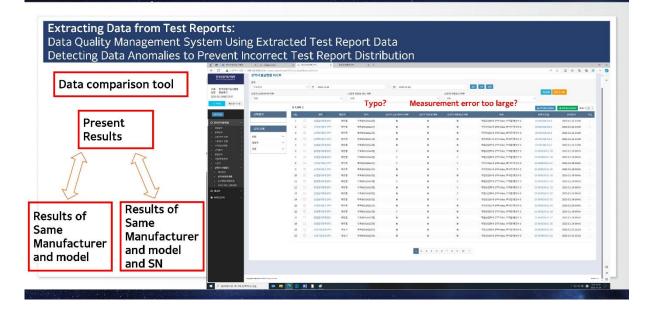
- Having nominal value in DB helps a lot in grouping the measurement results

Standard weight

Conventional Mass
= 9 999.93 g

same model may have
9 999.95 g = SAME?

Could be difficult to make a group

Nominal value
– Very useful in grouping and analyzing data

2. Research field : Digitalization of Certificate

Extracting Data from Test Reports:
Data Quality Management System Using Extracted Test Report Data
Detecting Data Anomalies to Prevent Incorrect Test Report Distribution

Data comparison tool

Present Results

Results of Same Manufacturer and model

Results of Same Manufacturer and model and SN

Typo?   Measurement error too large?

2. Research field : Digitalization of Certificate

Example 1 torque wrench

- Minimal results included in DB to maximize application fields (Ref., Error, U)

- Results are checked compared to
1) Guideline range of the same model
2) Previous results of the same instrument

No.   item   model   manufacturer   SN   SN2   SN3

Ref. Value   Error   Uncertainty

Guideline

Guideline range based on previous results of same model

Previous results of same SN

Results are within The guideline range
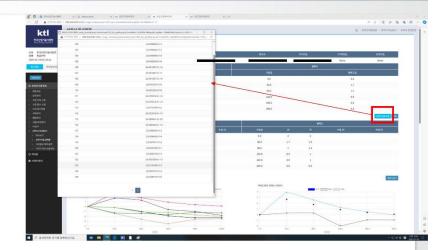
2. Research field : Digitalization of Certificate

It is possible to check how many certificates are present on the same manufacturer & model.
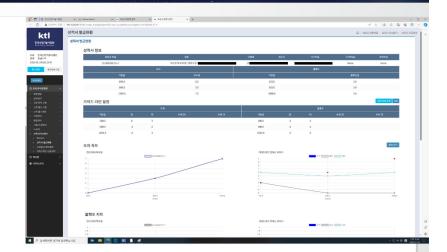
This guideline was made based on the 125 results of same model

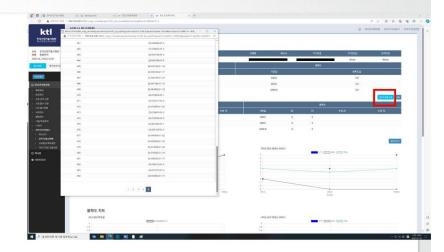## 2. Research field : Digitalization of Certificate

Example 2
Micro pipette

- Example of outlying data
- Current guideline is 25 % and 75 % range of all previous results
- Still needs more elaborated tool to set up the permissible range

2. Research field : Digitalization of Certificate

- Current guideline is 25 % and 75 % range of 484 results

- Manual input by each field expert is possible.

3. Future Plan

Certificate pre-check service:
The Certificate Pre-Check Service employs AI-powered OCR to extract and analyze data from certificates, identifying critical errors before approval

1. A calibration technician performs calibration

2. To prepare a calibration certificate.

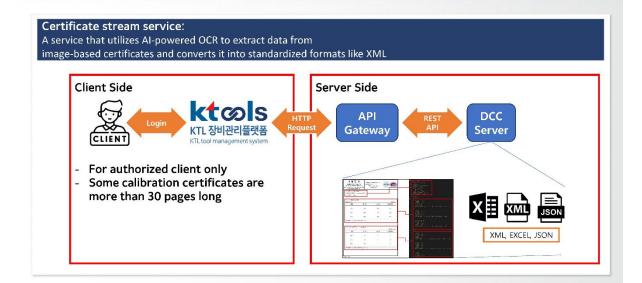3. To submit a calibration certificate for approval.

   + Certificate Pre-Check Service :
   detects errors in calibration data (incorrect results, equipment information, certificate forms, etc.) and notifies key review points

4. The technical manager reviews the certificate and makes the final approval.

5. The approved certificate is provided to the customer.

3. Future Plan

Certificate stream service:
A service that utilizes AI-powered OCR to extract data from
image-based certificates and converts it into standardized formats like XML

Summary

- Certificates Database accumulation and analysis example
- Future plan

Example
1. We issue 120k+ calibration certificates every year and want to make use of results
2. Trained AI to extract data from the past pdf certificates and accumulated DB
3. To make a statistical analysis, more work were needed.
   - unique identifier : manufacturer & model & SN works. But correction is needed.
   - nominal value needs : reference value may vary very slightly. Nominal value is useful.

Future Plan
1. Making a certificate check agent to enhance the quality.
2. Making a client service to digitized certificates.

20

008　The Web-Based Digital Calibration Certificate Generation Platform developed by NIMT

Presenting author: Praiya Thongluang
Email: praiyat@nimt.or.th
Additional authors:None

Abstract

The National Institute of Metrology Thailand (NIMT) has continuously studied the Digital Calibration Certificates (DCCs) in order to find the most suitable type of DCC for our staffs and customers. We have investigated and have experimented with both PDF/A3 format and XML format. Both formats possess distinct advantages. The PDF/A3 allows attachment of additional files possible and facilitates the inclusion of a digital signature. This format ensures both versatility and ease of use. On the other hand, the XML is suitable for machine-readable processes and offers significant benefits for automation and integration with other systems.

Upon these findings, NIMT has adopted a hybrid approach to DCC generation in order to complement strengths of both formats. Currently, NIMT's DCC is generated in PDF/A3 format with an XML file as an attachment. To facilitate this process, NIMT has developed a dedicated web-based platform accessible from dcc.nimt.or.th. This platform is made available for the general XML generation. Hence, the platform consists of two sections: one tailored for NIMT staffs with security and linkage to other NIMT's platforms and another part for general users.

For NIMT's part, the platform seamlessly integrates user information, administrative data, and calibration work orders with NIMT's existing systems. This integration is to ensure accuracy and efficiency when generate DCCs. NIMT staffs may create DCCs in PDF/A3 format with XML files attached, and both components are digitally signed for security and authenticity. For general users' part, the platform enables the generation of DCCs in XML format only, fulfilling the machine-readable requirements.

5thnd international DCC-Conference

Additionally, the platform includes functionality verify schema and Schematron of DCCs in order to ensure that the DCC adheres to predefined standards. In order to validate digital signatures, the platform leverages the Electronic Transactions Development Agency (ETDA) verification service, guaranteeing compliance with recognized digital signature protocols. This comprehensive approach ensures that NIMT's DCC format meets the needs of users, both human and machine, while maintains the highest standards of accuracy, security, and interoperability.

Presentation of Praiya Thongluang

INTRODUCTION

In 2022, NIMT surveys customers and NIMT's staff about their opinion with Digital Calibration Certificate (DCC). The summary of the surveys is described below.

1. Most participants agree with changing the calibration format to digital.

2. Their **apprehension** depends on the type of organization and job position.

For the type of organization

•» The **private sector** has biggest concerned about *changing organizational culture*

•» The **government sector** has most concerned about *the staff's lack of the new knowledge to support the DCC system.*

For the job position

•» The laboratory head and staff are concerned about the *operation process.*

•» The department head focuses on *budget and costs.*

IMPLEMENTATION PROCESS

•» **DCC in PDF/A3 and using datalink as a middleware**

•» **Using Developer function in MS Excel to generate DCC in XML**

•» **Using Python to generate DCC in XML**

•» **The Web-based DCC generate platform**

4
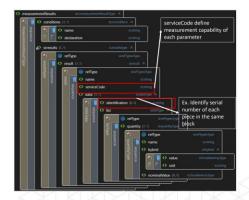
NIMT's schema version 1.1

- Announcement NIMT DCC Schema version 1.1 based on PTB XML DCC v.3.2.1 with some modification.
- Publish Schema Repository in ETDA website for reference in Thailand.

5

FEATURES AND FUNCTIONALITIES

1. Automated Accreditation Scope Verification
The system automatically verifies accreditation scope and selects the correct certificate template.

2. Hybrid Approach (PDF/A3 & XML)
- The system generates DCCs in **both PDF/A3 and XML formats**, ensuring data integrity and accessibility.
- Both formats are digitally signed by NIMT for authenticity.
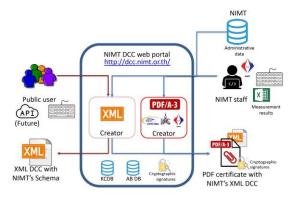
3. Verification Platform
- XML Schema & Schematron validation
- Digital signatures for both PDF and XML files
- Compatibility with ETDA's platform for cross-validation

6

NIMT Web Portal

7

DCC Automating accreditation scope verification concept

Automated accreditation scope verification has been implemented in the NIMT DCC web portal for certificate template type selection

8
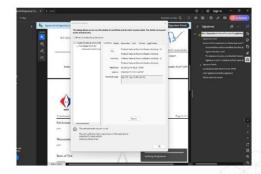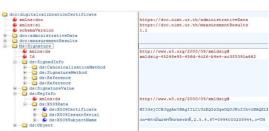
Hybrid approach

PDF/A3

XML

Both document was signed by NIMT

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Verification Platform
(For NIMT's schema version 1.1)

NIMT's Platform

ETDA's Platform

NIMT's Platform	ETDA's Platform
✅ ⟫ XML - Schema	❌ ⟫ XML - Schema
✅ ⟫ XML - Schematron	❌ ⟫ XML - Schematron
❌ ⟫ XML- Digital Signature	✅ ⟫ XML- Digital Signature
❌ ⟫ PDF - Digital Signature	✅ ⟫ PDF - Digital Signature

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CONCLUSION

DIGITAL CALIBRATION CERTIFICATE

Can create DCC via NIMT's platform in PDF/A3 format (Attach an XML file)

TYPE CLASSIFICATION

Automatically classify the type of certificate (NIMT, TISI, or CIPM)

DIGITAL SIGNATURE

Can sign digital signature and timestamp both PDF and XML file

VERIFICATION

NIMT's platform supports DCC validation

11

FUTURE WORK

General User •» • Can generate platform in PDF/A3
• Add feature to help customer extract the xml file

NIMT's staff User •» • Improve platform to support the complex structure data

Validation •» • Support digital signature and time-stamp verify
• Accreditation scope validation

12

009 Generating Mass DCC based on DKD expert report using a spreadsheet

Presenting author: Itzel Dominguez Mendoza (CENAM),
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Additional authors: Carlos Galvan (CENAM), Siegfried Hackel (PTB), J. Armando Lopez-Celis (CENAM), Gregorio Alvarez-Calva (CENAM), Luis Peña-Perez (CENAM)
Keywords: DCC, DCC-Schema, Excel, Subschema, Machine-readable, Digitalization, DKD-Expert reports

Abstract

The DCC has been reported on in the context of many international conferences. The DCC format, which has been developed internationally with all parties involved (industry, laboratories, NMI, accreditors) under the coordination of PTB, is used and further developed by many. A comprehensive collection of quotations can be found in [1].

Meanwhile, there are several activities under way to integrate the DCC into production operations. In particular, it should be emphasised that intensive work is being done to create Good Practice (GP) DCCs. In addition to the initial activities, which can be found on the DCC homepage [2], the DKD [3] is particularly involved in the creation of Good Practice DCCs. These are published in the DKD expert reports. A first expert report on the determination of mass is already available [4]. Further expert reports are shortly to be finalised.

There is also a need in smaller calibration laboratories without larger IT departments, where Microsoft Excel is very often used to create calibration reports. To make it easier for these laboratories to get started with the DCC, the authors have developed a procedure [5] for automatically transferring the calibration measurement results to the corresponding area of the DCC. Based on a DCC subschema, which is tailored to the DKD expert report for determining the mass, an algorithm was further developed that carries out the transfer.

References:

[1] Hackel, Siegfried, et al., Digitization versus Digitalization & Digital Transformation in the field of calibrations and their subsequent use (2024). Physikalisch-Technische Bundesanstalt (PTB). Available at: https://doi.org/10.7795/120.20240126

[2] https://www.ptb.de/dcc, see tile "Good Practice"

[3] https://www.ptb.de/cms/metrologische-dienstleistungen/dkd.html

[4] Foyer, Gisa, et al., Expert Report DKD-E 7-2: Instructions on how to use the DCC schema to create a digital calibration certificate for weights and weight sets,

https://www.ptb.de/cms/fileadmin/internet/dienstleistungen/dkd/archiv/Publikationen/Expertenberichte/DKD-E_7-2_rev1_en.pdf

[5] Lopez-Celis J. Armando, Galvan-Hernandez Carlos, DCC measurement results XML code through a spreadsheet, available https://doi.org/10.1016/j.measen.2024.101483

Presentation of Itzel Dominguez

Generating Mass DCC based on DKD Expert Report using a Spreadsheet

Itzel Dominguez (CENAM), Carlos Galvan (CENAM),
Siegfried Hackel (PTB), José Armando Lopez-Celis (CENAM),
Gregorio Alvarez-Calva (CENAM), Luis Peña-Perez (CENAM)

Initially

➢ Joint lecture by CENAM and PTB

➢ Aim of presentation:
  ▪ Demonstrating a way of DCC automation

➢ Background:
  ▪ Some colleagues feel that DCC
    is too complex

Outline

➢ Siegfried Hackel (PTB)
  ▪ Introduction
  ▪ DKD Expert Report: DCC for weights
    and weight sets
  ▪ DCC-Subschema for DKD Expert Report

Introduction

- ➢ DCC has been well received by the community
- ➢ Many publications
  - ▪ Listing: https://doi.org/10.7795/120.20240126
- ➢ In particular, it is used in the broad area of the pyramid
  - ▪ → Plenary talk tomorrow:
    "DCC in production mode"

DKD Expert Report : DCC for weights and weight sets
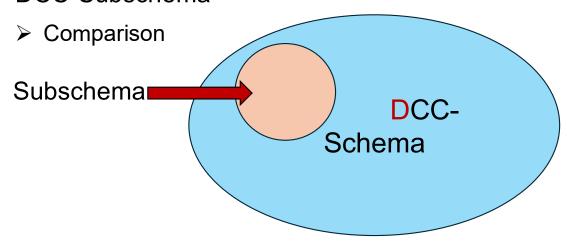
- ➢ 1st DKD Expert Report: DCC Good Practice
  - ▪ https://www.ptb.de/cms/fileadmin/internet/dienstleistungen/dkd/archiv/Publikationen/Expertenberichte/DKD-E_7-2_rev1_en.pdf
- ➢ Many presentations about DCC Good Practice
  - ▪ See e. g. parallel sessions
    - o Key Aspects of DCC I
    - o Industry Applications

DCC-Subschema

➢ Comparison

Subschema ⟶

DCC-Schema

DCC-Subschema for DKD Expert Report

➢ DCC is based on a generic approach
  ▪ Almost all calibration reports can be displayed with it
  ▪ Specific informations on each value possible
    o e. g.: Mobile calibration of particle filters
  ▪ Very often not necessary at this level of detail
    o e. g.: Ambient conditions in an
      air-conditioned laboratory
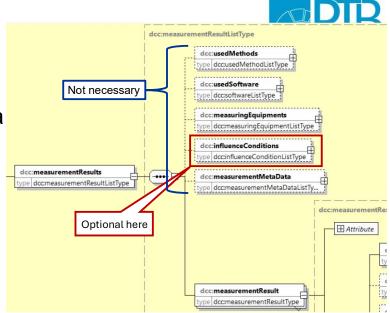
DCC-Subschema for DKD Expert Report

➢ The path to the subschema

  ▪ What is not necessary?

    o Specific informations on each value

      • E. g. ambient conditions are global

  ▪ Are list-in-list elements necessary?

    o No

  ▪ ...

An Example

➢ DCC Schema

An Example

➢ DCC Subschema

An Example

➢ DCC Schema

➡ **José**
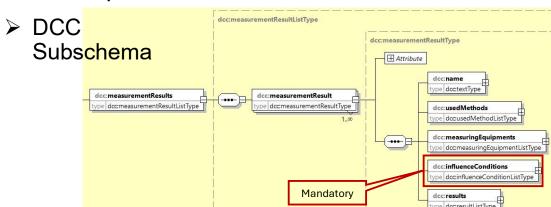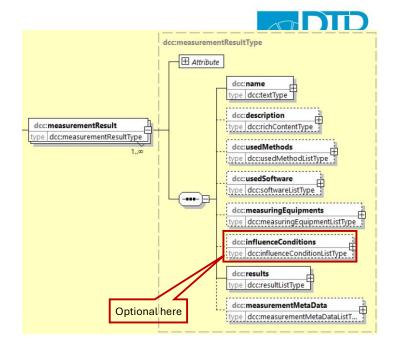
Data Analysis Process

The data analysis process for the time being and to favor natural change, it was decided to find a way to export the results directly from the work environment to the XML file.

DCC Subschema for DKD Expert Report

DCC SubSchema

These **subschema** contain the necessary **elements required by the service**.

13

Generic spreadsheet template

The **MS Excel template** was subdivided into the following 4 areas:
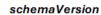
Adapted subschema for use in MS Excel

Types of elements to bind

schemaVersion

3.3.0

Nonrepeating XML elements

```
<xs:attribute name="schemaVersion" use="required">
  <xs:simpleType>
    <xs:restriction base="xs:string">
      <xs:pattern value="3\.3\.0"/>
    </xs:restriction>
  </xs:simpleType>
</xs:attribute>
</xs:complexType>
```

Types of **elements** to bind

```
<xs:complexType name="identificationListType">
  <xs:annotation>
    <xs:documentation>List of additional identifications.</xs:documentation>
  </xs:annotation>
  <xs:sequence>
    <xs:element name="identification" type="dcc:identificationType" maxOccurs="unbounded"/>
  </xs:sequence>
</xs:complexType>
```

```
      <xs:element name="name" type="dcc:textType" minOccurs="0"/>
    </xs:sequence>
    <xs:attribute name="id" type="xs:ID" use="optional"/>
    <xs:attribute name="refType" type="dcc:refTypesType" use="optional"/>
  </xs:complexType>
```

Repeating XML elements

If Identifications			
Name	**Lang**	**Issuer**	**Value**
Serial number	en		
ID number	en		

```
digitalCalibrationCertificate_Map
        ns1:identifications
          ns1:identification
        ns1:measuringEquipment
```

An **XML mapping cannot be exported if** …

</Solve list of lists>

List of lists

```
<xs:complexType name="usedMethodListType">
  <xs:annotation>
    <xs:documentation>
      List of the methods used in the calibration.
    </xs:documentation>
  </xs:annotation>
  <xs:sequence>
    <!--<xs:element name="usedMethod" type="dcc:usedMethodType" maxOccurs="unbounded"-->
    <xs:element name="usedMethodDevelop" type="dcc:usedMethodType"/>
    <xs:element name="usedMethodGUM" type="dcc:usedMethodType"/>          nded">
    <xs:element name="usedMethodOTHER" type="dcc:usedMethodType"/>
  </xs:sequence>
</xs:complexType>
```

Extract from DCC subschema: type definition **"usedMethodListype".**

An XML mapping cannot be exported if …

</Solve list of lists>

List of lists

```
<!-- mandatory list of real elements -->
<xs:element name="real" type="si:realInListType" maxOccurs="unbounded">
  <xs:annotation>
    <xs:documentation xml:lang="en">
      Meta data element definition for a real measurement quantity in list.
      This implementation differs from the pure real quantity in the way that
      the unit component is optional in order to allow a combination with
      a global unit in the list of real quantities.
    </xs:documentation>
  </xs:annotation>
</xs:element>

<xs:element name="realOnce" type="si:realInListType"> <!--Added-->
  <xs:annotation>
    <xs:documentation xml:lang="en">
      Meta data element definition for a real measurement quantity in list.
      This implementation differs from the pure real quantity in the way that
      the unit component is optional in order to allow a combination with
      a global unit in the list of real quantities.
    </xs:documentation>
  </xs:annotation>
</xs:element>
```

Extract from D-SI schema: new type definition **"realOnce"**

An XML mapping cannot be exported if …

</Solve choice schema construct>

Choice

```
<xs:complexType name="dataType">
  <xs:choice maxOccurs="unbounded">
    <!-- ######################### -->
    <xs:element name="text" type="dcc:richContentType"/>
    <xs:element name="formula" type="dcc:formulaType"/>
    <xs:element name="byteData" type="dcc:byteDataType"/>
    <xs:element name="xml" type="dcc:xmlType"/>
    <xs:element name="list" type="dcc:listType"/>
    <xs:element name="quantityOnce" type="dcc:quantityType"/>
    <xs:element name="quantity" type="dcc:quantityType" maxOccurs="unbounded"/>
  </xs:choice>

  <xs:attribute name="id" type="xs:ID" use="optional"/>
  <xs:attribute name="refId" type="xs:IDREFS" use="optional"/>
  <xs:attribute name="refType" type="dcc:refTypesType" use="optional"/>
</xs:complexType>
```
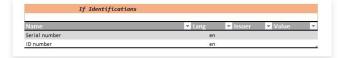
Extract from DCC subschema: type definition **"dataType",** choice construct.

```xml
<?xml version="1.0" encoding="UTF-8" standalone="yes"?>
<ns1:digitalCalibrationCertificate xmlns:ns1="https://ptb.de/dcc" xmlns:ns2="https://ptb.de/si" schemaVersion="3.3.0">
  <ns1:measurementResults>
    <ns1:measurementResult refId="weightABC1234" refType="isInCMC">
      <ns1:name>
        <ns1:content lang="de">Massekalibrierung</ns1:content>
        <ns1:content lang="en">mass calibration</ns1:content>
      </ns1:name>
      <ns1:usedMethods>
        <ns1:usedMethodDevelop>
          <ns1:name>
            <ns1:content lang="de">Bestimmung des konventionellen Wägewerts</ns1:content>
            <ns1:content lang="en">Determination of the conventional weighing value</ns1:content>
          </ns1:name>
          <ns1:normOnce>OIML R111-1:2004</ns1:normOnce>
        </ns1:usedMethodDevelop>
        <ns1:usedMethodGUM refType="basic_uncertainty">
          <ns1:name>
            <ns1:content lang="de">Messunsicherheit</ns1:content>
            <ns1:content lang="en">Measurement uncertainty</ns1:content>
          </ns1:name>
          <ns1:description>
            <ns1:content lang="de">Angegeben ist die erweiterte Messunsicherheit, die sich aus der Standardmessunsicherhei
              Der Wert der Messgröße liegt mit einer Wahrscheinlichkeit von 95 % im zugeordneten V
            <ns1:content lang="en">The reported expanded uncertainty is stated as the standard uncertainty multiplied by a
              The coverage factor k=2 for a normal distribution corresponds to a coverage probability
          </ns1:description>
          <ns1:normOnce>EA-4/02 M:2022</ns1:normOnce>
        </ns1:usedMethodGUM>
      </ns1:usedMethods>
```



```xml
<dcc:digitalCalibrationCertificate xmlns:si="https://ptb.de/si" xmlns:ds="http://www.w3.org/2000/09/xmldsig#" xmlns:
  <dcc:administrativeData>
    <dcc:dccSoftware>
    <dcc:coreData>
    <dcc:items>
    <dcc:calibrationLaboratory>
    <dcc:respPersons>
    <dcc:customer>
    <dcc:statements>
  </dcc:administrativeData>
  <dcc:measurementResults>
    <dcc:measurementResult refId="weightABC1234">
      <dcc:name>
        <dcc:content lang="de">Massekalibrierung</dcc:content>
        <dcc:content lang="en">mass calibration</dcc:content>
      </dcc:name>
      <dcc:usedMethods>
        <dcc:usedMethod>
          <dcc:name>
            <dcc:content lang="de">Bestimmung des konventionellen Wägewerts</dcc:content>
            <dcc:content lang="en">Determination of the conventional weighing value</dcc:content>
          </dcc:name>
          <dcc:norm>OIML R111-1:2004</dcc:norm>
        </dcc:usedMethod>
        <dcc:usedMethod refType="basic_uncertainty">
          <dcc:name>
            <dcc:content lang="de">Messunsicherheit</dcc:content>
            <dcc:content lang="en">Measurement uncertainty</dcc:content>
          </dcc:name>
          <dcc:description>
            <dcc:content lang="de">Angegeben ist die erweiterte Messunsicherheit, die sich aus der Standardmessunsicherheiten V
              Der Wert der Messgröße liegt mit einer Wahrscheinlichkeit von 95 % im zugeordneten by a c
            <dcc:content lang="en">The reported expanded uncertainty is stated as the standard uncertainty multiplied by ability
              The coverage factor k=2 for a normal distribution corresponds to a coverage probabili
          </dcc:description>
          <dcc:norm>EA-4/02 M:2022</dcc:norm>
        </dcc:usedMethod>
      </dcc:usedMethods>
```
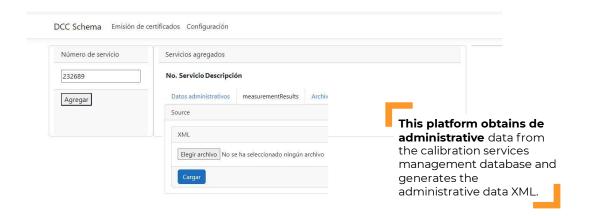
"Remove all tags added to item names with the editor of your choice."

Revert the XML generated to the original valid schema

This platform obtains de **administrative** data from the calibration services management database and generates the administrative data XML.

One example of this subschema can be found at:

Currently, this method has been successfully tested in several calibration services, such as **gauge blocks** by interferometry, **step gauges**, **RTDs** and **weights** in mass.

23

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More questions? Please contact:

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www.ptb.de/dcc

010   Real-World Applications of Digital Calibration Certificates (DCC): Use Cases and Implementation Stories

Presenting author: Yoshitha Weerasinghe, Sri Lanka Standards Institution, Metrology Division, Sri Lanka
E-mail address: yoshitha@slsi.lk

Abstract

Digital Calibration Certificates (DCC) are revolutionizing quality assurance by providing efficient, traceable, and automated solutions for calibration processes. This paper explores practical use cases and user stories that highlight the real-world applications and benefits of implementing DCC in diverse industries. In quality management systems, DCCs enable seamless integration, significantly reducing manual interventions and errors. They support industries in achieving regulatory compliance, such as with ISO/IEC 17025, by providing consistent, traceable documentation for calibration processes. Additionally, DCCs facilitate global collaboration by allowing stakeholders across borders to exchange harmonized and interoperable data smoothly. User stories from various sectors illustrate the transformative impact of DCCs. Metrology laboratories have reported improved efficiency and reduced administrative overhead by automating data handling and report generation. In industrial applications, companies in fields such as automotive manufacturing have adopted DCCs to digitize their calibration workflows, resulting in cost savings and enhanced audit readiness. Similarly, in the healthcare sector, the use of DCCs has improved the calibration of medical devices, ensuring reliability in diagnostics and better patient outcomes. The paper also outlines key implementation strategies for adopting DCCs, including collaboration with software developers to create machine-readable formats, training end-users for effective adoption, and building stakeholder confidence through pilot projects. These examples demonstrate the transformative potential of DCCs in advancing digital quality infrastructure, providing inspiration and a roadmap for broader adoption.

Keywords: Digital Calibration Certificates, quality assurance, interoperability, regulatory compliance, healthcare diagnostics, calibration workflows.

Presentation of Yoshitha Weerasinghe

INTRODUCTION

- Revolutionizing Quality Assurance with Digital Calibration Certificates (DCC)
- Their role in modern quality assurance
- Overview of today's discussion

BENEFITS OF DCCS
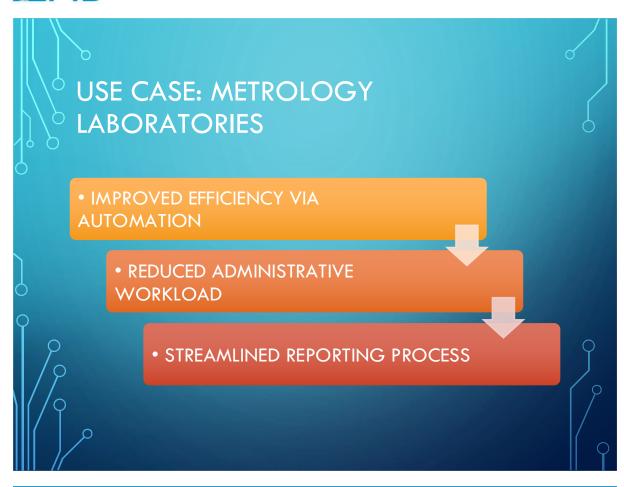
Efficient, traceable processes

Fewer manual errors

Seamless integration with quality systems

REGULATORY COMPLIANCE

Support for ISO/IEC 17025

Consistent, traceable documentation

Simplifies audit preparation

GLOBAL COLLABORATION

- Harmonized calibration data
- Facilitates international data exchange
- Enhances global cooperation

USE CASE: METROLOGY LABORATORIES

- IMPROVED EFFICIENCY VIA AUTOMATION

- REDUCED ADMINISTRATIVE WORKLOAD

- STREAMLINED REPORTING PROCESS

USE CASE: INDUSTRIAL APPLICATIONS

EXAMPLE: AUTOMOTIVE MANUFACTURING

COST SAVINGS THROUGH DIGITIZATION

ENHANCED AUDIT READINESS

USE CASE: HEALTHCARE SECTOR

Calibration of medical devices

More accurate diagnostics

Improved patient outcomes

IMPLEMENTATION STRATEGIES

COLLABORATE WITH SOFTWARE DEVELOPERS

USE MACHINE-READABLE FORMATS

TRAIN END-USERS EFFECTIVELY

BUILDING STAKEHOLDER CONFIDENCE

Pilot projects for initial testing

Collect feedback for improvements

Share success stories
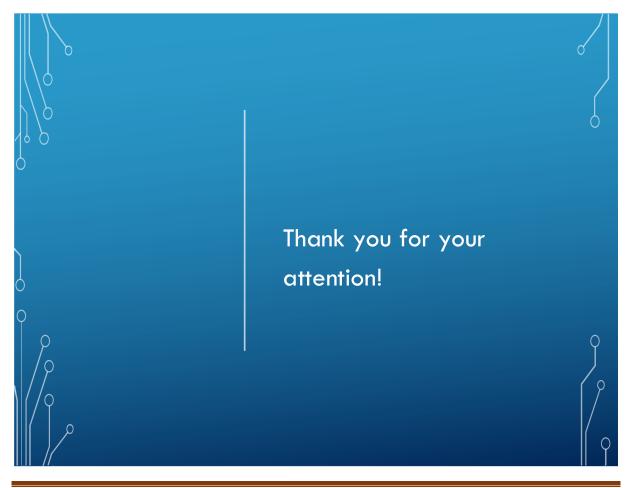
CHALLENGES AND SOLUTIONS

- Technical integration issues → Collaborate with IT experts

- Resistance to change → Conduct user training

- Data security concerns → Implement secure data protocols

CONCLUSION

✓ Recap of benefits and real-world applications

✓ Future potential for digital quality infrastructure

✓ Encouragement for broader adoption

Thank you for your attention!

Day 2 (2025-02-26 Wednesday)
Plenary Session (Chair: Hugo Gasca)

P03 Advances in the DCC enablement at Beamex

Presenting author: Tuukka Mustapää, Beamex Oy Ab, Finland
E-mail address: tuukka.mustapaa@beamex.com
Additional authors:

Abstract

During the recent years, Beamex has been involved in multiple projects and co-development Initiatives related to the adoption of the DCC in the process industry. As the development of the DCC has progressed, the focus of the co-development initiatives has been shifting from prototypes and proof-of-concepts towards the readiness to support early adaptors in taking the DCC into use in their production environments.

As there are still many topics around the DCC that require further development, the enablement of the use of the DCC will be take place in multiple stages. This presentation discusses the ongoing projects and development activities at Beamex, the expected outcomes of those projects, and the outlines of a roadmap for the eventual support for the DCC in Beamex systems.
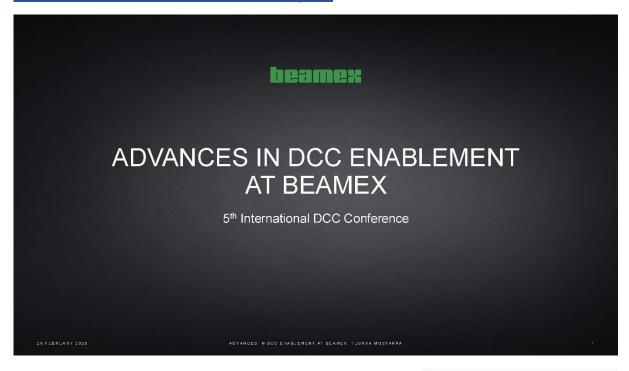
Initially, the support for the DCC will cover the possibility for a customer to import calibration results directly from a DCC into their calibration management system. The capability to import data from DCCs will be dependent on the establishment of good practices for the application in question and likely requiring co-development. In practice, this means that early on the scalability for different applications will have some limitations.

More extensive automation of the data exchange processes will require additional harmonization such as a standardized format for digital calibration requests (DCR) for enabling the two-way communication between the customer and calibration service provider. Additionally, the machine-to- machine communication can be further enhanced by use of centralized interfaces that can streamline the communication within calibration ecosystems consisting of numerous customer-service provider relationships.

Presentation of Tuukka Mustapää

BEAMEX IN BRIEF

Who are we?

- A trusted partner for calibration solutions and services
  - Field and workshop calibration equipment
  - Calibration management systems
  - Accredited calibration laboratory
  - Expert services
- Technology and expertise available in over 90 countries
- Over 15 000 customers worldwide

Our customer industries:

Pharmaceutical   Chemical   Power Generation   Oil & Gas

Food & Beverage   Service Companies   Water & Wastewater   Other industries

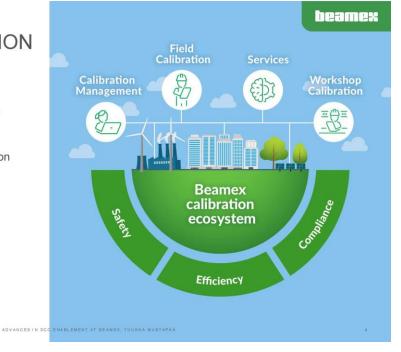26 FEBRUARY 2025   ADVANCES IN DCC ENABLEMENT AT BEAMEX, TUUKKA MUSTAPÄÄ   3

BEAMEX CALIBRATION ECOSYSTEM

Combination of calibration equipment, software tools and services

- On-prem and cloud-based calibration management solutions
- Digital workflows
- Platform for collaboration

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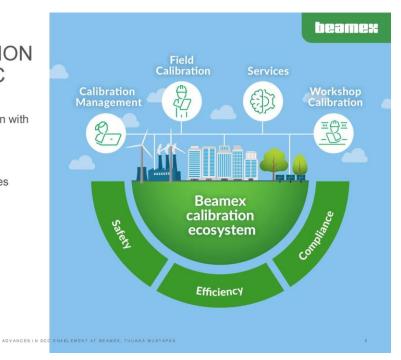
5th International DCC Conference

BEAMEX CALIBRATION ECOSYSTEM & DCC

Aims of the DCC have a lot in common with ideas behind the Beamex calibration ecosystem

- Optimization of calibration processes
- Secure digital data flow
- Data-based decision making

5th International DCC Conference

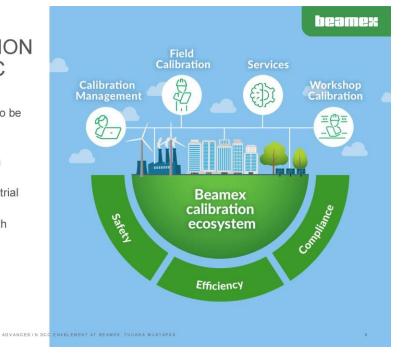# BEAMEX CALIBRATION ECOSYSTEM & DCC

However, many things will also need to be reconsidered or redefined

- Transition from a closed to an open ecosystem
- Differences in accredited and industrial processes
- Dependencies and compatibility with other systems

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DCC RELATED DEVELOPMENT

- Beamex has been involved in multiple co-development projects
- Proof-of-concepts (PoCs):
  - Importing calibration results from DCCs
  - Exporting calibration results as DCCs
  - Digital calibration requests (DCR)
  - DCC exchange platform
- Participation in DKD's DCC working groups

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LEARNINGS FROM POCS

- Overall, there is still a lot of work to be done regarding harmonization and good practices
  - The DCC needs to be flexible to support all use cases
  - The good practices must be precisely defined for them to be usable
- Current state of the DCC development allows us to get started with adding support for DCCs in our systems
- Ongoing development and PoCs will provide the basis for supporting DCC in production environments
- Even limited capabilities can provide value for the early adopters and help them prepare for wider use of DCCs

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DCC ENABLEMENT – INITIAL PHASE

Basic features to support DCC for early adopters that we can already get started with

- Conceptualization and definition of requirements for the DCC services
- Definition of DCC related features for the first releases
- Primary focus: importing calibration results from DCCs
- Support for limited number of use cases
- Implementing enhancements helping in enabling the use of DCCs

Calibration service provider ⟶ End-user
DCC
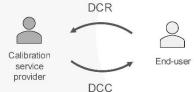
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DCC ENABLEMENT – EXTENDING SUPPORT

Features that we can get started with when certain conditions are met

- Adding support for more use cases as the good practices are defined
- Extending DCC support to more products and services
- Introduction of DCR to allow end-to-end communication in both ways in a similar manner
- Developing an interface that provides the basis for the data exchange platform

DCR
Calibration service provider ⟷ End-user
DCC

beamex
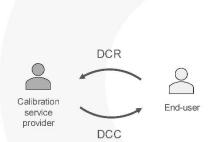
DCR

DCR is needed as an assurance that the whole calibration process is completed according to plan

- Calibration procdures are defined in the calibration managment system
- Exchange of the DCR and DCC will be included in the audit trail
- Differences between accredited and industrial processes
- Agreements on the used procedures will need to be in place first

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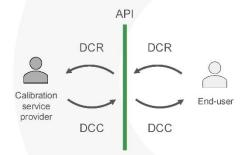
COMMON INTERFACE

Exchange of DCCs and DCRs can be done similarly to exchange conventional calibration certificates, but it is not ideal

- Establishing an interface between the parties involved in the data exchange enables further automation of the process
- Simplified exchange of DCCs and DCRs between organizations that have several contractors or customers

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DCC ENABLEMENT – MAXIMIZING VALUE

Features that will maximize the benefits from
digitalization, but require most of the aforementioned
features and frameworks to be established first

- Setting up the platform-based calibration ecosystem
- Introducing additional services to enhance the
  platform
- Big data and analytics based decision making
- Investigating new opportunities to leverage the
  machine-actionable data
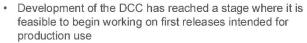
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SUMMARY

- Development of the DCC has reached a stage where it is
  feasible to begin working on first releases intended for
  production use
- Support and features will be incrementally added to
  Beamex systems
- A lot of collaborative development is still needed to
  optimize the processes concerning DCCs

For more information
- Publications
- White papers, Beamex blog and more: resources.beamex.com
- Social media: LinkedIn, YouTube, ...
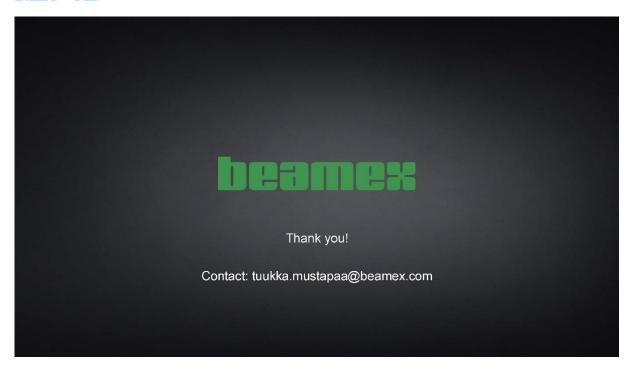
26 FEBRUARY 2025   ADVANCES IN DCC ENABLEMENT AT BEAMEX, TJUKKA MUSTAPÄÄ   14

P04　Python-based DCC Tools Development and Implementation

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Abstract

This paper introduces DCC Tools, a suite of open-source Python-based software tools developed to streamline the handling of Digital Calibration Certificates (DCCs). These tools are designed to generate DCCs compliant with the XML schema proposed by the Physikalisch-Technische Bundesanstalt (PTB) [1] [2] and facilitate the embedding and extraction of human-readable PDF versions of calibration certificates. The transition from traditional paper-based or PDF certificates to machine-readable DCCs addresses the limitations of current practices, which often involve manual transcription of calibration data, leading to inefficiencies and errors. The proposed tools aim to enhance the digitalization of calibration processes, enabling seamless integration with modern digital workflows and improving accessibility, interoperability, and efficiency.

The DCC Tools package includes several key functionalities: dccGenerator, which generates PTB-compliant DCCs from JSON inputs; dccAddPdf, which embeds human-readable PDFs into DCCs; and dccGetPdf, which extracts PDFs from XML DCCs. Future plans include the development of dccReader, a tool for extracting measurement data from DCCs and converting it into JSON or spreadsheet formats. For this task we plan to use the pyDCC library developed by Siemens, which is available on GitHub [3]. The system architecture is serverless, using AWS Lambda for scalability, cost-efficiency, and ease of integration with existing workflows. The tools are designed to operate within the AWS Lambda free tier, making them accessible to calibration laboratories of various sizes and budgets. The tools are implemented

as Python scripts, so they can be easily adapted for running on a local server or private cloud if needed.

The adoption of DCCs represents a significant step toward true digitalization in calibration processes. Unlike traditional methods, which rely on paper or closed digital formats like PDF, DCCs store data in a machine- readable XML format, enabling automated processing and integration with digital systems. This is particularly important in the context of Industry 4.0, where real-time data exchange and automation are critical. The proposed tools also support the inclusion of digital cryptographic signatures, enhancing trust and security in the calibration process. DCC Tools software is freely available on GitHub [4] under the GPLv3 license, providing a practical and cost-effective solution for calibration laboratories seeking to modernize their workflows.

In conclusion, the DCC Tools represent a significant advancement in the digitalization of calibration processes. By enabling the generation, embedding, and extraction of machine-readable DCCs, these tools reduce the reliance on manual transcription, minimize errors, and improve productivity. The serverless architecture ensures scalability and cost-efficiency, making the tools accessible to a wide range of laboratories. Future work will focus on expanding the tools' capabilities and integrating them with emerging standards and technologies, such as the Digital SI (D-SI) format and metrology clouds, to further enhance their utility and impact.

References:

[1] Hackel, Siegfried, Shanna Schönhals, Lutz Doering, Thomas Engel, und Reinhard Baumfalk. „The Digital Calibration Certificate (DCC) for an End-to-End Digital Quality Infrastructure for the Industry 4.0". *SCI* 5, Nr. 1 (2023). https://doi.org/10.3390/sci5010011.

[2] PTB DCC Project. Available online: https://www.ptb.de/dcc (accessed on 20 th January 2025).

[3] PyDCC. Available online: https://github.com/siemens/pydcc (accessed on 27 th January 2025).

[4] DCC Tools GitHub Repository. Available online: https://github.com/gmgeronymo/dcc_tools accessed on 27th January 2025).

Presentation of Gean Marcos Geronymo

Python-based DCC Tools Development and Implementation
5th International DCC Conference

Gean Marcos Geronymo

Inmetro - Brazil

February 26th, 2025

Digital Calibration Certificates: True Digitalization

Digital Transformation
- Beyond simple digitization:
  - Content transfer not enough
  - Need for machine interpretation
  - Structured data format

DCC Advantages
- Machine-readable format
- Interpretable data structure
- Efficient storage system

Traditional Approach
- Paper to PDF conversion
- Focus on human readability
- Limited machine processing

Implementation Benefits
- Clearly defined format
- Precise data storage
- Automated processing
- System integration ready
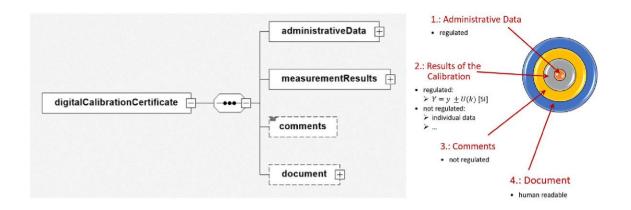
Digital Calibration Certificate Structure – PTB proposal

Digital System of Units (D-SI)

Overview of D-SI

- XML format for seamless integration of measurement data
- Includes:
  - Numerical values
  - Associated units
  - Measurement uncertainties (value and distribution)

Visual Representation

- D-SI data model: See Slide 5
- Application example: Resistance value in ohms (Slide 6)

D-SI Structure

Minimum requirement   Maximum information

$$Y = y \text{ [SI]} \quad U_{95}(k) \text{ distribution UTC}$$

- Coordinated Universal Time
- type of distribution normal, uniform, ...
- coverage factor
- measurement uncertainty + confidence interval
- SI-unit
- measurement value

Figure: DCC Structure. Source: `https://gitlab1.ptb.de/d-ptb/d-si/xsd-d-si/-/blob/master/wiki/doc/RealQuantity.md`

D-SI XML Example

```
<si:quantity>
  <si:real>
    <si:value>0.99999397</si:value>
    <si:unit>\metre\tothe{2}\kilogram\second\tothe{-3}\ampere\tothe{2}</si:unit>
    <si:expandedUnc>
      <si:uncertainty>2.10E-07</si:uncertainty>
      <si:coverageFactor>2</si:coverageFactor>
      <si:coverageProbability> 0.9545 </si:coverageProbability>
    </si:expandedUnc>
    <si:dateTime>2023-02-09T13:37:37-03:00</si:dateTime>
  </si:real>
</si:quantity>
```

Figure: Example of a fully compliant D-SI quantity statement. The electrical resistance unit (ohm) is stated in term of the SI base units (m^2 kg s^{-3} A^2) for a "platinum" quality class in terms of machine-readability. Alternatively, the unit can be represented as **ohm** for a "gold" quality class.

Digitalization of Calibration Process

Metrology Cloud (MC)
- Most desirable path for digitalization
- Enables seamless integration of DCCs
- Supports real-time data exchange

DCC Tools Support
- Initial DCC adoption
- Future integration with MC
- Flexible for various calibration workflows

DCC Tools Benefits
- Digitalization even with simple methods (e.g., email)
- Real-time action on instrumentation
- Key for smart factories and Industry 4.0

Existing Solutions

PTB Tools
- GEMIMEG Tool:
  - Web-based, open-source
  - Manual data creation
- Excel Tool:
  - Macro-enabled
  - Generates DCC XML from blocks

SIEMENS: PyDCC
- Python library for DCC access and processing
- Simplifies extraction and manipulation of DCC data
- Enables seamless integration into digital manufacturing
- Available on : `https://github.com/siemens/pydcc`

Our Proposal: DCC Tools

Overview

- Initial prototype available on `https://github.com/gmgeronymo/dcc_tools`
- Implemented in Python
- Designed for cloud-based technologies (AWS Lambda)
- API for system integration

Future Plans

- Implement `dccReader` using PyDCC
- Extract measurement data as JSON or spreadsheets
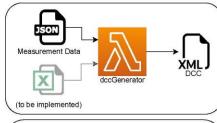
Main Tools
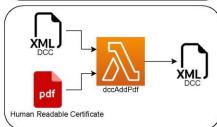
- `dccGenerator`:
  - Generates PTB DCC compliant XML from JSON
- `dccAddPdf`:
  - Adds human-readable PDF to XML
- `dccGetPdf`:
  - Extracts human-readable PDF from XML
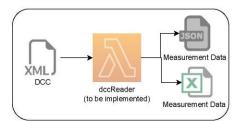
DCC Tools Diagram
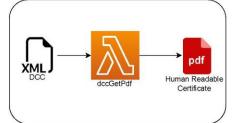
Figure: DCC Tools diagram.

DCC Tools: Input Data Format Selection

Traditional Lab Workflows
- Common approaches:
  - Excel spreadsheets
  - Manual data entry
  - Standalone systems

Study Case Environment
- Modern lab infrastructure:
  - Web-based systems
  - SQL databases
  - LabVIEW automation
  - MS Access integration

JSON Format Benefits
- Already structured data
- Easy API integration
- Language-agnostic
- Lightweight format
- Better human readability than XML

Future Extensions
- Excel support planned
- Multiple input formats
- Custom data mappings

DCC Tools: Simplified Data Structure Approach

PTB DCC Structure
- Comprehensive XML schema:
  - Complex structure
  - Covers all calibration types
  - Extensive metadata options
  - Generic requirements

Real-world Usage
- Labs typically use:
  - Specific certificate types
  - Limited data fields
  - Consistent structure
  - Repetitive patterns

Our Approach
- Lab-specific JSON schema:
  - Simplified structure
  - Custom field mapping
  - Minimal required data

Benefits
- Reduced complexity
- Easier implementation
- Better maintainability
- Lower error risk

JSON to DCC: Transformation Strategy

Implementation Strategy
- dccGenerator function:
  - Accepts simple JSON
  - Maps to DCC structure
  - Validates output
  - Ensures compliance

Customization Features
- Lab-specific templates
- Configurable mappings
- Flexible field definitions
- Extensible structure

Key Advantages
- Labs work with familiar data
- No need to understand full DCC
- Automated transformation
- Validated output

Future-proofing
- Easy schema updates
- New certificate types
- Additional field mappings
- Version compatibility

Implementation Strategy

Initial Prototype Focus
- Target advanced labs:
  - Automated systems
  - Structured databases
  - API-ready infrastructure
- Quick implementation:
  - Minimal data transformation
  - Direct integration

Development Roadmap
- Phase 1: JSON API
- Phase 2: dccReader (JSON)
- Phase 3: Excel support (read and write)

Integration Benefits
- Seamless data flow
- Reduced processing time
- Lower error rates
- Simplified deployment

System Architecture

Serverless Design
- Core compute service: AWS Lambda
- Advantages:
  - Automatic scaling
  - Pay-as-you-go pricing
  - Reduced operational overhead

Cost Efficiency
- Operates within AWS Lambda free tier limits:
  - 1M requests/month
- Cost-efficient for calibration labs
- No additional costs for typical usage

Suitable Use Cases
- Limited trusted clients
- Internal systems
- Efficient data submission and retrieval

Lambda Function URLs
- Direct and efficient data handling
- Simplifies communication process
- Reduces API Gateway overhead

AWS Lambda Serverless Architecture

What is Serverless?
- No server management needed
- Auto-scaling capabilities
- Pay-per-use model

DCC Tools Implementation
- Direct function URLs
- Stateless architecture
- HTTPS encryption
- Free tier compatible

AWS Lambda Features
- Function-as-a-Service (FaaS)
- Multiple language support
- Event-driven execution
- Native AWS integration

Alternative Deployment: Traditional Server Architecture

Adapting to Traditional Server Approach

The certificate generation service can be easily adapted from serverless to a traditional server architecture using Python FastAPI:

- Core business logic remains unchanged
- More predictable costs for consistent workloads
- Full control over runtime environment
- Simplified local development and debugging
- Multiple deployment options (servers, containers, platforms)
- Privacy requirements

Example Calibration Certificate

Constants

Variables

JSON Version of the Calibration Certificate (Part 1)

```json
{
    "nome_lab": "Laboratório de Metrologia em Padronização Elétrica",
    "sigla_lab": "Lampe",
    "nome_div": "Divisão de Metrologia Elétrica",
    "sigla_div": "Diele",
    "num_certif": "2502/2024",
    "num_processo": "0052600.005271/2024-53",
    "tipo_item": "Resistor Padrão",
    "fabricante": "Fluke",
    "modelo": "742A-1",
    "num_serie": "SN-2023-RES-001",
    "cod_identificacao": "RES-100-001",
    "valor_nominal": "1",
    "valnom_unit": "\\metre\\tothe{2}\\kilogram\\second\\tothe{-3}\\ampere\\tothe{2}",
    "data_calibracao" : "2024-12-10",
    "cmc" : true,
    "chefe_div" : "Edson Afonso",
    "chefe_lab" : "Gean Marcos Geronymo",
    "tecnico_executor" : "Márcio Cândido da Silva",
    "desc_tecnico_executor" : "Técnico Executor",
    "cliente": {
        "nome": "Indústria Brasileira de Componentes Eletrônicos (IBCE)",
        "email": "contato@ibce.com.br",
        "cidade": "Cidade Tecnológica",
```

Part 1 of the JSON representation of the calibration certificate.

JSON Version of the Calibration Certificate (Part 2)

```json
        "pais": "BR",
        "cep": "12345-678",
        "uf": "RJ",
        "endereco": "Rua das Indústrias",
        "numero": "1234"
    },
    "condicoes_ambientais": [
        {
            "name": "Temperatura no banho de ar",
            "value": "22.94",
            "unc": "0.11",
            "unit": "\\degreecelsius"
        },
        {
            "name": "Umidade relativa",
            "value": "53.0",
            "unc": "1.6",
            "unit": "\\percent"
        }
    ],
    "rastreabilidade": [
        {
            "name": "Resistor Padrão",
            "certificado": "DIMCI 0145/2024",
            "cod_id": "TR 654"
```

Part 2 of the JSON representation of the calibration certificate.

JSON Version of the Calibration Certificate (Part 3)

```
50        }
51     ],
52     "resultados": [
53        {
54           "value": "1.00005512",
55           "unit": "\\metre\\tothe{2}\\kilogram\\second\\tothe{-3}\\ampere\\tothe{2}",
56           "unc": "0.25",
57      "unctype" : "ppm",
58           "k": "2"
59        }
60     ],
61     "condicoes_resultados": [
62        {
63           "name": "Corrente Aplicada",
64           "value": "0.003",
65           "unit": "\\ampere"
66        }
67     ]
68
69
70  }
```

Part 3 of the JSON representation of the calibration certificate.

XML Version of the Calibration Certificate (Part 1)

```xml
1  <?xml version='1.0' encoding='utf-8'?>
2  <dcc:digitalCalibrationCertificate xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
       xmlns:dcc="https://ptb.de/dcc" xmlns:si="https://ptb.de/si" xsi:schemaLocation="https://ptb.de/dcc
       https://ptb.de/dcc/v3.2.0/dcc.xsd" schemaVersion="3.2.0">
3    <dcc:administrativeData>
4      <dcc:dccSoftware>
5        <dcc:software>
6          <dcc:name>
7            <dcc:content>dccGenerator</dcc:content>
8          </dcc:name>
9          <dcc:release>0.2</dcc:release>
10        </dcc:software>
11      </dcc:dccSoftware>
12      <dcc:coreData>
13        <dcc:countryCodeISO3166_1>BR</dcc:countryCodeISO3166_1>
14        <dcc:usedLangCodeISO639_1>pt</dcc:usedLangCodeISO639_1>
15        <dcc:mandatoryLangCodeISO639_1>pt</dcc:mandatoryLangCodeISO639_1>
16        <dcc:uniqueIdentifier>DIMCI 2502/2024</dcc:uniqueIdentifier>
17        <dcc:identifications>
18          <dcc:identification>
19            <dcc:issuer>calibrationLaboratory</dcc:issuer>
20            <dcc:value>0052600.005271/2024-53</dcc:value>
21            <dcc:name>
22              <dcc:content>Processo Inmetro</dcc:content>
23            </dcc:name>
24          </dcc:identification>
25        </dcc:identifications>
26        <dcc:beginPerformanceDate>2024-12-10</dcc:beginPerformanceDate>
27        <dcc:endPerformanceDate>2024-12-10</dcc:endPerformanceDate>
```

XML Version of the Calibration Certificate (Part 2)

```
28          <dcc:performanceLocation>laboratory</dcc:performanceLocation>
29      </dcc:coreData>
30      <dcc:items>
31        <dcc:item>
32          <dcc:name>
33            <dcc:content>Resistor Padrão</dcc:content>
34          </dcc:name>
35          <dcc:manufacturer>
36            <dcc:name>
37              <dcc:content>Fluke</dcc:content>
38            </dcc:name>
39          </dcc:manufacturer>
40          <dcc:model>742A-1</dcc:model>
41          <dcc:identifications>
42            <dcc:identification>
43              <dcc:issuer>manufacturer</dcc:issuer>
44              <dcc:value>SN-2023-RES-001</dcc:value>
45              <dcc:name>
46                <dcc:content>Número de Série</dcc:content>
47              </dcc:name>
48            </dcc:identification>
49            <dcc:identification>
50              <dcc:issuer>customer</dcc:issuer>
51              <dcc:value>RES-100-001</dcc:value>
52              <dcc:name>
53                <dcc:content>Código de Identificação</dcc:content>
54              </dcc:name>
```

Gean Marcos Geronymo (Inmetro - Brazil)   Python-based DCC Tools Development and Implementat   February 26th, 2025   25 / 38

XML Version of the Calibration Certificate (Part 3)

```
55              </dcc:identification>
56            </dcc:identifications>
57          </dcc:item>
58        </dcc:items>
59        <dcc:calibrationLaboratory>
60          <dcc:contact>
61            <dcc:name>
62              <dcc:content>Laboratório de Metrologia em Padronização Elétrica(Lampe)</dcc:content>
63            </dcc:name>
64            <dcc:eMail>samci@inmetro.gov.br</dcc:eMail>
65            <dcc:phone>+55 21 2679 9077/9010</dcc:phone>
66            <dcc:location>
67              <dcc:city>Xerém - Duque de Caxias</dcc:city>
68              <dcc:countryCode>BR</dcc:countryCode>
69              <dcc:postCode>25250-020</dcc:postCode>
70              <dcc:state>RJ</dcc:state>
71              <dcc:street>Av. Nossa Senhora das Graças</dcc:street>
72              <dcc:streetNo>50</dcc:streetNo>
73            </dcc:location>
74          </dcc:contact>
75        </dcc:calibrationLaboratory>
76        <dcc:respPersons>
77          <dcc:respPerson>
78            <dcc:person>
79              <dcc:name>
80                <dcc:content>Edson Afonso</dcc:content>
81              </dcc:name>
```

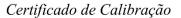Gean Marcos Geronymo (Inmetro - Brazil)   Python-based DCC Tools Development and Implementat   February 26th, 2025   26 / 38

XML Version of the Calibration Certificate (Part 4)

```
82            </dcc:person>
83            <dcc:role>Chefe da Divisão de Metrologia Elétrica</dcc:role>
84            <dcc:mainSigner>true</dcc:mainSigner>
85          </dcc:respPerson>
86          <dcc:respPerson>
87            <dcc:person>
88              <dcc:name>
89                <dcc:content>Gean Marcos Geronymo</dcc:content>
90              </dcc:name>
91            </dcc:person>
92            <dcc:role>Chefe do Laboratório de Metrologia em Padronização Elétrica</dcc:role>
93          </dcc:respPerson>
94          <dcc:respPerson>
95            <dcc:person>
96              <dcc:name>
97                <dcc:content>Márcio Cândido da Silva</dcc:content>
98              </dcc:name>
99            </dcc:person>
100           <dcc:role>Técnico Executor</dcc:role>
101         </dcc:respPerson>
102       </dcc:respPersons>
103       <dcc:customer>
104         <dcc:name>
105           <dcc:content>Indústria Brasileira de Componentes Eletrônicos (IBCE)</dcc:content>
106         </dcc:name>
107         <dcc:eMail>contato@ibce.com.br</dcc:eMail>
108         <dcc:location>
```

XML Version of the Calibration Certificate (Part 5)

```
109           <dcc:city>Cidade Tecnológica</dcc:city>
110           <dcc:countryCode>BR</dcc:countryCode>
111           <dcc:postCode>12345-678</dcc:postCode>
112           <dcc:state>RJ</dcc:state>
113           <dcc:street>Rua das Indústrias</dcc:street>
114           <dcc:streetNo>1234</dcc:streetNo>
115         </dcc:location>
116       </dcc:customer>
117       <dcc:statements>
118         <dcc:statement>
119           <dcc:declaration>
120             <dcc:content>Este certificado é consistente com as Capacidades de Medição e Calibração (CMCs) que
                  estão incluídas no apêndice C do Acordo de Reconhecimento Mútuo (MRA) estabelecido pelo Comitê
                  Internacional de Pesos e Medidas (CIPM). Conforme os termos do MRA, todos os institutos
                  participantes reconhecem entre si a validade dos seus certificados de calibração e medição
                  para cada uma das grandezas, faixas e incertezas de medição declaradas no Apêndice C (para
                  maiores detalhes ver http://www.bipm.org).</dcc:content>
121           </dcc:declaration>
122         </dcc:statement>
123         <dcc:statement>
124           <dcc:norm>ABNT NBR ISO/IEC 17025</dcc:norm>
125           <dcc:declaration>
126             <dcc:content>O presente certificado de calibração atende aos requisitos da norma ABNT NBR ISO/IEC
                  17025 e é válido apenas para o item acima caracterizado, não sendo extensivo a quaisquer
                  outros. Este certificado de calibração somente pode ser reproduzido em sua forma integral.
                  Reproduções parciais devem ser previamente autorizadas pelo Inmetro.</dcc:content>
127           </dcc:declaration>
128         </dcc:statement>
129         <dcc:statement>
```

XML Version of the Calibration Certificate (Part 6)

```
130          <dcc:declaration>
131            <dcc:content>Características do Item</dcc:content>
132          </dcc:declaration>
133          <dcc:data>
134            <dcc:quantity>
135              <dcc:name>
136                <dcc:content>Valor Nominal</dcc:content>
137              </dcc:name>
138              <si:real>
139                <si:value>1</si:value>
140                <si:unit>\metre\tothe{2}\kilogram\second\tothe{-3}\ampere\tothe{2}</si:unit>
141              </si:real>
142            </dcc:quantity>
143          </dcc:data>
144        </dcc:statement>
145      </dcc:statements>
146    </dcc:administrativeData>
147    <dcc:measurementResults>
148      <dcc:measurementResult>
149        <dcc:name>
150          <dcc:content>Resultados e Declaração da Incerteza de Medição</dcc:content>
151        </dcc:name>
152        <dcc:usedMethods>
153          <dcc:usedMethod>
154            <dcc:name>
155              <dcc:content>Declaração da Incerteza de Medição</dcc:content>
156            </dcc:name>
157            <dcc:description>
```

XML Version of the Calibration Certificate (Part 7)

```
158            <dcc:content>As incertezas expandidas de medição (U) relatadas são declaradas como a incerteza
                   padrão combinada multiplicada pelo fator de abrangência k, que, para uma distribuição t, com
                   um número efetivo de graus de liberdade ν eff , o qual corresponde a uma probabilidade de
                   abrangência de 95,45 %. A incerteza de medição expandida foi relatada de acordo com a
                   publicação Avaliação de Dados de Medição - Guia para a Expressão de Incerteza de medição -
                   GUM 2008.</dcc:content>
159            </dcc:description>
160          </dcc:usedMethod>
161          <dcc:usedMethod>
162            <dcc:name>
163              <dcc:content>Método de Medição</dcc:content>
164            </dcc:name>
165            <dcc:description>
166              <dcc:content>O resultado fornecido refere-se ao valor médio de seis séries de trinta medições
                     pelo método de comparação de corrente na configuração 04 (quatro) terminais. Utilizou-se uma
                     Ponte Automática de Resistência modelo 6010D.</dcc:content>
167            </dcc:description>
168          </dcc:usedMethod>
169        </dcc:usedMethods>
170        <dcc:measuringEquipments>
171          <dcc:name>
172            <dcc:content>Os resultados da calibração são rastreados ao Sistema Internacional de Unidades (SI),
                   por intermédio dos padrões metrológicos nacionais. As medições realizadas estão referenciadas
                   aos padrões relacionados.</dcc:content>
173          </dcc:name>
174          <dcc:measuringEquipment>
175            <dcc:name>
176              <dcc:content>Resistor Padrão</dcc:content>
177            </dcc:name>
```

XML Version of the Calibration Certificate (Part 8)

```
178            <dcc:certificate>
179              <dcc:referral>
180                <dcc:content>DIMCI 0145/2024</dcc:content>
181              </dcc:referral>
182              <dcc:referralID>TR 654</dcc:referralID>
183              <dcc:procedure>analog</dcc:procedure>
184              <dcc:value>analog</dcc:value>
185            </dcc:certificate>
186          </dcc:measuringEquipment>
187        </dcc:measuringEquipments>
188        <dcc:influenceConditions>
189          <dcc:influenceCondition>
190            <dcc:name>
191              <dcc:content>Temperatura no banho de ar</dcc:content>
192            </dcc:name>
193            <dcc:data>
194              <dcc:quantity>
195                <si:real>
196                  <si:value>22.94</si:value>
197                  <si:unit>\degreecelsius</si:unit>
198                  <si:expandedUnc>
199                    <si:uncertainty>0.11</si:uncertainty>
200                    <si:coverageFactor>2</si:coverageFactor>
201                    <si:coverageProbability>0.9545</si:coverageProbability>
202                  </si:expandedUnc>
203                </si:real>
204              </dcc:quantity>
205            </dcc:data>
206          </dcc:influenceCondition>
```

XML Version of the Calibration Certificate (Part 9)

```
207            <dcc:influenceCondition>
208              <dcc:name>
209                <dcc:content>Umidade relativa</dcc:content>
210              </dcc:name>
211              <dcc:data>
212                <dcc:quantity>
213                  <si:real>
214                    <si:value>53.0</si:value>
215                    <si:unit>\percent</si:unit>
216                    <si:expandedUnc>
217                      <si:uncertainty>1.6</si:uncertainty>
218                      <si:coverageFactor>2</si:coverageFactor>
219                      <si:coverageProbability>0.9545</si:coverageProbability>
220                    </si:expandedUnc>
221                  </si:real>
222                </dcc:quantity>
223              </dcc:data>
224            </dcc:influenceCondition>
225          </dcc:influenceConditions>
226          <dcc:results>
227            <dcc:result>
228              <dcc:name>
229                <dcc:content>Resultados</dcc:content>
230              </dcc:name>
231              <dcc:data>
232                <dcc:quantity>
233                  <si:real>
234                    <si:value>1.00005512</si:value>
```

XML Version of the Calibration Certificate (Part 10)

```
235                <si:unit>\metre\tothe{2}\kilogram\second\tothe{-3}\ampere\tothe{2}</si:unit>
236                <si:expandedUnc>
237                    <si:uncertainty>2.50E-07</si:uncertainty>
238                    <si:coverageFactor>2</si:coverageFactor>
239                    <si:coverageProbability>0.9545</si:coverageProbability>
240                </si:expandedUnc>
241            </si:real>
242            <dcc:influenceConditions>
243                <dcc:influenceCondition>
244                    <dcc:name>
245                        <dcc:content>Corrente Aplicada</dcc:content>
246                    </dcc:name>
247                    <dcc:data>
248                        <dcc:quantity>
249                            <si:real>
250                                <si:value>0.003</si:value>
251                                <si:unit>\ampere</si:unit>
252                            </si:real>
253                        </dcc:quantity>
254                    </dcc:data>
255                </dcc:influenceCondition>
256            </dcc:influenceConditions>
257        </dcc:quantity>
258    </dcc:data>
259  </dcc:result>
260  </dcc:results>
261  </dcc:measurementResult>
262  </dcc:measurementResults>
263 </dcc:digitalCalibrationCertificate>
```

Example - embedded PDF

```
252                    </dcc:quantity>
253                    </dcc:data>
254                </dcc:influenceCondition>
255            </dcc:influenceConditions>
256        </dcc:quantity>
257    </dcc:data>
258  </dcc:result>
259  </dcc:results>
260  </dcc:measurementResult>
261  </dcc:measurementResults>
262 <dcc:document><dcc:fileName>CC_DIMCI_2502_2024.pdf</dcc:fileName><dcc:mimeType>application/pdf</dc\
    c:mimeType><dcc:dataBase64>
```

JVBERi0xLjcKJCKcOkw7zDtsOfCjIgMCBvMoKPDwvTGVuZ3RoIDMgMCBSL0ZpbHRlci9GbGGF\
0ZURlY29kZT4+CnN0cmVhbQp4nM0byYrlRvJeXyHwzVByRkZmSoLiwVtnbPDB44Y5mDk03k23PW5s/PsTW6ZSUuq9avBhaKpaS\
8aSsUekyvXQ/fX02fHDHz//8PbbP7rTl+en3zvXud75sYtT7P0QuzFAPyboPnz/9O9Pu1+frrSqAUP/Pvz4dHrz5KPvfeyGYej\
DOHVvvus+u0E3dm9++ObFwSG8OO/w4F9F9ccPHwTP8nN7iRH0xye3Qnd5areMAXd5G3z3z3R1VdibwD+HF3C07j9vvni6vnn6asUEp\
KlHYiKNvV8zAXAw5OCVBUAI9AyiIlbCmezN2IMkTHlA+vGHxBsYjFPbCgwHWeEFnRtAMQj0xJfA7B+NnEpBAR2IBGGQ9HIU8IeN\
NRl12WTLlVWKgLG3kSTwK0RP/AsGTeL9TwQ/7ohtSn0h0cerdRnQTI/R5A8q7iO5C/z0bg3R71V0VtgnGmayE8ZvsgJkBFZkJh\
KXPQhWYW0M43ik1V9vIjW4LRpONz7K5kNC3KCv5mGay8nQfqArcldIQeohdYlmhCcl3wZuVs0pYH45sBohJFoubxLQneneiFaM\
7My/AqiVtuStbxh61AGOPXQrj7FLYQcg+BS9KUC+iehT9ngR/kusFbhDc0C3xfvv+CfrQ/WWk/WPJ9c9e1rwgM39IPevOu+3+3\
uMPh9lksJuUvdMhvrCyAu9UfJjVFQH4NwmJNq4WRT8REj+fWX0UbMLUU4gC2kDEla16T7TEUsUoDs9DEBsaxJvUZ+wlG5HHcuk\
uYk/DDDKSH64QsEnjInyY47eoiTMPviBzgPUK8kgxSh9mlzGbrheO4jcLQPUed8uu72PNtl9wMprnL1znVGLpBla9Q1mD+fI87\
4S8LMFlScPl6LBFN5aIe1HycPHicLeIMEZesmSDxQJHmDcpBNNYbep5gEpCC2g/GcvqLr1Sqwh0x+liSL1rGhdDv/ml6ahgi0j\
```

# Cryptographic Signatures

### Digital Signatures in DCC
- DCC XML can be digitally signed
- Ensures trust between institute and customer

### Common Practice
- Adding digital signatures to XML is common
- Various free tools available

### Assinador Serpro
- Free tool by a federal state-owned company in Brazil
- URL: `https://www.serpro.gov.br/links-fixos-superiores/assinador-digital/assinador-serpro`
- Requires a valid digital certificate from a certification authority

# Conclusion

### Pragmatic Solution
- Efficient DCC handling via cloud-based serverless application
- Tools offer potential for enhancement and customization

### Digitalization Benefits
- Seamless integration into calibration workflows
- Supports genuine digitalization of processes

### Productivity Gains
- Adoption of DCCs eliminates manual transcription tasks
- Improves productivity and reduces errors

## Thank You!

# Thank You for Your Attention!

**Contact:**
**G M Geronymo**
gmgeronymo@inmetro.gov.br

**INMETRO**

# P05    DCC in production mode

Presenting author: Thomas Engel, Siemens AG, Germany
E-mail address: engelthomas@siemens.com
Additional authors: Klaus Fickinger, Sami Koskinen, André Lemke, Christian Sander, Shanna Schönhals

## Abstract

In Summer 2024 a group of DCC enthusiast have teamed up to finalize, apply and validate the DCC for applications for a real-world application scenario of a temperature sensor in pharmaceutical industry. The team covers all stakeholders along the process chain, from system owner (Boehringer Ingelheim) to industry partners as instrument manufacturers, calibration service providers, calibration management systems and process automation and control solutions manufacturers (Beamex, Endress & Hauser, Siemens, Testo) and the German national metrology institute PTB as DCC development partners. The project initiative was structured in three phases.

Phase 1: DCC generation and DCC harmonization among partners and alignment with DKD good practices

Phase 2: Development and specification of a digital calibration request (DCR) to specify all requirements

Phase 3: DCC exchange and application in the asset administration shell, digital product passport and dataspaces

After 5 months, phase 1 is close to completion. The team will present the requirements and benefits from a sensor system owner perspective and share detailed information and lessons learnt when implementing a full process chain for DCC generation in sensor system production and recalibration. The goal of phase 1 was to have a harmonized content of the DCC irrespective of the issuer of the DCC as system manufacturer or calibration service provider. The DCCs was transferred to the calibration management system (CMS) and all calibration information extracted and automatically entered into the CMS. Finally, the CMS data was evaluated and validated by the sensor system owner with respect to completeness and correctness as endpoint of phase 1.

The presentation will be concluded by an update of recent and up-coming DCC schema developments and a perspective on the integration of DCCs into the concepts and systematic of AAS and the digital product passport as they constitute the futures system of digital asset representation and documentation.

## Presentation of Thomas Engel

## DCC Digital Calibration Customer View / Pain
Call to action to digitalize calibration in pharmaceutical industry / @BI

PTB provides the templates for everyone who is using DCC

**Challange:**
Too many arrowheads in combination with too many business models

DCR Part Specification

DCC/DCR Part Calibration

DCR Part Classification

The DCC is powered by: testo  beamex  PTB  SIEMENS  Boehringer Ingelheim  Endress+Hauser



## DCC Production Mode Part 1–3

**Part 1:**
Automatic data transfer of the **DCC** between Manufacturer / Service Provider and Boehringer Ingelheim into the System BIgCAL

**Part 2:**
Automatic data transfer of the **DCR** between Boehringer Ingelheim and Service Provider for regular calibration from BIgCAL

**Part 3:**
DCC exchange and application in the Asset Administration Shell AAS, digital product passport and dataspaces

Part 1

Part 2

Part 3

The DCC is powered by: testo  beamex  PTB  SIEMENS  Boehringer Ingelheim  Endress+Hauser

# Introduction and Role of Instrument Manufacturer

**Project role of Endress+Hauser:**
**Instrument manufacturer**

- Agreed scope for the PoC project: Focus on temperature sensors
- Typical temperature measuring point was configured and considered:
  - Sensor element
  - Transmitter
  - Process indicator

The DCC is powered by: testo · beamex · PTB · SIEMENS · Boehringer Ingelheim · Endress+Hauser

# Current situation at Instrument Manufacturer

*Global Factory Calibration Certificate*

Endress+Hauser
People for Process Automation

*Original Calibration Certificate from the production site*

**Currently Endress+Hauser provides two calibration certificates to our customers:**

+ Global Factory Calibration Certificate
+ Original calibration certificate from the production site

| Device details | |
| --- | --- |
| Serial number | WA026914457 |
| Order code | TMA11-93SC6/115 |
| Short description | iTHERM ModuLine TMA11 |
| Device type | Temperature, Thermometer |
| Supplier | Endress+Hauser |
| Manufacturing date | 10/2024 |

Export as pdf

| Product Status | ● Available | | |
| --- | --- | --- | --- |
| Phase out date | not applicable | Order stop | not applicable |
| Spare sensor until | not applicable | Calibration until | not applicable |
| Spares availability | not applicable | Repair until | not applicable |
| New alternative | - | | |
| Maintenance advice | - | | |

**Identification link according to IEC 61406-1**

The DCC is powered by: testo · beamex · PTB · SIEMENS · Boehringer Ingelheim · Endress+Hauser

# DCC creation in Production

**Modeling and data transfer of the DCC:**

+ Information from the calibration certificates were converted to the DCC structure

+ First version available:
Modeled DCC for the temperature measuring point

+ Prototypical data transfer: Via E-Mail

The DCC is powered by: testo beamex PTB SIEMENS Boehringer Ingelheim Endress+Hauser

# Role of Calibration Software Solution Provider

**BACKGROUND**

+ Beamex Calibration Solution has been in place at Boehringer Ingelheim 10+ years

+ Solution is widely used within BI manufacturing network world wide

+ BI has been managing calibration certificates from instuments and service providers manually. Only one copy of the paper and/or PDF certificate has been available. They both are designed human readably only.

+ Vendors paper/PDFs are all in different formats and speak different „language"
→ no harmonization nor labeled data available.

+ With DCC we are able to get vendor's calibration data as part of the existing solution and utilize data for analysis and process optimization

The DCC is powered by: testo beamex PTB SIEMENS Boehringer Ingelheim Endress+Hauser

# Role of Calibration Software Solution Provider

## CHALLENGES

+ In this case Calibration solution is part of the enterprise level ecosystem and therefore changes to existing processes need to be planned carefully

+ Digital Calibration Request (DCR) is a crucial part of future development to fully automate new digital processes with vendors

+ Current calibration solution is running on premises which requires additional configuration and/or external cloud based services (DCC Hub) to manage DCR/DCC coming outside of existing enterprise ecosystem

## NEW SOLUTION

+ Receive DCC from vendors and import harmonized and labeled data to existing calibration solution

+ New process provides better data quality by avoiding media breakes between BI and their calibration vendors

+ Vendor's calibration data can be used for data analysis and future process improvements

The DCC is powered by: testo  beamex  PTB  SIEMENS  Boehringer Ingelheim  Endress+Hauser

# Recalibration of sensors using DCC

Boehringer Ingelheim → testo Calibration Lab → beamex → Boehringer Ingelheim

| DCR | Calibration | DCC Creation | DCC Transfer | DCC Import | DCC in Production |

| Instructions, measuring points, identification | Recording and processing of calibration data | Creation of DCC with digital seal | Electronic exchange of DCC | Automated import of data in proccessing system | Application using correction data from DCC |

The DCC is powered by: testo  beamex  PTB  SIEMENS  Boehringer Ingelheim  Endress+Hauser

# How to identify instruments in a DCC



The DCC is powered by: testo beamex PTB SIEMENS Boehringer Ingelheim Endress+Hauser

# DCC Production Mode    The Game Changer



Meeting 24.10.2024 Ingelheim

The DCC is powered by: testo beamex PTB SIEMENS Boehringer Ingelheim Endress+Hauser

## DCC Production Mode    The Game Changer



Meeting 15.01.2025 Gerlingen

**DCC Temperature Manufacturer and Service Provider**
**Ready to use in Production Mode**

The DCC is powered by: testo  beamex  PTB  SIEMENS  Boehringer Ingelheim  Endress+Hauser

## Key Facts about the Digital Calibration Certificate (DCC) XML Schema



**DCC**

XML–based exchange format for calibration certificates

Developed with international partners including industry

Automated Validation via XSD-Schema and Schematron

Complies with many important norms and standards

18.02.2025    PTB  SIEMENS  Boehringer Ingelheim  Endress+Hauser    19

## Status DCC Schema

+ https://gitlab.com/ptb/dcc/xsd-dcc

GitLab

Physikalisch-Technische Bundesanstalt / DCC / xsd-dcc

### DCC xsd-dcc

| master ∨ | xsd-dcc | | Datei finden | Code ∨ |

**fix relative links**
Justin Jagienlak erstellt vor 2 Monaten · 8d804ad4 · Verlauf

| Name | Letzter Commit | Letzte Aktualisierung |
| --- | --- | --- |
| assets | Add missing logo | vor 3 Jahren |
| scripts | DCC Schema Release 3.2.0 | vor 1 Jahr |
| .gitignore | Add validation of xsd and exam... | vor 5 Jahren |
| .gitlab-ci.yml | Release 3.1.2 | vor 2 Jahren |
| COPYING.LESSER | Add LGPLv3 License | vor 3 Jahren |
| README.md | fix relative links | vor 2 Monaten |
| dcc.xsd | Release version 3.3.0 | vor 2 Monaten |

**Projektinformation**
This repository contains the XML Schema Definition (XSD) for the DCC (Digital Calibration Certificate).

dcc   PTB   XML   + 1 weitere

pipeline passed   Latest Release   v3.3.0

◇ 346 Commits
⑂ 2 Branches
🏷 23 Tags
🚀 12 Veröffentlichungen

📄 README
⚖ LICENSE

For more details on the new schema version see presentation Ali Demir, Thursday, 14:20, Tools & Sofware

Release on 2024-10-29
Version 3.3.0

The DCC is powered by: testo  beamex  PTB  SIEMENS  Boehringer Ingelheim  Endress+Hauser

20

## Evolution of the DCC Schema

+ Version 3.X.X longtime available

+ Parallel development of modular (XSD) Digital Schema X (DX)

+ Basis for DCC v4.X, Digital Calibration Requests (DCR), and further Digital Quality Documents

+ Definition of semantic model (harmonised terms and definitions, ontology)

The DCC is powered by: testo  beamex  PTB  SIEMENS  Boehringer Ingelheim  Endress+Hauser

Digital Quality Documents & Asset Administration Shell



DQD sub-model of the Asset Administration Shell

Digital Quality Documents characterize the performance of a system / product over its entire life span via the following documents by recurring tests over time:
➢ Calibration (DCC)
➢ Conformity asessment (DCoC)
➢ Legal metrology (DCC, DCoC)
➢ Test reports (DTC)
  ➢ Acceptance tests
  ➢ Field Tests
  ➢ Check lists e.g. function / completeness

Signed document for
Originality and Authenticity

# DQD in Dataspaces



The DCC is powered by: testo beamex PTB SIEMENS Boehringer Ingelheim Endress+Hauser

# The value of a digital quality infrastructure



The DCC is powered by: testo beamex PTB SIEMENS Boehringer Ingelheim Endress+Hauser

# Day 2  (2025-02-26 Wednesday)
## Parallel Session "Tools & Software"
## (Chair: Anjali Sharma)

## 011   Digital Calibration Exchange (DCX): Software Tools, Interfaces, and Workflow Integration

Presenting author: David Balslev-Harder; DFM – Danish National Metrology Institute
Email: dbh@dfm.dk
Additional authors: Søren Kynde srk@dfm.dk

## Abstract

The Digital Calibration Exchange (DCX) framework was developed by DFM with input from members of TC-IM 1448 WG1 and WG2. The aim of DCX is to investigate the impact on software-tools and architectures when the schema emphasizes use of reference pointers within the DCC's, as compared to tree-structure emphasis as applied in the PTB DCC-schema. This presentation will explore these developed software-tools and discuss aspects relevant to user-interface. In particular software tool implemented using Python and Excel, which allows users to read, edit and export data to xml, will be presented.

Additionally, we will introduce a query tool designed for clients to efficiently lookup specific data within Digital Calibration Certificates (DCCs) which the client may want to transfer to internal databases. This tool simplifies the process of preparing the data retrieval, to enable quick and accurate access to essential calibration information.

The presentation will also cover the generation of PDF documents from DCX data, emphasizing the use of human-readable headings for all elements. This feature enhances the readability and usability of the generated documents, making them accessible to a wider audience. Finally, we will discuss the workflow and architecture of DCX in relation to the XSD

schema, providing a comprehensive understanding of how these components interact to ensure data integrity and consistency. In conclusion, the DCX user-interfaces and software tools provide important steps toward offering a powerful and intuitive solution for managing calibration data, streamlining processes, and enhancing the overall user experience.

Outline of presentation

- What is DCX
- Availability of software tools for DCX
- o User interface for DCX for: reading, editing and eporting to xml
- o Querry tool for clients to lookup data in xml
- o PDF generation - utilizing Human readable headings for all elements.
- Workflow and architecture relation to DCX schema
- Solution available on github.com/TC-IM-1448/DCC-Tables
- See the other presentations for information on DCX schema and DCX certificate examples.

# Presentation of David Balslev-Harder

**Getting Started with Digital Calibration Exchange (DCX): Software Tools, Interfaces, and Workflow Integration**

**5th international DCC conference,**

**February 26th 2025**

*By David Balslev-Harder & Søren R. Kynde*

**DFM**
Danish National Metrology Institute

DFM

DFM's incentive for DCC:
*To support creation of FAIR DCC formats that are globally recognized/standardized, in order to support quality and efficiency in production companies, through automation.*

*Develop simple user interface software tool that can accept and modify DCC, DCR and Templates regardless of origin.*

*DFM receives funding by:*
*Danish Agency for Institutions and Educational Grants*

## Background and Roadmap

| Year | 2021 | 2022 | 2023 | 2024 | 2025 |
|------|------|------|------|------|------|
| **DFM DCX dev.** | Request from industry stakeholders, for DFM to join standardisation work on DCC | Developed python tools for generating DCC for temperature, humidity, ... | Presented new ideas for DCC schema, and Initiated parallel demo development. | - Incorporate BIPM-SI-Digital-Framework and ISO 80000. - Model for DCR & Templates introduced | **DCX v1.0.0 released** Use cases on Template-> DCR-> Tender -> PO -> DCC -> Client Database. Draft Template standards |
| **PTB & DKD** | | DFM participated in PTB DCC summerschool, and joined DCC user community. | Proposal for modifications to the DCC-schema discussed w. PTB at visit to Braunschweig | DFM joined: - DKD Interdisciplinary - PTB WG on pipette's | Meeting w. PTB in Braunschweig discussing roadmap for Harmonising requirements DCX/DCC |
| **EURAMET TC-IM 1448** | | WG's were formed 1. Harmonisation (DFM) 2. Software Tools (PTB) 3. Dissemination (PTB) | WG meetings: focus on DCC status. Dialog w. BIPM regarding units and quantities | WG meetings Focus on requirements for DCC | |
| **DK activities** | DK focus-group on DCC Teknologisk Institute (DI), FORCE Technology (DI) and DFM (NMI) | 1st DK DCC conference Concerns rasied about operability of DCC. | 2nd DK DCC conference Concerns rasied about development and operability of DCC. | 3rd DK DCC conference Concerns rasied about Harmonisation of DCC and DCX. | |

## Motivation for DCX:

1. *Explore impact on middleware architecture when schema is designed w. focus on:*
   a) *Use of references rather than emphasis on tree structure (PTB-DCC approach):*
      i. *Extend use of xs.ID and xs.IDREF and utilizing xs.key and xs.keyref to restrict pointing options*
      ii. *Introduce new attribute-names and restricted options to guide machine interpretability*
      iii. *avoid multiple re-entry of identical data*
   b) *Represent data content in tables for easier integration with Excel and databases and provide better overview in user interface experience.*
   c) *Emphasis on descriptive query expressions for finding and interpreting measurement data.*
   d) *Same elements/structure for all calibration/metrology areas.*
   e) *Define as much as possible in one Schema, to simplify interoperability and facilitate validation data machine interpretability and ability level to support automatic data extraction.*

2. DCC is more than just a data-file, it may act as a legal document.
   a) Support human readable fields for all elements in the xml-file.
   b) Support PDF-generation w. low level of middleware assumptions.

3. *Simplify software/middleware management*
   a) Use schema in middleware to adapt for received xml's used schema version.
   b) *Provide tools for Excel that support file reading across different metrology area's*

dbh@dfm.dk          Motivations were developed through discussions with stakeholders and within TC-IM 1448 WG1.

# Roadmap digital calibration exchange (DCX)

**DCX Schema (.xsd)**  Same schema validates all xml files

**DCC (.xml)**  Content specified by calibration lab
limited automation ability for client.

**DCR (.xml)** → **DCC (.xml)**  Content specified by client in DCR and
adopted in DCC by calibration lab
Enables full automation for client

**DCX Templates (.xml)** → **DCR (.xml)** → **DCC (.xml)**

Content specified by community in DCX templated and adopted in client DCR
as well as by calibration lab in DCC, but now the calibration lab can automate their
process.

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# DCX Tool to ENABLE :

Calibration Database

Excel User Interface ✓  Generate ✓
DCC, DCR,...

**DCC XML**

Load, query &
validate DCR,DCC,...

Middleware generates whole
setup in the Excel interface

load definitions &
element structures

**XSD Schema**

&

**Broad coverage**

Temperature ✓

Mass, volume, density ✓

Geometry

Flow

Pressure ✓

Electric ✓

Humidity, Force, torque ✓

**Parallel development of user interface and Schema**

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## DCX Implementation is available on github:

https://github.com/TC-IM-1448/DCC-Tables

dcc.xsd  - Schema file for DCC - direct link:
raw.githubusercontent.com/TC-IM-1448/DCC-Tables/refs/tags/v1.0.0/dcc.xsd

ioDCCGuiTool.py - for interfacing with Excel.

dccQueryGui.py – for data querying into Excel.

DCChelpfunctions.py – used for validation

Examples: Folder with DCC examples

dcc-env.yml – Anaconda/Python environment file

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v1.0.0
Released
in start Feb. 2025

## Updates since last year

1. New default system for Quantities and Units based on ISO 80000 and BIPM SI-Digital-Framework unit representation introduced in schema including:
   - Incorporated in the data result tables.
   - RegEx for validating BIPM-SI unit expression.
   - Section for defining other quantities and units.

2. Simplified and improved query expressions for extracting measurement data and meta data.

3. Introduced human readable fields for all elements.

4. *Simplified the layout of administrative data*

5. *Introduced DCX (Digital Calibration Exchange) as name to distinguish from PTB-DCC schema.*

6. *DCR and Templates incorporated in the same schema.*

7. *User interface builds up based on the used schema, enabling dynamic adoption between schema versions.*

dbh@dfm.dk

*The power of uniquely combining a set of multiple descriptive attributes*

# calibrationResults and measurement table structure new Quantity Unit lines added

| | | reference | indication | bias |
|---|---|---|---|---|
| 17 | @scope | reference | indication | bias |
| 18 | dataCategory | value | value | value |
| 19 | @dataCategoryRef | - | - | - |
| 20 | @quantity | 5-2\|Celsius temperature\|℃ | 5-2\|Celsius temperature\|℃ | 5-2\|Celsius temperature\|℃ |
| 21 | @unit | ℃ | ℃ | ℃ |
| 22 | @quantityUnitDefRef | | | |
| 23 | @settingRef | | | |
| 24 | heading[da] | Referencetemperatur i instru | Instrumentvisning | Visningsfejl |
| 25 | heading[en] | Reference Temperature in in | Instrument indication | Instrument Error |
| 26 | 1 | -6.076 | -6.06 | 0.016 |
| 27 | 2 | 5.017 | 5.05 | 0.033 |
| 28 | 3 | 27.054 | 27.16 | 0.106 |
| 29 | | | | |
| 30 | | | | |

```
<xs:restriction base="xs:string">
    <xs:pattern value="quantityUnitDefRef|-|1|%|ppm|(((h|d|min|°|t)|(Y|Z|E|P|T|G|M|k|h|da|d|c|m|µ|n|p|f|a|z|y)?(A|Bq|cd|C|°C|F|
    Gy|H|Hz|J|kat|K|g|lm|lx|m|mol|N|Ω|Pa|rad|s|S|Sv|sr|T|V|W|Wb|au|B|Da|eV|ha|L))([-]?[1-9]\d*)?)((\.(((min|t)|(Y|Z|E|P|T|G|M|
    k|h|da|d|c|m|µ|n|p|f|a|z|y)?(A|Bq|cd|C|°C|F|Gy|H|Hz|J|kat|K|g|lm|lx|m|mol|N|Ω|Pa|rad|s|S|Sv|sr|T|V|W|Wb|au|B|Da|eV|ha|L)|
    (d|h|min|°|t))([-]?[1-9]\d*)?))*)?"/>
```

DCX Architecture

All row entries in the tables have unique identifiers – which can be referenced /linkedto as required or needed.

Administrative	Statements	Equipment	Settings	MeasurementConfig	EmbeddedFiles	QuantityUnitDefs	Result 1...N:

DCC schema ver.
certificate #
Order #
arrival Date
start Date
end Date
issue Date
performance Loc.
...
ServiceProv. addr.
client address
Equip. return addr.
Cert. return addr.
Locations...
 	
Accreditation:
Lab ID code
Accred. Norm
Accred. Body
Accred. Country
Accred.
Applicability
	@id
	@imageRef
	@category
	heading [lang]
	body [lang]
	ext. Reference
		@id
		@category
		heading [lang]
		manufacturer
		modelName
		modelNumber
		serialNumber
		lotNumber
		productClass
		clientId
		serviceProvId
		prevCalibDate
		calibDueDate
		prevCertId
		prevCertProvider
			@id
			@equipmentRef
			parameter
			    value
			    unit
			connectedTo
			softwareInstruction
			heading [lang]
			body [lang]
				@id
				devForMeasRefs
				devForMeasSettingRefs
				referanceStandardRef
				referanceStandSettingRef
				statementRefs
				operationalStatus
				    [as found/as left]
				heading [lang]
				body [lang]
					@id
					@category
					Heading [lang]
					Body [lang]
					fileExtension
						@id
						@statementRefs
						quantityCodeSys.
						quantityCode
						unitUsed
						functionToSIunit
						unitSI
						externalRefs
							tableCategory
							    [calibrationResult/
							    measurementSeries]
							@tableId
							@serviceCategory
							@measurementConfigRef
							statementRefs
							heading [lang]
							(numRows, numColumns)
							Columns:
							    scope
							    dataCategory
							    dataCategoryRef
							    quantity (ISO80000)
							    unit (BIPM-SI-Digital)
							    quantityUnitRef
							    heading [lang]
							    dataList

Excel U

Excel U

First screenshot (Definitions / quantityUnitDefList sheet):

	A	B	...					
1	heading[en]	Quantity and Units definitions						
2	colHead[en]							
3	in xml	@id	@statementRefs	heading[en]	quantityCodeSystem	quantityCode	unitUsed	functionToSIunit	unitSI
4	y	megaOhm			ISO/IEC 80000		MΩ	1000000*value	Ω

Sheet tabs: Definitions | administrativeData | statementList | equipmentList | settingList | measurementConfigList | embeddedFileList | quantityUnitDefList | R_AbsCal_Ohm | cal_ZERO

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Second screenshot (TempCal sheet):

	A	B	C	D	E	F	G	H
1	tableCategory	calibrationResult						
2	@tableId	TempCal						
3	@measurementConfigRef	ms1						
4	@serviceCategory	T/T-2.2.3 Thermistors and other resistive thermometers						
5	@statementRefs							
6	@embeddedFileRefs							
7	@numRows	3						
8	@numCols	17						
9	heading[da]	-						
10	heading[en]	calibrationResult 1_T1						
11	body[da]							
12	body[en]							
13	indexFollowMeasurementSequence							
14	conformityStatus							
15	conformityStatusRef							
16								
17	@scope	-	reference	reference	indication	bias	bias	bias
18	dataCategory	rowTag	targetValue	value	value	value	expandedUncertainty	uncertaintyCoverageFactor_k
19	@dataCategoryRef	-	-	-	-	-	value	expandedUncertainty
20	@quantity	-	5-2|Celsius temperature|°C	5-2|Celsius temperature|°C	5-2|Celsius temperature|°C	5-2|Celsius temperature|°C	5-2|Celsius temperature|°C	5-2|Celsius temperature|°C
21	@unit	-	°C	°C	°C	°C	°C	°C
22	@quantityUnitDefRef							
23	@settingRef							
24	heading[da]	Kundens kode	Kalibreringspunkt	Referencetemperatur i instr	Instrumentvisning	Visningsfejl	Ekspanderet kalibreringsusikk	k
25	heading[en]	Customer Tags	Calibration Point	Reference Temperature in in	Instrument indication	Instrument Error	Uncertainty	k
26	1	T1	-6	-6.076	-6.06	0.016	0.108	2
27	2	T2	5	5.017	5.05	0.033	0.108	2
28	3	T3	27	27.054	27.16	0.106	0.108	2

Sheet tabs: Definitions | administrativeData | statementList | equipmentList | settingList | measurementConfigList | embeddedFileList | quantityUnitDefList | TempCal | +

Xpath Query for measurement data.

Xpath-Color-code:

- **Orange**: attributes keywords defined in schema
- **Purple** : keywords defined in schema which can be selected to identify data.
- **Green** : keywords specific for the certificate needed to identify data.

Xpath:

//dcx:calibrationResult[@tableId="Table1"]/[@scope="bias"] [@quantity="3-4|volume|m3"][@unit="µL"]/
    dcx:value/*[@idx="1"]/text() = 10.5

//dcx:calibrationResult [@tableId="Table1"]/[@scope="bias"][@quantity="3-4|volume|m3"][@unit="µL"]/
    dcx:conformity/*[@idx="1"]/text() = 'pass'

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DCX demo pilot process

Process for Pilot study of DCX v1.0.0

1. *Client map their data-base information needs to DCR format.*
   1. *if no DCR we experience low client stakeholder engagement.*
2. *Create mapping for preparing extraction of data from DCC to client DB.*
3. *Tender and PO process will run in parallel*
4. *Can the relevant data be extracted reliably from the different providers.*
5. *Certificates will be generated by several Service Providers to test if they return DCC's with equivalent content, structure and formats.*

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Path forward

1. *We envision the presented tools as a tool for*
   1. *establishing templates for specific kinds of calibration tasks in different metrology areas, such that both clients and service providers can automate processes based on the templates.*
   2. *Provide simple-tool for small Service Providers so they can receive DCR, and generate DCC's.*
2. *With PTB investigate how the DCX requirements can be merged/harmonized with DCC, TemaTres*
3. *In TC-IM 1448: Harmonize semantics and structures, international perspectiv*
4. *Establish standardized regular expression based on BIPM Digital SI unit expression and a standardized schema for ISO 80000 through TC12.*
5. *Incorporate NCSLI metrology Taxonomy into settingCodes.*
6. *Pilot study and Full process cost analysis (Template, DCR, DCC, extraction)*
   1. *Cost of deployment, maintenance, versatility, for both clients and Service Providers.*

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DFM's incentive for DCC:
To support creation of FAIR DCC formats that are globally recognized/standardized, in order to support quality and efficiency in production companies, through automation.

Develop simple user interface software tool that can accept and modify DCC, DCR and Templates regardless of origin.

Danish collaboration partners:

DANDIAG: Tove Søgaard, Rene, Charlotte Rugaard

Novo Nordisk: Heidi Foldal, Jan Laursen, Johan Schroll-Flaischer

FORCE Technology: Ahmed Khan Leghari, Andreas Lyndrup Jensen, …

Teknologisk Institut: Jonas Vind, Peter Friis Østergaard, Jan Nielsen, …

DANAK: Erik Øhlenschlæger

Contact: David Balslev-Harder (dbh@dfm.dk)

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Thank You

Members in TC-IM 1448 WG1 and WG2:

DFM, Denmark:	David Balslev-Harder (Chair)
BEV, Austria:	Zoltan Zelenka
INTI, Argentina:	Diego Nahuel Coppa,
IPQ, Portugal:	Carlos Pires
NPL, UK:	Michael Chrubasik, Ian Smith
NPLI, India:	Anjali Sharma
PTB, Germany:	Shanna Schönhalls, Daniel Hutzschenreuter, Gamze Soeylev-oektem, Clifford Brown, Wiebke Heeren.
SMD, Belgium:	Quentin Baire,
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Clifford Brown
Wiebke Heeren
Siegfried Hackel
Frank Härtig …

012 GEMIMEG 2.0: Evolution of the concept and implementation of the GEMIMEG Tool

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Abstract

GEMIMEG II is a successor of the GEMIMEG tool [1] that strives to fulfil the purpose and goals of the predecessor. GEMIMEG II is designed to provide an accessible graphical user interface (GUI) for human users to create a Digital Calibration Certificate (DCC) without requiring prior knowledge of the underlying XML structure nor the DCC schema. It continues the successful work of the previous software tool. Furthermore, it produces a human readable format of the DCC, to facilitate the work of auditors and streamlining accreditation procedures.

GEMIMEG II supports for the first time the DCC schema version 3.3.0 and the support of the Digital System of Units (D-SI) [2] and its corresponding interlinked schema. This improves, e.g., the expanded measurement uncertainty and its correct notation in the digital realm.

GEMIMEG II is provided as a webservice and can be easily accessed via an Internet browser like a web page. A desktop version for offline use will be provided for all major operating systems. By employing container technology, GEMIMEG II is independent of the underlying operating system.

Additionally, GEMIMEG II provides a standardised application programming interface (API). This facilitates the seamless integration of GEMIMEG II into an existing laboratory workflow [3]. Implementing standardised REST interfaces enable a seamless communication and data exchange of upstream process steps and specialised software tools. This provides the opportunity to employ GEMIMEG II without media discontinuity. Furthermore, laboratories can create a fully automatised DCC creation workflow in their customised working environment.

GEMIMEG II is published under an Open-Source license and will be free of charge. This allows to use the tool without restrictions including the right to copy, to change, to publish, to distribute, to lend or rent it, or use it commercially.

- o [1] Machine-readable and machine-actionable digital calibration certificate (DCC) and its use in practice S. Hackel, S. Schönhals, T. Krah, L. Doehring – Technisches Messen 2024; 91(1): 51–62, DOI: https://doi.org/10.1515/teme-2022-0117
- o [2] SmartCom Digital System of Units (D-SI) Guide for the use of the metadata-format used in metrology for the easy-to-use, safe, harmonised and unambiguous digital transfer of metrological data - Second EditionHutzschenreuter, Daniel, et al., *Zenodo. DOI* 10 (2019).
- o [3] Digital transformation in metrology: Building a metrological service ecosystem A Oppermann, S Eickelberg, J Exner, T Bock… - Procedia Computer Science, 2022

Presentation of Alexander Reissert

General digital transformation in the lab | Prolog

- Avoid proprietary data formats and platform with export functionalities

- Embrace the FAIR principles

- Make data and algorithms available between labs, groups and disciplines

Trustworthy machine-readable information | Prolog

Image: PD (https://nzz.ch)

Providing exactly the information that is needed with a high level of confidence

- Interfaces between platforms
- Machine-readable data
- Protection against manipulation
- High level of automation

Integration Areas | Prolog

User centric application

Cloud System

On Premise

IoT

Devices / Instruments

Integration: Systems, Data and Processes | Prolog

Data Tier

OP-Layer

Processes

API

Services

Systems

FAIR principles – not only in science! | Prolog

F_indable A_ccessible I_nteroperable R_eusable

- Uniquely findable data is the pre-requisite for application of machine learning and AI

- Data must be accessible by other systems in the workflow

- Interoperability is required to use the data in different contexts

- Re-using data may lead to new insights

Core metrology competences underpin the FAIR principles

5th International DCC Conference
Dr. Alexander Reissert

6

26. Feburary 2025

GEMIMEG Tool 2.0

Gemimeg Tool 2.0 | Presentation

■ Backend

- Java / Spring Boot Framework
- REST – Interfaces
- OpenAPI – Documentation (Swagger)
- Container – Technology (Docker)
- Support DCC schema version 3.3.0

Fully functional service unit
to create and issue DCC

Gemimeg Tool 2.0 | Presentation

■ Frontend

- Angular Framework
- Web Application
- Container – Technology (Docker)

Graphical User Interface
for the Backend Service

GEMIMEG Tool 2.0 | Presentation

- Connect GEMIMEG Tool 2.0 now to your service infrastructure through REST APIS

- Or run GEMIMEG Tool 2.0 as a standalone tool

- Create fully digitalised workflows with many different data sources

- Create a DCC via JSON and receive a fully functional DCC XML

Gemimeg Tool 2.0 | Presentation

- Open-Source License
- Public Beta Test will start at 31. March 2025
- Multilanguage Support – more localisation needs your help
  - English,
  - French,
  - German,
  - Spanish and
  - Portuguese
- We need your feedback @ gemimeg@ptb.de

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Dr. Alexander Reissert

20

26. Feburary 2025

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Dr. Alexander Reissert

21

26. Feburary 2025

Gemimeg Tool 2.0 | Presentation

AVAILABLE AT 31. March 2025

VISIT: https://www.gemimeg.ptb.de/gemimeg-tool**/2.0**

Basic Workflow | Use Case

Calibration application	Calibration Laboratory	GEMIMEG Tool 2.0	Customer Contact
1. User registration	1. Create file	1. Retreive administrative data	1. Send DCC to User
2. Fill out form	2. Copy administrative data	2. Retreive measurment data	2. Bill Customer
3. Submit application	3. Start calibration	3. Create DCC	

Exemplary workflow for a service-oriented architecture

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26. Feburary 2025

Questions? | Discussion

Thank you for your attention

Operation – Layer Team

AVAILABLE AT 31. March 2025

VISIT: https://www.gemimeg.ptb.de/gemimeg-tool/**2.0**

PTB 5th International DCC Conference
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25

26. Feburary 2025

013 Formula Evaluation and MathML: Processing in Python: A High-Precision Framework for XML documents like the DCC

Presenting author: Justin Jagieniak, PTB Germany
Email: Justin.Jagieniak@ptb.de
Additional authors: Siegfried Hackel, Jan Loewe

Abstract

This presentation introduces a Python library designed for processing and evaluating mathematical expressions with high precision, leveraging sympy library. A key feature of this library is its ability to parse and process XML-based MathML content, enabling the extraction and evaluation of mathematical formulas represented in MathML format. The library supports dynamic variable management, symbolic expression handling, and high-precision numerical computations, making it suitable for applications in scientific computing. By integrating MathML processing capabilities, the library bridges the gap between symbolic mathematics and XML-based mathematical representations, providing a versatile tool for working with complex mathematical data. The presentation will highlight the library's core functionalities, its use cases, and its advantages in scenarios requiring both high computational precision and interoperability with MathML standards for the DCC.

Presentation of Justin Jagieniak

Automating Formula Evaluation in Digital Calibration Certificates (DCCs) with Python

26.02.2025
Justin Jagieniak, PTB, 1.24
Jan Loewe, PTB, 1.24
Siegfried Hackel, PTB, 1.01

1

Why this?

Physikalisch-Technische Bundesanstalt
Bundesallee 100

Workflow
The transformation of calibration into an XML document

Formulas

1. https://www.sympy.org | Justin Jagieniak | Jan Loewe | Siegfried Hackel | Automating Formula Evaluation in Digital Calibration Certificates (DCCs) with Python   12.02.2025   3

The Utility Model
Formulas in the utility model by IDiS

Level 5: Machine controllable Contents	AI Dig. Twin
Level 4: Machine readable and interpretable content	
Level 3: Machine readable and executable content	
Level 2: Machine readable document	
Level 1: Digital document	
Level 0: Paper	

Formulas

From: „IDiS – Initiative Digitale Standards". [Online].
see: https://www.dke.de/resource/blob/2076816/facc9bde1806e2194a3d26a60c79bf77/idis -
whitepaper-1-en—download-data.pdf

https://www.sympy.org | Justin Jagieniak | Jan Loewe | Siegfried Hackel | Automating Formula Evaluation in Digital Calibration Certificates (DCCs) with Python   12.02.2025   4

2

Introduction to Content MathML

Physikalisch-Technische Bundesanstalt
Bundesallee 100

Formula in Content MathML
An example how a formula is written in Content MathML

```
<dcc:mathml>
  <ml:math>
    <ml:declare type="fn">
      <ml:ci>f</ml:ci>
      <ml:lambda>
        <ml:bvar><ml:ci>x</ml:ci></ml:bvar>
        <ml:apply>
          <ml:plus/>
          <ml:apply>
            <ml:times/>
            <ml:ci xref="m">m</ml:ci>
            <ml:ci>x</ml:ci>
          </ml:apply>
          <ml:ci xref="b">b</ml:ci>
        </ml:apply>
      </ml:lambda>
    </ml:declare>
  </ml:math>
</dcc:mathml>
```

$$f(x) = m * x + b$$

1. https://www.sympy.org | Justin Jagieniak | Jan Loewe | Siegfried Hackel | Automating Formula Evaluation in Digital Calibration Certificates (DCCs) with Python   12.02.2025   6

2

MathML Evaluator in Python

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Modules of the MathML Evaluator
The three modules of the python program

- The program is divided in 3 modules:
  - XMLFormulaExtractor - extracts the formulas of an XML like DCC.
  - ContentMathMLEvaluator – evaluate the extracted formula and convert it into a Python algorithm.
  - GUI / Terminal – A GUI or Terminal for work with.

Problem fields for metrology
Identify, analyze and resolve problems

- A formula is not an algorithm. The polish notation of content MathML needs to be interpreted step by step and converted.
  - ▶ Resolution 1: The XML needs to be interpreted in a way that is understandable for an algorithm. This resolution was developed by us.
  - ▶ Resolution 2: SymPy[1] (open source library) offers many advantages for symbolic mathematics. The formula can be converted into an algorithm using a function pointer that references it.
- Values for variables (measurement results) need to be extracted by id and xrefs in the DCC.
  - ▶ Resolution: We have achieved this with our own solution in the XMLFormulaExtractor.

1. https://www.sympy.org

Problem fields for metrology 2
Identify, analyze and resolve problems

- Normally programming languages use limited data types like float, double, etc.
  - ■ The precision might not be sufficient for specialized fields of metrology
    - ▶ Resolution: SymPy works with a library called mpmath[2]. With mpmath, SymPy can achieve a precision of up to 100 decimals.
- Units of variables needs to be calculated too.
  - ▶ Resolution: Units in formulas can also be calculated. This functionality is supported in SymPy. The feature is currently in progress and is planned for future implementation.

1. https://mpmath.org

3

Consolidation into a Python library

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Goals
Consolidation into a Python library

Consolidate existing functionality into a Python library

Development of additional interfaces (REST-API, CLI)

Extensible module structure

Automated quality assurance

Release as open-source software

4

Summary

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Future plans
Summary

- ▦ Distribution
  - ■ A REST API hosted by PTB for working with the latest developments from the DCC team at PTB.
  - ■ A free-to-use Docker image for running the REST API locally or on your own server.
  - ■ A Python library to integrate into your own development projects.
- ▦ Features
  - ■ Integrate the SI system of units into the code to handle units in formulas as well.
  - ■ Integrate more advanced mathematical functions that can be used in Content MathML.

014 Consistent Representation and Usage of Tabulated Data in the DCC. Enable Easy-To-Use Computer-Aided Processing and Visualization of Your Data

Presenting author: Benedikt Seeger
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Abstract

In metrological measurements, tabulated data is omnipresent - almost all data consists of different values that stand in relation to each other. The Digital Calibration Certificate (DCC) presents us with a unique opportunity to make this data accessible more efficiently than ever. The accessibility of the data enables direct processing of the data, e.g. as human-readable plots, such that the data becomes easy to understand and interpret correctly. The current state of the DCC schema definition allows for multiple different representation of tabulated data. For efficient use of the DCC as a universal exchange format for metrological data between different applications, it is crucial that the table format is consistent across all DCCs, regardless of calibration task. One such format is proposed in which all kind of tables can be represented, and which can then be efficiently parsed by suitable software.

It is discussed how computers process relational data and how modern design principles enable efficient interaction with and consistency of such data. The different possible structures of the DCC that could represent the relations of the data are discussed. A suitable, efficient format for representing tabulated data is proposed, and its efficiency and reliability is evaluated. We present an open-source reference implementation project in Python to show the underlying de- sign principles that could analogously be used in all object oriented programming languages.

Keywords: Tables; DCC; Indexing

Presentation of Benedikt Seeger

**Physikalisch-Technische Bundesanstalt
Braunschweig und Berlin**
Nationales Metrologieinstitut

Consistent Representation and Usage of Tabulated Data in the DCC

5th DCC Conference

Benedikt Seeger, Vanessa Stehr, PTB, 1.73

Outline

1 Data in the DCC

   1 Tables

   2 dcc:quantities

2 Representation options of this data

   1 Motivation

   2 dcc:quantities

   3 Tables

Why we use tables

- **Calibration:** Establishes a **relationship** between known **quantity values** (with uncertainties) and **corresponding indications** under **specified conditions.** *JCGM 200:2008 International vocabulary of metrology*

  - Tables are used in analog and digital domain to store calibration data efficiently.

  - Relational databases and tables share the same basic principles

    - They store "rows" with identical kind and structure of information

    - We look up a specific "row/dataset" by searching for one (or more) specific value

Physical quantities and tables

Table Columns are
Phyiscal Quantites

Quantity				Index position
Frequenz	Beschleunigungs-amplitude	Übertragungskoeffizient		
		Betrag	Phasenverschiebung	
f in Hz	$\hat{a}$ in m/s²	S_{qa} in pC/(m/s²)	$\Delta\varphi_{qa}$ in 1°	
10	5	0,1301	-0,02	0
12,5	5	0,1302	-0,03	1
16	5	0,1302	-0,02	2
20	10	0,1302	-0,02	3
25	10	0,1302	-0,01	4
31,5	10	0,1302	-0,01	5
40	10	0,1302	-0,02	6
50	50	0,1302	-0,01	7
63	50	0,1301	0,00	8
80	50	0,1301	0,01	9
100	50	0,1301	-0,01	10
125	50	0,1301	-0,01	11
160	50	0,1301	0,00	12

Name
Label
Unit
Values

Dcc:quantites

- Dcc:quantities are structures containing
  - Name (multi language)
  - Description (multi language)
  - Unit as D-SI string
  - Values (scalar) or **lists**
  - Uncertanties (scalar) or **lists**
  - Rich metadata as XML elements
    - Nested quantities are allowed here

- Software should use **dcc:quantities** as the smallest unit of information.

dccQuantities library

| Read DCC file | → | Parse XML | → | Filter matching elements |

| Implement desired functionality | ← | Implement basic functionality | ← | Extract data from elements |

dccQuantities library

Read DCC file	→	Parse XML	→	Filter matching elements

DccQuantities-Library

Implement desired functionality	←	Implement basic functionality	←	Extract data from elements

dccQuantities library

- Read DCC and parse quantities

- Standard Python functions

- Arithmetic operations with uncertainties

  Work in Progress

- Serialize quantities back into DCC-XML

  Work in Progress

dccTables-Library?

A similar library for tables?

- Most data is tabulated

- We need to be able to work with this data digitally!

  - We want to parse the data into a format that is easy to understand for humans, e.g. as plots

- **Problem**: There are a large number of ways to represent tabulated data in the DCC…

Table formats

Why is that problematic?

- First, we would need to find every table format that is used anywhere

- Some formats increase the size of file so much that it can not be easily parsed

- Every format needs its own parser

Table formats

- **We need a standardized table format in order to be able to productively use data from the DCC!**

- Keep in mind: DCC is not intended to be directly read by humans!

Table format requirements

What are tables?

- Rows of data taken under the same conditions

- Columns of the same kind of data, taken under different conditions

- Entries can be found via the index columns

Table format requirements

- Indexing
  - One, two, or *n* dimensions
    - Most cases only have one dimension
  - Numeric or categorical indexes
    - Can be mixed in multi-dimensional tables
- Some metadata (like units) is the same for each element, include option to avoid repetition

Proposed Table Format: 1D

```
<dcc:list refType="basic_1IndexTable">
  <dcc:quantity refType="basic_tableIndex0">
  <dcc:quantity>
  <dcc:quantity>
  <dcc:measurementMetaData>
  <dcc:influenceCondition>
```

Proposed Table Format: 1D

```
<dcc:list refType="basic_1IndexTable">
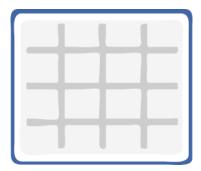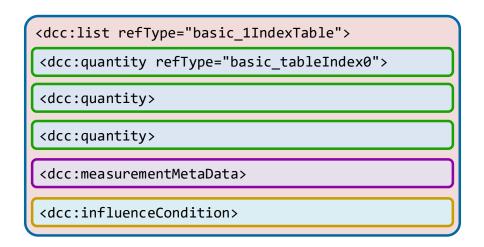
    <dcc:quantity refType="basic_tableIndex0">

    <dcc:quantity>

    <dcc:quantity>

    <dcc:measurementMetaData>      <dcc:quantity>
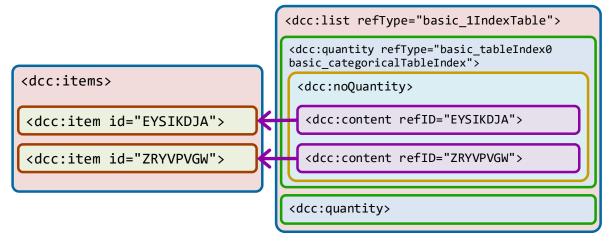
    <dcc:influenceCondition>       <dcc:quantity>
```

Proposed Table Format: categoric index

```
<dcc:list refType="basic_1IndexTable">

    <dcc:quantity refType="basic_tableIndex0
    basic_categoricalTableIndex">

        <dcc:noQuantity>

            <dcc:content refID="EYSIKDJA">

            <dcc:content refID="ZRYVPVGW">

    <dcc:quantity>
```

```
<dcc:items>

    <dcc:item id="EYSIKDJA">

    <dcc:item id="ZRYVPVGW">
```

Proposed Table Format

More than one index vector

- In most cases, it's sufficient to repeat index vector values ("long format")

- Then, format can follow 1D case

Pos	Index 1	Index 2	Index 3	Result
0	1.3	a	1	2.8 ± 0.2
1	1.3	a	2	8.2 ± 0.9
2	1.3	b	1	9.0 ± 0.6
3	1.3	b	2	1.2 ± 0.8
4	3.7	a	2	7.7 ± 0.6
5	3.7	b	1	6.5 ± 0.2
6	3.7	b	2	9.2 ± 0.4

Proposed Table Format: > 1D

```
<dcc:list refType="basic_1IndexTable">

<dcc:quantity refType="basic_tableIndex0">

<dcc:quantity>

<dcc:quantity>

<dcc:measurementMetaData>     <dcc:quantity>

<dcc:influenceCondition>     <dcc:quantity>
```

Proposed Table Format: > 1D

```
<dcc:list refType="basic_2IndexTable">

    <dcc:quantity refType="basic_tableIndex0">

    <dcc:quantity refType="basic_tableIndex1">

    <dcc:quantity>

    <dcc:quantity>

    <dcc:measurementMetaData>        <dcc:quantity>

    <dcc:influenceCondition>         <dcc:quantity>
```

Proposed Table Format

- Avoiding index value repetition is only necessary for very large tables (≥ 1000 entries, ≥ 2 dimensions)

- We are working on a proposition for such a format ("flat format")
  - Please contact us if you have use cases, so we can take them into account

Proposed Table Format: Benefit

- Proposed format covers all use cases we know of

- Writing a parser for a strict format is very easy

- Enables better software, and thus greatly increases usability

Discussion

Contact

Benedikt Seeger
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gitlab1.ptb.de/Seeger

Vanessa Stehr
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gitlab1.ptb.de/stehr01

Images: Illustrations CC0, Screenshots own work

dccQuantities-library: gitlab1.ptb.de/digitaldynamicmeasurement/dccQuantities/ -/tree/devel-class-restructuring

015   A framework for digitising dimensional metrology

Presenting author: Arif Sanjid
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Additional authors: Naveen Garg, R Srinivas Rao
CSIR- National Physical Laboratory, New Delhi, India

Abstract

The ISO 17450 (2011) entitled Geometrical product specifications (GPS)—General concepts: Model for geometrical specification and verification recommends framework of

dealing developing models for dimensional metrology applications. Moreover, its part 2, describes operators of the coordinate measurement data. Likewise, there are assorted document standards, literature and standard operating procedures to perform dimensional metrology calibrations. The KCDB (the BIPM key comparison database) web portal enlisted the calibration services of length along with their key comparison data. Accordingly, Calibration and measurement capabilities the national measurement institutes (NMIs) across the globe are endorsed after an approved peer reviewed audit.

In the era of industry 5.0, a framework that transforms metrological activities into digital format is inevitable. National Physical Laboratory, India has identified the significance of digitalising the dimensional metrology and initiated the efforts to device digital calibration certificates (DCC) in collaboration with the centre for calibration and testing (CFCT) of NPL, India. These attempts may lead to an evolution of the generic framework to meet the requirement of (Findable, Accessible, Interoperable, and Reusable data and services) FAIR.

This work aims to discuss a framework to digitalise the dimensional metrology practices and application. Present, the proposed abstract model is explained with a dimensional measurement application. The proposed model involves a process flow which emphasizes (1) metrological traceability of the reference measures and materials (2) Geometric product specification of the device under test (3) static and dynamic characteristics of the metrological loop of the measuring system (4) measurement process and raw measurement data. In dimensional metrology, the metrological loop comprises of the influences due to the structural rigidity, geometric imperfection – orientations of the workpiece, and the kinematics - the kinetic interactions. The abstract model is used to compose the measurement data in a format to supplement the requirement of FAIR. The procedure of measurement data is suggested in ISO 17450-2. The digitalization of the dimensional metrology also includes development of digital twins by implementing simulations using different artificial intelligence algorithms and techniques.

Keywords: DCC, FAIR, Artificial intelligence

A framework for digitising dimensional metrology

M Arif Sanjid*, Naveen Garg, Srinivas Rao

CSIR- National Physical Laboratory, New Delhi, India

Outline

▸ Introduction
▸ Dimensional Metrology
▸ Specific Application
▸ Future prospects
▸ Conclusion

National Physical Laboratory

▸ History
  ◦ The National Physical Laboratory is one of the earliest national laboratories set up under the Council of Scientific & Industrial Research(CSIR).

  ◦ Late Shri Jawaharlal Nehru laid the foundation stone of NPL on the 4th January 1947.

  ◦ Late Dr. K. S. Krishnan, FRS, was the first Director of the laboratory.

  ◦ The main building of the laboratory was formally opened by Late Deputy Prime Minister. Sardar Vallabhbhai Patel. on the 21st January 1950.

CSIR –NPL Organization Chart

NPL Organization for Quality System

Chart # 2. Organization Chart for Quality System

Dimension Metrology at NPLI

Calibration Certificate: **250/Annual**
No. of CMCs – **46**
Team members – **6**
Revenue : **$60K /Annual**

Dimension Metrology at NPLI

Digitalization for FAIR

Requirements for FAIR
▸ Traceability
▸ Measurement
▸ Expression of results

▸ *Digital Twin*
  ◦ *Machine kinematics*
  ◦ *GPS of reference artefacts*
  ◦ *GPS of measuring instruments*
  ◦ *Simulation – using AI algorithms*

Useful Document Standard

▸ ISO 17450 : Model for geometrical specification and verification
  ◦ surface model– skin model – features – operators –
▸ ISO 1101:2017 : Geometrical product specifications (GPS)

▸ ISO 14406:2010 GPS — Extraction
▸ ISO 16610–21:2025 (GPS) — Filtration — Part 21: Linear profile filters: Gaussian filters

▸ **Y14.5 – Dimensioning and Tolerancing(R2024)**
▸ **Y 14.5.1 M– MATHEMATICAL DEFINITION OF DIMENSIONING AND TOLERANCING PRINCIPLES**

Measurement

▸ Traceability to SI units
  ◦ Reference Artifact –Length Bar, Hemisphere, Surface specimen, etc
  ◦ Reference instruments– laser wavelength , autocollimator
▸ Workpiece – GPS
▸ Verification operation
▸ Measurement techniques
  ◦ Taylor envelope principle
  ◦ Reversal Technique
  ◦ Closure method
  ◦ Multistep error separation method
▸ Results
  ◦ Measurement Model– Uncertainty estimation
  ◦ Conformity assessment

Specific Application

◦ Diameter Measurement

◦ Digitalization
◦ the verification of the specification

Diameter Measurement Application

◦ Substitution method - The circumference of the piston is scanned to detect the peaks (i.e., reversal points) of its curvature.

◦

◦ The zenith point searching and the misalignment .

Operators for diameter Measurement (ISO-17450)

Partition-

the ability to locate the centre of a rectangular GB in mechanical comparison calibration is limited to 0.5 mm. Then the uncertainty contribution due to imperfect form is 2 nm

The scanned circumference constitutes the ROI for the given specimen.

$$\Delta\theta_{max} = 2cos^{-1}[1 - 2h_{max}/D]$$

The optimal angle between ROIs that minimizes the uncertainty of the measured quantity—is 120° for the radius and the Euclidean centre position

Operators for diameter Measurement (ISO–17450)

Extraction-

The operator decides the reversal point based on the least change (i.e. by one least count) in the reading of probe .

▸ Instead, the coordinates of the circumference of the specimen under test are sampled.

▸ The peak of this profile curve is determined by employing the **gradient method (Different AI algorithm can be applied–e.g. Gradient search)**

▸ Such an interpolation improves the uncertainty as we can convincingly assign a triangular distribution to the detection of peak.

Operators for diameter Measurement (ISO–17450)

Filtration-

F meli et al scanned three spheres with a resolution 10° (5°) in longitude (latitude), respectively to map their radius. This method measures the variations of radius as a function of angle

Collection-

The parameters associated with the circular cross-section of the specimen are roundness and diameter. Other additional parameters such as straightness, and parallelism, are required for cylindrical surfaces.

Operators for diameter Measurement (ISO–17450)

Association-

▸ **The surface model** : The matrix of the definition of geometric features and their interrelationships are illustrated in ISO 14660-1

▸ The diameter measurement is associated with (i) at least three measurements of roundness along the length of the cylindrical specimen, (ii) measurement of straightness and parallelism of the cylindrical surface parallel to its axis [Calibration Guide, EURAMET/cg-06/v.01, 2007]

Operators for diameter Measurement (ISO–17450)

Construction-

▸ The profiles of the diameter and faces of the reference GB is extracted using two LVDT displacement sensors.

▸ Asymmetric datum is constructed from the coordinates of these profiles. The displacement of translation is read perpendicular to the constructed datum.

▸ The laser beam of displacement measuring interferometer is set coaxial to the constructed datum line [Meas. Sci. Technol. 8 (1997) 849–856.]. Consequently, the kinematics of the experiment is aligned referring to this datum.

Operators for diameter Measurement (ISO–17450)

Reconstruction –

▸ Usually, the coordinate data is registered by considering their root mean square of residue.

▸ The consolidated discrepancy has been accounted for the uncertainty estimation.

Reduction –

▸ A spindle axis serves as a datum for the roundness measurements.

▸ On the contrary, the diameter does not need a datum.

▸ However, the fusion-based diameter measurement needs a center to construct a reference circle

Digital Twins

▸ GPS for automative, manufacturing
▸ Digital twins for
  ◦ Management of measurement process
  ◦ Optimization of conformity
  ◦ Different applications

▸ Metrological Loop
  ◦ Datum
  ◦ Kinematics –
    • Orientation – Abbe
    • Situational – Bryan
  ◦ Kinetics
    • Contact force
▸ Simulation – Not unique

Measuring Equipment

ISO 14253-2:2011, (GPS) — Inspection by measurement of workpieces and measuring equipment —

- Decision rules for verifying conformity or nonconformity with specifications

- Guidance for the estimation of uncertainty in GPS measurement, in calibration of measuring equipment and in product verification

ISO 10012:2003- Measurement management systems — Requirements for measurement processes and measuring equipment

▸ Statics – ISO 3534, ISO 2602, , ISO 2854, ISO 5479, ISO 5725, ISO 7870

▸ ISO 10017:2021Quality management — Guidance on statistical techniques for ISO 9001:2015

Conclusion

▸ A uniform Matrix for definitions
  ◦ VIM- Based
    · Parameters as per IS 1101
      · Deviation in Diameter
      · Cylindricity – Straightness , Roundness
    · Uncertainty of measurement – model equation
      · Matrix of coefficients and input data

▸ Results in the digital certificates
  ◦ Metrological Traceability
  ◦ Measured value , Associated uncertainty
  ◦ Conformity statements –
    · Qualifiers – CMC based , tolerance based

THANK YOU

HAVE A GOOD DAY

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Back to "Table of Contents" above

Day2 (2025-02-26 Wednesday)
       Parallel Session "Industry Applications"
       (Chair: Carlos Galvan)

016   Instructions for using the DCC scheme to create a digital calibration certificate for gauge blocks

Presenting author: Christian Sander; Testo Calibration Services GmbH
Email:
Additional authors: Katharina Janzen [1], Guido Bartl [1], Daniel Heißelmann [1], Ralf Liske [2]
[1] Physikalisch-Technische Bundesanstalt (PTB)
[2] L & W GmbH

Abstract

Introduction

In the course of digitization in metrology, the Physikalisch-Technische Bundesanstalt (PTB) developed the digital calibration certificate (DCC), which enables the reporting of calibration results for all measurands in a machine-interpretable format and meets the requirements of DIN EN ISO/IEC 17025:2018 for the reporting of results. For this purpose, an XML schema definition (XSD) was created, which specifies the data types and structure of an XML document. The developed XSD schema offers flexible and diver se solutions for presenting

the results for each individual measured variable, provided they are reported in a schema-compliant XML document. Within each metrology community, the uniform use of terminology for the communication of measurement results is also essential, which is why the universally defi ned XML elements must be supplemented with human- and machine-interpretable information. This additional information must be individually coordinated in each community to ensure the interpretability of the data exchange. For this reason, a good practice example (GP) for a DCC for gauge blocks was developed within the framework of the DKD Technical Committee on Length in cooperation with PTB, which is presented in this expert report.

The developed and presented DCC is based on schema version 3.3.0. As the schema definition is subject to continuous further development, this presentation represents the status of the discussion at the time of publication.

Calibration object

Gauge blocks (e.g. according to EN ISO 3650:1998) made of steel, ceramic or carbide are cuboid blocks with two parallel functional surfaces with very high surface quality and accuracy (distance, parallelism, flatness). Gauge blocks can be assembled to different lengths, which is referred to as 'wringing'. In practice, gauge blocks are used as individual items or in the form of ready-made sets of individual gauge blocks with specific increments of the nominal size (e.g. 125-piece set). A set can contain several gauge blocks of the same nominal size and different materials.

Objective

The use of the machine-readable DCC eliminates the error-prone manual transfer of the determined calibration results, such as the centre dimension or the deviation of the centre dimension from the nominal dimension, on the user side when using gauge block sets for metrological purposes. To avoid interpretation errors between the generating and processing systems of the DCC, a uniform representation of the usable data in DCC format is desirable. For the example of gauge block sets, a solution is presented in this report as "good practice".

Presentation of Christian Sander

Physikalisch-Technische Bundesanstalt
Braunschweig und Berlin
Nationales Metrologieinstitut

DKD

A good practice example applying the
DCC schema in gauge block calibrations

Katharina Janzen [1], Guido Bartl [1], Daniel Heißelmann [1], Ralf Liske [2], Christian Sander [3]

[1] Physikalisch-Technische Bundesanstalt (PTB)
[2] L & W GmbH
[3] Testo Calibration Services GmbH

Introduction

PTB

DKD – German Calibration Service – a forum of PTB

- More than 400 calibration laboratories
- Goal: promote uniformity in metrology
- 13 technical committees
  - Implementation of good practice examples of DCCs
  - Standardized DCCs for various device types
- First DCC of TC Length → calibration of gauge blocks (https://doi.org/10.7795/550.20250131)

Physikalisch-Technische Bundesanstalt

DKD

| Expertenbericht DKD-E 4-3 | Anleitung zur Nutzung des DCC-Schemas für die Erstellung eines digitalen Kalibrierscheins für Parallelendmaße |

Ausgabe 12/2024
https://doi.org/10.7795/550.20250131

DCC

2024-04-16   2

Introduction

Gauge blocks (ISO 3650:1998)

- cuboid blocks with two parallel functional surfaces to transfer the length quantity
- Used as reference standards for dimensional calibrations in industry
- Can be joined/wrung with low uncertainties
- Sets of blocks with various nominal lengths
  - Made of steel, ceramics or carbides
  - Available in different grades/accuracy classes
  - Identification of individual block by marking

Introduction

Gauge block calibration

- Functional tests
  - Visual inspection
  - Wringability
- Dimensional calibration
  - a) central length l_c or
  - b) deviation of central length l_c from nominal length l_n
  - Optional: deviation span f_o and f_u
- Method: VDI/VDE/DGQ 2618 3.1:2004-01

DCC GP gauge blocks

Structure of DCC with focus elements

dcc:dccSoftware
dcc:refTypeDefinitions
dcc:coreData
dcc:items
dcc:calibrationLaboratory
dcc:respPerson
dcc:customer
dcc:statements

dcc:administrativeData

DCC GP gauge blocks

dcc:measurementResult
refType ="length_visualInspection"

dcc:measurementResult
refType ="length_wringability"

dcc:measurementResult
refType="length_dimensionalResults"

dcc:measurementresults

2024-04-16   5

DCC GP gauge blocks

dcc:items structure

```
dcc:items
    dcc:item refType="length_gaugeBlockSet" id=" setOfItems"
        dcc:subItems
            dcc:item refType="length_gaugeBlock" id="Item_1"
            dcc:item refType="length_gaugeBlock" id="Item_2"
        /dcc:subItems
    /dcc:item
/dcc:items
```


60 mm   70 mm

dcc:identifications
dcc:itemQuantities

dcc:items

dcc:item (gauge block set)
refType ="length_gaugeBlockSet"
id="setOfItems"

dcc:subitems

dcc:item (gauge block 60 mm)
refType ="length_gaugeBlock"
id="Item_1"

dcc:item (gauge block 70 mm)
refType ="length_gaugeBlock"
id="Item_2"

2024-04-16   6

DCC GP gauge blocks

dcc:items structure

```
dcc:items
    dcc:item refType="length_gaugeBlockSet" id=" setOfItems"
        dcc:subItems
            dcc:item refType="length_gaugeBlock" id="Item_1"
            dcc:item refType="length_gaugeBlock" id="Item_2"
        /dcc:subItems
    /dcc:item
/dcc:items
```

DCC schema 3.3.0 enables a structred representation of set of calibration objects

2024-04-16   7

DCC GP gauge blocks

dcc:identifications of the set of gauge blocks

▪ Information for identifying the complete set of gauge blocks

2024-04-16   8

DCC GP gauge blocks

dcc:itemQuantities of the set of gauge blocks
▪ Properties valid to the complete set of gauge blocks


```
<dcc:itemQuantities>
    <dcc:itemQuantity refType="length_accuracyClass">
        <dcc:name>
            <dcc:charsXMLList>1</dcc:charsXMLList>
    </dcc:itemQuantity>
```

2024-04-16   9

DCC GP gauge blocks

dcc:itemQuantities of the set of gauge blocks
▪ Properties valid to the complete set of gauge blocks


```
<dcc:itemQuantity refType="length_linearThermalExpansionCoefficient">
    <dcc:name>
    <dcc:description>
    <si:real>
        <si:value>11.5e-6</si:value>
        <si:unit>\kelvin\tothe{-1}</si:unit>
        <si:measurementUncertaintyUnivariate>
            <si:expandedMU>
                <si:valueExpandedMU>0.6e-6</si:valueExpandedMU>
                <si:coverageFactor>2</si:coverageFactor>
                <si:coverageProbability>0.95</si:coverageProbability>
            </si:expandedMU>
        </si:measurementUncertaintyUnivariate>
    </si:real>
</dcc:itemQuantity>
```

2024-04-16   10

DCC GP gauge blocks

dcc:itemQuantities of the set of gauge blocks

- Properties valid to the complete set of gauge blocks


```
<dcc:itemQuantity refType="length_material">
    <dcc:name>
        <dcc:noQuantity>
            <dcc:content lang="de">Stahl</dcc:content>
            <dcc:content lang="en">Steel</dcc:content>
        </dcc:noQuantity>
    </dcc:name>
</dcc:itemQuantity>
```

2024-04-16   11

DCC GP gauge blocks

dcc:item (individual gauge block in the set)

- Properties valid to idividual gauge blocks

DCC GP gauge blocks

dcc:item (individual gauge block in the set)
- Properties valid to ididual gauge blocks

dcc:identification refType="basic_basicmarking"
dcc:issuer   manufacturer

dcc:item (gauge block 60 mm)
refType ="length_gaugeBlock"
id="Item_1"

dcc:identifications

```
<dcc:identification refType="basic_marking">
    <dcc:issuer>manufacturer</dcc:issuer>
    <dcc:value>{MarkingOnGaugeBlock}</dcc:value>
    <dcc:name>
        <dcc:content lang="de">Markierung auf Parallelendmaß</dcc:content>
        <dcc:content lang="en">Marking on gauge block</dcc:content>
    </dcc:name>
</dcc:identification>
```

dcc:item gauge block set
refType ="length_gaugeBlockSet" id="setOfItems"

dcc:items

dcc:subitems

dcc:item refType ="length_gaugeBlock"
id="Item_1"
(gaugeblock 60 mm)

refType ="length_gaugeBlock" id="Item_2"
(dcc:item gaugeblock 70 mm)

DCC

DCC GP gauge blocks

dcc:item (individual gauge block in the set)
- Properties valid to ididual gauge blocks

```
<dcc:itemQuantity refType="length_nominalLength">
    <dcc:name>
    <si:real>
        <si:value>60e-3</si:value>
        <si:unit>\metre</si:unit>
    </si:real>
</dcc:itemQuantity>
```

dcc:identification refType="basic_basicmarking"
dcc:issuer   manufacturer

dcc:itemQuantity refType ="length_nominalLength"

dcc:identifications
dcc:itemQuantities

dcc:item gauge block set
refType ="length_gaugeBlockSet" id="setOfItems"

dcc:items

dcc:subitems

dcc:item refType ="length_gaugeBlock"
id="Item_1"
(gaugeblock 60 mm)

refType ="length_gaugeBlock" id="Item_2"
(dcc:item gaugeblock 70 mm)

DCC

DCC GP gauge blocks

Structure of DCC

dcc:dccSoftware
dcc:refTypeDefinitions
dcc:coreData
dcc:items
dcc:calibrationLaboratory
dcc:respPerson
dcc:customer
dcc:statements

dcc:administrativeData

DCC GP gauge blocks

dcc:measurementResult
refType ="length_visualInspection"

dcc:measurementResult
refType ="length_wringability"

dcc:measurementResult
refType="length_dimensionalResults"

dcc:measurementresults

2024-04-16   15

DCC GP gauge blocks

dcc:usedMethod

▪ Description of the test or calibration method

```xml
<dcc:usedMethods>
    <dcc:usedMethod refType="length_inspectionMethod">
        <dcc:name>
            <dcc:content lang="de">Die Anschubprüfung erfolgt mit einem geeigneten Planglas</dcc:content>
            <dcc:content lang="en">For the wringing test an appropriate plane face glass is used.</dcc:content>
        </dcc:name>
        <dcc:norm>VDI/VDE/DGQ 2618 Blatt 3.1:2004-01</dcc:norm>
    </dcc:usedMethod>
</dcc:usedMethods>
```

dcc:usedMethod refType="length_inspectionMethod"

dcc:measurementResult
refType ="length_wringability"

dcc:measuringEquipments

dcc:results

dcc:result refId="setOfItems"

2024-04-16   16

DCC GP gauge blocks

dcc:measuringEquipments

- Applied reference standards (optical flat)

```xml
<dcc:measuringEquipment>
    <dcc:name>
    <dcc:certificate>
        <dcc:referral>
        <dcc:referralID>{CertificateNumber}</dcc:referralID>
        <dcc:procedure>analogue</dcc:procedure>
        <dcc:value>noValue</dcc:value>
    </dcc:certificate>
    <dcc:identifications>
        <dcc:identification refType="basic_identificationNumber">
    </dcc:identifications>
</dcc:measuringEquipment>
```

dcc:measurementResult refType ="length_wringability"

dcc:measuringEquipments

dcc:results

dcc:result refId="setOfItems"

2024-04-16

17

DCC GP gauge blocks
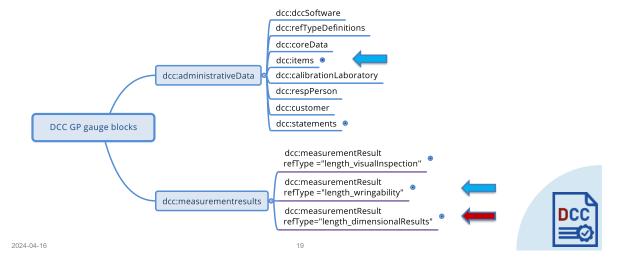
dcc:results (for functional test - wringability)

```xml
<dcc:result refId="setOfItems">
    <dcc:name>
    <dcc:data>
        <dcc:quantity>
            <dcc:name>
            <si:real>
                <si:value>1</si:value>
                <si:unit>\one</si:unit>
            </si:real>
            <dcc:measurementMetaData>
                <dcc:metaData>
                <dcc:declaration>
                    <dcc:content lang="de">Wert=1:Anschiebbarkeit in Ordnung; Wert=0:Anschiebbarkeit nicht in Ordnung</dcc:content>
                    <dcc:content lang="en">Value=1: Wringability is o.k.; Value=0: Wringability is not o.k.</dcc:content>
                </dcc:declaration>
                </dcc:metaData>
            </dcc:measurementMetaData>
        </dcc:quantity>
    </dcc:data>
</dcc:result>
```

:-(Boolean quantity types urgently needed

dcc:measurementResult refType ="length_wringability"

dcc:measuringEquipments

dcc:results

dcc:result refId="setOfItems"

2024-04-16

18

DCC GP gauge blocks

Structure of DCC

DCC GP gauge blocks

dcc:results

- Dimensional calibration results

DCC GP gauge blocks

dcc:results

- Dimensional calibration results

```
<dcc:quantity refType="length_centralLength">
    <dcc:name>
    <si:real>
        <si:value>0.06000014</si:value>
        <si:unit>\metre</si:unit>
        <si:measurementUncertaintyUnivariate>
            <si:expandedMU>
                <si:valueExpandedMU>0.136e-06</si:valueExpandedMU>
                <si:coverageFactor>2</si:coverageFactor>
                <si:coverageProbability>0.95</si:coverageProbability>
            </si:expandedMU>
        </si:measurementUncertaintyUnivariate>
    </si:real>
</dcc:quantity>
```

dcc:quantity refType="length_centralLength"
dcc:quantity refType="length_deviationFromNominalLength"
dcc:quantity refType="length_upperDeviationFo"
dcc:result refId="Item_1"
dcc:quantity refType="length_lowerDeviationFu"
dcc:quantity refType="lenght_accuracyClass" ● dcc:metaData refType="basic_conformity"

dcc:results

dcc:result refId="Item_2"

dcc:result refId="setOfItems"
dcc:quantity refType="length_accuracyClass" ● dcc:metaData refType="basic_conformity"

DCC GP gauge blocks

dcc:results

- Dimensional calibration results

```
<dcc:quantity refType="length_deviationFromNominalLength">
    <dcc:name>
    <si:real>
        <si:value>0.14e-06</si:value>
        <si:unit>\metre</si:unit>
        <si:measurementUncertaintyUnivariate>
            <si:expandedMU>
                <si:valueExpandedMU>0.136e-06</si:valueExpandedMU>
                <si:coverageFactor>2</si:coverageFactor>
                <si:coverageProbability>0.95</si:coverageProbability>
            </si:expandedMU>
        </si:measurementUncertaintyUnivariate>
    </si:real>
</dcc:quantity>
```

dcc:quantity refType="length_centralLength"
dcc:quantity refType="length_deviationFromNominalLength"
dcc:quantity refType="length_upperDeviationFo"
dcc:result refId="Item_1"
dcc:quantity refType="length_lowerDeviationFu"
dcc:quantity refType="lenght_accuracyClass" ● dcc:metaData refType="basic_conformity"

dcc:results

dcc:result refId="Item_2"

dcc:result refId="setOfItems"
dcc:quantity refType="length_accuracyClass" ● dcc:metaData refType="basic_conformity"

DCC GP gauge blocks

dcc:results

- Dimensional calibration results

```xml
<dcc:quantity refType="length_upperDeviationFo">
    <dcc:name>
    <si:real>
        <si:value>0.07e-06</si:value>
        <si:unit>\metre</si:unit>
        <si:measurementUncertaintyUnivariate>
            <si:expandedMU>
                <si:valueExpandedMU>0.07e-06</si:valueExpandedMU>
                <si:coverageFactor>2</si:coverageFactor>
                <si:coverageProbability>0.95</si:coverageProbability>
            </si:expandedMU>
        </si:measurementUncertaintyUnivariate>
    </si:real>
</dcc:quantity>
```


DCC GP gauge blocks

dcc:results

- Dimensional calibration results

```xml
<dcc:quantity refType="length_accuracyClass">
    <dcc:name>
        <dcc:content lang="de">Genauigkeitsklasse</dcc:content>
        <dcc:content lang="en">Accuracy class</dcc:content>
    </dcc:name>
    <dcc:charsXMLList>1</dcc:charsXMLList>
    <dcc:measurementMetaData>
        <dcc:metaData refType="basic_conformity">
            <dcc:name>
                <dcc:content lang="de">Konformität</dcc:content>
                <dcc:content lang="en">Conformity</dcc:content>
            </dcc:name>
            <dcc:norm>DIN EN ISO 3650:1999</dcc:norm>
            <dcc:conformity>pass</dcc:conformity>
        </dcc:metaData>
    </dcc:measurementMetaData>
</dcc:quantity>
```

DCC GP gauge blocks

dcc:results

- Dimensional calibra
  results

```
<dcc:result refId="setOfItems">
    <dcc:name>
    <dcc:data>
        <dcc:quantity refType="length_accuracyClass">
            <dcc:name>
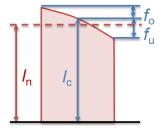            <dcc:charsXMLList>1</dcc:charsXMLList>
            <dcc:measurementMetaData>
                <dcc:metaData refType="basic_conformity">
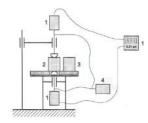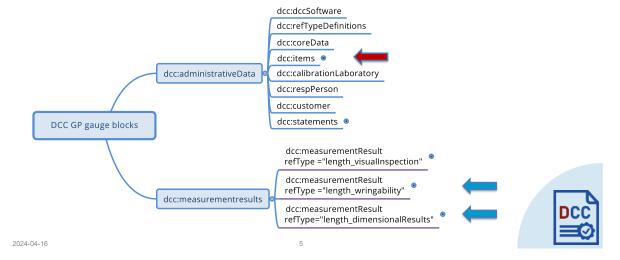                    <dcc:name>
                        <dcc:content lang="de">Konformität</dcc:content>
                        <dcc:content lang="en">Conformity</dcc:content>
                    </dcc:name>
                    <dcc:norm>DIN EN ISO 3650:1999</dcc:norm>
                    <dcc:conformity>pass</dcc:conformity>
                </dcc:metaData>
            </dcc:measurementMetaData>
        </dcc:quantity>
    </dcc:data>
</dcc:result>
```


dcc:result refId="Item_1"

dcc:results

dcc:result refId="Item_2"

dcc:result refId="setOfItems" — dcc:quantity refType="length_accuracyClass" — dcc:metaData refType="basic_conformity"

DCC GP gauge blocks

Summary

- Machine interpretable DCCs for gauge blocks can be implemented using schema 3.3.0 with specific refTypes and ids/refIds
- Sets of objects are well represented by dcc:item and dcc:subitems
- General structure is assumed to be easily adapted to other dimensional artefacts

- The schema 3.3.0 should be extended to boolean quantity types

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https://www.ptb.de/cms/de/metrologische-dienstleistungen/dkd.html
https://www.dkd.eu

017 Automation in calibration process using DCC, primary to secondary labs.

Presenting author: Aldo Adrián García González
Email:
Additional authors:

Abstract

This work shows how DCC can be implemented at acceleration primary laboratory to calibrate accelerometers that can be implemented directly to acceleration secondary labs. The solution uses excel sheets, python and LabView to generate results subscemes. The integration of all good practices allows to reduce calibration process.

The work also will show.
o Implemented method.
o Developed software.
o Results and future work.
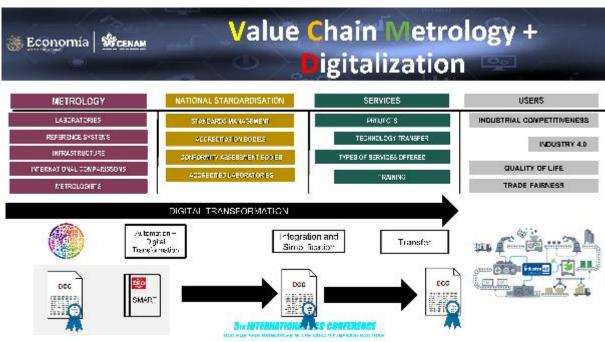
Presentation of Aldo Adrián García González

018   Semantic registration of DCC and DCoC onto Information Model of International Data Spaces

Presenting author: Tomasz Sołtysiński; Physikalisch-Technische Bundesanstalt (PTB), Abbestraße 2-12, D-10587 Berlin-Charlottenburg, Germany
Email:
Additional authors:

Abstract

Many processes in the quality infrastructure require the provision of a document of compliance or conformity with legal, contractual or regulated requirements. For digital quality infrastructure, these proofs need to be provided using digital communication protocols and connected data sources. Data spaces allow to comprise an ecosystem connecting different participants offering their assets, like resources, services and exchanging protocols with metadata and data. Focused on such applications, we discuss and demonstrate different scenarios allowing us to exchange specific protocols, like a digital certificate of conformity (D-CoC) or digital calibration certificate (DCC), as used for instance, in legal metrology.

To enable a semantic-driven flow of content carried by D-CoC and DCC within an ecosystem adhering to the principles of digital quality infrastructure, such as Quality-X, based on International Data Spaces (IDS), a unified and interoperable framework is essential. In this context, a new approach is proposed: registering the vocabulary embedded in certificates onto a semantic information model of the de facto standardized IDS. This ensures secure, traceable, and harmonized metadata exchange. Such a framework lays the foundation for efficient implementation of digital processes, including quality assurance through interlaboratory comparisons and round trials, as well as the validation of AI methods and software.

Combining our approach with specific standardized interfaces being operated by industry, like asset administration shell (AAS), the unified data communication protocol OPC UA and

the industrial digital twin association (IDTA), we discuss solutions paving the way towards effective, interoperable, automated, machine -readable pipelines shaping prospective digital quality infrastructure framework.

Presentation of Tomasz Sołtysiński

SEMANTIC REGISTRATION OF DCC AND D -CoC ONTO INFORMATION MODEL OF INTERNATIONAL DATA SPACES

Tomasz Sołtysiński

Metrology for digital transformation

Physikalisch -Technische Bundesanstalt
The National Metrology Institute

Agenda

1. **Information Model vs DCC**
2. **Information Model vs D-CoC**
3. **Semantics for DCC (temperature , pressure or mass)**
4. **Registration of DCC onto Informaton Model of IDS**
5. **Semantics for D-CoC (process monitoring)**
6. **Federated digital ecosystems to ensure trustworthy performance of processes by circulating the certificates**
7. **Integration with OPC UA & AAS**
8. **Summary and conclusions**

Process | Information model vs DCC

- **Semantics from DCC:**
  - DCC for temperature calibration
  - DCC for pressure calibration
  - DCC for mass calibration

```
<dcc:itemQuantities>

<dcc:itemQuantity refType="basic_nominalValue">
  <dcc:name>
   <dcc:content lang="en">Nominal
mass</dcc:content>
  </dcc:name>
 <si:real>
  <si:value>1</si:value>
  <si:unit>\kilogram</si:unit>
 </si:real>
 </dcc:itemQuantity>
</dcc:itemQuantities>
```

```
<dcc:measurementResults >
 <dcc:measurementResult refId="weight01 meas1">
  <dcc:name >
...</dcc:name >
  <dcc:usedMethods >
...</dcc:usedMethods >
  <dcc:results>
   <dcc:result refType="mass_mass">
    <dcc:name>
     <dcc:content lang="en">Result: weighted mean
         value</dcc:content>
    </dcc:name>
    <dcc:data>
     <dcc:quantity refType="basic_nominalValue ">
      <dcc:name>
       <dcc:content lang="en">nominal
         value</dcc:content>
      </dcc:name>
      <si:real>
       <si:value>1</si:value>
       <si:unit>\kilogram</si:unit>
      </si:real>
     </dcc:quantity>
     <dcc:quantity refType="basic_measuredValue">
      <dcc:name>
       <dcc:content lang="en">mass</dcc:content>
      </dcc:name>
      <si:real>
       <si:value>1.000467</si:value>
       <si:unit>\kilogram</si:unit>
       <si:expandedUnc >
        <si:uncertainty>0.000024</si:uncertainty>
        <si:coverageFactor >2</si:coverageFactor >
        <si:coverageProbability >0.95</si:coverageProbability >
       </si:expandedUnc >
      </si:real>
     </dcc:quantity>
    </dcc:data>
   </dcc:result>
  </dcc:results>
 </dcc:measurementResult >
</dcc:measurementResults >
```

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Process | Information model vs D-CoC

Umgebungsbedingungen und Einflussgrößen:
Environmental conditions and influence factors:

Temperaturbereich *Temperature range*		-10 °C / +40 °C
Feuchtigkeit *Humidity*		bis 85 % bei 40 °C, nicht betauend *up to 85 % at 40 °C, not condensing*
Mechanisch *Mechanical*		Nicht anwendbar *Not applicable*
Elektromagnetisch *Electromagnetic*		E2 (gemäß OIML D11) *E2 (according to OIML D11)*

Genauigkeitsklasse: 2,0
Durchflussbereich: Praxisgerecht innerhalb des Durchflussbereichs des Messwertaufnehmers

Kleinste Messmenge: 1 kg
Maximaler Gasdruck: 875 bar
Minimaler Gasdruck: 50
Umgebungsbedingungen/Einflussgrößen:
  klimatisch: -25°C bis 55°C (betauend)
  mechanisch: M2
  elektromagnetisch: E1
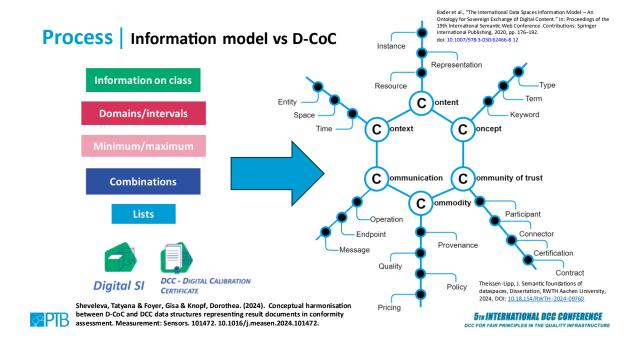
Débit permanent Q3 (m³/h) **Q3 Permanent flowrate (m³/h)**	1,6	2,5
Débit de surcharge Q4 (m³/h) **Q4 Overload flowrate (m³/h)**	2,0	3,125

Information on class

Domains/intervals

Minimum/maximum

Combinations

Lists

Digital SI

DCC - DIGITAL CALIBRATION CERTIFICATE

Sheveleva, Tatyana & Foyer, Gisa & Knopf, Dorothea
d-coc@ptb.de

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DCC FOR FAIR PRINCIPLES IN THE QUALITY INFRASTRUCTURE

Process | Information model vs D-CoC

Information on class

Domains/intervals

Minimum/maximum

Combinations

Lists

Digital SI

DCC - DIGITAL CALIBRATION CERTIFICATE

Bader et al., "The International Data Spaces Information Model – An Ontology for Sovereign Exchange of Digital Content." In: Proceedings of the 19th International Semantic Web Conference. Contributions: Springer International Publishing, 2020, pp. 176–192. doi: 10.1007/978-3-030-62466-8 12

Instance

Representation

Resource

Type

Content

Term

Keyword

Entity

Concept

Space

Context

Time

Communication

Community of trust

Operation

Participant

Endpoint

Connector

Message

Provenance

Certification

Quality

Contract

Policy

Pricing

Commodity

Theissen-Lipp, J. Semantic foundations of dataspaces, Dissertation, RWTH Aachen University, 2024, DOI: 10.18,154/RWTH -2024-09760

Sheveleva, Tatyana & Foyer, Gisa & Knopf, Dorothea. (2024). Conceptual harmonisation between D-CoC and DCC data structures representing result documents in conformity assessment. Measurement: Sensors. 101472. 10.1016/j.measen.2024.101472.

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DCC FOR FAIR PRINCIPLES IN THE QUALITY INFRASTRUCTURE

Semantics for DCC | Pressure, temperature, mass

Semantics
Application of specific ontology

| Ontology for pressure | Vocabulary for pressure |

| Ontology for temperature | Vocabulary for temperature |

| Ontology for mass | Vocabulary for mass |

Process driven with Digital Calibration Certificate (DCC)

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DCC FOR FAIR PRINCIPLES IN THE QUALITY INFRASTRUCTURE

Semantics for DCC | Registration of DCC onto Informaton Model of IDS

- **Registration of semantics into/onto domain-agnostic information model of IDS:**
  classes, objects, values
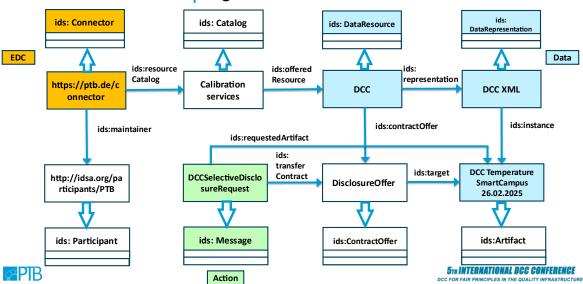
- **DCC and D-CoC as metadata protocol (no connectors needed for a process driven with credentials)**

- **One information model = one process cycle (full process flow)**

- **DCC and D-CoC as a specific protocol for exchange of metadata along the process**

- **Harmonized (meta)data model to be adopted to DX, DCR, DCA**
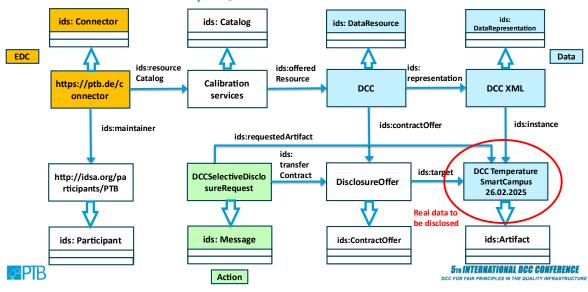
PTB

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Semantics for DCC | Registration of DCC onto Information Model of IDS
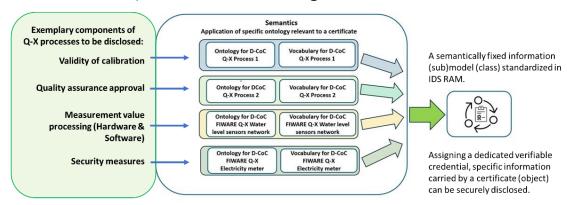
Semantics for DCC | Registration of DCC onto Informaton Model of IDS
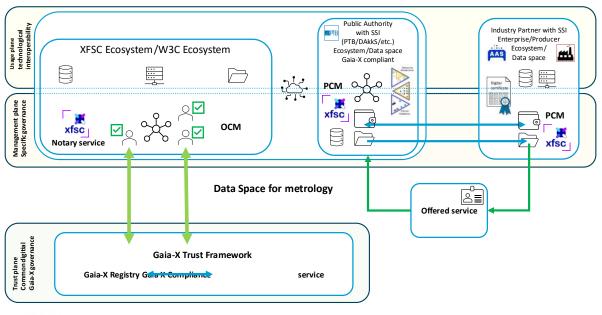
Semantics for D-CoC | Semantics-driven exchange and disclosure of certificates
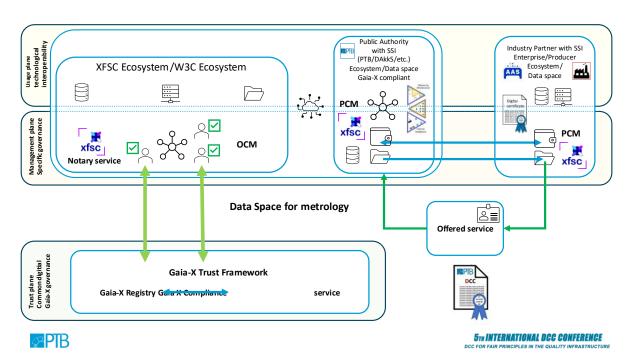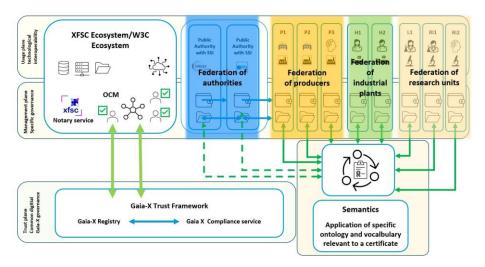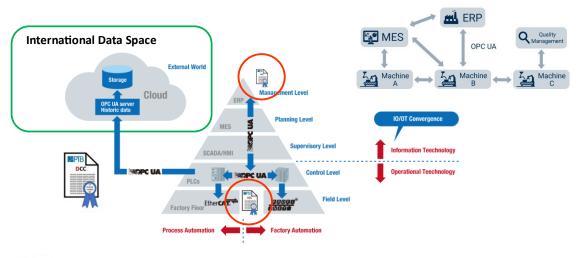
Federated digital ecosystems | Performance of processes by circulating the certificates

OPC UA & AAS | Integration of DCC and D-CoC with information model of OPC UA

OPC UA & AAS | Integration of DCC and D-CoC with information model of OPC UA

OPC UA & AAS | Integration of DCC and D-CoC with information model of OPC UA
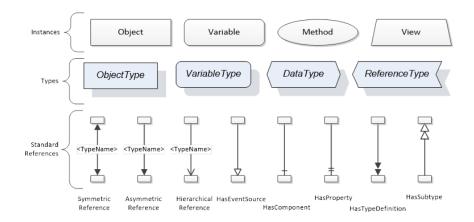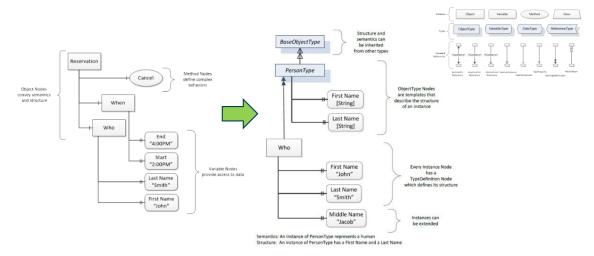
DCC in trusted QI │ **Summary and discussions**

Constructed scenario:
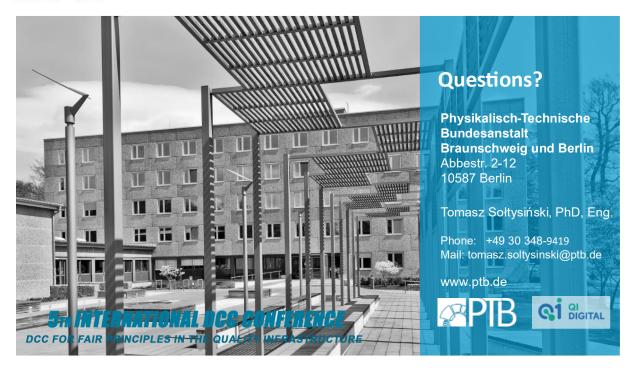
- demonstrates how **selective disclosure of** confidential data contained in a **DCC, DCoC, or DPP** can be automatically and interoperable accessed using standardized information model of IDS

- such a protocol can be used, for example, to extract and publish information on **metrological traceability** of specific measurements, including their uncertainties performed across a chain of calibrations

- the protocol facilitates the **exchange of metadata, data, and certificates** related to, for instance, the calibration of weighting scales

- is directly applicable across industrial interfaces like **OPC UA** and **AAS**

- provides a framework for communication between **stakeholders** (such as **legal or accrediting authority, companies, warehouses, and calibration laboratories**) across different participants of data space

- can be successfully achieved if the proposed protocols operate within the European Metrology Cloud and its ecosystem, **adhering to the rules of international data spaces**.

Thank you very much for your attention!

Physikalisch-Technische Bundesanstalt
Bundesallee 100

5TH INTERNATIONAL DCC CONFERENCE
DCC FOR FAIR PRINCIPLES IN THE QUALITY INFRASTRUCTURE

019   DCC in a Mass Calibration Software

Presenting author: Lisa Busser, Keysight Technologies Deutschland GmbH
Email: lisa.busser@maro.de
Additional authors:

Abstract

ScalesNet is an already existing and well-known Software in mass metrology. As such a stakeholder the developing team of ScalesNet has been asked to be the industrial partner of PTB with the goal of embedding the DCC in an already existing software.

This presentation includes a short demonstration of the already existing possibilities to generate a DCC automatically with results of a real measurement that validates against the schema of PTP. On top of that, the current state of development regarding the import of the data out of the DCC and into the software will be shown. Finally, two suggestions for changing the schema will be made. These proposals aim to facilitate repeatability of development for other software developers and to improve the interoperability of DCCs from different software vendors. In addition, it is particularly important to be able to make the import of data from the DCC back into software as automated as possible. The general data fields into which continuous text is inserted are particularly problematic here. Because different spellings of a company name or address are not automatically recognized as the same by software. This lecture promotes a suggestion as to how these text fields can be handled in the import to make importing possible with as little intervention as possible, without having to resort to a globally central database or having many duplicates of the same entry in your own database.

Presentation of Lisa Busser

DCC IN A MASS-CALLIBRATION SOFTWARE

Lisa Busser, MARO Elektronik
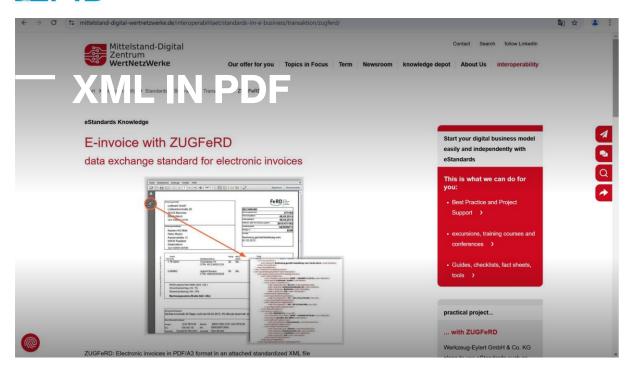
Disclaimer

- Close partnership with PTB
- DCC checked by PTB

Physikalisch-Technische Bundesanstalt
Braunschweig und Berlin
Nationales Metrologieinstitut
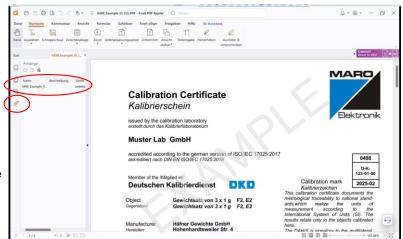
XML in PDF

Foxit PDF Reader

Collection form with
any number of
attachments possible

XML in PDF

Visual Studio Code

XML in PDF

Visual Studio Code

XML in PDF – Digital Signature

- Accreditation Symbol is applicable

- Sign PDF digitally Sis easy

- XML is an attachment to PDF and is therefore automatically signed when the PDF is signed

XML in PDF – Digital Signature

- Accreditation Symbol is applicable
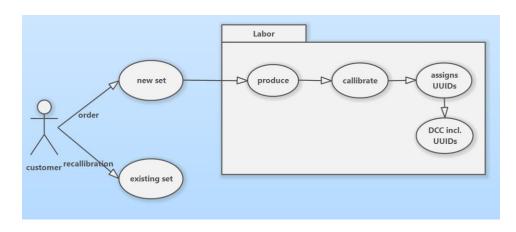
- Sign PDF digitally is easy

- XML is an attachment to PDF and is therefore automatically signed when the PDF is signed
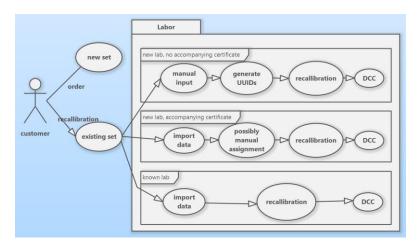
The total size of the file is significantly smaller!

UUID (<u>U</u>NIVERSALLY <u>U</u>NIQUE <u>ID</u>ENTIFIER)

UUID (<u>U</u>NIVERSALLY <u>U</u>NIQUE <u>ID</u>ENTIFIER)

— UUID (<u>U</u>niversally <u>U</u>nique <u>I</u>dentifier)

- Is the UUID really unique?
  - 128 Bit „number" = 2^{128} possibilities
- Crossreference-Table
  (to handle multiple UUIDs of the same object)
- Risc of duplications negligible
  (MAC-Adress, system time)
- Different ways to generate UUIDs

— Contact

	Lisa Busser
@	lisa.busser@maro.de
☎	+49 671 83999-15
🖥	https://www.maro.de/

020 Progress Towards Producing DCC with Standard Structured Measurand Information

Presenting author: Jens Leinhos
Email:
Additional authors: Mark Kuster, Colin Walker, Mike Schwartz, and Jonathan Harben

Abstract

Advances in machine-actionable information and data for the quality infrastructure require further exploration. This includes the implementation of Digital Calibration Certificates (DCC)

by producing real-world measuring instrument examples to investigate potential use cases with consumers. The integration of units and quantity information from three primary sources — ISO 80000 quantities and units, DCC Reference Types, and NCSLI measurand taxonomy will be examined. The study will review the progress made so far and identify any gaps, outlining goals for future work. This investigation aims to provide a foundation for further research and development in the field.

Day 2 (2025-02-26 Wednesday)
Parallel Session "Applications NMI II"
(Chair: Jariya Buajarern)

021 Digital Calibration Certificates for Radioactivity and FAIR Data Exchange

Presenting author: Henrike Fleischhack
Email: henrike.fleischhack@ptb.de
Additional authors: Stefan Röttger stefan.roettger@ptb.de, Matthias Oliver Stein matthias.stein@ptb.de (PTB)

Abstract

The future is digital: Our increasingly interconnected world requires fast, accurate exchange of data and information. DCCs (digital, machine-interpretable calibration certificates) will play a large role in digitalizing our quality infrastructure, allowing for automated, streamlined communication between calibration laboratories, research institutes, and manufacturing facilities. Simultaneously, the scientific community needs machine-interpretable data formats to support the exchange of complex datasets and measurement results.

In this contribution, we present work towards implementing DCCs for radioactivity and related calibration quantities, following the XML -DCC pioneered by PTB. Calibration certificates must describe the calibration item (activity standard) in terms of its size, shape, and isotope composition, as well as the calibration quantities such as activity, activity concentration or uniformity. We will also discuss a proposed data exchange format based on the DCC schema that allows the addition of raw data such as count rates or gamma-ray spectra, and meta data such as observing times and experimental setup. This new data format will support the sharing of datasets following the FAIR principles (findable, accessible, interoperable, reusable), in particular improving the aspects of interoperability and reusability over existing data formats.

Presentation of Henrike Fleischhack

Physikalisch-Technische Bundesanstalt
Braunschweig and Berlin
National Metrology Institute

DCC 4 ☢

Digital Calibration Certificates for radioactivity and FAIR data exchange

Henrike Fleischhack, Matthias Oliver Stein & Stefan Röttger
4th international DCC conference

Calibration Certificates in Radioactivity

What's next?

2025-02-26

2

DCC 4 ☢

Content
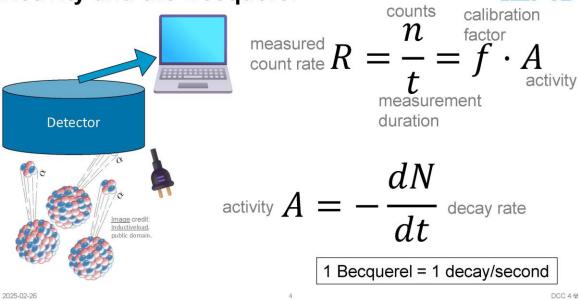
1. Introduction
   - Activity calibration -> DCC requirements
   - Existing formats for digital data exchange
2. Implementation of the DCC for activity standards
   - Nuclide nomenclature
   - Measurement results
3. Future extensions of the DCC format

Activity and the Becquerel

$$R = \frac{n}{t} = f \cdot A$$

measured count rate R counts n measurement duration t calibration factor f activity A

$$A = -\frac{dN}{dt}$$

activity   decay rate

Image credit: Inductiveload, public domain.

Detector

1 Becquerel = 1 decay/second

Radioactive Decay

Activity A(t)

$$A(t) = A_0 \cdot e^{-\lambda \cdot (t-t_0)} = A_0 \cdot \left(\frac{1}{2}\right)^{\frac{t-t_0}{T_{1/2}}}$$

$$\lambda = \frac{\ln(2)}{T_{1/2}}$$

Activity value is valid for a given reference time and nuclide.

nuclide B

nuclide A

Time $t - t_0$

Activity Standards

point sources

area sources

liquid solutions

gas

powders

Requirements of a DCC for radioactivity

Calibration item (one per DCC):

- Shape, size, macroscopic composition, …

Calibration results:

- Detected nuclides
- Activity, activity per mass/volume, activity ratio, uniformity, …
- Decision limit & limit of detection (for impurities).
- Associated with reference time and nuclide.
- Metadata: assumed half lives (with uncertainties); measurement methods.

Gegenstand: *Object:*	Aktivitätsnormal *Activity standard*
Typ: *Type:*	Wässrige Lösung in Glasampulle (AM05) *Aqueous solution in glass ampoule (AM05)*
Kenn-Nummer: *Serial number:*	AI-3231
Radionuklide: *Radionuclides:*	Mn-54, Co-57, Zn-65, Sr-85, Y-88, Ba-133, Cs-137 und Ce-139
Kalibrierverfahren: *Method of calibration:*	Die Aktivitäten der Radionuklide in der eingereichten Referenzlösung wurden durch Messung der Gamma-strahlung mit einem Halbleiterspektrometer im Zeit-raum vom 18. Januar 2017 bis 20. Januar 2017 bestimmt. Das Halbleiterspektrometer ist eine Sekundärnormal-Messeinrichtung, kalibriert mit Aktivitätsnormalen der PTB. *The activities of the radionuclides in the submitted reference solution were determined by measuring the gamma radiation in a semiconductor spectrometer in the period from 18 January 2017 to 20 January 2017. The semiconductor spectrometer is a secondary-standard measuring system calibrated by means of activity standards of PTB.*
Aktivität: *Activity:*	A (Mn-54) = (12,07 ± 0,14) kBq A (Co-57) = (6,26 ± 0,09) kBq A (Zn-65) = (30,2 ± 0,5) kBq A (Sr-85) = (32,10 ± 0,30) kBq A (Y-88) = (30,41 ± 0,20) kBq A (Ba-133) = (6,30 ± 0,05) kBq A (Cs-137) = (11,70 ± 0,17) kBq A (Ce-139) = (6,18 ± 0,04) kBq
Bezugszeitpunkt: *Reference date:*	1. Juli 2016, 13:00 Uhr MEZ *13:00 CET on 1 July 2016*

In the following table, the results are listed at the time of measurement, including the gamma emission energies E of the stated nuclides located in the selected regions.

Under the conditions stated above, contributions to the pulse-height spectra due to Fe-59, Rb-84 and Cs-134 were not recognised as being present.

Nuklid *Nuclide*	E/keV	A/Bq	A'/Bq	A⁸/Bq
Fe-59	1099,2	0 (6)	7	10
Rb-84	881,61	1 (6)	9	13
Cs-134	604,7	2 (6)	7	10

2025-02-26   7   DCC 4 ⚛

IEEE/ANSI N42.42 format

https://www.nist.gov/pml/radiation-physics/ansiieee-n4242-2020-version

"American National Standard Data Format for Radiation Detectors Used for Homeland Security"

- XML-based, with schema.
- Contains information on detectors, raw data & measurement results.
- Lacking in metrology information (e.g. units!)
- Partially extensible - specific format for specific use case.

```xml
<NuclideAnalysisResults>
    <Nuclide>
        <NuclideIdentifiedIndicator>true</NuclideIdentifiedIndicator>
        <NuclideName>Cs-137</NuclideName>
        <NuclideIDConfidenceValue>0.99</NuclideIDConfidenceValue>
        <NuclideActivityValue>804.5<NuclideActivityValue>
        <NuclideActivityUncertaintyValue>0.5<NuclideActivityUncertaintyValue>
    </Nuclide>
</NuclideAnalysisResults>
```

2025-02-26   8   DCC 4 ⚛

BIPM-KC format

"Machine-readable data and metadata of international key comparisons in radionuclide metrology" (Coulon et al, https://doi.org/10.1088/1361-6501/accd0b, Michotte et al, https://doi.org/10.1088/0026-1394/61/1A/06005)

- xml or json embedded in pdf.

- Supports metrology information (e.g., D-SI).

- Description of radioactive solution (InChi, SMILES)

- Currently only supports single-nuclide measurements.

- Under development.

```
<kc:measurement>
    <kc:referenceDate>2019-08-22T12:00:00Z</kc:referenceDate>
    <kc:solutionID>Tb-161IRA2019-1</kc:solutionID>
    <kc:methodID>4P-PS-BP-CB-GR-CO</kc:methodID>
    <kc:description>4pi (PS) beta-gamma coincidence</kc:description>
    <kc:activity>
        <kc:measurementResult>
            <dsi:value>61970</dsi:value>
            <dsi:unit>\kilo\becquerel</dsi:unit>
            <dsi:expandedUnc>
                <dsi:uncertainty>0.582</dsi:uncertainty>
                <dsi:coverageFactor>1</dsi:coverageFactor>
                <dsi:coverageProbability>0.68</dsi:coverageProbability>
            </dsi:expandedUnc>
        </kc:measurementResult>
        <kc:relStdUncertTypeA>0.16</kc:relStdUncertTypeA>
        <kc:relStdUncertTypeB>0.56</kc:relStdUncertTypeB>
    </kc:activity>
</kc:measurement>
```

Towards a DCC for radioactivity
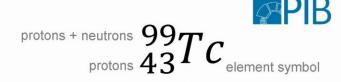
- (PTB-)DCC: Flexible, powerful data format.
- Interoperability with other branches of metrology/QI.
- Mandated by PTB (as alternative to paper/pdf).

- Requires community conventions/good practices:

  - Nuclides.

  - Measurement results & quantities.

  - Calibration item.

Nuclide definition

protons + neutrons
$$^{99}_{43}Tc$$
protons — element symbol

- Isotope: defined by number of protons & number of neutrons:
  Tc-99, 99Tc, ^{99}Tc, (Z=43, N=56), (Z=43, A=99), …
- Some isotopes have several (metastable) isomers: Tc-99 vs Tc-99m
- Approaches for machine-readable nuclide ID:
  - Pick one format, e.g. Tc-99(m)
  - Refer to online database.
  - **Fully define nuclear state (quantum numbers) in DCC.**

2025-02-26   11   DCC 4 ☢

Suggestion: Nuclide definition

http://www.lnhb.fr/accueil/
donnees-nucleaires/module-lara/

#	Jp	En [keV]
2	1/2-	142.6836
1	7/2+	140.5110
0	9/2+	0

$$^{99}_{43}Tc_{56}$$

https://www.nds.iaea.org/relnsd/
vcharthtml/VChartHTML.html

- Nuclides defined in <dcc:statement>
  - InChI (isotope)
  - J^P quantum numbers (isomer)
- Specify nuclear data, e.g. half life.
- Reference via id/refId.

12

Suggestion: Activity measurements

```
<dcc:result refId="Na-22">
    <dcc:name>
        <dcc:content lang="de">Aktivität von Na-
        22</dcc:content>
        <dcc:content lang="en">activity of Na-22</dcc:content>
    </dcc:name>
    <dcc:data>
        <dcc:quantity refType="basic_measuredValue
        rad_activity" refId="Na-22">
            <si:real>
                <si:value>2.52</si:value>
                <si:unit>\mega\becquerel</si:unit>
                <si:dateTime>2022-08-01T13:00:00</si:dateTime>
                <si:expandedUnc>
                    <si:uncertainty>0.06</si:uncertainty>
                    <si:coverageFactor>2</si:coverageFactor>
                    <si:coverageProbability>0.95
                    </si:coverageProbability>
                </si:expandedUnc>
            </si:real>
        </dcc:quantity>
    </dcc:data>
</dcc:result>
```

Activity (Bq):
- <dcc:result> per nuclide.
- refType:
  - quantity (activity)
  - measured value vs limit of detection.
- refId: Nuclide
- Referenze time:
  - SI datetime?
  - Or metadata?

13

Status of DCC for Radioactivity

Available refTypes and good practice examples for common situations:
- Activity calibration with single nuclide and mixtures.
- Check for impurities.
- Comparison with customer-provided measurements.

In progress:
- Detailed description of calibration item.
- Area sources with uniformity measurements.
- Calibration solutions sold by weight.
- **Stylesheet to mimic look of current calibration certificates.**

2025-02-26

14

DCC 4 ✿

Extension: FAIR data exchange

- Data format for measurement results (e.g., spectra) and metadata.
- XML-based, compatible with DCC and D-SI.
- Use cases:
  - Digital validation of gamma-ray spectrometry software
  - Data exchange in research
  - Possible extension of DCCs (on request).
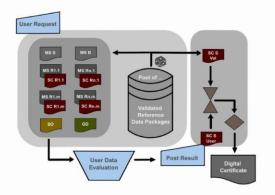
Image source: M.O. Stein, H.Fleischhack, S. Röttger: "TraGamma – A digital service for validating gamma-ray spectrometry analysis software", in: Measurement: Sensors 2024 (Proceedings of the IMEKO world congress 2024), 101471, in press, https://doi.org/10.1016/j.measen.2024.101471; licensed under CC-BY-NC-ND

2025-02-26   15   DCC 4

Thank you! Any questions?

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Henrike Fleischhack: henrike.fleischhack@ptb.de

022   Transport of DCC with cryptographic signature in PDF/A

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Keywords: DCC, PDF-A, Machine-readable, Digitalization, Cryptographic signatures, DCC transport

Abstract:

The DCC has been reported on in the context of many international conferences. The DCC format, which has been developed internationally with all parties involved (industry, laboratories, NMI, accreditors) under the coordination of PTB, is used and further developed by many. A comprehensive collection of quotations can be found in [1]. One question that has come up again and again over time is how DCC is transferred from the laboratory to the customer. Several methods have emerged, which have one thing in common: the DCC must be passed on with integrity and authenticity. This can be solved by using cryptographic signatures. There will probably also be presentations from industry at this conference on this topic. In some cases, there are government restrictions on the selection of cryptographic methods. For example, in some countries the algorithms are specified, and some of them are not implemented in PDF/A. In other countries, such as Argentina, only PDF/A is allowed for sending cryptographically signed documents from the government. This presentation will discuss how the DCC XML file can be transported using the PDF-A transport container. It will also be discussed how the human-readable content should be handled, which can then be seen in the PDF-A. In this context, PDF-A should not be viewed as a machine-readable Calibration Certificate. It is only with the DCC-XML in the PDF-A container that this composite becomes machine-executable or even machine-interpretable. [1] [2].

References:

o [1] Hackel, Siegfried, et al., Digitization versus Digitalization & Digital Transformation in the field of calibrations and their subsequent use (2024). Physikalisch-Technische Bundesanstalt (PTB). Available at: https://doi.org/10.7795/120.20240126

o [2] D. N. Coppa, et al., "Software for the Creation of Machine-Readable and Human-Friendly Reports" in 3rd International DCC Conference 2023-02-28 to 2023-03-02 Proceedings, p.18, 2023. doi: 10.7795/810.20230331. Available at: https://oar.ptb.de/resources/show/10.7795/810.20230315

Presentation of Diego Coppa

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Transport of DCC with cryptographic signature in PDF/A

Authors: Diego Coppa (INTI), Siegfried Hackel (PTB), Hector Laiz (INTI)

February, Online, DCC Conference 2025
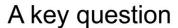
Initially

> Joint lecture by INTI and PTB
> Aim of presentation:
>   ▪ Demonstrating a way of DCC transport with PDF/A
> Background:
>   ▪ In some cases it is necessary to transport the DCC in this way

A key question

> The DCC has been created
> ISO/IEC 17025:
>   ▪ Transport from CalLab to Customer
> **How should that happen?**
> Many answers...
> ISO/IEC 17025 does not address signatures
>   ▪ What about integrity and authenticity?
> Cryptographic methods are necessary

What are the different types of signature?

➢ Signature on the document: inbound signature

➢ Signature on the envelope or transport container: outbound signature

Inbound vs. Outbound

Inbound:
➢ Each one is robust
➢ "DCC-Atom"

Outbound:
➢ Possibility to combine many documents
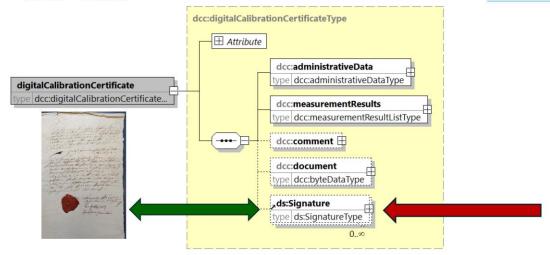
Inbound Signature

Outbound Signature

> Some examples:

PDF / A3

• • •
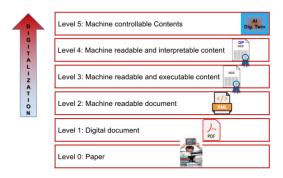
Outbound Signature with PDF / A3

PDF / A3

➢ Important:
- Digitization vs. Digitalization & Digital Transformation
- See https://doi.org/10.7795/120.20240126

D I G I T A L I Z A T I O N	Level 5: Machine controllable Contents — AI Dig. Twin
	Level 4: Machine readable and interpretable content — GP DCC
	Level 3: Machine readable and executable content — DCC
	Level 2: Machine readable document — XML
	Level 1: Digital document — PDF
	Level 0: Paper

Please note

PDF / A3

➢ Take care when creating human readable
- Also important for the human-readable in the fourth ring of the DCC
- Some reports are very extensive, e.g. in the high frequency

➢ What should be readable in PDF / A3 itself?
- Note regarding DCC in the container
- Any further information?

Diego

- Why? What? How?

- INTI's Traceability of documents

- Hashing Fundamentals: Uniqueness, Irreversibility, and Integrity

- PDF/A-3

- Authenticity and integrity for a disembeded XML

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Why? What? How?

Why does INTI have to ensure the traceability of an XML (DCC) without signing it?

INTI, Argentina's NMI, is only capable to sign Calibration Certificates in PDF/A-3. Since DCC-XML is digitally signed, its traceability must be ensured without direct signing.

What does INTI do to ensure traceability of XMLs that can be requested by machines or by human?

INTI links the XML to a traceable PDF/A-3 document.

What does INTI do to ensure traceability of XMLs that can be requested by machines or by human?

INTI links the XML to a traceable

PDF/A-3 document.

How does INTI link an XML to a PDF/A-3 and provide traceability to an XML?

INTI uses PDF/A-3 and HASH

properties to establish authenticity

and integrity of the XML file.

Name: MassDcCxMl.xml

HASH: SHA-256

HASH Value: 1f3a3732d1e9c5d9f 6f8bff07c9db8e56 c9f8e8c258d

INTI's Traceability of documents

INTI's Traceability of documents

MassDcCpDF.pdf

PDF/A-3

Digital signature

Non-repudiation and Authenticity Check

PKI

ADVANTAGES
- Authenticity
- Integrity
- Non-repudiation
- Increase of trust

DISADVANTAGES
- Different types
- Scope of validation

INTI's Traceability of documents

MassDcCpDF.pdf

PDF/A-3

Digital signature

Non-repudiation and Authenticity Check

PKI

ADVANTAGES
- Authenticity
- Integrity
- Non-repudiation
- Increase of trust

DISADVANTAGES
- Different types
- Scope of validation

CURRENT DOCUMENT CHECK

Name: MassDcCpDf.pdf
HASH: SHA-256
HASH Value:
1f3a3732d1e9c5d9f6f8bff07c9db8e
56c9f8e8c258d
Validation: YES

Not yet implemented at INTI!

ADVANTAGES
- Version Control
- Transparency: Hash verifiable by a Machine or by a Human
- Easy to implement through a web page
- File integrity verification

DISADVANTAGES
- Web page vulnerability
- False positives

INTI's Traceability of documents

Non-repudiation and Authenticity Check

MassDcCxML.xml

XML

Digital signature

PKI

ADVANTAGES
- Authenticity
- Integrity
- Non-repudiation
- Increase of trust

DISADVANTAGES
- Different types
- Scope of validation

CURRENT DOCUMENT CHECK

Name: MassDcCpDf.pdf
HASH: SHA-256
HASH Value:
1f3a3732d1e9c5d9f6f8bff07c9db8e56c9f8e8c258d
Validation: YES

Not yet implemented at INTI!

ADVANTAGES
- Version Control
- Transparency: Hash verifiable by a Machine or by a Human
- Easy to implement through a web page
- File integrity verification

DISADVANTAGES
- Web page vulnerability
- False positives

Hashing Fundamentals:
Uniqueness, Irreversibility, and Integrity

Unique Hash Generation
Random examples

HASH	+	FILE	+	FILE'S NAME	CALCULATE	UNIQUE HASH VALUE
SHA 256	+	XML	+	ThIsIsAnXmL.xml	→	1f3a3732d1e9c5d9f6f8bff0 7c9db8e56c9f8e8c258d5a 4b60c2d8d7a2f3f173
MD5	+	PDF/A-3	+	ThIsIsAnpDf.pdf	→	34f9j4kg9j49gje933jf03j0u 402jty0h4r9g9fjgf9dg9dg 4tj0r9e03tj09k23tj09yj0
MD5	+	Excel	+	ThIsIsAnXlsX.xlsx	→	4er475y5r324tytr57regerg e57e4te47564ter6e5urte4 5e4tye575e6

Hash Irreversibility

HASH	+	FILE	+	FILE'S NAME	CALCULATE	UNIQUE HASH VALUE
SHA 256	+	XML	+	ThIsIsAnXmL.xml	→	1f3a3732d1e9c5d9f6f8bff0 7c9db8e56c9f8e8c258d5a 4b60c2d8d7a2f3f173

Hash Irreversibility

HASH	+	FILE	+	FILE'S NAME	CALCULATE	UNIQUE HASH VALUE
SHA 256	+	XML	+	ThIsIsAnXmL.xml	→	1f3a3732d1e9c5d9f6f8bff0 7c9db8e56c9f8e8c258d5a 4b60c2d8d7a2f3f173

HASH	+ UNIQUE HASH VALUE +	FILE'S NAME	CAN'T REPRODUCE	FILE
SHA 256	+ 1f3a3732d1e9c5d 9f6f8bff07c9db8 e56c9f8e8c258d 5a4b60c2d8d7a2 f3f173	+ ThIsIsAnXmL.xml	→	✖ XML

Hash Irreversibility

HASH	+	FILE	+	FILE'S NAME	CALCULATE	UNIQUE HASH VALUE
SHA 256	+	XML	+	ThIsIsAnXmL.xml	→	1f3a3732d1e9c5d9f6f8bff0 7c9db8e56c9f8e8c258d5a 4b60c2d8d7a2f3f173

HASH	+ UNIQUE HASH VALUE +	FILE'S NAME	CAN'T REPRODUCE	FILE
SHA 256	+ 1f3a3732d1e9c5d 9f6f8bff07c9db8 e56c9f8e8c258d 5a4b60c2d8d7a2 f3f173	+ ThIsIsAnXmL.xml	→	✖ XML

HASH	+ UNIQUE HASH VALUE +	FILE'S NAME	
SHA 256	+ 1f3a3732d1e9c5d 9f6f8bff07c9db8 e56c9f8e8c258d 5a4b60c2d8d7a2 f3f173	+ ThIsIsAnXmL.xml	→ This information may not be considered sensitive therefore it may be given for public knowledge

Hash Integrity

HASH	+	FILE	+	FILE'S NAME	CALCULATE	HASH VALUE	
SHA 256	+	XML	+	ThisIsAnXmL.xml	→	1f3a3732d1e9c5d9f6f8bff0 7c9db8e56c9f8e8c258d5a 4b60c2d8d7a2f3f173	The same HASH VALUE
SHA 256	+	XML	+	ThisIsAnXmL.xml	→	1f3a3732d1e9c5d9f6f8bff0 7c9db8e56c9f8e8c258d5a 4b60c2d8d7a2f3f173	The same input document

Hash Integrity

HASH	+	FILE	+	FILE'S NAME	CALCULATE	HASH VALUE	
SHA 256	+	XML	+	ThisIsAnXmL.xml	→	1f3a3732d1e9c5d9f6f8bff0 7c9db8e56c9f8e8c258d5a 4b60c2d8d7a2f3f173	The same HASH VALUE
SHA 256	+	XML	+	ThisIsAnXmL.xml	→	1f3a3732d1e9c5d9f6f8bff0 7c9db8e56c9f8e8c258d5a 4b60c2d8d7a2f3f173	The same input document
SHA 256	+	XML	+	ThisIsAnXmL.xml	→	1f3a3732d1e9c5d9f6f8bff0 7c9db8e56c9f8e8c258d5a 4b60c2d8d7a2f3f173	Not the same HASH VALUE
SHA 256	+	XML	+	ThisIsAnXmL.xml	→	r3rsefsdf463634t47fyh5u5 b858tnh58h8tn58rtht85t8 t5845ntu58tn545	Not the same input document

PDF/A-3

PDF, PDF/A, PDF/A-3
Not the same format, not the same functionality

ADVANTAGES OF PDF/A

1. ISO standard 32000-1:2008 – embed and long-term archiving
2. XMP as metadata of the PDF/A
3. Free programs/Python exist for displaying and editing PDF/A files.
4. The multi-part PDF/A standard offers great flexibility to users.
5. PDF/A files can be used on any platform.
6. PDF can act as a container (similar to ZIP)
7. XSL-FO can be used to create PDFs from XMLs

ISO 32000-1:2008. Document management - Portable document format – Part 1: PDF 1.7. International Organization for Standardization.
https://www.youtube.com/watch?v=g-tJRSsZHyc
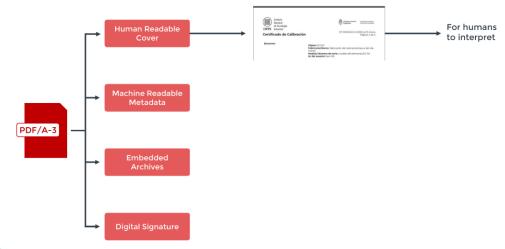
How is a PDF/A-3 composed?

How is a PDF/A-3 composed?

How is a PDF/A-3 composed?
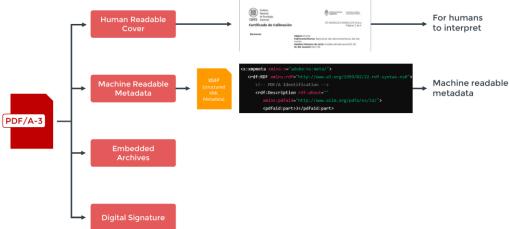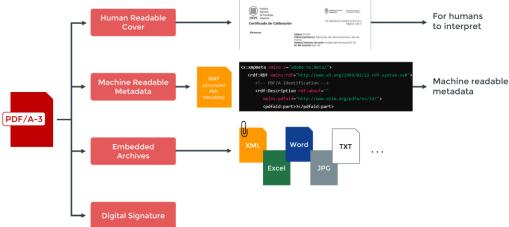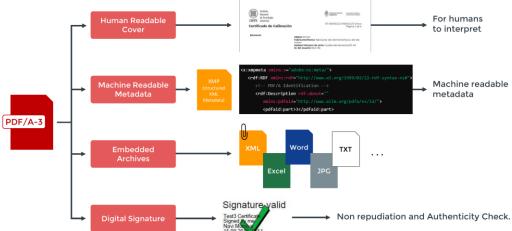
How is a PDF/A-3 composed?

Authenticity and integrity for a disembeded XML

Authenticity and integrity for a disembeded XML

Authenticity and integrity for a disembeded XML

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PDF/A-3

Human Readable Cover

Machine Readable Metadata

Embedded Archives

XML embedded

MassDcCxMl.xml

Equality?

XML disembedded

MassDcCxMl.xml

Authenticity and integrity for a disembeded XML

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PDF/A-3

Human Readable Cover

Machine Readable Metadata

Embedded Archives

MassDcCxMl.xml
Hash: SHA-256
Hash Value: qer34314...

MassDcCxMl.xml
Hash: SHA-256
Hash Value: qer34314...

CALCULATE

CALCULATE

CALCULATE

XML embedded

MassDcCxMl.xml

Equality?

XML disembedded

MassDcCxMl.xml

MassDcCxMl.xml
Hash: SHA-256
Hash Value: qer34314...

Authenticity and integrity for a disembeded XML

Boschung, Gregor & Wollensack, Michael & Zeier, Markus & Blaser, Cédric & Hof, Christian & Stathis, Manuel & Blattner, Peter & Stuker, Florian & Basic, Nina & Grasso Toro, Federico. (2021). PDF/A-3 solution for digital calibration certificates. Measurement: Sensors. 18. 100282. 10.1016/j.measen.2021.100282.

Authenticity and integrity for a disembeded XML

Conclusions
PDF/A-3 as solution to XML traceability

- PDF/A-3 is a MACHINE READABLE and a HUMAN READABLE format.

- PDF/A-3 can act as a storage container (similar to ZIP).

- XSL-FO to assure no misinformation

- PDF/A-3 assures long term stability https://www.iso.org/standard/57229.html.

DCC

Paper: https://doi.org/10.7795/120.20240126

Thanks!

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023   A service to authenticate documents issued by MSL

Presenting author: Blair Hall; Measurement Standards Laboratory of New Zealand
Email: blair.hall@measurement.govt.nz
Additional authors: Joseph Borbely joseph.borbely@measurement.govt.nz; Measurement Standards Laboratory of New Zealand

Abstract

This talk describes an online service that is being developed at the Measurement Standards Laboratory of New Zealand (MSL) to authenticate documents. The service will allow clients to check whether a digital document in their possession was issued by MSL and is currently valid.

Currently, MSL issues calibration reports either as PDF files or paper documents. PDF reports are sent to clients as email attachments, accompanied by a digital checksum to allow an integrity check of the file received.

The planned new web-based service will provide greater flexibility. By submitting a document's checksum to the service, clients can query its status at any time. The service will return one of three possible responses:

o Valid: The document was issued by MSL and is currently valid.

o Cancelled: The document was issued but has since been cancelled and is no longer valid.

o Unrecognised: There is no record of the document, indicating it is not valid.

To ensure confidentiality, the service relies on checksums and does not expose document contents. Additionally, it does not require user authentication, simplifying the verification process for both MSL and clients.

This new service will enable MSL to indicate a cancelled report status, which is difficult to communicate effectively under the existing system. It will allow clients to perform dynamic document verification, protecting against inadvertent corruption at any time after receiving a file. Furthermore, the service can authenticate other file types, such as spreadsheets. This capability will enable MSL to provide supplementary information alongside reports in formats suited to clients' needs.

Presentation of Blair Hall
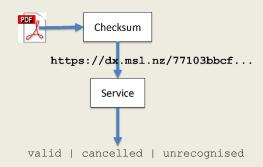
Why are we doing this?

- MSL issues electronic calibration and measurement reports (PDF)

- We currently provide a checksum with each report

- We wish to offer a better service to our customers

4ce9f022b77befff88e55cdf79b48efa

What will this project deliver?

- An online verification service for electronic documents issued by MSL

- ➤ Clients can verify the integrity of documents at any time

- ➤ MSL can change the status of documents

- ➤ Long-term solution with low cost of ownership for MSL

https://dx.msl.nz/77103bbcf...

valid | cancelled | unrecognised

How does it work?

Anyone can query a cloud-based service—no authentication needed

Provide checksums to the service and receive a response

```
58463ec72964de1bf98f4ff67eee3aa2
fc4c68f094e3647c2c6ab8694544bcdd
72b302bf297a228a75730123efef7c41
```

```
{
  "58463ec72964de1bf98f4ff67eee3aa2": "valid"
  "fc4c68f094e3647c2c6ab8694544bcdd": "cancelled"
  "72b302bf297a228a75730123efef7c41": "unrecognised"
}
```

Private (MSL)

MSL maintains three local text files: 'valid.txt', 'cancelled.txt', 'log.txt', which are safe behind the corporate firewall

Two files: 'valid.txt' and 'cancelled.txt', containing only checksums, are uploaded to a cloud server (using an authenticated—access key—connection)

No confidential information is stored in the cloud

Local (MSL) command line tool

```
PS C:\Users\j.borbely> checksum generate photons.xml
502b33f00f5637211b542a122f8fcac4
```

valid.txt
- valid checksums
- one checksum per line

cancelled.txt
- cancelled checksums
- one checksum per line

log.txt
- Stores information about each operation

```
2024-11-28T12:22:37 [ valid  ] [ci\j.borbely ] Appended 8cd5a16fe0274922f62bc4a5df37bdbe to "nas\valid.txt"
2024-11-28T12:22:37 [ cancel ] [ci\j.borbely ] Moved 227bc609651f929e367c3b2b79e09d5b from "nas\valid.txt" to "nas\cancelled.txt"
2024-11-28T12:22:37 [rollback] [ci\j.borbely ] Moved 227bc609651f929e367c3b2b79e09d5b from "nas\cancelled.txt" to "nas\valid.txt"
```

Query

https://kapua.measurement.govt.nz/checksum?9d38a9a45d24640cc33b583507465e09

```
kapua.measurement.govt.nz/checksum?9d38a9a45d24640cc33b583507465e09

Pretty-print ☐

{
  "9d38a9a45d24640cc33b583507465e09": "valid"
}
```

Or with the command line tool at MSL

```
PS C:\Users\j.borbely> checksum query 9d38a9a45d24640cc33b583507465e09 8cd5a16fe0274922f62bc4a5df37bdbe kiwi
{
  "9d38a9a45d24640cc33b583507465e09": "valid",
  "8cd5a16fe0274922f62bc4a5df37bdbe": "cancelled",
  "kiwi": "unrecognised"
}
```

Final remarks

- Accepted in-principle by the MSL Chief Metrologist and MSL Quality Manager

- Currently a beta-version is being evaluated by MSL's Quality Council (responsible for the quality system)

- A more detailed description of the idea, with a proof-of-concept working example in Python, is available: https://apmp-dxfg.github.io/dxfg-checksum-tut

- We are happy to get feedback about this project.

Thank you 🙂

blair.hall@measurement.govt.nz

joseph.borbely@measurement.govt.nz

024 Progressive Shift towards Digitalization in TUBITAK UME Mass Laboratory

Presenting author: Beste Korutlu
Email: beste.korutlu@tubitak.gov.tr
Additional authors:

Abstract

In this rapidly evolving digital era, the adoption of Findable, Accessible, Interoperable and Reusable (FAIR) Data Principles is inevitable in metrological data and metadata. Digital

calibration certificates (DCC) and digital comparison reports emerged as the outcome of the comprehensive work within this period. The concept of this paper is built on progressive work towards a synergic co-operation of mass metrology and digitalization.

In mass metrology, the calibration of the test weight is typically performed by substitution weighing with reference standard of higher accuracy class. The most commonly used weighing cycle is Reference-Test-Test-Reference (or in-short ABBA-cycle where "A" represents weighing the reference standard and "B" represents weighing the test weight), thereby eliminating the linear drift. The ABBA-cycle is repeated at least by the minimum number specified in the relevant international recommendations/standards/guidelines for the particular accuracy class of the test weight. The average weighing difference between the test weight and the reference standard is used in finding the error in the mass of the test weight. During the calibration, the environmental conditions are recorded in order to take into account the air buoyancy effect in the weighing process.

TUBITAK UME Mass Laboratory has recently undergone an infrastructure renewal in weighing instruments in the range of 2 kg – 50 kg. The calibration reports by these instruments are in human readable Tanner Database format with .tdb extension. We reconstruct the calibration report into a machine-readable Extensible Markup Language format having .xml extension by developing precise functions in Python Programming Language. The calibration report is composed of two parts as administrative data and measurement results. Initially, the report is split into two so that the administrative data is stored for further producing a digital calibration certificate while the measurement results for determining the error in the mass of the test weight. The analysis of the data is performed using the calibration data in the measurement results and the relevant data of the reference standard.

On the onset of this work, we use GEMIMEG tool in order to generate a DCC for the reference standard with .xml extension. Once the reference standard data is in the machine-readable format, it will be possible to call it into the same environment with the measurement results and assign the mass error for the test weight without human-intervention. In this paper, we demonstrate how the mass error of a single test weight is determined with minimum involvement of the operator.

Presentation of Beste Korutlu

Progressive Shift Towards
DIGITALIZATION
in TUBITAK UME Mass Laboratory

Assoc. Prof. Dr. Beste Korutlu Yılmaz
Head of Mass Laboratory
TUBITAK UME
Türkiye
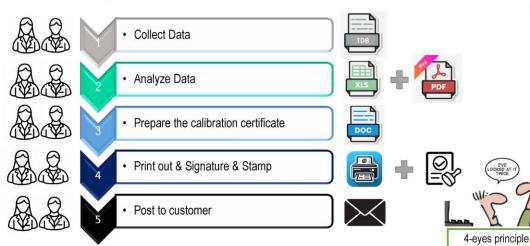
26.02.2025

5TH INTERNATIONAL DCC CONFERENCE
DCC FOR FAIR PRINCIPLES IN THE QUALITY INFRASTRUCTURE

Current Calibration Flow

TÜBİTAK UME

1 • Collect Data — TDB

2 • Analyze Data — XLS + PDF Pro

3 • Prepare the calibration certificate — DOC

4 • Print out & Signature & Stamp

5 • Post to customer

I'VE LOOKED AT IT TWICE

4-eyes principle

2

DIGITALIZED CALIBRATION FLOW

- 1 • Collect Data
- 2 • Analyze Data
- 3 • Prepare the digital calibration certificate (DCC)
- 4 • E-signature & E-Stamp
- 5 • E-mail to the customer

3

Mass Calibration

INTERNATIONAL RECOMMENDATION

OIML R 111-1
Edition 2004 (E)

Weights of classes E_1, E_2, F_1, F_2, M_1, M_{1-2}, M_2, M_{2-3} and M_3
Part 1: Metrological and technical requirements

Air Buoyancy Force
Gravitational Force

R   T

Air Buoyancy Force
Gravitational Force

Mean value of weighing difference $\propto$ Net force on test $-$ Net force on reference

4

Mass Calibration

$\overline{\Delta m}$:Average value of weighing difference

ρ_a : Air density

m_r :True mass of reference
V_r : Volume of reference

m_t :True mass of test
V_t : Volume of test

Air buoyancy correction

$$m_t = m_r + \rho_a(V_t - V_r) + \overline{\Delta m}$$

Laboratory — DCC of reference — xml

Laboratory — DCC of test — xml

Administrative Data
Measurement Results
Summary Results
tdb

A B B A

Subtract ← → Subtract

Average $= \Delta m_i$

$$\overline{\Delta m} = \frac{1}{n}\sum_{i=1}^{n}\Delta m_i$$

5

RECIPE OF DIGITALIZED CALIRATION FLOW

COMING SOON

TÜBİTAK UME

INGREDIENTS

Current DCC of Reference	Calibration Report	Previous DCC of Test		New DCC of Test

$$m_t = m_r + \rho_a(V_t - V_r) + \overline{\Delta m}$$

MIX WELL using PYTHON

Generated by GEMIMEG Tool	Generated by Mass Comparator	Generated by GEMIMEG Tool		Generated by TUBITAK UME Mass Lab

6

Libraries

1 — xml.etree.ElementTree: xml manipulation

2 — re: separate numbers and units

3 — math: data analysis

7

Calibration Report

Split into three via python

To be used for generating the DCC of the test weight

Δm_i

To be used if there are outliers in the data

A B B A

Subtract ← → Subtract

$\overline{\Delta m}$ Average $= \Delta m_i$ $\overline{\Delta m} = \dfrac{1}{n}\sum_{i=1}^{n}\Delta m_i$

To be used in calculating the true mass and conventional mass of the test weight

8

Summary Results

$$m_t = m_r + \rho_a(V_t - V_r) + \overline{\Delta m}$$

$$\overline{\Delta m} = 0.000645\ g$$

Air Buoyancy Correction

Air buoyancy correction

$$m_t = m_r + \rho_a(V_t - V_r) + \overline{\Delta m}$$

$$\rho_a = \frac{0{,}34848\ p\ -\ 0{,}009\ h\ e^{(0{,}061\ t)}}{273{.}15 + t}$$

Get the Root Element in summary_results.xml
Extract the numerical value of Min_parameter
Extract the numerical value of Max_parameter
Take the average of Max & Min values

```
tree.getroot()
root.find()
float()
```

```
Mean Temperature T_mean (°C): 20.8595
Mean Humidity h_mean (%rh): 44.09
Mean Pressure P_min (hPA): 1008.0385
```

```
Air density ρ_a in kg/m^3: 1.189984639231692
```

$$\rho_a = 1.189985\ \text{kg/m}^3$$

Current DDC of the Reference

Stainless Steel Reference Mass of 10 kg

Prepare the DCC of the Reference using GEMIMEG
Call the DCC of the Reference
Find The Root Element
Find all si:value elements
Collect the si:value elements in a column vector of vs

$$m_t = m_r + \rho_a(V_t - V_r) + \overline{\Delta m}$$

```
tree.getroot()
root.findall()
float()
```

```
Root element: {https://ptb.de/dcc}digitalCalibrationCertificate
True Mass Error of Reference (g): -0.0024          vs[0]
Conventional Mass Error of Reference (g): -0.0002  vs[1]
Volume of Reference (cm^3): 1248.1                 vs[2]
Nominal Mass of Reference (g): 10000.0             vs[3]
```

$$m_r = -0.0024\ \text{g} \qquad V_r = 1248.1\ \text{cm}^3$$

11

Previous DDC of the Test

Stainless Steel Test Mass of 10 kg

Prepare the DCC of the Test using GEMIMEG
Call the DCC of the Test
Find The Root Element
Find all si:value elements
Collect the si:value elements in a column vector of vs_test

$$m_t = m_r + \rho_a(V_t - V_r) + \overline{\Delta m}$$

```
tree.getroot()
root.find()
float()
```

```
Root element: {https://ptb.de/dcc}digitalCalibrationCertificate
True Mass Error of Test in Previous Certificate (g): -0.0013         vs_test[0]
Conventional Mass Error of Test in Previous Certificate (g): -0.001  vs_test[1]
Volume of Test in Previous Certificate (cm^3): 1248.1                vs_test[2]
Nominal Mass of Test (g): 10000.0                                    vs_test[3]
```

$$V_t = 1248.1\ \text{cm}^3$$

12

True Mass of the Test

$$m_t = m_r + \rho_a(V_t - V_r) + \overline{\Delta m}$$

```
m_test_true = vs[0] + rho_a * (vs_test[2]-vs[2]) * 1E-3 + mean_diff_value
print(f"True Mass of Test (g): {m_test_true}")
```

```
True Mass of Test (g): -0.0017549999999999998
```

```
Root element: {https://ptb.de/dcc}digitalCalibrationCertificate
True Mass Error of Test in Previous Certificate (g): -0.0013
Conventional Mass Error of Test in Previous Certificate (g): -0.001
Volume of Test in Previous Certificate (cm^3): 1248.1
Nominal Mass of Test (g): 10000.0
```

$$\Delta m_t = (-0.0018\ g) - (-0.0013\ g) = -0.0005\ g$$
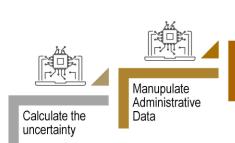
Is it smaller than the uncertainty?

COMING SOON

13

FUTURE TASKS

Apply the concept with a volunteering customer for interoperability

Create a drag and drop Interface for the users

COMING SOON

Generate DCC

Manupulate Administrative Data

Calculate the uncertainty

Drag and Drop the Calibration Report

Drag and Drop Current DCC of Reference

Drag and Drop Previous DCC of Test

Click to Generate DCC of Test

14

THANK YOU!

5TH INTERNATIONAL DCC CONFERENCE
DCC FOR FAIR PRINCIPLES IN THE QUALITY INFRASTRUCTURE

025 Practical Applications of Digital Calibration Exchange (DCX) covering Certificates, Requests, and Templates

Presenting author: Søren Kynde; DFM – Danish National Metrology Institute
Email: srk@dfm.dk
Additional authors: David Balslev-Harder dbh@dfm.dk

Abstract

This presentation provides a comprehensive exploration of the Digital Calibration Exchange (DCX) through practical examples and scenarios. We begin by examining four general scenarios of calibration, and how this creates a basis for simplifying the representation of calibration results in a FAIR maner. These scenarios will be demonstrated with XML examples, highlighting the versatility and adaptability of the DCX framework. A key focus will be on the PDF representation of XML data, demonstrating how similarities across these scenarios can be leveraged to create standardized and easily interpretable documents. The presentation will also delve into the commonalities observed across different metrology areas, showcasing how DCX facilitates a unified approach to calibration data management. By presenting examples of Digital Calibration Certificates (DCCs), Digital Calibration Requests (DCRs), and Digital Calibration Templates (DCTs), we will illustrate the practical implementation and benefits of DCX in real-world settings. Furthermore, we will outline the workflow involving templates, requests, and certificates, providing a clear understanding of how these components interact within the DCX framework. This workflow ensures a seamless and efficient process for managing calibration data, from initial request to final certification. In conclusion, the DCX framework offers a robust and standardized solution for the digital management of calibration data, enhancing accuracy, traceability, and interoperability across the metrology community.
Outline of presentation
o Four general scenarios of calibration
o PDF representation of xml certificates utilizing the similarities across the four scenarios
o Similarities across different metrology areas

- o Workflow with templates, requests and certificates
- o Examples of Digital Calibration Certificates (DCC's)
- o Examples of Digital Calibration Requests (DCR's)
- o Examples for Digital Calibration Templates (DCT's)
- o Solution available on github.com/TC-IM-1448/DCC-Tables
- o See other presentations for information on schema and software tools.

Presentation of Søren Kynde

DFM
Danmarks Nationale Metrologiinstitut

Digital calibration exchange: DCX

Practical applications with examples

Søren Kynde, DFM
David Balslev-Harder, DFM
5'th DCC-conference
2025-02-26

Motivation for DCX

1. *Explore impact on middleware architecture when schema is designed w. focus on:*
   a) Use of references rather than emphasis on tree structure (PTB-DCC approach):
      i. Extend use of xs.ID and xs.IDREF and utilizing xs.key and xs.keyref to restrict pointing options
      ii. Introduce new attribute-names and restricted options to guide machine interpretability
      iii. avoid multiple re-entry of identical data
   b) Represent data content in tables for easier integration with Excel and databases
      and provide better overview in user interface experience.
   c) Emphasis on descriptive query expressions for finding and interpreting measurement data.
   d) Same elements/structure for all calibration/metrology areas.
   e) Define as much as possible in one Schema, to simplify interoperability and facilitate validation data machine interpretability and ability
      level to support automatic data extraction.
2. *DCC is more than just a data-file, it may act as a legal document.*
   a) Support human readable fields for all elements in the xml-file.
   b) Support PDF-generation w. low level of middleware assumptions.
3. *Simplify software/middleware management*
   a) Use schema in middleware to adapt for received xml's used schema version.
   b) Provide tools for Excel that support file reading across different metrology area's

Motivation for DCX

1. *Explore impact on middleware architecture when schema is designed w. focus on:*
   a) **Use of references rather than emphasis on tree structure** (PTB-DCC approach):
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      ii. Introduce new attribute-names and restricted options to guide machine interpretability
      iii. avoid multiple re-entry of identical data
   b) Represent data content in tables for easier integration with Excel and databases
      and provide better overview in user interface experience.
   c) Emphasis on descriptive query expressions for finding and interpreting measurement data.
   d) **Same elements/structure for all calibration/metrology areas.**
   e) **Define as much as possible in one Schema, to simplify interoperability and facilitate validation data machine interpretability and ability level to support automatic data extraction.**
2. *A calibration certificate is more than just a data-file, it may act as a legal document.*
   a) **Support human readable fields for all elements in the xml-file.**
   b) **Support PDF-generation w. low level of middleware assumptions.**
3. *Simplify software/middleware management*
   a) Use schema in middleware to adapt for received xml's used schema version.
   b) Provide tools for Excel that support file reading across different metrology area's

A modular build of a calibration certificate

Calibration certificate
- Administrative data
- Statements
- Description of equipment
- Specification of equipment settings
- List of uniqure measurement configurations
- Results
    - Each result refers to a unique measurement configuration
- Annexes
    - Definitions of non SI-units
    - List of embedded files
    - List of codeable elements

Example

- Thanks to Dandiag for sharing this sample certificate

Administrative data

Core data

- Core data has a heading
- All other element in core data are fields
  - A field has a value
  - All fields may have a heading
  - The heading can be stated in one or more languages

```xml
<dcx:coreData>
    <dcx:heading lang="en">Core data</dcx:heading>
    <dcx:heading lang="da">Dokumentdata</dcx:heading>
    <dcx:uniqueDocumentIdentifier value="SKH_10112_2">
        <dcx:heading lang="en">Certificate number</dcx:heading>
        <dcx:heading lang="da">Certifikatnummer</dcx:heading>
    </dcx:uniqueDocumentIdentifier>
    <dcx:clientTaskIdentifier value="xx28">
        <dcx:heading lang="en">Order number</dcx:heading>
        <dcx:heading lang="da">Ordrenummer</dcx:heading>
    </dcx:clientTaskIdentifier>
    <dcx:issueDate value="2022-02-11"/>
        <dcx:heading lang="en">Issue date</dcx:heading>
        <dcx:heading lang="da">Udsteddelsesdato</dcx:heading>
    <dcx:issueDate/>
    <dcx:beginPerformanceDate value="2022-02-10"/>
    <dcx:endPerformanceDate value="2022-02-10"/>
    <dcx:equipmentReceiptDate value="2022-02-09"/>
    <dcx:performanceLocation value="atProvider"/>
    <dcx:requestedLanguages value="en da"/>
</dcx:coreData>
```

Administrative data

Accreditation
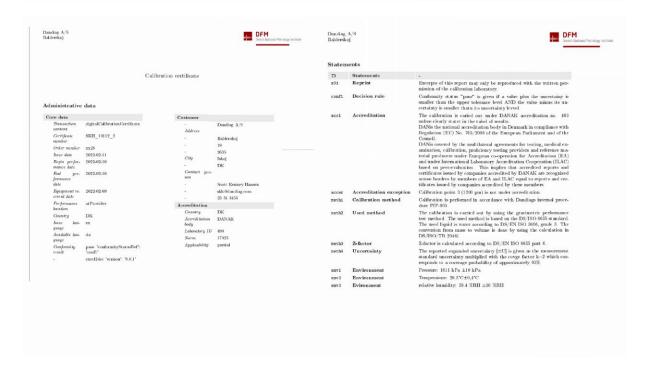
- The dcx:accreditationType consists of a heading and a number of fields
- Information can be given in accordance with ISO17025

```
<dcx:accreditation>
    <dcx:heading lang="en">Accreditation</dcx:heading>
    <dcx:accreditationNorm value="ISO 17025"></dcx:accreditationNorm>
    <dcx:accreditationLabId value="255">
        <dcx:heading lang="en">DANAK id of the laboratory</dcx:heading>
    <dcx:accreditationLabId/>
    <dcx:accreditationBody value="DANAK">
        <dcx:heading lang="en">Accrditation body</dcx:heading>
    <dcx:accreditationBody/>
    <dcx:accreditationCountry value="DK"/>
    <dcx:accreditationApplicability value="wholly">
        <dcx:heading lang="en">Applicability of accreditation for results
                            in this DCC: 'wholly' (applies to all results)
                            or 'partial' (exceptions occur)
        </dcx:heading>
    <dcx:accreditationApplicability/>
</dcx:accreditation>
```

Administrative data

Contacts and locations

- The contactAndLocationType consists of an address and contact info
- Contacts and locations are organized as a table with common headings

```
<dcx:contactColumnHeadings>
    <dcx:column name="address">
        <dcx:heading lang="en">Address</dcx:heading>
    </dcx:column>
    <dcx:column name="contactInfo">
        <dcx:heading lang="en">Contact info</dcx:heading>
    </dcx:column>
</dcx:contactColumnHeadings>
<dcx:client>
    <dcx:heading lang="en">Customer</dcx:heading>
    <dcx:name>SST International A/S</dcx:name>
    <dcx:address>
        <dcx:city>Søborg</dcx:city>
        <dcx:country>DK</dcx:country>
        <dcx:postalCode>2860</dcx:postalCode>
        <dcx:street>Halvvejen</dcx:street>
        <dcx:streetNo>17</dcx:streetNo>
    </dcx:address>
    <dcx:contactInfo>
        <dcx:attPerson>Mads Olsen</dcx:attPerson>
        <dcx:email>mo@sst.dk</dcx:email>
        <dcx:phone>+45 6160 7019</dcx:phone>
    </dcx:contactInfo>
</dcx:client>
<dcx:serviceProvider>
    <dcx:heading lang="en">Calibration laboratory</dcx:heading>
    <dcx:name>DFM A/S</dcx:name>
    <dcx:address>
        <dcx:city>Hørsholm</dcx:city>
        <dcx:country>DK</dcx:country>
        <dcx:postalCode>2970</dcx:postalCode>
        <dcx:street>Kogle alle</dcx:street>
        <dcx:streetNo>5</dcx:streetNo>
    </dcx:address>
</dcx:serviceProvider>
```

Statements

- id for internal reference
- Heading and body in requested languages
- Optional external reference

Rule of thumb
- If you don't know were something should go:
  Put it in a statement

```xml
<dcx:statementList>
    <dcx:heading lang="da">Bemærkninger</dcx:heading>
    <dcx:heading lang="en">Statements</dcx:heading>
    <dcx:statement id="s01"
                   category="general">
        <dcx:heading lang="en">Reprint</dcx:heading>
        <dcx:heading lang="da">Gengivelse af rapport i uddrag</dcx:heading>
        <dcx:body lang="en">Excerpts of this report may only be reproduced with
            the written permission of the calibration laboratory.</dcx:body>
    </dcx:statement>    <dcx:statement id="meth03" category="method">
        <dcx:heading lang="en">Uncertainty</dcx:heading>
        <dcx:body lang="en"> The reported expanded uncertainty of measurement is
            stated as the standard uncertainty multiplied by the coverage
            factor k = 2, which for a normal distribution corresponds to a
            coverage probability of approximately 95 %. The standard
            uncertainty of measurement is determined in accordance with the
            guidelines of EA-4/02.</dcx:body>
        <dcx:externalReference>EA-4/02, Expression of the uncertainty of measurement
            in calibration, (1997).</dcx:externalReference>
    </dcx:statement>
    …

<dcx:statementList>
```

Used equipment

ID	Used equipment	Manufacturer	Product name	Product type	Customer ID	Serial number	DFM number
item1	Pipette with 12 channels 50-1200 μm	Biohit	Picus	-	ID107	12008522	-
item2	Pipette tip (1200 μl)	Satorius	Optifit	-	-	ss23987	-
ref1	Balance. resolution: 0.00001 g. calibrated: 2021-11-25.	Satorius	-	-	-	-	ID148

Settings

ID	-	description	parameter	value	unit
ch1	Channel	-	-	1	-
ch2	Channel	-	-	2	-
ch3	Channel	-	-	3	-
sin	Speed in	Same speed is used in all measurements	speed-in	5	-
sout	speed out	Same speed is used in all measurements	speed-out	5	-

Measuring Systems Under Calibration

ID	Measuring system	Client equipment	References used	Setting ref.		Method ref.	Operational status.
ms1	Channel 1	item1 item2	ref1	ch1 sout	sin	meth2	as found
ms2	Channel 2	item1 item2	ref1	ch2 sout	sin	meth2	as found

Used equipment

ID	Used equipment	Manufacturer	Product name	Product type	Customer ID	Serial number	DFM number
item1	Pipette with 12 channels 50-1200 μm	Biohit	Picus	-	ID107	12008522	-
item2	Pipette tip (1200 μl)	Satorius	Optifit	-	-	ss23987	-
ref1	Balance. resolution: 0.00001 g. calibrated: 2021-11-25.	Satorius	-	-	-	-	ID148

Settings

ID	-	description	parameter	value	unit
ch1	Channel	-	-	1	-
ch2	Channel	-	-	2	-
ch3	Channel	-	-	3	-
sin	Speed in	Same speed is used in all measurements	speed-in	5	-
sout	speed out	Same speed is used in all measurements	speed-out	5	-

Measuring Systems Under Calibration

ID	Measuring system	Client equipment	References used	Setting ref.		Method ref.	Operational status
ms1	Channel 1	item1 item2	ref1	ch1 sout	sin	meth2	as found
ms2	Channel 2	item1 item2	ref1	ch2 sout	sin	meth2	as found

Measurement results

REF calRes0	Pipette - channel1 Measuring System:ms1								
Customer Tags	Calibration point	Reference Value	Data-series used for calculation of repeatability and systematic error	Systematic error	Systematic error (relative)	Repeatability	Repeatability (relative)	Exception to accreditation
1	μL	μL	1	μL	%	μL	%	-
pt1	120	121.21	ser11	1.21 ± 0.35	1.01 ± 0.29	0.13	0.11	-
pt2	600	600.3	ser12	0.3 ± 1.5	0.05 ± 0.25	0.24	0.04	-
pt3	1200	1199.1	ser13	−0.9 ± 2.4	−0.08 ± 0.2	0.48	0.04	accex

REF ser11	Series of measurement channel 1 Measuring System:ms1			REF ser12	Series of measurement channel 1 Measuring System:ms1		
Customer Tags	Calibration Point	Reference value	Item indication	Customer Tags	Calibration Point	Reference value	Item indication
-	μL	μL	μL	-	μL	μL	μL
p1	120	121.3229	120	p1	600	600.5463	600
p2	120	121.1223	120	p2	600	600.466	600
p3	120	121.1724	120	p3	600	599.784	600
p4	120	121.1022	120	p4	600	600.5262	600
p5	120	121.2025	120	p5	600	600.4058	600
p6	120	121.1825	120	p6	600	600.1049	600
p7	120	121.3129	120	p7	600	600.3457	600
p8	120	121.042	120	p8	600	600.3757	600
p9	120	121.1724	120	p9	600	600.7067	600
p10	120	121.5034	120	p10	600	600.1952	600

…multiple language support

Målesultater

REF	Pipette - channel1							
calRes0	Measuring System:ms1							
Kundens kode	Kalibre-ringspunkt	Referen-cens værdi	Måleserier som danner grundlag for beregning af repeterbarhed og sy-stematisk fejl	Systematisk fejl	Systematisk fejl (relativ)	Repeter-barhed	Repeter-barhed (relativ)	Und-tagelse fra ak-kredi-tering
1	µL	µL	1	µL	%	µL	%	-
pt1	120	121.21	ser11	1.21 ± 0.35	1.01 ± 0.29	0.13	0.11	-
pt2	600	600.3	ser12	0.3 ± 1.5	0.05 ± 0.25	0.24	0.04	-
pt3	1200	1199.1	ser13	−0.9 ± 2.4	−0.08 ± 0.2	0.48	0.04	accex

REF	Series of measurement channel 1			REF	Series of measurement channel 1		
ser11	Measuring System:ms1			ser12	Measuring System:ms1		
Kundens kode	Kalibre-ringspunkt	Referen-ceværdi	Emnets visning	Kundens kode	Kalibre-ringspunkt	Referen-ceværdi	Emnets visning
-	µL	µL	µL	-	µL	µL	µL
p1	120	121.3229	120	p1	600	600.5463	600
p2	120	121.1223	120	p2	600	600.466	600
p3	120	121.1724	120	p3	600	599.784	600

Workflow
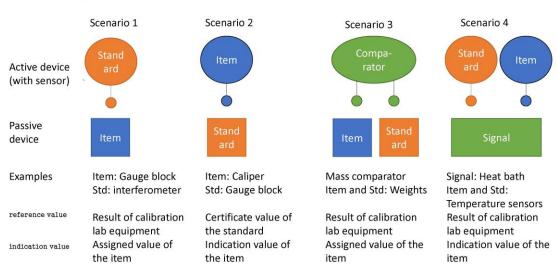
Workflow

Four types of calibration.

	Scenario 1	Scenario 2	Scenario 3	Scenario 4
Active device (with sensor)	Standard	Item	Compa-rator	Standard / Item
Passive device	Item	Standard	Item / Standard	Signal
Examples	Item: Gauge block Std: interferometer	Item: Caliper Std: Gauge block	Mass comparator Item and Std: Weights	Signal: Heat bath Item and Std: Temperature sensors
reference value	Result of calibration lab equipment	Certificate value of the standard	Result of calibration lab equipment	Result of calibration lab equipment
indication value	Assigned value of the item	Indication value of the item	Assigned value of the item	Indication value of the item

A modular build of a calibration certificate

Calibration certificate

- …
- Results
  - Each result refers to a unique measurement configuration
  - Important columns are:
    - Reference value
    - Indication value
    - Bias = indication value – reference value
    - Uncertainty of bias
    - …
- …

Example of DCR (temperature)

```
<dcx:calibrationResult tableId="calRes0" measurementConfigRef="config1" numRows='3' numCols='2'>
    <dcx:heading lang="en">Caliration of temperature sensor</dcx:heading>

    <dcx:column dataCategoryRef="-" quantity="-" scope="-" unit="1">
        <dcx:heading lang="en">Customer Tags</dcx:heading>
        <dcx:heading lang="da">Kundens kode</dcx:heading>
        <dcx:rowTag>
            <dcx:row idx="1">MIC01</dcx:row>
            <dcx:row idx="2">MIC02</dcx:row>
            <dcx:row idx="3">MIC03</dcx:row>
        </dcx:rowTag>
    </dcx:column>

    <dcx:column dataCategoryRef="-" quantity="5-2|Celsius temperature|°C" unit="°C" scope="refere
        <dcx:heading lang="en">Target value</dcx:heading>
        <dcx:targetValue>
            <dcx:row idx="1">0</dcx:row>
            <dcx:row idx="2">5</dcx:row>
            <dcx:row idx="3">15</dcx:row>
        </dcx:targetValue>
    </dcx:column>
```
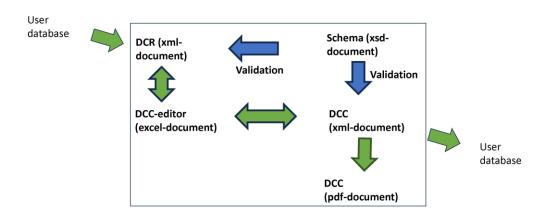
Example of DCR (temperature explicit)

```
<dcx:calibrationResult tableId="calRes0" measurementConfigRef="config1">
…
  <dcx:column dataCategoryRef="-" quantity="5-2|Celsius temperature|°C" unit="°C" scope="indicati
    <dcx:heading lang="en">Value of the dut</dcx:heading>
    <dcx:value>
    </dcx:value>
  </dcx:column>

  <dcx:column dataCategoryRef="-" quantity="5-2|Celsius temperature|°C" unit="°C" scope="referenc
    <dcx:heading lang="en">Value of the reference in unit of the dut</dcx:heading>
    <dcx:value>
    </dcx:value>
  </dcx:column>

  <dcx:column dataCategoryRef="value" quantity="5-2|Celsius temperature|°C" unit="°C" scope="bias
    <dcx:heading lang="en">uncertainty of calibration</dcx:heading>
    <dcx:expandedUncertainty>
    </dcx:expandedUncertainty>
  </dcx:column>
```
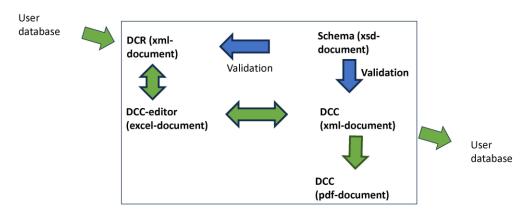
Example of DCR (With tolerances)

```
<dcx:column dataCategoryRef="value" quantity="5-2|Celsius temperature|°C" unit="°C" scope="bias">
  <dcx:heading lang="en">Lower tolerance limit of the bias</dcx:heading>
  <dcx:toleranceLimitLower>
    <dcx:row idx="1">-0.375</dcx:row>
    <dcx:row idx="2">-0.375</dcx:row>
    <dcx:row idx="3">-0.375</dcx:row>
  </dcx:toleranceLimitLower>
</dcx:column>

<dcx:column dataCategoryRef="value" quantity="5-2|Celsius temperature|°C" unit="°C" scope="bias">
  <dcx:heading lang="en">Lower acceptance limit of the bias</dcx:heading>
  <dcx:acceptanceLimitLower>
  </dcx:acceptanceLimitLower>
</dcx:column>

<dcx:column dataCategoryRef="conformity" quantity="5-2|Celsius temperature|°C" unit="°C" scope="b
  <dcx:heading lang="en">Conformity statement</dcx:heading>
  <dcx:decisionRuleRef>
    <dcx:row idx="1">accept1</dcx:row>
    <dcx:row idx="2">accept1</dcx:row>
    <dcx:row idx="3">accept1</dcx:row>
  </dcx:decisionRuleRef>
</dcx:column>
```

Workflow
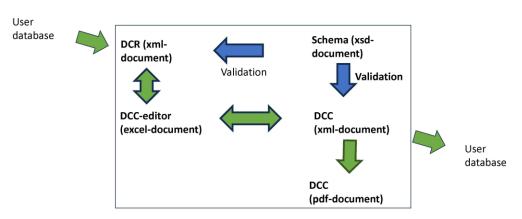
Workflow

Released january 2025 !
https://github.com/TC-IM-1448/DCC-Tables

Thank you!

Released january 2025 !
https://github.com/TC-IM-1448/DCC-Tables

Day 3 (2025-02-27 Thursday)
Plenary Session
(Chair: Hector Laiz)

P06 Motivation for using DCC

Presenting author: Martin Koval, CMI, Czech Metrology Institute
Email: mkoval@cmi.cz
Additional authors: Nil

ABSTRACT

The concept of DCC emerged in the field of digital metrology almost a decade ago. Despite its long history and many advances in this field, DCC has not yet gained wide acceptance by the metrology community. Over the years, several key steps have been taken in the promotion and implementation of DCC. Working Groups have been set up, allowing the coordination of activities at international level. Projects that have provided practical examples of DCC implementation. A number of conferences, trainings and workshops have been held and are planned to help disseminate information on DCC. There are even freely available software tools and case studies. DCCs off er a multitude of benefits including, better access to data, efficiency in process management (time savings, data analysis, flexibility) and many more.

From the many discussions in terms of motivation, we can identify three main key groups. Group 1 Users who want to benefit from the majority of DCC benefits. This group often manage hundreds to thousands of devices and need an effective digital solution. Group 2 Users who have a positive attitude towards DCC but are waiting for final solutions or a broader consensus in the metrology community. This group needs to work with calibration data, but for the time being makes do with the different mix of solutions available, whether it is classic PDF or paper. Group 3 are users who only need a calibration certificate for auditing purposes. Usually these are instruments that are in lower units and the value of the information from the calibration

certificate is not very meaningful to them. Hence, we can also deduce several remaining barriers to full implementation of DCC which include financial but also capacity constraints. Many organizations do not have the resources to create additional jobs or to maintain digital systems. Most importantly, they are concerned about price increases for IT-related services. Another major barrier is the conservative approach where practices in metrology prevent the adoption of innovative technologies where information on paper with a stamp is trusted more than data in digital form. Thus, the question remains how to effectively motivate users to adopt DCC.

One of the key problems is that society has lost its understanding of the importance of calibration and metrology in general. We are increasingly seeing metrology confused with meteorology, which is a sign that metrology has a weaker awareness. One of the first steps for motivation should be to raise awareness of metrology. Despite the fact that every person is surrounded by thousands of sensors every day, few are aware of the fact that the quality of services and products often depends on the correct calibration of instruments and sensors and, above all, the correct and efficient use of calibration data. Metrology is so often a background issue. Therefore, one of the necessary steps is to raise awareness of metrology, which will undoubtedly contribute to the growing curiosity and interest in what accurate and reliable data looks like. At the same time, a period is coming when the emphasis will again be on quality of services and products over quantity, where DCC can play a key role.
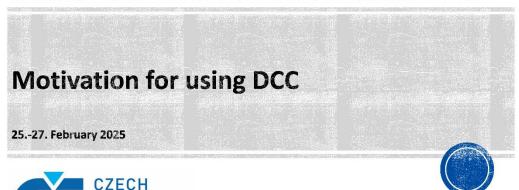
Presentation of Martin Koval
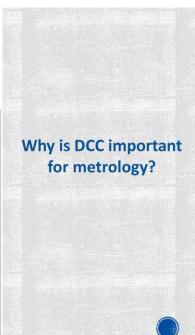
- It is one of the fundamental pillars of digitalization in metrology.
- Brings many advantages over "still widely" deployed solutions.
- It can bring popularity to metrology, especially among the younger generation.

Why is DCC important for metrology?

- The DCC concept has been around for several years.
- DCC is a topic at almost every conference that includes digitalization in metrology.
- Several working groups and projects dealing with DCC have been established around the world - most of them communicate with each other.
- There are implementations of DCC.
- There are guidance documents on how to get started with DCC.

Where do we stand today?
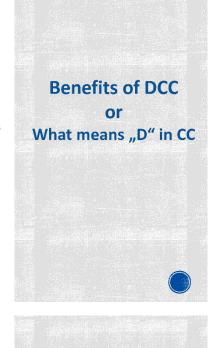
- DCC is still not widely deployed.

What should bring „D" for „CC"
- better access to data (streamline information),
- machine readable,
- the possibility of implementation into internal systems,
- the possibility of automatization of metrological activities,
- with higher numbers of calibrations, easier and more effective management,
- "Green deal effect" – elimination of papers, reduction of the load on resources (distribution, printing, etc.),
- Life cycle monitoring of sensors/devices,
- DCC can make it easy to analyze calibration data and create digital twins that help increase efficiency and safety in the process industry,
- DCC can support digital transformation by enabling suppliers and laboratories to connect to a digital calibration system with centralized management easily,
- DCC should use a standardized approach to data entry, which facilitates the comparison and harmonization of data from different sources.
- DCC can enable preventive maintenance by alerting the need for instrument inspection instead of relying on fixed intervals, leading to a better risk-based approach to maintenance and calibration.
- DCC can increases the speed of traceability by replacing paper-based processes with easy digital search capabilities.
- DCC should be flexible so stakeholders can use their preferred calibration processes while still creating easily shareable and searchable digital certificates.
- and others..

**Benefits of DCC
or
What means „D" in CC**

- Instant access to calibration data.
- Easier tracking and compliance.
- No risk of losing paper documents.
- Faster decision-making.
- Secure and traceable storage.

Key Benefits of DCC

More efficient data management

- Faster data processing.

- Less manual work.

- Automation of calibration workflows.

- Reduced human errors.

- Less storage space required.

Key Benefits of DCC

Time and resource savings

- The DCC concept is (should be) ready to adapt to new technologies.

- Scalable for different areas.

- Flexible for large and small organizations.

- Supports remote audits and inspections.

Key Benefits of DCC

Flexibility and scalability

- USERS
- AUDITORS/REGULATORS
- PUBLISHERS

Stakeholders

1 Group

- Manage thousands of devices.
- Require automation and integration.
- High data volume processing.
- Strong motivation for DCC adoption.

Stakeholders (users)

2 Group

- Interested in DCC, but hesitant.
- Waiting for standardization.
- Use a mix of digital and paper.
- Concerned about compatibility.
- Need proven success cases.
- Open to gradual transition.

Stakeholders (users)
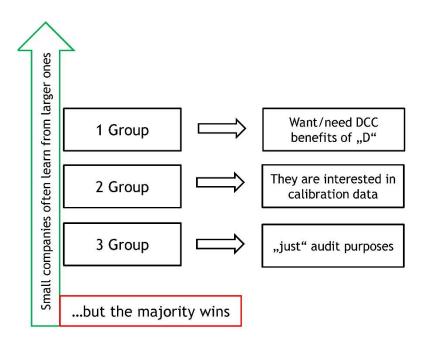
3 Group

- Only need a certificate for audits.
- Use a small number of instruments.
- No real benefit from digitalization.
- Prefer traditional paper format.
- Concerned about IT-related costs.

Stakeholders (users)

Small companies often learn from larger ones

1 Group	⟹	Want/need DCC benefits of „D"
2 Group	⟹	They are interested in calibration data
3 Group	⟹	„just" audit purposes

…but the majority wins

Sociaty rules

- Each country should define its own interpretation of DCC.
- What are the differences in conducting an audit between CC and DCC?
- Auditors have a weaker awareness of what DCC actually entails.
- Set requirements for DCC.
- Legal acceptance of DCC is not guaranteed everywhere – if digital certificates are not formally recognized, users will continue to prefer „paper/electronic" version of CC.

Stakeholders (regulators/auditors)
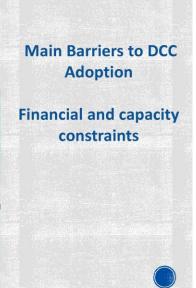
- Many Publisher are ready to start issuing DCC or are working on it.

- The rule is that if there is demand, the service will be provided.

- Not every country has a demand for DCC.

Stakeholders (publisher)

- High initial costs for DCC implementation.
- Lack of IT infrastructure in small organizations.
- Limited staff capacity.
- Need for investment in training and education.
- Ongoing maintenance and support costs.

Main Barriers to DCC Adoption

Financial and capacity constraints
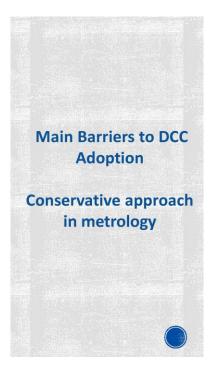
- Strong preference for paper certificates.
- Trust in physical stamps & signatures.
- Low level of trust in new technologies.
- Resistance to change in established workflows.
- Lack of regulatory enforcement for DCC.

Main Barriers to DCC Adoption

Conservative approach in metrology

- High initial investment in IT infrastructure.

- Cost of software licenses and updates.

- Need for cybersecurity and data protection.

- Ongoing maintenance and technical support.

- Uncertainty about cost-benefit ratio.

Main Barriers to DCC Adoption

Fear of increased IT-related costs

- Uncertainty about legal acceptance of DCC.

- Lack of clear guidelines for digital audits.

- Resistance from auditors used to paper CC.

- Need for secure IT systems for DCC.

Main Barriers to DCC Adoption

How to pass an audit

- Many people confuse metrology with meteorology (never-ending story).
- Meteorology is more attractive than metrology to the general society.
- Metrology often overlooked despite its impact.

Low Awareness of Metrology as a Challenge

Common confusion between metrology and meteorology

- Calibration ensures product quality and safety.

- Impact on health, industry and daily life.

- Unnoticed but essential for reliable measurements.

- Lack of interest outside metrology community.

- Low media coverage on metrology topic.

Low Awareness of Metrology as a Challenge

General public does not recognize calibration as crucial.

- People already rely on digital tools daily.

- Younger generations knows just "online" data.

- Consumers research product details before buying.

- DCC can make calibration data more visible.

- Digital access increases transparency and trust.

- Widely deployment of DCC can brings better interest in metrology.

Low Awareness of Metrology as a Challenge

How can raising awareness help drive DCC adoption?

Positive motivation:
- There are many benefits.
- Successful user stories.
- Guidelines document on how to get started.

Forced by circumstances:
- Young generation.
- Future technology development.

How to motivate?

Widely deployment of DCC is just a matter of time.

Questions and discussion

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Czech Metrology Institute
Digitalization of metrology
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e-mail: *mkoval@cmi.cz*

Source of pictures: OpenAI. (2024). ChatGPT (4o)

P07   Modeling Digital Calibration Certificates Using Object - Oriented Technologies to Address Heterogeneity and Harness FAIR Principles

Presenting author: Dr. Anjali Sharma; NPL, India
Email: anjali@nplindia.res.in
Additional authors: Niharika Bhatia
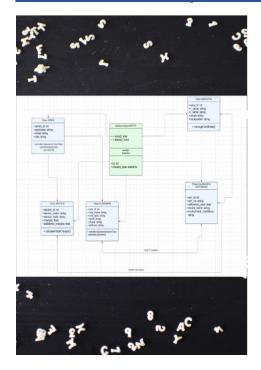
ABSTRACT

The increasing digitization of calibration processes necessitates a unified and standardized approach to managing calibration data. This work explores the application of object-oriented technologies in the development of Digital Calibration Certificates (DCCs) to address the heterogeneity of calibration data formats and protocols. By employing a structured object-oriented model, the system resolves compatibility issues across diverse instruments, laboratories, and measurement standards, enabling seamless integration and data exchange. The proposed DCC model leverages key object-oriented concepts such as encapsulation, inheritance, and polymorphism to defi ne and manage calibration entities such as certificates, instruments, calibration methods, and environmental conditions. These objects are mapped to essential attributes in calibration systems, ensuring consistency and reusability across platforms. Through this approach, the model promotes interoperability, extensibility, and the ability to handle complex data relationships inherent to calibration activities.

Presentation of Anjali Sharma

5th INTERNATIONAL DCC CONFERENCE

Modelling Digital Calibration Certificates Using Object oriented Technologies To Address Heterogeneity & Harness FAIR Principles

Dr. Anjali Sharma

Sr Principal Scientist & Assoc. Prof. AcSIR

anjali@nplindia.res.in

Introduction

- Calibration ensures **measurement reliability and traceability**.
- DCCs aim to offer a standardized, traceable, and secure solution
- Future calibration certificates will be Digital Calibration Certificates (DCCs)
- DCCs will be successful if we achieve
  - Broad willingness of internal and external stakeholders to engage with DCCs
  - Interoperability

Introduction

- Different level of implementations.
- In 2023-24, 05 APMP NMIs started with the DCC interoperability study.
- The findings were discussed in DCC 4 conference, 2024
- Few APMP NMIs have conducted surveys and awareness programs to understand the APMP Stakeholder's viewpoints about DCC
- Major findings were presented in the BIPM FORUM-MD plenary meeting on 21st Feb 2025
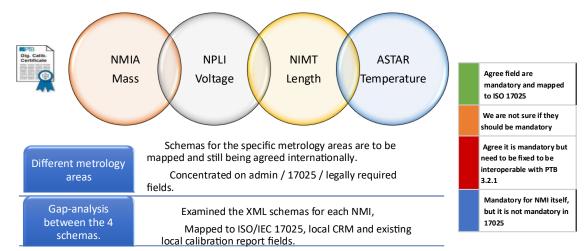
Schema Comparison Gap Analysis

NMIA Mass	
NPLI Voltage	
NIMT Length	
ASTAR Temperature	

Agree field are mandatory and mapped to ISO 17025

We are not sure if they should be mandatory

Agree it is mandatory but need to be fixed to be interoperable with PTB 3.2.1

Mandatory for NMI itself, but it is not mandatory in 17025

Different metrology areas

Schemas for the specific metrology areas are to be mapped and still being agreed internationally.

Concentrated on admin / 17025 / legally required fields.

Gap-analysis between the 4 schemas.

Examined the XML schemas for each NMI,

Mapped to ISO/IEC 17025, local CRM and existing local calibration report fields.

Concerns & Strategy

Stakeholder's Concerns	**Strategy**
❖ Will it require continuous reengineering of code/systems developed for the implementation of DCC (w.r.t new Schema launched)? ❖ How DCC will integrate with the existing systems? ❖ How DCC will cater to the national and international regulations? ❖ What will be the impact on their business if they do not accept DCC? ❖ Why should we adopt DCC? Its too early to invest into the infrastructure, human resources and organizational changes required for implementation of DCC.	❖ Harmonized and standardized DCC schema ❖ Showcase direct benefits through early DCC adopter success stories/Lighthouse Projects ❖ Build trust by providing increased document security and better turnaround time. ❖ *Incremental Approach:* Provide bundle measurement data with the certificate on request. ❖ Solution should not require lot of changes at the receiving end ❖ Give them a business model which shows how its helpful

- NMIs can Push but Pull from stakeholders is critical for DCC to be a success

- DCC is the future but needs more

Why?

❖ Heterogeneous data formats

❖ Heterogeneous calibration schema formats, semantics, languages, laws & regulations, data formats etc.

❖ Manual errors and inefficiencies

❖ Lack of interoperability across platforms

❖ Difficulties in traceability and standardization

APMP-DXFG

EURAMET
TC-IM 1448,
PTB-DKD

FORUM-MD
TG DCC & DRMC
Harmonization

Stakeholders
Feedback

What?

❖ A unified, **machine-readable and interoperable format** for calibration certificates.

❖ Traceable measurement data

❖ Semantics & data

❖ Modelling

Harmonization

• Forum-MD Task Group on DCC & DRMC Harmonization

• APMP-DXFG DCC Interoperability Task Group

• TC-IM 1448

• PTB-DKD

Machine
Readable
schema

Schema
Conversion and
Validation

Semantic framework

Definition of canonical terms

Identification of canonical terms

Understand the Existing Schemas

- **Schema Mapping**: Analyze the existing schemas to understand the different formats, data types, and structures used in various calibration certificates.

- **Identify Key Elements**: Identify the common elements (e.g., measurement data, calibration date, instrument details, etc) and the specific differences in how these elements are represented across the schemas.

Harmonization

- **Create a Canonical Schema**: Design and define in unabmigious way a unified or canonical schema that covers the essential components of all the source schemas.
    - **Identification of fields that are mandatory and mapped to ISO 17025**
    - **Not mandatory fields mapped to ISO 17025**
    - **Mandatory for organization itself, but it is not mandatory in 17025**
    - **Fields required for digitalization**
- Administrative Data:
- Measurement Results: Representation of measurement data, quantities, scales, units, traceability, and uncertainty.

How?
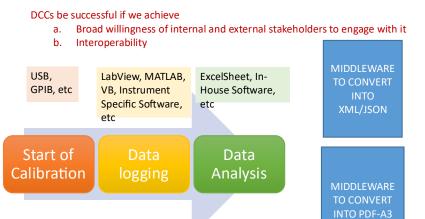
- Develop a **scalable, modular, and ISO-compliant** DCC system.
- Implement a **Model-View-Controller (MVC)** framework for system organization.
- Leverage **object-oriented programming (OOP)** for flexibility and maintainability.
- Ensure **data security, integrity, and authenticity** using cryptographic methods.
- Support **interoperability and digital transformation** in metrology.

NPLI's Approach

DCCs be successful if we achieve
    a. Broad willingness of internal and external stakeholders to engage with it
    b. Interoperability

DCC Generation Workflow

1) User submits calibration request via web interface.

2) Calibration process is executed & relevant data is recorded.

3) DCC generated in machine-readable PDF/A-3 format.

4) SHA-256 checksum is applied for integrity verification.

5) Certificate securely stored & delivered to the customer.

System Architecture Overview

MODEL-VIEW-CONTROLLER (MVC) APPROACH

❖ **Model:** Defines data structures and business logic.
❖ **View:** Presents user interface via Flask.
❖ **Controller:** Manages communication between model and view.

OPEN-SOURCE TECHNOLOGIES USED

❖ **ReactJS v18.3.1**   ❖ **Python v3.11.7**

❖ **Flask v3.0.3**   ❖ **Pandas v2.1.4**

❖ **PostgreSQL v16.3**   ❖ **Miktex v24.4 (Windows)**

Object Oriented Approach

ENCAPSULATION

POLYMORPHISM

INHERITANCE

MODULARITY

ADVANTAGES

•**Improved Maintainability** – Easier debugging and enhancements.
•**Enhanced Collaboration** – Clear structure helps teamwork.
•**Better Code Efficiency** – Optimized through abstraction and reuse.

IMPLEMENTATION

•Used **Encapsulation** to bundle data and methods, improving modularity.
•Applied **Inheritance** to reuse code across related components.
•Leveraged **Polymorphism** to design flexible and scalable systems.

KEY FEATURES

•**Modularity:** Components are self-contained and easy to manage.
•**Reusability:** Common functionalities are inherited, reducing redundancy.
•**Scalability:** New features can be integrated seamlessly.
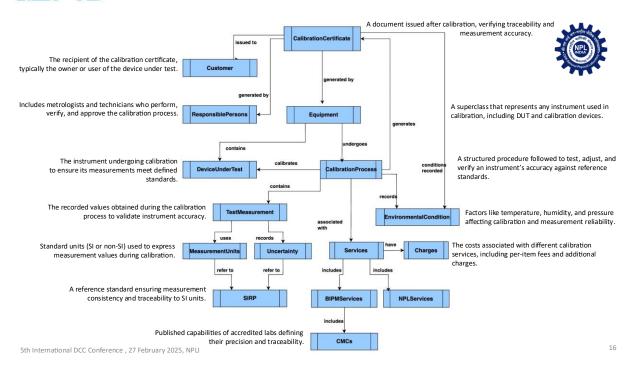
Class Diagrams-Key Entities

1. **CalibrationCertificate**
2. **DeviceUnderTest**
3. **CalibrationProcess**
4. **CalibrationMetrologists**
5. **CustomerDetails**
6. **TestMeasurement**
7. **EnvironmentalCondition**
8. **MeasurementUnits**
9. **Uncertainty**
10. **Statements**
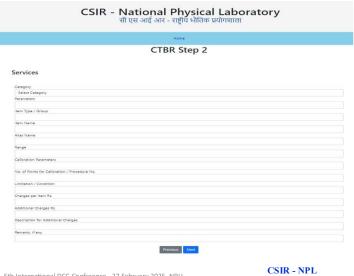
• **CalibrationCertificate → DeviceUnderTest** (Association): A certificate is issued for the device under test.

• **CalibrationCertificate → CalibrationMetrologists** (Association): The metrologists involved in performing, checking, reviewing and signing the certificate.

• **CalibrationCertificate → Customer** (Association): The certificate is issued to a customer.

• **CalibrationProcess → CalibrationMetrologists** (Association): A technician is responsible for the process.

• **CalibrationProcess → EnvironmentalCondition** (Association): The environmental conditions are recorded during the calibration.

• **CalibrationProcess → TestMeasurement** (Aggregation): Multiple test measurements are part of the process.

• **DeviceUnderTest → CalibrationProcess** (Association): An instrument undergoes several calibration processes over time.

A document issued after calibration, verifying traceability and measurement accuracy.

The recipient of the calibration certificate, typically the owner or user of the device under test.

Includes metrologists and technicians who perform, verify, and approve the calibration process.

A superclass that represents any instrument used in calibration, including DUT and calibration devices.

The instrument undergoing calibration to ensure its measurements meet defined standards.

A structured procedure followed to test, adjust, and verify an instrument's accuracy against reference standards.

The recorded values obtained during the calibration process to validate instrument accuracy.

Factors like temperature, humidity, and pressure affecting calibration and measurement reliability.

Standard units (SI or non-SI) used to express measurement values during calibration.

The costs associated with different calibration services, including per-item fees and additional charges.

A reference standard ensuring measurement consistency and traceability to SI units.

Published capabilities of accredited labs defining their precision and traceability.

16

CTBR Form

Exploring ways to map the service categories to the BIPM SIDF

CSIR - NPL

17

CTBR Form

```python
@app.route('/send_charges', methods=['POST'])
def send_charges():
    data = request.get_json()
    totalCharge = data.get('totalCharge')
    print(f"Stored totalCharge: {totalCharge}")
    session['totalCharge'] = totalCharge
    return jsonify({"status": "success", "totalCharge": totalCharge})

@app.route('/ctbr3', methods=['GET'])
def ctbr3():
    totalCharge = session.get('totalCharge')
    print(f"Received totalCharge: {totalCharge}")
    return render_template('ctbr3.html', totalCharge=totalCharge)
```

CSIR - National Physical Laboratory
सी एस आई आर - राष्ट्रीय भौतिक प्रयोगशाला

Home

CTBR Step 3

Instrument(s)/Sample(s)/Reference Material/BND:

SR. No.	Name of Instrument/Sample/Reference Material (BND)	Make/Model/Sr. No./Batch/Lot No. or any other identification	Quantity	Total Charge	Calibration/Testing Requirements/Specifications	Remarks (If Any)	Actions
1							Delete

Add Row

Previous Next

DCC Form

CSIR - National Physical Laboratory
Calibration Services

① Customer Details   ② Administrative Data   ③ DateAnd Location   ④ Manufacturer And Item Information   ⑤ Calibration Laboratory Information   ⑥ Calibration Laboratory Equipment Information   ⑦ Measurement Results   ⑧ Calibration Authorities   ⑨ Measurement Result Calculation

Upload Excel File

Choose File No file chosen

Upload

Uploaded excel document

Sr. No.	Energy applied (J) to UUC	Calculated (J) level	Measured Energy (J) level of UUC	Energy correction (J) (Ecalculated-Emeasured	Uncertainty (J)	Coverage Factor (k)
1	10	9.5	9.6	(-) 0.1	± 0.1	2
2	20	19.3	19.4	(-) 0.1	± 0.1	2
3	50	48.2	48.4	(-) 0.2	± 0.2	2
4	100	97.1	97.4	(-) 0.3	± 0.3	2
5	150	146.1	146.4	(-) 0.3	± 0.5	2
6	270	259.5	260.3	(-) 0.8	± 0.9	2

Sr. No.	Discharge Time	Calculated Discharge Time (ms)	Measured Discharge Time (ms)	Uncertainty (J)	Coverage Factor (k)
1	charge Time (Positive Pulse Wi	6.6	6.4	± 0.1	2.17
2	charge Time (Negative Pulse W	4.4	4.5	± 0.1	2

Sr. No.	Defribillator Analyser Load Resistance (Ω)	Expected Value (Ω)	Measured Value (Ω)	Uncertainty (Ω)	Coverage Factor (k)
1	50	50	50.0179	± 0.00041	2.05

Sr. No.	Defribillator Analyser Load Resistance (Ω)	Expected Value (Ω)	Measured Value (Ω)	Uncertainty (Ω)	Coverage Factor (k)
1	50	50	51.0128	± 0.0005	2.11

DCC (Via Excel)

Generated PDF A3

CSIR - NPL

Customer Welcome Page

```
@app.route('/verify/<checksum>')
def verify(checksum):
    response = registration.get_checksum(checksum=checksum)
    if response and response.status == 'active':
        return jsonify({'message': 'Checksum verification successful', 'checksum': checksum, 'certificate no.': response.certificate_no}), 200
    else:
        return jsonify({'message': 'Checksum verification failed'}), 400
```

CSIR - NPL

Summary

An incremental approach for the **modular and scalable** DCC implementation at NPLI using **MVC architecture** and **object-oriented principles.**

F — Unique certificate identifiers & metadata indexing related to year, date, time, laboratory name and appended with a unique serial number.

A — Secure yet user-friendly digital access through PDF/A3 format with checksum error integration

I — Compatible with diverse calibration systems as measurement data is provided on demand to customers as a csv file embedded in PDF/A3 format.

R — Object-oriented principles and MVC architecture to ensure standardized structure for future expansions.

DCC Value Drivers

GENERATION

- How easy is it to generate a Calibration Certificate
- What level of effort is reliant on a human to generate the Calibration Certificate

SECURITY & TRUST

- How secure is the Calibration Certificate once it is generated
- How can the Calibration Certificate provide trust in the issuing actor
- Can this security/trust be revoked

TRANSMISSION

- How are the Calibration Certificates transmitted
- Is the process secure and automatic
- Can the transmission be reversed

MACHINE & HUMAN READABLE

- Can a machine automatically read and access the data in a Calibration Certificate
- Can a human read and understand the certificate and its implications
- Is the Calibration Certificate data accessible for secondary purposes i.e. analytics and insights

OPEN & STANDARDS

- Is the Calibration Certificate technology open and does it prevent vendor/technology lock in
- Does it facilitate standards through either design or configuration

EASE OF ACCESS

- Does the Calibration Certificate facilitate access for all users i.e. does not require new software or technology
- Are the barriers to entry low to ensure adoption
- Are the skills easy to learn/procure

LONGEVITY & PRESERVATION

- Does the creation and output of the Calibration Certificate allow for long term reference and preservation
- Will the Calibration Certificates be supported and accessible by future technology

EXTENSIBILITY

- Does the underlying technology and Calibration Certificate design allow for flexibility to address jurisdiction differences (i.e. internationally compatible) and future industry changes
- Does the underlying design support growing into other certificates (investment reuse)
- Can we utilise middleware to extend the DCC solution to other systems within the organisation

Path Ahead
NPL, India

- Recognises the need to evolve in small steps towards delivering digital products to our customers.

- Establish a strong IT infrastructure required for a secured and reliable system for generating electronic calibration certificates.

- Awareness programs for both internal and external stakeholders

- Path ahead for us is to conduct internal trials and evaluation on DCC and to find out the actual needs in industry (e.g. whether a PDF/A-3 report with embedded raw data is sufficient for the near future).

- Create models for DCC

Acknowledgment

Thank you !

💡 Questions?

Anjali Sharma, NPLI

✉ **anjali@nplindia.res.in**

5th International DCC Conference , 27 February 2025, NPLI   28

P08   DCC Sharing within a Government Agency

Presenting author: Sajiv Perera, Measurement Canada
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Additional authors: John Scott john.scott2@ised-isde.gc.ca, Daljit Dhaliwal
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ABSTRACT

Measurement Canada [1] is the legal metrology agency responsible for trade measurement within the Government of Canada. Calibration of our primary standards is traced through and performed by the National Research Council of Canada, [2] and in some cases other designated laboratories as well. We provide calibration and certification services that are used by Measurement Canada's post market sector and which in turn provides services to Measurement Canada Authorized Service Providers (ASPs) [3].

In this presentation we will briefly show how our agency's size and narrow scope allows for rapid implementation and is ideal for early testing of machine-readable information and allows us to be agile in changes to the DCC standard. We will demonstrate our rationale for starting our digital certificate project with electricity measuring standards, as well as the wider context in how that information can be used in subsequent certifications. We will demonstrate how we transmit this information from our labs to our customers while maintaining traceability. We will highlight the potential increase in efficiency and improved quality which can be achieved by incorporating machine readable certification data within our department.

Finally, we will outline our goals for cooperating with other government organizations to receive and distribute FAIR [4] measurement data. This will demonstrate a use case for DCC that does not simply encompass a single agency or process, but how the DCC may be used across sectors and organizations.

PTB

References:

[1] Measurement Canada, Government of Canada,
URL: https://ised-isde.canada.ca/site/measurement-canada/
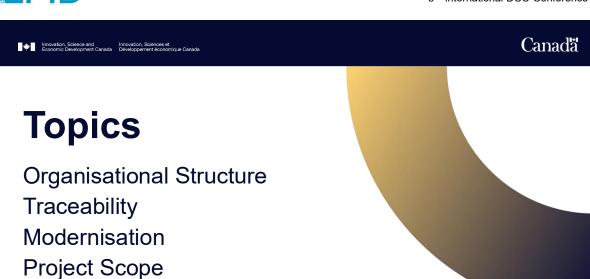
[2] National Research Council, Government of Canada, URL: https://nrc.canada.ca/en

[3] "Authorized service providers", Measurement Canada, Government of Canada, URL:
https://ised-isde.canada.ca/site/measurement-canada/en/authorized-service-providers

[4] "Roadmap for Open Science", Government of Canada,
https://science.gc.ca/site/science/en/office-chief-science-advisor/open-science/roadmap-open-science

Presentation of Sajiv Perera

Innovation, Science and Economic Development Canada   Innovation, Sciences et Développement économique Canada

Canada

DCC Sharing in a Government Agency

Measurement Canada

2025-02-27

Topics

Organisational Structure

Traceability

Modernisation

Project Scope

Automated DCC Generation

Roadmap

Organisational Structure

Minister of Innovation, Science and Economic Development

National Research Council of Canada (NRC) ~ 4000 👥	Ministry of Innovation, Science and Economic Development
	Small business and marketplace services branch
	Measurement Canada ~ 300 👥

3

Traceability

Primary standard for electrical power traceable to NRC
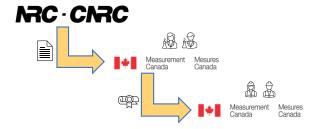
Incoming calibration information from the NRC still manual entry in our systems.

Our certificates generated by directly reading this information from database.

4

Modernisation

- Calibration results still transmitted in a static format, not machine-readable.
- Opportunity for improvement through digital transformation of this traceability chain.

5

Project Scope

Narrow scope of work allows for quick implementation and acceptance.

Large impact due to large volume of data transmitted.

Beneficial to increase efficiency of existing process.

6

Calibration of an Electrical Standard

- Chosen due to:
  - Certification procedure already largely automated
  - Large amount of repetitive data created
    - Low cost to calculate error values
  - Large set of correction values
    - Machine readable data saves input time and reduces transcription errors

7

Automated DCC Generation


```python
self.dcc_results = our_worksheet.get_results()

# Set up our Admin variables
self.lab_address = init_lab_address
self.lab_contact = init_lab_contact

self.document_number=our_worksheet.get_document_number()
self.revision=our_worksheet.get_revision()
self.project_number=our_worksheet.get_project_number()
self.standard_group=our_worksheet.get_standard_group()
self.reference_standard=our_worksheet.get_reference_standard()
self.serial_number=our_worksheet.get_serial_number()
self.maufacturer=our_worksheet.get_maufacturer()
self.characteristics=our_worksheet.get_characteristics()


self.date=str(our_worksheet.get_date())[:10]
self.calibration_date=str(our_worksheet.get_calibration_date())[:10]

self.procedures_used=our_worksheet.get_procedures_used()
self.software_used=our_worksheet.get_software_used()
self.owner=our_worksheet.get_owner()
```

https://ar.inspiredpencil.com/pictures -2023/microsoft -excel-logo-png

https://cdn -icons-png.flaticon.com/512/9496/9496555.png

Roadmap

Receiving data from NRC

🖼️Tool for automatic parsing of existing calibration data

❓Receive FAIR traceable data for primary standard

Reading data from local database

✅Convert SQL Queries from VBA

✅API Layer in Python

✅Generating JSON test results

Generating DCC

✅DCC generator in python with GUI

🚧Reading JSON results directly into generator

❓Fully replace Excel method

Transmission and Input

🚧Method for direct input into field consoles

🖼️Tool to regenerate human-readable certificate

🖼️Replace legacy certificates with DCC by default

🖼️Planned
🚧In progress
✅Complete
❓Proposed

Roadmap

- Further opportunities
  - DCC for Gas Mixtures
  - Acceptance of external DCC

- Timeline
  - Lab calibration-to-DCC process complete by spring 2025

10

Innovation, Science and Economic Development Canada   Innovation, Sciences et Développement économique Canada

Canada

Thank you! / Merci!

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References:

- NRC Canada - nrc.canada.ca
- Measurement Canada - ised-isde.canada.ca/site/measurement-canada
- FAIR Principles - www.go-fair.org/fair-principles/

Day 3 (2025-02-27 Thursday)
Parallel Session: Schema & Semantics
(chair: Robert Hanisch)

026   Augmenting the DCC Framework with the DSI Ontology: Enabling Semantic Web Integration in Calibration Data Management

Presenting author: Moritz Jordan
Email: moritz.jordan@ptb.de
Additional authors: Giacomo Lanza Giacomo.Lanza@ptb.de, Daniel Hutzschenreuter Daniel.Hutzschenreuter@ptb.de

ABSTRACT

The Digital System of Units (DSI) Ontology represents a crucial step toward enabling seamless interoperability, reasoning, and traceability in metrology within the framework of Digital Calibration Certificates (DCCs). This presentation highlights the role of the DSI Ontology as a bridge between related standards and schemas, including the SI Reference Point, the DSI XML Schema, and the DCC Schema/Ontology. By aligning these frameworks, the ontology ensures consistency and coherence in the representation and exchange of calibration data.

Through its modular structure, the DSI Ontology formalizes essential concepts such as quantities, units, and measurement uncertainties, enabling not only smarter querying but also logical reasoning over calibration data. This reasoning capability facilitates the inference of implicit knowledge, validation of data consistency, and automation of workflows within metrology knowledge graphs. A core focus will be on showcasing its connections to related

ontologies and standards via an intuitive diagram, as well as demonstrating its use in real-world calibration scenarios.

The presentation will also delve into the ontology's adherence to international standards, its validation process, and tools supporting its development and application. Finally, we explore future directions for expanding the ontology to further facilitate automation, reasoning, and precision in calibration processes, driving innovation in the metrology domain.

Presentation of Moritz Jordan

Physikalisch-Technische Bundesanstalt
Braunschweig and Berlin
National Metrology Institute

The D-SI Ontology

Enabling Semantic Web Integration into the DCC

Moritz Jordan, Giacomo Lanza,
Daniel Hutzschenreuter, PTB

Motivation for the D-SI Ontology

Why do we need a digital representation of SI?
- Make it more *FAIR*
- Increase interoperability by linking to other ontologies
- Format-agnostic semantic model of the Digital SI
   -> More applications possible (API, Data Repositories...)

SI Brochure > D-SI XML Schema > D-SI Update 2.2.0 > D-SI Ontology

D-SI

D-SI XSD Version 2.2.1

The Role of Ontologies in Metrology

- Benefits of using ontologies: interoperability, formal semantics, automated reasoning
- Reasoning can detect inconsistencies,
- BIPM SI Reference Point -> metrological perspective, not complete
- QUDT -> Community Project, application perspective

What the D-SI Ontology Covers

- Quantity values (Real, Constant, Complex, etc…)
- Measurement uncertainty (Standard, Expanded, Multivariate…)
- Measurement units (D-SI, BIPM SI Ref. Framework)
- Quantity kind (BIPM SI Ref. Framework, QUDT)
- Fundamental constants as instances of Constant (i.e. Planck)
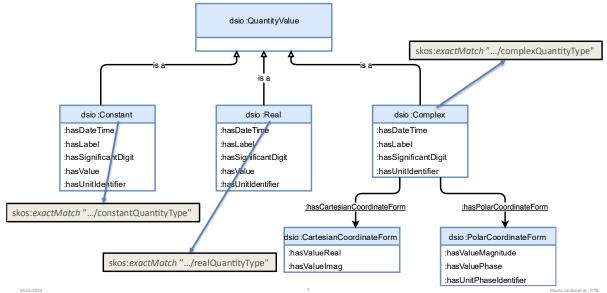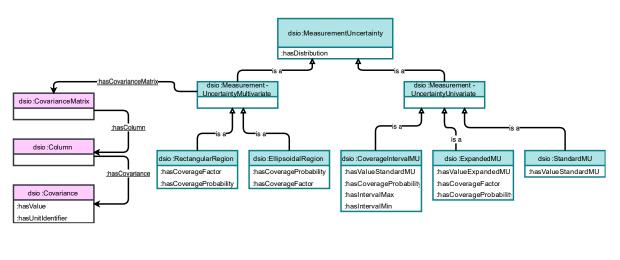
Key Components: QuantityValue

Key Components: MeasurementUncertainty
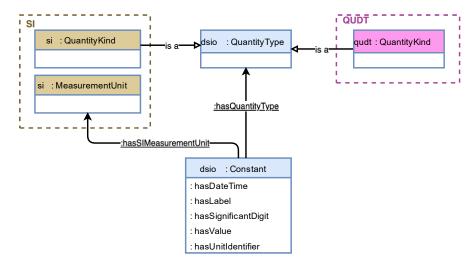
Alignment with BIPM SI and QUDT
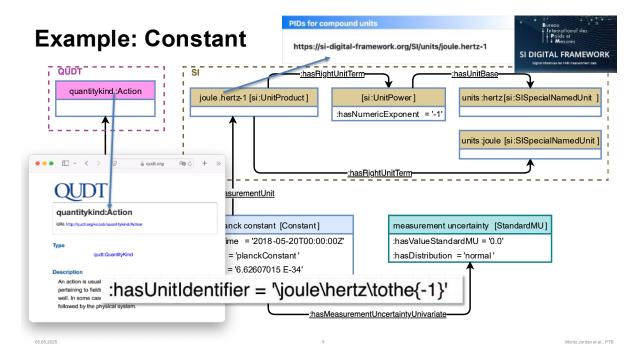
Example: Constant

Validation & Challenges
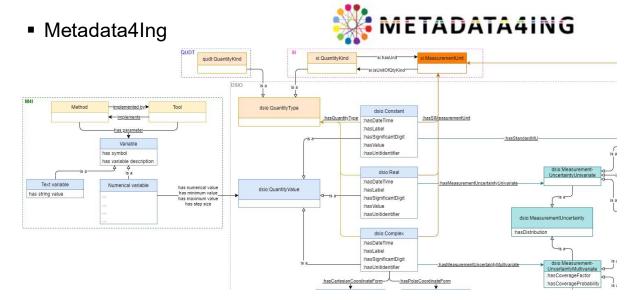
- Python Mapping for converting XML D-SI data to DSIO instances
- Testing conversion with pytest for each instance of QuantityValue
- Reasoning with RDFS, OWLRL and HermiT
- Validating data instances with SHACL
- Limitations of OWL to map XML Simple Type with restrictions on xsd:double

DSI Ontology Applications

- Metadata4Ing

Future Work & Roadmap

- Expanding ontology coverage (List, RealXMLList, Hybrid..)
- Links to VIM, Links to chapters in GUM
- Publish D-SI Ontology (Documentation, Use Cases, Tools XML2DSIO)

About

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027   Changes in DCC Schema V.3.3.0

Presenting author: Muhammed-Ali Demir
Email: muhammed.demir@ptb.de
Additional authors: Et. al.

ABSTRACT

In this presentation we will show the latest changes in the DCC schema version V.3.3.0 with examples. The changes consist of changes to the documentation. Changes due to update of the referenced SI schema, consistency changes and additions to the schema.

Presentation of Muhammed-Ali Demir

**Physikalisch-Technische Bundesanstalt
Braunschweig and Berlin**
National Metrology Institute
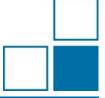
Changes in DCC Schema V.3.3.0

5th DCC Conference

Muhammed-Ali Demir et al., WG1.24

New DCC schema V.3.3.0

- Release date: 29th of October 2024
- Source of changes:
  - DKD cross sectional group
  - DCC Core Team
- Let's have a closer look…

Changes in DCC Schema V.3.3.0

- Schema documentation
- D-SI Schema Update
- Consistency
- Additions
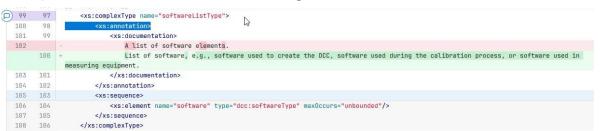
Schema documentation

- Updated xs:documentation-Tags

```
 99   97        <xs:complexType name="softwareListType">
100   98            <xs:annotation>
101   99                <xs:documentation>
102   -                    A list of software elements.
      100  +                    List of software, e.g., software used to create the DCC, software used during the calibration process, or software used in
                        measuring equipment.
103  101                </xs:documentation>
104  102            </xs:annotation>
105  103            <xs:sequence>
106  104                <xs:element name="software" type="dcc:softwareType" maxOccurs="unbounded"/>
107  105            </xs:sequence>
108  106        </xs:complexType>
```

D-SI Schema 1/5

- Update from D-SI version 2.1.0 to 2.2.1

```
<xs:import namespace="https://ptb.de/si"
- schemaLocation="https://ptb.de/si/v2.1.0/SI_Format.xsd"/>
+ schemaLocation="https://ptb.de/si/v2.2.1/SI_Format.xsd"/>
```

- primitiveQuantityType/ quantityType now contain also: si:complexListXMLList
- Example: dcc:quantity

D-SI Schema 2/5

```
<xs:complexType name="quantityType">
    <xs:sequence>
        <xs:element name="name" type="dcc:textType" minOccurs="0"/>
        <xs:element name="description" type="dcc:richContentType" minOccurs="0"/>
        <xs:choice>
            <xs:element name="noQuantity" type="dcc:richContentType"/>
            <xs:element name="charsXMLList" type="dcc:charsXMLListType"/>
            <xs:element ref="si:real"/>
            <xs:element ref="si:list"/>
            <xs:element ref="si:hybrid"/>
            <xs:element ref="si:complex"/>
            <xs:element ref="si:constant"/>
            <xs:element ref="si:realListXMLList"/>
            <xs:element ref="si:complexListXMLList"/>
        </xs:choice>
        <xs:element name="relativeUncertainty" type="dcc:relativeUncertaintyType" minOccurs="0" />
        <xs:element name="usedMethods" type="dcc:usedMethodListType" minOccurs="0"/>
        <xs:element name="usedSoftware" type="dcc:softwareListType" minOccurs="0"/>
        <xs:element name="measuringEquipments" type="dcc:measuringEquipmentListType" minOccurs="0"/>
        <xs:element name="influenceConditions" type="dcc:influenceConditionListType" minOccurs="0"/>
        <xs:element name="measurementMetaData" type="dcc:measurementMetaDataListType" minOccurs="0"/>
    </xs:sequence>
    <xs:attribute name="id" type="xs:ID" use="optional"/>
    <xs:attribute name="refId" type="xs:IDREFS" use="optional"/>
    <xs:attribute name="refType" type="dcc:refTypesType" use="optional"/>
</xs:complexType>
```

D-SI Schema 3/5

```
<!-- cartesian complex quantity -->
<si:complex>
    <si:label>amplifier signal</si:label>
    <si:valueReal>-10.310</si:valueReal>
    <si:valueImag>5.010</si:valueImag>
    <si:unit>\volt</si:unit>
    <si:dateTime>2024-12-03T13:25:00Z</si:dateTime>
</si:complex>

<!-- polar coordinate complex quantity -->
<si:complex>
    <si:label>amplifier signal</si:label>
    <si:valueMagnitude>11.463</si:valueMagnitude>
    <si:valuePhase>2.689</si:valuePhase>
    <si:unit>\volt</si:unit>
    <si:unitPhase>\radian</si:unitPhase>
    <si:dateTime>2024-12-03T13:25:00Z</si:dateTime>
</si:complex>
```

```
<!-- cartesian complex list quantity -->
<si:complexListXMLList>
    <si:labelXMLList>amplifier signal</si:labelXMLList>
    <si:valueRealXMLList>-10.310 ...</si:valueRealXMLList>
    <si:valueImagXMLList>5.010 ...</si:valueImagXMLList>
    <si:unitXMLList>\volt ...</si:unitXMLList>
    <si:dateTimeXMLList>2024-12-03T13:25:00Z ...</si:dateTimeXMLList>
</si:complexListXMLList>

<!-- polar coordinate complex list quantity -->
<si:complexListXMLList>
    <si:labelXMLList>amplifier signal</si:labelXMLList>
    <si:valueMagnitudeXMLList>11.463 ...</si:valueMagnitudeXMLList>
    <si:valuePhaseXMLList>2.689 ...</si:valuePhaseXMLList>
    <si:unitXMLList>\volt ...</si:unitXMLList>
    <si:unitPhaseXMLList>\radian ...</si:unitPhaseXMLList>
    <si:dateTimeXMLList>2024-12-03T13:25:00Z ...</si:dateTimeXMLList>
</si:complexListXMLList>
```

D-SI Schema 4/5

- Update from D-SI version 2.1.0 to 2.2.1

```
<xs:import namespace="https://ptb.de/si"
- schemaLocation="https://ptb.de/si/v2.1.0/SI_Format.xsd"/>
+ schemaLocation="https://ptb.de/si/v2.2.1/SI_Format.xsd"/>
```

- Deprecated uncertrainty types -> use measurementUncertaintyUnivariate instead

```
<!-- optional choice of uncertainty statements -->
<xs:choice minOccurs="0">
    <xs:annotation>
        <xs:documentation xml:lang="en">
            univariate measurement uncertainty
        </xs:documentation>
    </xs:annotation>
    <xs:element name="measurementUncertaintyUnivariate" type="si:measurementUncertaintyUnivariateType"/>
    <!-- deprecated types -->
    <xs:element name="expandedUnc" type="si:expandedUncType"/>
    <xs:element name="coverageInterval" type="si:coverageIntervalType"/>
</xs:choice>
```

D-SI Schema 5/5

```
<si:realListXMLList>
        <si:valueXMLList>0.072 0.089 0.107 -0.009 -0.084</si:valueXMLList>
        <si:unitXMLList>\kelvin</si:unitXMLList>
        <si:expandedUncXMLList>
                <si:uncertaintyXMLList>0.061</si:uncertaintyXMLList>
                <si:coverageFactorXMLList>2</si:coverageFactorXMLList>
                <si:coverageProbabilityXMLList>0.95</si:coverageProbabilityXMLList>
                <si:distributionXMLList>normal</si:distributionXMLList>
        </si:expandedUncXMLList>
</si:realListXMLList>
```

```
<si:realListXMLList>
        <si:valueXMLList>0.072 0.089 0.107 -0.009 -0.084</si:valueXMLList>
        <si:unitXMLList>\kelvin</si:unitXMLList>
        <si:measurementUncertaintyUnivariateXMLList>
                <si:expandedMUXMLList>
                        <si:valueExpandedMUXMLList>0.061</si:valueExpandedMUXMLList>
                        <si:coverageFactorXMLList>2</si:coverageFactorXMLList>
                        <si:coverageProbabilityXMLList>0.95</si:coverageProbabilityXMLList>
                        <si:distributionXMLList>normal</si:distributionXMLList>
                </si:expandedMUXMLList>
        </si:measurementUncertaintyUnivariateXMLList>
</si:realListXMLList>
```

Possible children of si:measurementUncertaintyUnivariate …:
- standardMU
- expandedMU
- coverageIntervalMU

Consistency 1/4

- Added dcc:link everywhere parallel to dcc:reference, in order to make it possible to specify links specifically e.g., in equipmentClassType

- Updated type from dcc:link to xs:anyURI instead of string (machine interpretability of the schema)

```
- <xs:element name="link" type="dcc:notEmptyStringType"/>
+ <xs:element name="link" type="xs:anyURI"/>
```

```
<dcc:link>https://forcetechnology.com/en/events/2024/</dcc:link>
```

Consistency 2/4

- contactType now has a refType (compare to contactNotStrictType)

```
<xs:complexType name="contactType">
    <xs:sequence>
        <xs:element name="name" type="dcc:textType"/>
        <xs:element name="eMail" type="dcc:notEmptyStringType" minOccur
        <xs:element name="phone" type="dcc:notEmptyStringType" minOccur
        <xs:element name="fax" type="dcc:notEmptyStringType" minOccurs:
        <xs:element name="link" type="xs:anyURI" minOccurs="0"/>
        <xs:element name="location" type="dcc:locationType"/>
        <xs:element name="descriptionData" type="dcc:byteDataType" min
    </xs:sequence>
    <xs:attribute name="id" type="xs:ID" use="optional"/>
    <xs:attribute name="refId" type="xs:IDREFS" use="optional"/>
+   <xs:attribute name="refType" type="dcc:refTypesType" use="optional"/>
</xs:complexType>
```

```
<dcc:contact refType="...">
    <dcc:name>
        <dcc:content>Muhammed-Ali Demir</dcc:content>
    </dcc:name>
    <dcc:eMail>muhammed.demir@ptb.de</dcc:eMail>
    <dcc:location>
        <dcc:city>Braunschweig</dcc:city>
    </dcc:location>
</dcc:contact>
```

Consistency 3/4

- Added attribute "refId" everywhere, where attribute "id" was defined e.g., in softwareType

```
<xs:complexType name="softwareType">
    <xs:annotation>
        <xs:documentation>
            Information about a software including its name, version and a desc
            Information about the software, including its name, version, type,
        </xs:documentation>
    </xs:annotation>
    <xs:sequence>
        ...
    </xs:sequence>
    <xs:attribute name="id" type="xs:ID" use="optional"/>
+   <xs:attribute name="refId" type="xs:IDREFS" use="optional"/>
    <xs:attribute name="refType" type="dcc:refTypesType" use="optional"/>
</xs:complexType>
```

```
<dcc:software refId="xyz">
    <dcc:name>
        <dcc:content lang="en">Firmware abc</dcc:content>
    </dcc:name>
    <dcc:release>1.0</dcc:release>
</dcc:software>
```

Consistency 4/4

- Added id & refId to itemListType

```
<xs:complexType name="itemListType">
    <xs:sequence>
        <xs:element name="owner" type="dcc:contactType" minOccurs="0"/>
        <xs:element name="manufacturer" type="dcc:contactNotStrictType" minOccurs="0" />
        <xs:element name="identifications" type="dcc:identificationListType" minOccurs="0"/>
        <xs:element name="item" type="dcc:itemType" maxOccurs="unbounded"/>
    </xs:sequence>
+    <xs:attribute name="id" type="xs:ID" use="optional"/>
+    <xs:attribute name="refId" type="xs:IDREFS" use="optional"/>
    </xs:complexType>
```

```
<dcc:items id="items01" ref="xyz">
    <dcc:item>
    </dcc:item>
</dcc:items>
```

Additions 1/4

- Items can now be nested to any depth, examples: PXI system with slots/sensors, MEMS – Inertial measurement unit

```
<xs:complexType name="itemType">
    <xs:sequence>
        <xs:element name="name" type="dcc:textType"/>
        <xs:element name="equipmentClass" type="dcc:equipmentClassType" minOccurs="0" maxOccurs="unbounded"/>
        <xs:element name="description" type="dcc:richContentType" minOccurs="0"/>
+        <xs:element name="owner" type="dcc:contactType" minOccurs="0"/>
        <xs:element name="installedSoftwares" type="dcc:softwareListType" minOccurs="0" />
        <xs:element name="manufacturer" type="dcc:contactNotStrictType" minOccurs="0"/>
        <xs:element name="model" type="dcc:notEmptyStringType" minOccurs="0"/>
        <xs:element name="identifications" type="dcc:identificationListType"/>
        <xs:element name="itemQuantities" type="dcc:itemQuantityListType" minOccurs="0"/>
+        <xs:element name="subItems" type="dcc:itemListType" minOccurs="0"/>
    </xs:sequence>
    <xs:attribute name="id" type="xs:ID" use="optional"/>
+    <xs:attribute name="refId" type="xs:IDREFS" use="optional"/>
    <xs:attribute name="refType" type="dcc:refTypesType" use="optional"/>
    </xs:complexType>
```

```
<dcc:items>
    <dcc:item>
        <dcc:name>
            <dcc:content lang="en">Piston-operated pipette</dcc:content>
            <dcc:content lang="de">Kolbenhubpipette</dcc:content>
        </dcc:name>
        <dcc:identifications>
        <dcc:subItems>
            <dcc:item>
                <dcc:name>
                    <dcc:content lang="en">Pipette</dcc:content>
                    <dcc:content lang="de">Pipette</dcc:content>
                </dcc:name>
                <dcc:identifications>
            </dcc:item>
            <dcc:item>
                <dcc:name>
                    <dcc:content lang="en">Pipette tip</dcc:content>
                    <dcc:content lang="de">Pipettenspitze</dcc:content>
                </dcc:name>
                <dcc:identifications>
            </dcc:item>
        </dcc:subItems>
    </dcc:item>
</dcc:items>
```

Additions 2/4

- measuringEquipmentType now has installedSoftware to specify software for dcc:measuringEquipment

Additions 3/4

- It is now possible to place quantities in dcc:usedMethod so that quantities can now be specified in a machine interpretable manner
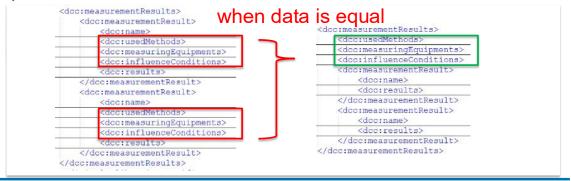
Additions 4/4

- Now usedMethods, usedSoftware, measuringEquipments, influenceConditions and measurementMetaData can be placed in dcc:measurementResults

when data is equal

Information sources

- D-SI V.2.2.1: link
- D-SI example for si:complex: link
- DCC release page: https://gitlab.com/ptb/dcc/xsd-dcc/-/releases/v3.3.0
- DCC schema link: https://www.ptb.de/dcc/v3.3.0/dcc.xsd
- Documentation: https://www.ptb.de/dcc/v3.3.0/autogenerated-docs/Doku Oxygen 3.3.0.html
- Some XML fragments from the BAM temperature GP (Michael Melzer et al.) link

Contributions

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Version: 02/25

028   An In-Depth Look at the DCX Schema

Presenting author: David Balslev-Harder; DFM – Danish National Metrology Institute
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Additional authors: Søren Kynde srk@dfm.dk

ABSTRACT

The advent of Digital Calibration Certificates (DCC) marks a significant advancement in the field of metrology, offering enhanced accuracy, traceability, and interoperability. This presentation delves into the DCX Schema, a pivotal component in the implementation of DCCs. The DCX schema has been developed by DFM, with input from members of TC-IM

1448 WG1&2, aiming to investigate the use of reference pointers within the XML rather than the tree-structure emphasis applied in the PTB DCC-schema.

We begin with an overview of the DCX Schema's overall XSD structure, highlighting its robust framework designed to ensure data integrity and consistency. The schema's alignment with ISO 80000 standards is discussed, emphasizing its role in maintaining uniformity in the representation of physical quantities. Additionally, the integration of the BIPM-SI-Reference point within the schema is explored, underscoring its importance in providing a universally accepted reference for measurements.

A critical aspect of the DCX Schema is its ability to restrict entry-data, thereby preventing erroneous or non-compliant data entries. This presentation will outline the specific restrictions imposed by the schema, providing a comprehensive list of relevant constraints that ensure the accuracy and reliability of calibration data.

Furthermore, the schema's design includes human-readable fields on all elements, facilitating ease of interpretation and verification by end-users. This feature enhances the usability of DCCs, making them accessible to a broader audience, including those without extensive technical expertise.

In conclusion, the DCX Schema represents a significant step forward in the digitalization of calibration certificates, offering a standardized, reliable, and user-friendly solution for the metrology community.

Outline of presentation

o DCX Schema Overview
o Incorporation of VIM, ISO 80000 and BIPM-SI-Reference point
o Data interpretation integrity using xsd restrictions
o Human-Readable Fields
o Solution available on github.com/TC-IM-1448/DCC-Tables
o See the implementation examples and user-interfaces in other presentations.

Presentation of David Balslev-Harder

An In-Depth Look at the DCX Schema

5th international DCC conference,

February 27th 2025

By David Balslev-Harder & Søren R. Kynde
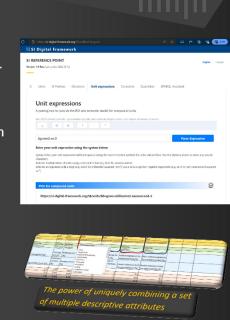
DFM
Danish National Metrology Institute

DFM

DFM's incentive for DCC:
To support creation of FAIR DCC formats that are globally recognized/standardized, in order to support quality and efficiency in production companies, through automation.

Develop simple user interface software tool that can accept and modify DCC, DCR and Templates regardless of origin.
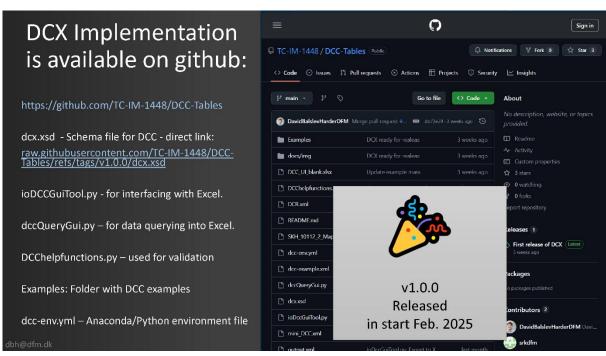
DFM receives funding by:
Danish Agency for Institutions and Educational Grants
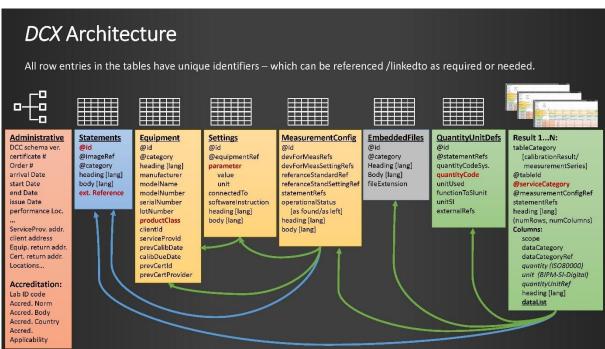
Schema updates since last year

1. *Introduced dcx: as namespace*
2. *DCR and Templates incorporated in the same schema.*
3. Introduced human readable fields for all elements.
4. *Simplified layout of administrative data*
5. New default system for Quantities and Units based on ISO 80000 and BIPM SI-Digital-Framework unit representation introduced in schema including:
   1. Incorporated in the data result tables.
   2. RegEx for validating BIPM-SI unit expression.
   3. Section for defining other quantities and units.
6. Restriction on data type in columns depending on dataCategory introduced
7. Simplified and improved query expressions for extracting measurement data and meta data.

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The power of uniquely combining a set of multiple descriptive attributes

DCX Implementation is available on github:

https://github.com/TC-IM-1448/DCC-Tables

dcx.xsd - Schema file for DCC - direct link:
raw.githubusercontent.com/TC-IM-1448/DCC-Tables/refs/tags/v1.0.0/dcx.xsd

ioDCCGuiTool.py - for interfacing with Excel.

dccQueryGui.py – for data querying into Excel.

DCChelpfunctions.py – used for validation

Examples: Folder with DCC examples

dcc-env.yml – Anaconda/Python environment file

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v1.0.0
Released
in start Feb. 2025

DCX Architecture

All row entries in the tables have unique identifiers – which can be referenced /linkedto as required or needed.

Administrative
DCC schema ver.
certificate #
Order #
arrival Date
start Date
end Date
issue Date
performance Loc.
...
ServiceProv. addr.
client address
Equip. return addr.
Cert. return addr.
Locations...

Accreditation:
Lab ID code
Accred. Norm
Accred. Body
Accred. Country
Accred.
Applicability

Statements
@id
@imageRef
@category
heading [lang]
body [lang]
ext. Reference

Equipment
@id
@category
heading [lang]
manufacturer
modelName
modelNumber
serialNumber
lotNumber
productClass
clientId
serviceProvId
prevCalibDate
calibDueDate
prevCertId
prevCertProvider

Settings
@id
@equipmentRef
parameter
    value
    unit
connectedTo
softwareInstruction
heading [lang]
body [lang]

MeasurementConfig
@id
devForMeasRefs
devForMeasSettingRefs
referanceStandardRef
referanceStandSettingRef
statementRefs
operationalStatus
    [as found/as left]
heading [lang]
body [lang]

EmbeddedFiles
@id
@category
Heading [lang]
Body [lang]
fileExtension

QuantityUnitDefs
@id
@statementRefs
quantityCodeSys.
quantityCode
unitUsed
functionToSIunit
unitSI
externalRefs

Result 1...N:
tableCategory
    [calibrationResult/
    measurementSeries]
@tableId
@serviceCategory
@measurementConfigRef
statementRefs
heading [lang]
(numRows, numColumns)
Columns:
    scope
    dataCategory
    dataCategoryRef
    quantity (ISO80000)
    unit (BIPM-SI-Digital)
    quantityUnitRef
    heading [lang]
    dataList

Basic structure — dcx.xsd (schema)

- Administrative data
- Statements
- Description of equipment
- Specification of equipment settings
- List of unique measurement configurations
- Results
  - Each result refers to a unique measurement configuration
- Annexes
  - Definitions of non SI-units
  - List of embedded files
  - List of codeable elements

```xml
<xs:complexType name="digitalCalibrationExchangeType">
    <xs:annotation>
        <xs:documentation>
        </xs:documentation>
    </xs:annotation>
    <xs:sequence>
        <xs:element name="title" type="dcx:transactionContentFieldType"/>
        <xs:element name="subtitle" type="dcx:fieldType" minOccurs="0" maxOccurs="un
        <xs:element name="administrativeData" type="dcx:administrativeDataType"/>
        <xs:element name="statementList" type="dcx:statementListType" minOccurs="0"/
        <xs:element name="equipmentList" type="dcx:equipmentListType"/>
        <xs:element name="settingList" type="dcx:settingListType" minOccurs="0"/>
        <xs:element name="measurementConfigList" type="dcx:measurementConfigListType
        <xs:element name="measurementResultList" type="dcx:measurementResultListType
            <xs:unique name="calibrationResult">
                <xs:selector xpath="dcx:calibrationResult"/>
                <xs:field xpath="@measurementConfigRef"/>
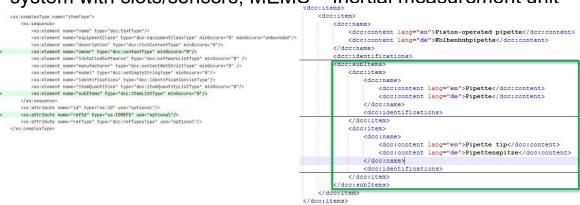            </xs:unique>
        </xs:element>
        <xs:element name="quantityUnitDefList" type="dcx:quantityUnitDefListType" mi
        <xs:element name="embeddedFileList" type="dcx:embeddedFileListType" maxOccur
        <xs:element name="codeableElementsAnnex" type="dcx:anyType" minOccurs="0"/>
    </xs:sequence>
    <xs:attribute name="schemaVersion" use="required">
        <xs:simpleType>
            <xs:restriction base="xs:string">
                <xs:pattern value="1\.0\.0"/>
            </xs:restriction>
        </xs:simpleType>
    </xs:attribute>
</xs:complexType>
```

Declaration of the document and Titles

Temperature.xml (document)

```xml
<?xml version="1.0" ?>
<dcx:digitalCalibrationExchange schemaVersion="1.0.0" …>
    <dcx:title value="digitalCalibrationCertificate">
        <dcx:heading lang="en">Calibration certificate</dcx:heading>
        <dcx:heading lang="da">Kalibreringscertifikat</dcx:heading>
    </dcx:title>
    <dcx:subtitle>
        <dcx:heading lang="en">Temperature sensor</dcx:heading>
        <dcx:heading lang="da">Temperaturprobe</dcx:heading>
    </dcx:subtitle>
    <dcx:administrativeData>
        <dcx:heading lang="en">Administrative data</dcx:heading>
        <dcx:heading lang="da">Administrative data</dcx:heading>
        <dcx:coreData>
            <dcx:uniqueDocumentIdentifier value="T2502_2">
                <dcx:heading lang="en">Certificate number</dcx:heading>
                <dcx:heading lang="da">Certifkatnummer</dcx:heading>
            </dcx:uniqueDocumentIdentifier>
            …
```

dcx.xsd (schema)

```xml
<xs:complexType name="transactionContentFieldType">
    <xs:complexContent>
        <xs:extension base="dcx:fieldType">
            <xs:attribute name="value" type="dcx:transactionContentType"
                          use="required"/>
        </xs:extension>
    </xs:complexContent>
</xs:complexType>

<xs:simpleType name="transactionContentType">
    <xs:restriction base="xs:string">
        <xs:enumeration value="digitalCalibrationCertificate"/>
        <xs:enumeration value="digitalTestReport"/>
        <xs:enumeration value="digitalReportOfSampling"/>
        <xs:enumeration value="digitalMeasurementReport"/>
        <xs:enumeration value="digitalExaminationCertificate"/>
        <xs:enumeration value="digitalCertificateOfConformity"/>

        <xs:enumeration value="request:digitalCalibrationCertificate"/>
        <xs:enumeration value="request:digitalTestReport"/>
        <xs:enumeration value="request:digitalReportOfSampling"/>
        <xs:enumeration value="request:digitalMeasurementReport"/>
        <xs:enumeration value="request:digitalExaminationCertificate"/>
        <xs:enumeration value="request:digitalCertificateOfConformity"/>

        <xs:enumeration value="template:digitalCalibrationCertificate"/>
        <xs:enumeration value="template:digitalTestReport"/>
    </xs:restriction>
</xs:simpleType>
```

Administrative data: Finite Tree structure

mini_DCC.xml (Document)

```xml
<?xml version='1.0' encoding='utf-8'?>
<dcx:digitalCalibrationExchange xmlns:dcx="https://dfm.dk" …>
  <dcx:title value="digitalCalibrationCertificate"/>
   <dcx:administrativeData>
      <dcx:coreData>
         <dcx:uniqueDocumentIdentifier value="SKH_10112_2"/>
         <dcx:clientTaskIdentifier value="POx28"/>
         <dcx:uniqueTemplateIdentifier value="t32_OIML"/>
         <dcx:issueDate value="2022-02-11"/>
         <dcx:beginPerformanceDate value="2022-02-10"/>
         <dcx:endPerformanceDate value="2022-02-10"/>
         <dcx:equipmentReceiptDate value="2022-02-09"/>
         <dcx:performanceLocation value="atProvider"/>
         <dcx:requestedLanguages value="en da"/>
      </dcx:coreData>
      <dcx:dcxSoftware>
         <dcx:heading lang="en">Document software</dcx:heading>
         <dcx:manufacturer value="DFM"/>
         <dcx:productName value="Manually"/>
         <dcx:version value="1.0.0"/>
      </dcx:dcxSoftware>
      <dcx:accreditation>
         <dcx:heading lang="en">Accreditation</dcx:heading>
         <dcx:accreditationNorm value="ISO 17025"/>
         <dcx:accreditationLabId value="04-490"/>
         <dcx:accreditationBody value="DANAK"/>
         <dcx:accreditationCountry value="DK"/>
         <dcx:accreditationApplicability value="wholly"/>
      </dcx:accreditation>
      <dcx:conformitySummary>
         <dcx:conformityResult value="pass"/>
```

dcx.xsd (schema)

```xml
<xs:complexType name="administrativeDataType">
   <xs:sequence>
      <xs:element name="heading" type="dcx:stringWithLangType"
      <xs:element name="coreData" type="dcx:coreDataType"/>
      <xs:element name="dcxSoftware" type="dcx:dcxSoftwareType"
      <xs:element name="accreditation" type="dcx:accreditationT
      <xs:element name="conformitySummary" type="dcx:conformity
      <xs:element name="documentAuthorization" type="dcx:docume
      <xs:element name="client" type="dcx:filledContactAndLocat
      <xs:element name="serviceProvider" type="dcx:filledContac
      <xs:element name="clientBillingInfo" type="dcx:contactAnd
      <xs:element name="equipmentReturnInfo" type="dcx:contactA
      <xs:element name="certificateReturnInfo" type="dcx:contac
      <xs:element name="location" type="dcx:contactAndLocationT
   </xs:sequence>
</xs:complexType>
```

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Using SI-Digital-Framework repr. in schemas

- The SI-Digital-Framework unit expressions is well suited for incorporation in schemas (e.g. xsd) because it can be expressed as regular expressions:

- Suggestion: Standardize a regular expression for use in schemas.

Unit expressions

A parsing tool to provide the PID and semantic model for compound units.

Non-ASCII characters used for representation of prefix micro and unit degree Celsius, ohm, degree, arcminute, arcsecond.

| µ | °C | Ω | ° | ' | " |

kg.mm2.ns-2   **Parse Expression**

```xml
<xs:restriction base="xs:string">
    <xs:pattern value="quantityUnitDefRef|-|1|%|ppm|(((h|d|min|°|t)|(Y|Z|E|P|T|G|M|k|h|da|d|c|m|µ|n|p|f|a|z|y)?(A|Bq|cd|C|°C|F|
    Gy|H|Hz|J|kat|K|g|lm|lx|m|mol|N|Ω|Pa|rad|s|S|Sv|sr|T|V|W|Wb|au|B|Da|eV|ha|L))([-]?[1-9]\d*)?)((\.(((min|t)|(Y|Z|E|P|T|G|M|
    k|h|da|d|c|m|µ|n|p|f|a|z|y)?(A|Bq|cd|C|°C|F|Gy|H|Hz|J|kat|K|g|lm|lx|m|mol|N|Ω|Pa|rad|s|S|Sv|sr|T|V|W|Wb|au|B|Da|eV|ha|L)|
    (d|h|min|°|t))([-]?[1-9]\d*)?))*)?"/>
```

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Using SI-Digital-Framework repr. in schemas

- The SI-Digital-Framework unit expressions is well suited for incorporation in schemas (e.g. xsd) because it can be expressed as regular expressions:
- Suggestion: Standardize a regular expression for use in schemas.

PIDs for compound units

https://si-digital-framework.org/SI/units/kilogram.millimetre2.nanosecond-2

Expression analysis

Compound unit **kg.mm2.ns-2**

Compound unit	Prefix	Unit	Exponent	Relation
kg : kilogram		kg: kilogram	1	
mm : millimetre	m: milli	m: metre	2	$1\ mm^2 = 10^{-6}\ m^2$
ns : nanosecond	n: nano	s: second	-2	$1\ ns^{-2} = 10^{18}\ s^{-2}$

```
<xs:restriction base="xs:string">
    <xs:pattern value="quantityUnitDefRef|-|1|%|ppm|(((h|d|min|°|t)|(Y|Z|E|P|T|G|M|k|h|da|d|c|m|µ|n|p|f|a|z|y)?(A|Bq|cd|C|°C|F|
Gy|H|Hz|J|kat|K|g|lm|lx|m|mol|N|Ω|Pa|rad|s|S|Sv|sr|T|V|W|Wb|au|B|Da|eV|ha|L))([-]?[1-9]\d*)?)((\.(((min|t)|(Y|Z|E|P|T|G|M|
k|h|da|d|c|m|µ|n|p|f|a|z|y)?(A|Bq|cd|C|°C|F|Gy|H|Hz|J|kat|K|g|lm|lx|m|mol|N|Ω|Pa|rad|s|S|Sv|sr|T|V|W|Wb|au|B|Da|eV|ha|L)|
(d|h|min|°|t))([-]?[1-9]\d*)?))*)?"/>
```

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Quantities – ISO 80000

- A full discription of the data in the column requires definition of the quantity beeing measured and the unit used.
- The values of the quantity attribute relates to a single entry of the standards in the ISO 80000 series.

Item No.	Quantity			Unit
	Name	Symbol	Definition	
4-10	impulse	I	vector (ISO 80000-2) quantity describing the effect of force acting during a time interval: $$I = \int_{t_1}^{t_2} F\,dt$$ where F is force (item 4-9.1), t is time (ISO 80000-3) and $[t_1, t_2]$ is considered time interval	N s $kg\ m\ s^{-1}$
4-11	angular momentum	L	vector (ISO 80000-2) quantity described by the vector product: $$L = r \times p$$ where r is position vector (ISO 80000-3) with respect to the axis of rotation and p is momentum (item 4-8)	$kg\ m^2\ s^{-1}$
4-12.1	moment of force	M	vector (ISO 80000-2) quantity described by the vector product: $$M = r \times F$$ where r is position vector (ISO 80000-3) with respect to the axis of rotation and F is force (item 4-9.1)	N m $kg\ m^2\ s^{-2}$
4-12.2	torque	T, M_Q	quantity described by the scalar product:	N m

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Initial attempt to digitize ISO 80000

563 quantities from the 9 ISO 80000 norms mentioned earlier, was transferred to str format:

"4-31|volume flow rate|m3.s-1"

Unit was converted to BIPM SI-digital-Framework representation.

The full list can be included within schema's e.g. xsd.

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```
<xs:simpleType name="quantityType">
    <xs:annotation>
        <xs:documentation>
            The quantityType is restricting the value of the quantity attribute of the columnType.
            For data columns this attribute is used to describe the data.
            For meta data columns the attribute is used to match the data column(s) that is enriched with the meta data.

            For quantities defined is restricted to strings that represent entries from the ISO 80000 series.
            The string contains information on Item number, quantity name and unit is as follows

            "[Item number] | [Quantity Name] | [Unit]"

            Example:
            "5-2|Celsius temperature|°C"

            If one needs to define a quantity not covered in the restriction list, one may use the "quantityUnitDefRef",
            in which case an "id" from quantityUnits should be provided in the quantityUnitDefRef attribute.

            Included from the ISO 80000 Series
            -----------------------------------
            ISO 80000-3:2020   Space and time
            ISO 80000-4:2020   Mechanics
            ISO 80000-5:2019   Thermodynamics
            ISO 80000-6:2022   Electromagnetism
            ISO 80000-7:2019   Light
            ISO 80000-8:2020   Acoustics
            ISO 80000-9:2019   Physical chemistry and molecular physics
            ISO 80000-10:2019  Atomic and nuclear physics
            ISO 80000-11:2020  Solid state physics

            Not included from the ISO 80000 Series
            -----------------------------------
            ISO 80000-1  General
            ISO 80000-2  Mathematical signs and symbols to be used in the natural sciences and technology
            ISO 80000-11 Characteristic numbers
            ISO 80000-13 Information science and technology
            ISO 80000-14 Telebiometrics related to human physiology

            https://si-digital-framework.org/SI/
            TODO: Description on how to parse the restriction expressions.
                 5-2|Celcius Temperature|°C |
        </xs:documentation>
    </xs:annotation>
    <xs:restriction base="xs:string">
        <xs:enumeration value="-" />
        <xs:enumeration value="quantityUnitDefRef"/> <!--the quantity may be expressed in the quantityUnitTable -->
        <xs:enumeration value="3-1.1|length|m"/>
        <xs:enumeration value="3-1.2|width, breadth|m"/>
        <xs:enumeration value="3-1.3|altitude, depth, height|m"/>
        <xs:enumeration value="3-1.4|thickness|m"/>
        <xs:enumeration value="3-1.5|diameter|m"/>
        <xs:enumeration value="3-1.6|radius|m"/>
        <xs:enumeration value="3-1.7|path length, arc length|m"/>
        <xs:enumeration value="3-1.8|distance|m"/>
        <xs:enumeration value="3-1.9|radial distance|m"/>
        <xs:enumeration value="3-1.10|position vector|m"/>
        <xs:enumeration value="3-1.11|displacement|m"/>
```

Columns: quantities and unit units

dcx.xsd (schema)

```xml
<xs:complexType name="columnType">
  <xs:choice>
    <xs:element name="value" type="dcx:valueType" />
    <xs:element name="targetValue" type="dcx:targetValueType"/>
    <xs:element name="expandedUncertainty" type="dcx:expandedUncertaintyType"/>
    <xs:element name="statStd" type="dcx:statStdType" />
    <xs:element name="statMin" type="dcx:statMinType" />
    <xs:element name="statMax" type="dcx:statMaxType" />
    <xs:element name="correction" type="dcx:correctionType" />
    …
  <xs:complexType name="valueType">
    <xs:complexContent>
        <xs:extension base='dcx:realDataType'>
        </xs:extension>
    </xs:complexContent>
  </xs:complexType>
</xs:complexType>

……………………………… .
<xs:restriction base="xs:double">
  <xs:pattern value="[-+]?((\d*\.\d+)|(\d+\.\d*)|(\d+\.?))([Ee][-+]?\d+)?"/>
</xs:restriction>
```

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weights.xml (document)

```xml
<dcx:calibrationResult tableId="WeightCal1"  measurementConfigRef="ms1" numRows="2" numCol
    <dcx:column scope="indication" dataCategoryRef="-" quantity="4-1|mass|kg" unit="kg">
        <dcx:heading lang="en">Nominal mass</dcx:heading>
        <dcx:value>
            <dcx:row idx="1">20</dcx:row>
            <dcx:row idx="2">20</dcx:row>
        </dcx:value>
    </dcx:column>
    <dcx:column scope="bias" dataCategoryRef="value" quantity="4-1|mass|kg" unit="mg">
        <dcx:heading lang="en">Mass correction $\Delta m$</dcx:heading>
        <dcx:correction>
            <dcx:row idx="1">27</dcx:row>
            <dcx:row idx="2">21</dcx:row>
        </dcx:correction>
    </dcx:column>
    <dcx:column scope="reference" dataCategoryRef="-" quantity="3-4|volume|m3" unit="cm3">
        <dcx:heading lang="en">Volume, (at 20 ℃)</dcx:heading>
        <dcx:value>
            <dcx:row idx="1">2516</dcx:row>
            <dcx:row idx="2">2515</dcx:row>
        </dcx:value>
    </dcx:column>
```

Path forward

1. With PTB investigate how the DCX requirements can be merged/harmonized with DCC, TemaTres
2. In TC-IM 1448: Harmonize semantics and structures, international perspectiv
3. Standardized regular expression for BIPM Digital SI unit expression
4. Standardized schema for ISO 80000 through ISO TC12.
5. Incorporate NCSLI metrology Taxonomy into settingCodes.
6. Pilot study and Full process cost analysis (Template, DCR, DCC, extraction)
   1. Use software tools presented yesterday.
   2. Cost of deployment, maintenance, versatility, for both clients and Service Providers.

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029   Compatible sub schemata of the DCC Schema

Presenting author: Muhammed-Ali Demir
Email: muhammed.demir@ptb.de
Additional authors: Et. al.

Abstract:

A need has arisen for a smaller, stricter version of the DCC schema with reduced flexibility. Rather than creating an entirely incompatible schema, it is possible to develop a subschema of the DCC schema that is both smaller and more restrictive. If certain rules are followed during

the subschema's creation, DCCs generated using it will remain valid under the main DCC schema.

Presentation of Muhammed-Ali Demir

Physikalisch-Technische Bundesanstalt
Braunschweig and Berlin
National Metrology Institute

Compatible sub schemata of the DCC Schema

5th DCC Conference

Muhammed-Ali Demir et al., WG1.24

Reasons for sub schemas of the DCC

- Questions:
  - The main DCC schema is flexible -> complexity
  - Flexibility may not be what small laboratories need -> small resources
- Needs:
  - Simpler & less flexible schema may be requested
- Problems:
  - This may lead to different incompatible schemas
  - This incompatibilities already have happened before …

The consequences of lacking uniformity

Solution

- There is a solution to have a simpler sub schemata, derived from the DCC (main) schema

- When specific rules are followed, the DCC XML files generated from the sub-schema are automatically valid against the DCC main schema.

- DKD expert reports should also be considered for the generation of sub schemas e.g., see the presentation of: Itzel Dominguez, Carlos Galvan, Siegfried Hackel et al. from our colleagues of CENAM with the title of "Generating Mass DCC based on DKD expert report using a spreadsheet" from Tuesday at this conference

Rules for generating the sub schema 1/9

- Optional schema elements can be made mandatory*
- Example: Manufacturer has to be specified in items

```
<xs:complexType name="itemType">
    <xs:annotation>
        <xs:documentation>
            Item that is calibrated in this DCC.
        </xs:documentation>
    </xs:annotation>
    <xs:sequence>
        <xs:element name="name" type="dcc:textType"/>
        <xs:element name="equipmentClass" type="dcc:equipmentClassType" minOccurs="0" maxOccurs="unbounded"/>
        <xs:element name="description" type="dcc:richContentType" minOccurs="0"/>
        <xs:element name="owner" type="dcc:contactType" minOccurs="0"/>
        <xs:element name="installedSoftwares" type="dcc:softwareListType" minOccurs="0" />
        <xs:element name="manufacturer" type="dcc:contactNotStrictType" />
        <xs:element name="model" type="dcc:notEmptyStringType" minOccurs="0"/>
        <xs:element name="identifications" type="dcc:identificationListType"/>
        <xs:element name="itemQuantities" type="dcc:itemQuantityListType" minOccurs="0"/>
        <xs:element name="subItems" type="dcc:itemListType" minOccurs="0"/>
    </xs:sequence>
    <xs:attribute name="id" type="xs:ID" use="optional"/>
    <xs:attribute name="refId" type="xs:IDREFS" use="optional"/>
    <xs:attribute name="refType" type="dcc:refTypesType" use="optional"/>
</xs:complexType>
```

* = not relevant for minimal schemas

Rules for generating the sub schema 2/9

- Optional schema elements can be deleted*
- Example: Item elements should not have any sub items

```
<xs:complexType name="itemType">
    <xs:annotation>
        <xs:documentation>
            Item that is calibrated in this DCC.
        </xs:documentation>
    </xs:annotation>
    <xs:sequence>
        <xs:element name="name" type="dcc:textType"/>
        <xs:element name="equipmentClass" type="dcc:equipmentClassType" minOccurs="0" maxOccurs="unbounded"/>
        <xs:element name="description" type="dcc:richContentType" minOccurs="0"/>
        <xs:element name="owner" type="dcc:contactType" minOccurs="0"/>
        <xs:element name="installedSoftwares" type="dcc:softwareListType" minOccurs="0" />
        <xs:element name="manufacturer" type="dcc:contactNotStrictType" minOccurs="0" />
        <xs:element name="model" type="dcc:notEmptyStringType" minOccurs="0"/>
        <xs:element name="identifications" type="dcc:identificationListType"/>
        <xs:element name="itemQuantities" type="dcc:itemQuantityListType" minOccurs="0"/>
    </xs:sequence>
    <xs:attribute name="id" type="xs:ID" use="optional"/>
    <xs:attribute name="refId" type="xs:IDREFS" use="optional"/>
    <xs:attribute name="refType" type="dcc:refTypesType" use="optional"/>
</xs:complexType>
```

* = deleting some optional elements can make references with id/refId necessary

Rules for generating the sub schema 3/9

- Choices can be simplified
- Example: We only want to keep si:real and si:realListXMLList in dcc:quantity

```
<xs:complexType name="quantityType">
    <xs:annotation>
        <xs:documentation>
            Single measurement quantity containing a name, description, a D-SI elem
            Additionally, e.g., used methods, used software, influence conditions, 
        </xs:documentation>
    </xs:annotation>
    <xs:sequence>
        <xs:element name="name" type="dcc:textType" minOccurs="0"/>
        <xs:element name="description" type="dcc:richContentType" minOccurs="0"/>
        <xs:choice>
            <xs:element ref="si:real"/>
            <xs:element ref="si:realListXMLList"/>
        </xs:choice>
```

Rules for generating the sub schema 4/9

- Optional attributes can be made mandatory *
- Example: every item has to have an id

```
<xs:complexType name="itemType">
    <xs:annotation>
        <xs:documentation>
            Item that is calibrated in this DCC.
        </xs:documentation>
    </xs:annotation>
    <xs:sequence>
        <xs:element name="name" type="dcc:textType"/>
        <xs:element name="equipmentClass" type="dcc:equipmentClassType" minOccurs="0" maxOccurs="unbounded"/>
        <xs:element name="description" type="dcc:richContentType" minOccurs="0"/>
        <xs:element name="owner" type="dcc:contactType" minOccurs="0"/>
        <xs:element name="installedSoftwares" type="dcc:softwareListType" minOccurs="0" />
        <xs:element name="manufacturer" type="dcc:contactNotStrictType" minOccurs="0" />
        <xs:element name="model" type="dcc:notEmptyStringType" minOccurs="0"/>
        <xs:element name="identifications" type="dcc:identificationListType"/>
        <xs:element name="itemQuantities" type="dcc:itemQuantityListType" minOccurs="0"/>
        <xs:element name="subItems" type="dcc:itemListType" minOccurs="0"/>
    </xs:sequence>
    <xs:attribute name="id" type="xs:ID" use="required"/>
    <xs:attribute name="refId" type="xs:IDREFS" use="optional"/>
    <xs:attribute name="refType" type="dcc:refTypesType" use="optional"/>
</xs:complexType>
```

* = not relevant for minimal schemas

Rules for generating the sub schema 5/9

- Optional attributes can be deleted:
- Example: item elements should have no refId

```
<xs:complexType name="itemType">
    <xs:annotation>
        <xs:documentation>
            Item that is calibrated in this DCC.
        </xs:documentation>
    </xs:annotation>
    <xs:sequence>
        <xs:element name="name" type="dcc:textType"/>
        <xs:element name="equipmentClass" type="dcc:equipmentClassType" minOccurs="0" maxOccurs="unbounded"/>
        <xs:element name="description" type="dcc:richContentType" minOccurs="0"/>
        <xs:element name="owner" type="dcc:contactType" minOccurs="0"/>
        <xs:element name="installedSoftwares" type="dcc:softwareListType" minOccurs="0" />
        <xs:element name="manufacturer" type="dcc:contactNotStrictType" minOccurs="0" />
        <xs:element name="model" type="dcc:notEmptyStringType" minOccurs="0"/>
        <xs:element name="identifications" type="dcc:identificationListType"/>
        <xs:element name="itemQuantities" type="dcc:itemQuantityListType" minOccurs="0"/>
        <xs:element name="subItems" type="dcc:itemListType" minOccurs="0"/>
    </xs:sequence>
    <xs:attribute name="id" type="xs:ID" use="optional"/>
    <xs:attribute name="refType" type="dcc:refTypesType" use="optional"/>
</xs:complexType>
```

Rules for generating the sub schema 6/9

- Maximal cardinality of elements can be limited if they are unbounded
- Example: at max. 2 dcc:equipmentClass elements in dcc:item

```
<xs:complexType name="itemType">
    <xs:annotation>
        <xs:documentation>
            Item that is calibrated in this DCC.
        </xs:documentation>
    </xs:annotation>
    <xs:sequence>
        <xs:element name="name" type="dcc:textType"/>
        <xs:element name="equipmentClass" type="dcc:equipmentClassType" minOccurs="0" maxOccurs="2"/>
        <xs:element name="description" type="dcc:richContentType" minOccurs="0"/>
        <xs:element name="owner" type="dcc:contactType" minOccurs="0"/>
        <xs:element name="installedSoftwares" type="dcc:softwareListType" minOccurs="0" />
        <xs:element name="manufacturer" type="dcc:contactNotStrictType" minOccurs="0" />
        <xs:element name="model" type="dcc:notEmptyStringType" minOccurs="0"/>
        <xs:element name="identifications" type="dcc:identificationListType"/>
        <xs:element name="itemQuantities" type="dcc:itemQuantityListType" minOccurs="0"/>
        <xs:element name="subItems" type="dcc:itemListType" minOccurs="0"/>
    </xs:sequence>
    <xs:attribute name="id" type="xs:ID" use="optional"/>
    <xs:attribute name="refId" type="xs:IDREFS" use="optional"/>
    <xs:attribute name="refType" type="dcc:refTypesType" use="optional"/>
</xs:complexType>
```

Rules for generating the sub schema 7/9

- Minimal cardinality of elements can be set to 1 (or higher if maximal cardinality is unbounded) *
- Example: at least one equipmentClass element has to be sepecified in itemType

```xml
<xs:complexType name="itemType">
    <xs:annotation>
        <xs:documentation>
            Item that is calibrated in this DCC.
        </xs:documentation>
    </xs:annotation>
    <xs:sequence>
        <xs:element name="name" type="dcc:textType"/>
        <xs:element name="equipmentClass" type="dcc:equipmentClassType" maxOccurs="unbounded"/>
        <xs:element name="description" type="dcc:richContentType" minOccurs="0"/>
        <xs:element name="owner" type="dcc:contactType" minOccurs="0"/>
        <xs:element name="installedSoftwares" type="dcc:softwareListType" minOccurs="0" />
        <xs:element name="manufacturer" type="dcc:contactNotStrictType" minOccurs="0" />
        <xs:element name="model" type="dcc:notEmptyStringType" minOccurs="0"/>
        <xs:element name="identifications" type="dcc:identificationListType"/>
        <xs:element name="itemQuantities" type="dcc:itemQuantityListType" minOccurs="0"/>
        <xs:element name="subItems" type="dcc:itemListType" minOccurs="0"/>
    </xs:sequence>
    <xs:attribute name="id" type="xs:ID" use="optional"/>
    <xs:attribute name="refId" type="xs:IDREFS" use="optional"/>
    <xs:attribute name="refType" type="dcc:refTypesType" use="optional"/>
</xs:complexType>
```

* = not relevant for minimal schemata

Rules for generating the sub schema 8/9

- ## Don't delete mandatory elements from the main schema

```xml
<xs:complexType name="itemType">
    <xs:annotation>
        <xs:documentation>
            Item that is calibrated in this DCC.
        </xs:documentation>
    </xs:annotation>
    <xs:sequence>
        <xs:element name="name" type="dcc:textType"/>
        <xs:element name="equipmentClass" type="dcc:equipmentClassType" minOccurs="0" maxOccurs="unbounded"/>
        <xs:element name="description" type="dcc:richContentType" minOccurs="0"/>
        <xs:element name="owner" type="dcc:contactType" minOccurs="0"/>
        <xs:element name="installedSoftwares" type="dcc:softwareListType" minOccurs="0" />
        <xs:element name="manufacturer" type="dcc:contactNotStrictType" minOccurs="0" />
        <xs:element name="model" type="dcc:notEmptyStringType" minOccurs="0"/>
        <xs:element name="identifications" type="dcc:identificationListType"/>
        <xs:element name="itemQuantities" type="dcc:itemQuantityListType" minOccurs="0"/>
        <xs:element name="subItems" type="dcc:itemListType" minOccurs="0"/>
    </xs:sequence>
    <xs:attribute name="id" type="xs:ID" use="optional"/>
    <xs:attribute name="refId" type="xs:IDREFS" use="optional"/>
    <xs:attribute name="refType" type="dcc:refTypesType" use="optional"/>
</xs:complexType>
```

Marie-Lan Nguyen, Public Domain

Rules for generating the sub schema 9/9

- Don't introduce new elements, that don't exist in the main schema

```
<xs:complexType name="itemType">
    <xs:annotation>
        <xs:documentation>
            Item that is calibrated in this DCC.
        </xs:documentation>
    </xs:annotation>
    <xs:sequence>
        <xs:element name="name" type="dcc:textType"/>
        <xs:element name="heading" type="dcc:textType"/>
        <xs:element name="equipmentClass" type="dcc:equipmentClassType" maxOccurs="unbounded"/>
        <xs:element name="description" type="dcc:richContentType" minOccurs="0"/>
        <xs:element name="owner" type="dcc:contactType" minOccurs="0"/>
        <xs:element name="installedSoftwares" type="dcc:softwareListType" minOccurs="0" />
        <xs:element name="manufacturer" type="dcc:contactNotStrictType" minOccurs="0" />
        <xs:element name="model" type="dcc:notEmptyStringType" minOccurs="0"/>
        <xs:element name="identifications" type="dcc:identificationListType"/>
        <xs:element name="itemQuantities" type="dcc:itemQuantityListType" minOccurs="0"/>
        <xs:element name="subItems" type="dcc:itemListType" minOccurs="0"/>
    </xs:sequence>
    <xs:attribute name="id" type="xs:ID" use="optional"/>
    <xs:attribute name="refId" type="xs:IDREFS" use="optional"/>
    <xs:attribute name="refType" type="dcc:refTypesType" use="optional"/>
</xs:complexType>
```

Marie-Lan Nguyen, Public Domain

Information sources

- Itzel Dominguez et al. - Generating Mass DCC based on DKD expert report using a spreadsheet

About

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Day 3 (2025-02-27 Thursday)
Parallel Session "Key Aspects of DCC II"
(Chair: Mark Kuster)

030   Calibration and metrological traceability

Presenting author: Blair Hall; Measurement Standards Laboratory of New Zealand
Email: blair.hall@measurement.govt.nz
Additional authors: Christian Mueller-Schoell christian.mueller-schoell@mt.com, Mettler-Toledo Int. Inc., Switzerland

Abstract:

In 1980, Belanger considered four alternative explanations of the term metrological traceability [1]. In 1982, Nicholas and White, in their monograph Traceable Temperatures, proposed a variation of one of Belanger's suggestions [2]. Then the first edition of the Vocabulary of Metrology (VIM), published in 1984, included an entry for traceability based on another of Belanger's suggestions [3], Since then, subsequent editions of the VIM have elaborated on traceability. The current edition not only refers to three specialized terms—measurement result, calibration, and measurement uncertainty—but also includes eight explanatory notes. The VIM now defines the terms metrological traceability chain and metrological traceability to a measurement unit [4].

The current VIM definition is:
- metrological traceability
- property of a measurement result whereby the result can be related to a reference through a documented unbroken chain of calibrations, each contributing to the measurement uncertainty

This highlights calibration and uncertainty; however, these concepts are absent in some of the earlier definitions. Are these elements essential?

Metrological traceability provides reliable information about the accuracy of a measurement, and we contend that its true value is realized when decisions are informed by measurements of real-world quantities. Calibration, as a metrological process, establishes some of the links in the traceability chain, but it is not sufficient on its own to complete the chain-measurement is also required.

This talk will explore metrological traceability through the lens of three key questions: why is traceability needed, what does traceability deliver, and how is traceability achieved? From this perspective, we frame the role of calibration - and, by extension, calibration reports - in the broader context of metrological traceability.

References:

[1] Belanger, B. C., Traceability: an evolving concept, ASTM Standardization News, 8(1) pp 22—28,1980.

[2] Nicholas, J. V, White, D. R., Traceable temperatures: an introductory guide to temperature measurement and calibration, 1982. (Now published by John Wiley & Sons)

[3] BIPM, IEC, ISO, OIML, Vocabulary of metrology, Part 1, basic and general terms (international), 1984.

[4] BIPM, IEC, IFCC, IUPAC, IUPAP, ISO, OIML, International Vocabulary of Metrology - Basic and general concepts and associated terms, 3"^ ed., 2012.

Presentation of #030 BlairHall

Why do we need metrological traceability?

- Only **metrologically traceable measurements** can be relied on when **decisions** depend on **real-world quantities**.

- **Traceable measurement results** are accompanied by reliable information about their **accuracy** (uncertainty).

- The **comparability** of traceable measurement results—whether with other traceable results or with nominal quantity values—is **fundamentally important**.

Image: de.wikipedia.org

What does metrological traceability deliver?

$$Y = y - E_y$$

The measured value y is an estimate (an approximation) of Y—the measurand.

There is a residual measurement error, E_y, which is not known, so we don't know the measurand either.

A traceable measurement **result** reports y and a probabilistic description of E_y in the form of an uncertainty statement.

This reflects the **doubt** remaining about the value of the measurand **after** a measurement.

Measuring is a dynamic process, but there is a definite outcome

The measured value, the measurement error, and the measurand are all considered **definite** values

However, the effects of influence-quantity errors accumulate, so the final error and measurand are **not known**.

The final result is determined by a 'snapshot' of definite values that arose during a particular measurement.

Known knowns,
known unknowns,
unknown knowns, and
unknown unknowns.

Image: de.wikipedia.org

How does metrological traceability work?

A traceable measurement is carried out in a sequence of measuring stages.
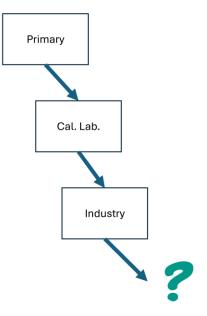
All stages contribute to the final result—their errors contribute to the residual measurement error.

A **trace** of influence-quantity effects is used to **assess** the accuracy of a measurement result.

The trace begins with the realisation of primary standards and ends when a decision is made.

Reporting between stages forges the links in traceability chain.

Calibration reports have this function.

Why is calibration needed?

Measuring systems respond to a quantity of interest, but the response is never perfect.

Calibration characterises a system, so it can be used to estimate measurands

What does calibration deliver?

Calibration measures certain system parameters and characterises the system's response to the quantity of interest.

This provides information that is **necessary** for the system to be used to estimate an unknown value of a quantity of interest.

Image: de.wikipedia.org

How does calibration work?

1. Establish a relationship between reference standards for the quantity of interest (with nominal values) and (raw) system indications.

2. Model the system, accounting for bias and response unpredictability, so that a raw response can be used to measure (estimate), with known accuracy, a quantity of interest.

Calibration involves measurement. So, calibration results are a 'snapshot' of what has happened with regards to time, location, environment etc.

Calibration establishes a link to the quantity of interest.

Image: de.wikipedia.org

What is the role of a calibration report (DCC)?

It provides information **necessary** to relate measuring system responses to estimates of the measured quantity.

It creates a quantifiable relation using references for that quantity

However, that is not **sufficient** to claim a calibrated system produces traceable measurement results.

We also need to:
1. quantify factors that influence system performance **as used**; and
2. establish a relationship (model) between indications and measured quantities in the "**as used**" situation.

This model delivers the measured value and information about the accuracy (uncertainty) of this value as an estimate of the quantity.

A calibration report (DCC) is part of the final measurement model

The measuring system may be used in ways and in an environment that are different from where it was calibrated.

Using the system produces **some new,** definite, influence values, but the effects reported during earlier calibrations do not change

A simple example would be if you use a length gauge at a different temperature to the reference temperature in a calibration report.

E.g. the calibration value refers to 20 °C, but it is used at 22 °C and so the user must work with the data in a calibration certificate to obtain a valid traceable measurement at 22 °C.

Another example would be when a system is used to evaluate the difference between two measurements (e.g., uniformity of lighting level).

Final remarks

Metrological traceability gives information about the accuracy of a measurement result. This enables reliable **decision** making.

Calibration forges links along a traceability chain.

It establishes a relation between the response of a measuring system and metrological references of the measured quantity, ensuring that traceable measurements are **comparable**.

Information provided by calibration is **necessary** to claim the traceability of measurements using the system, but it is not **sufficient**: modelling of the system **as used** is also required.

Not all the "**as used**" properties of the system are known at the time of calibration.

The metrologist must develop a suitable model—a calibration report alone is not sufficient.

031 Traceability chains using the DCC

Presenting author: Christian Mueller-Schoell, Mettler-Toledo Int. Inc., Switzerland
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Additional authors:

Abstract:

It is often claimed that a link (or even a digital hyperlink) in a DCC to the DCC of the higher-level reference standard used would be useful, or the prerequisite, or even the only prerequisite

to prove metrological traceability [1], [2], [3]. This is a false concept. It is based on a very simplified conceptual model of metrological traceability.

Metrological traceability is a property of a measurement (or calibration) result. The measurement result is the outcome of a measuring process, which, in turn (and obviously) has more inputs than just the calibration result of the higher level reference standard from the from the time of its calibration.

There are only a few sources [4], [5] where we can find a list of the necessary contributors to metrological traceability, these are (compiled, re-sorted, and re-worded by the author):

o calibration delivering metrologically traceable calibration results to establish the metrological traceability of all measuring instruments of the measuring system

o defined and reviewed calibration intervals for the measuring instruments (=the calibration program) serving both to establish the metrological traceability by each calibrations, and to maintain the metrological traceability during service life after a calibration,

o a documented, controlled, proven, accepted measurement procedure,

o documented measurement uncertainty,

o competence (not only of individuals, but of the organization in the sense of ISO 17025),

o established measurement process assurance.
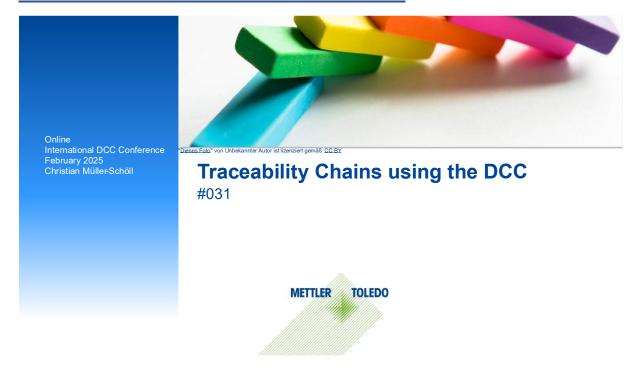
From this list, it is obvious that in order to deliver proof of traceability, we need much more than just a link to a higher-level DCC. This complete list is also in principle reflected in ISO 17025 and therefore, a measurement result gained under the scope of a laboratory accreditation according to ISO 17025, can be considered metrologically traceable. However, cancelling just one of the components of the list will breach metrological traceability.

In the context of calibrations and DCCs, particular attention must be paid to the second bullet point: Even for all the calibrated equipment used in the process, it is not enough to refer to the metrological properties established at the point of calibration: We need to consider the metrological properties of the equipment at the point and the time of use, after the calibration has taken place. Determining these (as all other points except the first one), is only possible to be done by the user of the equipment and consequently can never be part of a DCC issued by the calibration laboratory.

The reason that this misconception seems to be popular, is probably rooted in an unfortunate phrasing of the definition of metrological traceability in the VIM [6] which puts the focus on calibrations only.

[1] Oleg Korzhak, Vitalii Malisevych, Taras Kepeshchuk, Denys Serediuk, Volodymyr Hulyk, Digitalization, creation, and implementation of digital calibration certificates. Measurement: Sensors, 2024, 101467, ISSN 2665-9174, https://doi.Org/10.1016/j.measen.2024.101467

[2] Hackel, S.; Schönhals, S.; Doering, L.; Engel, T.; Baumfalk, R. The Digital Calibration Certificate (DCC) for an End-to-End Digital Quality Infrastructure for Industry 4.0. Sci 2023, 5, 11. https://doi.Org/10.3390/sci5010011

[3] Thomas Engel, Alexandru Popescu, GEMIMEG -Digitalization of calibration processes in metrology. Measurement: Sensors, 2025, 101474, ISSN 2665-9174, https://doi.Org/10.1016/j.measen.2024.101474.

[4] NISTIR 6969 Selected Laboratory and Measurement Practices and Procedures to Support Basic Mass Calibrations (2019 Ed), GMP-13

[5] ILAC, Newton, Australia, ILAC P-10:2002 (sic!)

[6] BIPM, Paris, VIMA, https://jcgm.bipm.org/vim/en/index.html

Presentation of Christian Mueller-Schoell

Online
International DCC Conference
February 2025
Christian Müller-Schöll

Traceability Chains using the DCC
#031

METTLER TOLEDO

What is Metrological Traceability?

METTLER TOLEDO | 2

Metrological Traceability:

- Is the property of a measurement (or calibration) result (not of an instrument)

- Is the result/effect of a measurement (or calibration) process

- Is the linking of the result to "a reference" (e.g. an SI unit)

- Is expressed by a result value and the measurement uncertainty

- "$L = 1.03\ \mathrm{m}, \mathrm{where}\ U = 0.14\ \mathrm{m}\ (95\ \%)$"

- The uncertainty qualifies the result. It expresses that, with a certain likelihood, the interval given by the uncertainty, embraces the true value of the measurand.

What is a metrologically traceable Calibration?

- A special kind of measurement process
- Is executed on a measuring instrument
- Establishes metrologically traceable results, at the point of calibration
- "Establishes a relation for obtaining a measurement result from an indication"

Attention:

- The results of this process are established at the time and location of the calibration (is a snapshot)
- Rarely does the calibration provider know under which circumstances and how long the calibrated instrument will be used
- The instrument will change its behaviour (performance) after the snapshot (time, location, temperature, gravity, air density, …)

- The user of the instrument is responsible for taking into account any changes after the calibration

Modelling the behaviour after calibration

- **The user of the instrument is responsible for taking into account any changes after the calibration**

This can be done in various ways:

- A) assume the calibration values stay constant and increase the uncertainty to account for any changes (e.g. weights according to OIML R111, …)
- B) model the calibration value to account for any changes and increase the uncertainty by the modelling uncertainty (e.g. high accuracy resistors, Pt -Ir standards after nettoyage-lavage, …)

- Note, that these values are dependent on the length of the calibration interval, chosen by the user

- We see: The values from the calibration certificate are not the ones being used during the service life of the instrument

What do we need apart from a calibrated instrument?
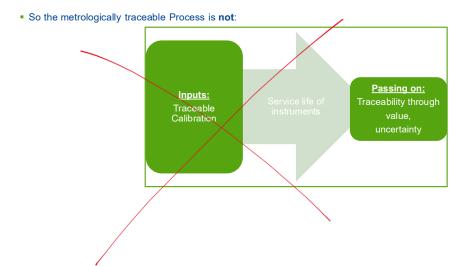
- **The values from the calibration certificate are not the ones being used during service life…**

What *is* releveant during the service life?

- Prerequisites for a process delivering metrological traceability (similar to ILAC P-10:2002 (sic!))
  - Metrologically traceable calibration of the instrument s (establish the metrological traceability by a calibration) = the calibration certificate, the DCC
  - Modelling the behaviour of the instrument after the calibration
  - defined and reviewed calibration intervals for the measuring instrument s used (=the calibration program),
  - a documented controlled, proven procedure,
  - documented measurement uncertainty,
  - competence,
  - established measurement process assurance.

1. The snapshot values gained at calibration are meaningless during service life
2. The calibration provider can impossibly deliver the "traceability information" for the service life.

The metrologically traceable measurement Process
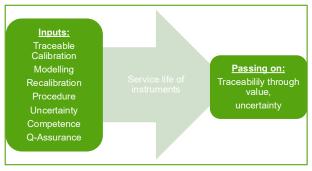
- So the metrologically traceable Process is **not**:

▪ The metrologically traceable Process is **in fact** :

Inputs:
Traceable Calibration
Modelling
Recalibration
Procedure
Uncertainty
Competence
Q-Assurance

Service life of instruments

Passing on:
Traceabiliy through value, uncertainty

Conclusions :

➢ Linking a calibration value to the values of a calibrated reference ALONE is meaningless and useless

➢ It conveys a false understanding of how "metrological traceability" is built

➢ Traceability is not a simple "chain"

METTLER TOLEDO | 8

Thank you!

Back to "Table of Contents" above

032 Applying FAIR Principles to Quality Infrastructure Data for Economic Analysis - Approaching Challenges in Data Availability, Accessibility, and Interoperability

Presenting author: Ulrich Harmes-Liedtke
Email: uhl@mesopartner.com
Additional authors: Ann-Sara Ramkissoon Annsara.Ramkissoon@unifi.it

Abstract:

Painting a complete picture of the true value of Quality Infrastructure (QI) remains an insurmountable challenge since a significant portion of its value is derived from its contribution to public goods, such as the support it provides in the health, environment, social, and safety sectors, which are difficult to quantify. Easier to quantify is the value of the trade-based economic benefits of QI, such as imports, exports. Gross Domestic Product, etc. However, researchers are hindered by disparate data sources, varying levels of accessibility, and a lack of standardized frameworks that hamper effective data sharing and utilisation. The integration of FAIR (Findability, Accessibility, Interoperability, and Reusability) principles into the management and dissemination of QI data presents a transformative opportunity to address the critical data gaps that currently exist. This paper explores how applying FAIR principles can improve existing QI data repositories and guide the collection and curation of QI data in the coming years as we transition to a digital QI ecosystem.

The FAIR framework aligns with the requirements for reliable, interoperable datasets that underpin the digital transformation of QI services. It offers a roadmap for improving metadata standards, ensuring data traceability, and facilitating the harmonisation of datasets across organisations and borders.

We analyse existing QI data repositories, such as the BIPM Key Comparison Data Base (KCDB), the ISO Survey and initiatives like IAF CertSearch and composite indexes like the Global Quality Infrastructure Index (GQII) and the Quality Infrastructure for Development (QI4SD) Index, highlighting their strengths and limitations in terms of compliance with FAIR principles. Particular emphasis is given to the challenges of metadata standardization, the need for machine-readable formats, and the lack of timeseries data for longitudinal analyses.

In addition, we explore the different QI-digital initiatives, such as digital calibration certificates, smart standards, eAttestation and the digital product passport, applying FAIR principles in our recommendations on collecting and building datasets that facilitate economic analysis.

The paper proposes actionable solutions, including adopting linked data technologies, enhancing cross-institutional collaboration, and developing open-access tools for QI data integration. By showcasing the potential of FAIR-aligned practices, we advocate for a future where QI data is accessible and reliable as we continue our efforts to quantify the value of QI.

Keywords: FAIR principles. Quality Infrastructure, QI-Digital, Digital Calibration Certificates, Data Interoperability, Smart standards, composite indexes

Presentation of Ulrich Harmes-Liedtke

CHALLENGE

Gaps in QI data prevent the application of various econometric approaches.

National and international organizations collect data for their own purposes, primarily for documentation and traceability.

Statistical data is a byproduct but is not specifically structured for statistical analysis.

Issues exist with data interoperability, transparency and accessibility.

FAIR PRINCIPLES: ENHANCING QI DATA COLLECTION AND CURATION FOR FUTURE RESEARCH

FAIR Principles

Findability
Accessibility
Interoperability
Reusability

Why they matter?

Enables reliable, interoperable datasets.
Enhances data traceability and standardization across different systems.
Facilitates harmonization of QI and economic datasets.

DCCs: A DATA SOURCE FOR FUTURE QI RESEARCH

• Large amounts of data are transmitted in DCCs.

• Administrative data and calibration results can serve as strong indicators of metrological competency and provide valuable insights for economic analysis.

Source: PTB
Available at: https://www.ptb.de/cms/en/researchdevelopment/ptbsinnovation-clusters/innovation-cluster-for-digitalization/kernziel1einheitlichkeitim/digitalcalibration-certificate-dcc.htm)

INDICATORS OF METROLOGICAL COMPETENCY FOR ECONOMIC RESEARCH

Source: Hackel, S., Schönhals, S., Doering, L., Engel, T., & Baumfalk, R. (2023). The Digital Calibration Certificate (DCC) for an End-to-End Digital Quality Infrastructure for Industry 4.0. Sci, 5(1), 11. https://doi.org/10.3390/sci5010011

• Total number of calibrations

• Number of accredited calibration labs

• Level of measurement uncertainty

• Required data disaggregation:
  • Country
  • Year
  • Metrology area
  • Measurement instrument
  • Economic sector

KEY CONSIDERATIONS FOR EXTRACTING, CURATING, AND STORING ECONOMICALLY RELEVANT DATA FROM DCCs

How can economically relevant data be extracted and aggregated from DCCs while maintaining data privacy?

Which institutions or governing bodies could oversee the collection and curation of this data?

Which platforms can be used to store this data securely while ensuring easy access for researchers?

FUTURE RESEARCH OPPORTUNITIES

Correspondence tables for metrology areas and economic sectors

FUTURE RESEARCH CONSIDERATIONS
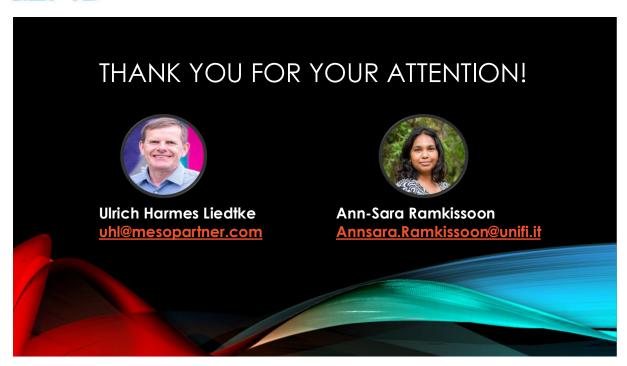
- How can the economic impact and effectiveness of Digital Calibration Certificates (DCCs) be assessed and measured?

- What metrics are being measured, and how frequently are they monitored?

- What data is needed to exploit different econometric approaches to examine the impact of DCCs?

CONCLUSIONS

- The introduction and implementation of DDCs present an opportunity for QI data collection for economic research, as well as new topics for research.

- When designing the data platform and system, it is essential to consider the statistical use of the collected data, ensuring that it is interoperable.

THANK YOU FOR YOUR ATTENTION!

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Ann-Sara Ramkissoon
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033   A new data structure for improved scientific data reporting in a FAIR compliant manner

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Abstract:

Scientific papers often lack effective methods for representing experimental results. Data is typically not provided in machine-readable formats, which hinders its accessibility and reusability. Additionally, the reported experimental information may omit crucial elements such as uncertainty values or details regarding data processing, making it difficult to reproduce results and conduct comparative studies. This issue is particularly acute when comparing measurement results obtained using widely differing methods, as is the case for the authors when determining the thermophysical properties of materials at very high temperatures.

To address these issues, we have developed PER (Framework for Experimental Results), which allows reporting data in a way that ensures its reusability and reproducibility. This framework consists of three main components: a data structure that determines how results are stored, a set of scripts to reproduce the results from the given raw data, and an open database or repository that will store both the data files and the scripts. The first step in developing FER is to define a data structure that ensures compliance with the FAIR principles of the data-reporting process. The presentation of this data structure forms the core of this contribution. Given the emphasis on uncertainty propagation at the core of FER, this data structure has been designed to be consistent with current practices in metrology, adopting a rigorous VIM-compliant nomenclature and allowing measurement uncertainty propagation following all the possibilities allowed by the GUM. Even though the data structure itself is

format-agnostic, we present a use-case using JSON as a working example (accessible at https://github.com/jongablop/fer) and developed a Python library to work with it: ferpy (available at https://github.com/jongablop/ferpy).

Widespread adoption of FER and the creation of domain-specific databases or repositories will ensure complete compliance with the FAIR principles and a more robust and transparent communication of scientific data.

Presentation of Jon Gabirondo-López

A new data structure for improved scientific data reporting in a FAIR-compliant manner

Jon Gabirondo-López[1], I. González de Arrieta[1], I. Arredondo[2],

G. A. López[1], K. Anhalt[3], J. M. Igartua[1]

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[2]Department of Electricity and Electronics, UPV/EHU, Spain
[3]Physikalisch-Technische Bundesanstalt (PTB), Berlin, Germany

1. Background

1. The necessity to **standardize emissivity measurements**.

1

1. Background

1. The necessity to **standardize emissivity measurements**.

2. The **integral upgrade of the HAIRL** emissometer during 2021-2025.

1

2. The framework

```
fer:

Framework for Experimental Results
```
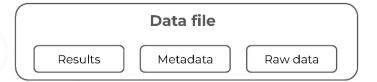
2

2. The framework

```
fer:
```

Framework for Experimental Results

Three main elements:

```
Data file

  Results    Metadata    Raw data
```

2

2. The framework

```
fer:
```

Framework for Experimental Results

Three main elements:

```
Data file

  Results    Metadata    Raw data
```

Scripts

2

2. The framework

```
fer:
```

Framework for Experimental Results
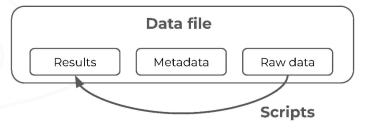
Three main elements:

- **Data files**: to store the results, the metadata and the raw data.
- **Scripts**: written in any open programming language.
- Open **databases** and **repositories**.
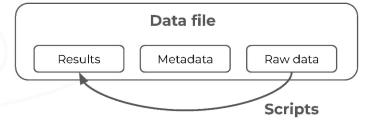
3

2. The framework

```
fer:
```

Framework for Experimental Results

Three main elements:

4

3. The data files

- FAIR principles
- Good reporting practices
  by IUPAC
- Open Data
- VIM
- GUM

`fer` data files

5

3. The data files

- `fer` data files are organized using **key-values**.

6

3. The data files

- `fer` data files are organized using **key-values**.

- They are **not limited** to a single **file format**.

6

3. The data files

- `fer` data files are organized using **key-values**.

- They are **not limited** to a single **file format**.

- The data file consists of **three main** data structures and **five auxiliary** data structures.

6

4. The data structure

```
Measurement:

-   id
-   changelog
-   description
-   correct
-   measurands
-   state
-   results
-   correlations
-   source
```

7

4. The data structure

```
Measurement:

-   id
-   changelog
-   description
-   correct
-   measurands
-   state
-   results        ⟵——— [ QuantityValues, QuantityValues, … ]
-   correlations
-   source
```

7

4. The data structure

```
QuantityValues:

    - id
    - name
    - description
    - changelog
    - quantities
    - symbols
    - units
    - values
    - standard_uncertainties
    - coverages
    - probability_density_function
    - correlation_indices
```

8

4. The data structure

```
Measurement:

    - id
    - changelog
    - description
    - correct
    - measurands
    - state
    - results         ←——— [ QuantityValues, QuantityValues, … ]
    - correlations
    - source
```

9

4. The data structure

```
Measurement:

  - id
  - changelog
  - description
  - correct
  - measurands
  - state
  - results          ←———— [ QuantityValues, QuantityValues, … ]
  - correlations
  - source    ←———— Source
```
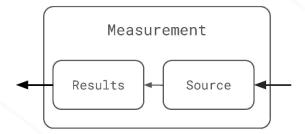
9

4. The data structure

```
Source:

  - id
  - name
  - description
  - model
  - influence_quantities
  - input_quantities
  - correlations
```

10

4. The data structure

4. The data structure

4. The data structure
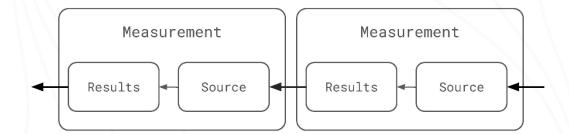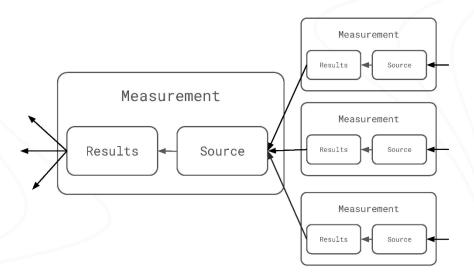
```
Source:

-  id
-  name
-  description
-  model
-  influence_quantities
-  input_quantities  ⟵  [ Measurement, Measurement, … ]
-  correlations
```

4. The data structure

13

4. The data structure

14

4. The data structure

Working example:

A thermocouple is used to perform a temperature measurement.

A voltmeter is used to measure the electromotive force between its wires, and the Seebeck coefficient is used to retrieve the temperature of the measuring junction.

15

4. The data structure

Measurement
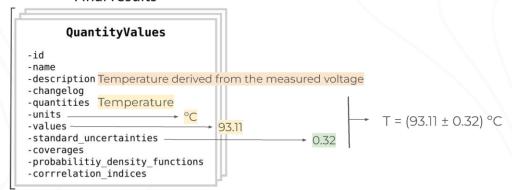
-id
-changelog
-description   Temperature measurement
-correct
-state
-results
-correlations
-measurands
-source

16

4. The data structure

Final results

QuantityValues
```
-id
-name
-description  Temperature derived from the measured voltage
-changelog
-quantities   Temperature
-units                        ⟶  °C
-values                          93.11
-standard_uncertainties              0.32
-coverages
-probabilitiy_density_functions
-corrrelation_indices
```

$$T = (93.11 \pm 0.32) \,°C$$

17

4. The data structure

Measurement
```
-id
-changelog
-description
-correct
-state
-results ⟶
-correlations
-measurands
-source
```

Final results

QuantityValues
```
-id
-name
-description
-changelog
-quantities
-units
-values
-standard_uncertainties
-coverages
-probabilitiy_density_functions
-corrrelation_indices
```

18

4. The data structure

18

4. The data structure

19

4. The data structure

Measurement

```
-id
-changelog
-description     Measurement of the electromotive force
-correct
-state
-results
-correlations
-measurands
-source
```

20

4. The data structure

Measurement

```
-id
-changelog
-description     Seebeck coefficient derived from the calibration curve
-correct
-state
-results
-correlations
-measurands
-source
```

21

4. The data structure

Measurement

-id
-changelog
-description   Seebeck coefficient derived from the calibration curve
-correct
-state
-results ——————→ ...
-correlations
-measurands
-source ——————→ ...

21

4. The data structure

Measurement

-id
-changelog

Temperature measurement

-state
-results —————————→   T = (93.11 ± 0.32) °C
-correlations
-measurands
-source

Final results

QuantityValues

-id
-name
-description
-changelog
-quantities

-coverages
-probabilitiy_density_functions
-corrrelation_indices

Source

Temperature inversion model

-model
-influence_quantities
-input_quantities ————
-correlations

Trace to indications

Measurement of the electromotive force   ——→ ...

Seebeck coefficient derived from the calibration curve   ——→ ...

22

4. The data structure

Measurement
- -id
- -changelog
- -description
- -correct
- -state
- -results
- -correlations
- -measurands
- -source

Final results

QuantityValues
- -id
- -name
- -description
- -changelog
- -quantities
- -units
- -values
- -standard_uncertainties
- -coverages
- -probabilitiy_density_functions
- -corrrelation_indices

Source
- -id
- -name
- -description
- -model
- -influence_quantities
- -input_quantities
- -correlations

Trace to indications

Measurement → Source → ···

Measurement → Source → ···

23

4. The data structure

State:
- name
- description
- quantity_value

ChangelogEntry:
- timestamp
- user
- description

ProbabilityDensity Function:
- name
- parameters
- values

Correlations:
- quantities
- correlation_matrix
- method

Coverage:
- intervals
- probabilities
- degrees_of_freedom
- method

24

5. Some implementations


```
https://github.com/jongablop/fer
```

JSON schema of the data
structure.

Examples.

25

5. Some implementations


```
https://github.com/jongablop/fer
```

JSON schema of the data
structure.

Examples.


```
https://github.com/jongablop/ferpy
```

Python implementation of the
data structure.

Easy to integrate.

25

6. Conclusions

- The proposed data structure **aligns with international standards** and can be applied across various fields.

26

6. Conclusions

- The proposed data structure **aligns with international standards** and can be applied across various fields.

- Its Python-based implementation allows **easy integration**.

26

6. Conclusions

- The proposed data structure **aligns with international standards** and can be applied across various fields.

- Its Python-based implementation allows **easy integration**.

- It serves as the **basis for open databases.**

26

A new data structure for improved scientific data reporting in a FAIR-compliant manner

Jon Gabirondo-López[1], I. González de Arrieta[1], I. Arredondo[2],
G. A. López[1], K. Anhalt[3], J. M. Igartua[1]

jon.gabirondol@ehu.eus

Day 3 (2025-02-27 Thursday)
Parallel Session "DCR & DRMC"
(Chair: Alexis Valqui)

035 Implementation of Digital Calibration Request, DCR

Presenting author: Heidi Foldal; Novo Nordisk A/S, Novo Alle 1, 2880 Bagsvaerd, Denmark
Email: hefo@novonordisk.com
Additional authors:

Abstract:

The project team at Novo Nordisk A/S is conducting pilots to implement the Digital Calibration Request (DCR) for digital calibration certificates from suppliers. The company's calibration process is managed through a centralised database where equipment information and calibration requirements are stored. The requirements transferred to the DCR XML files include calibration points, adjustment limits, maximum calibration uncertainty, and calibration methods for example the orientation of measuring equipment during calibration. The project team and IT developers have access to this data, which can be extracted from the database via middleware and used to generate a DCR XML file. Certain necessary data, such as contact information for the employee requesting the calibration, return address for the equipment, and whether the calibration is on-site or at a laboratory is not available in the database and must be manually entered into the middleware during the ordering process. Additionally, standard text that appears in all requests sent to suppliers, such as accreditation requirements according to ISO 17025 or Quality Agreement with Novo Nordisk A/S, is included. Excel is currently being utilised as the middleware tool for the pilot phase. Upon further development of the DCC (Digital Calibration Certificate) and DCR processes, full integration with the database is envisioned. Currently, the project team is mapping data to be implemented in the middleware. It is noted that not all data stored in the database is machine-readable or in a standardised format. This initiative serves an input for future standardisation and digitalisation of Novo Nordisk's work processes. For the execution of pilot projects, Novo Nordisk is collaborating with DFM, the NMI of Denmark, as well as various large and small calibration suppliers.

Presentation of Heidi Foldal

novo nordisk®

Implementation of Digital Calibration Request, DCR

Heidi Foldal, The 5 th DCC international conference

2025.02.27

Novo Nordisk Corporate Metrology Process

Corporate Metrology Process:

- Ensures reliable and traceable measurements for critical processes
- Strategic goals:
  - Remove manual transfer of data
  - Have FAIR and relevant data for decision -making
- Pilots for implementation of Digital Calibration Certificates (DCC) and Digital Calibration Request (DCR)

Novo Nordisk Calibration Programme

High level

- Define what to measure
- Identify the requirements for the measurand
- Calibration requirements for the measuring equipment is based on the requirements for the measurand
- Calibration intervals are specified based on a risk assessment assessing impact, probability and mitigation
- If measuring equipment does not comply with requirements   – Deviations are created to evaluate the use in the entire period back to the last passed calibration
- Outsourcing:
  - Execution of calibration can be outsourced
  - Responsibility of result evaluation cannot be outsourced
  - Conformity statements in calibration certificates are not wanted
  - Calibration certificates must be delivered to Novo Nordisk

Calibration Data Flow

- Corporate IT system manages calibration program
  - Centralized database used to records results from Novo Nordisk and supplier calibrations
  - Manual entry of calibration data into the system
  - IT system evaluates if a calibration is pass or fail
  - Performance monitored using dashboards
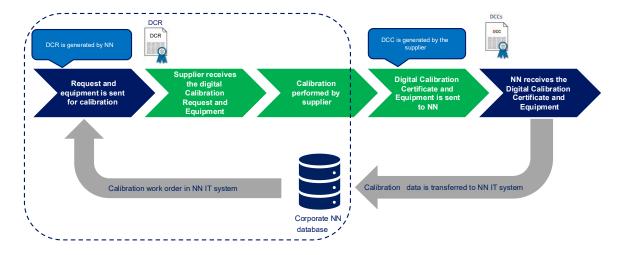
Future goals

- Predict equipment failure
- Optimize calibration program for efficiency and avoid over -processing and under -processing

Digital calibration process – focus on DCR

Why focus on the DCR

- The process commences with a calibration request rather than the issuance of a calibration certificate.
- It's crucial to emphasize that the entire calibration process holds significance, not just the ultimate deliverable, the certificate.
- Suppliers are also eager to digitize and automate, which is a prerequisite for NN to receive DCC.

SABRINA COLEY
Product Supply
USA

What is a DCR

- A DCR is a Digital Calibration Request in an XML format file sent from the customer to the supplier.

In the NN pilot project:
- Plan to use an empty DCC and complete it with the necessary information, such as:
  - Administrative data
  - Calibration points
  - Requirements Calibration Method

CLAES ROSENKRANTZ
Product Supply
Denmark
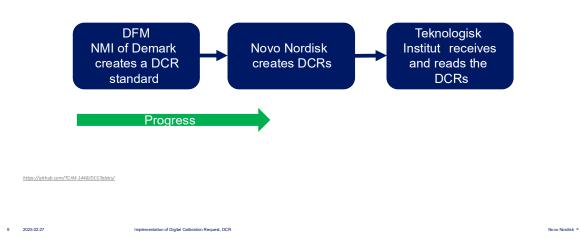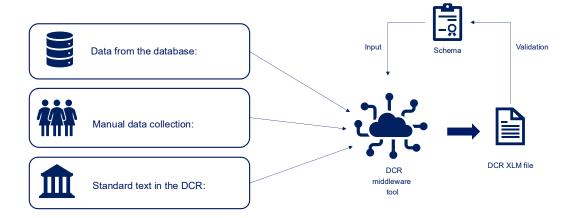
Pilot project

- The purpose of the current pilot project is to evaluate whether we can successfully pass a DCR through a chain of three stakeholders

https://github.com/TC-IM-1448/DCCTables/
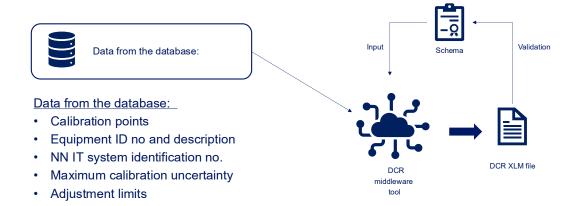
Input sources for the DCR
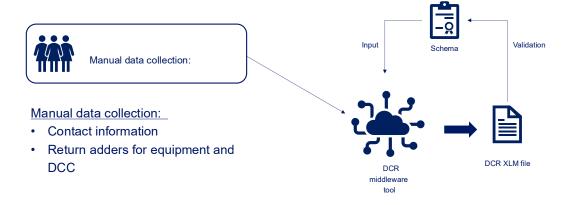
Input sources for the DCR

Data from the database:

Data from the database:
- Calibration points
- Equipment ID no and description
- NN IT system identification no.
- Maximum calibration uncertainty
- Adjustment limits

Input   Schema   Validation

DCR middleware tool

DCR XLM file

Input sources for the DCR

Manual data collection:

Manual data collection:
- Contact information
- Return adders for equipment and DCC

Input   Schema   Validation

DCR middleware tool

DCR XLM file

Input sources for the DCR

Standard text in the DCR:

Standard text in the DCR:
- Calibration must be performed accredited or according to Quality Agreement
- One calibration certificate for one calibration of one equipment
- As found calibration and as left must be documented in two individual DCC
- No conformity statements in the DCC

Input   Schema   Validation

DCR middleware tool

DCR XLM file

DCR middleware tool

Pilot phase:
- An Excel application is used as a pilot tool to generate the DCR
  - Data from ADA database pulled automatedly using the calibration work order
  - Manual data is typed in to a table
  - Standard text is in a table

Input   Schema   Validation

DCR middleware tool

DCR XLM file

Corp. database   calibration work order   ADA database   calibration work order

DCR XML structure

- In creation of a DCR, the structure of the DCC is followed for relevant content:

DCR XML structure

- "1" = mandatory
- "0" = not mandatory

Passing the DCR to Teknologisk Institut

- In the pilot NN will pass the DCR to TI by mail

DCR
middleware
tool

DCR XLM file

email

TI

WHY
- 20.000 supplier calibrations a year

Current status:

- Calibration certificates are analogue and not machine readable or interoperable
  - In average it takes 20 minutes to transfer data from the calibration certificate to the IT system including second person review

- Communication from Novo Nordisk to supplier is manual
  - In average it takes 25 minutes to transfer data from IT system to a letter
  - 5% of all revised calibration certificates are revised due to errors in NN calibration request

- Trending on calibration data
  - Transparent data insight via the dashboard above
  - Machine Learning under development to trend on data including metadata, and classify between equipment exhibiting systematic drift or not

036   Benefits of developing DCR with a focus on machine readability and automation.

Presenting author: Martin Cradock Østerlund, Teknologisk Institut, Denmark
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Additional authors:

Abstract:

As with the DCC, the development of a standard for a Digital Calibration Request (DCR) has huge implications for the transfer of calibration data and calibration requests. Moving away from the current standard of paper-based requests allows for automatic validation of calibration parameters, smoother integration into software and quality systems, and allows machines to parse data into a readable format, thus minimizing human error.

Additionally, a common DCR standard has massive implications for the development of fully automated calibration processes. By integrating DCR with calibration software, calibration laboratories have the potential to format a given DCR directly into instructions for calibration software to perform. Coupled with a standard for the DCC, this enables full automation of all steps in the calibration process, including validation of requests, performing the calibration, sending of calibration results and validating the results for the customer.

In this presentation, we discuss our visions for a DCR standard. We discuss what a DCR is, and what sort of information it should include. We will discuss the potential for developing a DCR standard with input from industry partners and how DCR can be integrated into fully automated software solutions. Along with this, we will discuss potential pitfalls that should be considered when developing DCR, with regards to automation and validation.

Presentation of Martin Cradock Østerlund

DANISH TECHNOLOGICAL INSTITUTE

DCC conference 2025

Benefits of developing DCR with a focus on machine readability and automation

Topics

- About me
- What is DCR?
- What are the benefits of DCR?
- Integration into automated software processes
- Steps in parsing a DCR
- Developing DCR with input from industry partners

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About me
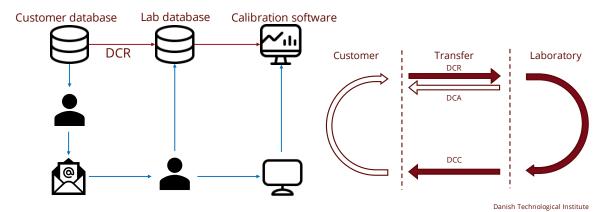
Martin Cradock Østerlund

- Background in physics
- Works with digitalization of DTI's calibration laboratories

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What is DCR?

- Digital Calibration Request

- System-to-system communication

Customer database   Lab database   Calibration software

DCR

Customer   Transfer   Laboratory

DCR

DCA

DCC

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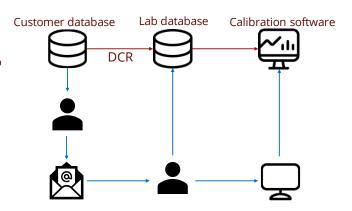
What are the benefits of DCR?
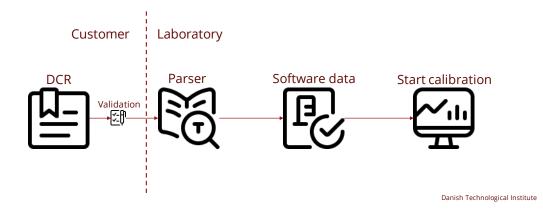
- Requests can be received faster
- Reduces human errors
- Combined with DCC a shorter round trip time

Customer database   Lab database   Calibration software

DCR

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Integration into automated software processes
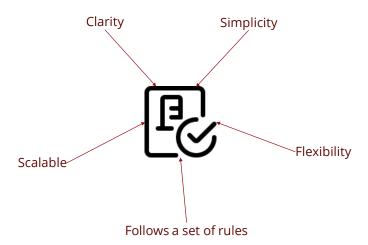
- Machine readability
- From DCR to software instructions

Customer   Laboratory

DCR   Parser   Software data   Start calibration

Validation

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Steps in parsing a DCR – Software data

• Characteristics of "good" software data

Clarity

Simplicity

Scalable

Flexibility

Follows a set of rules

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Example – Calibration of a thermometer

"The customer instrument is a Platinum Resistance Thermometer, with a nominal resistance at 0°C of 100Ω"

```
{dut: {
    type: 'thermometer';
    parameters:
        {subType: 'prt';
            nominalResistance: 100;
        };
    }
}
```

"The customer instrument is a thermocouple of Type-K.

```
{dut: {
    type: 'thermometer';
    parameters:
        {subType: 'thermocouple';
            type: 'Type-K';
        };
    }
}
```

• Depending on the different types and subtypes, the output changes

```
types = 'thermometer' || 'anemometer' || 'barometer'

thermometerSubTypes = 'prt' || 'thermocouple' || 'thermistor'
```

• Very flexible and also very structured

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Steps in parsing a DCR - Parsing

- Taking something with one structure and converting it to our "good" software data.

- What to consider

Input
- What is the input?
- How complex is it?
- What information do we expect it to contain?

Output
- What is the output?
- How structured does it need to be?
- What information do we need to extract?

Steps in parsing a DCR - Parsing

A hard example

"The customer instrument is a Platinum Resistance Thermometer, with a nominal resistance at 0°C of 100Ω"

```
{dut: {
    type: 'thermometer';
    parameters:
        {subType: 'prt';
            nominalResistance: 100;
        };
    }
}
```

- Input is ambiguous and unstructured
- Many difficult operations in order to structure properly
- What if string is altered slightly?
→ Parser becomes very complex

Steps in parsing a DCR - Parsing

An easier example

```
class Instrument
    {
    string Type = 'thermometer';
    string Kind = 'pt-100';
    }
```

```
{dut: {
    type: 'thermometer';
    parameters:
        {subType: 'prt';
            nominalResistance: 100;
        };
    }
}
```

- Input is much more structured
- Still a bit of work to do, but it's much more manageable
→ Parser becomes much simpler

Key takeaways:
- Keep inputs simple and strucutred
- Obey our good principles on data structure

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Steps in parsing DCR – The DCR

• Written in XML

- Data storage with tags

- Machine readable

- Structured and with predefined rules

```
<note>
    <heading>Important note</heading>
    <body>Register for the DCC conference!</body>
</note>
```

Important note

Register for the DCCconference!

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Taking inspiration from the DCC

The good:

```
<dcc:measuringEquipments>
  <dcc:measuringEquipment refType="PRT">
    <dcc:name>
      <dcc:content lang="de">Pt 100 Widerstandsthermometer</dcc:content>
      <dcc:content lang="en">Pt 100 thermometer</dcc:content>
    </dcc:name>
```

- We know were to start looking
- We have a specified instrument type
- We have a nominal resistance value

```
{dut: {
  type: 'thermometer';
  parameters:
    {subType: 'prt';
      nominalResistance: 100;
    };
  }
}
```

*DCC examples are created using the GEMIMEG tool:
https://www.gemimeg.ptb.de/gemimeg-tool/#/

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Taking inspiration from the DCC

The bad:

- refType and contents are free-text fields…

```
<dcc:measuringEquipments>
  <dcc:measuringEquipment refType="Resistance Thermometer made of highly enriched Platinum">
    <dcc:name>
      <dcc:content lang="de">Platin-Widerstandsthermometer mit einem Nennwiderstand von 100 Ohm bei 0 Grad Celsius.</dcc:content>
      <dcc:content lang="en">Platinum Resistance Thermometer with a nominal resistance of 100Ohms at 0 degrees celsius.</dcc:content>
    </dcc:name>
```

- Way too many edge cases for parser

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A more sound approach

- What a DCR could look like

Validated against a registry of valid keys

refType dependent

```
<dcr:measuringEquipment>
        <dcr:measuringEquipment refType="prt">
            <dcr:prtParameters>
                <dcr:nominalResistance> 100 </dcr:nominalResistance>
            </dcr:prtParameters>
        </dcr:measuringEquipment>
</dcr:measuringEquipment>
```

Challenges:

- Less open than the DCC
- Many interested parties, with each their opinions on the format
- Structure must be applied to ALL parts of the DCR!

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Developing DCR with input from industry partners

- DCC/DCR interpreter tool
- We take feedback from invested industry partners, like Novo Nordisk
- Collaboration and sharing our findings with PTB.

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Conclusions

- If the DCR is to be used for automation purposes, it requires a set of strict and stable rules.

- This allows for simpler parsing into software data, which is easier to maintain.

- XML is well suited for these purposes

- Compared to the DCC, a DCR needs further refinement and structure.

- Requires the format to be less open.

Thank you for listening

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Danish Technological Institute

037 The Digital Reference Material Document Derived from the DCC

Presenting author: Michael Melzer
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Additional authors: Silke Richter, Mehran Monavari, Johannes van de Kreeke (all from Bundesanstalt für Materialforschung und -prüfung (BAM), Unter den Eichen 87, 12205 Berlin)

Abstract:

The DCC enables automatization in the metrological traceability of measurements and the dissemination and processing of data from calibration services. Many calibration and measurement procedures, however, rely on certified reference materials (CRMs) to obtain metrological traceability, especially in the broad field of chemical quantities and analytics. The metrological information of those reference materials is also provided in the form of certificates, and hence, their digitization bears the same automatization potential for quality assurance and traceability as the DCC itself.

Although fairly similar, a reference material certificate contains some different information, and has a variable structure and proprietary requirements compared to a calibration certificate, as it relies on the dedicated ISO 33401 standard (formally known as ISO Guide 31) rather than the ISO/IEC 17025. Accordingly, the established DCC-schema does not fully fit the purpose of machine-readable reference material certificates. At the German Federal Institute for Materials Research and Testing (BAM), we started to adapt the DCC-schema in order to derive a dedicated schema for CRM certificates. For the seamless digital dissemination of its certified values, including expanded uncertainties, this schema also utilizes the Digital-SI and thus provides a direct link to the BIPM's digital reference point for a global harmonization of metrological quantities. Furthermore, it should also be suitable for non-certified reference materials to form a common data structure for digital reference material documents (DRMD) in general. As a validated XML report, a DRMD is also compatible with established digital security and verification infrastructure, such as electronic seals and the novel digital accreditation symbol.

In this presentation we will highlight some of the essential differences between reference material documents and calibration certificates, but also point out their similarities, which well justify the derivation of the DRMD-Schema from the DCC. In addition, the first related tools, e.g. a DRMD generator app, the DRMD availability in the COMAR reference material database and an LLM-supported certificate conversion algorithm will be presented briefly.

This work was supported in part by national QI-Digital initiative funded by the German Federal Ministry for Economic Affairs and Climate Action.

Presentation of Michael Melzer

5th International DCC Conference

THE DIGITAL RM DOCUMENT DERIVED FROM THE DCC

Michael Melzer, Mehran Monavari, Silke Richter, Johannes van de Kreeke, Claudia Koch

www.bam.de

Our mission: safety in technology and chemistry

The Digital RM Certificate Derived from the DCC

2

BAM as Reference Material Producer

➤ >100 years of RM production

➤ ISO 17034 accredited as RM producer

➤ Webshop with more than 400 products

(webshop.bam.de)

➤ Recent RM-developments in battery

and micro-/nano-materials research
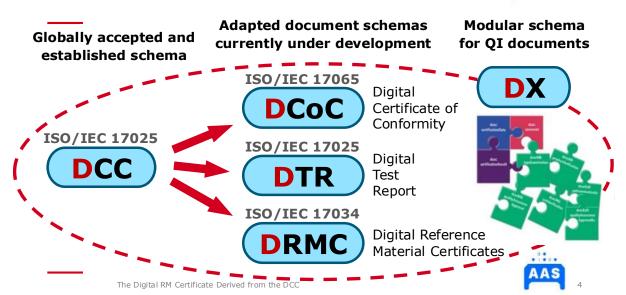
The Digital RM Certificate Derived from the DCC

3

The DCC as a Template for Other QI -Documents

Globally accepted and established schema

Adapted document schemas currently under development

Modular schema for QI documents

ISO/IEC 17025 — **DCC**

ISO/IEC 17065 — **DCoC** — Digital Certificate of Conformity

ISO/IEC 17025 — **DTR** — Digital Test Report

ISO/IEC 17034 — **DRMC** — Digital Reference Material Certificates

DX

The Digital RM Certificate Derived from the DCC

4

DRMD: Two Birds with One Stone

Digital Reference Material Document

(Digital) Reference Material Certificate

→ Contains certified RM-values

→ May also contain uncertified RM-values

→ Contains more mandatory details

(Digital) Product Information Sheet

→ Is similar to RM-certificate

→ Contains no certified RM-values

→ Some details are optional

→ **Must not be called "certificate"**

The Digital RM Certificate Derived from the DCC   5
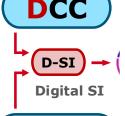
DCC vs. DRMD
Uncertainty

Measurement Uncertainty

DCC

D-SI →
Digital SI

$U_{DCC} = U_{cal}$ U_{stab}

U_{ref}

U_{res}

U_{rep}

...
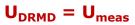
Long-term behavior to be considered by the DCC user

Calibration is valid only for the calibrated item

Uncertainty

DRMD

$U_{DRMD} = U_{meas} \quad + \quad U_{stab} \quad + \quad U_{hom}$

measurement uncertainty   uncertainty of stability   uncertainty of homogenity

https://si-digital-framework.org/   6

PTB

DCC vs. DRMD
Dissemination

BAM

Issuing

DCC

Kalibration Lab
DCC issuer

Customer
DCC holder

DCC contains customer information

Publishing

DRMD

RM producer
DRMD issuer

RM shop
published DRMD

DRMD is not customer specific

Customer
RM user

Relevant dates

- ❯ performanceDate
- ❯ receiptDate
- ❯ issueDate

- ▪ Validity
  - ❯ validityDate
  - ❯ timeAfterDispatch
  - ❯ untilRevoked
- ❯ approvalDate
- ❯ issueDate

7

The DRMD-Schema

BAM

digitalReferenceMaterialDocument
- coreData
  - titleOfTheDocument
  - uniqueIdentifier
  - identifications — identification
    - issuer
    - value
    - name
  - periodOfValidity
  - dateOfDispatch
  - dataOfIssue
  - dateOfValidity
  - dateOfCertificateApproval
- items — item
- administrativeData
  - referenceMaterialProducer
  - respPersons
- statements
  - intendedUse
  - commutability
  - storageInformation
  - instructionsForHandlingAndUse
  - metrologicalTraceability
  - healthAndSafetyInformation
  - subcontractors

8

The Digital RM Certificate Derived from the DCC   9

Automize the monkey work: Databases
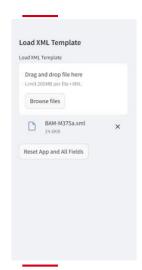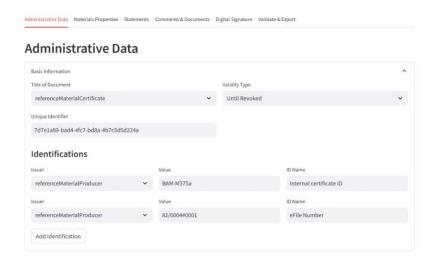
The Digital RM Certificate Derived from the DCC   10

DRMD Generator App

BAM
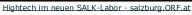
Automize the monkey work: Traceability

BAM

Calibration of many instruments with RM
(e.g. medical diagnostics lab)

Hightech im neuen SALK-Labor - salzburg.ORF.at

ML-training towards automated spectrum analysis ≥ BAM

	Fe in Cu-M382a [mg/kg]	SD
Predicted	8.19	0.91
Certified	10.3	0.7

- 50 Reference materials
- 80 % reference spectral data for traininng model
- 20 % reference spectral data for validation
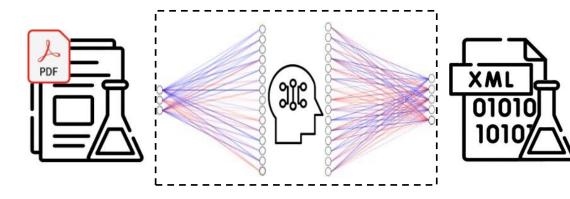
Outlook: AI-based DRMD generator ≥ BAM

Acknowledgements and Contact

038   The Digital NIST: Update on the Digital Transformation of Reference Materials

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E-mail address: william.camara@nist.gov
Additional authors:
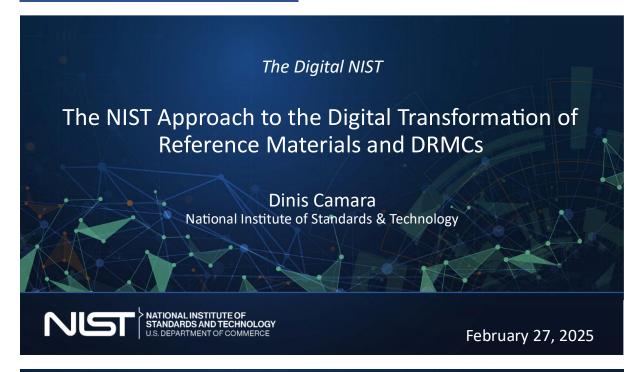
Abstract

At the beginning of 2022, NIST embarked on a pilot project to produce a few examples digital calibration reports and certificates of analysis for the purpose of assessing the scope and challenges of digital transformation in these measurement services. After completion of the pilot project, it was determined that a Digital Reference Material Certificate (DRMC) will require a new model for the data and schema. NIST identified the modelling of Reference Material Data and creation of a database to store the values contained in current certificates as a first step towards digital transformation of Reference Materials. To dive deeper into modelling the types of values, NIST and CENAM collaborated throughout the year. Utilizing the vast scope of over 1,100 NIST Standard Reference Materials (SRM) available, a sample of more than 130 different SRM were reviewed to determine the relationship between the data. The analysis led to a structure able to accommodate the wide variety of values, multipart materials, serialized materials, traceability statements, and other information related to measured values currently expressed in Reference Material Certificates. This talk will give an update on the progress and transition from prototype to production.

Presentation of Dinis Camara

The Digital NIST

The NIST Approach to the Digital Transformation of Reference Materials and DRMCs

Dinis Camara
National Institute of Standards & Technology

February 27, 2025

Acknowledgements

Digital NIST Team:

Angela Lee
Benjamin Long
Robert Hansich
Catherine Rimmer
James Fedchak
Steven Choquette
Catherine Cooksey
Katya Delak
Itzel Domínguez Mendoza (CENAM)

Scientists, Statisticians, and other Subject Matter Experts at NIST

Members of the SIM Digital Reference Material Certificate Subworking Group

What Goes in a DRMC   NIST

Current Draft of Schema
- Organization Identification
- Reference Material Identification
- Material Information
  - Unit Description
  - Usage Information
  - Measurement Information
  - Additional Information
- Context
- Provenance
- References

Based On:

ISO 17034

ISO Guide 31/ISO 33401:2024

NIST Quality Manual

NIST Policy

Customer Input

10

Material Information   NIST

- **Information about the material and its properties**
  - Unit Description
  - Usage Information
  - Measurement Information
  - Additional Information

13

Material Information   NIST

- **Measurement Information**
  - Period of Validity
  - Traceability
  - Measurand
  - Values
  - Units
  - Uncertainties
  - Type of value
    (Certified vs. Non-Certified)
  - Measurement Procedures

Expiration of Certification: The certification of **SRM 2940a** is valid, within the measurement uncertainty specified, until **01 September 2028**, provided the SRM is handled and stored in accordance with the instructions given here (see "Instructions for Use"). The certification is nullified if the SRM is damaged, contaminated, or otherwise modified.

16

NIST SRM Overview   NIST

>1100 SRM Products

- Ferrous Metals
- Nonferrous Metals
- Microanalysis
- High Purity Materials
- Health and Industrial Hygiene
- Inorganics
- Primary Gas Mixtures
- Fossil and Alternative Fuels
- Organics
- Food and Agriculture
- Geological Materials and Ores
- Ceramics and Glasses
- Cement
- Engine Wear Materials
- Forensics

- Ion Activity
- Polymeric Properties
- Thermodynamic Properties
- Optical Properties
- Radioactivity
- Electrical Properties
- Metrology, Liquids and Glasses
- X-Ray Diffraction
- Sizing
- Surface Finish
- Fire Research
- Nanomaterials
- Miscellaneous Performance Engineering Materials

4

Types of Values

- **Values with uncertainties**
- **Sequences**
- **Formulas**

Table 1. Certified Mass Fraction Value for SRM 2454a Hydrogen in Titanium Alloy

Constituent	Mass Fraction (mg/kg)	95 % Coverage Interval (mg/kg)
Hydrogen (H)	216.0	207.6 to 224.4

RM 8671 Heavy Chain Amino Acid Sequence

QVTLRESGPALVKPTQTLTLTCTFSGFSLSTAGMSVGWIRQPPGKALEWLADIWWDDKKHYNPSLKDRLTIS
KDTSKNQVVLKVTNMDPADTATYYCARDMIFNFYFDVWGQGTTVTVSS ASTKGPSVFPLAPSSKSTSGGTA
ALGCLVKDYFPEPVTVSWNSGALTSGVHTFPAVLQSSGLYSLSSVVTVPSSSLGTQTYICNVNHKPSNTKVD
KRV *EPKSCDKTHTCPPCP* **APELLGGPSVFLFPPKPKDTLMISRTPEVTCVVVDVSHEDPEVKFNWYVDGV
EVHNAKTKPREEQYNSTYRVVSVLTVLHQDWLNGKEYKCKVSNKALPAPIEKTISKAKGQPREPQVYTLPPS
REEMTKNQVSLTCLVKGFYPSDIAVEWESNGQPENNYKTTPPVLDSDGSFFLYSKLTVDKSRWQQGNVFSCS
VMHEALHNHYTQKSLSLSPGK**

RM 8671 Light Chain Amino Acid Sequence

DIQMTQSPSTLSASVGDRVTITCSASSRVGYMHWYQQKPGKAPKLLIYDTSKLASGVPSRFSGSGSGTEFTLT
ISSLQPDDFATYYCFQGSGYPFTFGGGTKVEIK RTVAAPSVFIFPPSDEQLKSGTASVVCLLNNFYPREAKV
QWKVDNALQSGNSQESVTEQDSKDSTYSLSSTLTLSKADYEKHKVYACEVTHQGLSSPVTKSFNRGEC

Figure A1. Primary amino acid sequence for RM 8671 with variable fragment antigen-binding (Fab) region in normal font, constant Fab region underlined, hinge region in italics, and Fc region in bold.

$$\lambda = -1.97313 \times 10^{-3} + 1.99227 \times 10^{-5}\rho + 1.07923 \times 10^{-4}T \pm 1.0\ \% \ (k=2)$$

8

Data vs. Format

Table 1. Certified Mass Fraction Value for Total Extractable Fat in SRM 2387

	Mass Fraction (g/100 g)
Fat (extractable)	51.6 ± 1.4

Table 2. Certified Mass Fraction Values for Elements in SRM 2387

	Mass Fraction (mg/kg)		
Calcium (Ca)	411	±	18
Copper (Cu)	4.93	±	0.15
Iron (Fe)	16.4	±	0.8
Magnesium (Mg)	1680	±	70
Manganese (Mn)	16.0	±	0.6
Phosphorus (P)	3378	±	92
Potassium (K)	6070	±	200
Sodium (Na)	4890	±	140
Zinc (Zn)	26.3	±	1.1

Table 3. Certified Mass Fraction Values for Tocopherols in SRM 2387

	Mass Fraction (mg/kg)		
δ-Tocopherol	10	±	3
γ- + β-Tocopherol	100	±	19

RM 8671 Heavy Chain Amino Acid Sequence

QVTLRESGPALVKPTQTLTLTCTFSGFSLSTAGMSVGWIRQPPGKALEWLADIWWDDKKHYNPSLKDRLTIS
KDTSKNQVVLKVTNMDPADTATYYCARDMIFNFYFDVWGQGTTVTVSS ASTKGPSVFPLAPSSKSTSGGTA
ALGCLVKDYFPEPVTVSWNSGALTSGVHTFPAVLQSSGLYSLSSVVTVPSSSLGTQTYICNVNHKPSNTKVD
KRV *EPKSCDKTHTCPPCP* **APELLGGPSVFLFPPKPKDTLMISRTPEVTCVVVDVSHEDPEVKFNWYVDGV
EVHNAKTKPREEQYNSTYRVVSVLTVLHQDWLNGKEYKCKVSNKALPAPIEKTISKAKGQPREPQVYTLPPS
REEMTKNQVSLTCLVKGFYPSDIAVEWESNGQPENNYKTTPPVLDSDGSFFLYSKLTVDKSRWQQGNVFSCS
VMHEALHNHYTQKSLSLSPGK**

RM 8671 Light Chain Amino Acid Sequence

DIQMTQSPSTLSASVGDRVTITCSASSRVGYMHWYQQKPGKAPKLLIYDTSKLASGVPSRFSGSGSGTEFTLT
ISSLQPDDFATYYCFQGSGYPFTFGGGTKVEIK RTVAAPSVFIFPPSDEQLKSGTASVVCLLNNFYPREAKV
QWKVDNALQSGNSQESVTEQDSKDSTYSLSSTLTLSKADYEKHKVYACEVTHQGLSSPVTKSFNRGEC

Figure A1. Primary amino acid sequence for RM 8671 with variable fragment antigen-binding (Fab) region in normal font, constant Fab region underlined, hinge region in italics, and Fc region in bold.

Table 2. Reference Values for SRM 1d Limestone, Argillaceous

Constituent	Mass Fraction (%)	Expanded Uncertainty (%)
C	11.50	0.25^b
TiO₂	0.0306	0.006^b
Cr₂O₃	0.0012	0.0002^b
BaO	0.0033	0.0011^b
Loss on Ignition (1000 °C)	41.57	0.06^a

Preparation of Material: All chemicals used in the preparation of this SRM were of the highest purity available and were obtained from a commercial source. The amino acid solution was prepared by weighing the individual amino acids, concentrated HCl, and water and mixing until the amino acids were completely dissolved. The total mass of this solution was measured. The concentration of each amino acid was calculated using the measured density of the 0.1 mol/L HCl solution at 20 °C of 1.00123 g/mL. Corrections were made to the calculated amino acid concentrations based on purity as determined by LC with absorbance detection with confirmatory data provided by the manufacturer. The purity of each amino acid was also evaluated by elemental analysis at Galbraith Laboratories (Knoxville, TN). Moisture content for all

Values and Their Data NIST

Values and Uncertainties NIST

Values and Uncertainties

Values and Uncertainties

Sequences

#	Type	Sub Type	Order	Type	Formatted Sequence	Detail?
1	Information	Non Certified	1		MKWVTFISLL LLFSSAYSRG VFRRDTHKSE IAHRFKDLGE EHFKGLVLIA FSQYLQQCPF DEHVKLVNEL TEFAKTCVA DESHAGCEKS LHTLFGDELC KVASLRETYG DMADCCEKQE PERNECFLSH KDDSPDLPKL K PDPNTLCD EFKADEKKFW GKYLYEIARR HPYFYAPELL YYANKYNGVF QECCQAEDKG ACLLPKIETM RE KVLASSA RQRLRCASIQ KFGERALKAW SVARLSQKFP KAEFVEVTKL VTDLTKVHKE CCHGDLLECA DDR ADLAKY ICDNQDTISS KLKECCDKPL LEKSHCIAEV EKDAIPENLP PLTADFAEDK DVCKNYQEAK DAFL GSFLY EYSRRHPEYA VSVLLRLAKE YEATLEECCA KDDPHACYST VFDKLKHLVD EPQNLIKQNC DQFEKLGEYG FQNALIVRYT RKVPQVSTPT LVEVSRSLGK VGTRCCTKPE SERMPCTEDY LSLILNRLCV LHEKTPVSEK VTKCCTESLV NRRPCFSALT PDETYVPKAF DEKLFTFHAD ICTLPDTEKQ IKKQTALVEL LKHKPKATEE QLKTVMENFV AFVDK CCAA DDKEACFAVE GPKLVVSTQT ALA	⧉

Identifications:

GROUP **IDENTIFICATIONS** CONFIDENCE LEVEL STATEMENTS PARTS

REFERENCES SOURCES CODES

Identification	Identification Type	Initial	Final	Sub Sequence [not stored]
Signal peptide	Common name	1	24	MKWVTFISLLLLLFSSAYSRGVFR
Bovine Serum Albumin	Common name	25	607	DTHKSEIAHRFKDLGEEHFKGLVLIAFSQYLQ... TEFAKTCVADESHAGCEKSLHTLFGDELCKVA... PDPNTLCDEFKADEKKFWGKYLYEIARRHPYF... KVLASSARQRLRCASIQKFGERALKAWSVARL... ADLAKYICDNQDTISSKLKECCDKPLLEKSHCI... GSFLYEYSRRHPEYAVSVLLRLAKEYEATLEEC... CCAADDKEACFAVEGPKLVV

Formula

SRM: **4328d**			
Srm Number 4328	**Batch** d	**Name** Thorium-229 Radioactivity Standard	

Identifications Lot **Certificate** Groups Mixtures Files

Certificate

IdCertificate	Document Type	Date of issue:
8	**Certificate of Analysis**	2023-01-13

Value Sequences **Formula**

Formula

Type	Output Type	Formula	Unit	Significant Digits	Period of Validity	Details
NonCertified	Value	$N(t) = N_0 \cdot \left(\frac{1}{2}\right)^{\frac{t}{\tau}}$	Bq*g⁻¹	4	null	

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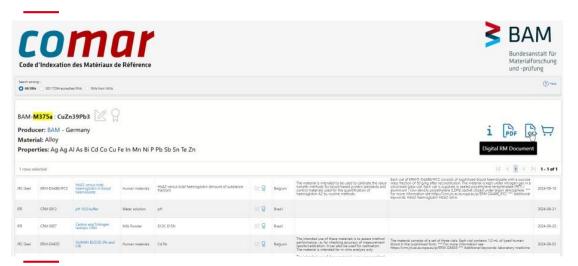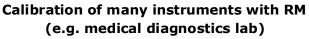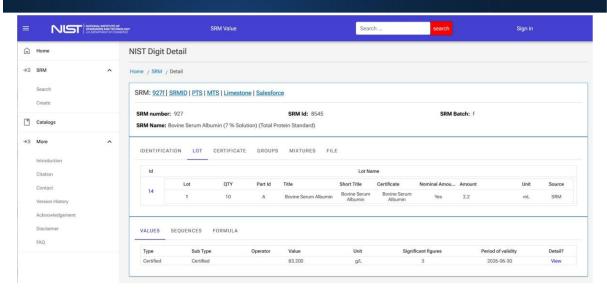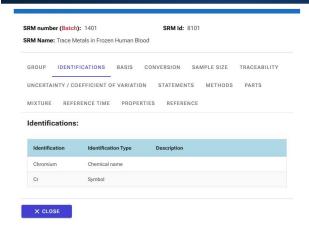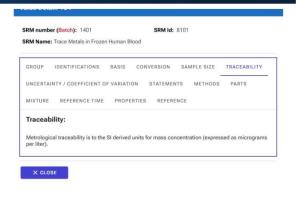<math display="block" class="tml-
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Variables Group Identifications Basis Convertion Traceability Uncertainty / Coefficient of variation Statements

Methods Part Mixture Reference Time Properties References

Variables

Variables

Symbol	Unit	Significant Digits	Properties	Statements
t	year	6		

Values

Symbol	Identification	Value	Unit	Significant Digits
null	Thorium-229	41.19	Bq*g⁻¹	4
null	Half-life	7889.0	a	4

Multiple Value Types in One Certificate

SRM: 927f | SRMID | PTS | MTS | Limestone | Salesforce

SRM number (Batch): 927 (f)   **SRM Id:** 8545

SRM Name: Bovine Serum Albumin (7 % Solution) (Total Protein Standard)

VALUES   SEQUENCES   FORMULA

#	Type	Sub Type	Operator	Value	Unit	Significant figures	Period of validity	Details
1	Certified	Certified		83.2	g/L	3	2026-06-30	

VALUES   SEQUENCES   FORMULA

#	Type	Sub Type	Order	Type	Formatted Sequence	Detail?
1	Information	Non Certified	1		MKWVTFISLL LLFSSAYSRG VFRRDTHKSE IAHRFKDLGE EHFKGLVLIA FSQYLQQCPF DEHVKLVNEL TEFAKTCVA DESHAGCEKS LHTLFGDELC KVASLRETYG DMADCCEKQE PERNECFLSH KDDSPDLPKL K PDPNTLCD EFKADEKKFW GKYLYEIARR HPYFYAPELL YYANKYNGVF QECCQAEDKG ACLLPKIETM RE KVLASSA RQRLRCASIQ KFGERALKAW SVARLSQKFP KAEFVEVTKL VTDLTKVHKE CCHGDLLECA DDR ADLAKY ICDNQDTISS KLKECCDKPL LEKSHCIAEV EKDAIPENLP PLTADFAEDK DVCKNYQEAK DAFL GSFLY EYSRRHPEYA VSVLLRLAKE YEATLEECCA KDDPHACYST VFDKLKHLVD EPQNLIKQNC DQFEKLGEYG FQNALIVRYT RKVPQVSTPT LVEVSRSLGK VGTRCCTKPE SERMPCTEDY LSLILNRLCV LHEKTPVSEK VTKCCTESLV NRRPCFSALT PDETYVPKAF DEKLFTFHAD ICTLPDTEKQ IKKQTALVEL LKHKPKATEE QLKTVMENFV AFVDK CCAA DDKEACFAVE GPKLVVSTQT ALA	

SRM Configuration

SRM number: 2373   **SRM Id:** 493   **SRM Batch:**

SRM Name: Genomic DNA Standards for HER2 Measurements

IDENTIFICATION   LOT   CERTIFICATE   GROUPS   MIXTURES   FILE

Id	Lot Name									
	Lot	QTY	Part Id	Title	Short Title	Certificate	Nominal Amount?	Amount	Unit	Source
8		1	A	Component A - white	SK-BR-3	SK-BR-3		100.00	µL	SRM
		1	B	Component B - blue	MDA-MB-231	MDA-MB-231		100.00	µL	SRM
	LOT 1	1	C	Component C - red	MDA-MB-361	MDA-MB-361		100.00	µL	SRM
		1	D	Component D - yellow	MDA-MB-453	MDA-MB-453		100.00	µL	SRM
		1	E	Component E - green	BT-474	BT-474		100.00	µL	SRM

SRM Configuration

Serialized SRMs

Database Creation NIST

- **Accommodates Values (Numbers), Sequences, and Formulas**
- **Accommodates NIST reported values and most of the additional values in certificates**
- **Created to integrate with current SRM IT applications and DBs**
- **Additional functionality added that will enhance other SRM applications**
- **Version 1**

Future Work NIST

- **Complete the Documentation of the Model**
- **Creation of usable XML Schema from modeling**
- **Expansion of other Measurement Information like Usage Information**
- **Best way to sign and secure certificates**
    - Centralized Signatory
    - Blockchain
- **Continued International Discussions**

Closing Session & Statistical information:

Final Numbers of the DCC Conference 2025

45 presentations

760 registered participants

3 panel sessions
8 parallel sessions

2 open exchanges

90 countries

5TH INTERNATIONAL DCC CONFERENCE
DCC FOR FAIR PRINCIPLES IN THE QUALITY INFRASTRUCTURE

A huge Thank You to the Conference Chairs

Session	Chairs
DAY 1	
Plenary Session	Martin Koval
Key Aspects of DCC I	Shanna Schönhals
Applications NMI I	Brett Hyland
DAY 2	
Plenary Session	Hugo Gasca
Tools & Sofware	Anjali Sharma
Industry Applications	Carlos Galvan
Applications NMI II	Jariya Buajarern
DAY 3	
Plenary Session	Hector Laiz
Schema & Semantics	Robert Hanisch
Key Aspects of DCC II	Mark Kuster
DCR & DRMC	Alexis Valqui

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DCC FOR FAIR PRINCIPLES IN THE QUALITY INFRASTRUCTURE

A huge Thank You to the Conference Team

Oksana Baer
Franziska Decker
Muhammed Ali Demir
Lutz Doering
Wiebke Heeren
Justin Jagieniak
Moritz Jordan
Shan Lin
Jan Loewe

5TH INTERNATIONAL DCC CONFERENCE

Announcement of Special Issue in Elsevier Measurement: Digitalization

- Based on the DCC Conference 2025
- Selected submissions will be invited to submit a paper for the journal
- Members of IPC invited to support review process /act as guest editors
- Open Access, with no publication fees
- Open Call will be issued in March/April

5TH INTERNATIONAL DCC CONFERENCE

Hoping to meeting you soon at M4DConf 2025

• Special Session on Calibration and Comparison in a Digital Era

• Do not hesitate to submit your work to this session
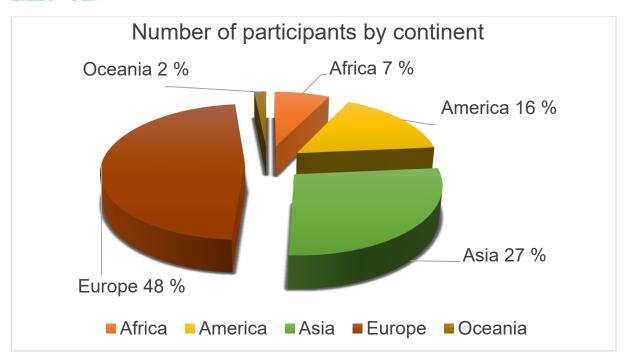
See you at the DCC Conference 2026
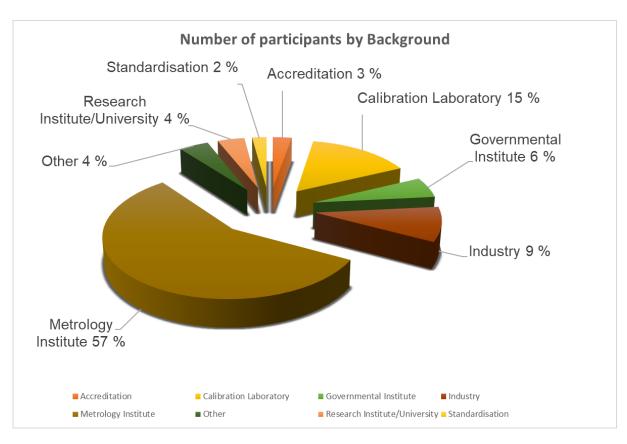
• 6th International DCC Conference

• 24. – 26. February 2026

• Online and free of charge

• Looking forward to meeting you again!

Number of participants by continent

Oceania 2 %

Africa 7 %

America 16 %

Asia 27 %

Europe 48 %

■ Africa ■ America ■ Asia ■ Europe ■ Oceania

Number of participants by Background

Standardisation 2 %

Accreditation 3 %

Research Institute/University 4 %

Calibration Laboratory 15 %

Other 4 %

Governmental Institute 6 %

Industry 9 %

Metrology Institute 57 %

■ Accreditation   ■ Calibration Laboratory   ■ Governmental Institute   ■ Industry
■ Metrology Institute   ■ Other   ■ Research Institute/University   ■ Standardisation