6th International DCC-Conference

2026-02-24 to 2026-02-26
Proceedings

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Chairs of the Program Committee

- Jariya Buajarern, Head of Digital Centre and Materials Metrology, Quality System and International Cooperation Office, NIMT, Thailand
- 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 Dansk Fundamental Metrologi (DFM), Denmark
- Jariya Buajarern, 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, Senior Metrologist at Measurement Standards Laboratory of New Zealand (MSL)
- James Fedchak, Associate Director for Measurement Services, Physical Measurement Laboratory (NIST)
- 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
- Hector Laiz, Director of Metrology and Quality, INTI, Argentina
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- Anjali Sharma, Senior Principal Scientist and Head, NPLI, India
- Shanna Schönhals, Group Lead and Head of DCC Development Team at PTB, Germany
- Alexis Valqui, Digitalisation Consultant

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Agenda and Chairpersons

2026-02-24 (Day 1 Tuesday)

UTC	2026-02-24 Tuesday		
12:00	Welcome and Key Notes Session Chair: Jariya Buajarern		
12:15			
12:30	#P01 Brett Hyland - Interoperable data exchange within digital quality infrastructure - an update on efforts underway at UNECE		
12:45			
13:00	#P02 Mark Kuster - Modeling measurement data with the MII measurand taxonomy		
13:15			
13:30	Break		
13:45			
Parallel Sessions	DCC in digital QI Session Chair: Brett Hyland	DCC Production I Session Chair: Carlos Galván	Digitalization to enable DCC Session Chair: Mark Kuster
14:00	#001 A. G. Ordoña *Implementing Blockchain-Enabled Digital Certificates and a Verification Portal at DOST-ITDI: A Use Case for Enhancing Quality Infrastructure*	#006 Hayati Amalia *An Initial Step Toward Digital Calibration Certificates (DCC) in SNSU BSN Indonesia: Preliminary Development of a DCC WebBased Application*	#010 S. Singh *Automation of Manual Balance for Mass Measurement Data Acquisition employing LabVIEW*
14:20	#002 J. Schüür *A web based revision validation system for (digital) calibration certificates*	#007 A. Mukhammad Aminov *Application of digital calibration certificates for acoustic calibrators*	#011 V. Malisevych *Digital representation and verification of metrological traceability chains in quality infrastructure systems*
14:40	#003 M.-A. Demir *An example of a DCC compatible sub schema*	#008 I. Yang *From PDF Certificates to DCCs for Cold Chain Applications*	#012 M. Sachica *Process Automation in Metrology: A Use Case for Enhanced Accuracy and Efficiency*
15:00	#004 P. Blattner *Swiss Quality Infrastructure: Digitalization of the Traceability*	#009 Paramita Guha *Development of a Machine-Readable Prototype Digital Calibration Certificate for a True RMS Clamp Meter*	#013 Saad Bin Qoud *Digitally Linking BIPM Service and Smart KCDB Data Acquisition to NMCC Calibration Services Platform based on Fast API*
15:20	#005 P. Thongluang *Measurement Capability Modeling and SI-Compliant Unit Representation for Digital Calibration Certificates*	*Discussion and Q&A*	#014 Alex Knaak *Presentation of the new website "Digital Metrology" (PTB) and open exchange*

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2026-02-25 (Day 2 Wednesday)

UTC	2026-02-25 Wednesday Session Chair: Anjali Sharma		
12:00	#P03 J. Fedchak - Challenges in Creating DCCs		
12:15			
12:30	#P04 C. Sander - Digital accreditation symbol: machine-readable, fraud-proof, and verifiable – benefits and experiences for the DCC		
12:45			
13:00	#P05 G. Foyer - A challenge to test interoperability of DCCs for weights		
13:15			
13:30	Break		
13:45			
Parallel Sessions	DCC Ecosystem Session Chair: Martin Koval	DCC Tools and Development I Session Chair: James Fedchak	DCC Management Session Chair: Shanna Schönhals
14:00	#015 Bin. Wang *Research and Application of Digital Reference Material Certificate System by NIM*	#020 L. Busser *Importing a DCC with the help of Globally Unique Identifers*	#024 S. Thirumalairaj *A Framework for a Hybrid Digital Calibration Certificate Architecture at CSIR-NPL India*
14:20	#016 Punith Durga Prasad Arumilli *The Digital Reference Material Document (DRMD): Transforming Static Certificates into Machine-Interpretable Quality Infrastructure*	#021 M. Jordan *Semantics of Digital Calibration Certificates: The DCCS and SIS Ontologies*	#025 L. Wyss *A Robust Data Pipeline for Raw Measurement Processing and Uncertainty Propagation using METAS UncLib*
14:40	#017 D. Balslev-Harder *DCX in Practice: Workflow and Generation of Digital Calibration Requests*	#022 J. Gonzalez-Gomez *dccQuantities: A Python library for the Automated Evaluation and Uncertainty Propagation of Digital Calibration Certificates*	#026 G. Geronymo *An End-to-End Framework for Electrical Metrology Digitalization: API-based DCC Integration, XSLT Visualization, and Workflow Automation*
15:00	#018 Martin Østerlund *Comparing the DCC with the DCX: Advantages, disadvantages and the tools developed*	#023 J. Loewe *dcclib – A Python Library for Automated DCC Processing*	
15:20	#019 D. Balslev-Harder *DCX from DCR to DCC: Digital Results and Round-Robin Evaluations*	*Discussion and Q&A*	*Discussion and Q&A*

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2026-02-26 (Day 3 Thursday)

UTC	2026-02-26 Thursday Session Chair: Hector Laiz		
12:00 12:15	#P06 Sami Koskinen - Live demonstration how DCC is created by the vendor and utilized by the end use		
12:30 12:45	#P07 A. Sharma - Assessing Feasibility of KCDB API–Driven Service Classification for NMI Service Catalogues: A Use Case from NPL India for Digital Calibration Requests		
13:00 13:15	#P08 D. Hutzschenreuter - Units of measurement at its best		
13:30 13:45	Break		
Parallel Sessions	DCC Tool and Development II Session Chair: Hugo Gasca Aragon	DCC Use Case Session Chair: David Balslev-Harder	DCC Production II Session Chair: Thomas Krah
14:00	#028 M.-A. Demir *Current developments for the next DCC schema version*	#032 W. Heeren *DCC to Industry - Processes in a Practical Use-Case*	#036 J. Haller *Expert Report DKD-E 7-3 on how to use the DCC schema for weighing instruments - content and first months of experience*
14:20	#029 J. Wenke *dccviewer-js: A solution to view and explore measurement data from DCCs*	#033 D. Taipe *Dynamic characterization of comparators for weight calibration through DCC integration*	#037 M. Melzer *Recommendations for DCCs for the ISO 376 calibration of uniaxial force measuring devices*
14:40	#030 D. Hutzschenreuter *Application of DCCs in the Digital Metrological Expert software tool for interlaboratory comparison data analysis*	#034 C. Sánchez *From Good Practice to Standardization: Advancing Digital Calibration Certificates at the Instituto Nacional de Metrología de Colombia (INM)*	#038 E. Danaci *From Fragmented Practices to Harmonized and Interoperable Models: Designing Common Templates for Measurement Results in Digital Calibration Certificates*
15:00	#031 Vashti Galpin *Digital calibration certificates for X-ray Photoelectron Spectroscopy*	#035 A.A. García González *Digitization of laboratories for the automation of measurement processes by implementing DCC*	#039 S. Kursin *Peculiarities of Data Representation in Digital Calibration Certificates for Measuring Antennas*
15:20	Closing Session		

Day 1 2026-02-24 Tuesday
Plenary Session
Chair: Jariya Buajarern

Welcome message I: Jariya Buajarern, NIM Thailand

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

- Chair: Jariya Buajarern, NIMT
- Co-Chair: Shanna Schönhals, PTB

6TH INTERNATIONAL DCC CONFERENCE
FROM GOOD PRACTICE TO STANDARDIZATION: DCC FOR A RELIABLE FUTURE

What Awaits You at the Conference ?

47 presentations

> 600 registered participants

3 panel sessions
9 parallel sessions

82 countries

4 open exchange sessions

6TH INTERNATIONAL DCC CONFERENCE
FROM GOOD PRACTICE TO STANDARDIZATION: DCC FOR A RELIABLE FUTURE

Key Notes

Frank Härtig, Vice President of PTB

Stephan Schlamminger, Physicist, NIST

6TH INTERNATIONAL DCC CONFERENCE
FROM GOOD PRACTICE TO STANDARDIZATION: DCC FOR A RELIABLE FUTURE

Conference Chairs

Session	Chairs
DAY 1	
Plenary Session	Jariya Buajarern
DCC in digital QII	Brett Hyland
DCC Production I	Carlos Galván
Digitalization to enable DCC	Mark Kuster
DAY 2	
Plenary Session	Anjali Sharma
DCC Ecosystem	Martin Koval
DCC Tools and Development I	James Fedchak
DCC Management	Shanna Schönhals
DAY 3	
Plenary Session	Hector Laiz
Schema & Semantics	Hugo Gasca Aragon
Key Aspects of DCC II	David Balslev-Harder
DCR & DRMC	Thomas Krah

6TH INTERNATIONAL DCC CONFERENCE
FROM GOOD PRACTICE TO STANDARDIZATION: DCC FOR A RELIABLE FUTURE

Conference Team

Oksana Baer
Franziska Decker
Lutz Doering
Muhammed-Ali Demir
Wiebke Heeren
Justin Jagieniak
Moritz Jordan
Jan Loewe

In case of technical questions or issues please contact the team at dcc-conference-2026@ptb.de

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FROM GOOD PRACTICE TO STANDARDIZATION: DCC FOR A RELIABLE FUTURE

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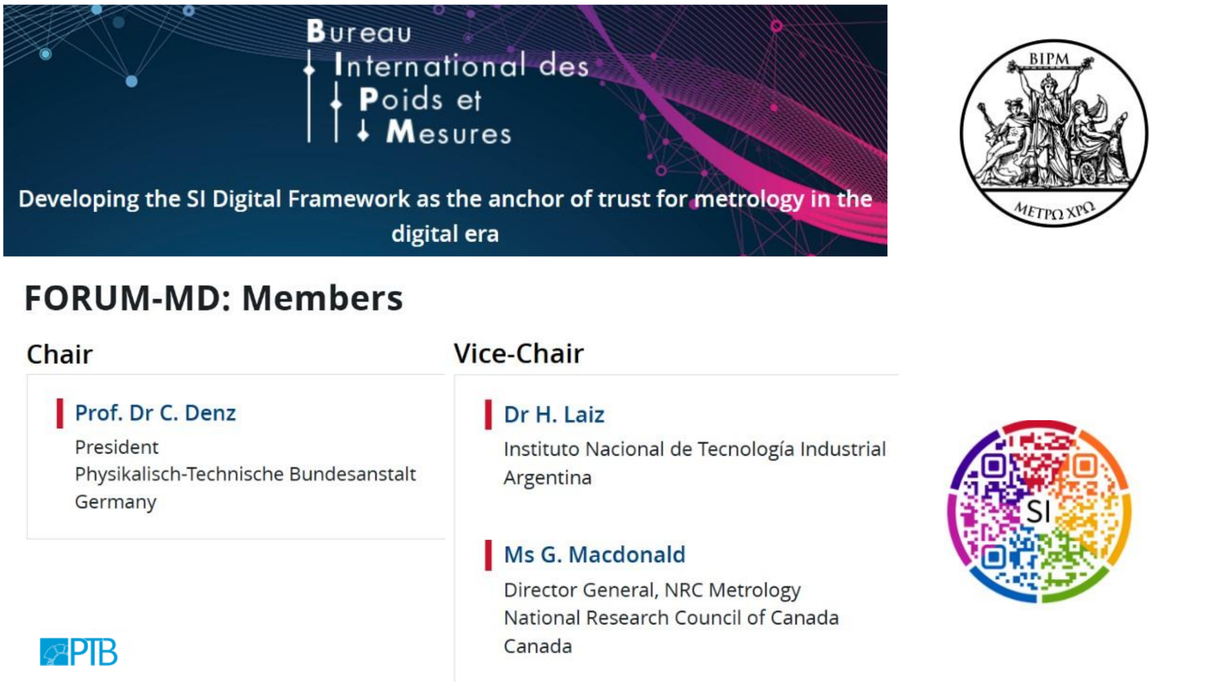
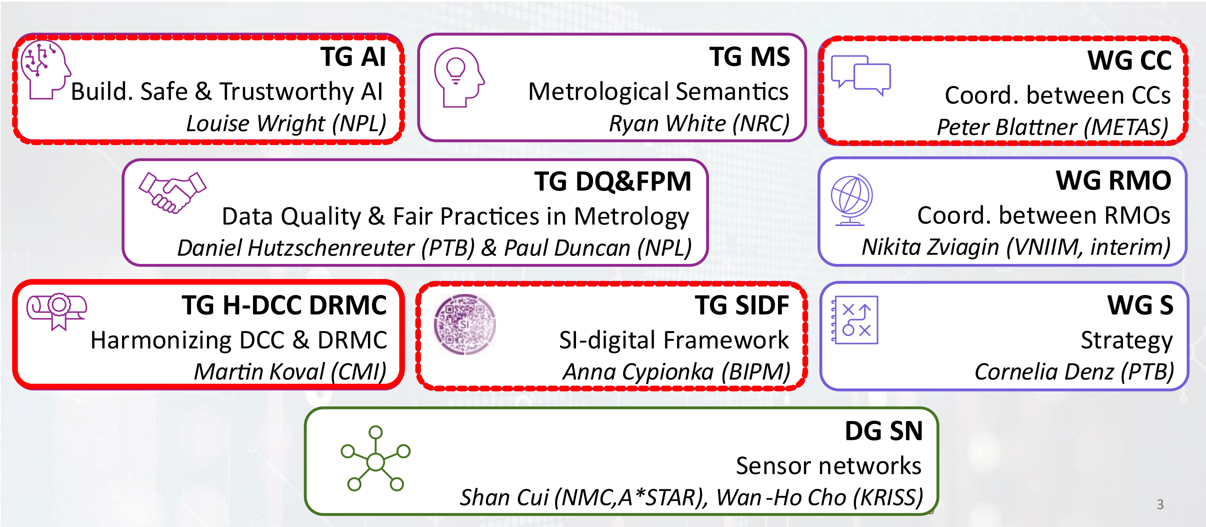
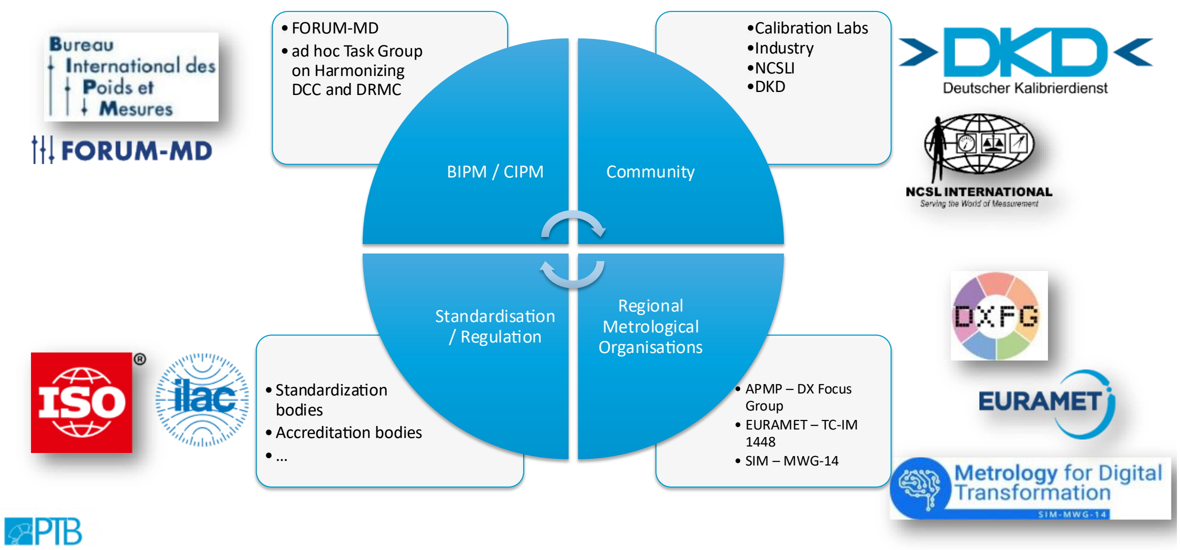
Welcome message II: Frank Härtig, PTB Germany



Updates | TG/WG Structure



International harmonization for full interoperability



Machine Actionable ISO 170xx Series for Metrology

Unique data structure, unique administrative date

ISO 17000 Terms and Definitions	ISO 17025 Test and Calibration	ISO 17034 Reference Material	ISO 17065 Conformity Assessment	ISO 170ii …

DCC: Calibration
DTR: Test Certificate
DVC: Verification Certificate

DCRM: Certificate for Reference Materials
DCoC: Certificate for Conformity Assessment

Expert report DKD-E 0-2
Common requirements for machine-readable certificates in the ISO 17000 series
Edition 08/2024 https://doi.org/10.7795/550.20240812

Important Documents

- (**D**CC)
  Pre-normative Documents
  - Expert Reports from German Calibration Service (DKD)

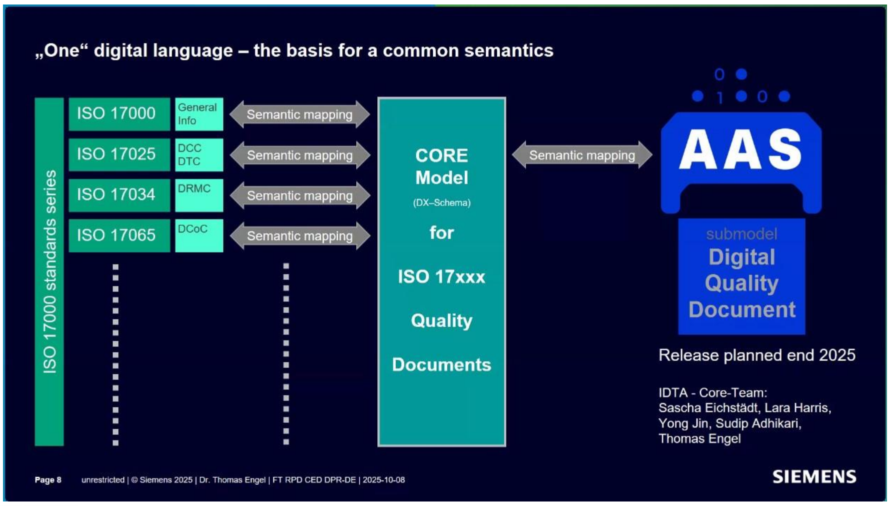
- (**D**-CoC)
  European coordination group of notified bodies in legal metrology

NoBoMet
European coordination group of Notified Bodies in Legal Metrology

https://www.ptb.de/cms/en/metrological-services/dkd.html
https://www.ptb.de/cms/ptb/fachabteilungen/abt9/forschungs-nachrichten-der-abteilung-9/nachrichten-2024.html

DCC in industry standards

- Asset Administration Shell and Industrial Digital Twin Association



IDTA

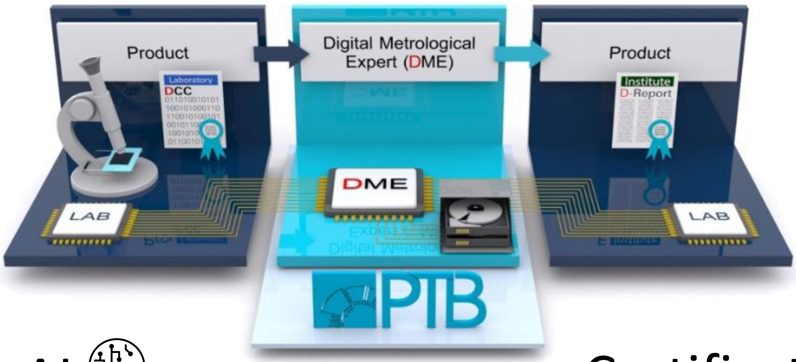
Courtesy T. Engel, QI Digital Forum 2025

DCC in numbers for a simple but relevant use case

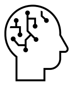
- Use Case:
  - Boehringer-Ingelheim as largest German pharma company started **DCC Production Mode** project in mid 2024
  - 150 000 calibrations per year globally
  - 45 min time saving per calibration (only admin and data transfer!)
  - 2 – 3 Mio Euro potential savings per year for one single company!!!

- Further use cases:
  - Use of data history
  - Extension of calibration intervalls from 1 to 2 years
  - 50% cost reduction…

DCC Validating AI evaluation units – virus load detection



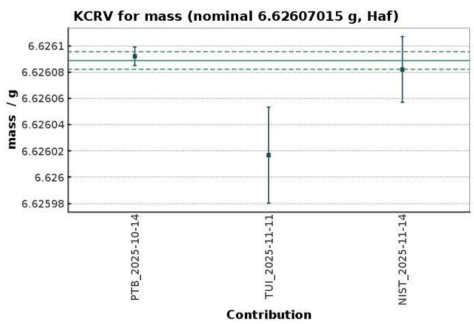
AI



Validation

Certification

The Kibble Balance Comparison - Nov 2025



Stephan Schlamminger, NIST presentation at BIPM, Nov 21, 2025.

https://www.linkedin.com/posts/stephan-schlamminger-40755498_exciting-day-today-at-the-bipm-for-my-colleagues-ugcPost-7396914510512476160-go1j?utm_source=share&utm_medium=member_android&rcm=ACoAAAE8pasBLeABcOS2k2HnGZvQVNRuk4i_koM

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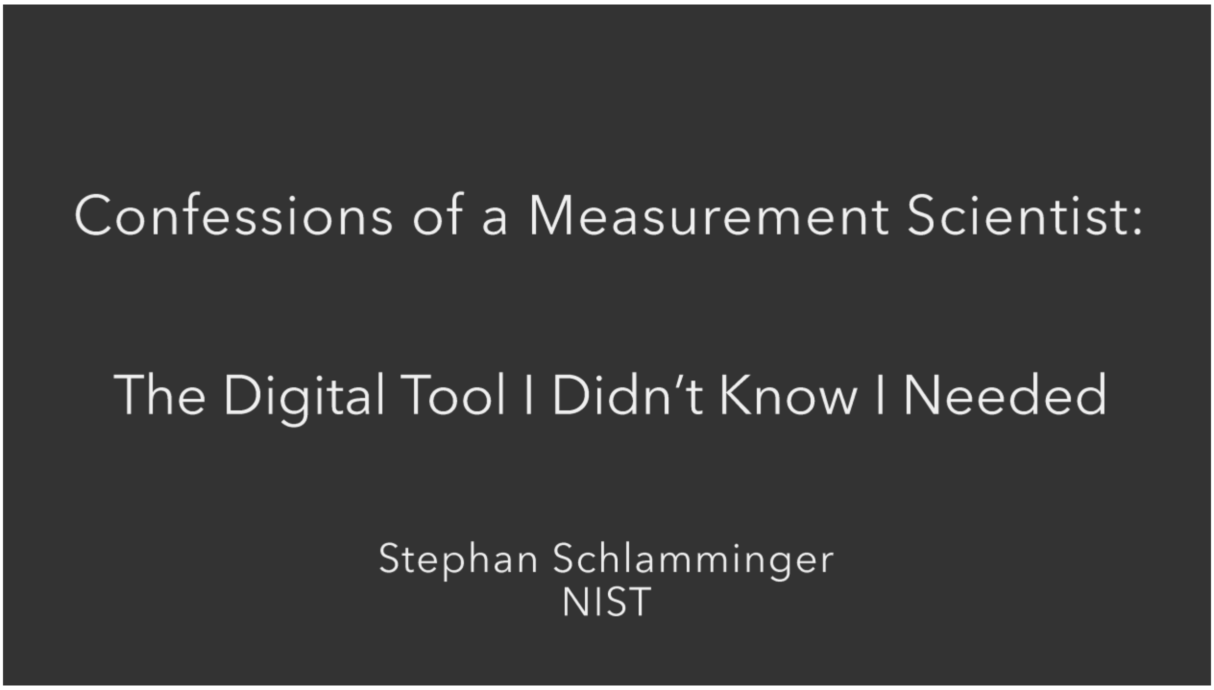
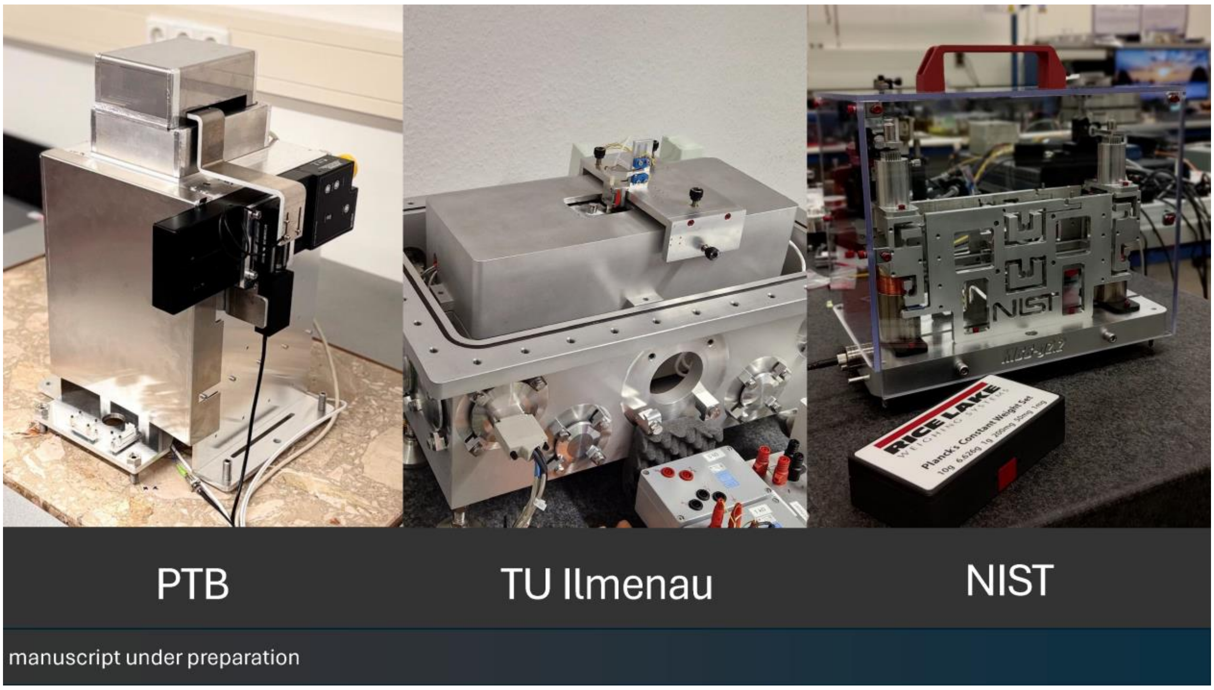
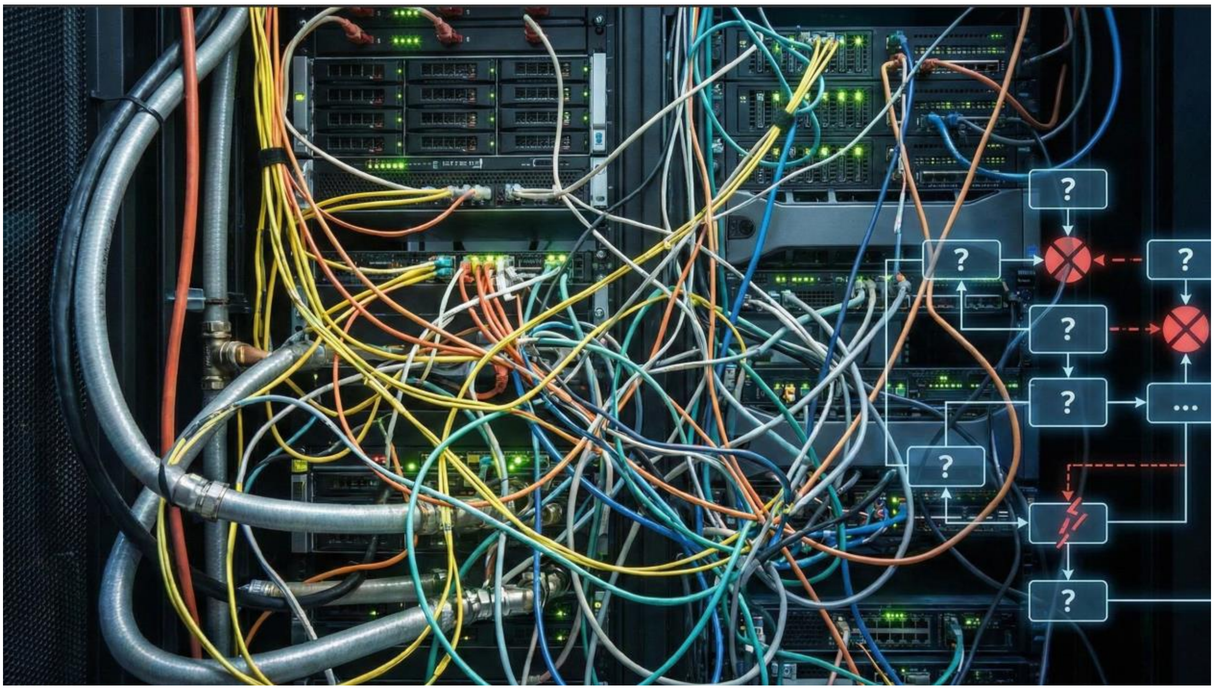
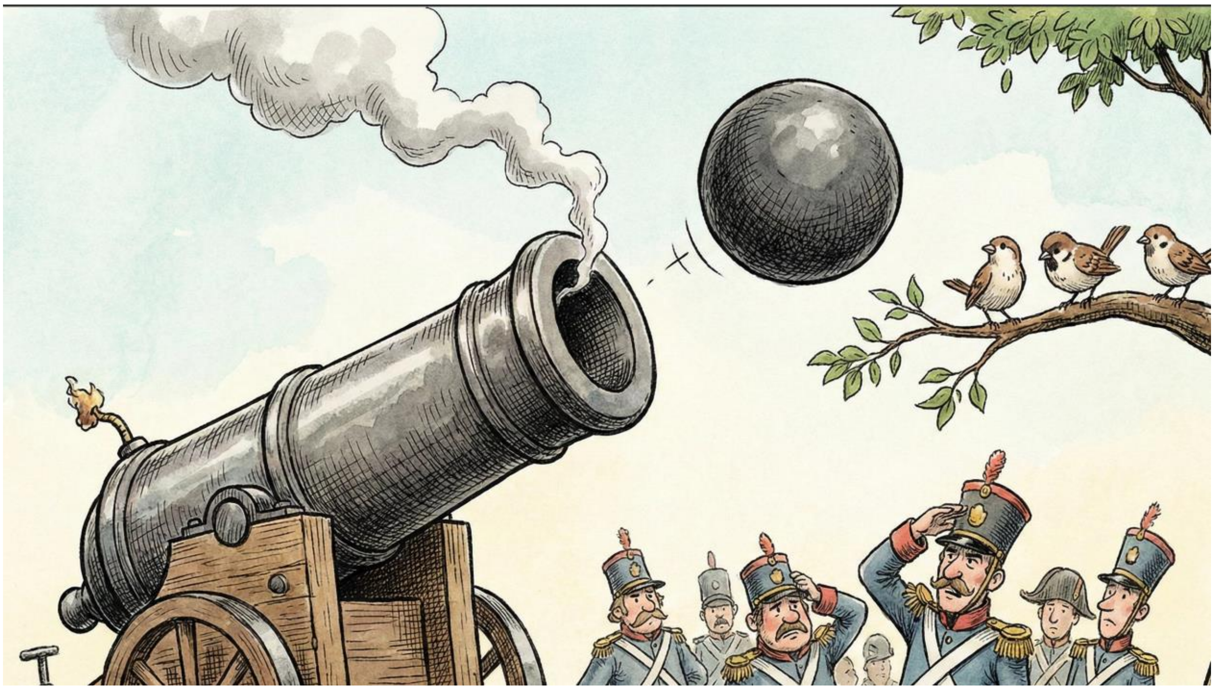
Welcome message III: Stephan Schlamminger, NIST




RICE LAKE
Planck's Constant Weight Set
PTB
TU Ilmenau
NIST
manuscript under preparation



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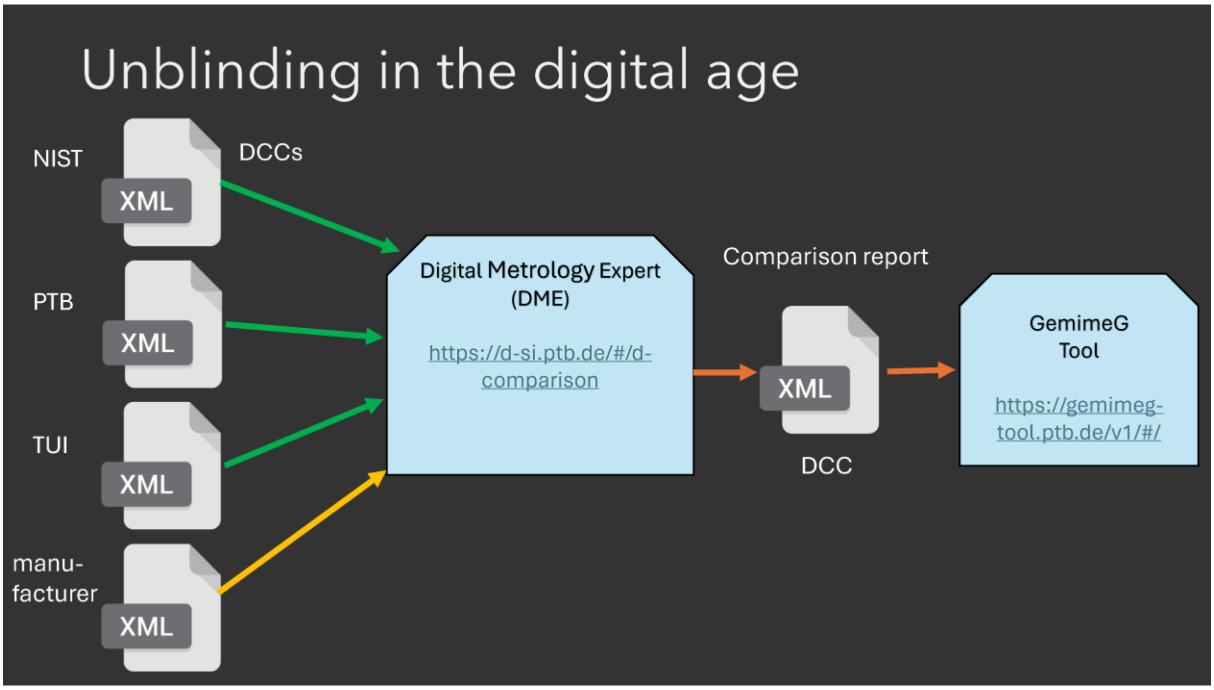


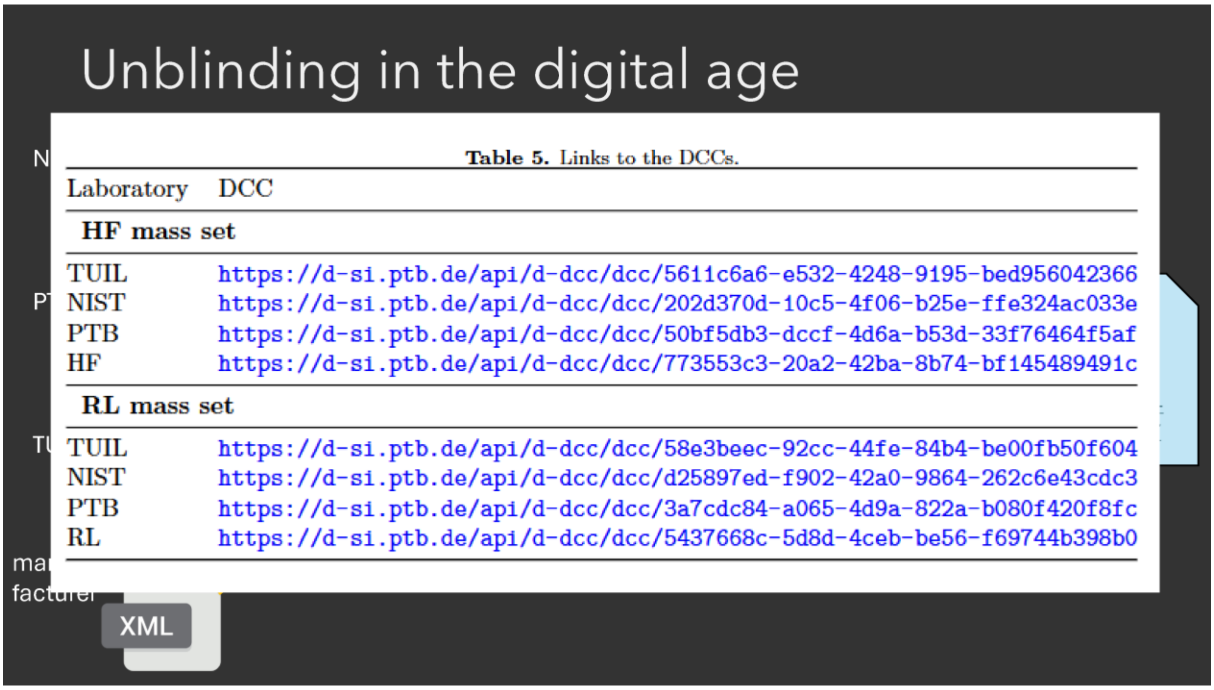
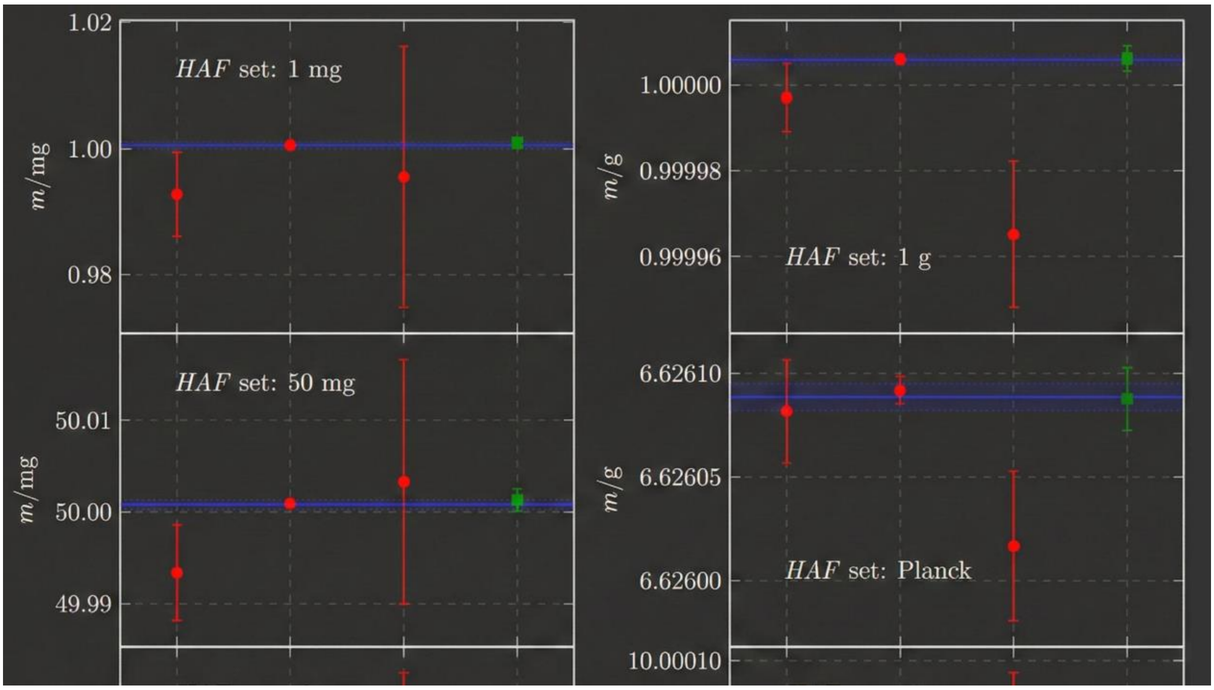
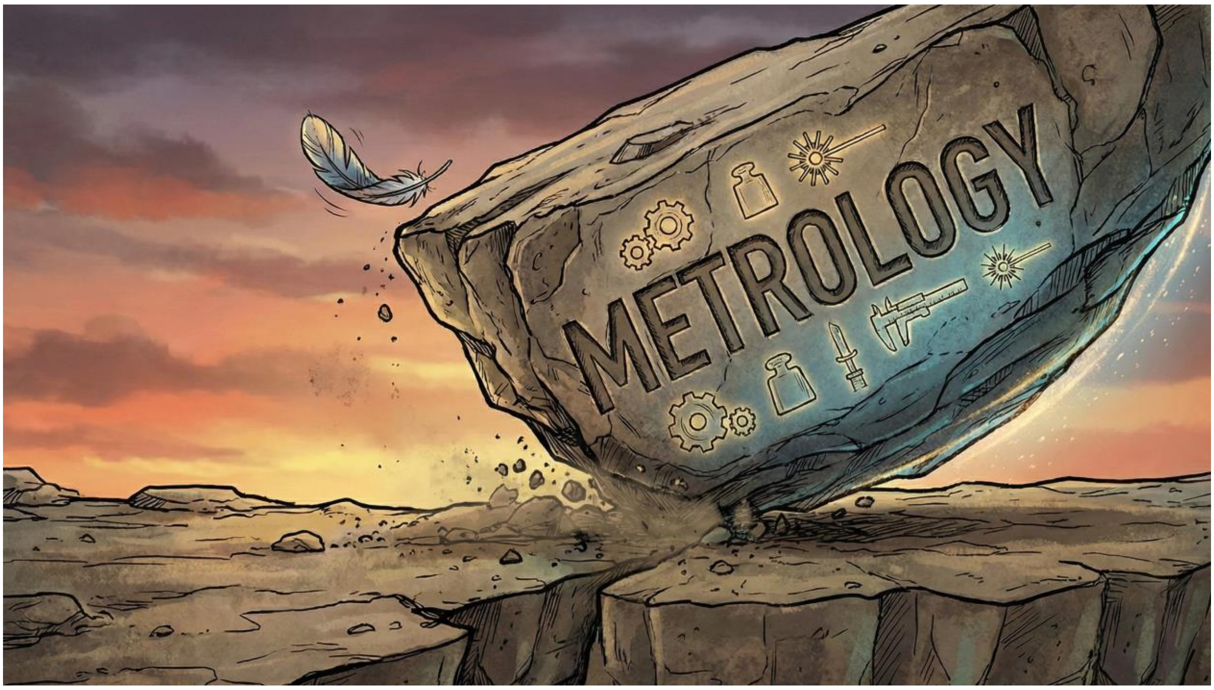


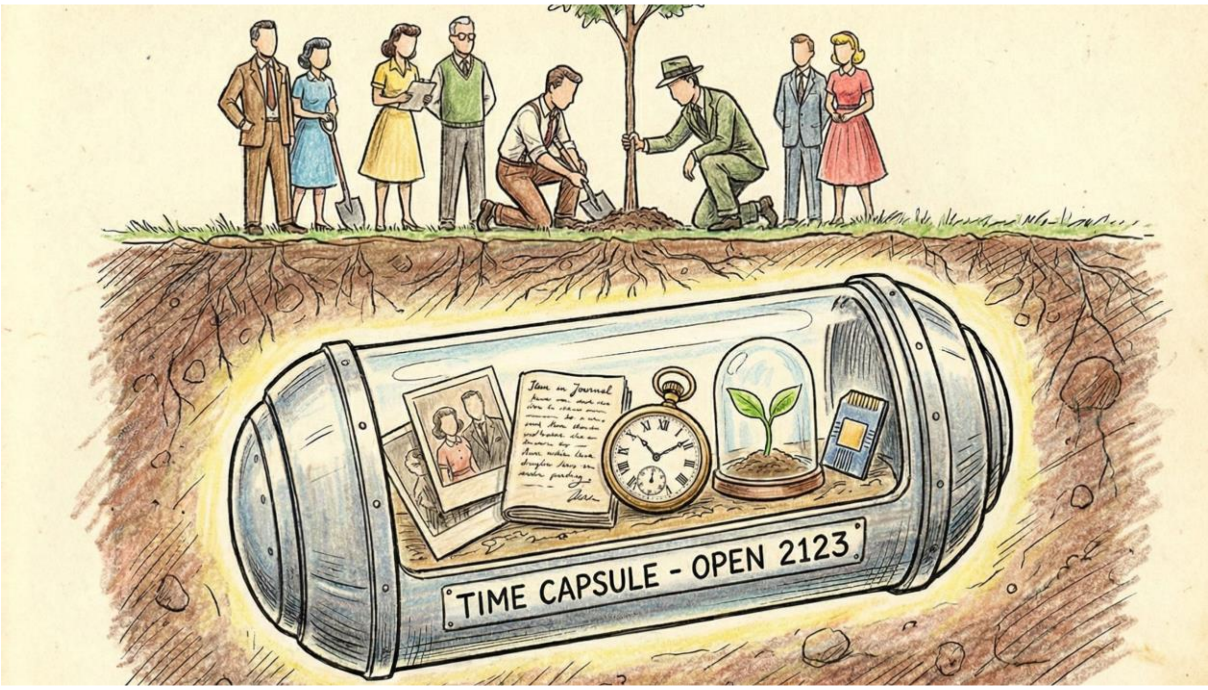
Table 5. Links to the DCCs.

Laboratory	DCC
HF mass set	
TUIL	https://d-si.ptb.de/api/d-dcc/dcc/5611c6a6-e532-4248-9195-bed956042366
NIST	https://d-si.ptb.de/api/d-dcc/dcc/202d370d-10c5-4f06-b25e-ffe324ac033e
PTB	https://d-si.ptb.de/api/d-dcc/dcc/50bf5db3-dccf-4d6a-b53d-33f76464f5af
HF	https://d-si.ptb.de/api/d-dcc/dcc/773553c3-20a2-42ba-8b74-bf145489491c
RL mass set	
TUIL	https://d-si.ptb.de/api/d-dcc/dcc/58e3beec-92cc-44fe-84b4-be00fb50f604
NIST	https://d-si.ptb.de/api/d-dcc/dcc/d25897ed-f902-42a0-9864-262c6e43cdc3
PTB	https://d-si.ptb.de/api/d-dcc/dcc/3a7cdc84-a065-4d9a-822a-b080f420f8fc
RL	https://d-si.ptb.de/api/d-dcc/dcc/5437668c-5d8d-4ceb-be56-f69744b398b0


nology
rt Rogge,
Hugo Gasca


HAF set: 1 mg
HAF set: 50 mg
HAF set: 1 g
HAF set: Planck
m/mg
m/g
1.02
1.00
0.98
50.01
50.00
49.99
1.00000
0.99998
0.99996
6.62610
6.62605
6.62600
10.00010


METROLOGY



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Welcome message Jariya Buajarern: Bridge to the conference

Jariya Buajarern introduces the start of the conference with a few words.

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

Presenting author: Brett Hyland, Project Lead at UN/CEFACT, NATA Australia
E-mail address: Brett.hyland@nata.com.au
Additional authors: Nil
Keywords: Certificates, Interoperability, Calibration, W3C, UNTP

Abstract

Following the July 2025 publication of United Nations Economic Commission for Europe (UNECE) Recommendation No. 49 [1] dealing with digital supply chains, it may be timely to consider whether the design principles for platform-independent exchange of product data, as outlined in this document, could play a role in facilitating the exchange of Digital Calibration Certificates. Numerous implementations of these design principles are proceeding under a specification known as the United Nations Transparency Protocol (UNTP) [2] . A central element of UNTP is a 'conformity credential' which is designed to digitally capture basic product conformity information within a hosted JSON LD file and which also links to an issued conformity certificate (which may be in analogue, digital or hybrid form and may also be encrypted). World Wide Web Consortium (W3C) protocols provide an interoperable basis for exchanging such credentials, while also ensuring that the credential is cryptographically verifiable back to the issuing party in a tamper-evident manner. This talk will consider possible relevance of W3C protocols within the legal metrology and scientific measurement sectors, as one potential support mechanism for the traceable exchange of Digital Calibration Certificates. It is hoped that awareness of these approaches may facilitate discussion among the scientific, trade measurement and wider conformity assessment communities.

[1] UNECE (2025): Recommendation No. 49: Transparency at Scale - Fostering Sustainable; Value Chains
[2] UN Transparency Protocol (2026), https://untp.unece.org, last accessed: 6 January 2026

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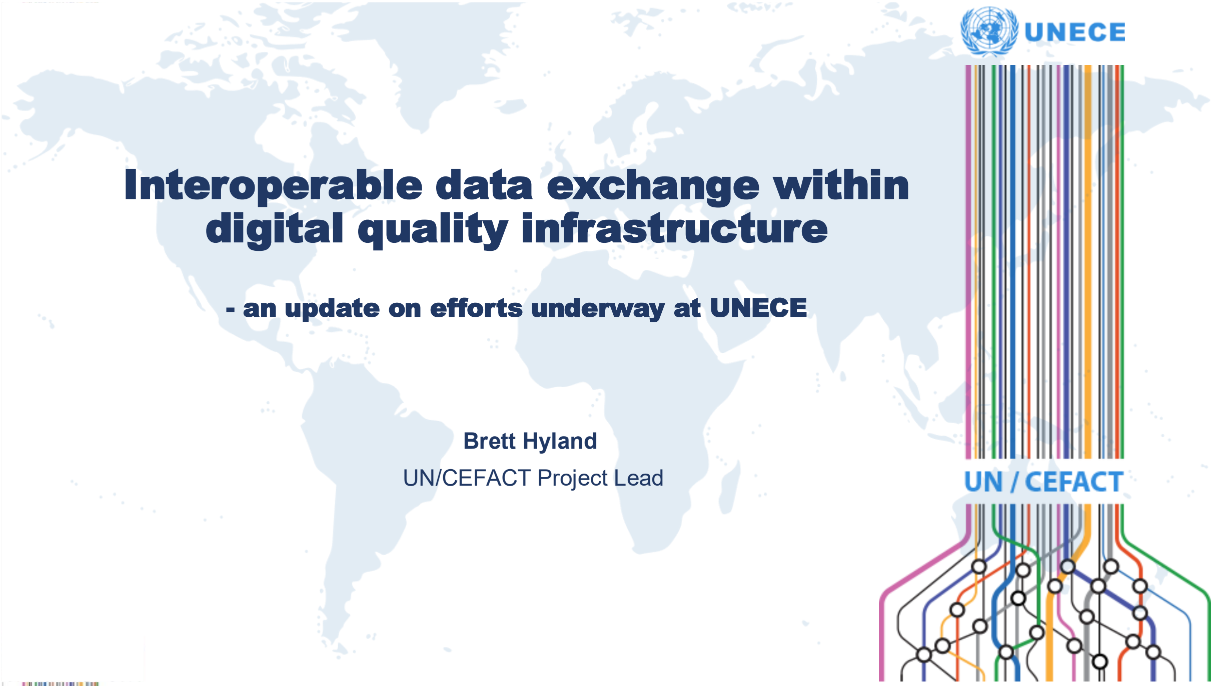
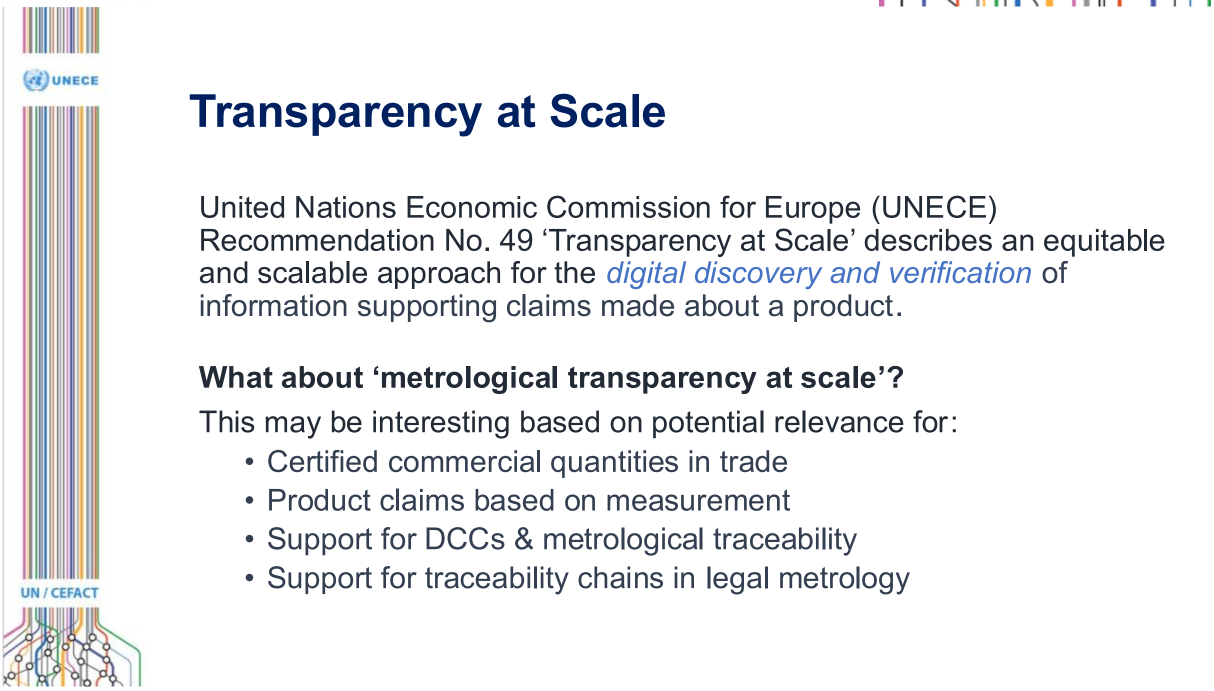
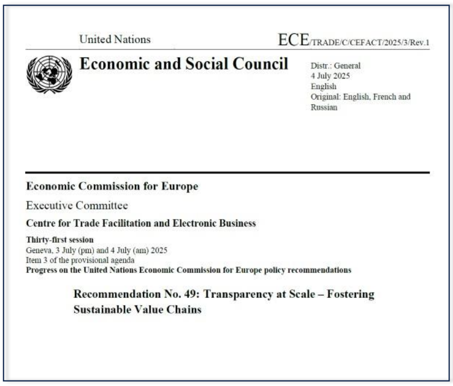
Presentation #P01 of Brett Hyland





UNECE Recommendation No. 49
Transparency at Scale


United Nations ECE/TRADE/C/CEFACT/2025/3/Rev.1

Economic and Social Council

Distr.: General
4 July 2025
English
Original: English, French and Russian

Economic Commission for Europe
Executive Committee
Centre for Trade Facilitation and Electronic Business
Thirty-first session
Geneva, 3 July (pm) and 4 July (am) 2025
Item 3 of the provisional agenda
Progress on the United Nations Economic Commission for Europe policy recommendations

Recommendation No. 49: Transparency at Scale – Fostering Sustainable Value Chains

https://unece.org/trade/uncefact/tf_recommendations

"Enhancing the reliability of sustainability claims…includes the possibility of using digitally verifiable documents, issued by recognized authorities, as formal declarations of compliance, sustainability, or product characteristics. This would also involve trustworthy actors such as government bodies and accredited conformity assessment organizations."

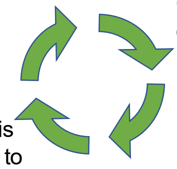
(Recommendation No. 49, page 6)

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!



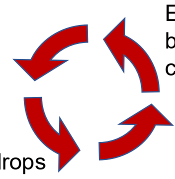
Consumer confidence improves

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

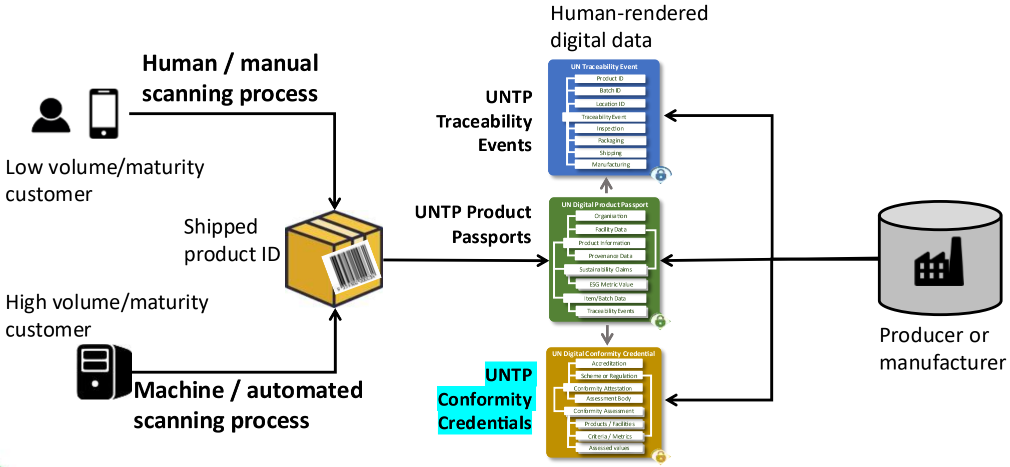
Digital Product Passport – EU Regulation

Digital Products Passports (DDPs) emerged under EU regulations requiring products to have an associated data set, accessible from a data carrier (such as a QR code) on the product. Consumers or authorities can use this to examine declarations and product information relating to product sustainability.

The concept is already being applied within EU Regs for product attributes beyond sustainability, such as hazardous substances in toys.

Separate to regulatory requirements, DPPs are also emerging as a general mechanism for aggregating product data along supply chains - various standardization initiatives are underway including ISO JTC5

UN Transparency Protocol - conceptual model



UN Centre for Trade Facilitation and eBusiness (UN/CEFACT)

UN/CEFACT is responsible for the reference implementation of Recommendation N0. 49, known as the United Nations Transparency Protocol (UNTP).

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

It represents a relevant forum for discussion regarding access to and exchange of conformity data relevant to international supply chains.

Reducing costs, increasing participation

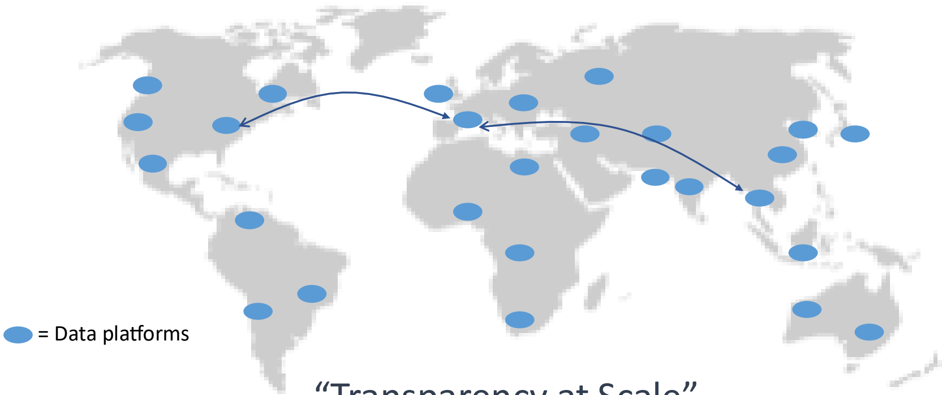
To encourage maximum inclusion, digital trade systems cannot favour rich countries or create unjustified barriers for small businesses.

This means:

- adopting internationally accepted approaches, emphasising open development and free resources, such as W3C verifiable credentials (VCs) and decentralized identifiers (DIDs)
- adopting an open architecture, so that stand-alone technology platforms do not add friction to data exchange, or be leveraged to the disadvantage of some participants
- providing a backbone of trust by making ‘trust anchors’, including Quality Infrastructure, verifiable by any participant

Interoperability protocols

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



"Transparency at Scale"

Support for issued certificates within UNTP

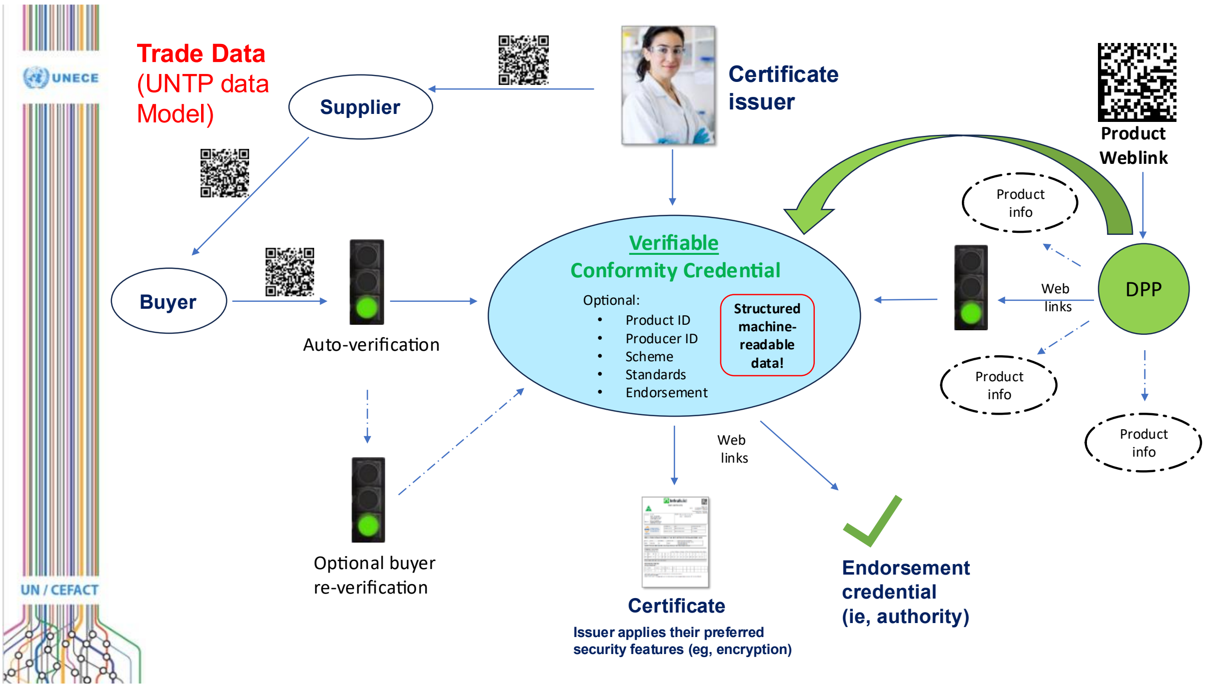
UN/CEFACT does **not seek** to specify certificate formats, certificate content or conformity assessment processes.

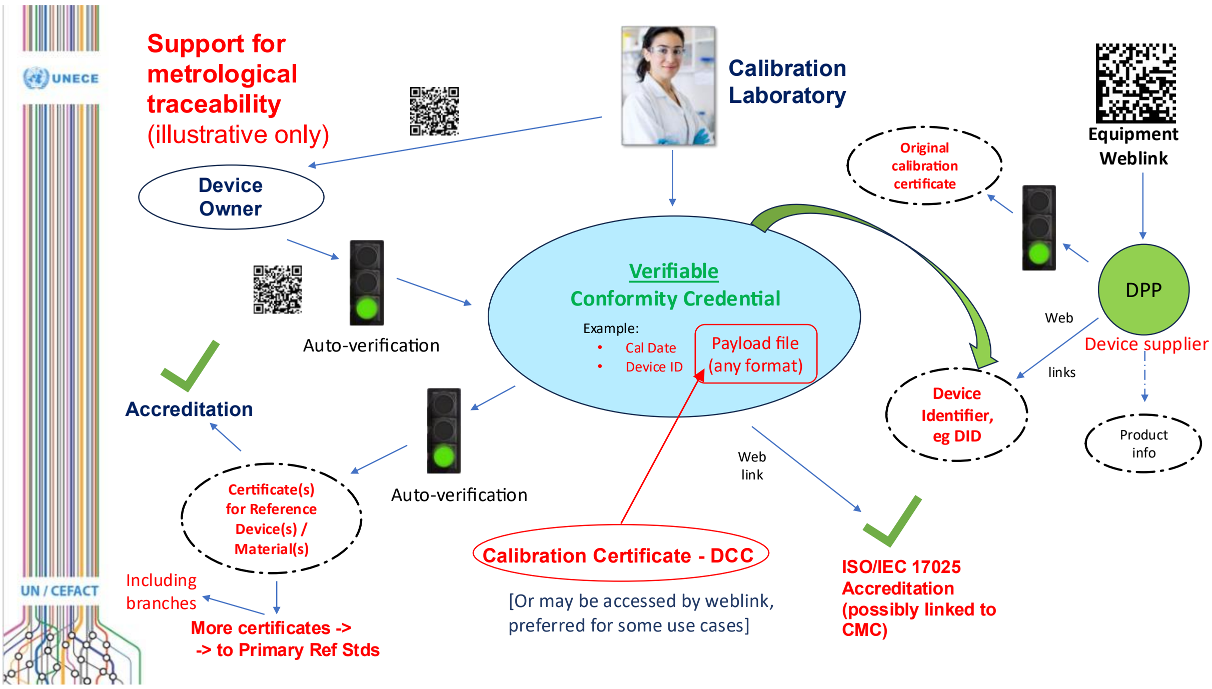
Rather, the focus is providing a surrounding framework for certificates - whether analogue, digital or hybrid - that offers:

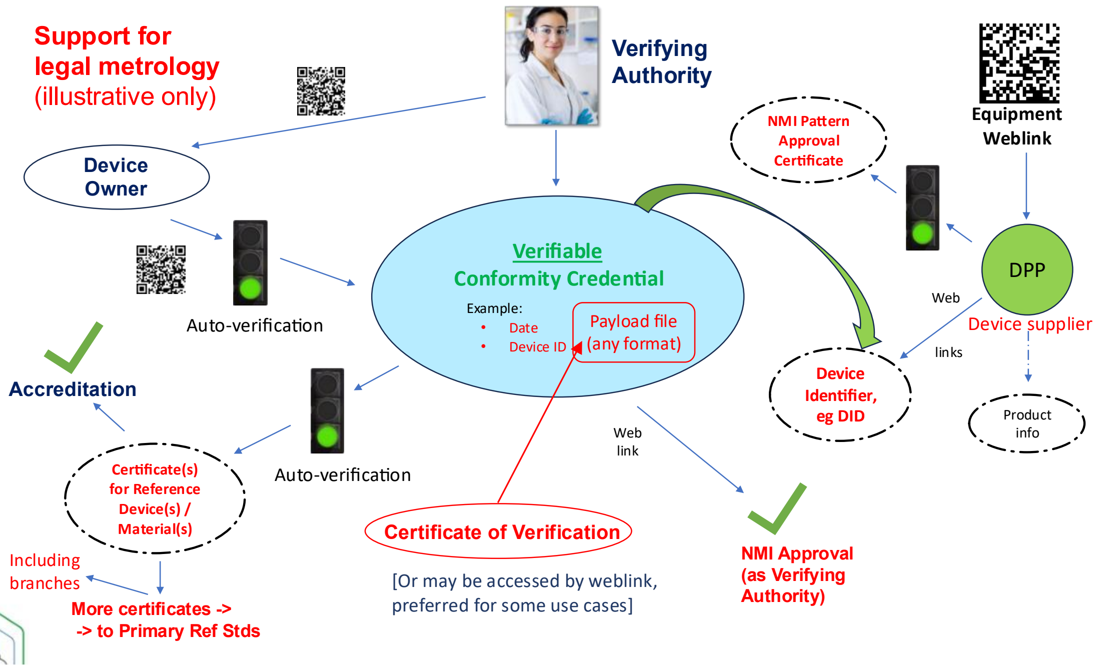
1. A means of discovering relevant certificates from products of interest in a tamper-evident & machine-readable manner.

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).


Trade Data
(UNTP data Model)
Supplier
Certificate issuer
Product Weblink
Buyer
Auto-verification
Verifiable
Conformity Credential
Optional:
Product ID
Producer ID
Scheme
Standards
Endorsement
Structured machine-readable data!
Product info
Web links
DPP
Product info
Product info
Optional buyer re-verification
Web links
Certificate
Issuer applies their preferred security features (eg, encryption)
Endorsement credential
(ie, authority)
UNECE
UN / CEFACT


Support for metrological traceability
(illustrative only)
Calibration Laboratory
Equipment Weblink
Device Owner
Original calibration certificate
Auto-verification
Verifiable
Conformity Credential
Example:
Cal Date
Device ID
Payload file
(any format)
DPP
Web
links
Device supplier
Accreditation
Device Identifier, eg DID
Product info
Auto-verification
Web link
Certificate(s) for Reference Device(s) / Material(s)
Calibration Certificate - DCC
Including branches
More certificates ->
-> to Primary Ref Stds
[Or may be accessed by weblink, preferred for some use cases]
ISO/IEC 17025 Accreditation (possibly linked to CMC)
UNECE
UN / CEFACT



Some remarks

1. Many aspects of traceability can be verified without even reading the DCCs. This is achieved through digitally matching the equipment item identity, confirming DCC issuer's identity, accreditation status and certificate validity, for all branches of the calibration chain, all the way back to primary reference standards.
2. This is not the same thing as achieving true metrological traceability, which requires ingestion of the DCC data, yet it may still be satisfactory for many use cases.
3. The non-proprietary protocol provides a roadmap for discovering and ingesting relevant DCC content, subject to access permissions.
4. It provides a potential protocol for interoperability across any national or regional data spaces that may be used to host DCCs.

Scope for further metrology data exploration

1. Digital identifiers (eg, DIDs) for reference materials as well as for measurement devices

2. Protocols for generating full device calibration history based on matching calibration/verification certificates - possibly issued by different CABs and held on different data platforms, but still matched to a common device identifier

3. Machine representation of Calibration & Measurement Capability statements) for digital verification of competence for transferring metrological traceability

Resources

All UNTP resources are open source, available without charge and are royalty free
https://untp.unece.org/docs/about/

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://untp.unece.org/docs/implementations/
https://untp.unece.org/docs/extensions/

Is it time for exchanging ideas?

UNTP deals with trade-related data. Standards for metrology certificate digitalisation and traceability are outside the activities of UN/CEFACT.

However, cross-domain exchange is welcome, noting the degree of overlap that exists:

1. Trust in the attributes of traded goods and the outputs of scientific/legal measurement both rely on national Quality Infrastructure

2. Laboratories providing test results for traded goods also undertake metrology activities in some cases

3. Most accreditation bodies work across testing/calibration/certification

UNTP-Conformity Group

Mailing list

https://gaggle.email/join/untp-conformity@gaggle.email

]

Thank you!

For more information

Brett Hyland brett.hyland@nata.com.au

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P02 Mark Kuster: Modeling measurement data with the Measurand taxonomy

Presenting author: Mark Kuster [1], Independent Researcher, Consultant, USA
Additional authors: Nil
Institute:
[1] NCSL International 141 MII and Automation Committee
Email: mjk@ieee.org

Abstract

The NCSL International 141 MII and Automation Committee continues to emphasize careful conceptualization for use in agile digitalization processes in order to instill value in digital transformation. Long-term value in digitalization depends on interoperability across systems and time and universal applicability across data types. This work presents an updated conceptual model designed for interoperable digitalized measurement data suitable for representing information in accreditation scopes, instrument specifications and calibration certificates. The technology-agnostic model, suitable for implementation in any exchange format (JSON, XML, etc.), rests on NCSLI's open-source MII measurand taxonomy and M-layer. We encourage industry collaboration to further extend and refine the model.

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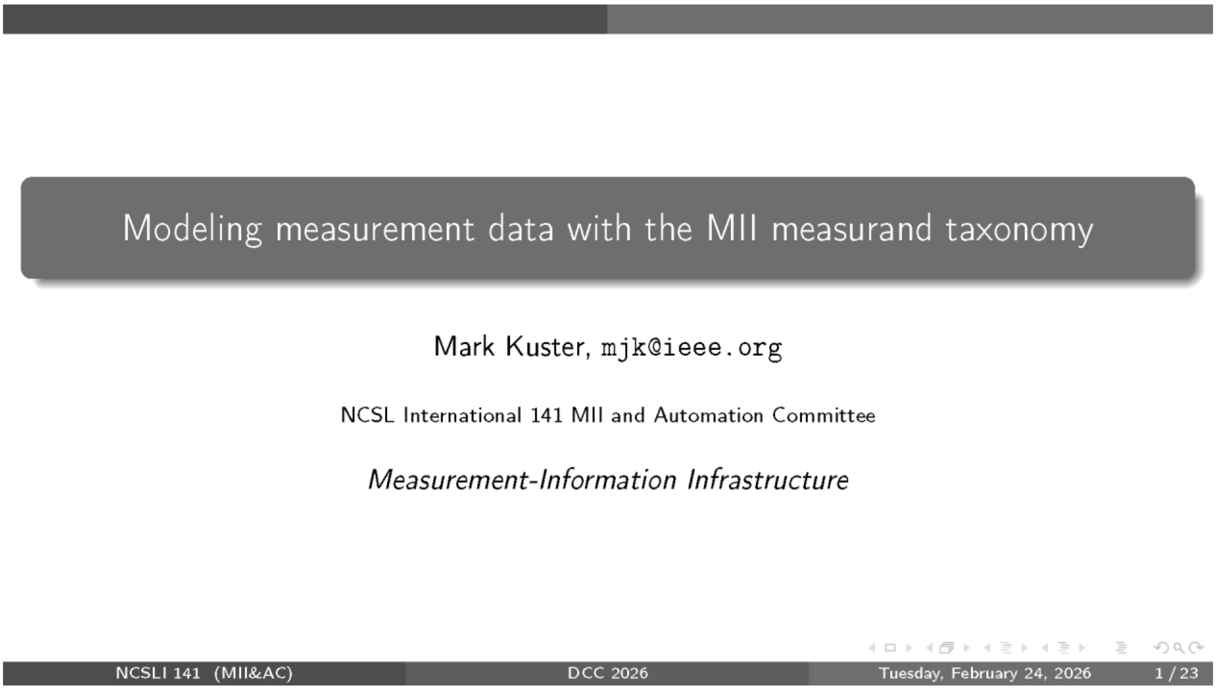
Presentation #P02 of Mark Kuster



Section 1

Introduction

Today's Topics

1. Introduction
2. Conceptualize, model, implement
3. Draft models
4. Conclusion

Acronyms

- IQI—international quality infrastructure
- MRA—mutual-recognition agreement
- CIPM—International Committee on Weights and Measures
- NMI—national metrology institute
- KCDB—key-comparison database
- ILAC—International Laboratory Accreditation Cooperation
- AB—accreditation body
- SoA—accreditation scope
- CMC—calibration and measurement capability
- DX—Digital Transformation
- MPE—maximum permissible error
- DCC—digital calibration certificate
- DCR—digital calibration request
- FAIR—findable, accessible, interoperable, reusable
- M-layer—metrology information layer to support measurement systems
- JSON—JavaScript object notation
- XML—eXtensible markup language
- MathML—mathematics markup language
- ETL—extract, transform, load

Section 2

Conceptualize, model, implement

DX reality

Facts

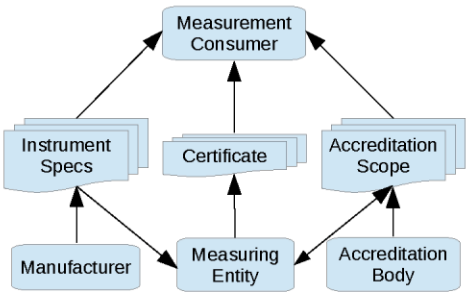
- Business thrives to the extent that customers receive positive net value.
- DX provides new value at lower cost: finance, B2B, online retail, travel, entertainment
- Metrology has consensus standards, plentiful computing power, lab and enterprise software, automated measurements and plenty of applicable information technologies.
- Despite resources and long-standing development, metrology has not yet achieved DX.

Success Factors: Other industries achieved DX by

- Carefully abstracting their processes and data flows (conceptualize)
- Modeling the supporting data
- Applying standardized technology solutions to implement those models in digital systems

Translating DX success to metrology

1. Metrology processes revolve around measurements and their quality.
2. Measurement data doesn't sit ignored; calibration laboratories, testing laboratories, inspection bodies, instrument manufacturers, ABs, scientific organizations and others exchange the data in vast quantities throughout the measurement economy.
3. To digitally transform metrology, we should therefore design, adopt and apply a common conceptual model for exchanging digitalized measurement data.



Conceptualize, model, implement!

Modeling costs

Modeling takes resources and time

- Modeling delays implementation and any expected revenue or savings.
  - Conceptual models require much careful abstract thought and refinement.
  - Models should cover all known process and feature variants within scope.
- Tooling for modeling leaves gaps.
  - No complete end-to-end system for all environments
  - Piecewise solutions: model-driven architecture, model-driven software engineering, object relational modeling, model-view-controller technology

Forget flying birds, just build a penguin!

- DCC: fast development, much interest, flexible but complex
- Implementation may fragment into separate cases that do not integrate well.
- Everyone reinvents the wheel for every case.

Conceptual modeling benefits

General benefits

- Agnosticism: no particular storage or transmission technology baked in
- Universal interoperability and reusability

Benefits for metrology

- Locate and rank laboratories to calibrate a given instrument or inventory.
- Locate and rank instruments to meet an application's measurement requirements.
- Generate customized instrument specifications or DCRs and issue purchase orders.
- Generate CMCs from instrument specifications and calibration certificates.
- Optimize instrument specifications or calibration intervals from calibration history.
- Generate automated, customized calibration procedures on the fly.
- Improve uncertainty estimates flowing through the traceability network.

Conceptual modeling benefits

- Recover lost value from over-simplified MPEs, CMCs and measurement uncertainties.
- Validate certificate uncertainties against accreditation scopes.
- Verify accreditation status and compliance to calibration requirements point-by-point.
- Verify an AB's ILAC MRA or an NMI's CIPM MRA status point-by-point.
- Automate non-conformance investigations.
- Calculate uncertainty, risk, reliability, et al. between and beyond calibration points.
- Propagate calibration uncertainties to all dependent test & measurement processes.
- Correct all measurements for instrument bias (transparent adjustments).
- Facilitate digital twins and smart instruments.
- Streamline assessments and audits.
- Validate all data automatically at every step.

Conceptual modeling benefits

Caveats

- The market will determine where the real value lies.
- Innovators will expand this list far beyond what we might predict.
- The benefits remain a pipe dream without interoperability.
  - Benefits stem from lowering the data-exchange hurtles between organizations.
  - Machines should exchange and process this data automatically.
  - If a pressure implementation differs from that of voltage, length or radiance, those multiple disjoint cases quickly burden software implementations, a significant development and maintenance cost that every software developer will suffer.
  - Since we already expect to ultimately transform the entire IQI—all measurement processes and quantities—it makes sense to model measurements generally, abstractly, from the start and to expect a higher return.

Section 3

Draft models

General model requirements

Interoperability and reusability (objectivity) require source-independent meaning and validity:

1. correct reasoning—well designed data & process models for the present and future,
2. data transformed to a standardized context—reference metadata and unique identifiers,
3. correct formulation—standardized meanings, (linked) definitions, controlled syntax;

AND freedom from subjectivity such as

1. arbitrariness—undefined or free-form data fields,
2. ambiguity—multipurpose data fields, missing unique identifiers, unclear definitions,
3. out-of-context placement—essential elements falling outside the modeled framework.

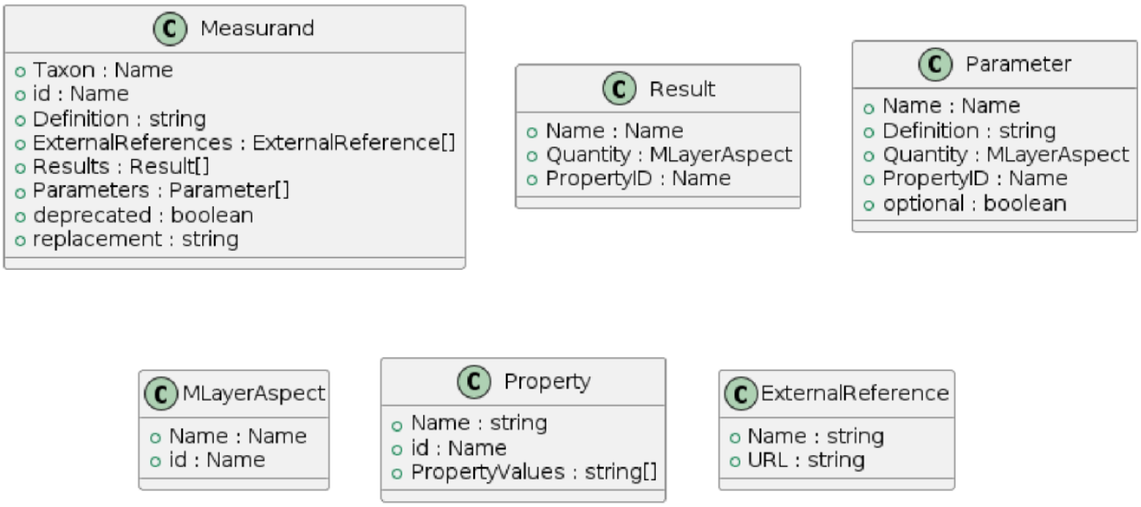
Metrology model requirements

Metrology DX requires an flexible, exacting, universal measurand model.

- Measurand: What an instrument measures, what we claim capabilities for, what we measured in a calibration or other measurement service.
- Universal: Abstract enough to cover any quantity, property, discipline or area
  - Proven idea: Labmate, MOX (Mudcats), IndySoft, U. Meas. Model (Mike Brown, Fluke)
  - Essentially expressed in the VIM—International Vocabulary of Metrology
- Exacting: Perfection commensurate with the uncertainty desired in specifying the quantity, its influence quantities, relevant properties and operating conditions
- Flexible: Unlimited, exacting measurand qualifiers, omitted when insignificant relative to the measurement uncertainty or irrelevant to the service procured

All together this means we want an abstract model that distinguishes any measurand which anyone may instantiate with only the relevant detail for a particular concrete application.

Abstract measurand model (essential elements only)



Differentiating parameters

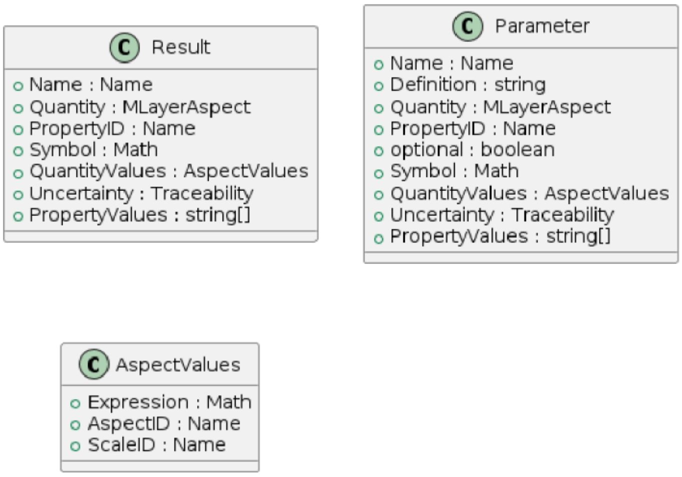
Model Element	Instrument Measurand		CMC Measurand
`Measurand.Taxon`	"Source.Ratio.Voltage.AC"	⇔	"Measure.Ratio.Voltage.AC"
`Result.Name`	"Gain"	⇔	"Gain"
`Parameter.Name`	"Frequency"	⇔	"Frequency"
`Parameter.Name`	"InputVoltage"	⇔	"InputVoltage"
`Parameter.Name`	"OutputVoltage"	⇔	"OutputVoltage"
`Parameter.Name`	not used (optional)		"AmbientRH"

Matching parameters between different instantiations of an abstract measurand. The two measurands match, pending further evaluation of measuring intervals and uncertainty requirements.

Concrete measurand model (essential elements only)

The concrete data model

- Adds value, range, uncertainty
- Covers specs, CMCs, measurement results
- M-layer: any property, quantity, scale type, unit
- Math expressions for generality
  - any number (x)
  - symbols $(q = x)$
  - ranges $(L \leq q < H)$
  - complexities $(L \leq Vf \leq H)$
  - interdependence $(V_1 < V_2 < 2V_1)$



Expanded QuantityValues

For a given measurand specification, a calibration Result has multiple QuantityValues with metadata IDs:

Result.Name	"Gain" (Symbol G)
Nominal	$100.00\,\mathrm{V}\cdot\mathrm{V}^{-1}$
Reference	$100.02\,\mathrm{V}\cdot\mathrm{V}^{-1}$
Measured	$100.00\,\mathrm{V}\cdot\mathrm{V}^{-1}$
Error	$-20\,\mathrm{mV}\cdot\mathrm{V}^{-1}$
Correction	$20\,\mathrm{mV}\cdot\mathrm{V}^{-1}$

Likewise, instrument specifications may specify multiple range elements in Result:

Nominal	$1.00\,\mathrm{V}\cdot\mathrm{V}^{-1} \leq G \leq 200.00\,\mathrm{V}\cdot\mathrm{V}^{-1}$
Indication	$1.00\,\mathrm{V}\cdot\mathrm{V}^{-1} \leq G \leq 199.99\,\mathrm{V}\cdot\mathrm{V}^{-1}$
Certified	$10.00\,\mathrm{V}\cdot\mathrm{V}^{-1} \leq G \leq 150.00\,\mathrm{V}\cdot\mathrm{V}^{-1}$

Open modeling questions

- Abstractly, expression model = mathematics
- Concretely, MathML content markup would work for expressions but presupposes XML.
- The Uncertainty : Traceability element awaits further work to cover
  - simple uncertainty expressions
  - various uncertainty representations and propagation methods
  - a representation of the entire traceability network
- Previous work covers all this but requires integration.
- Traceability chains would help document and maintain CMCs and MPEs also.

Modeling progress

- See GitHub (github.com/NCSLI-MII/measurand-taxonomy) for the latest actual info.
- The committee's model may vary from this conception.
- The actual model includes other niceties: measurement category and discipline, mappings to other quantity systems, etc.
- Currently documenting and populating the M-layer
- Working toward an official release of the measurand catalog (taxonomy)
- NCSLI 2026 Workshop & Symposium | July 25-29, 2026 | Kansas City, MO
  - A two-day technical track dedicated to digital metrology and "AI"
  - Technical papers, panel discussions, learning labs, tutorials

Section 4

Conclusion

Conclusion

- A common conceptual model for exchanging digitalized measurement data will power metrology's DX.
- Standardized reference metadata sets with a universal reference model for measurement data provides interoperability to aid application software to streamline the IQI.
- This in-progress model suffices to start using the measurand taxonomy to identify and exchange interoperable data.
- Perhaps workable as a DCC sub schema or data-block extension
- Also suitable for documentless point-to-point data exchange
  - Mike Schwartz (Cal Lab Solutions), Rob West (ATS, MOX): MDQF, ETL
- Unanticipated realities will arise, requiring agile conceptualize-model-implement iterations.

Acknowledgments

Please see the paper (NCSLI 2025) for further detail.

Many thanks to

- Wei Ren, Michael Schwartz, Colin Walker, Ryan White for modeling input
- Other NCSL International 141 MII and Automation Committee members for their MII development work
- PTB and the DCC conference organizers for the kind invitation
- Cherine Marie-Kuster

And Thank You for your time!

Questions?

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Day 1 2026-02-24 Tuesday
Parallel Session "DCC in digital QI"
Session Chair: Brett Hyland

001 Gennie A. Ordoña: Implementing Blockchain-Enabled Digital Certificates and a Verification Portal at DOST-ITDI: A Use Case for Enhancing Quality Infrastructure

Presenting author: Gennie A. Ordoña [1],
Email: gordona@itdi.dost.gov.ph
Additional authors:

- B. A. Ordoña

Institute:
[1] Department of Science and Technology, Industrial Technology Development Institute, Metrology Building, Bicutan Taguig City, Republic of the Philippines, 1631
Keywords: Blockchain technology; Digital document verification; Verifiable credentials; Digital certificates; Quality Digital Infrastructure.

Abstract

Document verification plays a critical role in ensuring the authenticity, integrity, and legal validity of official records within quality infrastructure frameworks. Traditional paper-based methods often lead to inefficiencies, increased risks of forgery, and delayed processing times, highlighting the need for robust, standardized digital solutions. The Industrial Technology Development Institute, under the Department of Science and Technology (DOST - ITDI), issues a variety of test certificates for technical services, including training, Formula of Conversio, laboratory testing and calibration certificates. These documents validate critical aspects such as proficiency, compliance, product safety, international traceability and quality assurance.

To address challenges around document security, efficiency, and standardization, DOST-ITDI has pioneered a blockchain-enabled digitalization of certificate platform. This innovative solution leverages a decentralized ledger to create immutable, tamper-proof records with unique identifiers, cryptographic hashes, and digital signatures. The platform also comes with real-time online verification of certificates issued by DOST - ITDI, significantly reducing turnaround times for validating stakeholders and eliminating the need for physical copies. The system supports seamless verification by stakeholders, including regulatory bodies and partner agencies, through a secure web interface. Launched on 13 May 2024 at Diamond Hotel Manila, the "ITDI Technical Services Certificates Verifiable Credential" initiative exemplifies effective application and standardization within digital quality infrastructure. The event gathered diverse stakeholders from different government institutions and academia, underscoring the collaborative effort to harmonize certification processes via interoperable frameworks.

This use case demonstrates how integrating blockchain technology with established quality assurance practices can foster greater trust, operational efficiency, and compliance in regulatory environments. It serves as a scalable model for future inter-agency collaboration and na-

tionwide adoption, supporting the broader goals of digital transformation and standardized quality infrastructure development.

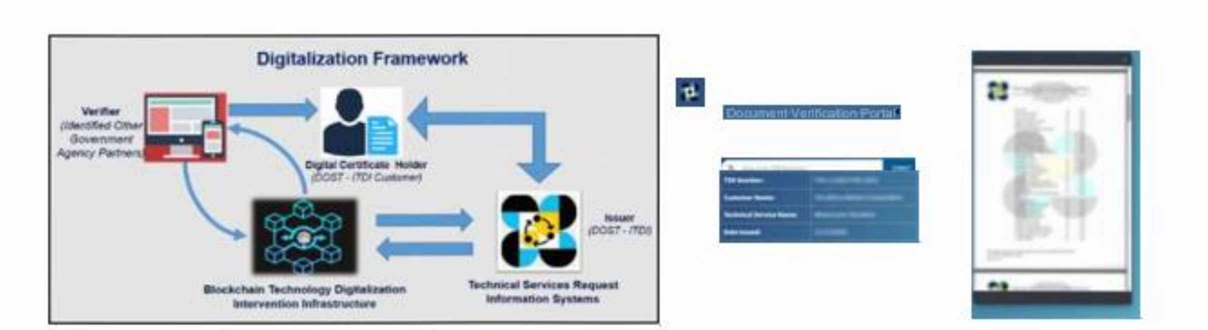

Figure 1. Digitalization Framework and The Verification Portal

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Presentation #001 of Gennie A. Ordoña

The Dry Seal Era

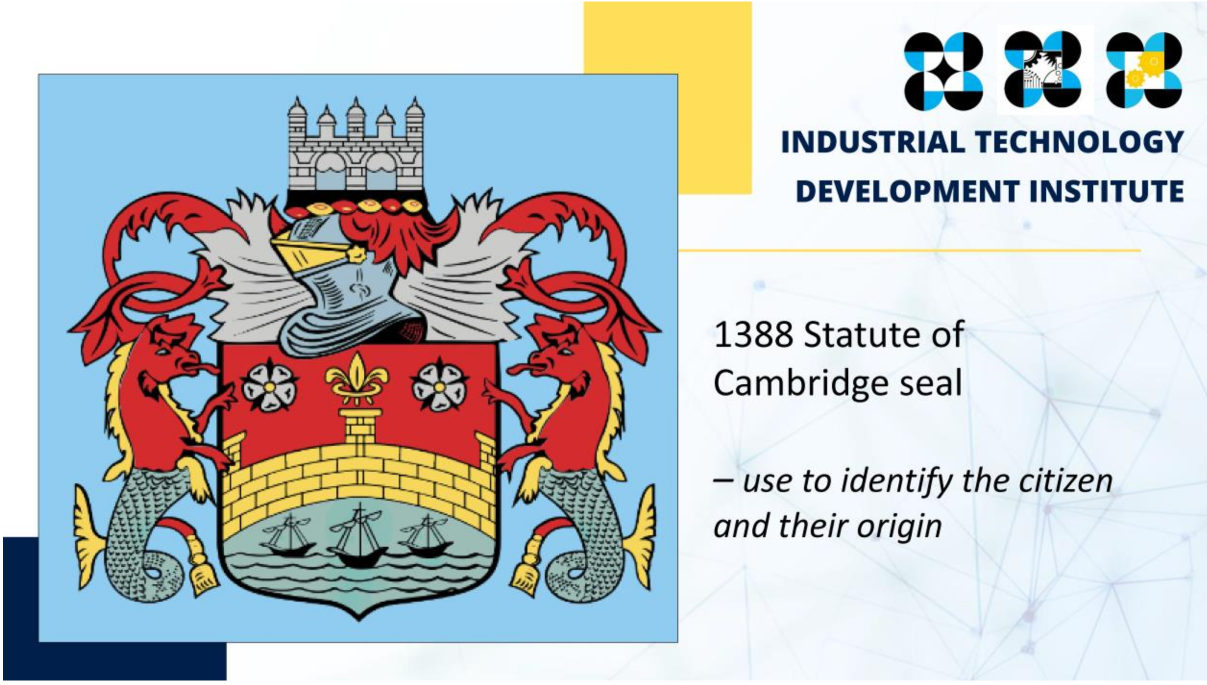
INDUSTRIAL TECHNOLOGY DEVELOPMENT INSTITUTE

- In an ancient time dry seal is popular as “pendant seal” use by town’s bishops and kings
- As early 12^{th} century, dry seals are use to establish the **authenticity** of documents
- Seals were used to close folded documents and thus to guarantee their **secrecy**

INDUSTRIAL TECHNOLOGY DEVELOPMENT INSTITUTE

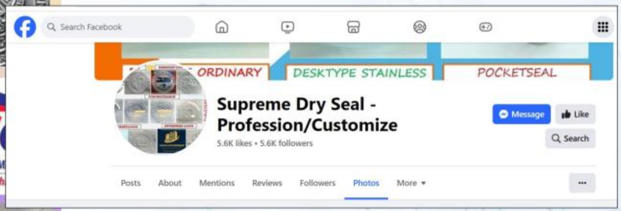
The National Seals of South Korea

- Use to identify government official documents


INDUSTRIAL TECHNOLOGY
DEVELOPMENT INSTITUTE
1388 Statute of
Cambridge seal
– use to identify the citizen
and their origin


INDUSTRIAL TECHNOLOGY
DEVELOPMENT INSTITUTE
The typical official dry
seal of a Philippine
Government Agencies

INDUSTRIAL TECHNOLOGY
DEVELOPMENT INSTITUTE

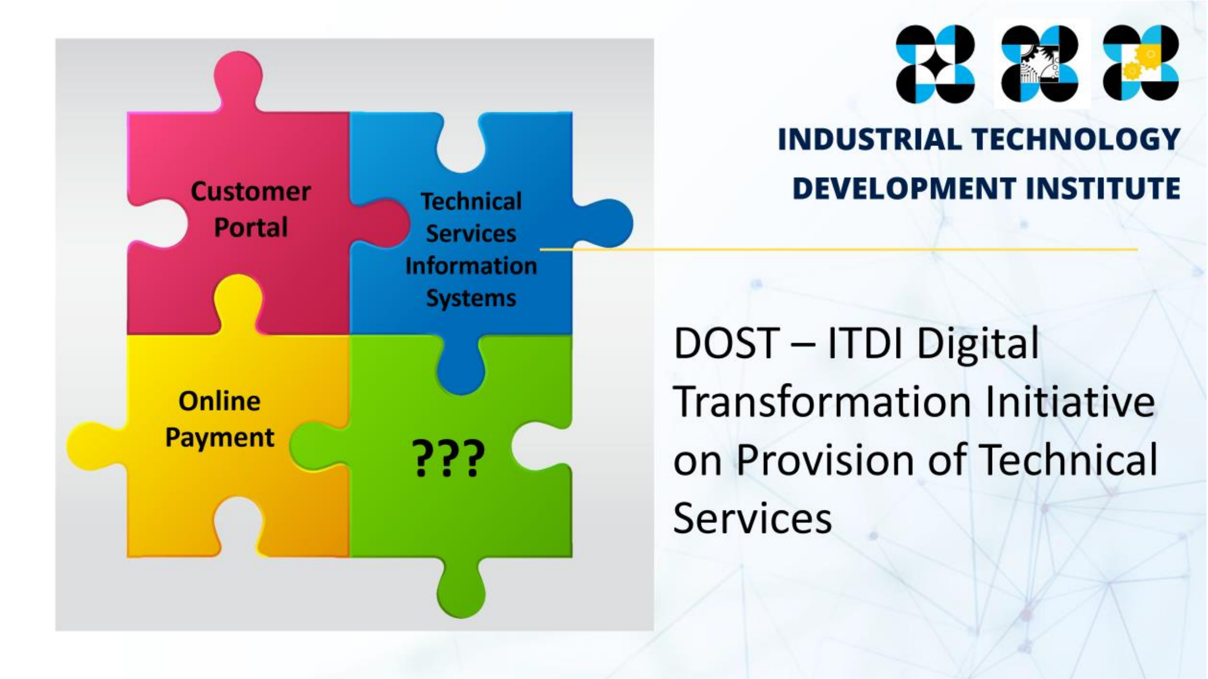


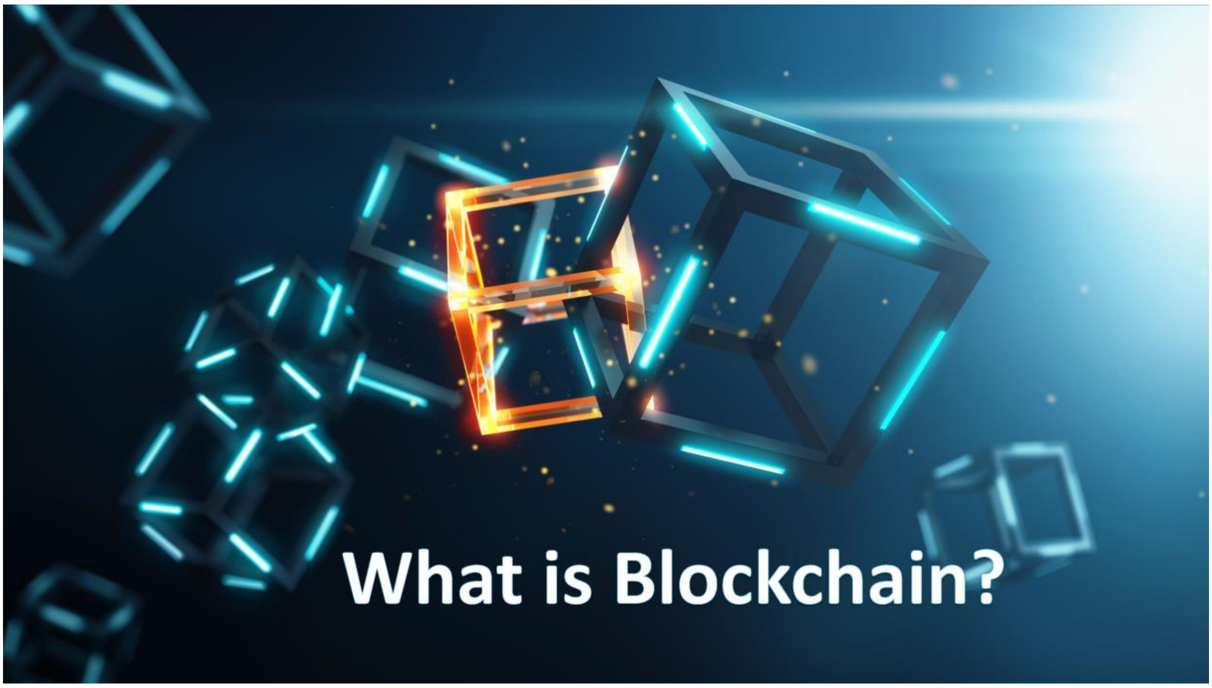
https://www.facebook.com/drysealphil.asc/photos/?ref=page_internal

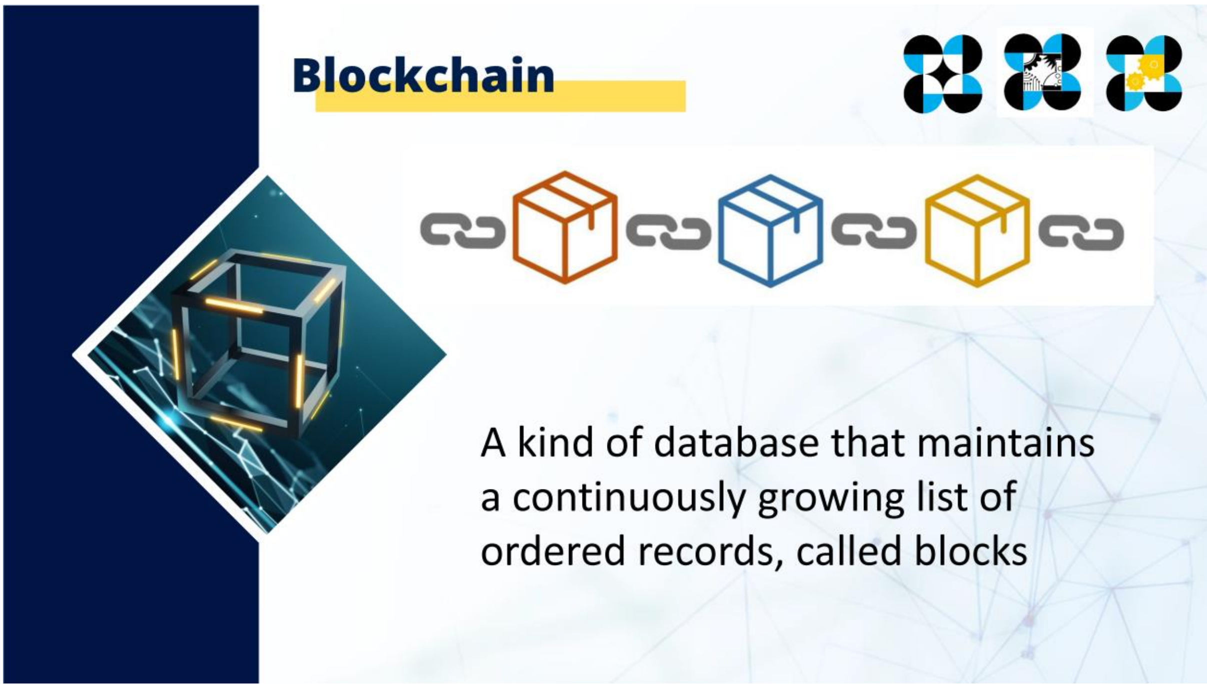
The Digital Age

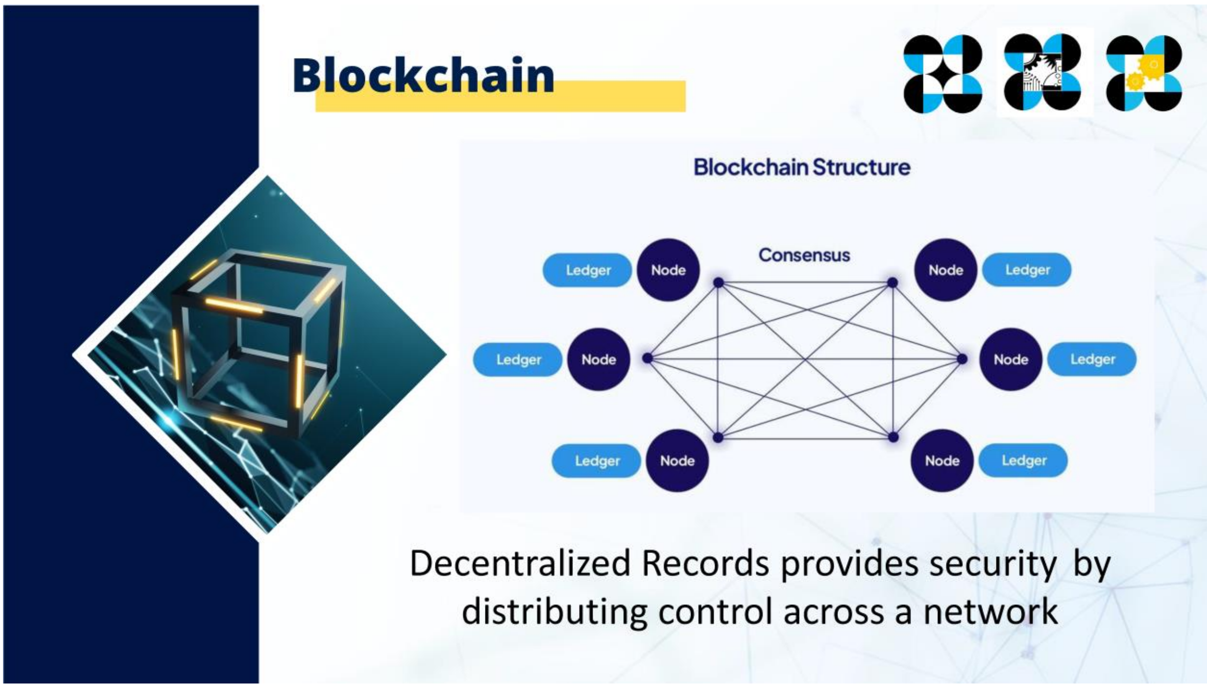
INDUSTRIAL TECHNOLOGY
DEVELOPMENT INSTITUTE

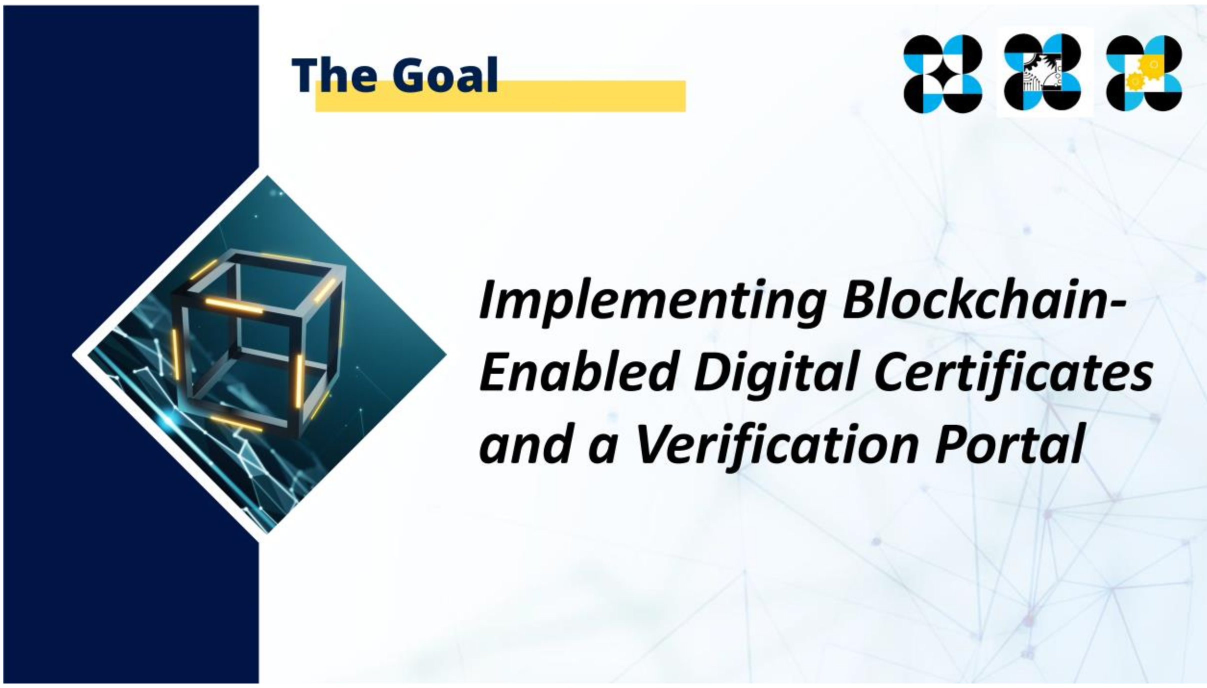
- The Digitization and Digitalization trend and initiatives worldwide for an online seamless and borderless transactions
- Fraud, Authenticity, Identity and Ownership of Documents

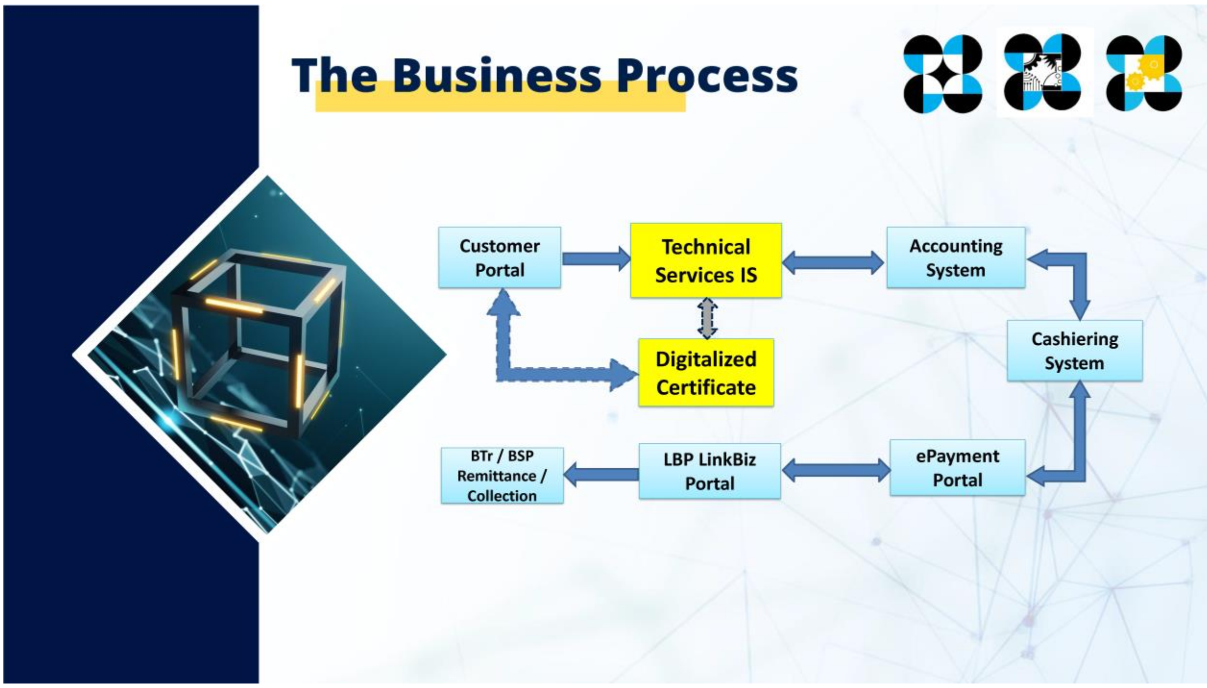

INDUSTRIAL TECHNOLOGY
DEVELOPMENT INSTITUTE
Customer Portal
Technical Services Information Systems
Online Payment
???
DOST – ITDI Digital Transformation Initiative on Provision of Technical Services

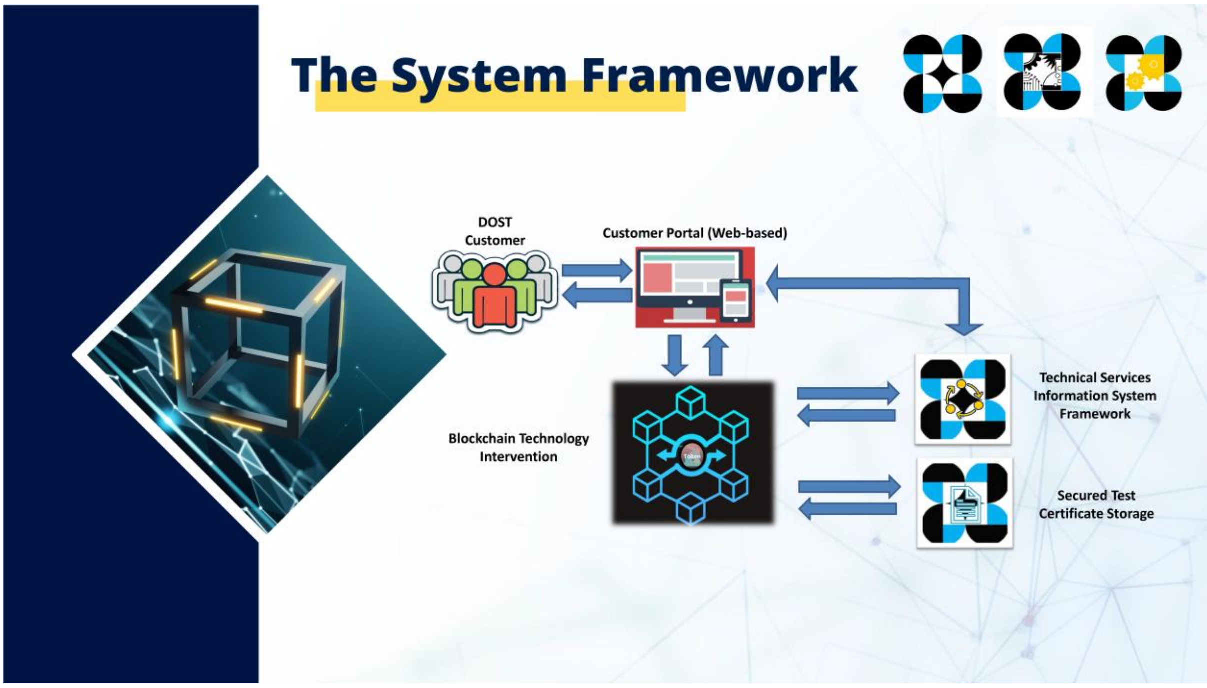

What is Blockchain?

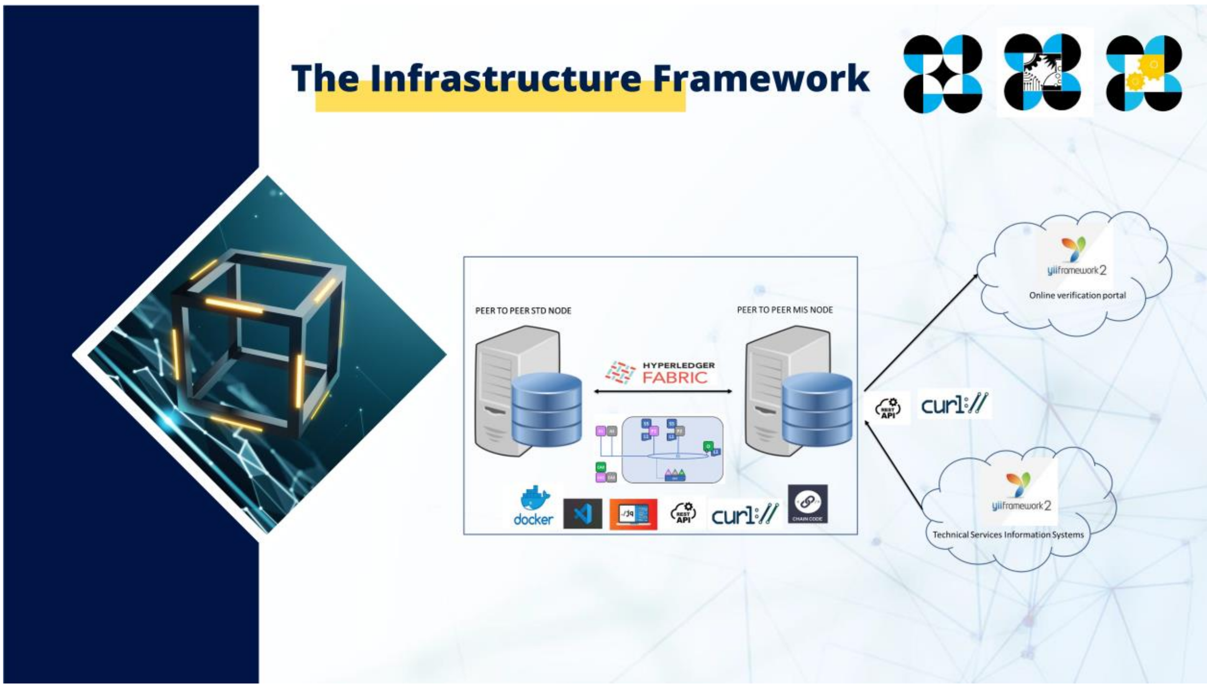

Blockchain
A kind of database that maintains a continuously growing list of ordered records, called blocks

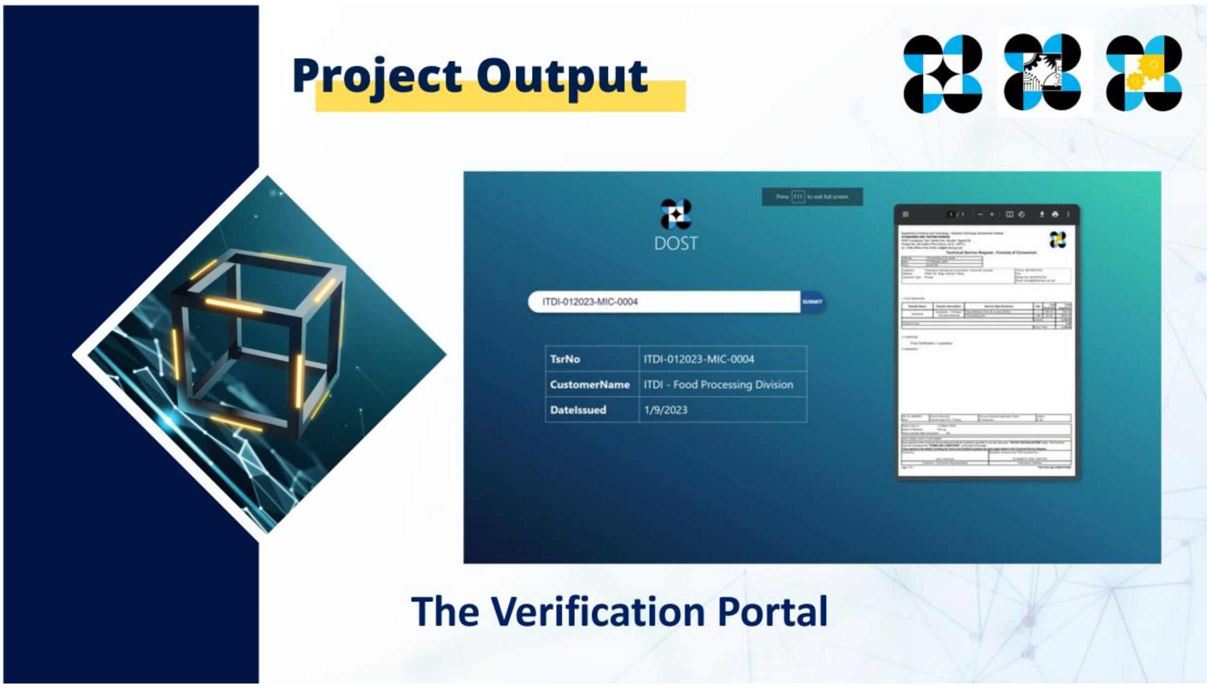

Blockchain
Blockchain Structure
Consensus
Ledger
Node
Ledger
Node
Ledger
Node
Node
Ledger
Node
Ledger
Node
Ledger
Decentralized Records provides security by distributing control across a network


The Goal
Implementing Blockchain-Enabled Digital Certificates and a Verification Portal


The Business Process
Customer Portal
Technical Services IS
Accounting System
Digitalized Certificate
Cashiering System
BTr / BSP Remittance / Collection
LBP LinkBiz Portal
ePayment Portal


The System Framework
DOST
Customer
Customer Portal (Web-based)
Technical Services
Information System
Framework
Blockchain Technology
Intervention
Secured Test
Certificate Storage


The Infrastructure Framework
PEER TO PEER STD NODE
PEER TO PEER MIS NODE
HYPERLEDGER
FABRIC
docker
curl://
yiiframework2
Online verification portal
yiiframework2
Technical Services Information Systems



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002 Jens Schüür: A web-based revision validation system for (digital) calibration certificates

Presenting author: Jens Schüür [1]
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Keywords: revision control, workflow, validation, database

Abstract

A digital calibration certificate, once issued and signed by the laboratory, is a static document. In case a revision of the calibration certificate is issued, the use of the withdrawn calibration certificate is still possible as there is no feedback implemented.

In the DatiPilot funded project DCCiInd [1] a solution for a web-based database has been developed and a demonstrator will be made available for free later in Q2/2026. A similar project has been presented in [2] and was extended in some aspects to the presented database as follows:

- each laboratory may implements a separate database so due to data privacy no information must be given to an external provider. This bypasses and avoids potential issues [3] with external web services or (metrology) clouds.
- the database contains only general information's of the certificate: the certificate number, the unique universal identifier (UUID) of the certificate, the date of issue and a string containing the hashed order number
- the UUID or the date of issue combined with the certificate number lead to the status of the calibration certificate
- hashed order number is given back to enable reverse validation of the certificate
- in case of a revision the UUID of the new revision is added to the entry of the withdrawn calibration certificate and a new entry for the new revision is created.

The main parts of the demonstrator are the web-database with software for the access, a demonstrator for creations or modifications in the database and a demonstrator for the validation of the status of the calibration certificate as website and as a software API.

Digital calibration certificates (DCC) offer the advantage that the information for using this database can be implemented in the calibration certificate, so that no external knowledge is required from the user. A suggestion for a template to be written in the DCC also will be presented.

References:

[1] www.ptb.de (2025): Home-DCC 2 Industry, [https://www.ptb.de/dcc2ind/home/], last accessed: 20.01.2026

[2] Hall, Blair (2025): A service to authenticate documents issued by MSL, pp. 312 to 317, in: "5th International DCC-Conference 2025-02-25 to 2025-02-27 Proceedings", Braunschweig, Germany, 2025. DOI: 10.7795/810.20250619[3];
www.dakks.de (2024): Amtliche Mitteilung: Keine Nutzungspflicht der Datenbank IAF-CertSearch, [https ://www. dakks. de/ de/ aktuelle-meldung/ amtliche-mitteilung-keine-nutzungspflicht-der-datenbank-iaf-certsearch.html], last accessed: 20.01.2026

Presentation #002 of Jens Schüür

Workflow of a calibration certificate

Simplified!

DCC

General workflow:

- Works for Paper / PDF / digital certificate
- Works for the initial issued certificate

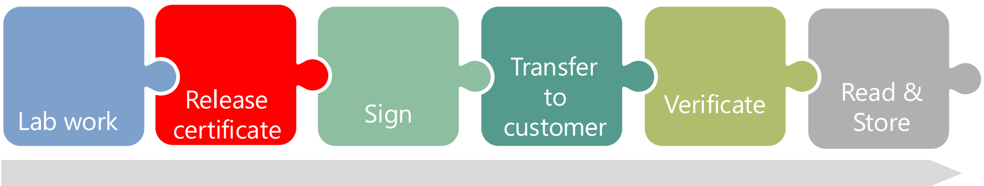
ELMTEC Ingenieurgesellschaft mbH

Nr. 3

Workflow of a calibration certificate

Simplified!

DCC



Does a revision reach the user?

- Maybe not.

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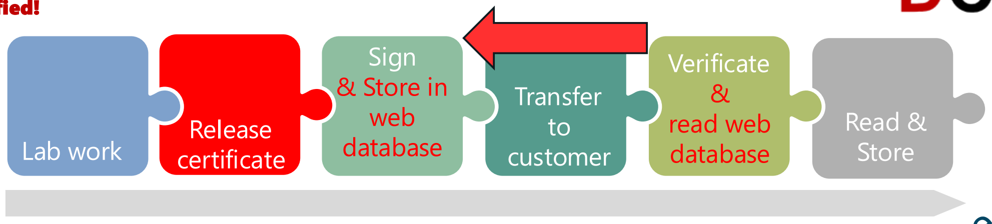
Nr. 4

Workflow of a calibration certificate

Simplified!

DCC



Not required by ISO/IEC 17025!

Does a revision reach the user?

- Yes, if a database is available for the user and user enters certificate data on a website.

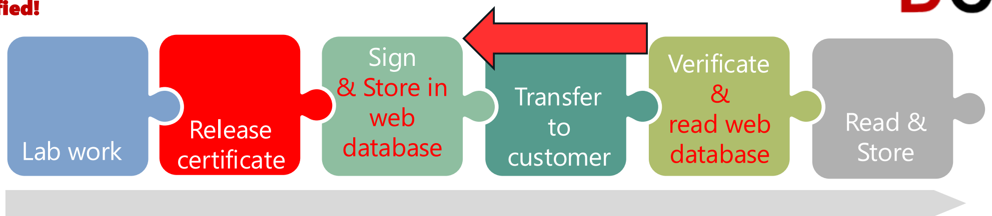
ELMTEC Ingenieurgesellschaft mbH

Nr. 5

Workflow of a calibration certificate

Simplified!

DCC



Not required by ISO/IEC 17025!

Does a revision reach the user?

- Yes, automated verification possible with a digital calibration certificate.

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Nr. 6

Web based system

Concept!

DCC

Data in the database:

- Identifier of the certificate
- Certificate number
- Date of issue
- SHA-Hash of customers order no
- Identifier of the newer certificate

No personal data in the database!

ELMTEC Ingenieurgesellschaft mbH

Nr. 7

Web based system

Benefits

DCC

A similar project has been presented in [1] and was extended in some aspects to the presented database as follows:

- each laboratory may implement a separate database so due to data privacy no information must be given to an external provider. This bypasses and avoids potential issues [2] by not using external web services or external (metrology) clouds.
- the database contains only general information's of the certificate: the certificate number, the unique universal identifier (UUID) of the certificate, the date of issue and a string containing the hashed order number
- the UUID or the date of issue combined with the certificate number lead to the status of the calibration certificate
- hashed order number is given back to enable reverse validation of the certificate
- in case of a revision the UUID of the new revision is added to the entry of the withdrawn calibration certificate and a new entry for the new revision is created.
- Keep it simple: no blockchain, no complex elements

[1] Hall, Blair (2025): *A service to authenticate documents issued by MSL*, pp. 312 to 317, in: "5th International DCC-Conference 2025-02-25 to 2025-02-27 Proceedings", Braunschweig, Germany, 2025. DOI: 10.7795/810.20250619
[2] www.dakks.de (2024): *Amtliche Mitteilung: Keine Nutzungspflicht der Datenbank IAF-CertSearch*, [https://www.dakks.de/de/aktuelle-meldung/amtliche-mitteilung-keine-nutzungspflicht-der-datenbank-iaf-certsearch.html], last accessed: 20.02.2026

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15.03.2026 Nr. 8

Web based system
Data in the database

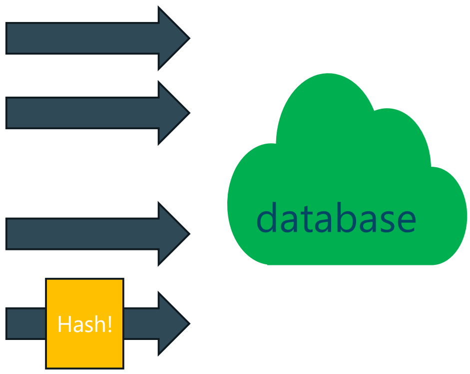
DCC

```
<dcc:uniqueIdentifier>88888888-4444-4444-4444-cccccccccccc</dcc:uniqueIdentifier>
<!--ISO/IEC 17025:2017 7.8.2.1d; UUID version 4 according to ISO/IEC 9834-8:2014-->

<dcc:identification refType="basic_certificateNumber">
    <dcc:issuer>calibrationLaboratory</dcc:issuer>
    <dcc:value>1234</dcc:value>
    <dcc:name>
        <dcc:content lang="de">Kalibrierscheinnummer</dcc:content>
        <dcc:content lang="en">Calibration certificate ID</dcc:content>
    </dcc:name>
</dcc:identification>

<dcc:issueDate>YYYY-MM-DD</dcc:issueDate>
<!--ISO/IEC 17025:2017 7.8.2.1j-->

<dcc:identification refType="basic_orderNumber">
    <dcc:issuer>customer</dcc:issuer>
    <dcc:value>1234-56-78</dcc:value>
    <dcc:name>
        <dcc:content lang="de">Auftrags Nr. des Kunden</dcc:content>
        <dcc:content lang="en">Order no. of customer </dcc:content>
    </dcc:name>
</dcc:identification>
```



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15.03.2026 Nr. 9

Web based system
for Web-Verifikation

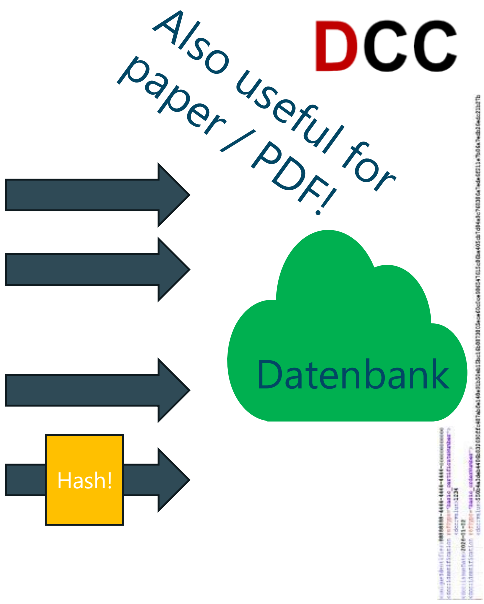
DCC

```
<dcc:uniqueIdentifier>88888888-4444-4444-4444-cccccccccccc</dcc:uniqueIdentifier>
<!--ISO/IEC 17025:2017 7.8.2.1d; UUID version 4 according to ISO/IEC 9834-8:2014-->

<dcc:identification refType="basic_certificateNumber">
    <dcc:issuer>calibrationLaboratory</dcc:issuer>
    <dcc:value>1234</dcc:value>
    <dcc:name>
        <dcc:content lang="de">Kalibrierscheinnummer</dcc:content>
        <dcc:content lang="en">Calibration certificate ID</dcc:content>
    </dcc:name>
</dcc:identification>

<dcc:issueDate>YYYY-MM-DD</dcc:issueDate>
<!--ISO/IEC 17025:2017 7.8.2.1j-->

<dcc:identification refType="basic_orderNumber">
    <dcc:issuer>customer</dcc:issuer>
    <dcc:value>1234-56-78</dcc:value>
    <dcc:name>
        <dcc:content lang="de">Auftrags Nr. des Kunden</dcc:content>
        <dcc:content lang="en">Order no. of customer </dcc:content>
    </dcc:name>
</dcc:identification>
```



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15.03.2026 Nr. 10

Web based system
for the initial certificate

DCC

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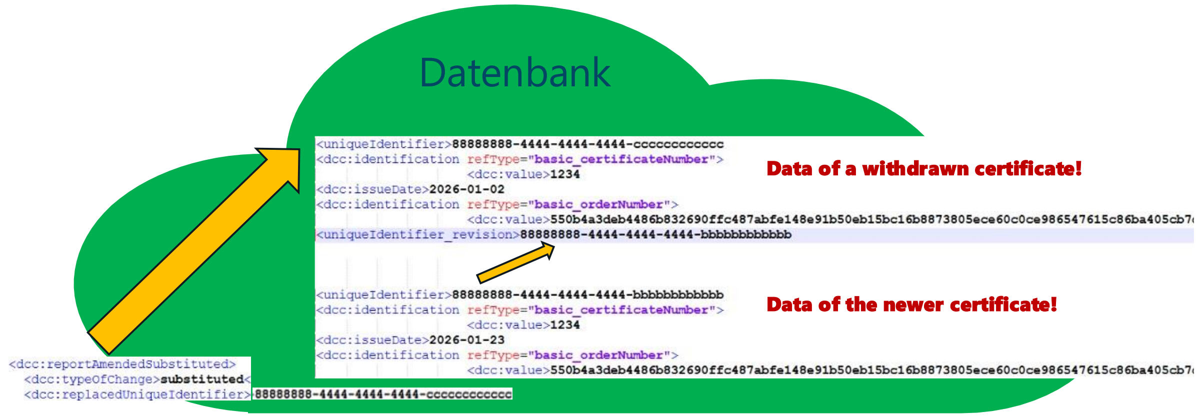
15.03.2026 Nr. 11

Web based system
for Web-Verifikation – data of a withdrawn certificate and the newer certificate!

DCC



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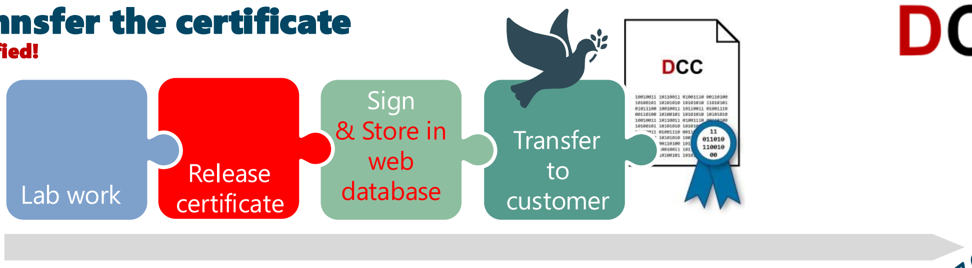
15.03.2026 Nr. 12

Trannsfer the certificate

Simplified!



E-Mail / Stick / API

ISO/IEC 17025 requires data protection!

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Nr. 13

Verification of the certificate

Simplified!

Check the seal:

Details zur Signatur von "ELMTEC Ingenieurgesellschaft mbH"

Durchgeführte Prüfungen

- ✓ **Signatur der Datei** (mathematische Prüfung).
  - Datei ist nicht verändert
  - Datei ist mit qualifiziertem Zertifikat gesiegelt
  - Verwendete Algorithmen zum Signaturzeitpunkt geeignet
  - Verwendete Algorithmen zum Verifikationszeitpunkt geeignet
- ✓ **Zertifikat & Pfad** (Signatur- und Gültigkeitprüfung).
  - Zertifikat und Pfad erfolgreich geprüft
  - Kettenmodell (SigG Profile)
- ✓ **Zertifikatsstatus** (OCSP / CRL).
  - Zertifikatsstatus erfolgreich geprüft

Zertifikatsinhalte:

Version
Seriennummer
Zertifikatsaussteller
Zertifikatsinhabername
Gültigkeitszeitraum
Signaturalgorithmus zum öffentlichen Schlü

Kalibrierlaboratorium
ELMTEC Ingenieurgesellschaft mbH
Kattreppeln 28, 38154 Königslutter am
D-K-15099-01-00 | Gültig seit: 03.06.2024

Details zum Zertifikat

```
Land                  : DE
Organisation          : ELMTEC Ingenieurgesellschaft mbH
Name                  : ELMTEC Ingenieurgesellschaft mbH
Stadt                 : Königslutter am Elm
Organisationskennung  : DT:DE-3957392625
Seriennummer          : DAkkS00-DE-K0-15099-01-00
```

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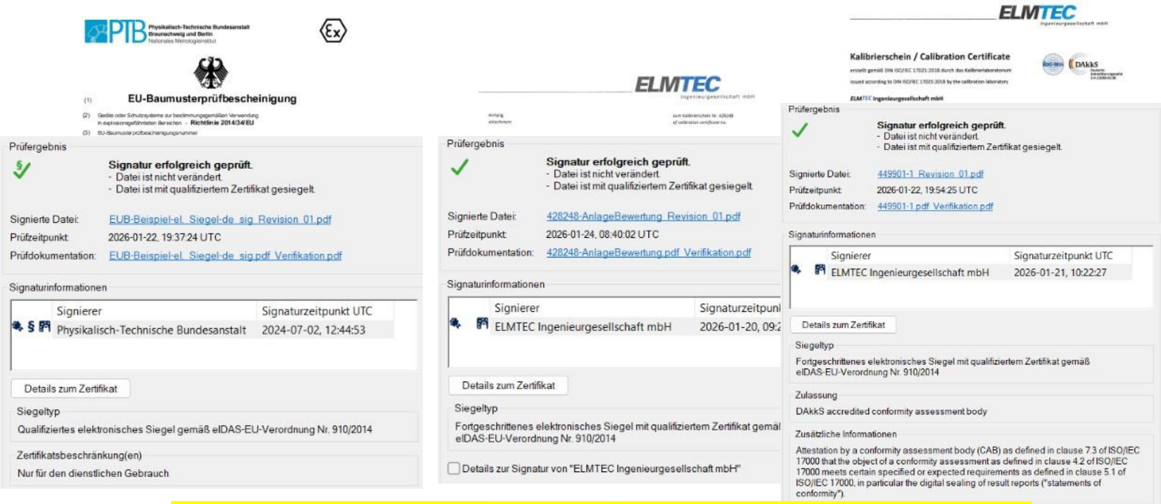
Nr. 14

Possible seals for digital certificates
For PDF / XML-Files!

DCC



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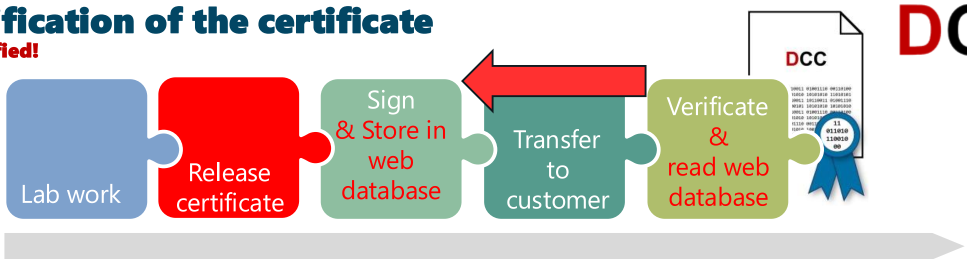
There is no need to use personal certificates – here used: Seal ID

.2026 Nr. 15

Verification of the certificate
Simplified!

DCC



Check for latest revision:

ELMTEC

KALIBRIERUNG GERÄTEVERKAUF SERVICE QUALITÄT

ZERTIFIKATSPRÜFUNG

VARIANTE 1: ZERTIFIKATSNUMMER UND AUSGABEDATUM

Zertifikatsnummer:

Ausgabedatum:

VARIANTE 2: UUID DES ZERTIFIKATS

UUID:

Prüfen

ELMTEC Ingenieurgesellschaft mbH

Nr. 16

Revisioning and DCC validity
Web-Verifikation – API

DCC

Write with passphrase only
Reading without passphrase

valid entry gives „VALID“ & HASH
invalid entry gives „INVALID“
in case of replace find „REPLACE“ and new UUID

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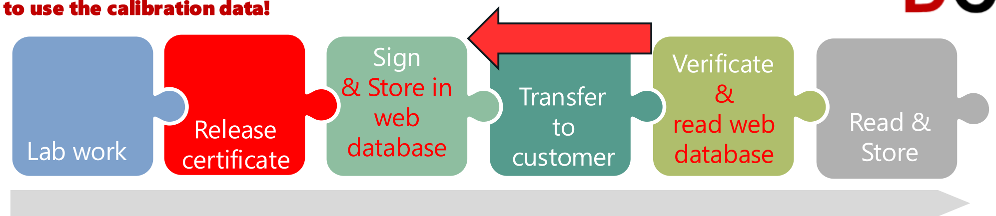
Verification of the certificate
Ready to use the calibration data!

DCC



Verified:

- Yes, unchanged digital calibration certificate,
- Yes, latest revision.

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Nr. 18

Summary

DCC

As presented

- Based on the workflow of a calibration certificate
- A web based revision validation system for (digital) calibration certificates
- Benefits for the user of the certificate, enables full power using a DCC

Next steps?

- Preparing all data as demonstrator
- Publishing the demonstrator
- See https://www.ptb.de/dcc2ind/home in Q2/Q3 2026
- Find the demonstrator for the implementation in your lab as download

More details about the project DCC2Ind:

- See talk #032, presented by Wiebke Heeren.

DATIpilot

#032 W. Heeren
DCC to Industry - Processes in a Practical Use-Case

Workflow of a calibration certificate

Simplified!

DCC

General workflow:

- Works for Paper / PDF / digital certificate
- Works for the initial issued certificate

Workflow of a calibration certificate

Simplified!

DCC

Does a revision reach the user?

- Maybe not.

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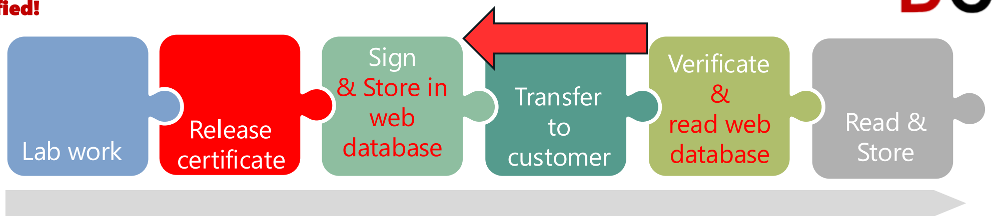
Nr. 4

Workflow of a calibration certificate

Simplified!

DCC



Does a revision reach the user?

- Yes, if a database is available for the user and user enters certificate data on a website.

Not required by ISO/IEC 17025!

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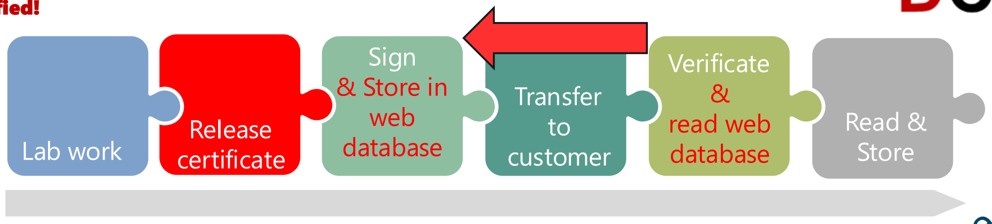
Nr. 5

Workflow of a calibration certificate

Simplified!

DCC



Not required by ISO/IEC 17025!

Does a revision reach the user?

- Yes, automated verification possible with a digital calibration certificate.

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Nr. 6

Web based system

Concept!

DCC

Data in the database:

- Identifier of the certificate
- Certificate number
- Date of issue
- SHA-Hash of customers order no
- Identifier of the newer certificate

No personal data in the database!

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Nr. 7

Web based system
Benefits

DCC

A similar project has been presented in [1] and was extended in some aspects to the presented database as follows:

- each laboratory may implement a separate database so due to data privacy no information must be given to an external provider. This bypasses and avoids potential issues [2] by not using external web services or external (metrology) clouds.
- the database contains only general information's of the certificate: the certificate number, the unique universal identifier (UUID) of the certificate, the date of issue and a string containing the hashed order number
- the UUID or the date of issue combined with the certificate number lead to the status of the calibration certificate
- hashed order number is given back to enable reverse validation of the certificate
- in case of a revision the UUID of the new revision is added to the entry of the withdrawn calibration certificate and a new entry for the new revision is created.
- Keep it simple: no blockchain, no complex elements

[1] Hall, Blair (2025): *A service to authenticate documents issued by MSL*, pp. 312 to 317, in: "5th International DCC-Conference 2025-02-25 to 2025-02-27 Proceedings", Braunschweig, Germany, 2025. DOI: 10.7795/810.20250619
[2] www.dakks.de (2024): *Amtliche Mitteilung: Keine Nutzungspflicht der Datenbank IAF-CertSearch*, [https://www.dakks.de/de/aktuelle-meldung/amtliche-mitteilung-keine-nutzungspflicht-der-datenbank-iaf-certsearch.html], last accessed: 20.02.2026

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15.03.2026 Nr. 8

Web based system
Data in the database

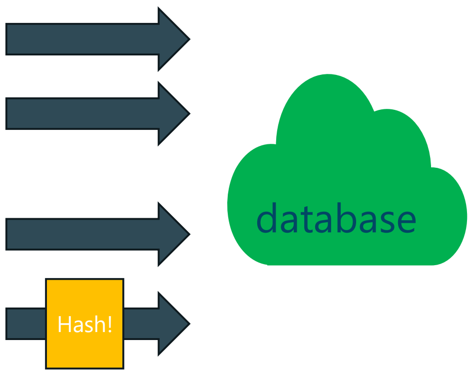
DCC

```
<dcc:uniqueIdentifier>88888888-4444-4444-4444-cccccccccccc</dcc:uniqueIdentifier>
<!--ISO/IEC 17025:2017 7.8.2.1d; UUID version 4 according to ISO/IEC 9834-8:2014-->

<dcc:identification refType="basic_certificateNumber">
    <dcc:issuer>calibrationLaboratory</dcc:issuer>
    <dcc:value>1234</dcc:value>
    <dcc:name>
        <dcc:content lang="de">Kalibrierscheinnummer</dcc:content>
        <dcc:content lang="en">Calibration certificate ID</dcc:content>
    </dcc:name>
</dcc:identification>

<dcc:issueDate>YYYY-MM-DD</dcc:issueDate>
<!--ISO/IEC 17025:2017 7.8.2.1j-->

<dcc:identification refType="basic_orderNumber">
    <dcc:issuer>customer</dcc:issuer>
    <dcc:value>1234-56-78</dcc:value>
    <dcc:name>
        <dcc:content lang="de">Auftrags Nr. des Kunden</dcc:content>
        <dcc:content lang="en">Order no. of customer </dcc:content>
    </dcc:name>
</dcc:identification>
```



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003 Muhammed-Ali Demir: An example of a DCC compatible sub schema

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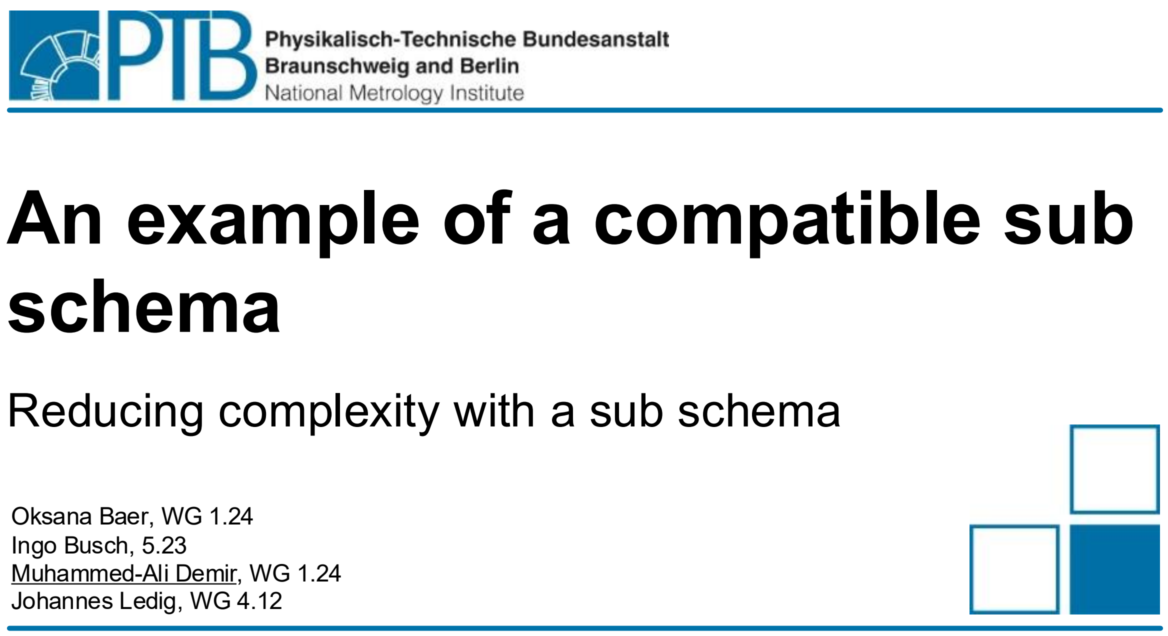
Keywords: DCC, compatible sub schema, QM

Abstract

In the 5th DCC Conference in 2025 we explained which rules have to be followed in order to generate a DCC sub schema, that would still be compatible with the DCC main schema. Meanwhile quality management representatives of PTB had asked for a sub schema in order to have a stricter schema covering also requirements from internal quality management procedures. This sub schema is dedicated to enable a more uniform appearance of the administrative data, including logos and statements. In this presentation we will give a practical example for such a DCC sub schema.

Presentation #003 of Muhammed-Ali Demir



Motivation

- Presentation at the 6th DCC Conference:
  Compatible sub schemata of the DCC Schema
- Content: 9 rules that make it possible to create a DCC sub schema compatible with the main DCC schema

Introduction

- PTB has released an internal DCC Template for its departments by end of 2025
- The PTB Template covers mainly Administrative Data of DCCs in a first step
- During development of this template, there were requirements that can be solved with a sub schema
- In the following we will look exemplarily at 7 requirements and propose a solution with a sub schema compatible to the DCC main schema

Obligatory statements

- Requirement: every DCC has to contain at least **one statement** (ISO 17025 7.8.2.1 l)
- Solution: dcc:statements has to be obligatory in dcc:administrativeData

Obligatory statements

```
<xs:complexType name="administrativeDataType">
   <xs:annotation>
      <xs:documentation>
         Contains all essential administrative information about the calibration.
         The entries in this section are regulated and essentially identical for all DCCs.
      </xs:documentation>
   </xs:annotation>
   <xs:all>
      <xs:element name="dccSoftware" type="dcc:softwareListType"/>
      <xs:element name="refTypeDefinitions" type="dcc:refTypeDefinitionListType" minOccurs="0"/>
      <xs:element name="coreData" type="dcc:coreDataType"/>
      <xs:element name="items" type="dcc:itemListType"/>
      <xs:element name="calibrationLaboratory" type="dcc:calibrationLaboratoryType"/>
      <xs:element name="respPersons" type="dcc:respPersonListType"/>
      <xs:element name="customer" type="dcc:contactType"/>
-     <xs:element name="statements" type="dcc:statementListType" minOccurs="0"/>
+     <xs:element name="statements" type="dcc:statementListType"/>
   </xs:all>
</xs:complexType>
```

Main schema
Subschema

Obligatory issue date

- Requirement: every DCC has to have an issue date (ISO 17025 7.8.2.1 j)
- Solution: dcc:issueDate has to be obligatory in dcc:coreData

Obligatory issue date

```
<xs:complexType name="coreDataType">
  <xs:annotation>
    <xs:documentation>
      Metadata of the DCC, containing the unique identifier and other identifications.
    </xs:documentation>
  </xs:annotation>
  <xs:sequence>
    <xs:element name="countryCodeISO3166_1" type="dcc:stringISO3166Type"/>
    <xs:element name="usedLangCodeISO639_1" type="dcc:stringISO639Type" maxOccurs="unbounded"/>
    <xs:element name="mandatoryLangCodeISO639_1" type="dcc:stringISO639Type" maxOccurs="unbounded"/>
    <xs:element name="uniqueIdentifier" type="dcc:notEmptyStringType"/>
    <xs:element name="identifications" type="dcc:identificationListType" minOccurs="0"/>
    <xs:element name="receiptDate" type="xs:date" minOccurs="0"/>
    <xs:element name="beginPerformanceDate" type="xs:date"/>
    <xs:element name="endPerformanceDate" type="xs:date"/>
    <xs:element name="performanceLocation" type="dcc:performanceLocationType"/>
-   <xs:element name="issueDate" type="xs:date" minOccurs="0"/>
+   <xs:element name="issueDate" type="xs:date"/>
    ...
  </xs:sequence>
</xs:complexType>
```

Main schema
Subschema

No amended in dcc:typeOfChange

- Requirement: “amended” should not be useable in dcc:typeOfChange (ISO 17025 7.8.8.2)
- Solution: remove enumeration from dcc:typeOfChange

No amended in dcc:typeOfChange

```
<xs:complexType name="reportAmendedSubstitutedType">
   <xs:annotation>
      <xs:documentation>
         Information about the replaced DCC and the reason for the replacement, used :
      </xs:documentation>
   </xs:annotation>
   <xs:sequence>
      <xs:element name="typeOfChange">
         <xs:simpleType>
            <xs:restriction base="xs:string">
-              <xs:enumeration value="amended"/>
               <xs:enumeration value="substituted"/>
            </xs:restriction>
         </xs:simpleType>
      </xs:element>
      <xs:element name="replacedUniqueIdentifier" type="dcc:notEmptyStringType"/>
   </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>
```

Main schema

Obligatory description in item

- Requirement: obligatory description of items (ISO 17025 7.8.2.1 g)
- Solution: dcc:description has to obligatory in dcc:item

Obligatory description in 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="un
-   <xs:element name="description" type="dcc:richContentType" minOccurs="0"/>
+   <xs:element name="description" type="dcc:richContentType"/>
    <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>
```

Main schema
Subschema

Obligatory cryptElectronicSeal

- Requirement: Obligatory dcc:cryptElectronicSeal in dcc:calibrationLaboratory (PTB DCCs are recommended to be sealed by PTB)
- Solution: dcc:cryptElectronicSeal must be obligatory in dcc:calibrationLaboratoryType
- A non-sealed DCC is inconsistent regarding the sealed=true and sub-schema and thus clearly identified as a draft, a PTB DCC that is not sealed requires adopting template content

Obligatory cryptElectronicSeal

```
<xs:complexType name="calibrationLaboratoryType">
   <xs:annotation>
      <xs:documentation>
         Information about the calibration laboratory.
      </xs:documentation>
   </xs:annotation>
   <xs:sequence>
      <xs:element name="calibrationLaboratoryCode" type="dcc:notEmptyStringType" minOccurs="0"/>
      <xs:element name="contact" type="dcc:contactType"/>
-     <xs:element name="cryptElectronicSeal" type="xs:boolean" minOccurs="0"/>
+     <xs:element name="cryptElectronicSeal" type="xs:boolean"/>
      <xs:element name="cryptElectronicSignature" type="xs:boolean" minOccurs="0"/>
      <xs:element name="cryptElectronicTimeStamp" type="xs:boolean" minOccurs="0"/>
   </xs:sequence>
</xs:complexType>
```

Main schema
Subschema

Obligatory eMail in contactType

- Requirement: obligatory eMail as contact information
- Solution: dcc:eMail must be obligatory in dcc:contact
- Caution: applies to dcc:customer, dcc:owner, dcc:calibrationLaboratory and dcc:respAuthority

Obligatory eMail in contactType

```
<xs:complexType name="contactType">
   <xs:sequence>
      <xs:element name="name" type="dcc:textType"/>
-      <xs:element name="eMail" type="dcc:notEmptyStringType" minOccurs="0"/>
+      <xs:element name="eMail" type="dcc:notEmptyStringType"/>
      <xs:element name="phone" type="dcc:notEmptyStringType" minOccurs="0"/>
      <xs:element name="fax" type="dcc:notEmptyStringType" minOccurs="0"/>
      <xs:element name="link" type="xs:anyURI" minOccurs="0"/>
      <xs:element name="location" type="dcc:locationType"/>
      <xs:element name="descriptionData" type="dcc:byteDataType" 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>
```

Main schema
Subschema

Sequence in administrative data

- Requirement: fixed sequence in dcc:administrativeData (increased usability and uniformity)
- Solution: change dcc:administrativeData from xs:all to xs:sequence

Sequence in administrative data

```
<xs:complexType name="administrativeDataType">
   <xs:annotation>
      <xs:documentation>
            Contains all essential administrative information about the calibration.
            The entries in this section are regulated and essentially identical for all DCCs.
        </xs:documentation>
   </xs:annotation>
-  <xs:all>
+  <xs:sequence>
      <xs:element name="dccSoftware" type="dcc:softwareListType"/>
      <xs:element name="refTypeDefinitions" type="dcc:refTypeDefinitionListType" minOccurs="0"/>
      <xs:element name="coreData" type="dcc:coreDataType"/>
      <xs:element name="items" type="dcc:itemListType"/>
      <xs:element name="calibrationLaboratory" type="dcc:calibrationLaboratoryType"/>
      <xs:element name="respPersons" type="dcc:respPersonListType"/>
      <xs:element name="customer" type="dcc:contactType"/>
      <xs:element name="statements" type="dcc:statementListType"/>
-  </xs:all>
+  </xs:sequence>
</xs:complexType>
```

Main schema
Subschema

Main schema
Subschema

Conclusions

- A DCC which fulfils the sub schema created in the previous steps is automatically also valid regarding the main DCC XML schema
- The resulting sub schema

  dcc_v3.3.0_SubPTB.xsd
- However the sub schemata is only one way, the requirements can also be fulfilled with Schematron validation

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From: 02/26

Appendix: How to use a local schema

- Save the sub schema on your harddisk e.g.: C:\temp
- Create a new DCC XML file or copy an existing DCC XML file into the same directory

```
<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/v3.3.0/dcc.xsd"
+       xsi:schemaLocation="https://ptb.de/dcc file://C:/Temp/dcc_v3.3.0_SubPTB.xsd"
        schemaVersion="3.3.0">
```

- Now you can validate the DCC XML against the sub schema

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004 Peter Blattner: Swiss Quality Infrastructure: Digitalization of the Traceability

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Additional Author(s):
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Institute:
[1] METAS Metrology Institute CHE
[2] Mettler-Toledo International Inc.
Keywords: Traceability, ISO/IEC 17025, quality infrastructure

Abstract

Digital transformation increasingly affects the quality infrastructure and the way metrological traceability is established, communicated, and trusted. However, stakeholders such as national metrology institutes, calibration and testing laboratories, accreditation bodies, and industry often use different definitions of the term “traceability”. This can lead to misunderstandings and inefficient processes. This contribution reports on a multi-stakeholder co-creation workshop organized by METAS on the digitalization of metrological traceability. It followed earlier workshops related to the digitalization of the Swiss Quality Infrastructure [1]. The workshop brought together representatives from metrology, accreditation, industry, and standardization to jointly explore conceptually and practically different aspects of traceability. One key outcome was the shared understanding that traceability is defined differently in standards such as ISO 9000 and the VIM which is referenced by ISO/IEC 17025, and that this plurality can cause confusion in practice. Participants agreed that metrological traceability is not mainly a document-based concept, but rather a functional relationship between input parameters and measurement results. Furthermore, the definition of metrological traceability includes requirements on documentation, and thus on the calibration and measurement processes themselves. In this context, calibration certificates were recognized as *partial* carriers of traceability information, but not as the sole element to constitute metrological traceability itself.

A second important outcome concerned trust models. Participants identified that digitalization would need a shift from implicit trust, based on institutional frameworks, accreditation, and human expertise, towards explicit and machine-actionable trust enabled by digital evidence and verifiable claims. This shift would need a fundamental change in respect to assessing the competence of people and systems. Digital capabilities such as structured data, persistent identifiers, explicit linking, and governance mechanisms were challenging to understand for non-experts but were seen as essential for scalable and reliable digital traceability.

The workshop also showed some interest in model-based approaches to metrological traceability, exemplified by METAS UncLib [2], and articulated the expectation that National Metrology Institutes should involve stakeholders in the development of digital traceability solutions. In addition, it also became clear that the scaling factor at the top of the metrological pyramid is very small and therefore the business model is not obvious, as the major pain point is not directly the metrological traceability but rather everything surrounding it including the assessment of people's competence. The results indicate that the digitalization of metrological traceability is not only a technical task, but also a conceptual and socio-technical transformation that requires shared understanding, new trust concepts, and participatory development within the quality infrastructure.

References:

[1] Blattner, Peter; De Feo, Oscar; Assi, Fabiano (2025): *Swiss Quality Infrastructure in Transition*, in: IMEKO TC-6 M4DConf 2025, Benevento, Italy, September 3-5, 2025

[2] Zeier, Markus et al. VNA Tools - A Metrology Software Supporting the Digital Traceability Chain, Metrology, 2025, 5(4), 72; https://doi.org/10.3390/metrology5040072

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Presentation #004 of Peter Blattner

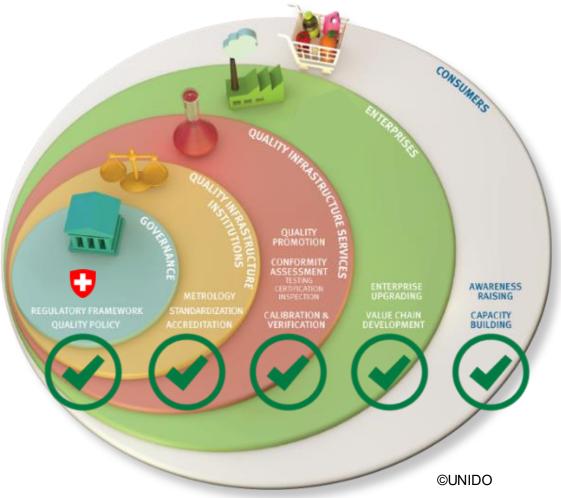
Swiss Quality Infrastructure: Digitalization of the Traceability

Peter Blattner (METAS) & Christian Müller -Schöll (Mettler-Toledo Int. Inc.)

2026-02-24

Serie of Workshops of the Swiss QI

METAS
METTLER TOLEDO



©UNIDO

Regulator
- State Secretariat for Economic Affairs SECO

Institutions
- METAS
- SNV, CES
- SAS

Services
- METAS cert
- Testing Labs
- Certification bodies

Enterprise
- Company 1, 2, 3,…

Consumers
- Consumer Organizations

Initiated by
INB NK 195
(Swiss mirror committee of ISO CASCO)

Swiss Quality Infrastructure: Digitalization of the Traceability 2026-02-24 2

Workshop 2: Pain points (extract)

METAS
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- **Media discontinuities** – paper ↔ PDF ↔ manual re-entry between LIMS/QMS/ERP
- **Provenance & traceability** – end-to-end lineage of who/what/when (incl. instruments, versions, SI units) is incomplete or inconsistent
- **Data comparability & consistency** – heterogeneous methods/units/uncertainty budgets make results hard to compare across labs
- **Big-data handling** – volume/velocity/variety/veracity challenges for high-frequency or multi-site measurement data
- **Verifiability of claims** – conformity claims and data origins are not easily checkable by machines
- **Machine-readable artifacts** – certificates, test reports, standards, and methods are PDFs; lack of structured, semantic data
- **Digital calibration processes & certificates** – fragmented approaches; limited adoption of fully digital, verifiable calibration/test certificates

Swiss Quality Infrastructure: Digitalization of the Traceability 2026-02-24 3

Major Outcomes from Workshop 1 and 2

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Technological Needs
- QI Data Spaces
- Digitalization of the calibration process/traceability, Digital Certificate
- IoT and Big Data
- Smart Standard

Common ground
- Business Cases and Value Propositions
- Establishment of seed funding mechanisms for prototyping of digital QI tools
- Exchange and alignment with international initiatives

Blattner, Peter; De Feo, Oscar; Assi, Fabiano (2025): *Swiss Quality Infrastructure in Transition*, in: IMEKO TC-6 M4DConf 2025, Benevento, Italy, September 3-5, 2025

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Workshop 3: Data Privacy by Design

Suppose your daughter or son would like to buy alcohol in a shop. Does the seller need to know their date of birth?

A "paper" document carries too much information for the seller because it includes details that are not relevant to the “transaction”.

A digital ID allows for data privacy by design.

Documents in the QI
Calibration Certificate
Certificate of Approval / Type-Approval Certificate
Certificate of Conformity (CoC)
Accreditation Scope Statement
CMC Declaration (Calibration & Measurement Capabilities)
Standards & Technical Reports
Laws & Regulations (machine-readable catalog)
Audit Report / Nonconformity Record
Annual Assurance Report (e.g., lab or CAB)
Technical Records

Swiss Quality Infrastructure: Digitalization of the Traceability

Workshop 4: Digital Traceability

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traceability is a polysemy!

METAS
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ISO - Online Browsing Platform (OBP)

https://www.iso.org/obp/

-> 162 results for «traceability»

Metrological Traceability (ISO/IEC Guide 99 (VIM), used by ISO/IEC 17025,…)
A property of a measurement result, not of an object, product, or information record.

"Generic" Traceability (ISO 9000:2015, …)
ability to trace the history, application or location of an object

"Information" Traceability (ISO 12176-4,ISO/IEC/IEEE 12207,…)
traceable relationships between information elements

It is a source of confusion, particularly since most companies are more familiar with the ISO 9000 definition than with the ISO/IEC Guide 99 (VIM).

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metrological traceability: functional relationship

METAS
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metrological traceability (ISO/IEC Guide 99:2007(en), 2.41)
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**

measurement uncertainty (ISO/IEC Guide 99:2007(en), 2.26)

non-negative parameter characterizing the dispersion of the quantity values being attributed to a measurand, based on the information used

The evaluation of measurement uncertainty requires typically **a functional relationship** ("Measurement Functions") between input quantities $Y_0, X_1, X_2, \ldots X_N$ and the output quantity Y

$$Y = f\left(X_1, X_2, \ldots, X_N\right)$$

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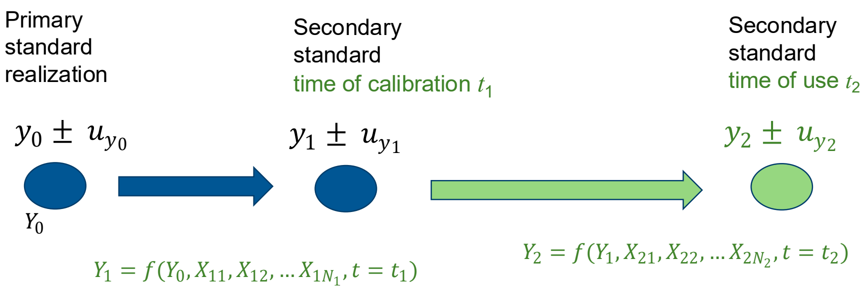
Maintaining metrological traceability



ISO/IEC 17025:2017 (6.5.1):
The laboratory shall **establish and maintain** metrological traceability of its measurement results

Functional relationships can be make "machine-actionable"

METAS UncLib Objects (introduced in 2009)

Metrological Traceability

GUID

Jacobi


```xml
<?xml version="1.0" encoding="utf-16"?>
<UncNumber xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
xmlns:xsd="http://www.w3.org/2001/XMLSchema">
  <Value>6</Value>
  <Dependencies>
    <DependsOn>
      <Input>
        <Id>C1-D8-58-4B-B5-C5-43-A0-BD-A1-66-CD-73-76-4C-06</Id>
        <Description>r</Description>
        <Distribution xsi:type="Normal">
          <mu>3</mu>
          <sigma>0.28</sigma>
        </Distribution>
      </Input>
      <Jacobi>3.5</Jacobi>
    </DependsOn>
...
      <Jacobi>1.5</Jacobi>
    </DependsOn>
  </Dependencies>
</UncNumber>
```


Example: VNA Tools

GUM Tree Calculator
https://github.com/MSLNZ/GTC
Blair Hall (2004)
DOI: 10.1142/9789812702647_0017

https://www.metas.ch/unclib
https://github.com/metas-ch/metas-unclib-python-wrapper
-> Presentation #025

«Reject metrological traceability claims»
Exercise – in teams

15 min

METAS METTLER TOLEDO

Assume you are a sceptical auditor.
Your task is to be creative and find reasons why you would reject a traceability claim.

Each team

- Write down as many reasons to reject traceability as you can. One reason per small sticker.
- For each reason add the consulted evidences (“data of issue of the Calibration Certificate”) on a separate sticker (one for each)

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Reject metrological traceability claims
Feedbacks from the teams

METAS METTLER TOLEDO

Reference not traceable to SI

Missing calibration certificate

Training records of operator missing

No uncertainty statements

Used outside validated range

Conditions for calibration not suitable

Accreditation of service provider expired at time of calibration

No serial number / unique ID

Subcontracting not declared

Competence of organization not proved

No validated procedures

Process not correctly described

Functional relationship undocumented

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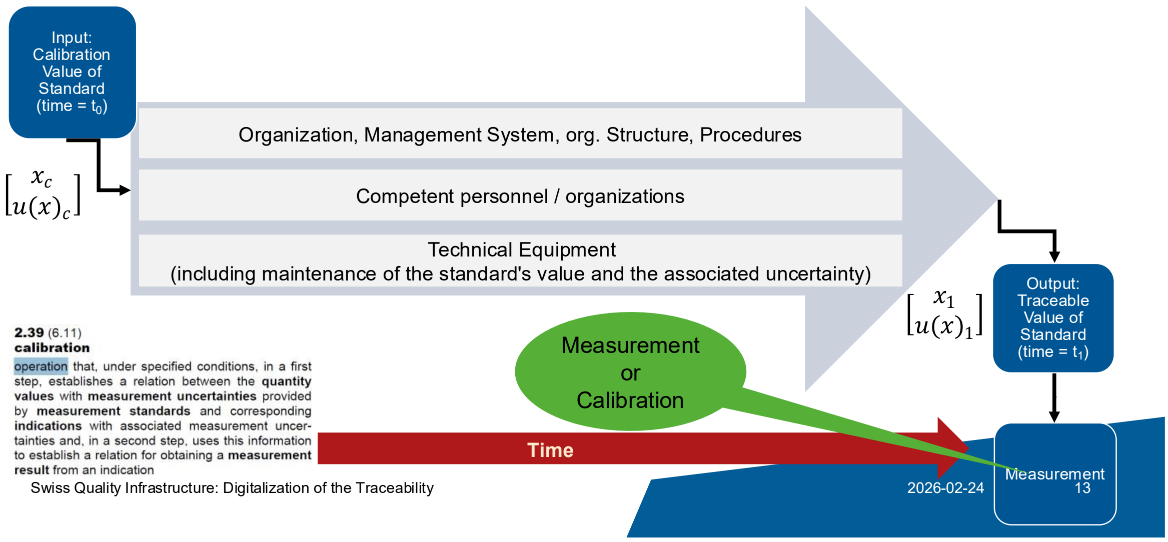
Metrological traceability requires a *process*

METAS
METTLER TOLEDO



2.39 (6.11)
calibration
operation that, under specified conditions, in a first step, establishes a relation between the **quantity values** with **measurement uncertainties** provided by **measurement standards** and corresponding **indications** with associated measurement uncertainties and, in a second step, uses this information to establish a relation for obtaining a **measurement result** from an indication

Evidences used to show traceability

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- Calibrations Certificates
  - Date
  - Object
  - Results incl. Uncertainty
  - Conditions
  - …
- Technical Records
  - Uncertainty budget
  - Raw data & evaluated data
  - Instruments & calibration status (and related documents)
  - Description Procedures
  - Validation & Verifications
  - …
- Competence
  - Training records
  - Witnessing
- Risk analysis

Major Pain Points

Follow-up exercise: Which digital capabilities are necessary to relieve these pain points ?

METAS
METTLER TOLEDO

1. Structured, machine-readable data
2. Persistent identifiers
3. Explicit linking between objects
4. Explicit uncertainty representation
5. Machine-verifiable claims
6. Strong digital identity and integrity
7. Time-aware validity and lifecycle
8. Versioning and immutability
9. System-to-system access (APIs)
10. Selective disclosure (privacy by design)
11. Governance and policy enforcement

"digitalization of competence"?
change of trust model

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Conclusions

METAS
METTLER TOLEDO

- "traceability" is a polysemy -> to avoid confusion state "metrological traceability" if applicable
- *metrological traceability* requires a process, not just a calibration value (i.e. a calibration certificate is only a *partial carrier*)
- functional relationships can be machine-actionable (METAS UncLib Objects, GUM Tree Calculator,…)
- Challenges: How to make other aspects of traceability machine-actionable ("proof of competence", …)? What is the value proposition?

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Thank you for your attention

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Christian.Mueller-Schoell@mt.com

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005 Praiya Thongluang: Measurement Capability Modeling and SI-Compliant Unit Representation for Digital Calibration Certificates

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Additional authors:

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- Narin Chanthawong narin@nimt.or.th
- Technical contact: praiyat@nimt.or.th

Institute:
[1] National Institute of Metrology (Thailand)
Keywords: Digital Calibration Certificate (DCC), Calibration and Measurement Capabilities (CMC), Accreditation Scope Database, SI Digital Framework

Abstract

The Digital Calibration Certificate (DCC) Web Portal of the National Institute of Metrology (Thailand) (NIMT) originally supported automatic certificate type selection, DCC generation in PDF/A-3 format, and XML schema and digital signature validation. However, measurement capability was not explicitly represented in a structured, machine-interpretable manner. This paper presents enhanced DCC architecture based on measurement capability modelling, consistent with the concept of Calibration and Measurement Capabilities (CMC) used in accreditation and mutual recognition frameworks. The main contribution is the design and implementation of a CMC Database and an associated Scope of Accreditation Database, derived from authoritative accreditation body information. These databases provide a formal digital representation of laboratory measurement capabilities, including measurement ranges, units, and accreditation status, enabling consistent and capability-based classification of DCC types. Three DCC generation scenarios demonstrate the approach: (1) calibration services accredited by an ILAC MRA signatory accreditation body, represented by the Thai Industrial Standards Institute (TISI); (2) services covered under the CIPM Mutual Recognition Arrangement (CIPM MRA); and (3) non-accredited calibration services. The scenarios show how DCC generation workflows adapt dynamically according to recognized measurement capability and institutional trust level. The measurement capability model focuses on scope modelling and Si-compliant unit representation. Measurement scopes are expressed as intervalbased numerical ranges defining the valid domain of a laboratory's capability and enabling machine-readable evaluation of calibration results. Scope information is digitally linked to accreditation data using structured JSON representations. Unit representation follows the SI Digital Framework published by the BIPM, with SI prefixes, base units, and exponents treated as separate semantic components to ensure unambiguous and standardized unit encoding. Overall, the proposed framework advances DCC generation from document-centric digitalization toward capability-driven digital metrology, strengthening interoperability, traceability, and digital trust in alignment with international DCC, CMC, and SI digitalization initiatives.

References:

[1] Bureau International des Poids et Mesures (2025): Digital transformation and the SI Digital Framework, https://www.bipm.org/en/digital-transformation, last accessed: 25.01.2026.
[2] Chalk, S.J., Coppa, D.N., Flamenco, F., Forbes, A., Hall, B.D., Hanisch, R.J., Hosaka, K., Hutzschenreuter, D., Park, J.S., White, R.M., 2021. International development of the

SI in FAIR digital data. Measurement: Sensors 18, 100293.

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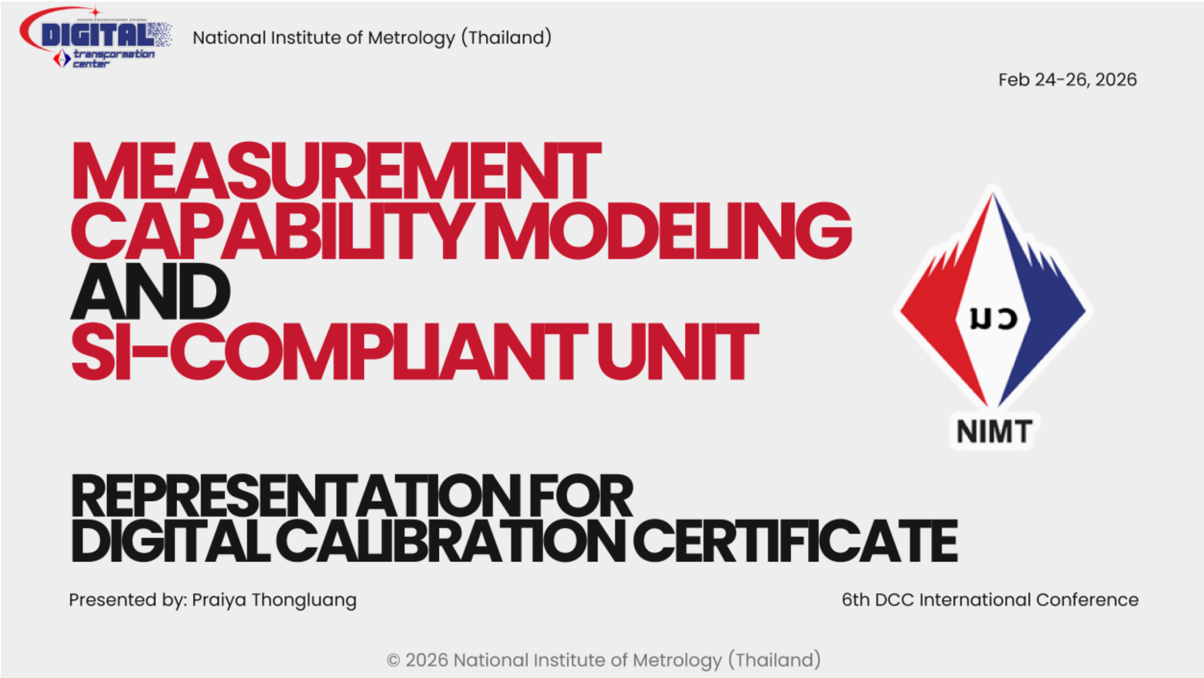
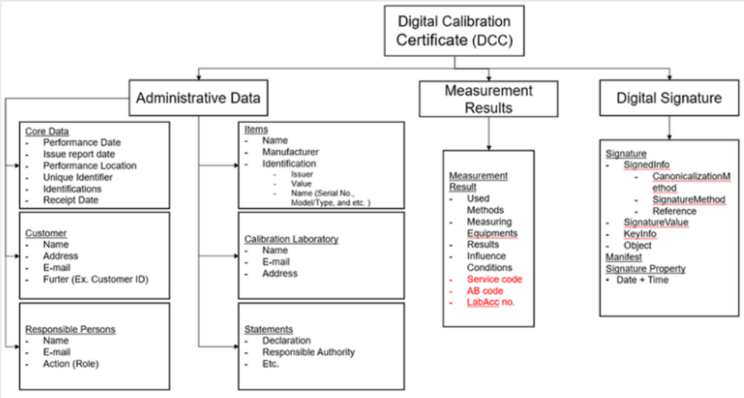
Presentation #005 of Praiya Thongluang



NIMT's XML Schema

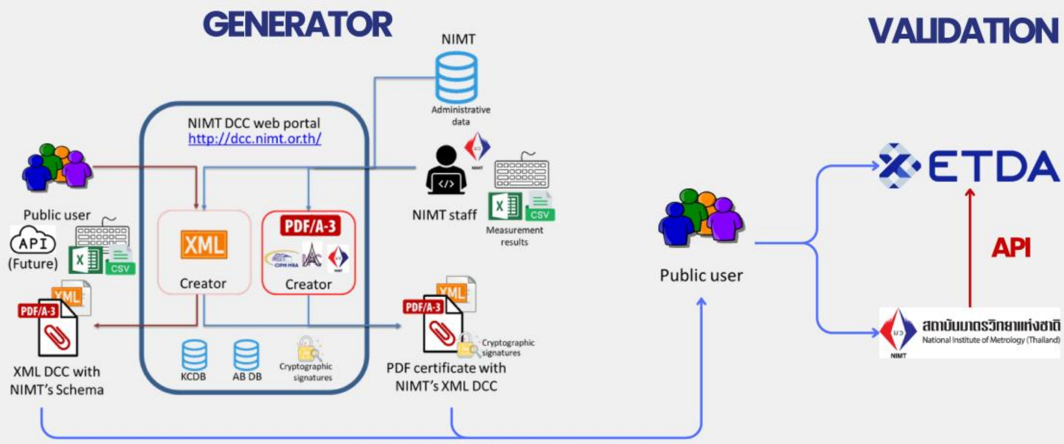


- Announcement NIMT DCC Schema version 1.1 based on PTB XML DCC v.3.2.1 with some modification.
- Publish Schema Repository in ETDA website for reference in Thailand.

Electronic Transactions Development Agency

3

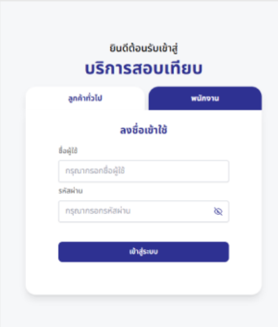
RECAP OUR SERVICE



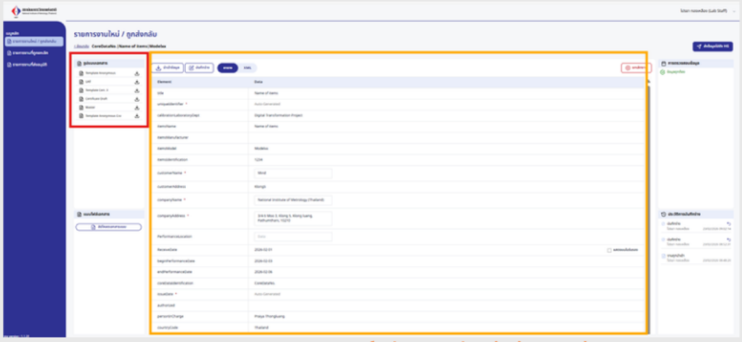
DCC WEB PORTAL

Log in

- NIMT staff can log in using their existing NIMT account, which is the same account used for other NIMT systems.

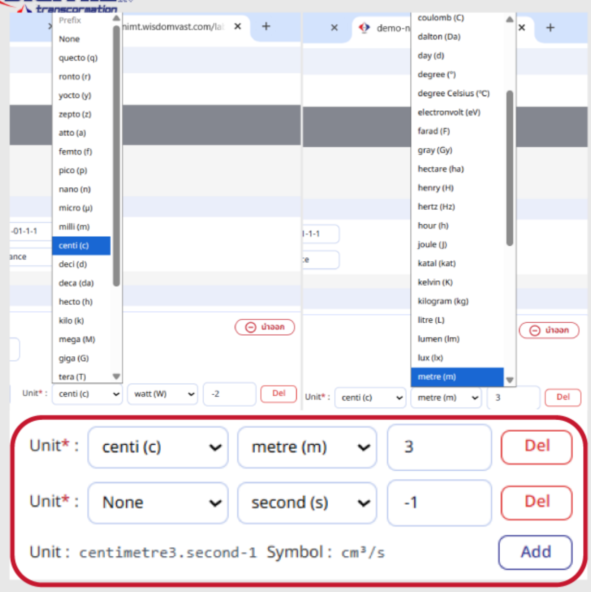


Template for downloading



Most of the administrative data is received from the customer service platform.

5

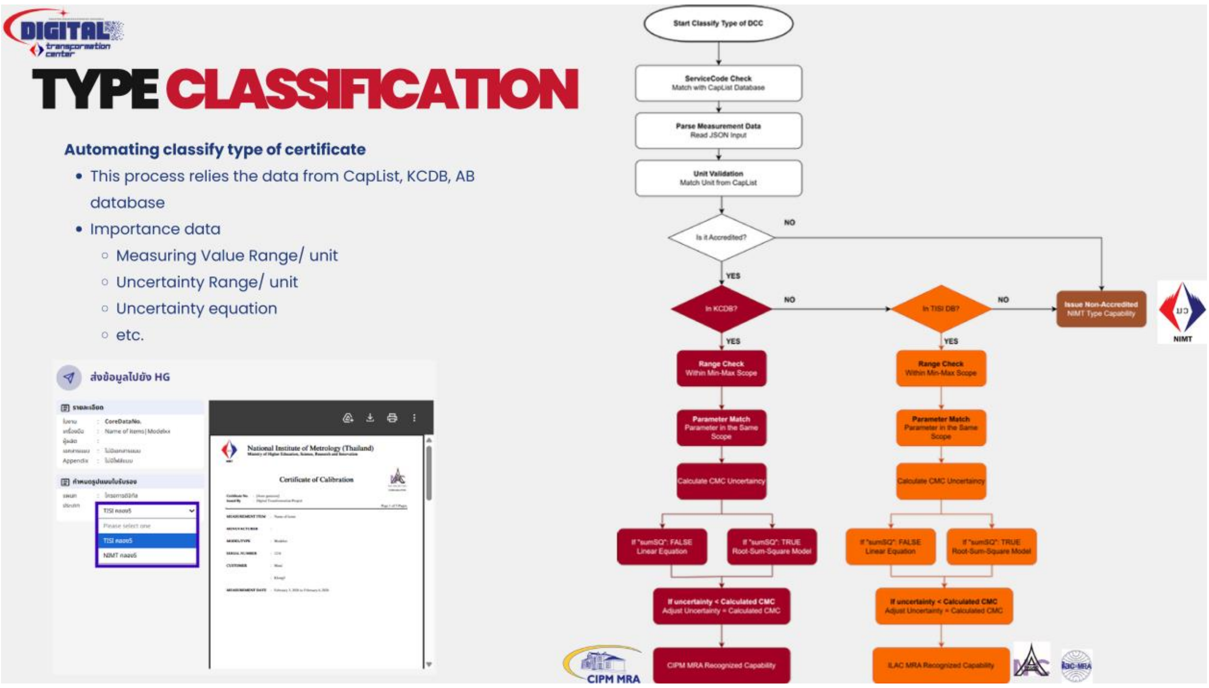


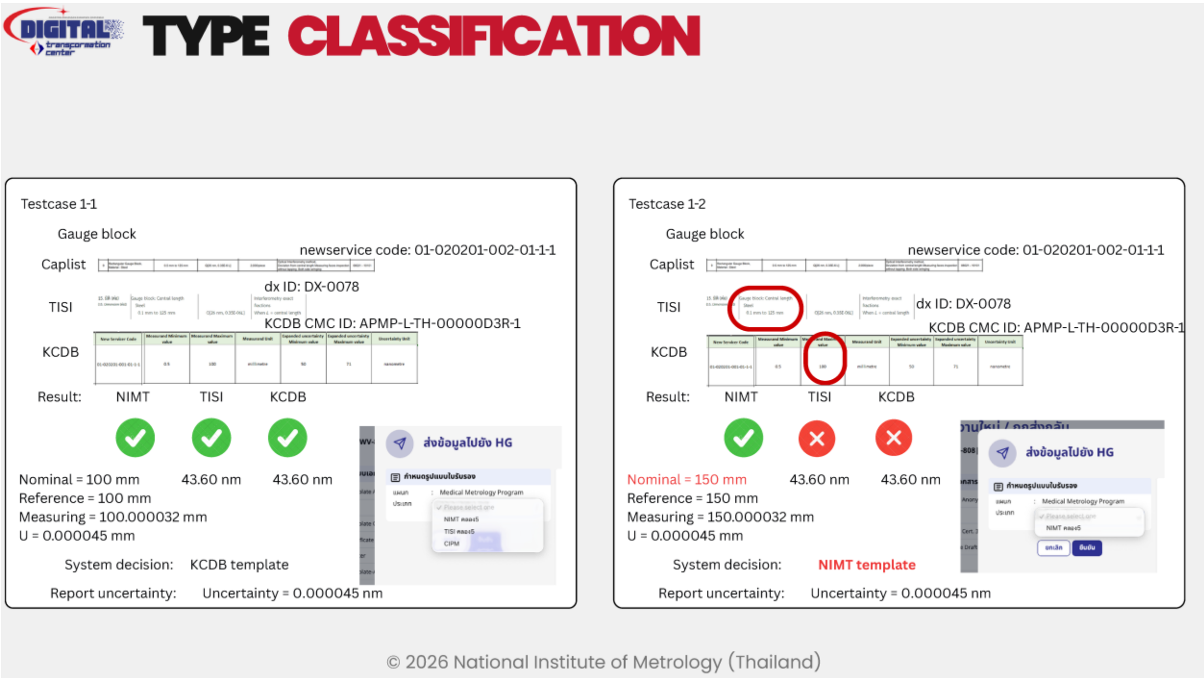
Unit Expreesion

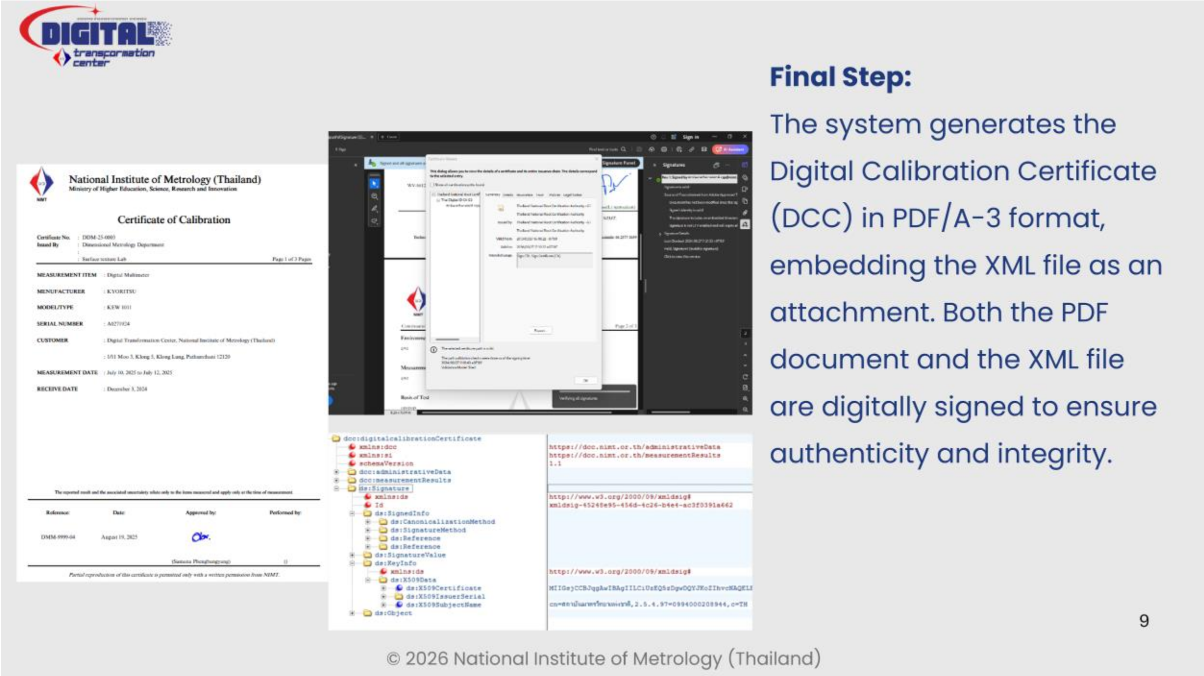
- Default unit display from CapList database
- Design into 3 boxes
  - prefix
  - unit
  - exponent
- Can display in term of symbol

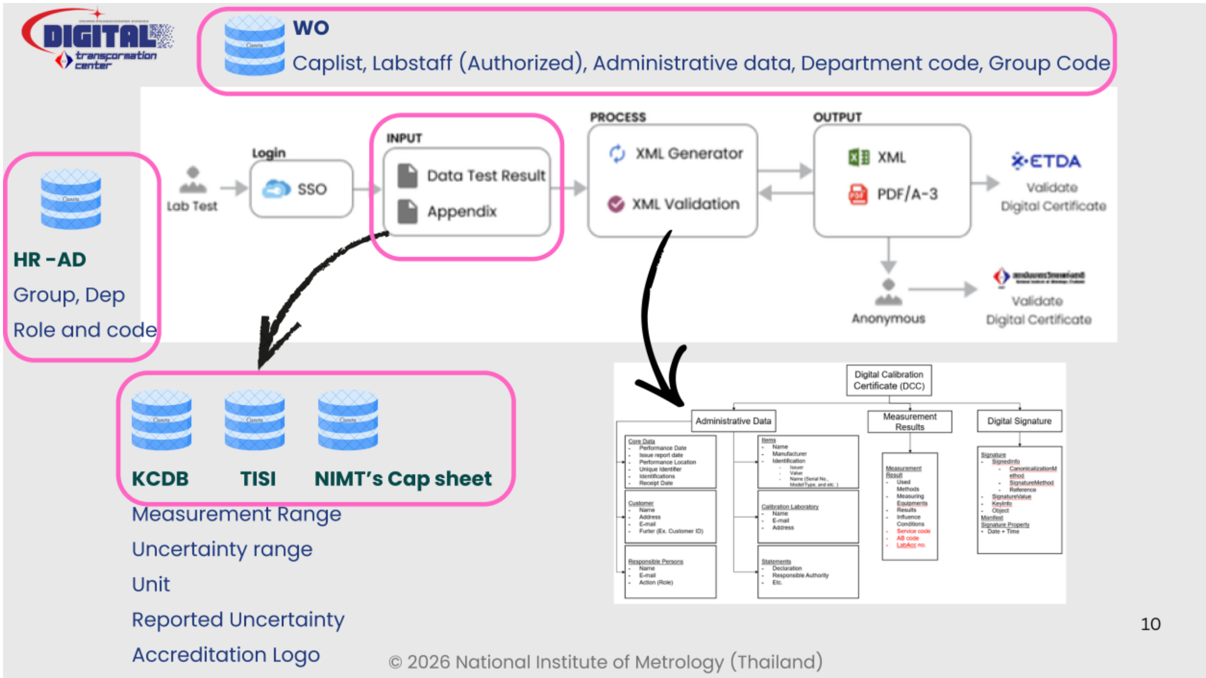
https://si-digital-framework.org/api-docs/swagger-ui/?urls.primaryName=SI%20REFERENCE%20POINT

6


TYPE CLASSIFICATION
Automating classify type of certificate
• This process relies the data from CapList, KCDB, AB database
• Importance data
◦ Measuring Value Range/ unit
◦ Uncertainty Range/ unit
◦ Uncertainty equation
◦ etc.
ส่งข้อมูลไปยัง HG
National Institute of Metrology (Thailand)
Certificate of Calibration
TISI ทดสอบ
NIMT ทดสอบ
Start Classify Type of DCC
ServiceCode Check
Match with CapList Database
Parse Measurement Data
Read JSON Input
Unit Validation
Match Unit from CapList
Is it Accredited?
NO
YES
In KCDB?
In TISI DB?
Issue Non-Accredited
NIMT Type Capability
Range Check
Within Min-Max Scope
Parameter Match
Parameter in the Same Scope
Calculate CMC Uncertainty
If "sumSQ": FALSE
Linear Equation
If "sumSQ": TRUE
Root-Sum-Square Model
If uncertainty < Calculated CMC
Adjust Uncertainty = Calculated CMC
CIPM MRA Recognized Capability
ILAC MRA Recognized Capability
CIPM MRA
NIMT


TYPE CLASSIFICATION
Testcase 1-1
Gauge block
newservice code: 01-020201-002-01-1-1
Caplist
dx ID: DX-0078
TISI
KCDB CMC ID: APMP-L-TH-00000D3R-1
KCDB
Result: NIMT TISI KCDB
Nominal = 100 mm
Reference = 100 mm
Measuring = 100.000032 mm
U = 0.000045 mm
43.60 nm
43.60 nm
System decision: KCDB template
Report uncertainty: Uncertainty = 0.000045 nm
ส่งข้อมูลไปยัง HG
Testcase 1-2
Gauge block
newservice code: 01-020201-002-01-1-1
Caplist
TISI
dx ID: DX-0078
KCDB CMC ID: APMP-L-TH-00000D3R-1
KCDB
Result: NIMT TISI KCDB
Nominal = 150 mm
Reference = 150 mm
Measuring = 150.000032 mm
U = 0.000045 mm
43.60 nm
43.60 nm
System decision: NIMT template
Report uncertainty: Uncertainty = 0.000045 nm
© 2026 National Institute of Metrology (Thailand)





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Day 1 2026-02-24 Tuesday
Parallel Session “DCC Production I”
Session Chair: Carlos Galván

006 Hayati Amalia:
An Initial Step Toward Digital Calibration Certificates (DCC) in SNSU BSN Indonesia: Preliminary Development of a DCC WebBased Application

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Additional authors:

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- Rachelle Stephanie Rianto [2], Siti Maryama Ramadhini Afifah [2]

Institute:
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Keywords: Digital Calibration Certificate, Web-based Application, XML, Digital SI.

Abstract:

The calibration services of Laboratory of National Measurement Standards - National Standardization Agency of Indonesia (SNSU BSN) have relied on PDF-based calibration certificates for more than five years. Although these certificates are digitally signed and distributed through a customer portal, the underlying workflow remains largely manual. Calibration data evaluation is performed using Microsoft Excel, followed by manual conversion to PDF, uploading, and digital signing via the customer portal. This approach limits automation, machine readability, interoperability, and long-term digital reuse of calibration data, which are key requirements for the adoption of Digital Calibration Certificates (DCC).

To address these challenges, SNSU BSN developed a dedicated web-based application for generating DCCs, known as DiCCA (Digital Calibration Certificate Application). The application is designed with a user-friendly interface to ensure accessibility for laboratory staff without programming or XML expertise. As a pilot implementation, the electrical quantity domain was selected, focusing on Digital Multimeter (DMM) calibration.

The system adopts a hybrid data input approach in which calibration result data are entered through predefined Excel templates, while all other certificate information is captured using structured digital forms. The Excel templates are designed to reflect the structure of calibration result tables commonly used in laboratory workflows, allowing users to input measurement values in a familiar spreadsheet environment without manual, item-by-item entry through the application interface. Once uploaded, the templates are automatically processed by the system to extract measurement values and associated units, which are then converted into an XML-based DCC structure using digital SI representations.

The structured digital forms are used to capture all remaining certificate information, including instrument identification, calibration methods, calibration statements, reference standards,

and administrative metadata. To enhance efficiency and consistency, the system provides a pre-filled forms template feature that automatically populates recurring information when generating certificates for the same type of instrument. Users are therefore only required to update instrument-specific details such as serial number, certificate number, and responsible personnel, etc.

The developed application enables laboratory staff to generate DCCs independently while reducing manual steps. The current prototype also supports digital signatures embedded in a QR code, providing an initial mechanism for certificate authenticity verification. However, this digital signature functionality has not yet been integrated with Indonesia's official electronic signature providers (PSrE KOMDIGI). Although the system currently operates independently from the existing customer portal and is limited to DMM calibration, the results demonstrate the practical feasibility of transitioning from PDF-based certificates to DCCs and establish a foundation for future expansion and system integration.

References:

[1] Digital Calibration Certificate (DCC) - Wiki, Digital Calibration Certificate - Wiki (n.d.). https://wiki.dcc.ptb.de/en/home (accessed May 4, 2026).

[2] D. Hutzschenreuter u. a., «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 Edition», Juli 2020, https://zenodo.org/records/3816686

3] SPARTA (2021): Sentra Pelayanan Metrologi Terpadu, [https://sparta.bsn.go.id/] accessed: 10.03.2025

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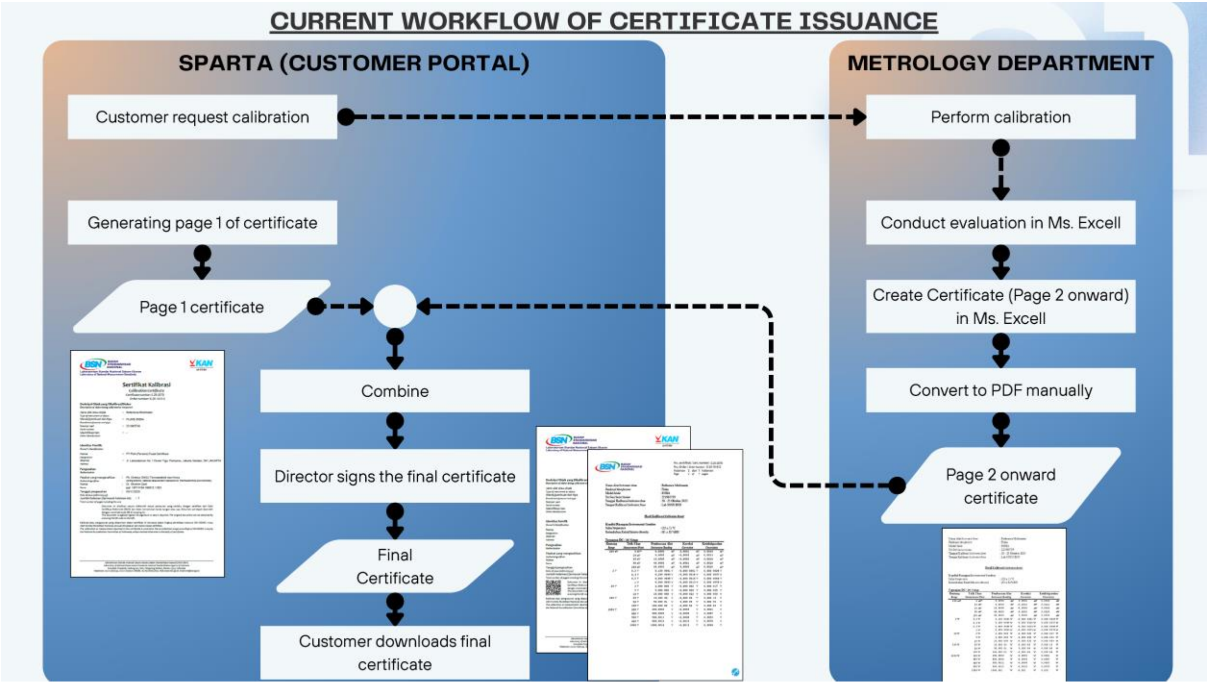
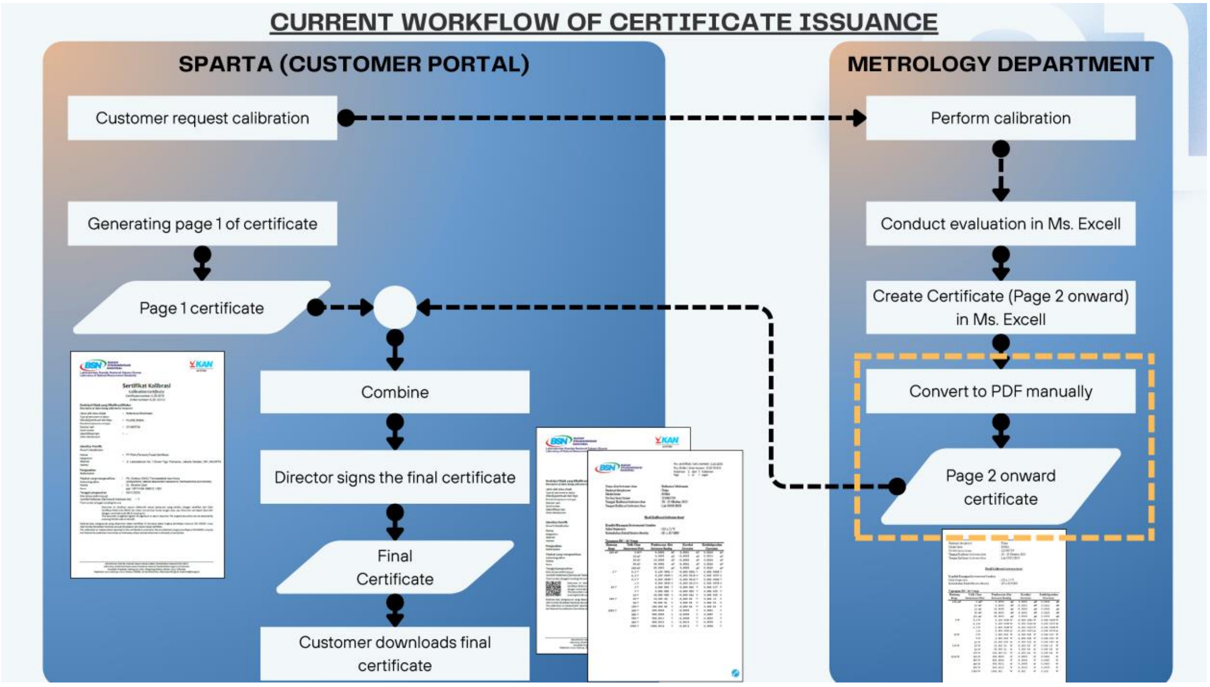
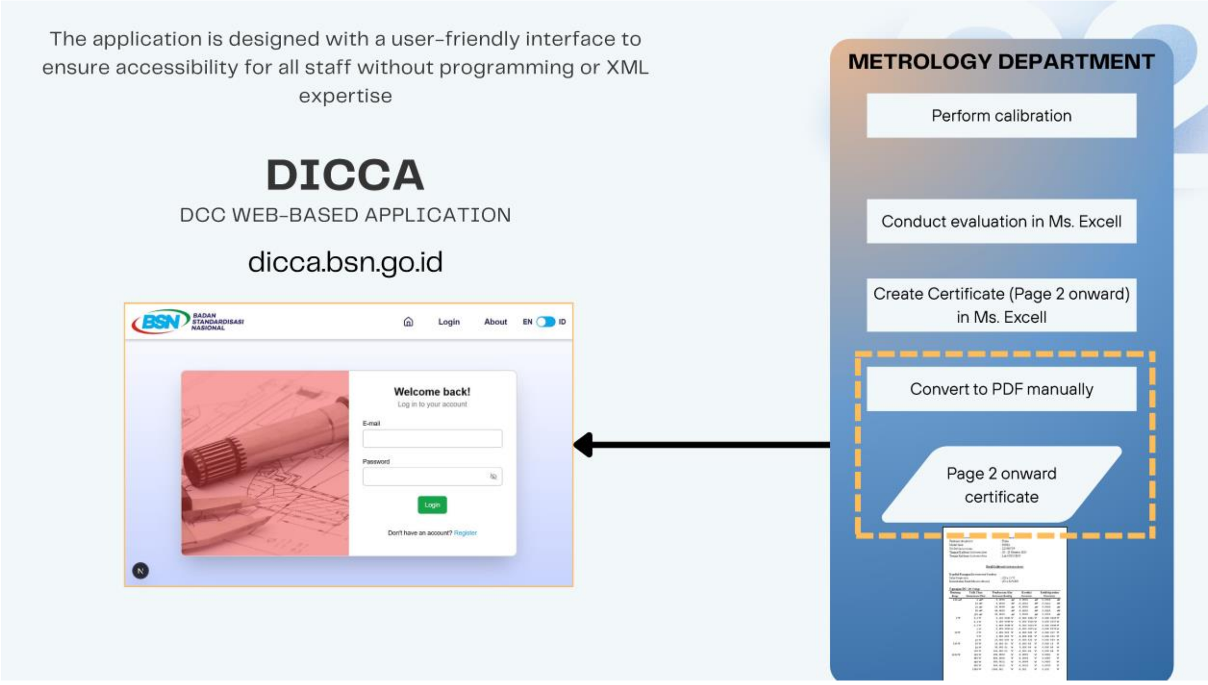
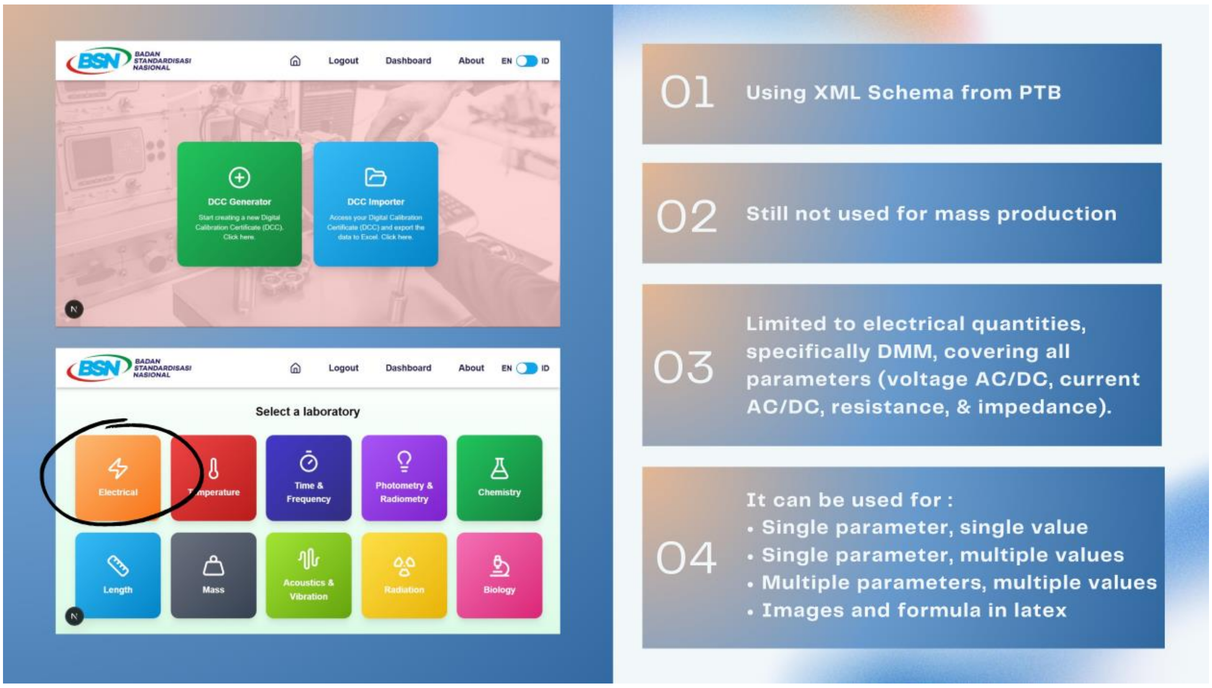
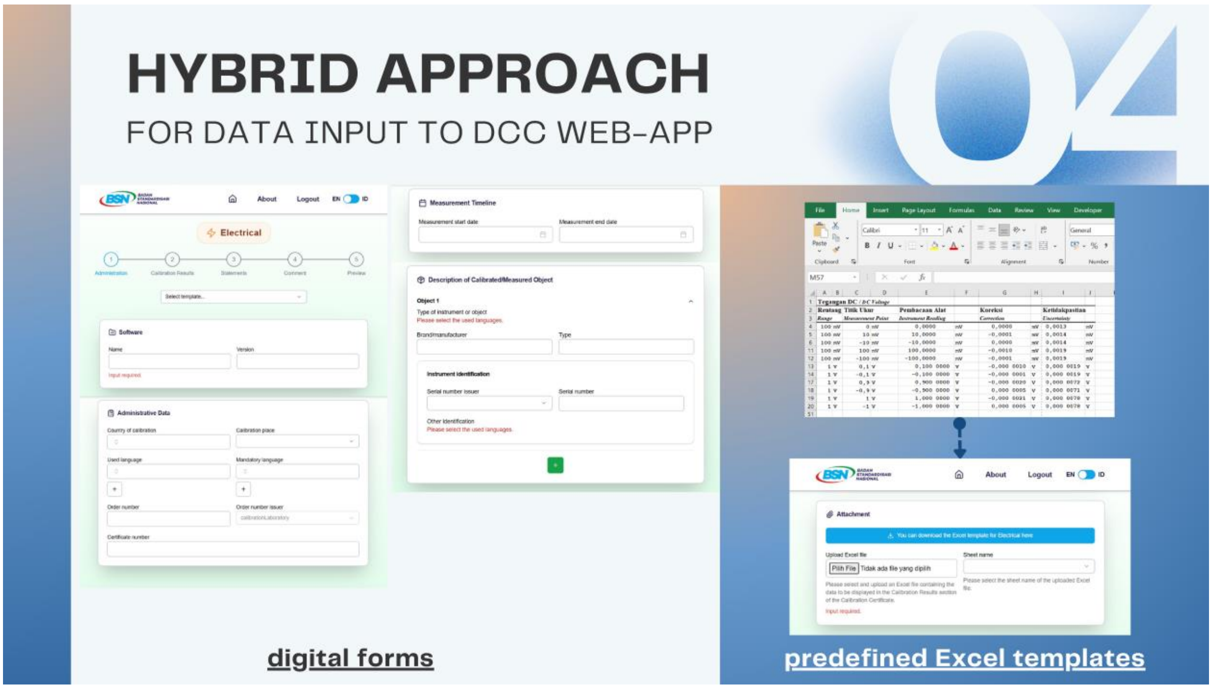
Presentation #006 of Hayati Amalia

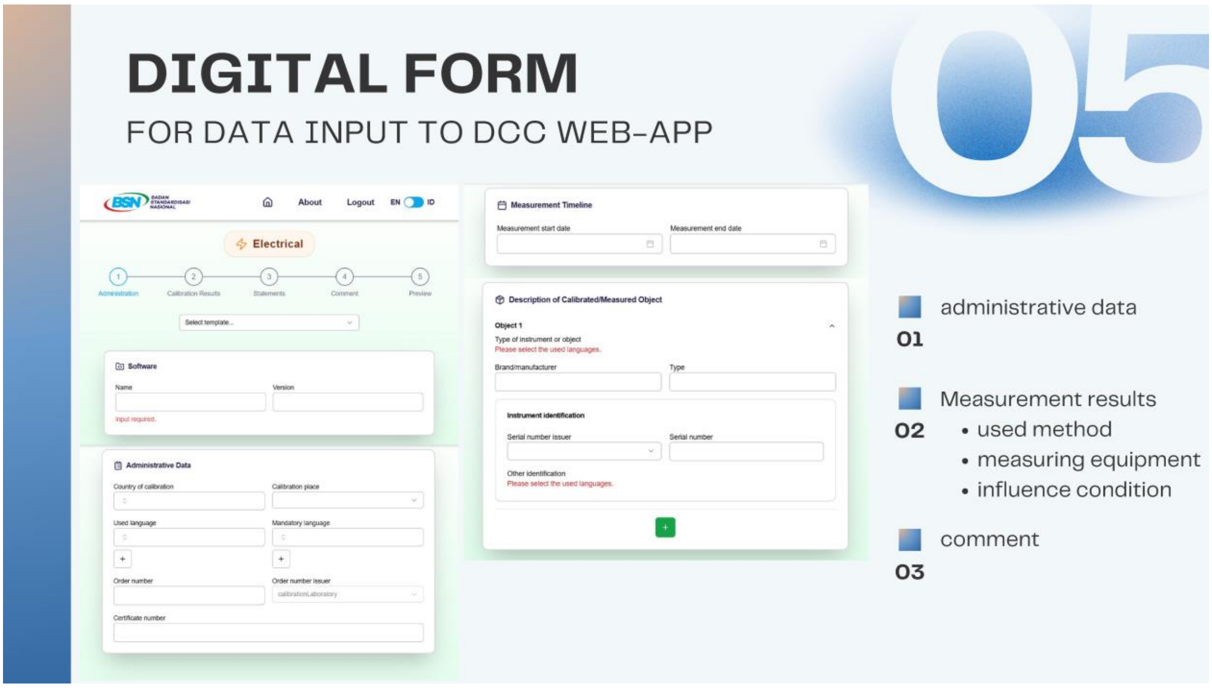

CURRENT WORKFLOW OF CERTIFICATE ISSUANCE
SPARTA (CUSTOMER PORTAL)
METROLOGY DEPARTMENT
Customer request calibration
Perform calibration
Generating page 1 of certificate
Conduct evaluation in Ms. Excell
Page 1 certificate
Create Certificate (Page 2 onward) in Ms. Excell
Combine
Convert to PDF manually
Director signs the final certificate
Page 2 onward certificate
Final Certificate
Customer downloads final certificate

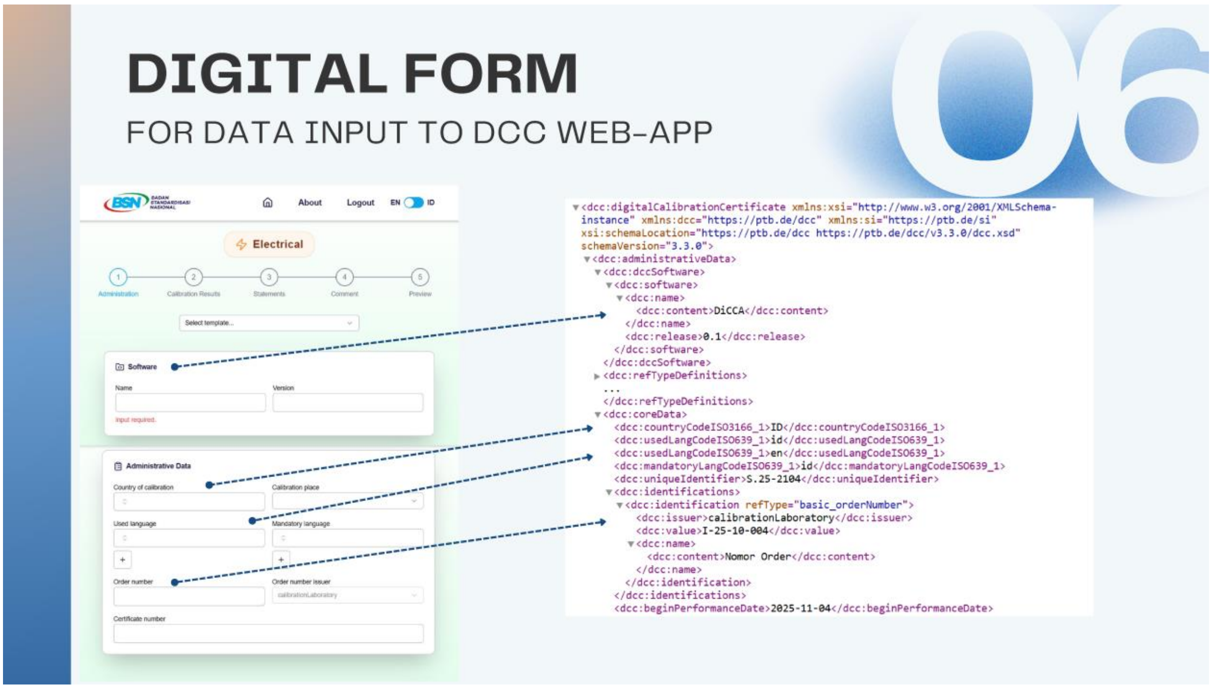

CURRENT WORKFLOW OF CERTIFICATE ISSUANCE
SPARTA (CUSTOMER PORTAL)
METROLOGY DEPARTMENT
Customer request calibration
Perform calibration
Generating page 1 of certificate
Conduct evaluation in Ms. Excell
Page 1 certificate
Create Certificate (Page 2 onward) in Ms. Excell
Combine
Convert to PDF manually
Director signs the final certificate
Page 2 onward certificate
Final Certificate
Customer downloads final certificate

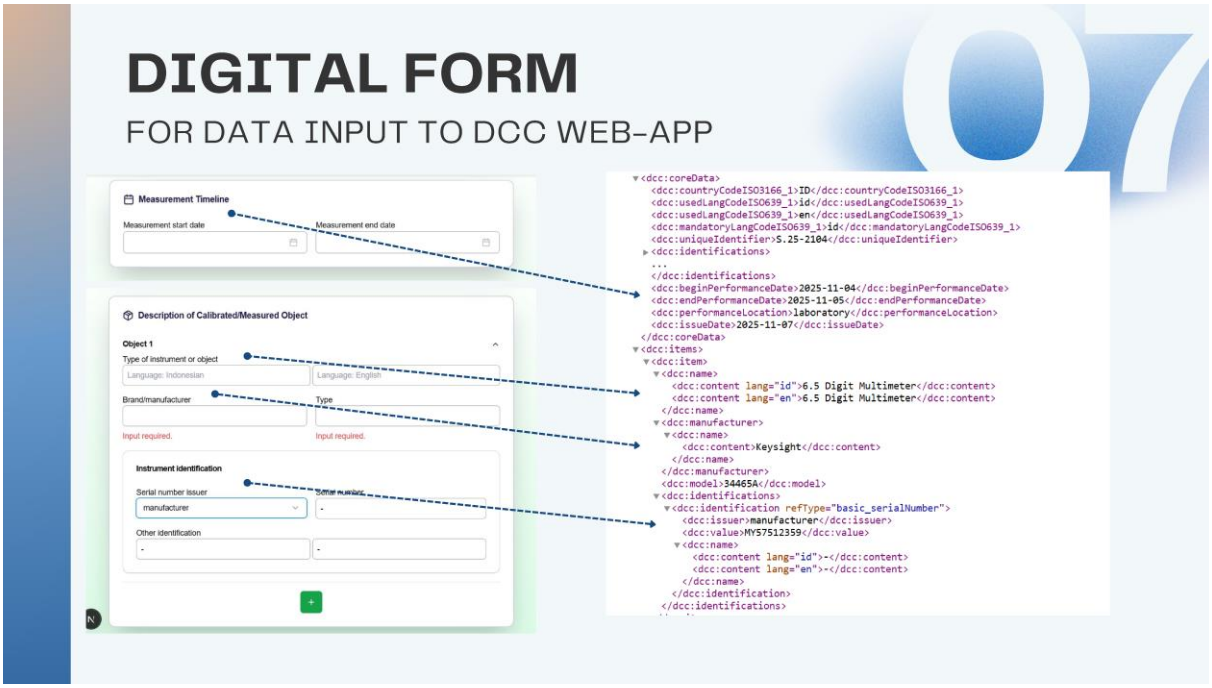

The application is designed with a user-friendly interface to ensure accessibility for all staff without programming or XML expertise
DICCA
DCC WEB-BASED APPLICATION
dicca.bsn.go.id
BSN BADAN STANDARDISASI NASIONAL
Login
About
EN ID
Welcome back!
Log in to your account
E-mail
Password
Login
Don't have an account? Register
METROLOGY DEPARTMENT
Perform calibration
Conduct evaluation in Ms. Excell
Create Certificate (Page 2 onward) in Ms. Excell
Convert to PDF manually
Page 2 onward certificate


BSN BADAN STANDARDISASI NASIONAL
Logout
Dashboard
About
EN ID
DCC Generator
Start creating a new Digital Calibration Certificate (DCC). Click here.
DCC Importer
Access your Digital Calibration Certificate (DCC) and export the data to Excel. Click here.
Select a laboratory
Electrical
Temperature
Time & Frequency
Photometry & Radiometry
Chemistry
Length
Mass
Acoustics & Vibration
Radiation
Biology
01 Using XML Schema from PTB
02 Still not used for mass production
03 Limited to electrical quantities, specifically DMM, covering all parameters (voltage AC/DC, current AC/DC, resistance, & impedance).
04 It can be used for :
• Single parameter, single value
• Single parameter, multiple values
• Multiple parameters, multiple values
• Images and formula in latex


HYBRID APPROACH
FOR DATA INPUT TO DCC WEB-APP
04
digital forms
predefined Excel templates

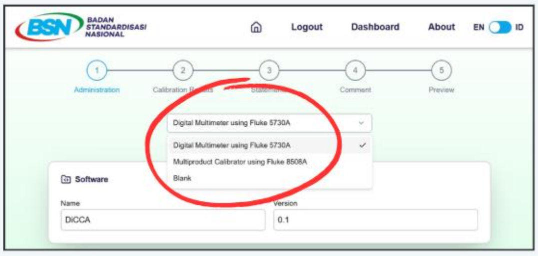

DIGITAL FORM
FOR DATA INPUT TO DCC WEB-APP
05
01 administrative data
02 Measurement results
• used method
• measuring equipment
• influence condition
03 comment


DIGITAL FORM
FOR DATA INPUT TO DCC WEB-APP
06
About
Logout
EN
ID
Electrical
Administration
Calibration Results
Statements
Comment
Preview
Select template...
Software
Name
Version
Input required.
Administrative Data
Country of calibration
Calibration place
Used language
Mandatory language
Order number
Order number issuer
calibrationLaboratory
Certificate number
<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/v3.3.0/dcc.xsd" schemaVersion="3.3.0">
<dcc:administrativeData>
<dcc:dccSoftware>
<dcc:software>
<dcc:name>
<dcc:content>DiCCA</dcc:content>
</dcc:name>
<dcc:release>0.1</dcc:release>
</dcc:software>
</dcc:dccSoftware>
<dcc:refTypeDefinitions>
...
</dcc:refTypeDefinitions>
<dcc:coreData>
<dcc:countryCodeISO3166_1>ID</dcc:countryCodeISO3166_1>
<dcc:usedLangCodeISO639_1>id</dcc:usedLangCodeISO639_1>
<dcc:usedLangCodeISO639_1>en</dcc:usedLangCodeISO639_1>
<dcc:mandatoryLangCodeISO639_1>id</dcc:mandatoryLangCodeISO639_1>
<dcc:uniqueIdentifier>S.25-2104</dcc:uniqueIdentifier>
<dcc:identifications>
<dcc:identification refType="basic_orderNumber">
<dcc:issuer>calibrationLaboratory</dcc:issuer>
<dcc:value>I-25-10-004</dcc:value>
<dcc:name>
<dcc:content>Nomor Order</dcc:content>
</dcc:name>
</dcc:identification>
</dcc:identifications>
<dcc:beginPerformanceDate>2025-11-04</dcc:beginPerformanceDate>


DIGITAL FORM
FOR DATA INPUT TO DCC WEB-APP
07
Measurement Timeline
Measurement start date
Measurement end date
Description of Calibrated/Measured Object
Object 1
Type of instrument or object
Language: Indonesian
Language: English
Brand/manufacturer
Type
Input required.
Input required.
Instrument identification
Serial number issuer
Serial number
manufacturer
Other identification
<dcc:coreData>
<dcc:countryCodeISO3166_1>ID</dcc:countryCodeISO3166_1>
<dcc:usedLangCodeISO639_1>id</dcc:usedLangCodeISO639_1>
<dcc:usedLangCodeISO639_1>en</dcc:usedLangCodeISO639_1>
<dcc:mandatoryLangCodeISO639_1>id</dcc:mandatoryLangCodeISO639_1>
<dcc:uniqueIdentifier>S.25-2104</dcc:uniqueIdentifier>
<dcc:identifications>
...
</dcc:identifications>
<dcc:beginPerformanceDate>2025-11-04</dcc:beginPerformanceDate>
<dcc:endPerformanceDate>2025-11-05</dcc:endPerformanceDate>
<dcc:performanceLocation>laboratory</dcc:performanceLocation>
<dcc:issueDate>2025-11-07</dcc:issueDate>
</dcc:coreData>
<dcc:items>
<dcc:item>
<dcc:name>
<dcc:content lang="id">6.5 Digit Multimeter</dcc:content>
<dcc:content lang="en">6.5 Digit Multimeter</dcc:content>
</dcc:name>
<dcc:manufacturer>
<dcc:name>
<dcc:content>Keysight</dcc:content>
</dcc:name>
</dcc:manufacturer>
<dcc:identifications>
<dcc:identification refType="basic_serialNumber">
<dcc:issuer>manufacturer</dcc:issuer>
<dcc:value>MY57512359</dcc:value>
<dcc:name>
<dcc:content lang="id">-</dcc:content>
<dcc:content lang="en">-</dcc:content>
</dcc:name>
</dcc:identification>
</dcc:identifications>

DIGITAL FORM

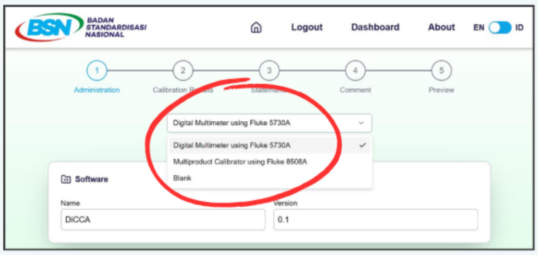
PRE-FILLED FORMS TEMPLATE



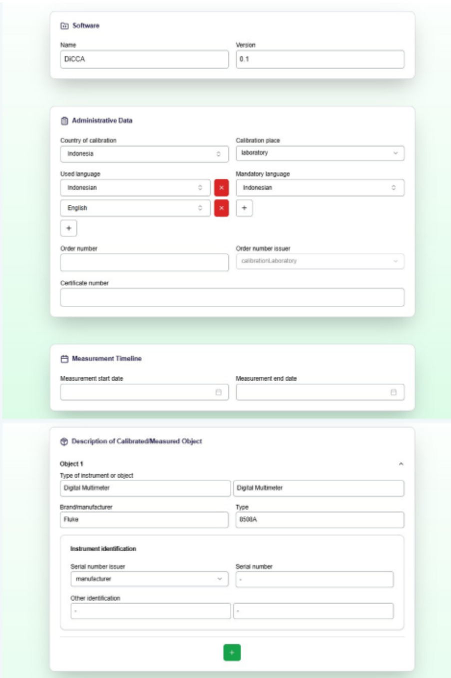
- A feature that automatically populates recurring information when generating certificates for the same type of instrument
- Users are only required to update instrument-specific details such as serial number, certificate number, and responsible personnel, etc.

DIGITAL FORM

PRE-FILLED FORMS TEMPLATE

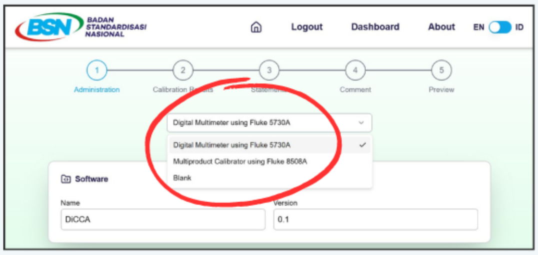


- A feature that automatically populates recurring information when generating certificates for the same type of instrument
- Users are only required to update instrument-specific details such as serial number, certificate number, and responsible personnel, etc.

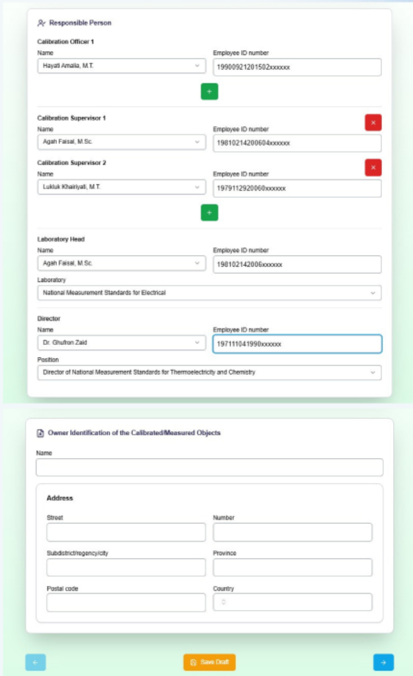


DIGITAL FORM

PRE-FILLED FORMS TEMPLATE

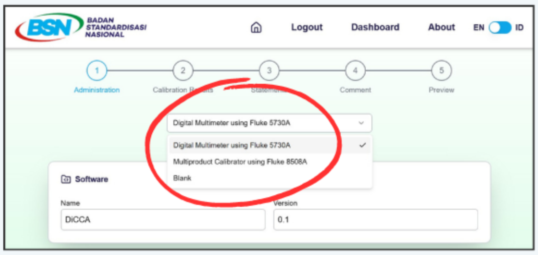


- A feature that automatically populates recurring information when generating certificates for the same type of instrument
- Users are only required to update instrument-specific details such as serial number, certificate number, and responsible personnel, etc.

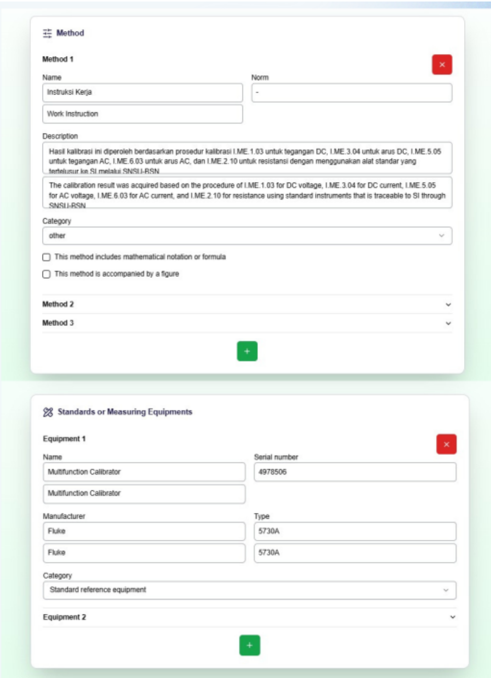


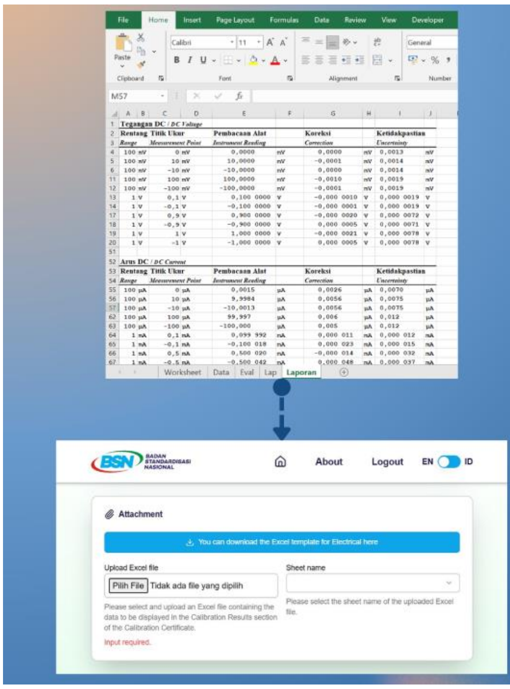
DIGITAL FORM

PRE-FILLED FORMS TEMPLATE



- A feature that automatically populates recurring information when generating certificates for the same type of instrument
- Users are only required to update instrument-specific details such as serial number, certificate number, and responsible personnel, etc.





PRE-DEFINED EXCEL TEMPLATES

FOR DATA INPUT TO DCC WEB-APP

Measurement results

01 • result - data

CHALLENGE

Too many measurement points → manual typing is not effective

SOLUTION

Calibration result template (MS Excel) + upload to DCC system

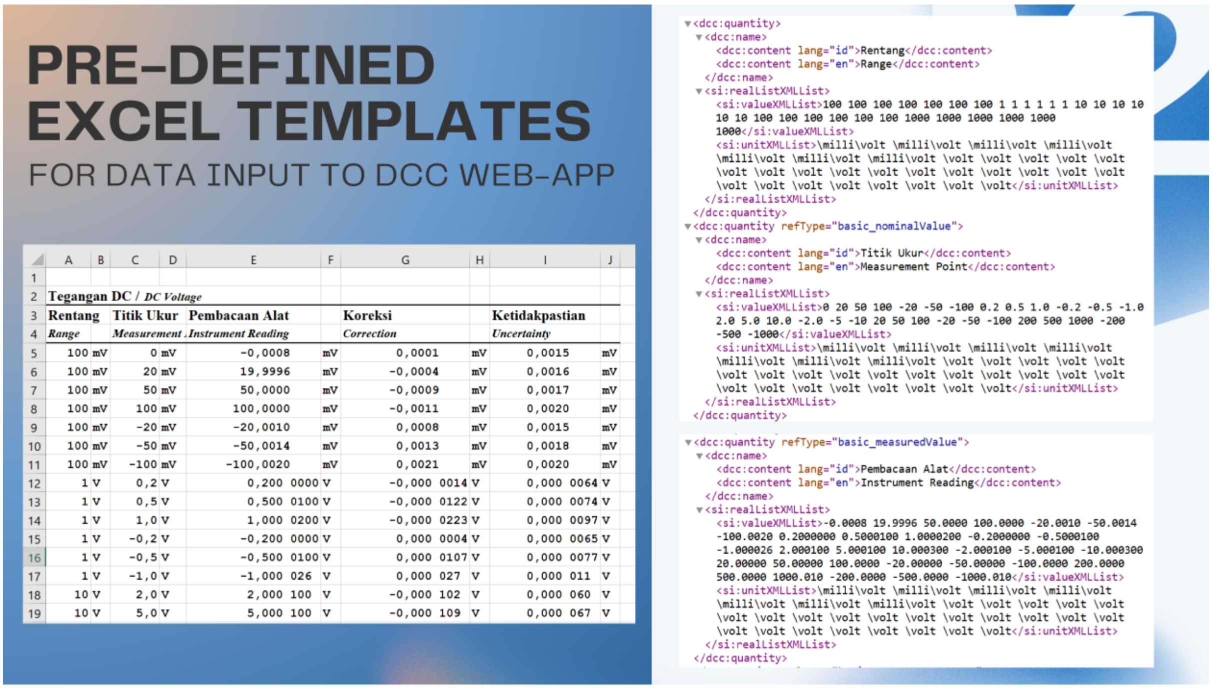
PRE-DEFINED EXCEL TEMPLATES

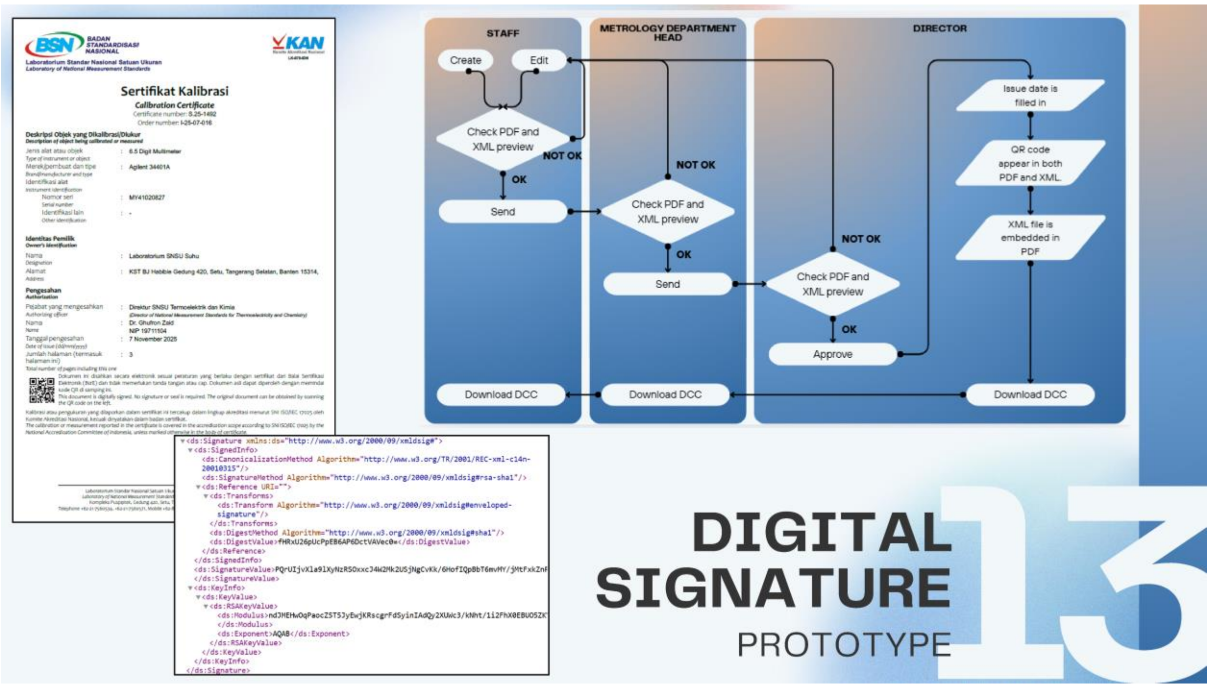
FOR DATA INPUT TO DCC WEB-APP

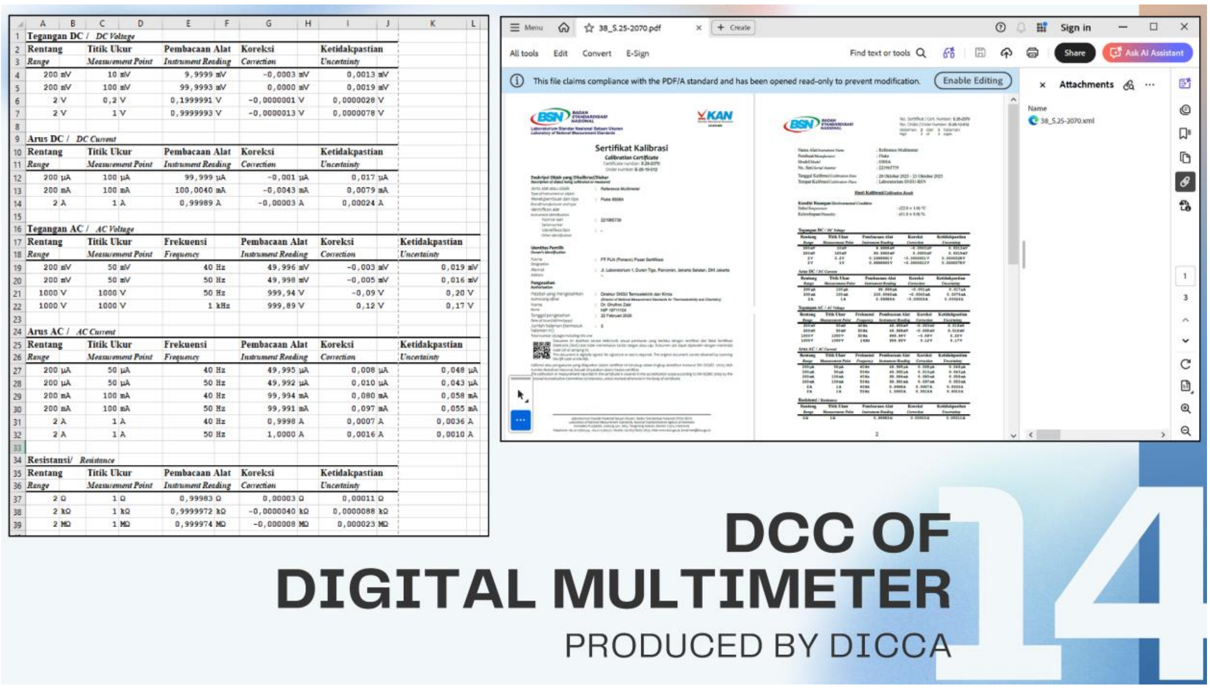
	A	B	C	D	E	F	G	H	I	J
1										
2	**Tegangan DC** / *DC Voltage*									
3	**Rentang**		**Titik Ukur**		**Pembacaan Alat**		**Koreksi**		**Ketidakpastian**	
4	*Range*		*Measurement*		*Instrument Reading*		*Correction*		*Uncertainty*	
5	100	mV	0	mV	-0,0008	mV	0,0001	mV	0,0015	mV
6	100	mV	20	mV	19,9996	mV	-0,0004	mV	0,0016	mV
7	100	mV	50	mV	50,0000	mV	-0,0009	mV	0,0017	mV
8	100	mV	100	mV	100,0000	mV	-0,0011	mV	0,0020	mV
9	100	mV	-20	mV	-20,0010	mV	0,0008	mV	0,0015	mV
10	100	mV	-50	mV	-50,0014	mV	0,0013	mV	0,0018	mV
11	100	mV	-100	mV	-100,0020	mV	0,0021	mV	0,0020	mV
12	1	V	0,2	V	0,200 0000	V	-0,000 0014	V	0,000 0064	V
13	1	V	0,5	V	0,500 0100	V	-0,000 0122	V	0,000 0074	V
14	1	V	1,0	V	1,000 0200	V	-0,000 0223	V	0,000 0097	V
15	1	V	-0,2	V	-0,200 0000	V	0,000 0004	V	0,000 0065	V
16	1	V	-0,5	V	-0,500 0100	V	0,000 0107	V	0,000 0077	V
17	1	V	-1,0	V	-1,000 026	V	0,000 027	V	0,000 011	V
18	10	V	2,0	V	2,000 100	V	-0,000 102	V	0,000 060	V
19	10	V	5,0	V	5,000 100	V	-0,000 109	V	0,000 067	V

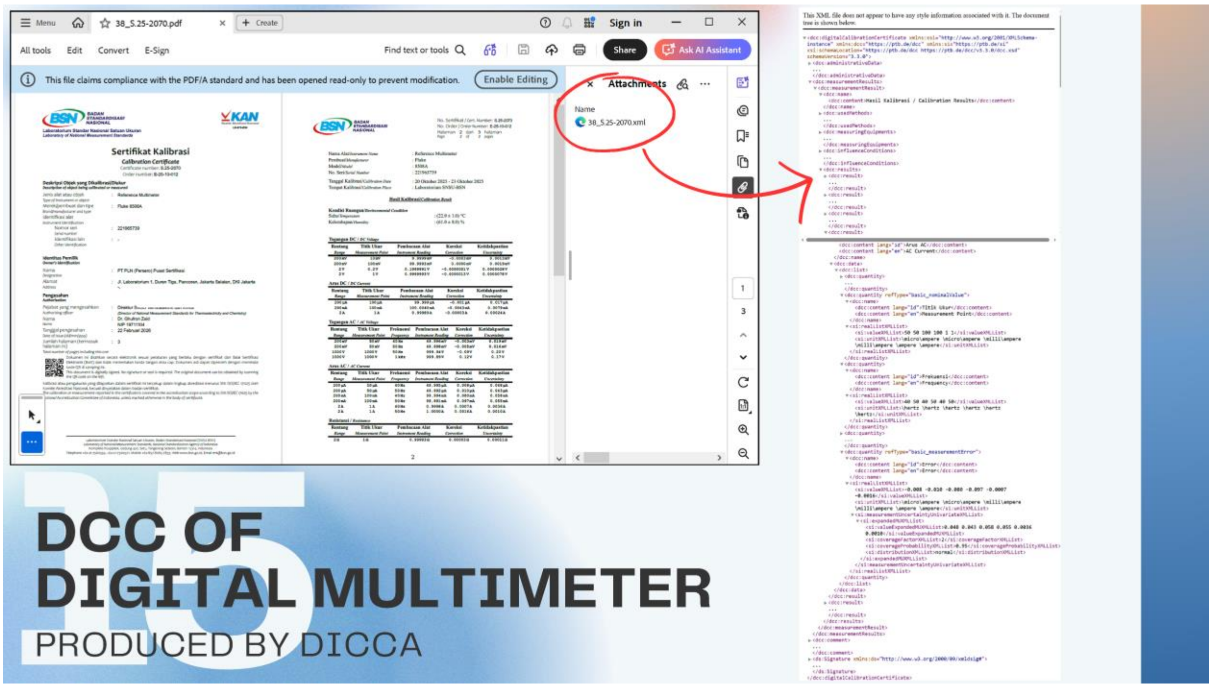
RULE OF EXCELL TEMPLATE

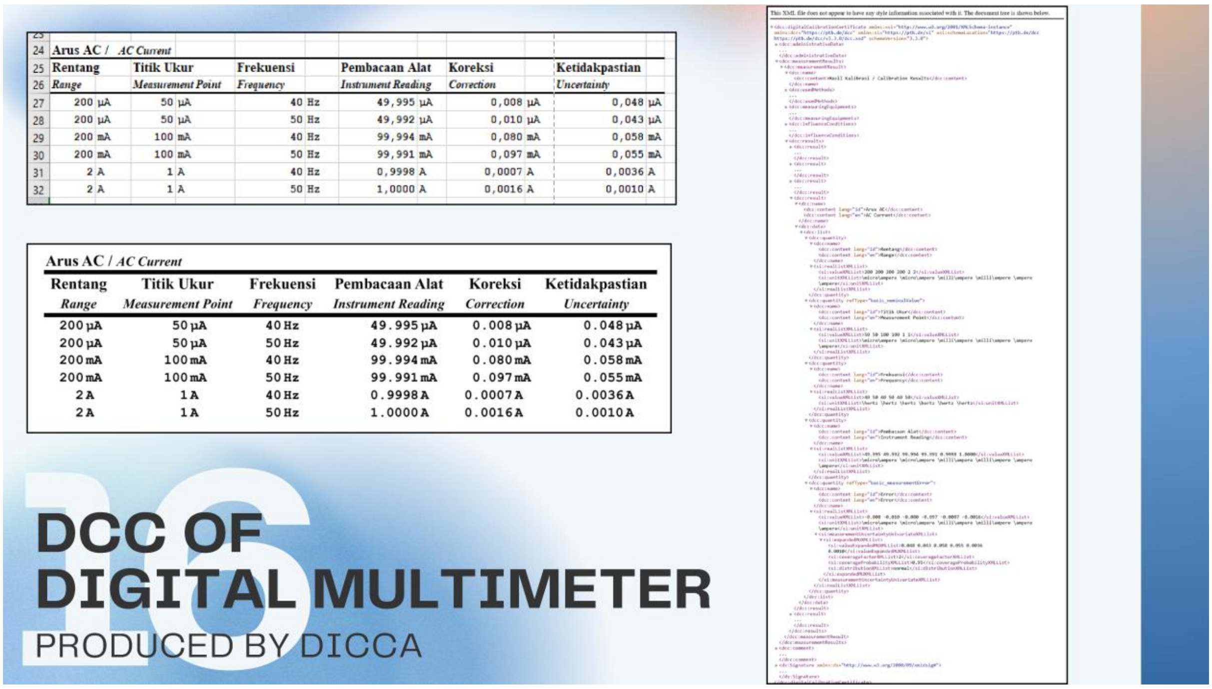
1. Any Excel file format may be used : it may either be combined with the calibration data evaluation Excel file or prepared as a separate Excel file
2. No merged cell
3. The unit shall be placed in the column directly next to the numerical value column
4. There shall be no intervening column between the data value and its unit
5. No blank column is allowed between each data categories.
6. No blank rows are allowed within the table.


PRE-DEFINED
EXCEL TEMPLATES
FOR DATA INPUT TO DCC WEB-APP
Tegangan DC / DC Voltage
Rentang | Titik Ukur | Pembacaan Alat | Koreksi | Ketidakpastian
Range | Measurement | Instrument Reading | Correction | Uncertainty
100 mV | 0 mV | -0,0008 mV | 0,0001 mV | 0,0015 mV
100 mV | 20 mV | 19,9996 mV | -0,0004 mV | 0,0016 mV
100 mV | 50 mV | 50,0000 mV | -0,0009 mV | 0,0017 mV
100 mV | 100 mV | 100,0000 mV | -0,0011 mV | 0,0020 mV
100 mV | -20 mV | -20,0010 mV | 0,0008 mV | 0,0015 mV
100 mV | -50 mV | -50,0014 mV | 0,0013 mV | 0,0018 mV
100 mV | -100 mV | -100,0020 mV | 0,0021 mV | 0,0020 mV
1 V | 0,2 V | 0,200 0000 V | -0,000 0014 V | 0,000 0064 V
1 V | 0,5 V | 0,500 0100 V | -0,000 0122 V | 0,000 0074 V
1 V | 1,0 V | 1,000 0200 V | -0,000 0223 V | 0,000 0097 V
1 V | -0,2 V | -0,200 0000 V | 0,000 0004 V | 0,000 0065 V
1 V | -0,5 V | -0,500 0100 V | 0,000 0107 V | 0,000 0077 V
1 V | -1,0 V | -1,000 026 V | 0,000 027 V | 0,000 011 V
10 V | 2,0 V | 2,000 100 V | -0,000 102 V | 0,000 060 V
10 V | 5,0 V | 5,000 100 V | -0,000 109 V | 0,000 067 V


Sertifikat Kalibrasi
Calibration Certificate
STAFF
Create
Edit
Check PDF and XML preview
NOT OK
OK
Send
Download DCC
METROLOGY DEPARTMENT HEAD
NOT OK
Check PDF and XML preview
OK
Send
Download DCC
DIRECTOR
Issue date is filled in
QR code appear in both PDF and XML
XML file is embedded in PDF
NOT OK
Check PDF and XML preview
OK
Approve
Download DCC
DIGITAL
SIGNATURE
PROTOTYPE
13


This file claims compliance with the PDF/A standard and has been opened read-only to prevent modification.
Enable Editing
Attachments
Sertifikat Kalibrasi
Calibration Certificate
DCC OF
DIGITAL MULTIMETER
PRODUCED BY DICCA
14


This file claims compliance with the PDF/A standard and has been opened read-only to prevent modification.
Enable Editing
Attachments
Sertifikat Kalibrasi
DCC OF
DIGITAL MULTIMETER
PRODUCED BY DICCA
15



	Arus AC / *AC Current*					
25	Rentang	Titik Ukur	Frekuensi	Pembacaan Alat	Koreksi	Ketidakpastian
26	*Range*	*Measurement Point*	*Frequency*	*Instrument Reading*	*Correction*	*Uncertainty*
27	200 µA	50 µA	40 Hz	49,995 µA	0,008 µA	0,048 µA
28	200 µA	50 µA	50 Hz	49,992 µA	0,010 µA	0,043 µA
29	200 mA	100 mA	40 Hz	99,994 mA	0,080 mA	0,058 mA
30	200 mA	100 mA	50 Hz	99,991 mA	0,097 mA	0,055 mA
31	2 A	1 A	40 Hz	0,9998 A	0,0007 A	0,0036 A
32	2 A	1 A	50 Hz	1,0000 A	0,0016 A	0,0010 A

Arus AC / *AC Current*

Rentang *Range*	Titik Ukur *Measurement Point*	Frekuensi *Frequency*	Pembacaan Alat *Instrument Reading*	Koreksi *Correction*	Ketidakpastian *Uncertainty*
200 µA	50 µA	40 Hz	49.995 µA	0.008 µA	0.048 µA
200 µA	50 µA	50 Hz	49.992 µA	0.010 µA	0.043 µA
200 mA	100 mA	40 Hz	99.994 mA	0.080 mA	0.058 mA
200 mA	100 mA	50 Hz	99.991 mA	0.097 mA	0.055 mA
2 A	1 A	40 Hz	0.9998 A	0.0007 A	0.0036 A
2 A	1 A	50 Hz	1.0000 A	0.0016 A	0.0010 A

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007 Akhmadbek Mukhammad Aminov: Application of digital calibration certificates for acoustic calibrators

Presenting author: Akhmadbek Mukhammad Aminov [1]
Email: m.axmadbek@nim.uz
Additional authors: Nil
Institute:
[1] Acoustics, ultrasound and vibration laboratory; Measurement of radio engineering quantities and ionization radiation, non-destructive testing department Uzbek National Institute of Metrology/ Farabi street 333 A and B, Tashkent, 100174, Uzbekistan
Keywords: DCC, acoustic calibrator, digital transformation

Abstract

Currently, digital transformation is rapidly developing in the field of metrology. At the same time, the application of digital calibration certificates (DCC), which are an element of digital transformation, in the branches of metrology is one of the pressing issues of today.

The purpose of this research is the application of digital calibration certificates for acoustic calibrators.

In this research, a function for generating a digital calibration certificate is added to the semi-automatic system which is developed for calibrating acoustic calibrators by the comparison method according to the international standard IEC 60942. This function automatically generates digital calibration certificates for acoustic calibrators based on PTB’s DCC 3.0 schema. Developed system successfully automates the data transfer from the measurement information to the machine-readable format that encapsulates all necessary metrological traceability information and measurement uncertainties specific to acoustic parameters. Research work provides the popularization of digital calibration certificates in the field of acoustics in the international metrological community. It also develops the standardization and harmonization of digital calibration certificates. It is analysed how beneficial this development would be for users of acoustic calibrators.

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Presentation #007 of Akhmadbek Mukhammad Aminov

O'ZBEKISTON MILLIY METROLOGIYA INSTITUTI

Application of digital calibration certificates for acoustic calibrators

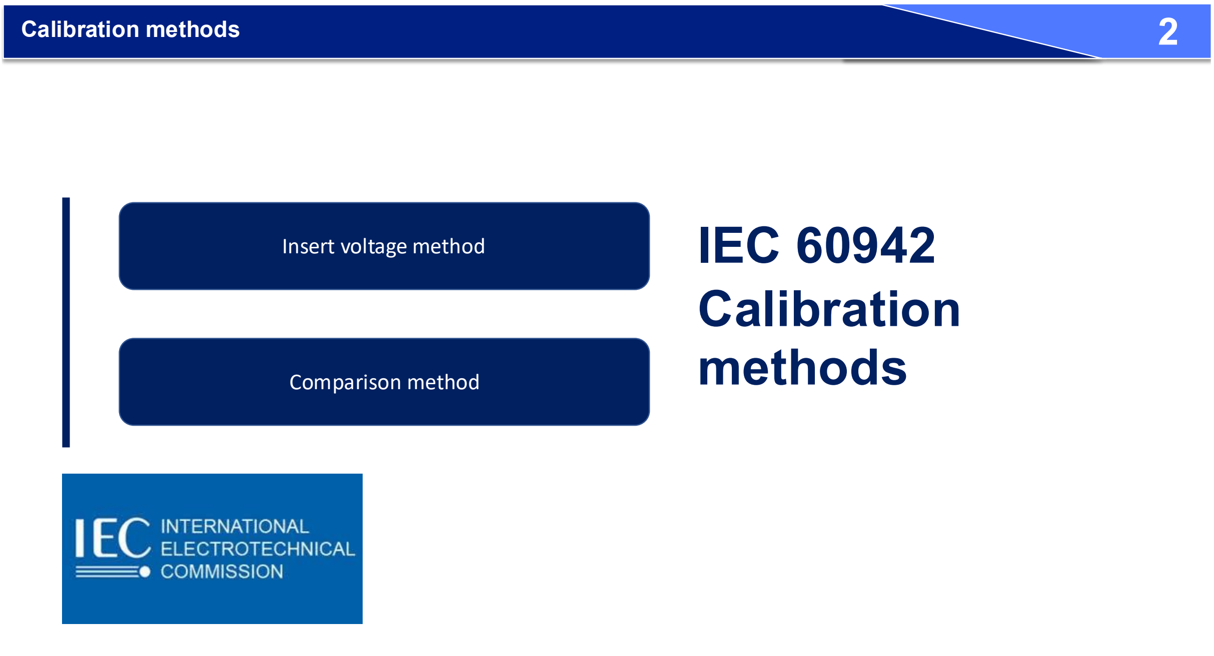
6th INTERNATIONAL DCC CONFERENCE

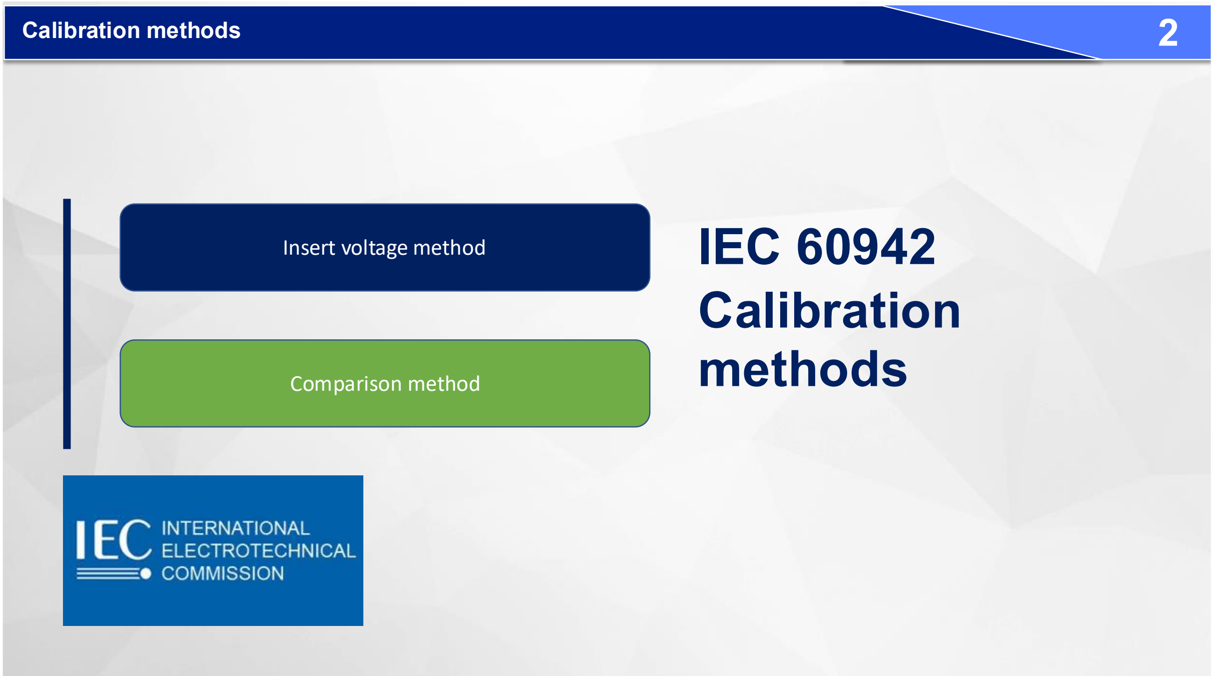
FROM GOOD PRACTICE TO STANDARDIZATION: DCC FOR A RELIABLE FUTURE

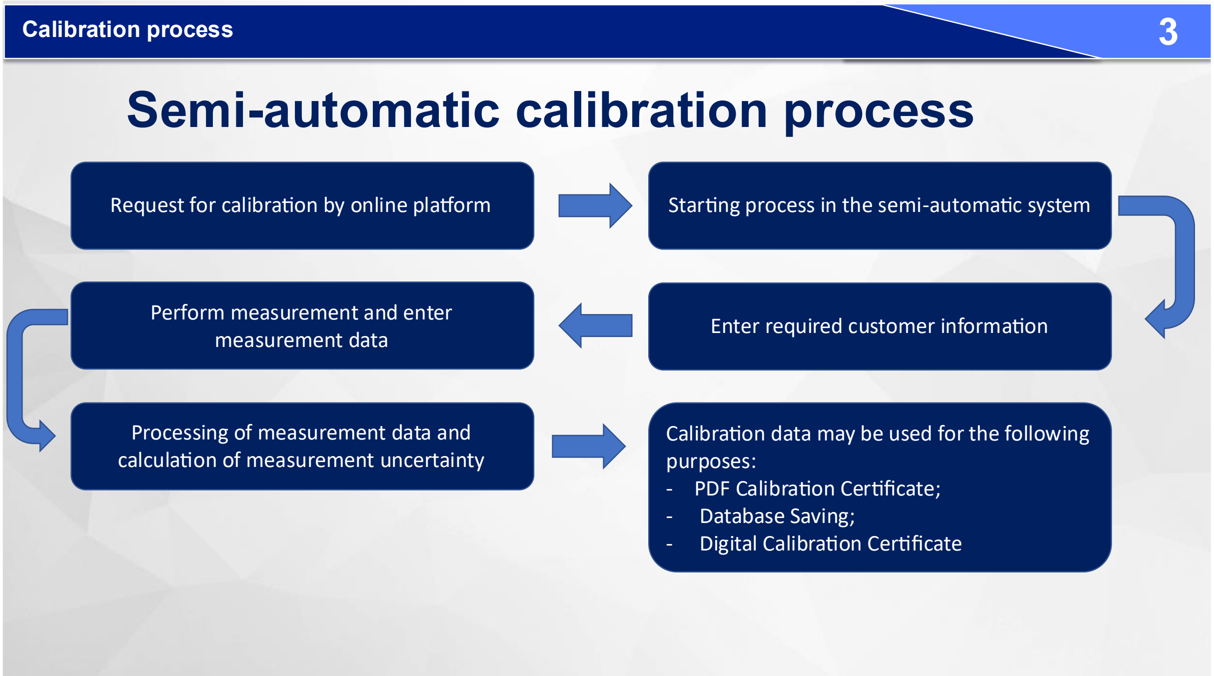
Akhmadbek Mukhammad Aminov
"UzNIM" SI standard keeper of AUV laboratory

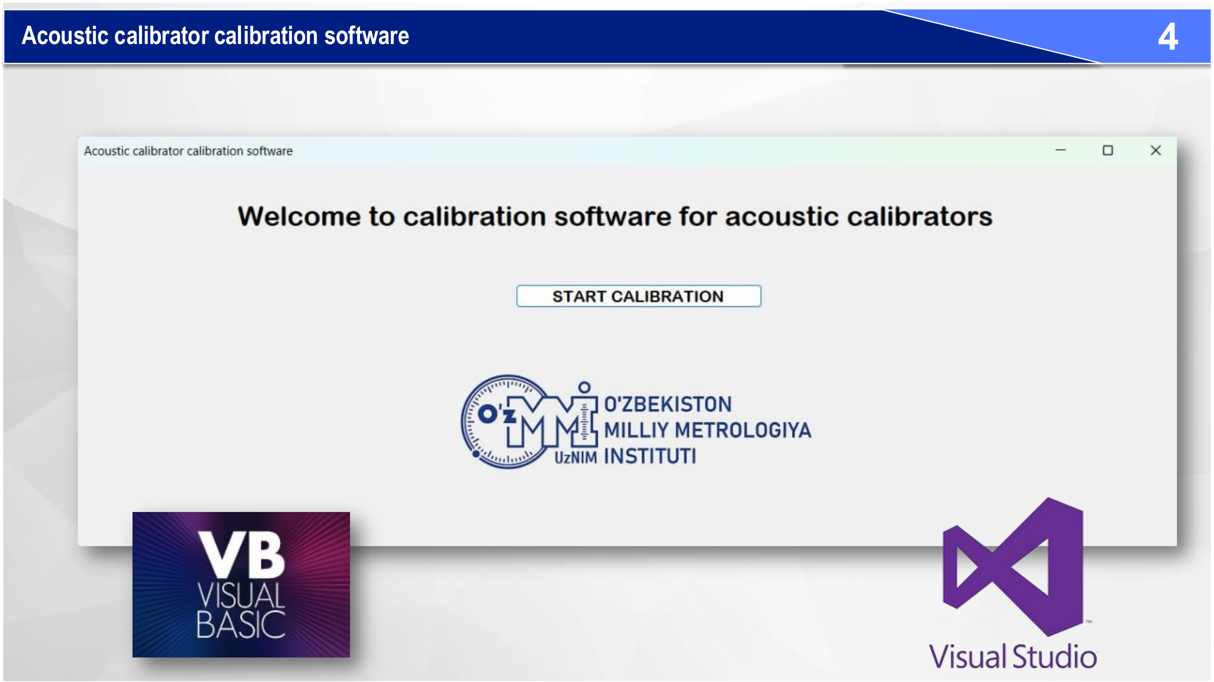
What purposes are acoustic calibrators used for? 1

- Calibration of sound level
- To ensure the reliability of measurements periodically
- Adjusting measurements

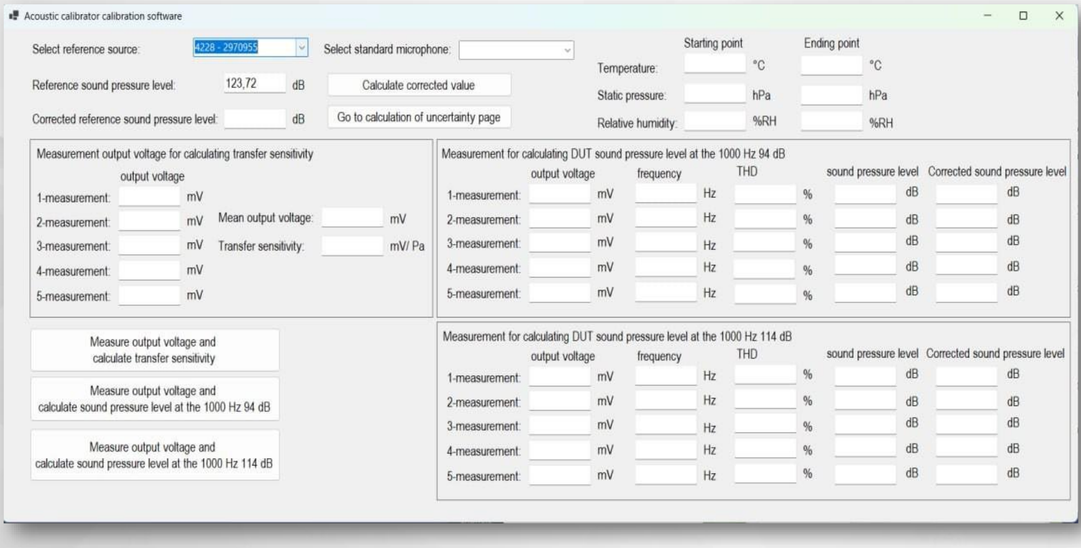

Calibration methods
2
Insert voltage method
Comparison method
IEC 60942
Calibration
methods
IEC INTERNATIONAL
ELECTROTECHNICAL
COMMISSION


Calibration methods
2
Insert voltage method
Comparison method
IEC 60942
Calibration
methods
IEC INTERNATIONAL
ELECTROTECHNICAL
COMMISSION


Calibration process
3
Semi-automatic calibration process
Request for calibration by online platform
Starting process in the semi-automatic system
Enter required customer information
Perform measurement and enter measurement data
Processing of measurement data and calculation of measurement uncertainty
Calibration data may be used for the following purposes:
- PDF Calibration Certificate;
- Database Saving;
- Digital Calibration Certificate


Acoustic calibrator calibration software
4
Acoustic calibrator calibration software
Welcome to calibration software for acoustic calibrators
START CALIBRATION
O'ZBEKISTON
MILLIY METROLOGIYA
UzNIM INSTITUTI
VB
VISUAL
BASIC
Visual Studio

Acoustic calibrator calibration software 5



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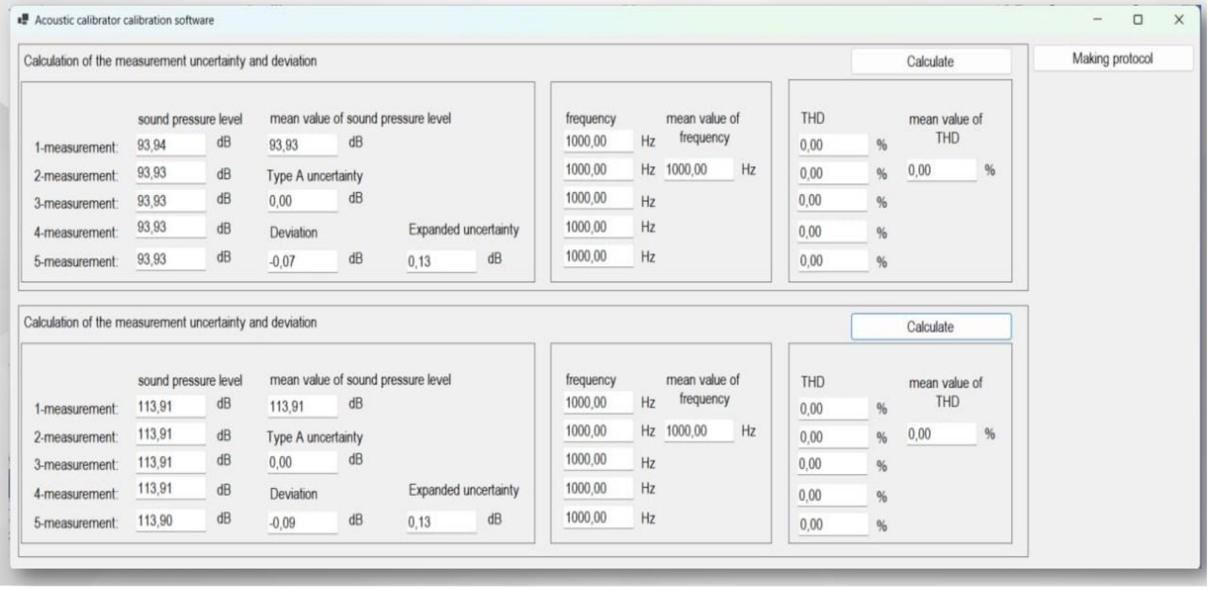
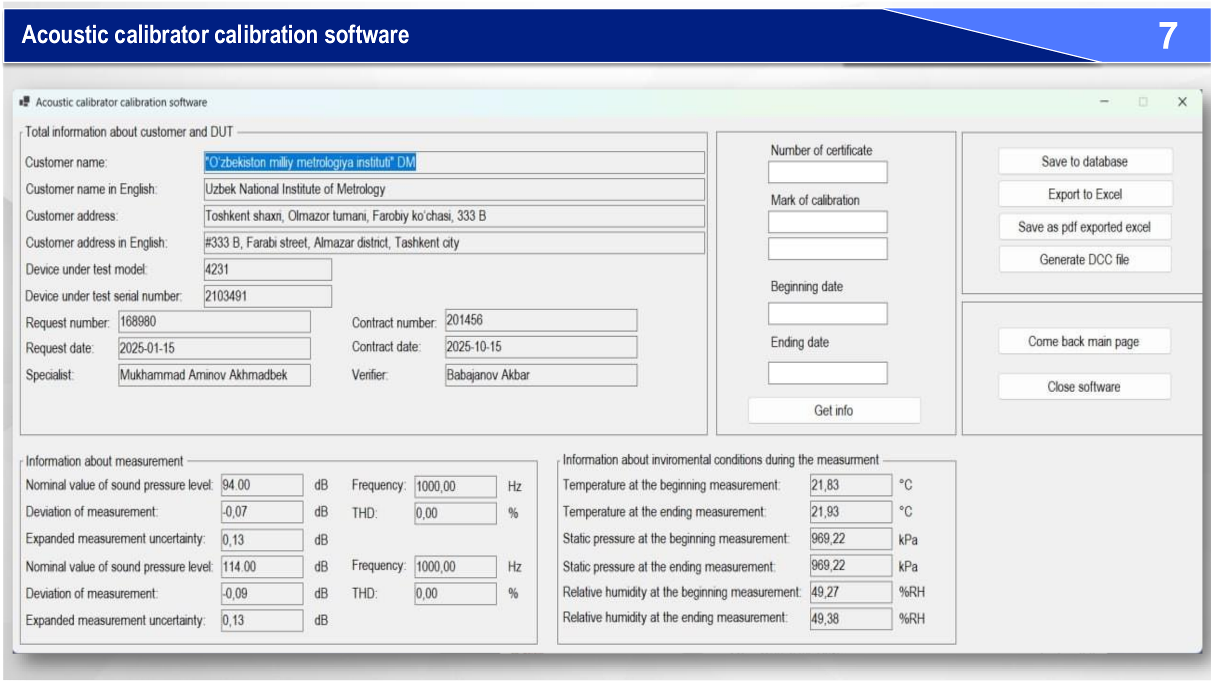
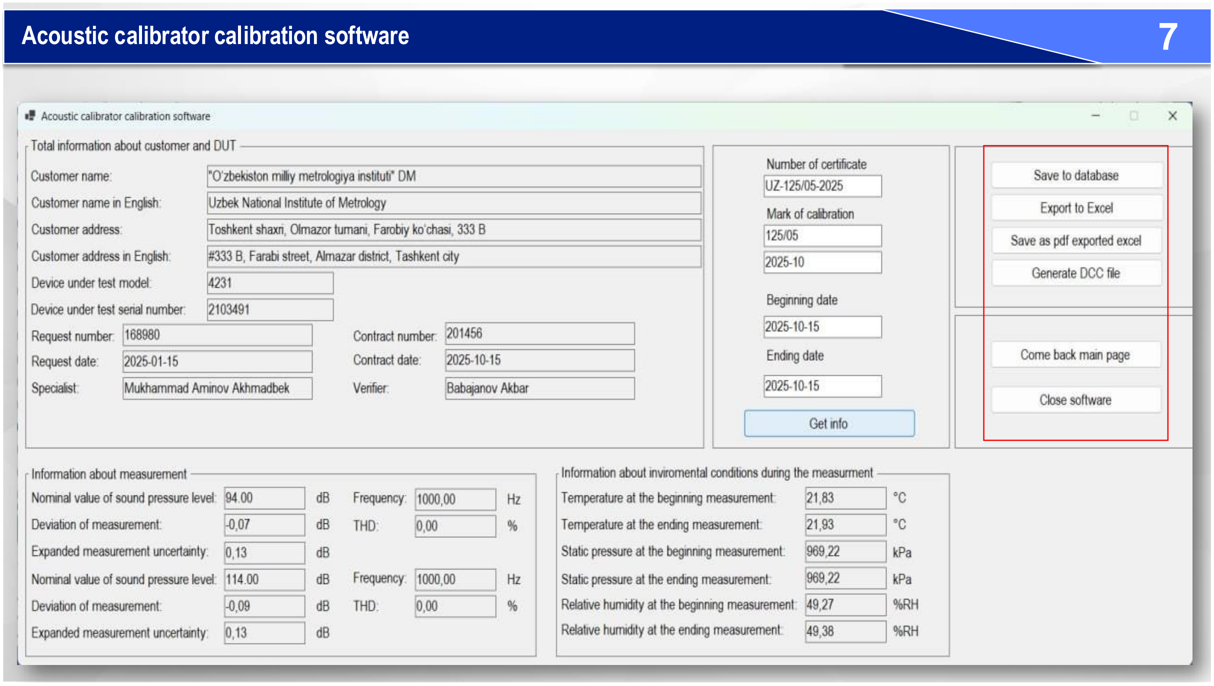



Acoustic calibrator calibration software
7
Acoustic calibrator calibration software
Total information about customer and DUT
Customer name: "O'zbekiston milliy metrologiya instituti" DM
Customer name in English: Uzbek National Institute of Metrology
Customer address: Toshkent shaxri, Olmazor tumani, Farobiy ko'chasi, 333 B
Customer address in English: #333 B, Farabi street, Almazar district, Tashkent city
Device under test model: 4231
Device under test serial number: 2103491
Request number: 168980
Request date: 2025-01-15
Specialist: Mukhammad Aminov Akhmadbek
Contract number: 201456
Contract date: 2025-10-15
Verifier: Babajanov Akbar
Number of certificate
Mark of calibration
Beginning date
Ending date
Get info
Save to database
Export to Excel
Save as pdf exported excel
Generate DCC file
Come back main page
Close software
Information about measurement
Nominal value of sound pressure level: 94.00 dB
Frequency: 1000,00 Hz
Deviation of measurement: -0,07 dB
THD: 0,00 %
Expanded measurement uncertainty: 0,13 dB
Nominal value of sound pressure level: 114.00 dB
Frequency: 1000,00 Hz
Deviation of measurement: -0,09 dB
THD: 0,00 %
Expanded measurement uncertainty: 0,13 dB
Information about inviromental conditions during the measurment
Temperature at the beginning measurement: 21,83 °C
Temperature at the ending measurement: 21,93 °C
Static pressure at the beginning measurement: 969,22 kPa
Static pressure at the ending measurement: 969,22 kPa
Relative humidity at the beginning measurement: 49,27 %RH
Relative humidity at the ending measurement: 49,38 %RH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7
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Specialist: Mukhammad Aminov Akhmadbek
Contract number: 201456
Contract date: 2025-10-15
Verifier: Babajanov Akbar
Number of certificate
UZ-125/05-2025
Mark of calibration
125/05
2025-10
Beginning date
2025-10-15
Ending date
2025-10-15
Get info
Save to database
Export to Excel
Save as pdf exported excel
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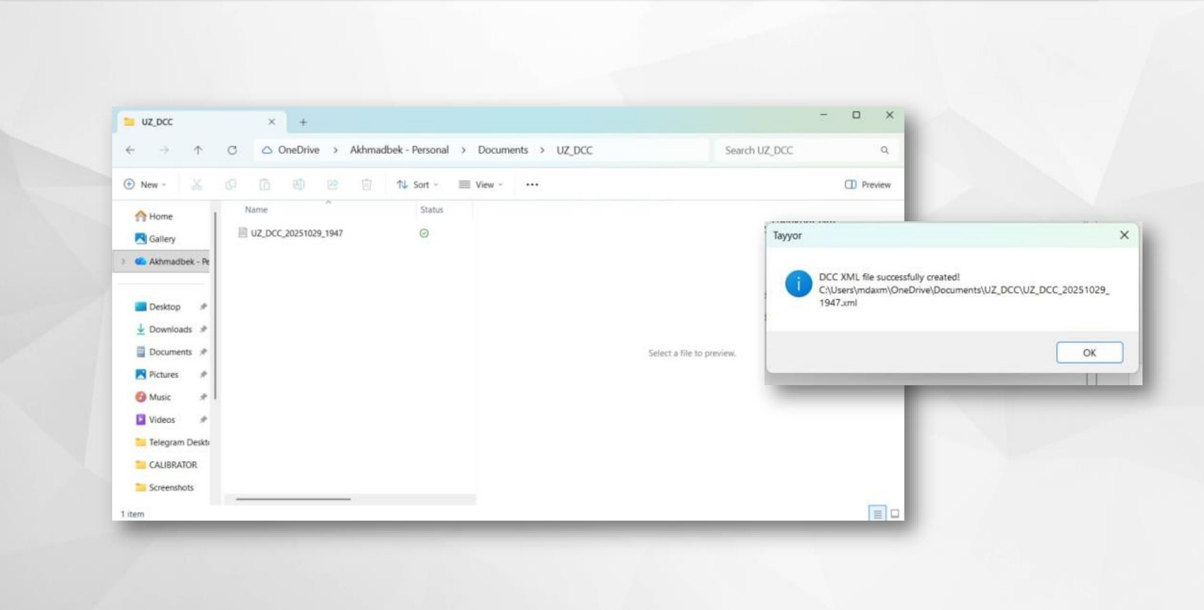
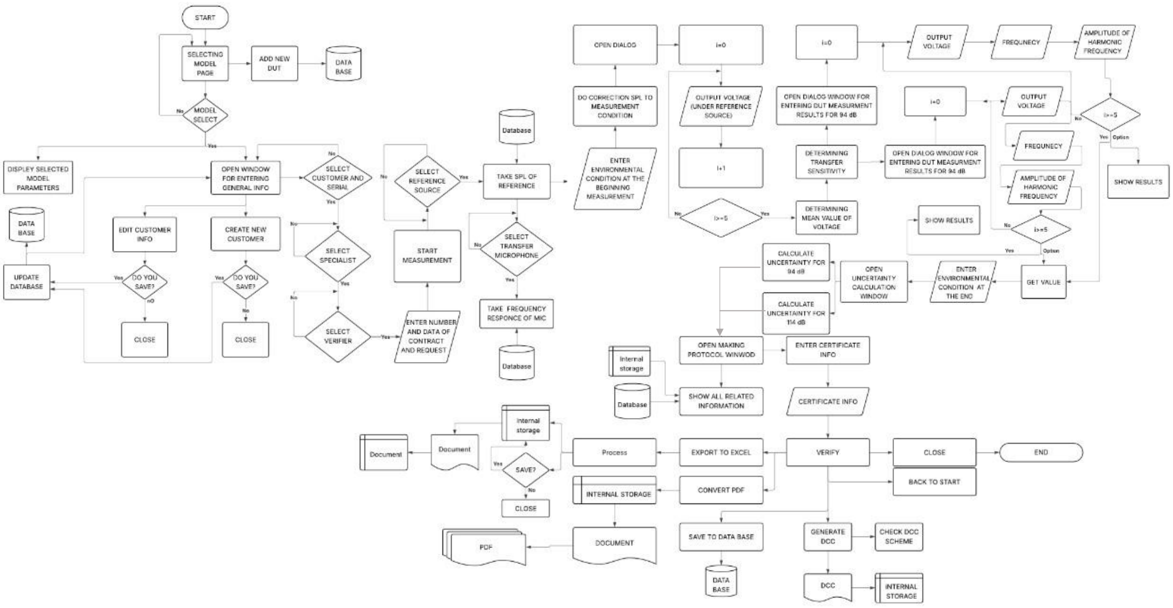
Relative humidity at the ending measurement: 49,38 %RH

Acoustic calibrator calibration software 8



Complex algorithm solution 9



Digital calibration certificate for acoustic calibrators

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```xml
<?xml version="1.0" encoding="utf-8"?>
<DigitalCalibrationCertificate xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
xsi:schemaLocation="urn:ptb.de:dcc:3.0 https://www.ptb.de/dcc/xml/schema/v3/DCC.xsd" version="3.0" xmlns="urn:ptb.de:dcc:3.0">
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            Almazar district, Tashkent, 100174, Uzbekistan, email: 05-bolim@nim.uz, webpage: www.nim.uz</Issuer>
    <CalibrationDate>2025-10-15</CalibrationDate>
    <Customer>#333 B, Farabi street, Almazar district, Tashkent city Toshkent shaxri, Olmazor tumani, Farobiy ko‘chasi, 333 B</Customer>
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    <Specialist>Mukhammad Aminov Akhmadbek</Specialist>
  </Header>
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```


Application of DCC

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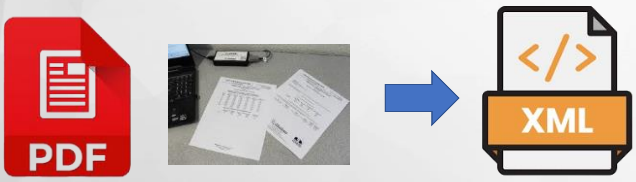
Periodic microphone sensitivity checks to ensure measurement reliability with DCC certificate

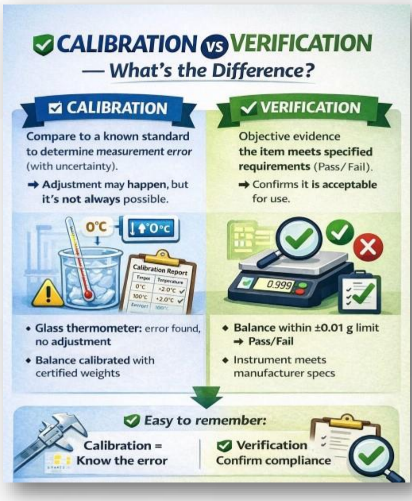
- Periodic microphone sensitivity checks to ensure measurement reliability with DCC certificate
- Integration of DCC with measurement systems eliminates the human error factor
- When determining the microphone sensitivity, it is important to determine the sound pressure level of the acoustic calibrator and its value in the current environment, in which case, along with the accuracy of measurements, the time expenditure is reduced. The program can perform automatic calculations.



Application of DCC

System that automatically gives a conclusion through DCC during the verification process

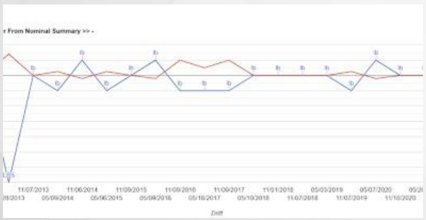
- ❑ The human factor does not affect the process;
- ❑ Time is saved as it is not necessary to review the technical specifications provided by the standard or manufacturer during each verification process;
- ❑ The verification process prevents the consumption of millions of tons of paper worldwide due to the fact that clients do not provide paper certificates;
- ❑ Also, large archive storage points are required for the permanent maintenance of paper certificates, which created the need for large servers in pdf;



Application of DCC

Convenient for monitoring the drift of permanent acoustic calibrators

- ❑ Several years of data can be analyzed in a minute and converted into a graph;
- ❑ In multi-frequency calibrators, errors in entering calibration values at frequencies are prevented;
- ❑ This will certainly create convenience for the user;



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008 Inseok Yang: From PDF Certificates to DCCs for Cold Chain Applications

Presenting author: Inseok Yang [1]
Email: iyang@kriss.re.kr
Additional authors: Nil
Institute:
[1] Division of Physical Metrology, Korea Research Institute of Standards and Science (KRISS), 267 Gajeong-ro, Yuseong-Gu, 34113, South Korea
Keywords: Cold Chain, High-Volume Calibration, Machine-Readable Data, Calibration Automation, Measurement Traceability

Abstract

One of the main barriers to the adoption of Digital Calibration Certificates (DCCs) is convincing accredited calibration laboratories - many of which perceive no serious shortcomings in current practices - of the need for change. In the field of temperature metrology, however, the limitations of conventional calibration certificates become apparent when large numbers of instruments of the same model must be calibrated and managed. This presentation uses a cold chain application as an example to demonstrate the clear advantages of DCCs over traditional PDF-based certificates.

Vaccines, biopharmaceuticals, and food products are highly temperature-sensitive and therefore require continuous monitoring during storage and transportation. Such monitoring typically involves hundreds to thousands of temperature sensors used in combination with data loggers. These instruments are generally calibrated annually in large batches at calibration laboratories. Although laboratories have optimized their calibration procedures to improve throughput, the overall workflow and the format of certificate issuance have remained largely unchanged.

Even when hundreds of identical thermometers are calibrated each day at the same temperature points, measurement data are entered manually, and a separate PDF certificate is generated for each unit using spreadsheet-based macros. This approach increases operational costs and introduces a significant risk of human error. In addition, calibration results are frequently underutilized. Instead of exploiting the full measurement information, a simplified screening process is applied, whereby instruments with correction values exceeding 1°C are removed from service, regardless of their repeatability or long-term stability.

The combination of automated calibration and DCCs addresses these limitations by transforming calibration results from static documents into structured, machine-readable data. AI camerabased optical character recognition can reduce manual data entry, while data-oriented management enhances traceability and enables long-term performance analysis. Calibration data can also be centrally managed and linked to data loggers, allowing calibrated interpretation of measurement data without directly updating individual devices. Consequently, instruments with relatively large correction values may remain in service, provided their performance characteristics are stable.

In conclusion, traditional PDF-based certificates are inefficient in high-volume cold chain environments. DCCs substantially enhance the usability and long-term value of calibration data.

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Presentation #008 of Inseok Yang

From PDF Certificates to DCCs for Cold Chain Applications

Division of Physical Metrology
Korea Research Institute of Standards and Science (KRISS)
Inseok Yang

2026-02-24

Need for DCCs: convincing customers of calibration

- Would customers want the transition from the traditional certificate to DCC?
  - Most customers are hesitant to change business routines, as calibration is a conservative industry.
  - Many are satisfied with their current PDF (paper) certificates.
  - Accredited calibration laboratories are often reluctant to adopt new technologies, such as DCCs.

Regulations on cold chain in biological products

Manufacturing and Sales Management Regulations for Biological Products

Storage
automatic temperature logger
calibration of the logger

Transportation
automatic temperature logger
calibration of the logger

Regulations on cold chain in biological products

- **Manufacturing and Sales Management Regulations for Biological Products**
  - For storage and transportation of biological products, temperature loggers must remain active at all times, continuously recording the current temperature.
  - These loggers must be calibrated periodically. (some logistics companies operate more than 10 000 loggers)

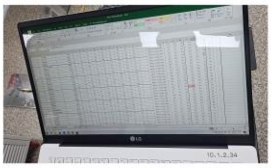
Logistics companies and IT-system providers

From DHL press release
"Smart warehouse" in Asia Pacific

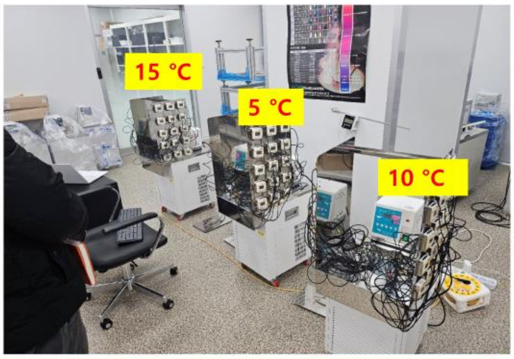
IT-solution company for cold chain logistics

A case study in the calibration of cold chain thermometers

- 4000 units of temperature loggers calibrated annually (all in December)
- 300 loggers are calibrated daily at three calibration points (5 °C, 10 °C, 15 °C)
- Loggers are grouped together as a batch of 30, and calibrated manually by an operator.



0.1 °C resolution data logger
with external sensor
40 USD/unit



A case study in the calibration of cold chain thermometers

- As a result of the calibration, a traditional PDF certificate is issued.
  - A VBA-based program is used to process the Excel date sheet into the PDF certificate.
  - Occasionally, a large “correction”, such as ΔT = 9.9 °C, may indicate a typographical error by the lab technician. This reading is then disregarded.
- The certificate mainly serves to meet regulatory requirements.
  - The calibration results are used to identify “bad” thermometers ($|\Delta T|$ > 1 °C), for which no calibration certificate is issued (effectively, it is a conformity assessment with a “simple decision rule”)
  - Corrections obtained during calibration, even when $|\Delta T|$ < 1 °C, are **NOT** applied.

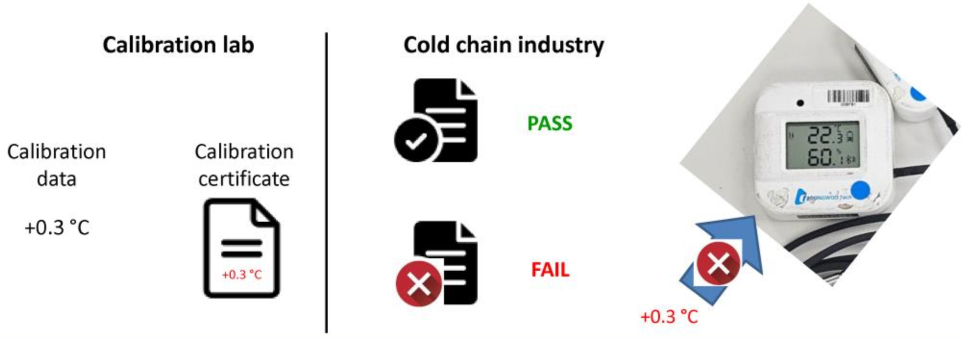
How to improve from here - Automation

- Automation with OCR (optical character recognition) can simplify measurement during calibration.
  - This reduces labor from human operators and minimizes input errors.
  - It also helps creating DCC certificates, making the process more efficient.

- Indications from multiple thermometers can be read with a properly set ROI (region of interest).
  - Use of LLM does not even require the setting of an ROI.

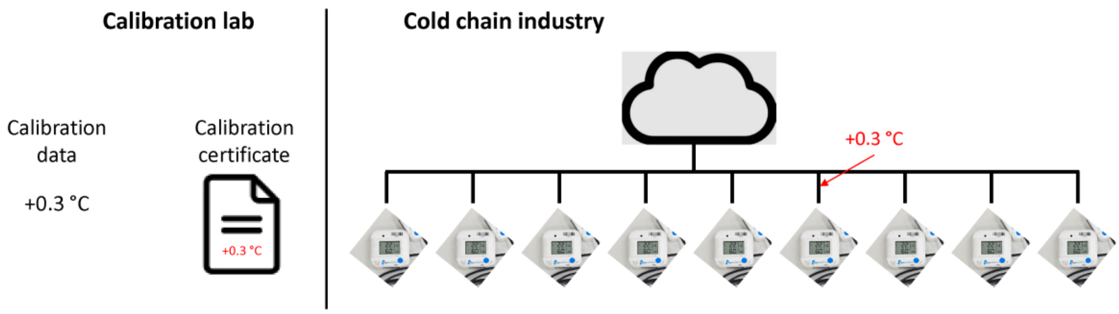
How to improve from here - DCC

- DCC can be easily issued without requiring (or at least minimizing) typing by the human operator.
- The “correction” can be applied to each temperature logger.

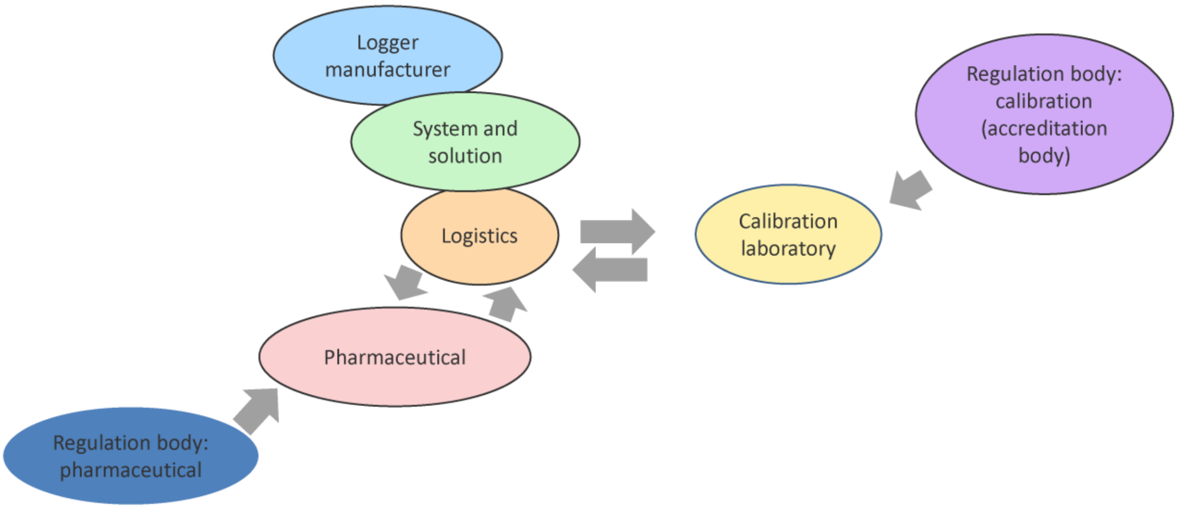


How to improve from here - DCC

- DCC can be easily issued without requiring (or at least minimizing) typing by the human operator.
- The “correction” can be applied to each temperature logger.
  - If not directly to the logger, it can be outside of the using in the central monitor.



Who are the stakeholders?



Outlook

- In cold chain industry, using DCC can greatly improve the process with OCR and automation.
- Multiple stakeholders play key roles in DCC expansion: logger manufacturers, system providers, logistics, pharmaceuticals, regulatory bodies, and calibration labs.
- Automation reduces manual labor and errors, simplifying DCC issuance and applying corrections.
- DCC adoption is ongoing, requiring continued collaboration among stakeholders.

Thank You!

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KRISS 한국표준과학연구원 Korea Research Institute of Standards and Science

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6th International DCC Conference
Online, 24th – 26th February 2026

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009 Paramita Guha: Development of a Machine-Readable Prototype Digital Calibration Certificate for a True RMS Clamp Meter

Presenting author: Paramita Guha [1]
E-mail address: paramita.nplindia@csir.res.in
Additional authors:

- Arun Ramprasath RT [1],
- Manish Kumar Tamrakar [1],
- Shrikrishan [1], Priyanka Jain [1]

Institute:
[1] Electrical & Electronics Metrology, CSIR-National Physical Laboratory, Dr KS Krishnan Marg, Delhi, 110012, India
Keywords: Digital Calibration Certificate, Clamp Meter, Smart Metrology, Machine-Readable Calibration Data, Laboratory Information Management System

Abstract

Digital Calibration Certificates (DCCs) represent a significant advancement in digital metrology by enabling secure, standardized, and machine-readable representation of calibration data. It facilitates the automated data exchange and integration across calibration laboratories, industrial facilities, and quality management systems. This study presents the development and implementation of a DCC framework for the calibration of clamp meters used in AC current measurements. Traditional calibration certificates are generally issued in paper or PDF formats which requires manual interpretation and data entry. This increases the risk of transcription errors and limits interoperability with asset management and automated compliance systems. In contrast, in this paper the authors have transformed the calibration information into a standardized digital format, viz., XML, so that the data exchange between the laboratory information management system and quality management system becomes seamless. The measurement results, uncertainty components, instrument identification, calibration conditions, and validity information are encoded into the DCC to ensure data integrity, authenticity, and long-term traceability. The prototype DCC model can be downloaded from the QR code given here. To view the certificate, please use the passcode as “abed”

Remark: A currently invalid QR code has been inserted here in the original document.

References:

[1] ‘Towards a New Generation of Digital Calibration Certificate: Analysis and Survey | Request PDF’, *ResearchGate*, doi: 10.1016/j.measurement.2021.109611.

[2] “GUM: Guide to the Expression of Uncertainty in Measurement.” https://www.bipm.org/en/publications/guides/gum.html, last accessed 23. July. 2025.

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Presentation #009 of Paramita Guha

Development of a Machine-Readable Prototype Digital Calibration Certificate for a True RMS Clamp Meter

Authors: Paramita Guha, Arun Ramprasath RT, Manish Kumar Tamrakar, Shrikrishan, Priyanka Jain

Presented by:
Dr Paramita Guha
CSIR-NPL, India

PROBLEM TO BE ADDRESSED AND RELEVANCE

Calibration certificates in digital formats for Clamp Meter for AC high voltage and current metrology to be developed

BENEFICIARY STAKEHOLDERS

- Customers of NPLI

2

PROBLEM & INDUSTRY RELEVANCE

Problem Statement (s)

- Development of DCC for AC high voltage and current metrological parameters. Parameters to be used: ratio error and phase error.

Motivation & Industry Relevance

- The reports of calibrations are mostly manually PDF generated documents
- This is laborious, time-consuming, cumbersome and prone to human errors
- CSIR-NPL aims to develop certified framework for machine readable calibration information to assure traceability to national measurement standards and further to SI units.
- It can solve the issues of accessibility, reliability, security, traceability, data mismanagement etc., most importantly it will allow the machines to communicate with each other (M2M) which will reduce the human interventions.
- Highly beneficial for various industries, particularly those who are from far lung or outside India.
- The proposed digital approach aligns with industry trends toward digitalization and automation, with benefits like, reduced operational costs, easier compliance with standards, and improved system integration.

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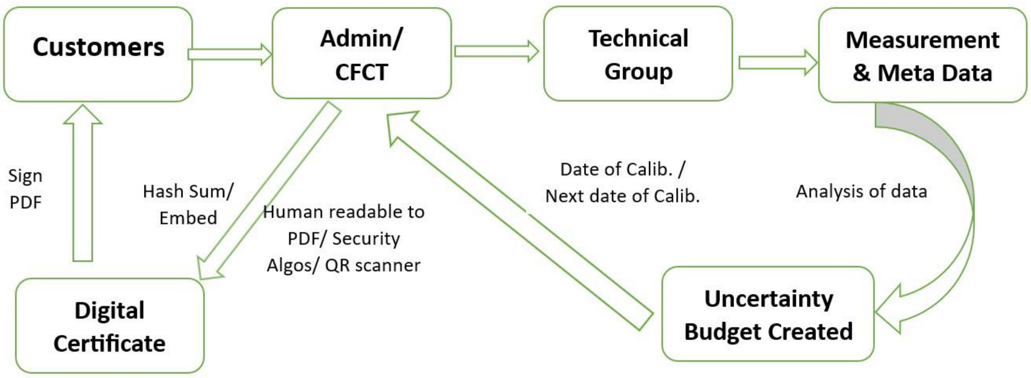
SOLUTION



4

SCOPE – CLAMP METER (AC HV & CURRENT)

• Used to measure high electrical current safely and conveniently without breaking the circuit or interrupting power.

• AC Current Measurement (A to kA)

• AC Voltage Measurement (V to kV)

• Frequency Dependency (50 Hz and extendable)

• Phase Angle Considerations

• Burden and loading Effects

5

OBJECTIVES OF DCC TECHNICAL DEVELOPMENT

• Unified digital certificate schema
  - Parameter-specific measurement structure
  - Integration with LIMS and asset systems
  - ISO/IEC 17025 compliant data structure
  - Secure digital signature & validation mechanism

6

SYSTEM ARCHITECTURE OVERVIEW

- Client Layer (Lab Software / Web Portal)
  - API Gateway (Authentication & Access Control)
  - Certificate Management Service
  - Measurement & Uncertainty Engine
  - Traceability Database
  - Digital Signature Service
  - Central DCC Repository

7

CORE DCC DATA STRUCTURE

- Certificate Metadata (ID, Date, Revision)
- Laboratory Information
- Instrument Details (Model, Serial No., Range)
- Calibration Conditions
- Traceability Information
- Approval & Digital Signature

8

PARAMETER-SPECIFIC MEASUREMENT SCHEMA – AC CURRE

- Set Current (A)
  - Measured Current (A)
  - Correction Value
  - Expanded Uncertainty (k=2)
  - Frequency (Hz)
  - Phase Angle Error
  - Resolution & Range

9

HIGH VOLTAGE MEASUREMENT CONSIDERATIONS

- Reference Voltage Standard
  - Voltage Divider Ratio
  - Insulation & Safety Compliance
  - Temperature Influence on HV measurements
  - Leakage and stray capacitance effects

10

UNCERTAINTY BUDGET – AC CURRENT & HV

- Type A (Repeatability)
- Reference Standard Uncertainty
- Resolution Contribution
- Frequency Influence (if any)
- Environmental Factors (Temp, Humidity)
- Combined & Expanded Uncertainty

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API FRAMEWORK FOR DCC

- POST /dcc – Create Certificate
  - POST /dcc/{id}/measurements – Add Data
  - POST /dcc/{id}/uncertainty – Store Budget
  - POST /dcc/{id}/sign – Digital Signature
  - GET /dcc/{id}/export – JSON/PDF Output
  - POST /dcc/validate – Verification

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SECURITY & VALIDATION MECHANISM : FUTURE WORK

- Role-based access control
  - Encrypted data storage
  - Hash-based digital signature
  - Audit trail logging
  - Certificate locking after approval
  - Online verification portal

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IMPLEMENTATION ROADMAP – NATIONAL LAB

- Phase 1: Electrical Parameter Pilot (Clamp Meter)
- Phase 2: Multi-parameter expansion
- Phase 3: Integration with accredited labs
- Phase 4: National DCC repository deployment
- Expected Impact: Faster processing, secure traceability, global interoperability

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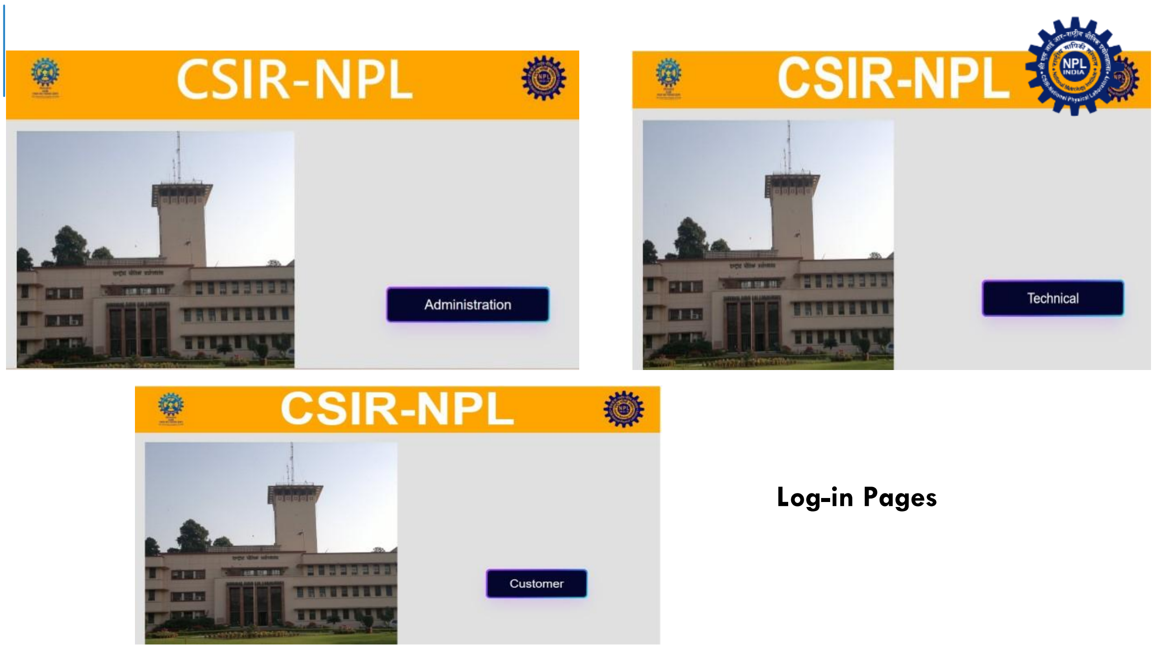

Log-in Pages

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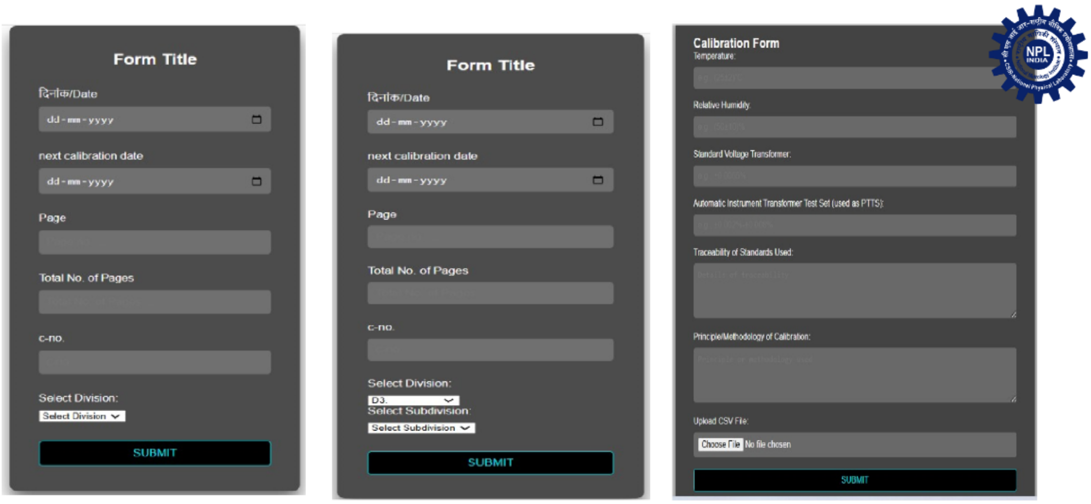

Administration forms

Calibration form for Technical people

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RESULTS

tfo9bQ_ba9d9a3cd46f021d.pdf

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GOOD PRACTICES IDENTIFIED SO FAR

- Data integrity and security
- Standardisation
- Traceability
- Digital format
- User friendly access
- Version control
- Calibration reminder systems
- Compliance to legal and industry-specific requirements

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LESSONS LEARNT SO FAR

- Standardization is critical
- Data integrity non-negotiable
- Importance of traceability
- Stakeholder collaboration essential
- Training and awareness
- Reduced carbon foot-prints & reduced paper wastage
- Initial setup and transition to DCCs costly, long run cost-effective

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Thank You!

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Day 1 2026-02-24 Tuesday
Parallel Session “Digitalization to enable DCC”
Session Chair: Mark Kuster

010 Sarita Singh: Automation of Manual Balance for Mass Measurement Data Acquisition employing LabVIEW

Presenting author: Sarita Singh [1]
E-mail address: saritas.nplindia@csir.res.in
Additional authors:

- Dr. Bushra Ehtesham, Research Associate, NPL India
- Mr. Dinesh Chandra Sharma, Senior Technical Officer, NPL India
- Dr. Nidhi Singh, Chief Scientist, NPL India

Institute:
[1] CSIR National Physical Laboratory India
Keywords: Automated Mass Measurement, FAIR Data Principles, Instruments Integration, LabVIEW, RS232 Communication

Abstract

The ongoing digital transformation of metrology, including the digitization of measurement results, and of quality infrastructure (QI) includes the automated, reliable, and structured acquisition of measurement data at the instrument level, which is essential for supporting machine-actionable and interoperable workflows. Within the context of Digital Calibration Certificates (DCCs), the availability of high-quality, traceable, and structured measurement data is a prerequisite for enabling FAIR (Findable, Accessible, Interoperable, and Reusable) data exchange across systems and organizations [1-3], Many laboratories continue to use cost-effective conventional weighing instruments alongside high-precision systems. In this context, an effort has been made to automate the acquisition and logging of measurement data from manual balances to a computer system.

This work presents the design and implementation of an automated instrument-level data acquisition system for mass measurements, developed in LabVIEW and interfaced with a laboratory analytical balance through an RS-232 communication link. The program uses NI-VISA to establish serial communication with defined parameters (9600 baud, 8-N-I, LF termination) for data transfer. In the present implementation, the balance operates in a print-on- request mode, transmitting measurement data only when the print command is activated. Each received ASCII data string is processed in real time to extract the numerical mass value, which is then converted to a floating-point format for subsequent processing. The measurement data are dynamically accumulated in arrays and automatically time-stamped for structured logging, with output stored in a Microsoft Excel (.xls) file or exported in formats suitable for downstream digital calibration workflows. The implemented architecture demonstrates the integration of legacy RS-232 instruments into modern digital measurement systems and provides a practical basis for interoperable data acquisition in line with emerging Digital Calibration Certificate and Digital Quality Infrastructure requirements. By enabling direct digital capture of measurement results at the instrument level, the system addresses common challenges in laboratory data handling, particularly those associated with manual data transcription. This approach reduces the risk of transcription errors, supports data integrity, and improves reproducibility in routine

mass measurement processes. In addition, the system architecture can be designed for straightforward export of data into other machine-readable formats, such as CSV or XML.

References

[1] Hackel, Siegfried, Frank Härtig, Julia Hornig, and Thomas Wiedenhöfer. (2017). " The Digital Calibration Certificate" In Metrology for the Digitalization of the Economy and Society. Braunschweig: Physikalisch-Technische Bundesanstalt. https://doi.org/10.7795/310.20170403

[2] Hackel, Siegfried, Shanna Schönhals, Lutz Doering, Thomas Engel, and Reinhard Baumfalk. (2023): "The Digital Calibration Certificate (DCC) for an End-to-EndDigital Quality Infrastructure for Industry 4.0" Sei 5, no. 1: 11. https://doi.org/10.3390/sci5010011

[3] Wilkinson, M., Dumontier, M., Aalbersberg, I. et al. (2016): “The FAIR Guiding Principles for scientific data management and stewardship" Sei Data 3, 160018. https://doi.org/10.1038/sdata.2016.18

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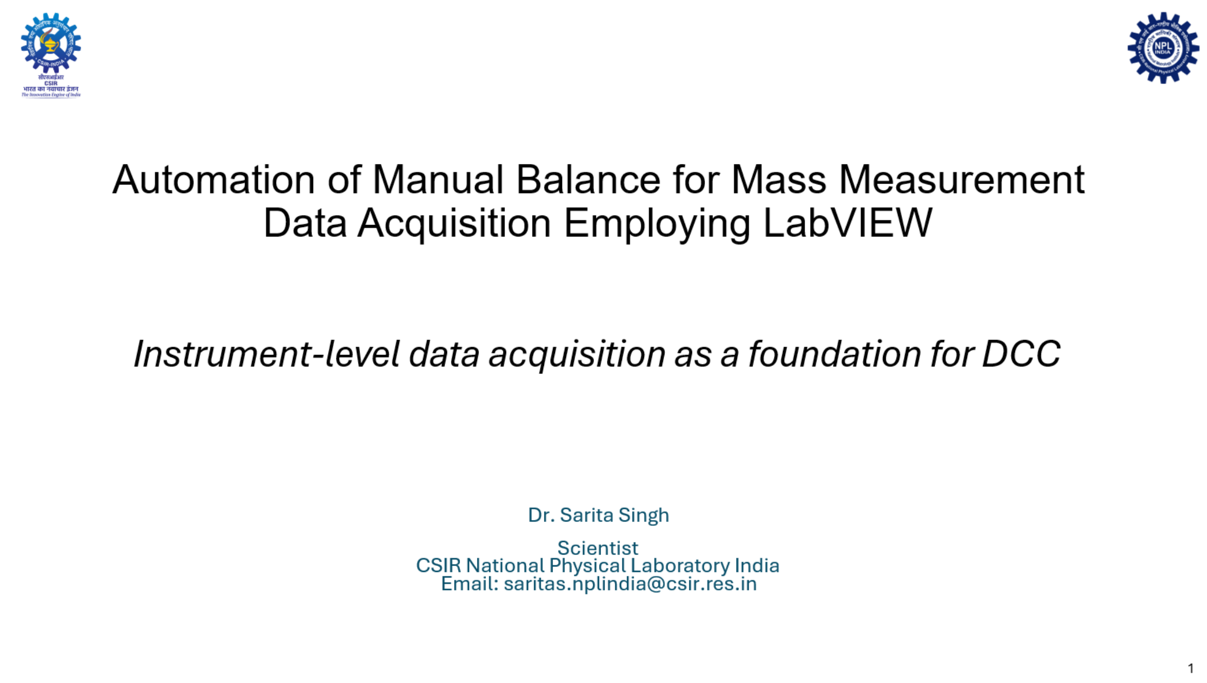
Presentation #010 of Sarita Singh



Digital Transformation in Metrology

- A **Digital Calibration Certificate (DCC)** enables electronic storage, authenticated and encrypted transmission, and uniform interpretation of calibration results.

- The digital transformation in metrology requires
  - Automated, structured, and semantically defined measurement data
  - Machine-readable and machine-actionable processing
  - FAIR-compliant data exchange

- **Integration of manual weighing instruments with digital logging systems helps improve efficiency and ensures more consistent measurement data management.**

2

Digital Transformation in Metrology

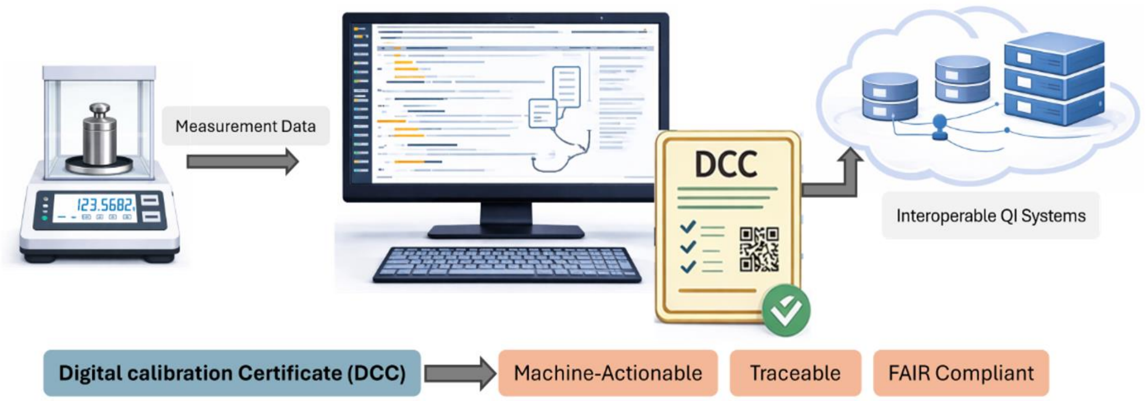


Fig 1. Digital Calibration Certificate (DCC) workflow from automated measurement data to interoperable, FAIR-compliant systems.

3

Research Motivation

To develop a method for automated acquisition and structured logging of mass measurement data from manual balances, enabling compatibility with DCC-based workflows.

4

Automated Instrument-Level Data Acquisition

- An automated data acquisition system for mass measurements was developed in LabVIEW, interfaced with an analytical balance via RS-232 communication.
- Serial communication is established using NI-VISA, configured with
  - 9600 baud rate, 8 data bits, no parity, 1 stop bit (8-N-1), 0x0F termination.
- The balance operates in **print-on-request mode**, transmitting measurement data only when triggered, enabling controlled data acquisition.

5

Automated Instrument-Level Data Acquisition Architecture

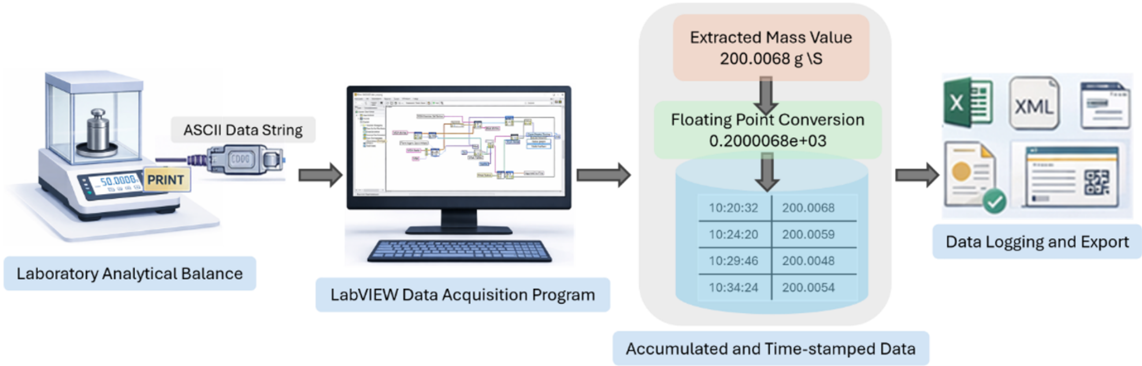
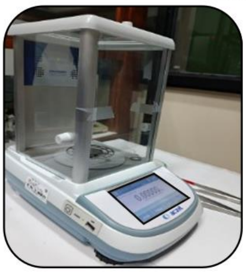


Fig 2. Automated Instrument-Level Data Acquisition for Mass Measurements: Designed in LabVIEW, interfaced with a balance via RS232 using NI-VISA to capture time-stamp and export measurement data.

6

Integration of Balance with LabVIEW via RS-232 Communication

- Dual-range **semi-micro analytical balance** with high resolution up to **0.01 mg (0.00001 g)** and scalable capacity up to **220 g**.
- Equipped with RS-232 communication and print function, enabling integration with external data acquisition systems (e.g., LabVIEW).



ACZET CY 285C Analytical Balance

Model: CY 285C
Max: 80/220gm
Min: 10mg
d:0.01/0.1 mg
e:0.1/1mg

Fig 3. ACZET CY 285C analytical balance displaying 0.00000 g, with model specifications shown.

- In LabVIEW, a **0x0F termination character** was configured to mark the end of each serial data message, to read the complete measurement string.

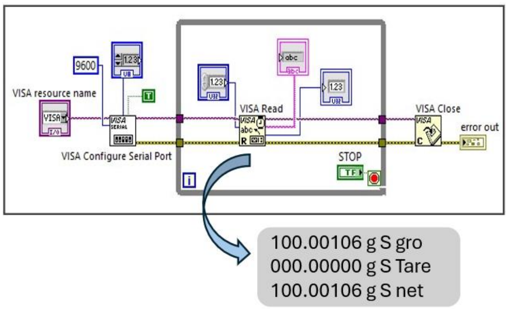


Fig 4. LabVIEW VISA serial read for weight data acquisition.

7

LabVIEW Data Acquisition Program

- Incoming ASCII data are parsed in real time to extract the numerical mass value and converted to floating-point format .
- Data conditioning and validation are performed using threshold comparison, and averaging; and time-stamped for structured logging.
- Processed data is exported in machine-readable formats (xls/XML), enabling integration into Digital Calibration Certificate (DCC) workflows.

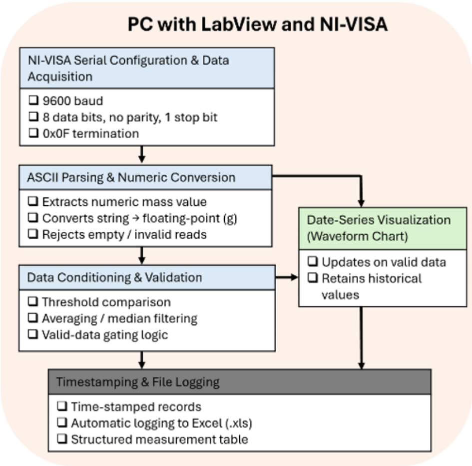


Fig 5. LabVIEW-Based Real-Time Data Processing and Logging Workflow

LabVIEW Data Acquisition Program Front Panel

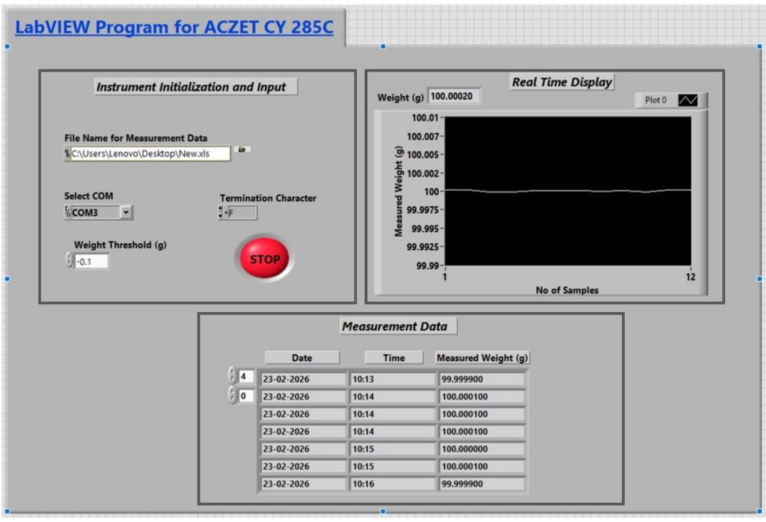


Fig 6. LabVIEW-Based Data Acquisition Interface for Automated Weighing and Logging

Data Logging and Export

LabVIEW program for Mass Measurement Values Logging based on Print Request

+

LabVIEW program for Environmental Conditions Logging in Real Time

	A	B	C	D	E	F	G	H
1	Date	Time	Weight (g)		Time	Temp. (°C)	RH (%)	Pressure (mbar)
2	17-02-2026	10:44:00 AM	100.0006		10:40:00 AM	22.19	52.63	995.4
3		10:44:00 AM	100.0007		10:41:00 AM	22.20	52.63	995.4
4		10:45:00 AM	100.0006		10:42:00 AM	22.21	52.62	995.4
5		10:46:00 AM	100.0005		10:43:00 AM	22.22	52.61	995.4
6		10:46:00 AM	100.0005		10:44:00 AM	22.24	52.71	995.4
7		10:47:00 AM	100.0006		10:45:00 AM	22.24	52.73	995.4
8		10:48:00 AM	100.0006		10:46:00 AM	22.24	52.74	995.4
9		10:49:00 AM	100.0006		10:47:00 AM	22.25	52.63	995.3
10		10:50:00 AM	100.0006		10:48:00 AM	22.25	52.64	995.4
11		10:50:00 AM	100.0007		10:49:00 AM	22.26	52.59	995.4
12		10:51:00 AM	100.0007		10:50:00 AM	22.26	52.52	995.4

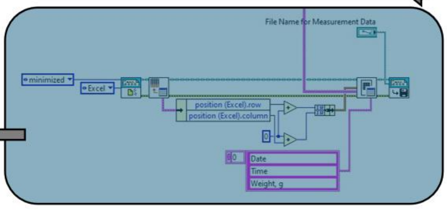


Fig 7. LabVIEW block diagram for Excel data logging with date–time stamp.

10

Conclusion and Future Work

- The proposed approach provides **a practical way for interfacing conventional laboratory instruments with a host computer** thus integrating into digital workflow.
- The **data logging process is fully automated**, eliminating the need for human intervention.
- The scope for future work is the **integration of the generated xls data into the standardized DCC schema** for uncertainty budget calculation and official Digital Calibration Certificate.
- The program currently uses an **RS-232 interface**; it can be extended to support GPIB, USB or other interfaces to enhance compatibility with more instruments.
- Further enhancement can include **host-controlled communication**, allowing LabVIEW to send print commands and acquire measurements on demand.

11

References

[1] Hackel, Siegfried, Frank Härtig, Julia Hornig, and Thomas Wiedenhöfer. (2017). “The Digital Calibration Certificate” In Metrology for the Digitalization of the Economy and Society. Braunschweig: Physikalisch-Technische Bundesanstalt. https://doi.org/10.7795/310.20170403

[2] Hackel, Siegfried, Shanna Schönhals, Lutz Doering, Thomas Engel, and Reinhard Baumfalk. (2023): "The Digital Calibration Certificate (DCC) for an End-to-End Digital Quality Infrastructure for Industry 4.0" Sci 5, no. 1: 11. https://doi.org/10.3390/sci5010011

[3] Wilkinson, M., Dumontier, M., Aalbersberg, I. et al. (2016): “The FAIR Guiding Principles for scientific data management and stewardship” Sci Data 3, 160018. https://doi.org/10.1038/sdata.2016.18

12

Digital Calibration Certificates begin at the instrument level.

Thank you

Authors:
Dr. Sarita Singh, Scientist, NPL India
Dr. Bushra Ehtesham, Research Associate, NPL India
Mr. Dinesh Chandra Sharma, Senior Technical Officer, NPL India
Dr. Nidhi Singh, Chief Scientist, NPL India

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011 Vitalii Malisevych: Digital representation and verification of metrological traceability chains in quality infrastructure systems

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E-mail address: vitalii.malisevych@ifdcsms.com.ua
Additional authors:

- Taras Kepeschuk [1],
- Denys Serediuk [1]

Institute:
[1] SE "Ivano-Frankivskstandartmetrology"; State Enterprise „Ivano-Frankivsk Scientific and Production Centre for Standardisation Metrology and Certification
Keywords: metrological traceability; digital calibration certificates; metrological data management; web-based information systems; quality infrastructure

Abstract

The ongoing digital transformation of the quality infrastructure requires a fundamental shift from paper-based calibration documents to machine-readable, interoperable, and verifiable digital representations [1]. Although Digital Calibration Certificates (DCC) provide a standardized container for calibration results, reliable digital verification of metrological traceability throughout the entire calibration chain remains a significant challenge.

The aim of this work is to develop and describe the architecture of a web portal designed to automate the collection, storage, and provision of access to the results of metrological activities in machine-readable formats. The object of the study is the process of metrological data management, while the subject is the methods for designing a specialized web-based resource to ensure transparency and metrological traceability in a digital environment.

The software implementation of the system is based on a relational data model in which metrological traceability is represented as a directed acyclic graph. In this graph, nodes correspond to reference standards and measuring instruments, while edges represent documented calibration events. This approach enables the correct description of both linear and branched calibration chains, which are characteristic of complex measurement systems, such as those used in gas metering applications.

The system architecture is implemented as a client–server web portal integrated with a relational database, providing centralized data storage, access control, and automated processing of calibration data. To enable automated traceability verification, a depth-first search algorithm implemented using recursive SQL queries is applied. This allows the system to instantly reconstruct a continuous calibration chain from a customer's working instrument to national measurement standards.

A key advantage of the proposed approach is the integration of traceability verification directly into the web portal. For end users, traceability is not only verified but also visualized in an intuitive graphical form, enhancing transparency and confidence in calibration results. The system maintains a complete calibration history for each instrument, supports version control, and prevents inconsistent or unauthorized modifications.

The developed solution was implemented and tested at the SE "IVANO-FRANKIVSKSTANDARTMETROLOGY", with a focus on instruments for gas volume and flow measurement. It enables automated traceability verification and supports the transition from

best practices to a standardized, interoperable digital quality infrastructure, providing a robust foundation for future workflows based on DCC.

References:

[1] Eichstädt, Sascha (2021): Metrology for the digital age, in: Measurement: Sensors, volume 18, https://doi.org/10.1016/j.measen.2021.100232

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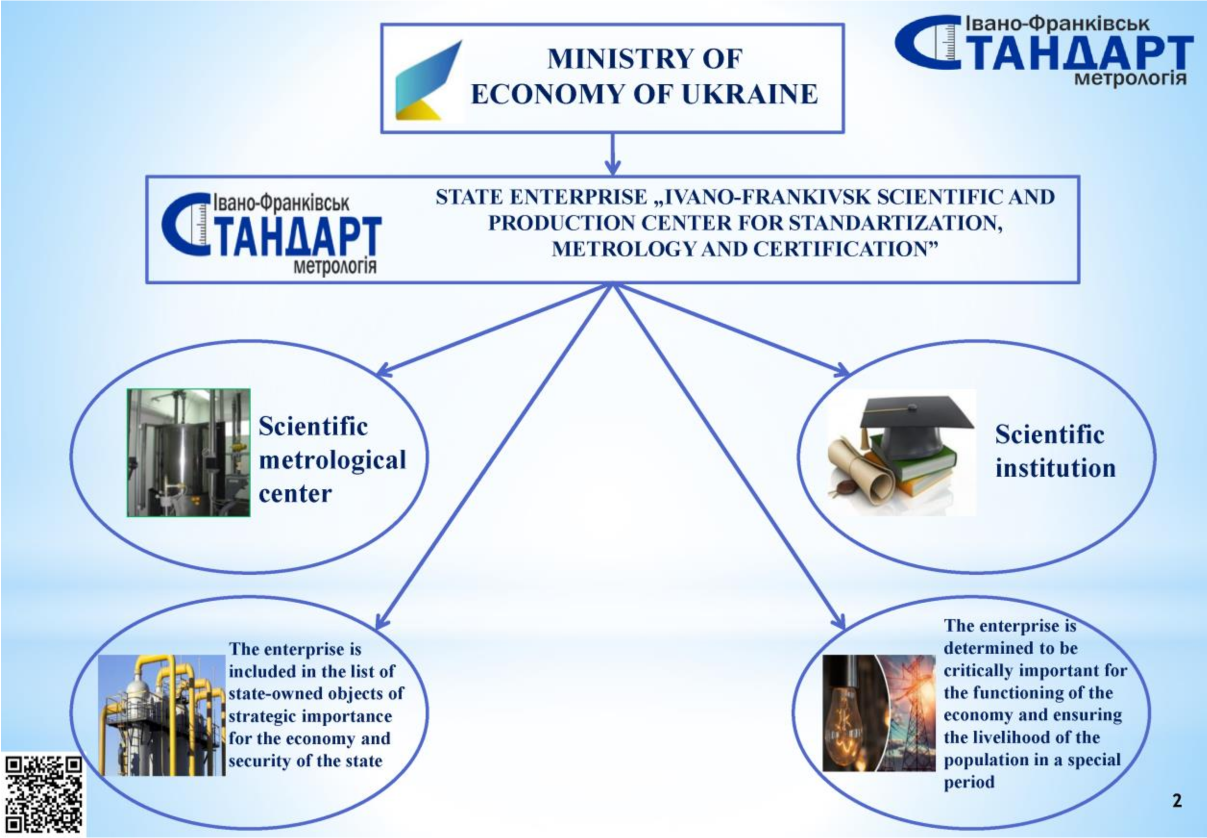
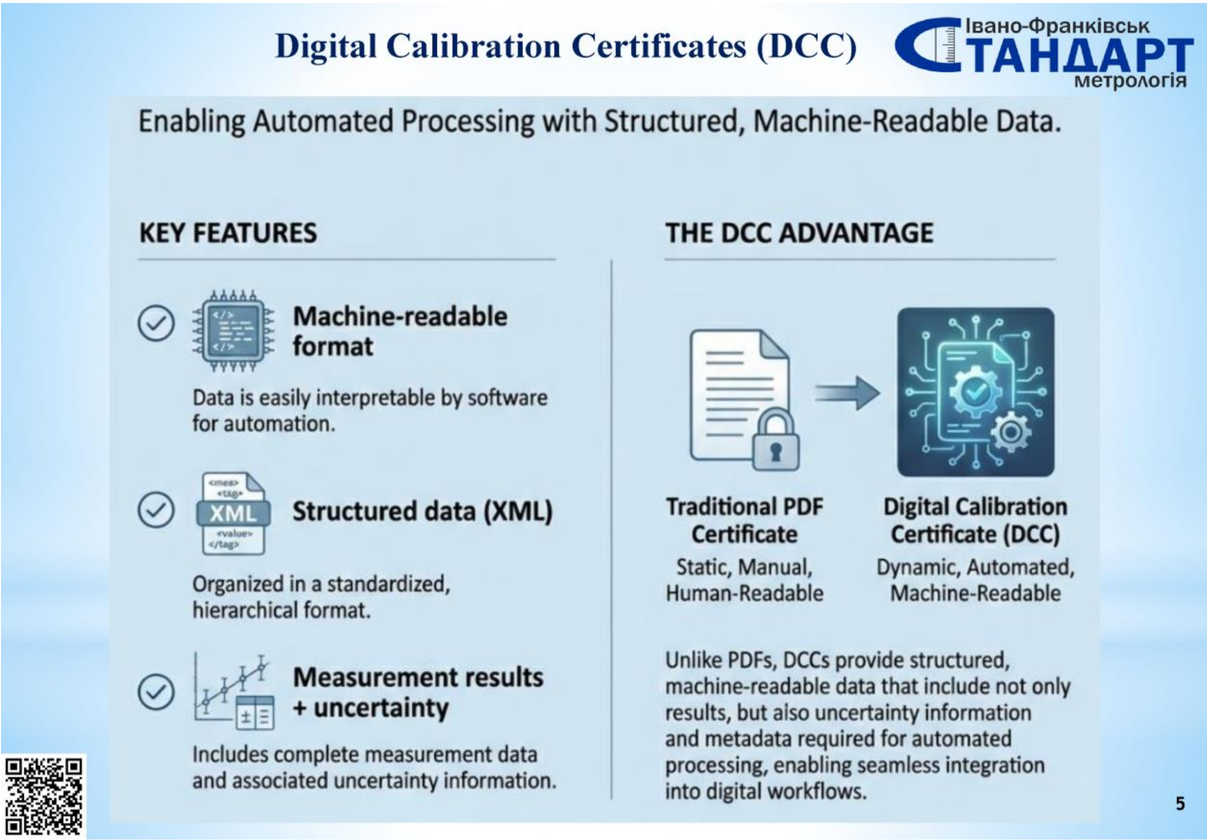
Presentation #011 of Vitalii Malisevych

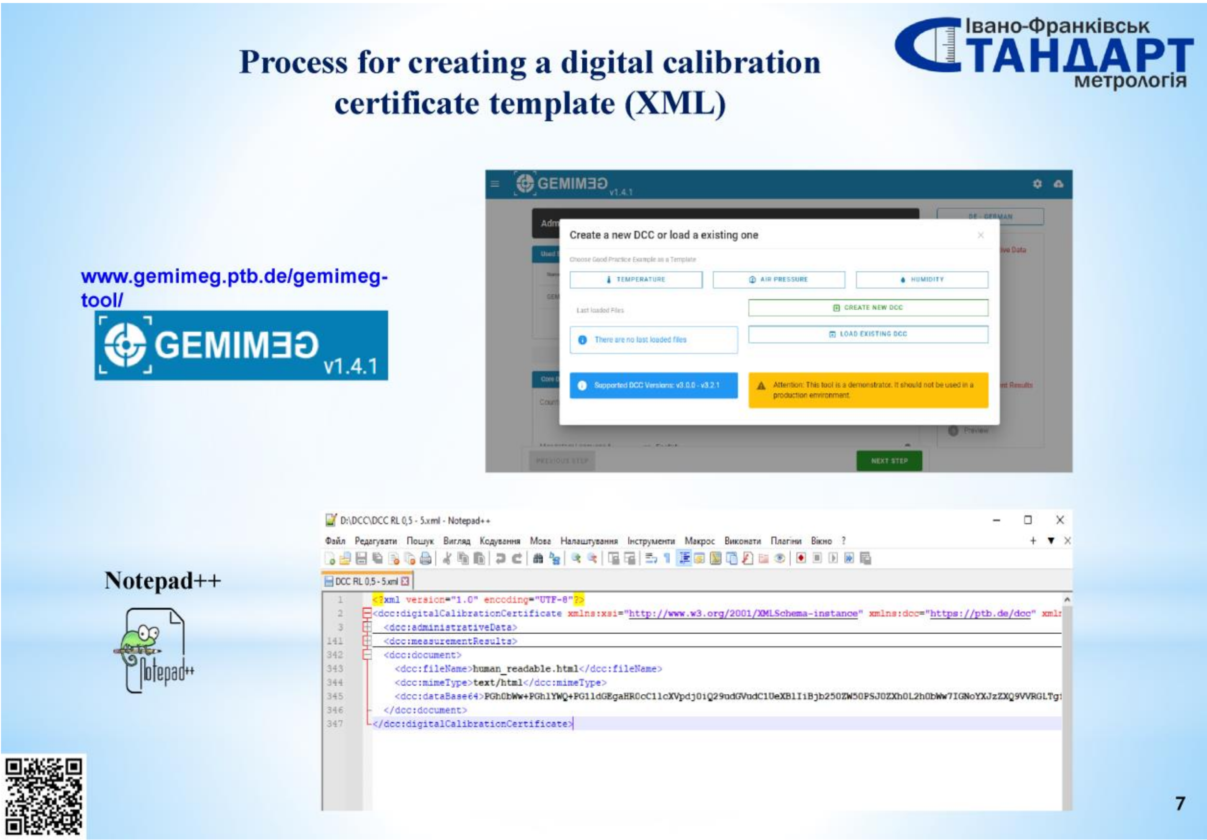

MINISTRY OF ECONOMY OF UKRAINE
Івано-Франківськ СТАНДАРТ метрологія
STATE ENTERPRISE „IVANO-FRANKIVSK SCIENTIFIC AND PRODUCTION CENTER FOR STANDARTIZATION, METROLOGY AND CERTIFICATION"
Scientific metrological center
Scientific institution
The enterprise is included in the list of state-owned objects of strategic importance for the economy and security of the state
The enterprise is determined to be critically important for the functioning of the economy and ensuring the livelihood of the population in a special period
2

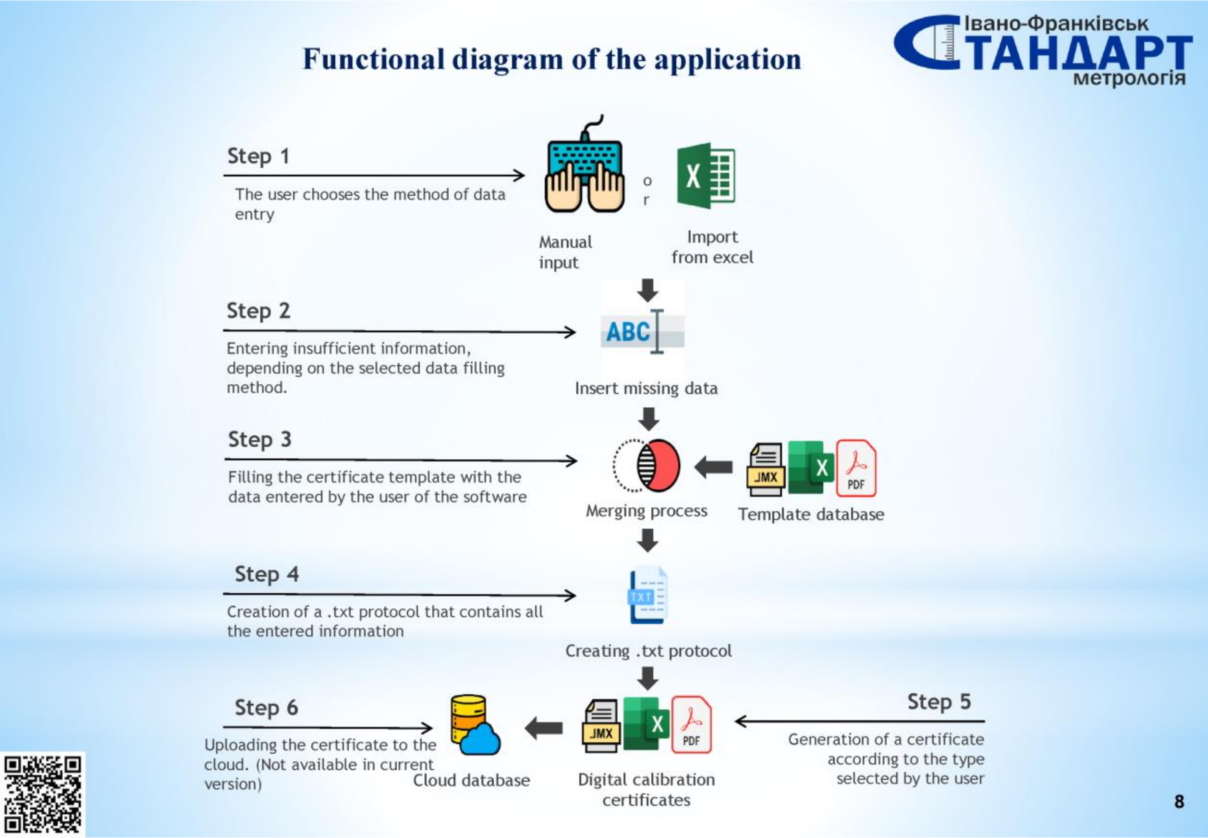

Motivation: Why Digital Traceability?
Івано-Франківськ СТАНДАРТ метрологія
Current Challenges
Paper Certificates
Closed PDF Reports
PDF
Manual traceability checks
Manual traceability checks
Manual Traceability Checks
Industry 4.0 Requirements
3

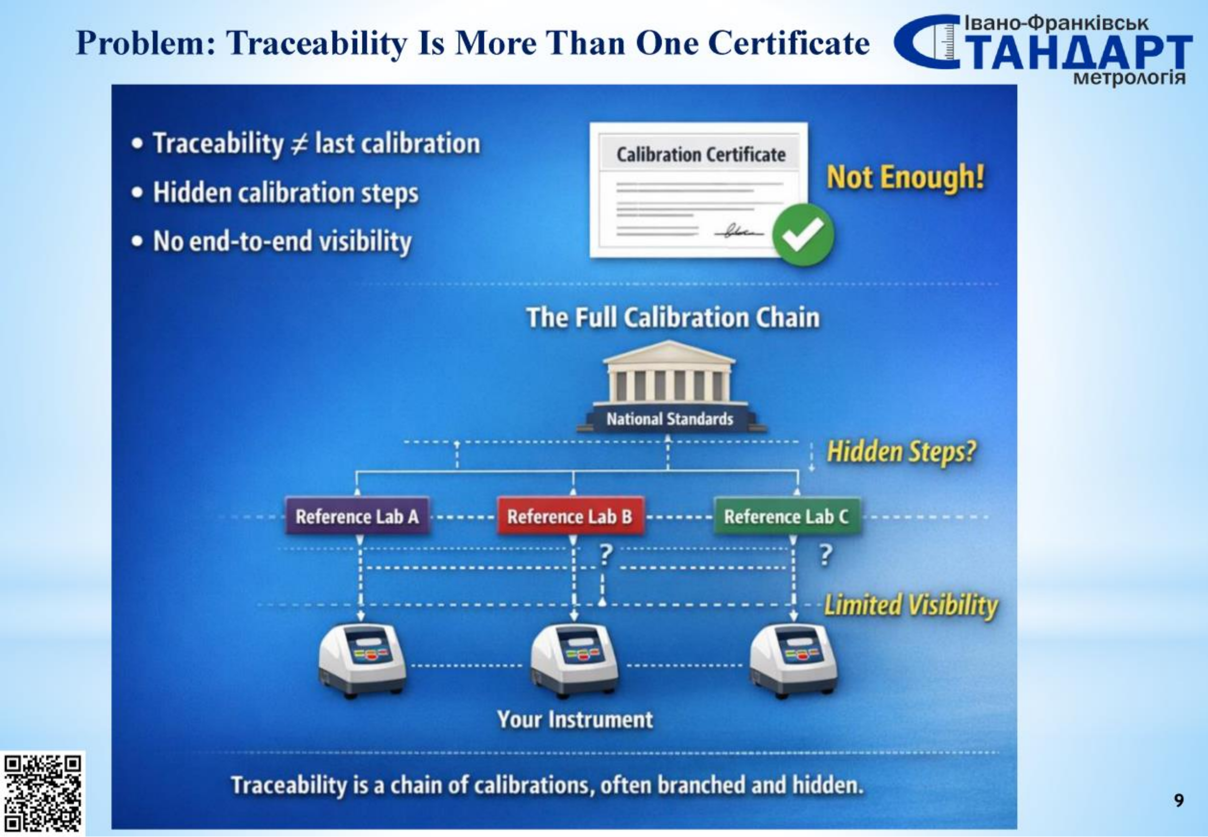

Metrology in digital transformation
Івано-Франківськ
СТАНДАРТ
метрологія
M4DT
Digital Quality Infrastructure (DQI)
Data as a trusted asset
Digital transformation in metrology, often referred to as *Metrology for Digital Transformation*, requires rethinking how measurement data are generated, exchanged, and verified. Digital Quality Infrastructure provides the framework in which trust is established not by paper documents, but by verifiable digital data.
4

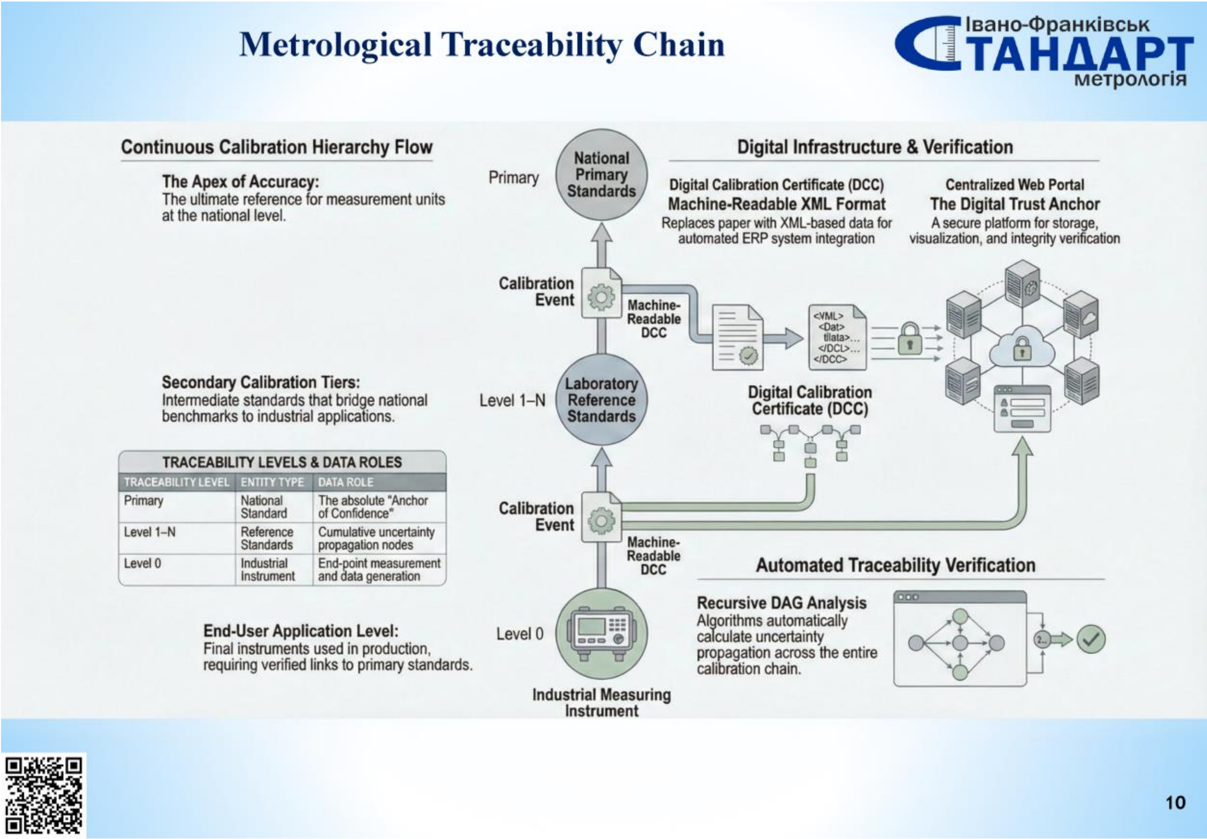

Digital Calibration Certificates (DCC)
Івано-Франківськ
СТАНДАРТ
метрологія
Enabling Automated Processing with Structured, Machine-Readable Data.
KEY FEATURES
Machine-readable format
Data is easily interpretable by software for automation.
Structured data (XML)
Organized in a standardized, hierarchical format.
Measurement results + uncertainty
Includes complete measurement data and associated uncertainty information.
THE DCC ADVANTAGE
Traditional PDF Certificate
Static, Manual, Human-Readable
Digital Calibration Certificate (DCC)
Dynamic, Automated, Machine-Readable
Unlike PDFs, DCCs provide structured, machine-readable data that include not only results, but also uncertainty information and metadata required for automated processing, enabling seamless integration into digital workflows.
5

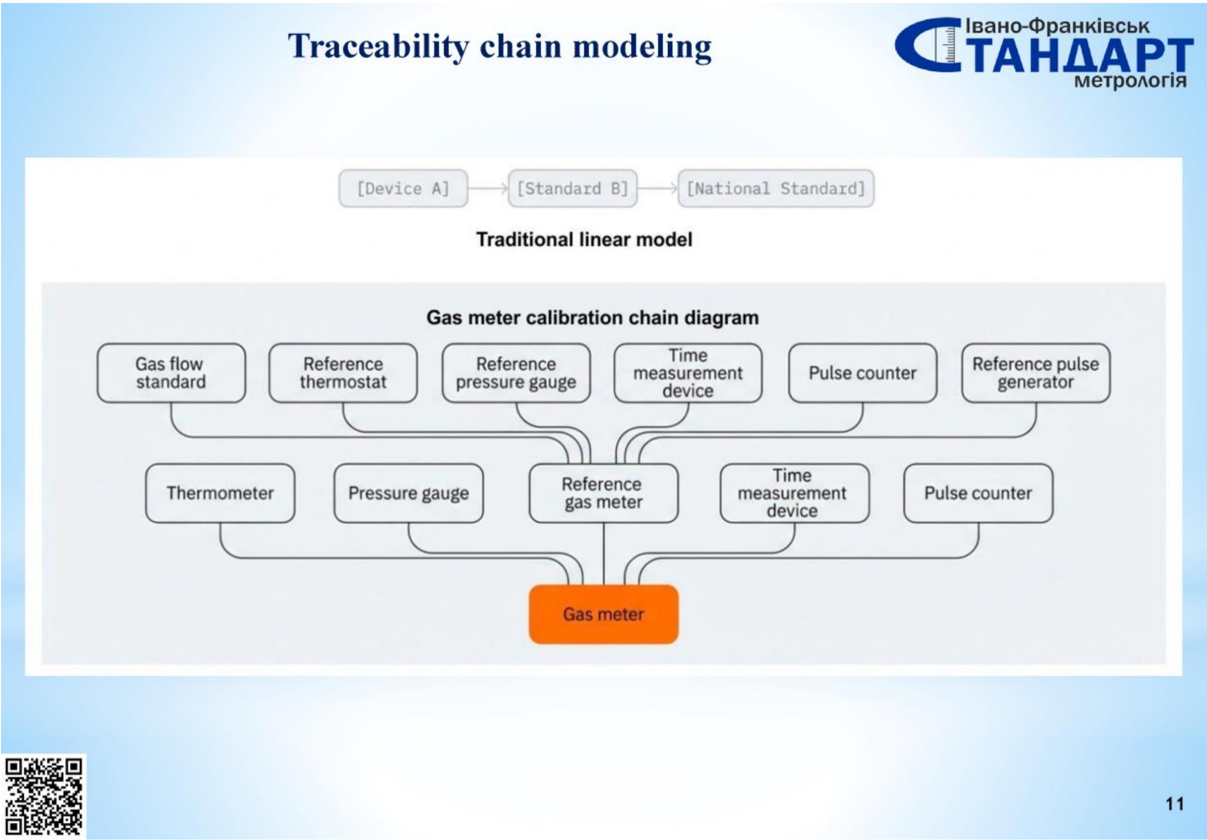

Analog calibration certificate
Івано-Франківськ
СТАНДАРТ
метрологія
Сертифікат калібрування
Calibration certificate
CIPM MRA
6

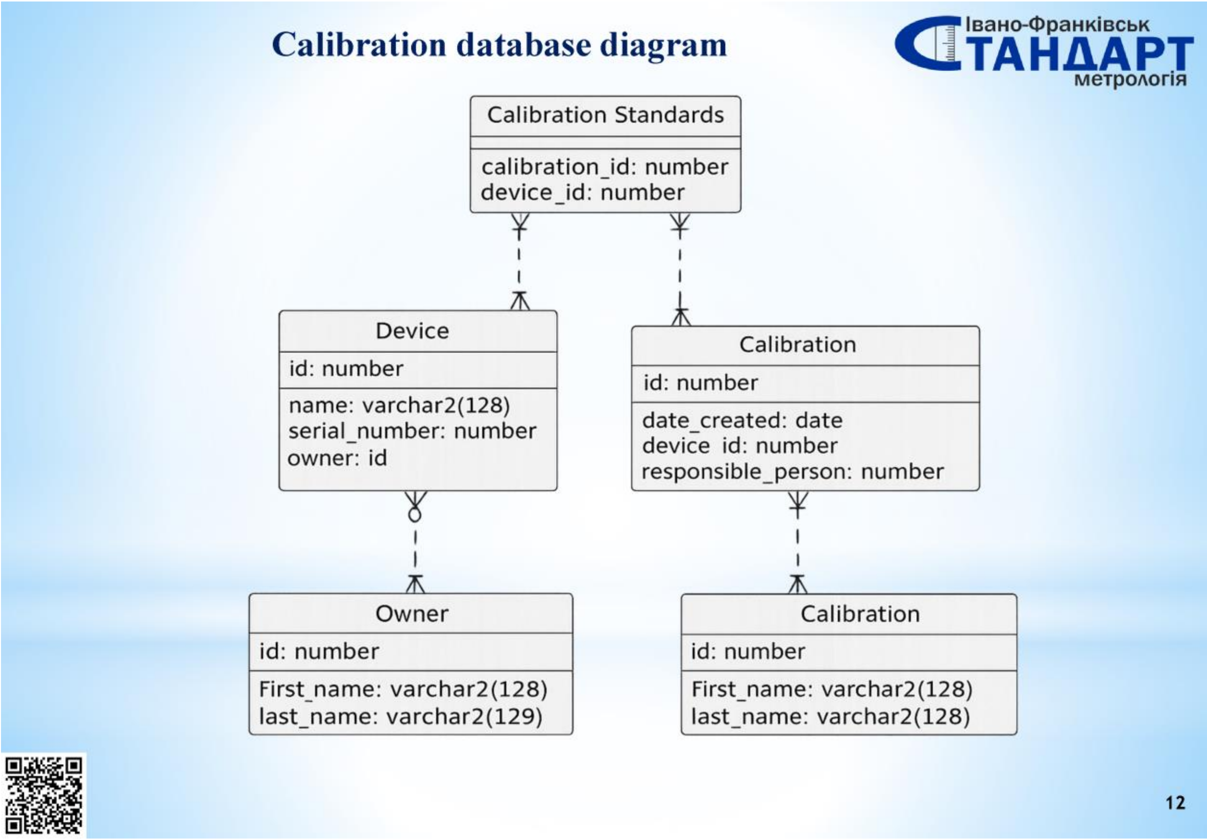

Process for creating a digital calibration certificate template (XML)
Івано-Франківськ
СТАНДАРТ
метрологія
www.gemimeg.ptb.de/gemimeg-tool/
GEMIMEG v1.4.1
Create a new DCC or load a existing one
TEMPERATURE
AIR PRESSURE
HUMIDITY
CREATE NEW DCC
There are no last loaded files
LOAD EXISTING DCC
Supported DCC Versions: v3.0.0 - v3.2.1
Attention: This tool is a demonstrator. It should not be used in a production environment.
NEXT STEP
Notepad++
D:\DCC\DCC RL 0,5 - 5.xml - Notepad++
<?xml version="1.0" encoding="UTF-8"?>
<dcc:digitalCalibrationCertificate xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance" xmlns:dcc="https://ptb.de/dcc"
<dcc:administrativeData>
<dcc:measurementResults>
<dcc:document>
<dcc:fileName>human_readable.html</dcc:fileName>
<dcc:mimeType>text/html</dcc:mimeType>
</dcc:document>
</dcc:digitalCalibrationCertificate>
7

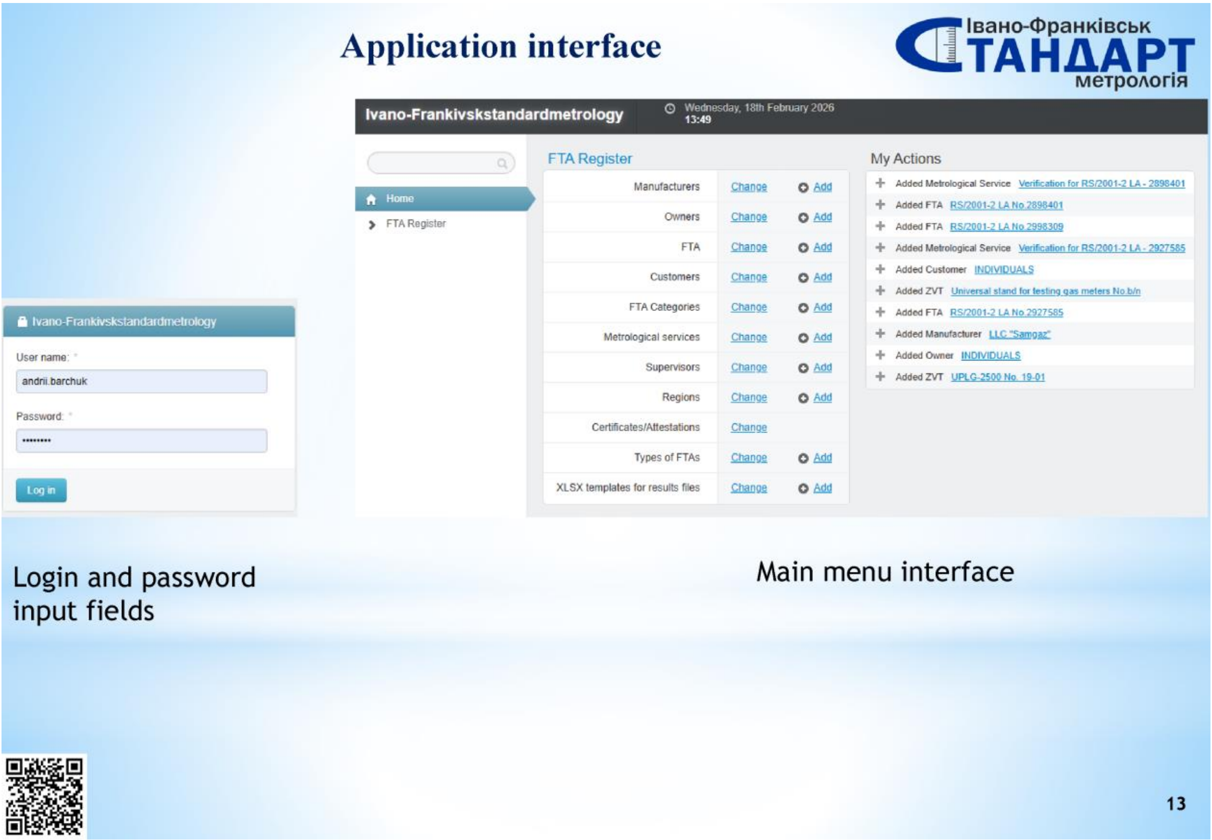

Functional diagram of the application
Івано-Франківськ
СТАНДАРТ
метрологія
Step 1
The user chooses the method of data entry
Manual input
or
Import from excel
Step 2
Entering insufficient information, depending on the selected data filling method.
ABC
Insert missing data
Step 3
Filling the certificate template with the data entered by the user of the software
Merging process
JMX
PDF
Template database
Step 4
Creation of a .txt protocol that contains all the entered information
TXT
Creating .txt protocol
Step 6
Uploading the certificate to the cloud. (Not available in current version)
Cloud database
Digital calibration certificates
Step 5
Generation of a certificate according to the type selected by the user
8

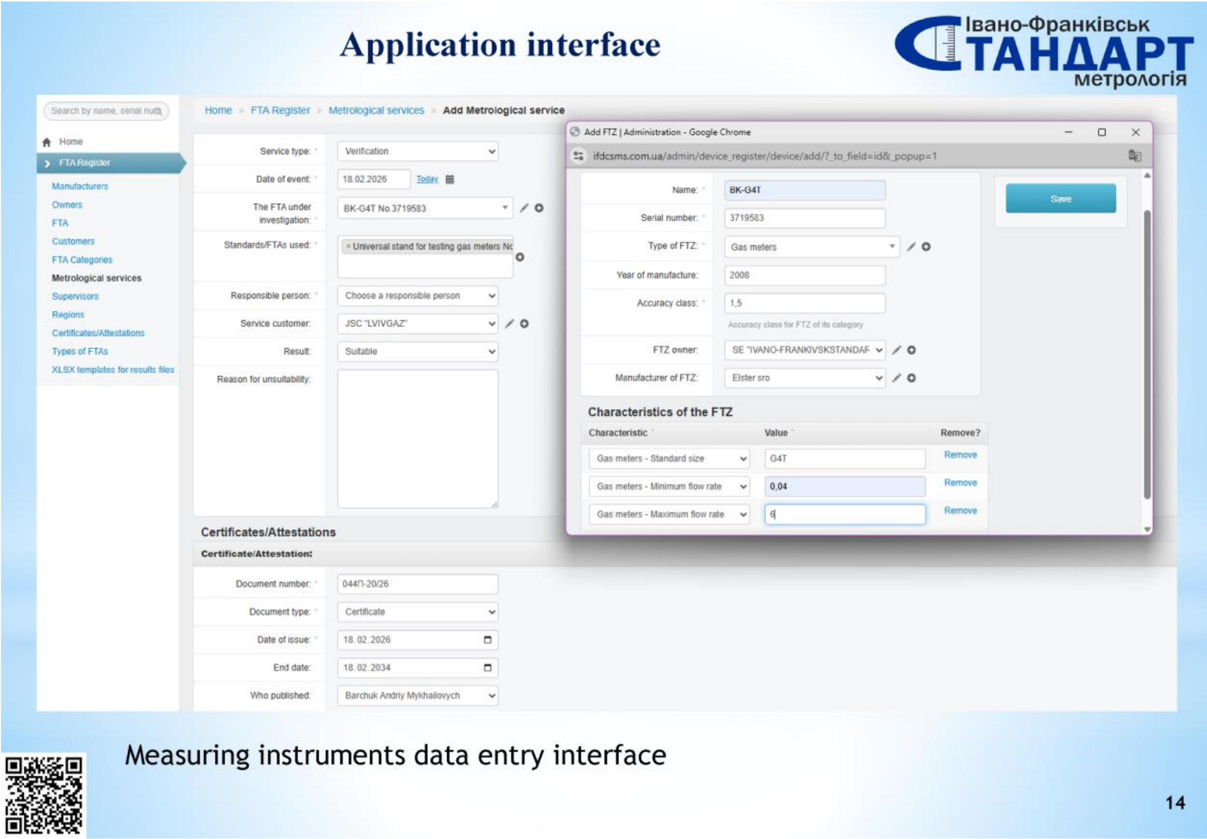

Problem: Traceability Is More Than One Certificate
Івано-Франківськ
СТАНДАРТ
метрологія
• Traceability ≠ last calibration
• Hidden calibration steps
• No end-to-end visibility
Calibration Certificate
Not Enough!
The Full Calibration Chain
National Standards
Hidden Steps?
Reference Lab A
Reference Lab B
Reference Lab C
?
?
Limited Visibility
Your Instrument
Traceability is a chain of calibrations, often branched and hidden.
9

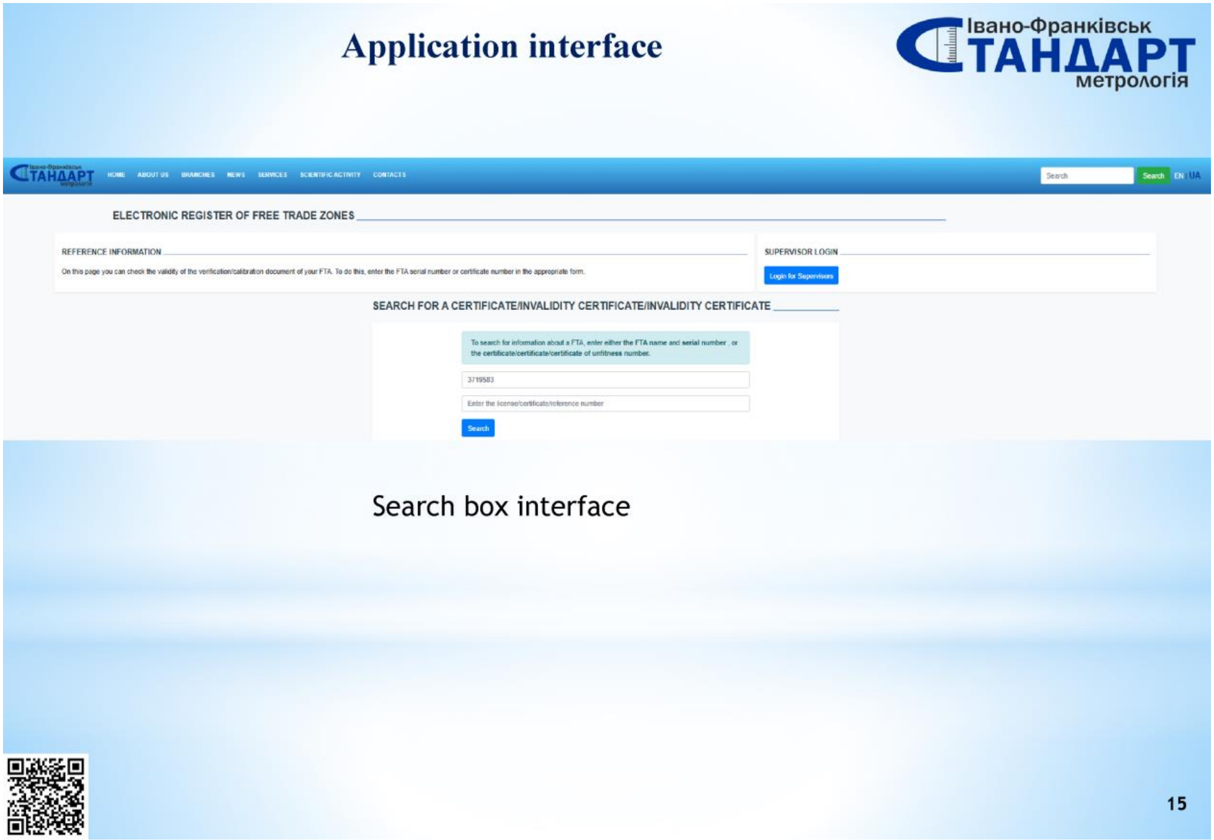

Metrological Traceability Chain
Івано-Франківськ
СТАНДАРТ
метрологія
Continuous Calibration Hierarchy Flow
The Apex of Accuracy:
The ultimate reference for measurement units at the national level.
Secondary Calibration Tiers:
Intermediate standards that bridge national benchmarks to industrial applications.
TRACEABILITY LEVELS & DATA ROLES
TRACEABILITY LEVEL | ENTITY TYPE | DATA ROLE
Primary | National Standard | The absolute "Anchor of Confidence"
Level 1–N | Reference Standards | Cumulative uncertainty propagation nodes
Level 0 | Industrial Instrument | End-point measurement and data generation
End-User Application Level:
Final instruments used in production, requiring verified links to primary standards.
Primary
National Primary Standards
Calibration Event
Machine-Readable DCC
Level 1–N
Laboratory Reference Standards
Calibration Event
Machine-Readable DCC
Level 0
Industrial Measuring Instrument
Digital Infrastructure & Verification
Digital Calibration Certificate (DCC)
Machine-Readable XML Format
Replaces paper with XML-based data for automated ERP system integration
Centralized Web Portal
The Digital Trust Anchor
A secure platform for storage, visualization, and integrity verification
Digital Calibration Certificate (DCC)
Automated Traceability Verification
Recursive DAG Analysis
Algorithms automatically calculate uncertainty propagation across the entire calibration chain.
10


Traceability chain modeling
Івано-Франківськ
СТАНДАРТ
метрологія
[Device A]
[Standard B]
[National Standard]
Traditional linear model
Gas meter calibration chain diagram
Gas flow standard
Reference thermostat
Reference pressure gauge
Time measurement device
Pulse counter
Reference pulse generator
Thermometer
Pressure gauge
Reference gas meter
Time measurement device
Pulse counter
Gas meter
11


Calibration database diagram
Івано-Франківськ
СТАНДАРТ
метрологія
Calibration Standards
calibration_id: number
device_id: number
Device
id: number
name: varchar2(128)
serial_number: number
owner: id
Calibration
id: number
date_created: date
device_id: number
responsible_person: number
Owner
id: number
First_name: varchar2(128)
last_name: varchar2(129)
Calibration
id: number
First_name: varchar2(128)
last_name: varchar2(128)
12


Application interface
Івано-Франківськ
СТАНДАРТ
метрологія
Ivano-Frankivskstandardmetrology
Wednesday, 18th February 2026
13:49
Home
FTA Register
FTA Register
Manufacturers Change Add
Owners Change Add
FTA Change Add
Customers Change Add
FTA Categories Change Add
Metrological services Change Add
Supervisors Change Add
Regions Change Add
Certificates/Attestations Change
Types of FTAs Change Add
XLSX templates for results files Change Add
My Actions
Added Metrological Service Verification for RS/2001-2 LA - 2898401
Added FTA RS/2001-2 LA No.2898401
Added FTA RS/2001-2 LA No.2998309
Added Metrological Service Verification for RS/2001-2 LA - 2927585
Added Customer INDIVIDUALS
Added ZVT Universal stand for testing gas meters No b/n
Added FTA RS/2001-2 LA No.2927585
Added Manufacturer LLC "Samgaz"
Added Owner INDIVIDUALS
Added ZVT UPLG-2500 No. 19-01
Ivano-Frankivskstandardmetrology
User name:
andrii.barchuk
Password:
Log in
Login and password input fields
Main menu interface
13


Application interface
Івано-Франківськ
СТАНДАРТ
метрологія
Home » FTA Register » Metrological services » Add Metrological service
Home
FTA Register
Manufacturers
Owners
FTA
Customers
FTA Categories
Metrological services
Supervisors
Regions
Certificates/Attestations
Types of FTAs
XLSX templates for results files
Service type: Verification
Date of event: 18.02.2026 Today
The FTA under investigation: BK-G4T No 3719583
Standards/FTAs used: × Universal stand for testing gas meters Nc
Responsible person: Choose a responsible person
Service customer: JSC "LVIVGAZ"
Result: Suitable
Reason for unsuitability:
Certificates/Attestations
Certificate/Attestation:
Document number: 044П-20/26
Document type: Certificate
Date of issue: 18.02.2026
End date: 18.02.2034
Who published: Barchuk Andriy Mykhailovych
Add FTZ | Administration - Google Chrome
ifdcsms.com.ua/admin/device_register/device/add/?_to_field=id&_popup=1
Name: BK-G4T
Serial number: 3719583
Type of FTZ: Gas meters
Year of manufacture: 2008
Accuracy class: 1,5
Accuracy class for FTZ of its category
FTZ owner: SE "IVANO-FRANKIVSKSTANDAR
Manufacturer of FTZ: Elster sro
Save
Characteristics of the FTZ
Characteristic
Value
Remove?
Gas meters - Standard size
G4T
Remove
Gas meters - Minimum flow rate
0,04
Remove
Gas meters - Maximum flow rate
6
Remove
Measuring instruments data entry interface
14


Application interface
Івано-Франківськ
СТАНДАРТ
метрологія
HOME
ABOUT US
BRANCHES
NEWS
SERVICES
SCIENTIFIC ACTIVITY
CONTACTS
Search
EN UA
ELECTRONIC REGISTER OF FREE TRADE ZONES
REFERENCE INFORMATION
On this page you can check the validity of the verification/calibration document of your FTA. To do this, enter the FTA serial number or certificate number in the appropriate form.
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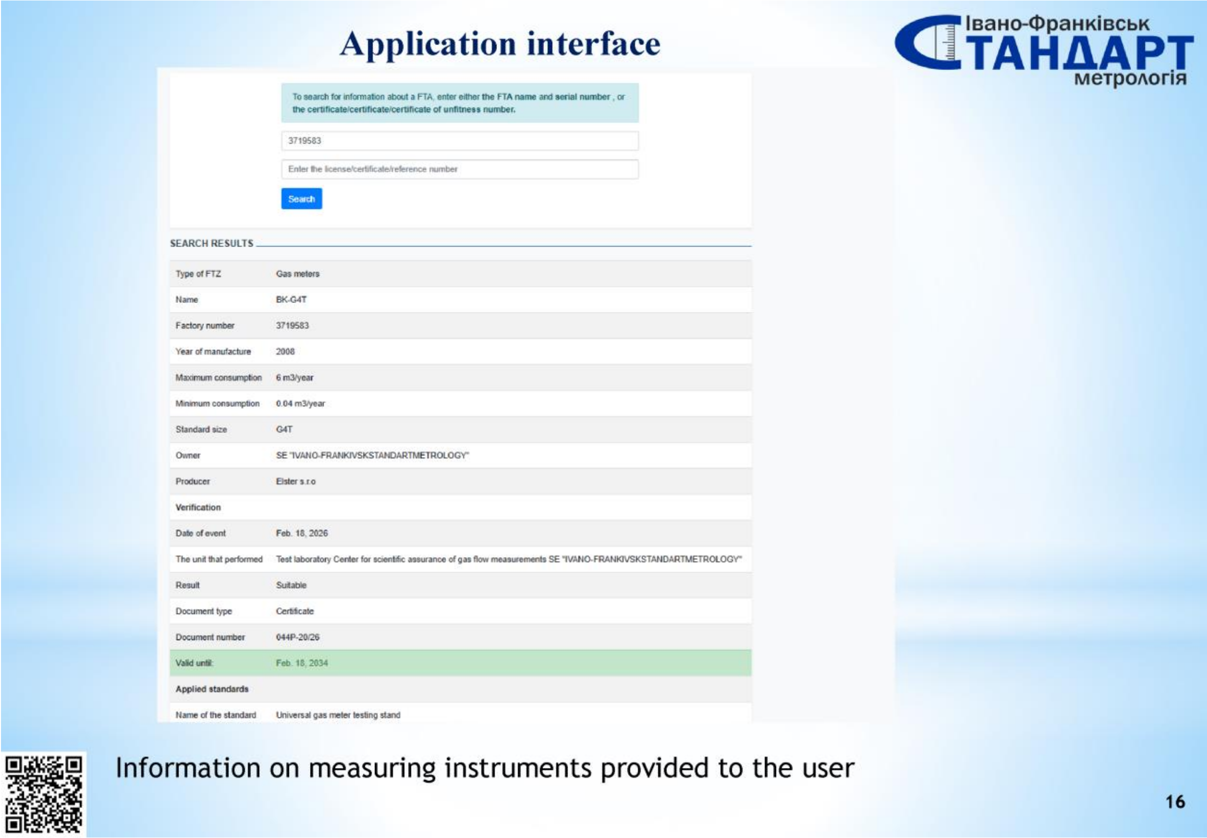
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Type of FTZ
Gas meters
Name
BK-G4T
Factory number
3719583
Year of manufacture
2008
Maximum consumption
6 m3/year
Minimum consumption
0.04 m3/year
Standard size
G4T
Owner
SE "IVANO-FRANKIVSKSTANDARTMETROLOGY"
Producer
Elster s.r.o
Verification
Date of event
Feb. 18, 2026
The unit that performed
Test laboratory Center for scientific assurance of gas flow measurements SE "IVANO-FRANKIVSKSTANDARTMETROLOGY"
Result
Suitable
Document type
Certificate
Document number
044P-20/26
Valid until:
Feb. 18, 2034
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Universal gas meter testing stand
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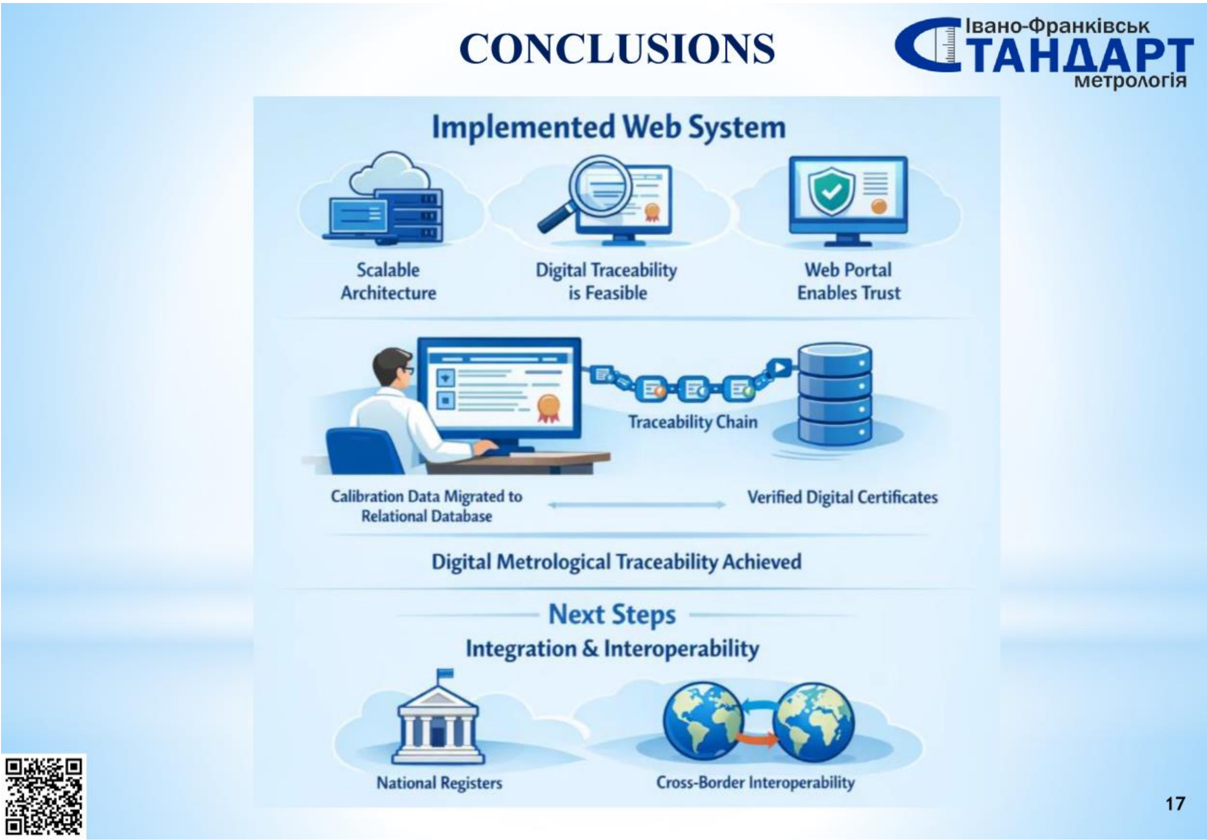
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QR: https://free-qr.com/link/XyYGdRFHsminrPsQ

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012 Mauricio Sáchica: Process Automation in Metrology: A Use Case for Enhanced Accuracy and Efficiency

Presenting author: Mauricio Sáchica [1]
E-mail address: msachica@inm.gov.co
Additional authors:

- M. Sachica [1],
- N. Vargas [1],
- F. Rubiano [1]

Institute:
[1] Instituto Nacional de Metrología de Colombia, Avenida Carrera 50 No. 26 – 55 Interior 2 CAN, Bogotá, Colombia
Keywords: Process automation, Electrical metrology, Characterization of measurement standards, Data processing, Interoperability

Abstract

The Direct and Alternating Current Laboratory of the National Metrology Institute of Colombia has developed software tools in multiple programming languages to automate data acquisition, processing, and analysis. This automation enabled process optimization, the maintenance of measurement standards, and the characterization and prediction of values.

A major advantage of most electrical measurement systems is their ease of automation through various communication interfaces. This is particularly important given the large volume of data involved in calibration and measurement processes. Thus, in a routine calibration process, an application controls the equipment within the measurement system and automatically acquires measurement data, while an application records the environmental conditions. The generated data files are subsequently processed using an application or spreadsheet that requires reference standard values. These values are obtained from an application that predicts the reference values and their associated measurement uncertainty by analysing instrument behaviour based on information reported in calibration certificates and stored in a laboratory database [1].

Accordingly, the laboratory has developed a set of applications as part of the ongoing evolution of its automation systems, enabling the use of multiple communication protocols and programming languages. These applications are used together in an interoperable manner within measurement and calibration processes. The next step is to further optimize the automation systems in order to reduce manual tasks, improve interoperability, and generate Digital Calibration Certificates (DCCs). These DCCs will also populate the laboratory database, which is used to predict values, characterize measurement standards, perform intermediate checks, determine calibration intervals, and support other metrological activities. This approach enables the laboratory to maximize the use of non-redundant information and ensure reliable measurement results.

Thanks to automation, large volumes of data can be collected and used to characterize the behaviour of measurement standards, thereby enabling the reduction of measurement uncer-

tainty through improved knowledge and statistical analysis [1]. Automation not only optimizes processes but also improves measurement accuracy, making it a key asset in metrology.

References:

[1] Mauricio Sáchica, Alexander Martínez (2021): Prediction of measurement standard values to improve uncertainty, under well-defined drift conditions, in: Measurement: Sensors, Volume 18.

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Presentation #012 of Mauricio Sáchica

The printed version of the proceedings originally required submissions in .pdf or .pptx format. Unfortunately, the author did not submit their presentation in one of the requested formats by the end of the editorial deadline.

Please contact the author directly for more insights in the topic.

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013 Saad Bin Qoud: Digitally Linking BIPM Service and Smart KCDB Data Acquisition to NMCC Calibration Services Platform based on Fast API

Presenting author: Saad Bin Qoud [1]
E-mail address: s.qoud@saso.gov.sa
Additional authors:

- Fahad A. AlMuhlaki [1],
- Rayan A. AlYousefi [1],
- I. AlFaleh [1],
- N. Qahtani [1],
- A. El-Matarawey [2]

Institute:
[1] MCC-SASO- Saudi Arabia
[2] National Institute of Standards (NIS-Egypt)
Keywords: Digital Metrology, SI Traceability, FastAPI, Automation, Key Comparison, Database (KCDB), NMCC, SASO.

Abstract

The establishment and preservation of robust digital traceability to the International System of Units (SI) have become a foundational requirement in modern metrology, driven by increasing automation, data integration, and regulatory expectations for transparency and reproducibility. In this context, the National Metrology Institute (NMI) face insistent challenges in maintaining a consistent, verifiable, and up-to-date linkage between locally issued calibration certificates and internationally recognized reference data.

This paper introduces a novel software architecture that automates and digitizes the critical traceability pathway between the services of NMCC -SASO and the authoritative international reference data maintained by the Bureau International des Poids et Mesures (BIPM). The proposed solution is implemented as a RESTful middleware layer developed using the FastAPI framework, designed to interface programmatically with BIPM digital services, including the Key Comparison Database (KCDB). Through this interface, the system enables automated retrieval and synchronization of Service categories classification, SI Units, Quantities, Prefixes, Constants, Decisions, Certified Calibration and Measurement Capability (CMC) entries, reference values from key comparisons (KCs), and associated technical guidance documentation. By embedding live, authoritative international metrology data directly within the NMCC laboratory management environment, the platform enables automated validation of locally issued calibration certificates against the most current SI realizations and comparison outcomes. This approach eliminates reliance on manual data searches, substantially reduces the risk of transcription and interpretation errors, and ensures that each calibration certificate is accompanied by a transparent and auditable digital extraction linking it directly to the KCDB. The paper details the system architecture, including data flow design, API security and key management strategies, and mechanisms for ensuring data integrity and availability. A case study from an operational electrical standards laboratory is presented to demonstrate the system's effectiveness in streamlining compliance workflows, enhancing traceability assurance, and supporting sustained conformity with international metrological requirements. The proposed architecture

provides a scalable and extensible framework for advancing digital SI traceability across national calibration infrastructures.

Presentation #013 of Saad Bin Qoud

The printed version of the proceedings originally required submissions in .pdf or .pptx format. Unfortunately, the author did not submit their presentation in one of the requested formats by the end of the editorial deadline.

Please contact the author directly for more insights in the topic.

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014 Alexander Knaak: Presentation of the new website “Digital Metrology” (PTB) and open exchange

Presenting author: Alexander Knaak [1]
E-mail address: alexander.knaak@ptb.de
Institute:
[1] Physikalisch-Technische Bundesanstalt, Braunschweig, Germany
Additional authors: Nil
Keywords: Digitalization, Metrology, Digital Metrology

Abstract

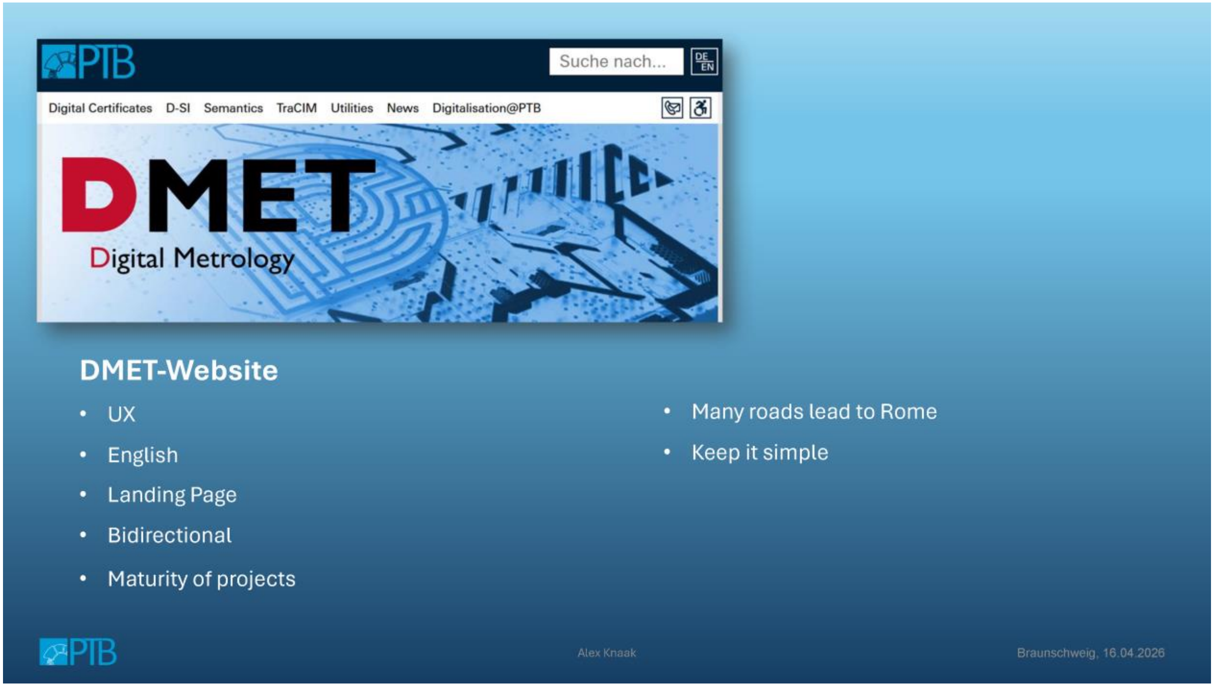
This presentation will highlight the main features of the upcoming new PTB website “Digital Metrology”, which will be accessible publicly in the next months.

The website will display all currently ready and planned digital certificates of PTB as well as many helpful tools and utilities to simplify the application of digital certificates. Furthermore there will be basic information about the Digitalisation of Metrology in general as well as the digitalisation of PTB itself.

After an overview of the structure of the website and some highlights, a discussion with the participants will hopefully generate new insights about expectations and needs from users outside of PTB and Germany.

References:
[1] https://www.dmet.ptb.de/

Presentation #014 of Alexander Knaak

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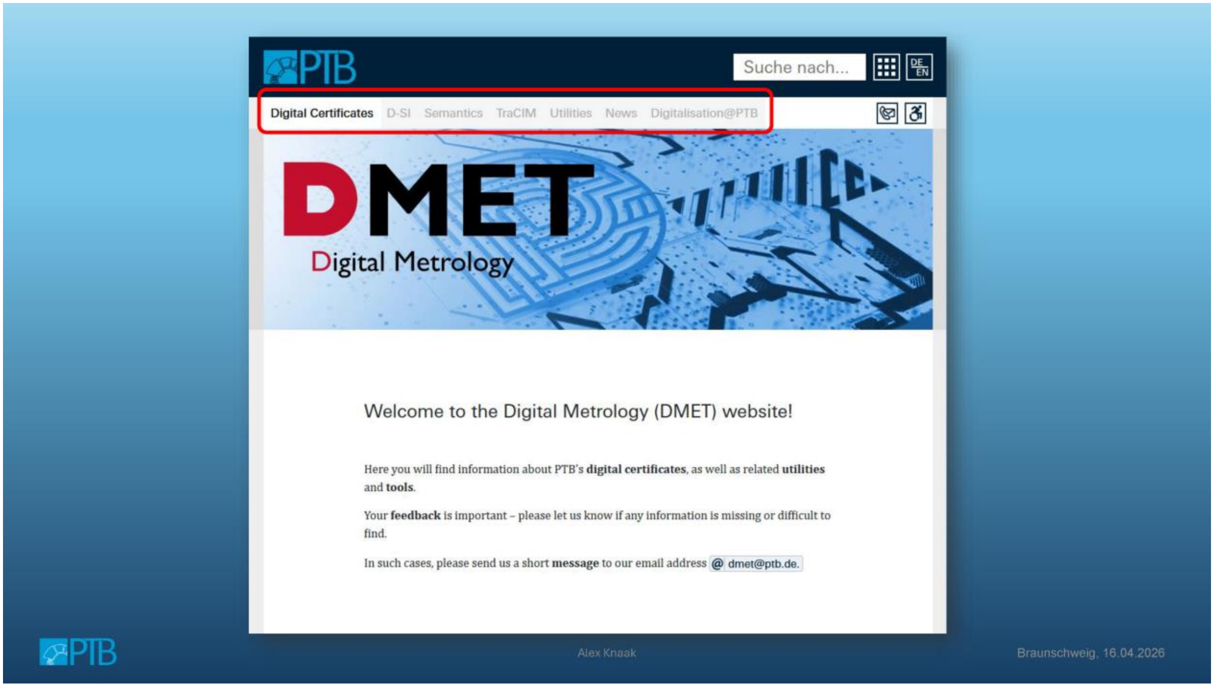
Digital Metrology
Timeline
Frühjahr 2025 – Konzeption
Sommer 2025 – Material-sammlung
Herbst 2025 – Seiten-aufbau
Winter 2025/2026 – Feintuning
16.04.2026 – Interne Präsentation PTB
Mai / Juni 2026 – externe Präsentation
Alex Knaak
Braunschweig, 22.05.2026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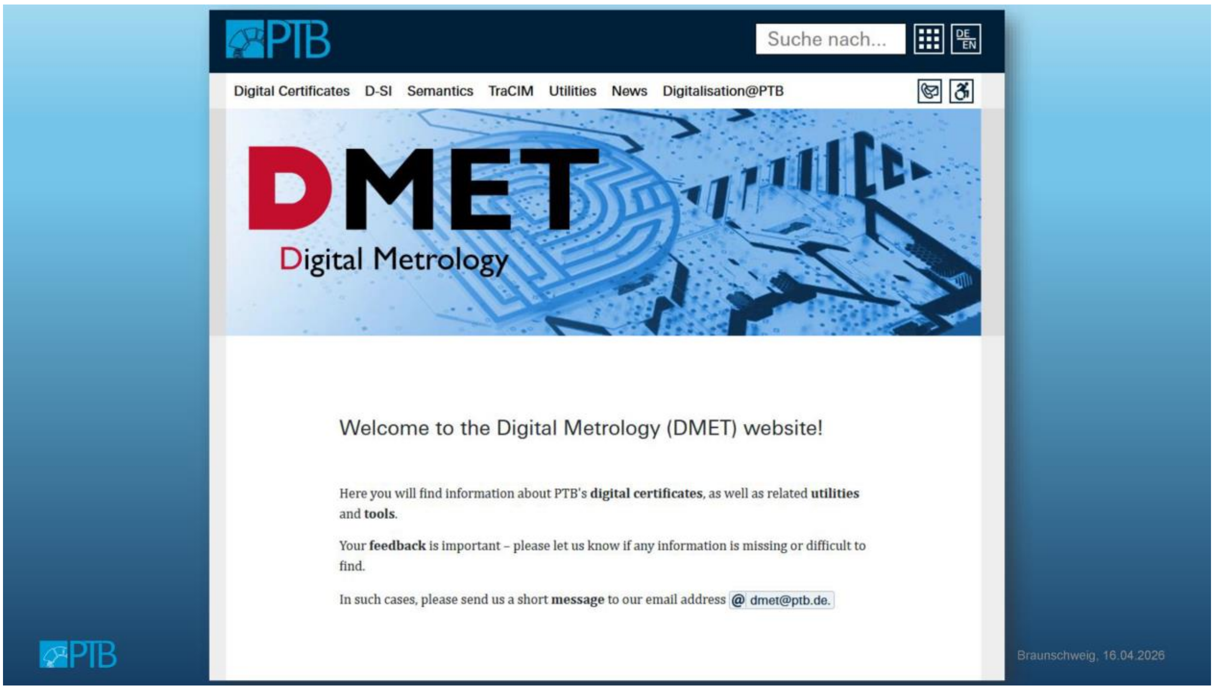
Welcome to the Digital Metrology (DMET) website!
Here you will find information about PTB's digital certificates, as well as related utilities and tools.
Your feedback is important – please let us know if any information is missing or difficult to find.
In such cases, please send us a short message to our email address @ dmet@ptb.de.
Alex Knaak
Braunschweig, 16.04.2026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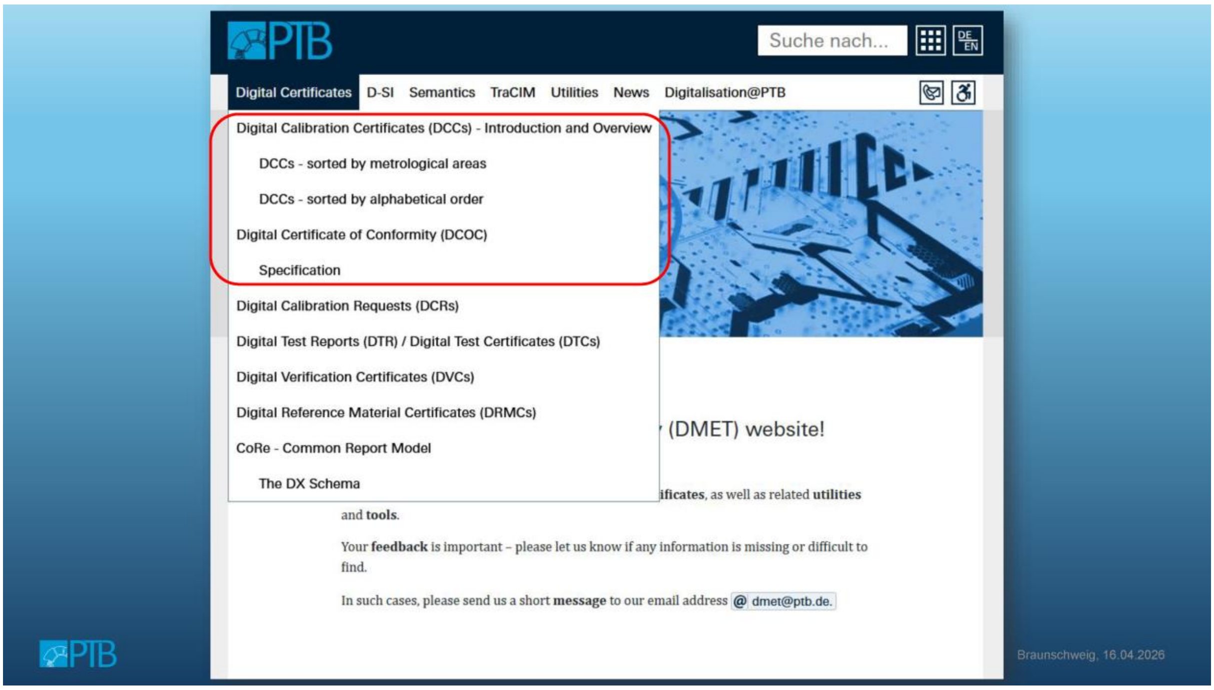
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DCCs - sorted by metrological areas
DCCs - sorted by alphabetical order
Digital Certificate of Conformity (DCOC)
Specification
Digital Calibration Requests (DCRs)
Digital Test Reports (DTR) / Digital Test Certificates (DTCs)
Digital Verification Certificates (DVCs)
Digital Reference Material Certificates (DRMCs)
CoRe - Common Report Model
The DX Schema
(DMET) website!
and tools.
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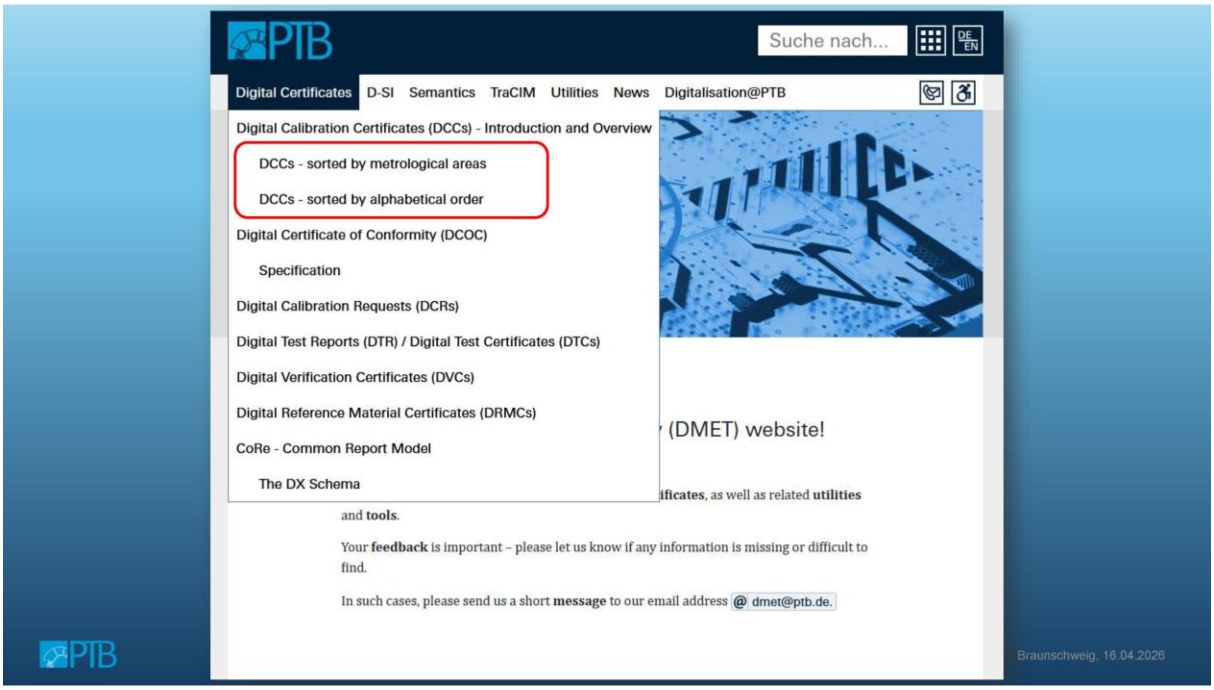
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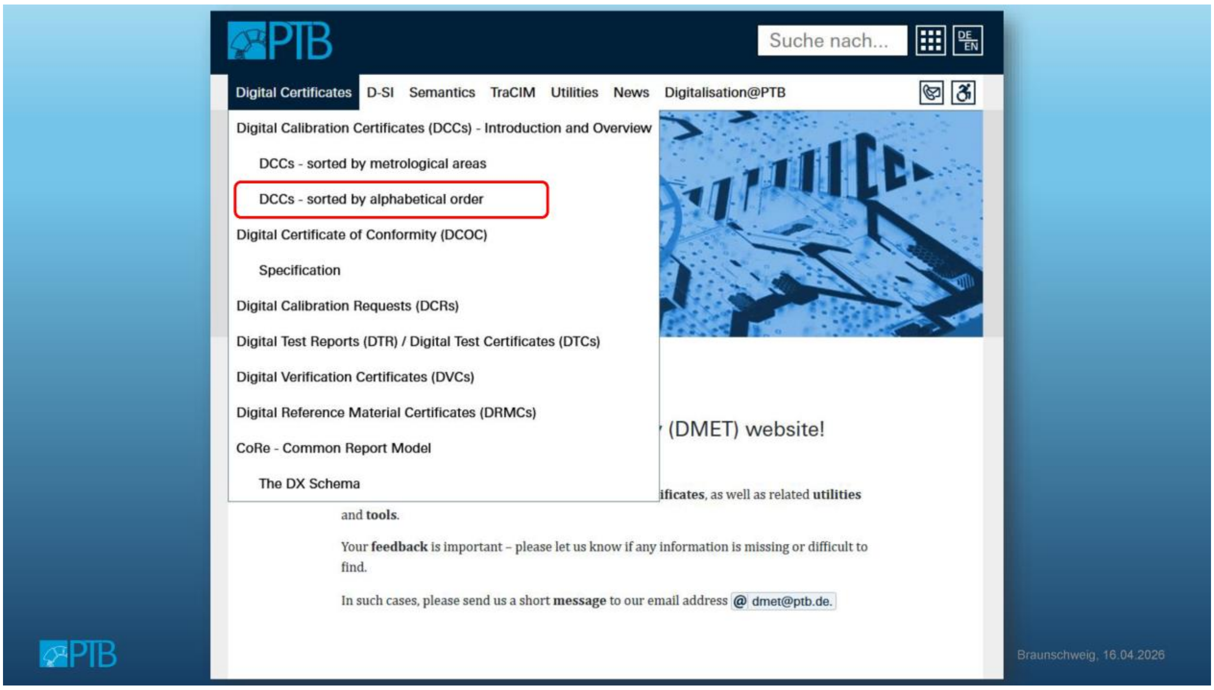
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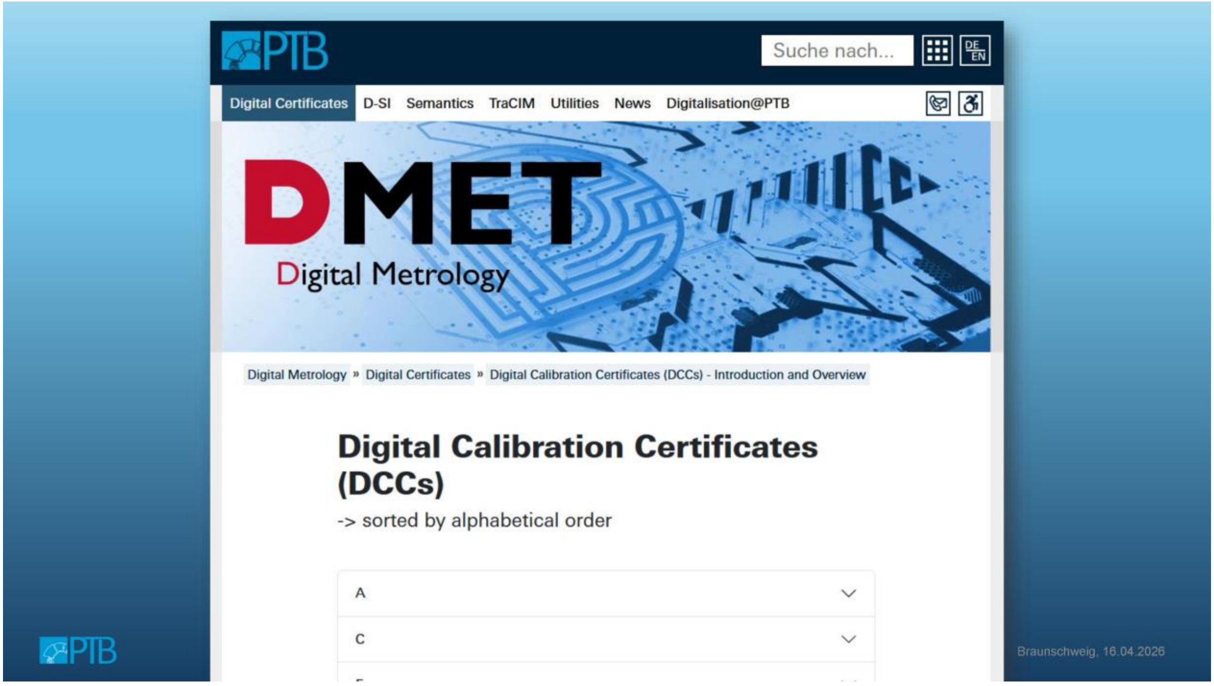
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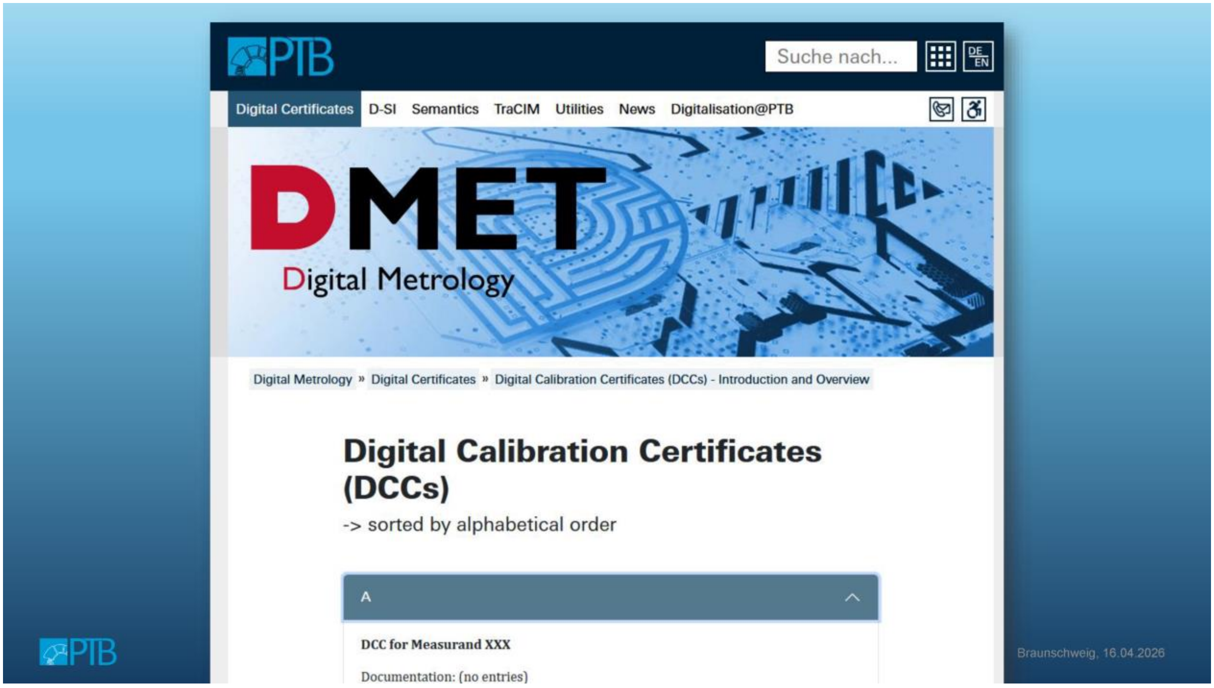
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Documentation: (no entries)
XML: (no entries)
Gitlab: (no entries)
contact: (no entries)
DCCs currently under development for:
• Acceleration sinusodial / sinusförmige Beschleunigung,
• Acceleration shock / Stoßbeschleunigung
Contact: @ Thomas Bruns (PTB) / +49 531 592 1700
Alex Knaak
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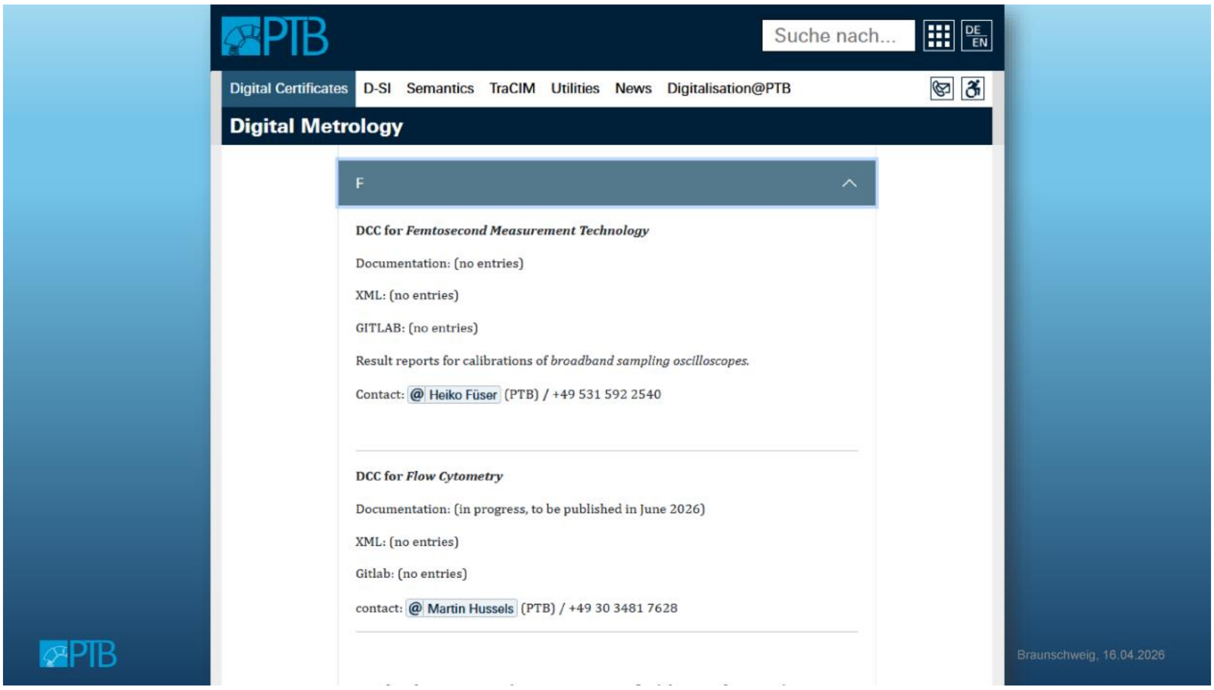
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DCC for Femtosecond Measurement Technology
Documentation: (no entries)
XML: (no entries)
GITLAB: (no entries)
Result reports for calibrations of broadband sampling oscilloscopes.
Contact: @ Heiko Füser (PTB) / +49 531 592 2540
DCC for Flow Cytometry
Documentation: (in progress, to be published in June 2026)
XML: (no entries)
Gitlab: (no entries)
contact: @ Martin Hussels (PTB) / +49 30 3481 7628
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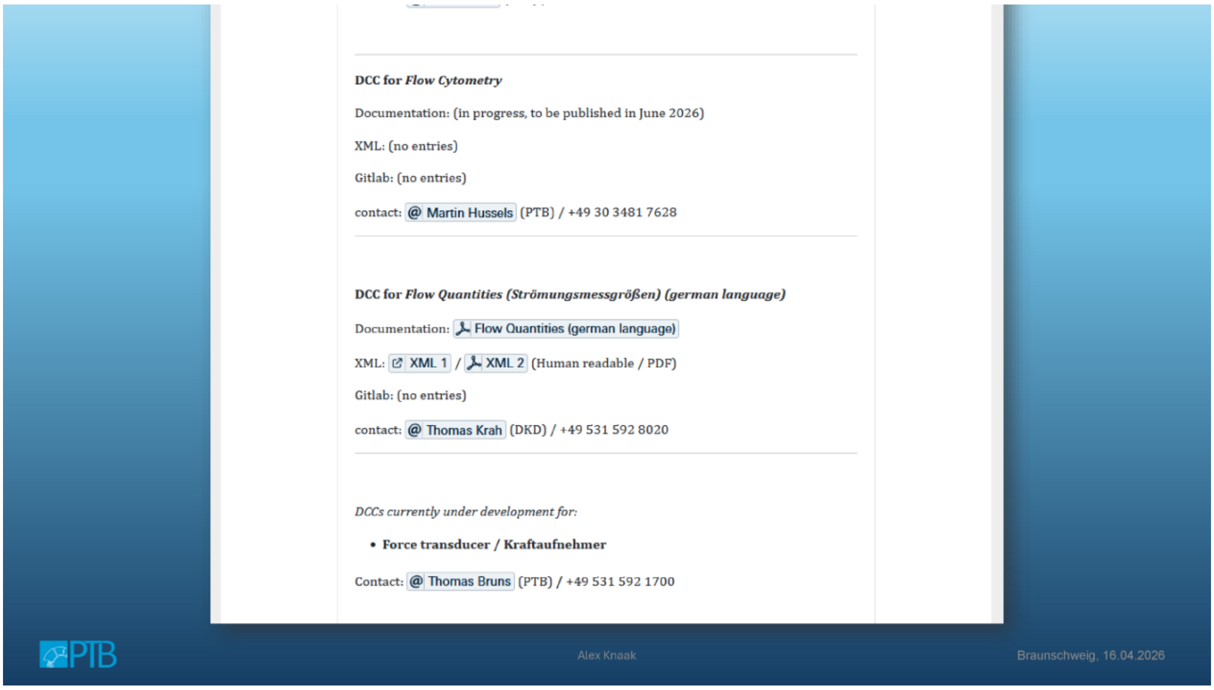
DCC for *Flow Cytometry*
Documentation: (in progress, to be published in June 2026)
XML: (no entries)
Gitlab: (no entries)
contact: @ Martin Hussels (PTB) / +49 30 3481 7628
DCC for *Flow Quantities (Strömungsmessgrößen) (german language)*
Documentation: Flow Quantities (german language)
XML: XML 1 / XML 2 (Human readable / PDF)
Gitlab: (no entries)
contact: @ Thomas Krah (DKD) / +49 531 592 8020
DCCs currently under development for:
• Force transducer / Kraftaufnehmer
Contact: @ Thomas Bruns (PTB) / +49 531 592 1700
Alex Knaak
Braunschweig, 16.04.2026


Please send questions and remarks to the following mail-address:
dmet@ptb.de
Alex Knaak
Braunschweig, 16.04.2026

Day 2 2026-02-25 Wednesday
Plenary Session
Session Chair: Anjali Sharma

P03 James Fedchak: Challenges in Creating DCCs

Presenting author: James Fedchak [1]
E-mail address: james.fedchak@nist.gov
Additional authors:

- Wei Ren [1]

Institute:
[1] National Institute of Standards and Technology: Physical Measurement Laboratory, 100
Keywords: DCC, calibration certificate generation, semantics, taxonomy.

Abstract

NIST was founded in 1901 and presently offers between 400 and 500 calibration services. Many have evolved organically over time; consequently, there are now a wide variety of calibration report (certificate) formats, data formats, and data repositories with formats and locations unique to various services. Report data and metadata come from several sources: an ecommerce system that contains customer metadata, the technical personnel performing the calibration, data and metadata contained in repositories local to the service, and data acquisition and analysis applications specific to the service. The digital transformation of such a large array of services and data sources with little to no harmonization of data and information formats among them is a daunting task. Nevertheless, we defined a goal to be able to generate a digital calibration report upon customer request. This task has several key elements: first we are developing an application to collect the calibration data and metadata and map it into a calibration report data model. The elements of that data model can then be mapped into a digital calibration certificate (DCC) [1], saved to a common repository, and used to generate a human readable report. We have now undertaken the project of creating a report generation application to accomplish these tasks. However, we have encountered many challenges in creating a DCC for NIST's services. For example, proper semantics and syntax for the uniquely identifying measurands for the plethora of quantities and measurands reported by NIST's services is a challenge. Creating an application flexible enough to handle the variety of human readable reports and data formats is another. And, after creating a DCC, can it be machine readable and interpretable by the applications of external customers? We will discuss these challenges and possible solutions in our evolving project to transform our measurement services.

References:
[1] https://www.ptb.de/dcc/DCC.xsd, version 3.3.0, last accessed: 01.01.2026

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Presentation #P03 of James Fedchak

Challenges in Creating DCCs

James Fedchak & Wei Ren

Physical Measurement Laboratory
National Institute of Standards and Technology

NATIONAL INSTITUTE OF STANDARDS AND TECHNOLOGY
U.S. DEPARTMENT OF COMMERCE

6th International DCC Conference
February 2026

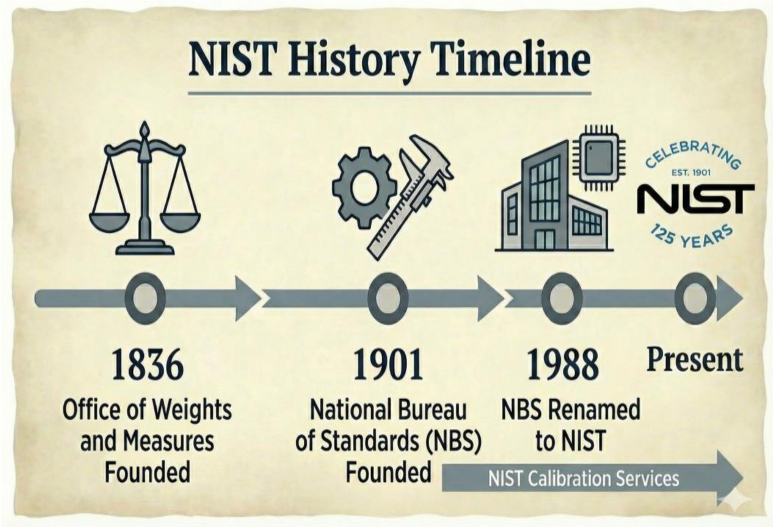
DCC and Digital Transformation

We will discuss our efforts to produce digital calibration reports (certificates) for NIST customers

- Little demand for DCC or other digital products
- However, US Industries and organizations want NIST's involvement, guidance, and leadership

Present efforts focus on:

- Develop ability to **produce DCC** for stakeholders
- **Increase internal efficiency**
- Develop tools for stakeholders to use DCCs and other digital products



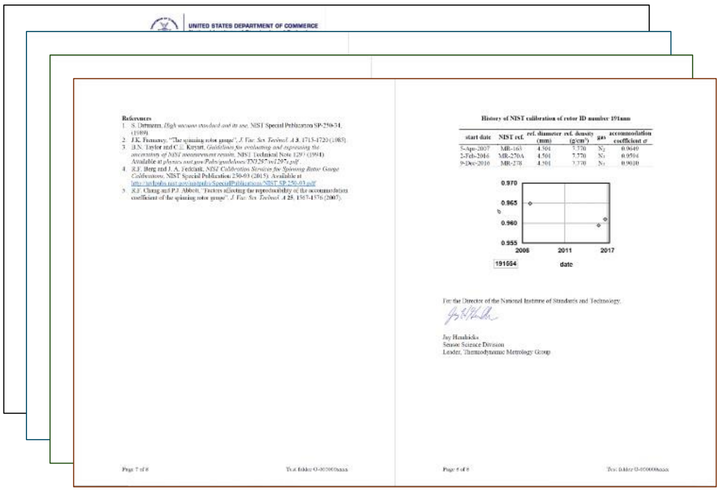
- NIST became the national standards laboratory for the US in 1901
- More than 100 years of measurement services
- Services have organically evolved over time

Digital Calibration Reports: Technical challenges

Digital Calibration Reports

Landscape of Technical Challenges

- NIST has between 400 - 500 services
- **Every report** seems to be a **different format**
  - NIST reports contain a lot of educational material
  - Often contain data history
- Report **metadata** & **data** comes from **various sources**
  - Customer metadata is collected through our e-commerce system
  - Other data & metadata comes from calibration operators or other databases
  - Local databases with unique formats



Example of NIST Calibration Report

Pages 1 and 2
- Report Metadata
- Calibration data
- Data from previous report

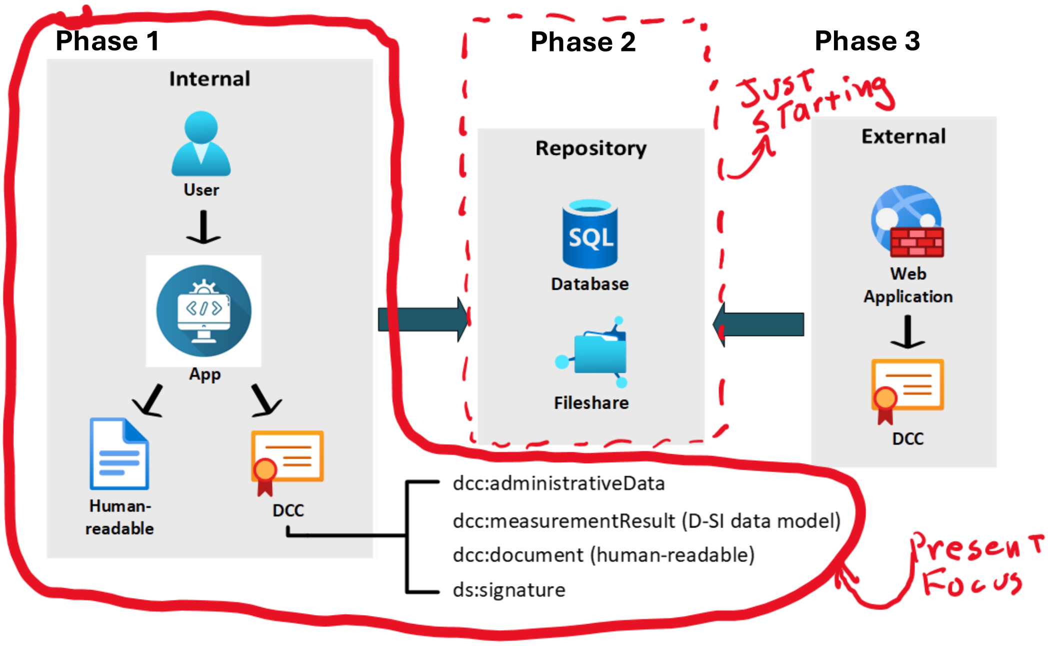
Pages 3 and 4
- Condition of items
- Description of methods
- Description of analysis
- Description of uncertainty budget
- Traceability Statement

Pages 5 and 6
- Description of uncertainty budget continued
- Additional comments

Pages 7 and 8
- References
- Tables and graphs of historic calibration data
- Signatures

Plan to create NIST DCC

- Phase 1 – Report Generation
  - Develop an internal Calibration Report Generation App
    - Produces human readable and DCCs
- Phase 2 – Data Model and Repository
  - Develop a comprehensive data model to support a data repository for the structured storage of measurement results, human-readable reports, and digital certificates.
- Phase 3 – Tools for External Stakeholders
  - Develop a Web App for external users to download digital certificates, browse history values and help to make decision about which measurement services best suit customer needs.



Phase 1:Develop a Report Template

NIST

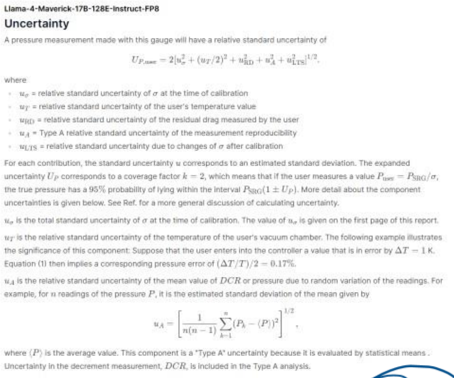
- We developed a calibration report template in LaTeX
- The application produces reports in a common template
- Report elements are now easy to identify
- Contains 17025 required elements

LaTeX has many advantages

- Allows complex formatting
  - Different style files
- LaTeX templates are robust
- Can be incorporated into a digital report
- AI tools make conversion to LaTeX easy

An LLM helps convert to LaTeX

This LLM helps convert to LaTeX
Little or no editing is needed!



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Uncertainty

A pressure measurement made with this gauge will have a relative standard uncertainty of

$$U_{P,\text{user}} = 2[u_\sigma^2 + (u_T/2)^2 + u_{\text{RD}}^2 + u_A^2 + u_{\text{LTS}}^2]^{1/2}.$$

where

- u_σ = relative standard uncertainty of σ at the time of calibration
- u_T = relative standard uncertainty of the user's temperature value
- u_{RD} = relative standard uncertainty of the residual drag measured by the user
- u_A = Type A relative standard uncertainty of the measurement reproducibility
- u_{LTS} = relative standard uncertainty due to changes of σ after calibration

For each contribution, the standard uncertainty u corresponds to an estimated standard deviation. The expanded uncertainty U_P corresponds to a coverage factor $k = 2$, which means that if the user measures a value $P_{\text{user}} = P_{\text{SRG}}/\sigma$, the true pressure has a 95% probability of lying within the interval $P_{\text{SRG}}(1 \pm U_P)$. More detail about the component uncertainties is given below. See Ref. for a more general discussion of calculating uncertainty.

u_σ is the total standard uncertainty of σ at the time of calibration. The value of u_σ is given on the first page of this report.

u_T is the relative standard uncertainty of the temperature of the user's vacuum chamber. The following example illustrates the significance of this component: Suppose that the user enters into the controller a value that is in error by $\Delta T = 1$ K. Equation (1) then implies a corresponding pressure error of $(\Delta T/T)/2 = 0.17\%$.

u_A is the relative standard uncertainty of the mean value of DCR or pressure due to random variation of the readings. For example, for n readings of the pressure P, it is the estimated standard deviation of the mean given by

$$u_A = \left[\frac{1}{n(n-1)}\sum_{k=1}^{n}(P_k - \langle P \rangle)^2\right]^{1/2},$$

where $\langle P \rangle$ is the average value. This component is a "Type A" uncertainty because it is evaluated by statistical means. Uncertainty in the decrement measurement, DCR, is included in the Type A analysis.

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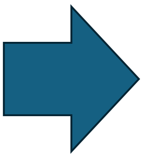

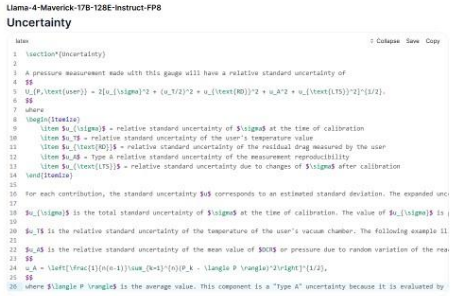

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Uncertainty

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\section*{Uncertainty}

A pressure measurement made with this gauge will have a relative standard uncertainty of
$$
U_{P,\text{user}} = 2[u_{\sigma}^2 + (u_T/2)^2 + u_{\text{RD}}^2 + u_A^2 + u_{\text{LTS}}^2]^{1/2}.
$$
where
\begin{itemize}
    \item $u_{\sigma}$ = relative standard uncertainty of $\sigma$ at the time of calibration
    \item $u_T$ = relative standard uncertainty of the user's temperature value
    \item $u_{\text{RD}}$ = relative standard uncertainty of the residual drag measured by the user
    \item $u_A$ = Type A relative standard uncertainty of the measurement reproducibility
    \item $u_{\text{LTS}}$ = relative standard uncertainty due to changes of $\sigma$ after calibration
\end{itemize}

For each contribution, the standard uncertainty $u$ corresponds to an estimated standard deviation. The expanded unc

$u_{\sigma}$ is the total standard uncertainty of $\sigma$ at the time of calibration. The value of $u_{\sigma}$ is

$u_T$ is the relative standard uncertainty of the temperature of the user's vacuum chamber. The following example il

$u_A$ is the relative standard uncertainty of the mean value of $DCR$ or pressure due to random variation of the rea
$$
u_A = \left[\frac{1}{n(n-1)}\sum_{k=1}^{n}(P_k - \langle P \rangle)^2\right]^{1/2},
$$
where $\langle P \rangle$ is the average value. This component is a "Type A" uncertainty because it is evaluated by
```

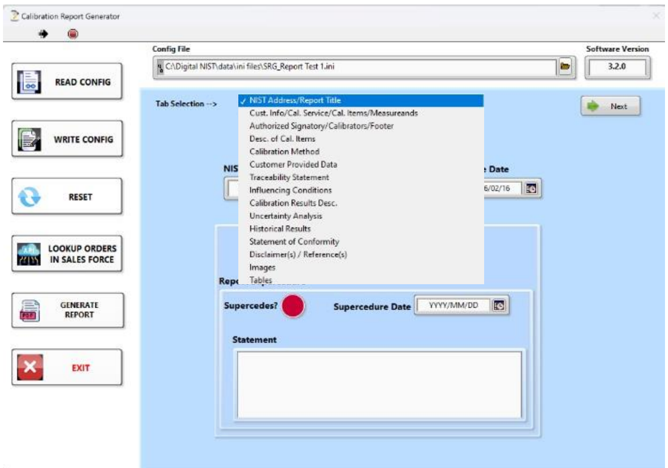
Phase 1: Report Generation Application

Vision of Cal Report Generation App

- Human readable reports
- Digital reports
- Places data in repository

Present version (in test stage)

- Pulls customer metadata from e-commerce system and other data bases
- Pulls required elements from a report template
- Allows user entry and editing
- Allows the importation of data into tables from various sources
- Allows importation of images.



Phase 1: Report Generation Application

NIST

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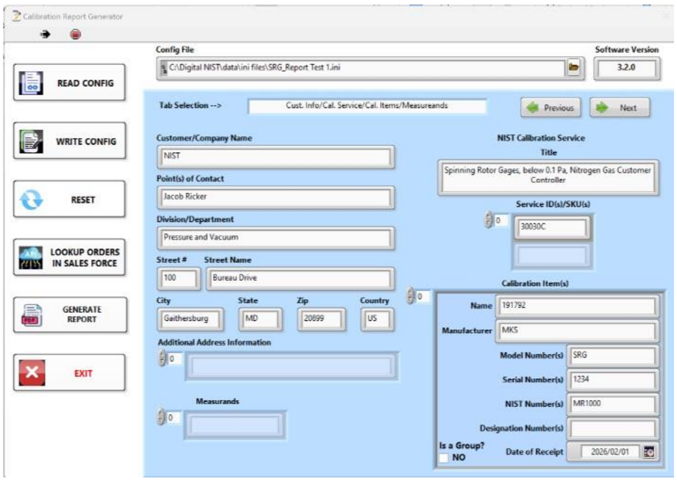

Phase 1: Report Generation Application

NIST

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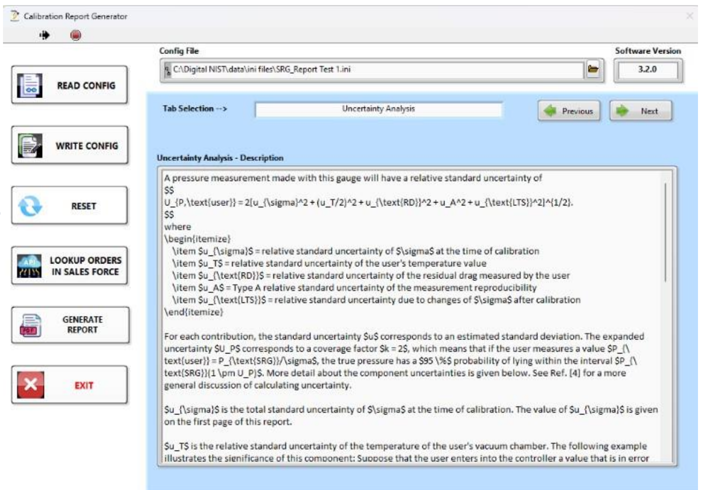
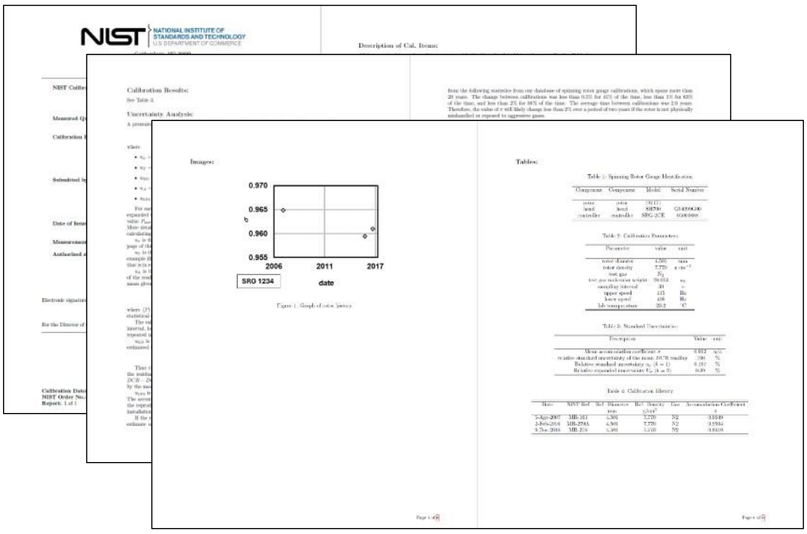


Generated Report



Application produces report in a standards format

Element for the DCC can be easily identified.

Challenges for Creating Digital Reports

We are using the dcc schema 3.3.0

Some challenges include:

- Semantics for measurands
- Representation of units

Challenge – measurement data

NIST

Gauge Block

Serial Number	Nominal Size	Deviation from Nominal	Deviation from Nominal	Expanded Uncertainty	Expanded Uncertainty	Thermal Coefficient
	(inches)	(microinch)	(nm)	(microinch)	(nm)	(ppm/deg.C)
3xx1	0.050000	-3.1	-79	1.6	40	11.5
29xx	0.062500	1.8	46	1.6	40	11.5
xx43	0.078125	0.6	16	1.6	40	11.5
xxxx	0.093750	2.2	55	1.6	40	11.5

Zerodur Standard

Nominal Length	Serial No.	Measured Length	Expanded Uncertainty
1066.8 mm	xxxxxxx	1069.061 581 mm	± 0.000 324

Ball Step Gauge

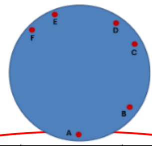
Serial #	ball #	3	4	5	6	7	8
8	X	0	84.978172	171.520669	347.529320	434.913054	519.931994
	Y	0	-0.0957902	-0.1773314	0.1774144	0.0947762	0
	Z	0	0.0809282	-0.0510297	0.1516302	-0.0531777	0

Step Gauge

Position	Measured Length (mm)
0	0.000 000
1	20.000 829
2	39.998 598
3	59.999 421
4	80.016 336
5	100.016 330
6	120.006 139
7	140.006 568

Center to center length

Pair	
AB	7.40026
AC	9.05156
AD	11.97934

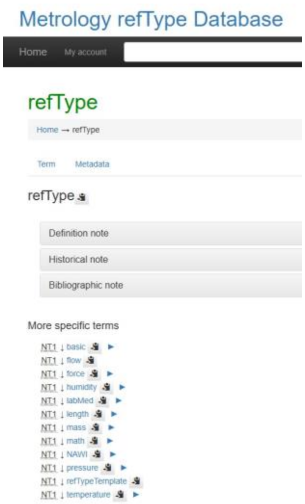


Sphere	Diameter (mm)	X (mm)	Y (mm)	Z (mm)
A	3.99808	0.00000	-60.57738	-0.04398
B	3.99817	51.93053	-30.77392	0.06518
C	3.99756	54.78614	25.70726	-0.02299
D	3.99793	33.46687	47.65531	-0.02495
E	3.99846	-15.34780	52.61138	-1.01232
F	3.99790	-30.60699	48.35448	0.13909

Metrology refType Database - PTB

NIST

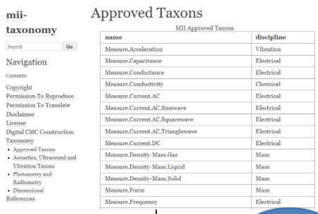
```xml
<dcc:data>
    <dcc:list>
        <dcc:quantity refType="length_nominalLength">
            <si:realListXMLList>
                <si:labelXMLList>4xxx 3xxx 2xxx 1xxx</si:labelXMLList>
                <si:valueXMLList>0.050000 0.062500 0.078125 0.093750</si:valueXMLList>
                <si:unitXMLList>\inch</si:unitXMLList>
            </si:realListXMLList>
        </dcc:quantity>

        <dcc:quantity refType="length_deviationFromNominalLength">
            <si:realListXMLList>
                <si:labelXMLList>4xxx 3xxx 2xxx 1xxx</si:labelXMLList>
                <si:valueXMLList>-3.1 1.8 0.6 2.2</si:valueXMLList>
                <si:unitXMLList>\micro\inch</si:unitXMLList>
                <si:expandedUncXMLList>
                    <si:uncertaintyXMLList>1.6 1.6 1.6 1.6</si:uncertaintyXMLList>
                    <si:coverageFactorXMLList>2</si:coverageFactorXMLList>
                    <si:coverageProbabilityXMLList>0.95</si:coverageProbabilityXMLList>
                </si:expandedUncXMLList>
            </si:realListXMLList>
        </dcc:quantity>

        <dcc:quantity refType="length_linearThermalExpansionCoefficient">
            <si:realListXMLList>
                <si:labelXMLList>4xxx 3xxx 2xxx 1xxx</si:labelXMLList>
                <si:valueXMLList>11.5 11.5 11.5 11.5</si:valueXMLList>
                <si:unitXMLList>\micro\degreecelsius\tothe{-1}</si:unitXMLList>
            </si:realListXMLList>
        </dcc:quantity>
    </dcc:list>
</dcc:data>
```



https://digilab.ptb.de/dkd/refType/vocab/index.php

Measurand Taxonomy - MII

```
<dcc:list>
    <dcc:quantity refType="Measure.Length_Length">
        <dcc:name>
            <dcc:content lang="en">Center to center distance AB</dcc:content>
        </dcc:name>
        <si:real>
            <si:label>AB</si:label>
            <si:value>7.67826</si:value>
            <si:unit>\milli\metre</si:unit>
            <si:expandedUnc>
                <si:uncertainty>0.00040</si:uncertainty>
                <si:coverageFactor>2</si:coverageFactor>
                <si:coverageProbability>0.95</si:coverageProbability>
            </si:expandedUnc>
        </si:real>
        <dcc:measurementMetaData>
            <dcc:metaData>
                <dcc:data>
                    <dcc:quantity refType="Measure.Length_StartPointX">
                        <si:real>
                            <si:value>0.00000</si:value>
                            <si:unit>\milli\metre</si:unit>
                        </si:real>
                    </dcc:quantity>
                    ...
                    <dcc:quantity refType="Measure.Length_EndPointZ">
                        <si:real>
                            <si:value>0.06198</si:value>
                            <si:unit>\milli\metre</si:unit>
                        </si:real>
                    </dcc:quantity>
                </dcc:data>
            </dcc:metaData>
        </dcc:measurementMetaData>
    </dcc:quantity>
        ...
</dcc:list>
```


mii-taxonomy

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- Acoustics, Ultrasound and Vibration Taxons
- Photometry and Radiometry
- Dimensional

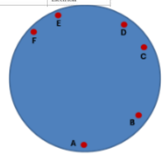
References

Approved Taxons

MII Approved Taxons

name	discipline
Measure.Acceleration	Vibration
Measure.Capacitance	Electrical
Measure.Conductance	Electrical
Measure.Conductivity	Chemical
Measure.Current.AC	Electrical
Measure.Current.AC.Sinewave	Electrical
Measure.Current.AC.Squarewave	Electrical
Measure.Current.AC.Trianglewave	Electrical
Measure.Current.DC	Electrical
Measure.Density-Mass.Gas	Mass
Measure.Density-Mass.Liquid	Mass
Measure.Density-Mass.Solid	Mass
Measure.Force	Mass
Measure.Frequency	Electrical

Center to center length	
Pair	
AB	7.67826
AC	10.43656
AD	10.96934



Sphere	Diameter (mm)	X (mm)	Y (mm)	Z (mm)
A	3.99998	0.00000	-60.45678	-0.14998
B	3.99967	51.93053	-30.76692	0.06198
C	3.99856	53.43614	28.70726	-0.26439
D	3.99893	33.46327	48.75531	-0.01995
E	3.99896	-15.34432	52.49038	-2.01542
F	3.99799	-20.79699	43.35448	1.13460

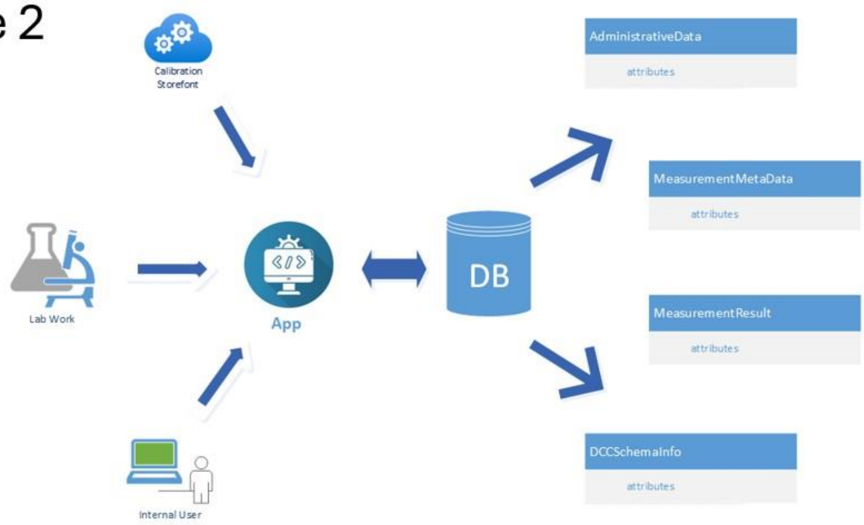
https://github.com/NCSLI-MII/measurand-taxonomy/blob/main/MeasurandTaxonomyCatalog.xml

Representation of units

- **This is a challenge we have not yet addressed**

- SI and non-SI units are used in reports
    - Can be defined in DCC schema
- SI units link to definitions in SI-reference point
- Possibly use D-SI
    - https://gitlab1.ptb.de/d-ptb/d-si/xsd-d-si

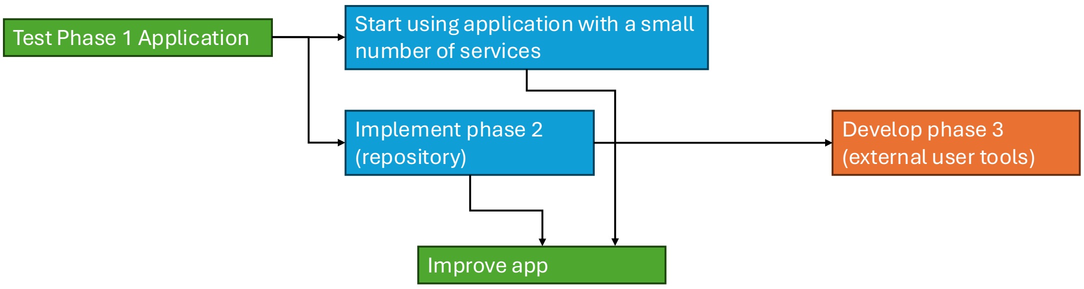
Phase 2



Summary

NIST

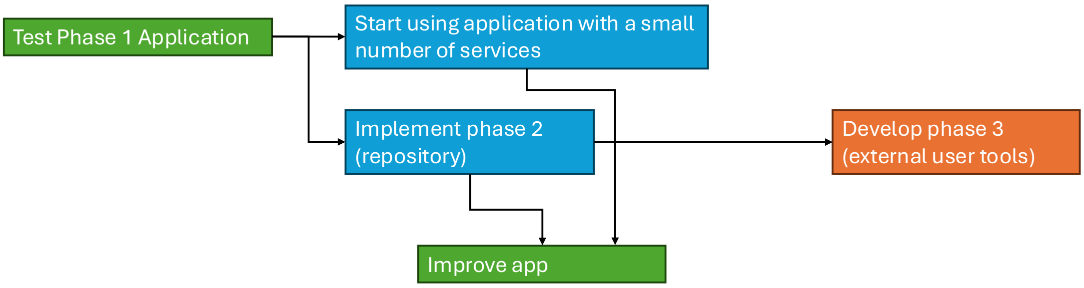
- We want to produce DCC upon request and give stakeholders digital access to their data
- We are developing an application and repository model to facilitate this
  - Presently, harmonized semantics formeaureands is required
- We will need to develop tools for external users to access DCCs and their data



Summary: what was not discussed

Challenges not discussed are related to infrastructure and culture

- Getting resources for development and implementation
- Getting calibration folks to adopt the new template and application
- Some services have their own automatic report generation which works well. How do we ingrate the new application?
- How do we fold historic databases into a common model?




Jim Fedchak


John Quintavalle


Wei Ren


Catherine Cooksey

Many thanks to the calibration digital transformation team

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P04 Christian Sander: Digital accreditation symbol: machine - readable, fraud - proof, and verifiable - benefits and experiences for the DCC

Presenting author: Christian Sander [1],
E-mail address: csander@testotis.de
Additional authors: Nil
Institute:
[1] Testo Industrial Services GmbH, Gewerbestraße 3, Kirchzarten, 79199, Germany
Keywords: Digital Quality Infrastructure, Digital Accreditation Symbol, Trusted Digital Attestations, Electronic Seal (eIDAS), Digital Calibration Certificate (DCC)

Abstract

The increasing digitalization of quality infrastructures and conformity assessment processes is transforming how accredited calibration laboratories create, secure, and communicate conformity statements. As industrial ecosystems adopt fully automated workflows, digital product passports, and machine-readable documentation, the need for trustworthy and technically verifiable digital attestations has become essential. This presentation introduces the concept, motivation, and practical experiences associated with the **Digital Accreditation Symbol** as implemented by the German Accreditation Body (DAkkS), and its integration into digital calibration certificates (DCCs) and other electronic conformity assessments.

The digital accreditation symbol acts as the machine-readable, tamper-evident counterpart to the traditional visual accreditation mark used in conformity assessments. Based on a qualified electronic seal—issued according to the EU eIDAS Regulation (EU No. 910/2014)—the system links the legal entity, accreditation number, accreditation activity, and issuing accreditation body into a cryptographically protected trust anchor. This ensures that digital conformity statements can be verified globally and in real time, independent of document format (PDF or XML), software environment, or data exchange platform.

The presentation outlines the technical architecture underlying the digital seal, the issuance and verification mechanisms, and the interoperability enabled through widely used validation services such as the EU DSS (Digital Signature Service) platform. Practical demonstrations illustrate how authenticity and integrity can be automatically validated in both PDF calibration certificates and XML-based DCCs, including detection of even minor modifications.

Finally, the presentation highlights the value for calibration laboratories and their customers: global real-time validation of accreditation status, strengthened protection against manipulation, the ability to replace legacy signature methods, and the acceleration of fully machine-driven processes. By enabling secure digital evidence chains, the DAkkS digital accreditation symbol forms a cornerstone for future-ready digital conformity assessment and supports the international deployment of digital calibration certificates.

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Presentation #P04 of Christian Sander

DR-ING. CHRISTIAN SANDER

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6TH INTERNATIONAL DCC CONFERENCE

Digital accreditation symbol:

machine-readable, fraud proof, and verifiable – benefits and experiences for the DCC

31.03.2026

www.testotis.de

Your speaker

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- Dr.-Ing Christian Sander
- csander@testotis.de
- www.testotis.de

- 2016 – Doctorate in MEMS technology at the University of Freiburg
- 2017 – Product engineer at TDK-Micronas in Freiburg
- 2018 – Metrology manager at Testo Industrial Services
- 2021 – Laboratory manager at Testo Industrial Services
- Since 2023 – Head of Innovation at Testo Industrial Services
- Since 2020 – Chair of the DKD Technical Committee for Length
- Since 2020 – Member of the German Accreditation Advisory Board in the field of metrology

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AGENDA

- DIGITAL QUALITY INFRASTRUCTURE AND DIGITAL SERVICES
- TECHNICAL AND LEGAL BASIS OF THE DIGITAL ACCREDITATION SYMBOL
- FAKE-PROOF AND AUTHENTIC
- IMPLEMENTATION AND APPLICATION
- ADDED VALUE FOR ACCREDITED BODIES AND THEIR CUSTOMERS

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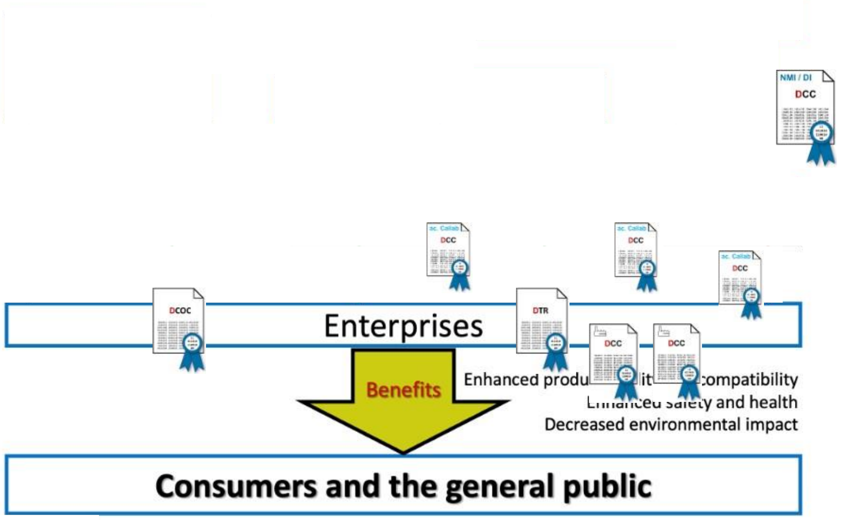
Quality Infrastructure



Source: Adapted from Guasch et al., Quality Systems and Standards for a Competitive Edge, The World Bank, 2007

Digital quality infrastructure

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- **Quality statements**, such as calibrations by accredited bodies, are required in international trade as evidence that products and services are **compliant**
  - Secure trust in conformity assessment
  - Chains of evidence are becoming increasingly digital (e.g., DPP)
- Industry and conformity assessment bodies are increasingly working in a digital interconnected and automated framework
  - **Digital attestations of conformity,** such as **DCC**, are being introduced
- The digital space poses risks for the reliability and recognition of conformity statements
  - **Trustworthy digital proof of accreditation**

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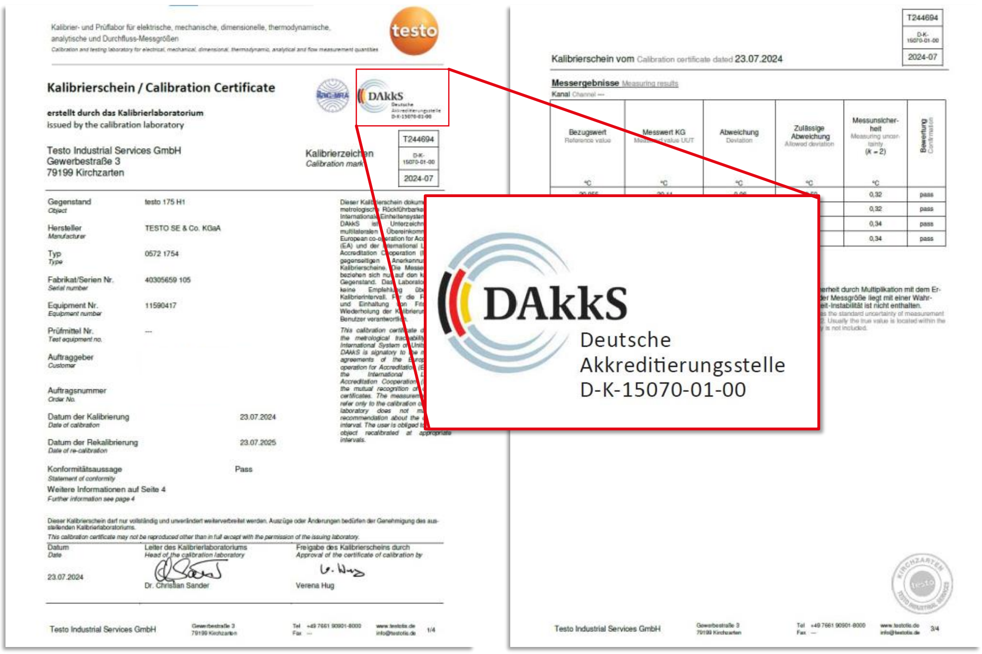

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Digital quality infrastructure

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  - **Digital attestations of conformity,** such as **DCC**, are being introduced
- The digital space poses risks for the reliability mutual recognition of conformity statements
  - **Trustworthy digital proof of accreditation**
- **Introduction of a digital accreditation symbol**
  - **QI-Digital with cooperation of DAkkS and BAM (Federal Institute for Materials and Testing) and many more**

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Goal of the digital accreditation symbol

Protection of accreditation statements in the digital space

Enable technically secure, machine-readable confirmation of conformity

Application in all sectors and accreditation activities

Supporting digital transformation

Enabling a secure global digital chain of traceability

Easy to use, cost-effective, globally scalable

Technical and legal requirements

- **Machine-readable counterpart** to the existing “pictorial” DAkkS **accreditation symbol**, which can be technically verified worldwide in real time
- The legal basis is the **eIDAS Regulation** (EU) No. 910/2014 – legal framework for electronic signatures, electronic seals, and electronic time stamps
- Technical basis is **electronic seal** – digital company stamp with **additional accreditation information**
  - Name of the legal entity (authenticity)
  - Intactness of document (integrity)
  - Unique accreditation number
    - e.g., DAkkS00-DE-K0-15070-01-00
  - Reference to accreditation body, country, and accreditation activity

DAkkS
Deutsche
Akkreditierungsstelle
D-K-15070-01-00

Requirements for Applying a Digital Seal under eIDAS

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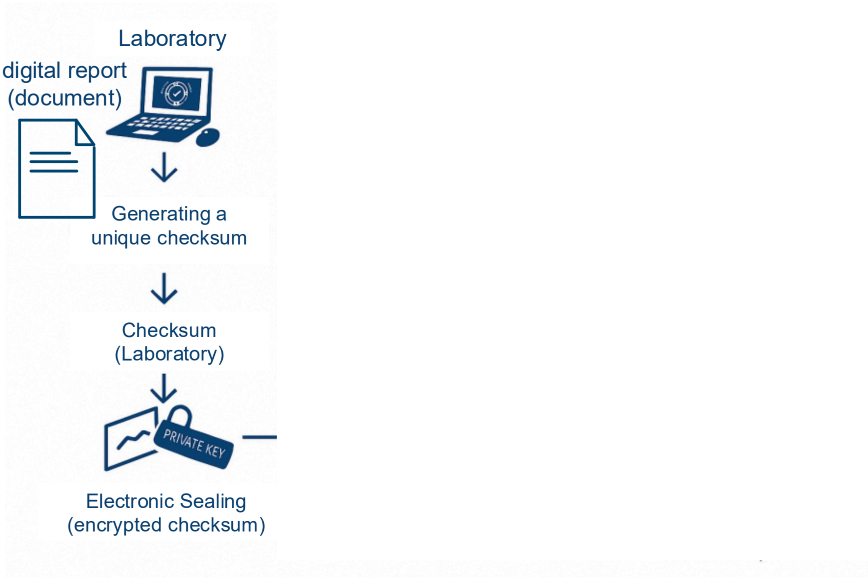
- Qualified Certificate
  - qualified certificate from a Qualified Trust Service Provider (QTSP)
  - granted EU-wide legal presumption of integrity and correctness
  - Contains public-key
- Qualified Electronic Seal Creation Device
  - Secure private-key storage (a digital safe for cryptographic keys)
  - Creation of legally recognized qualified seals
- Compliant workflow for seal application
  - generated seal (signed hash + certificate metadata) is attached to or embedded in the electronic document
  - Service is often provided by third-party providers



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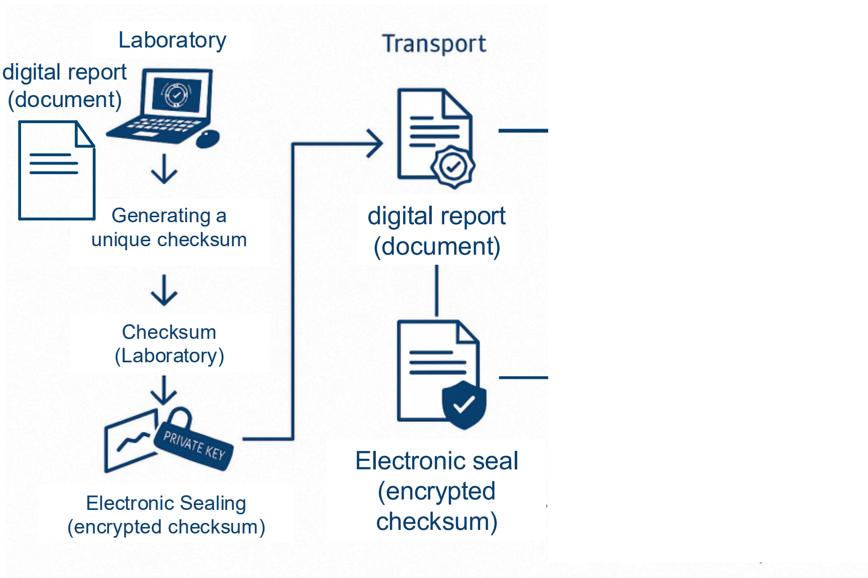

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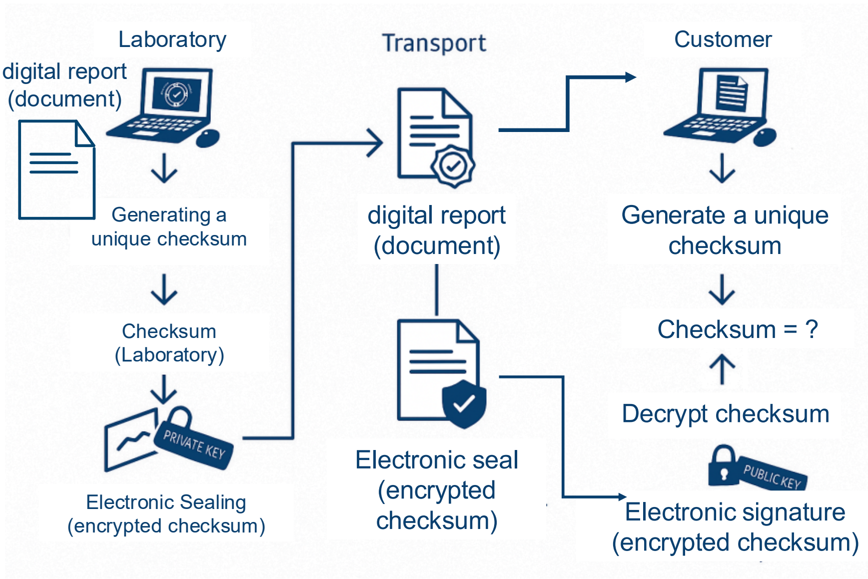

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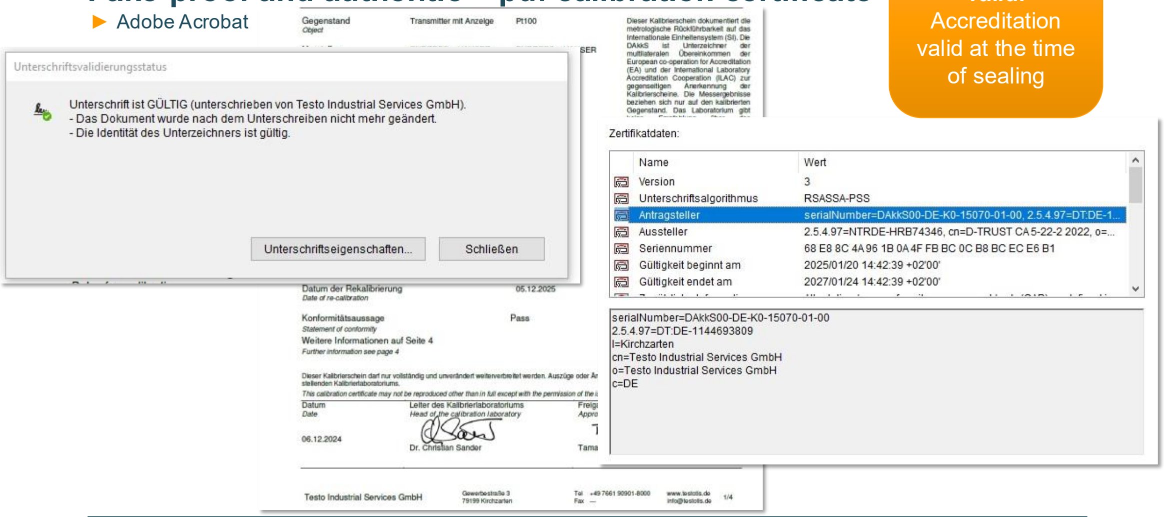
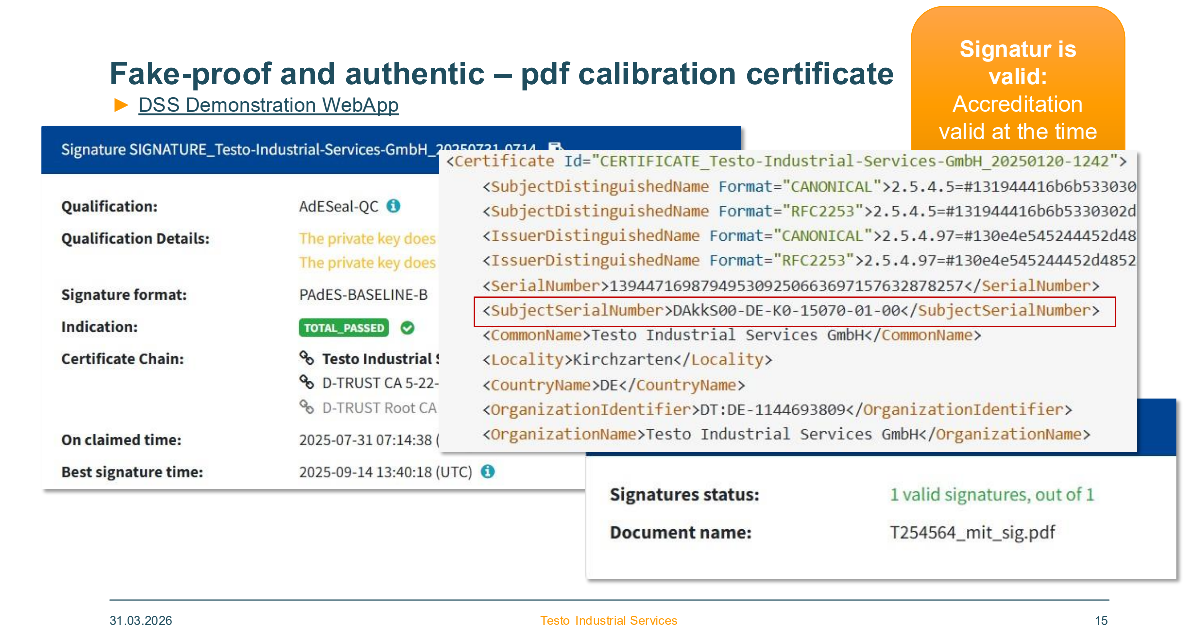
Fake-proof and authentic – pdf calibration certificate

- Adobe Acrobat

Signatur is valid:
Accreditation valid at the time of sealing




Fake-proof and authentic – pdf calibration certificate
DSS Demonstration WebApp
Signatur is valid: Accreditation valid at the time
Signature SIGNATURE_Testo-Industrial-Services-GmbH_20250731-0714
Qualification: AdESeal-QC
Qualification Details: The private key does
The private key does
Signature format: PAdES-BASELINE-B
Indication: TOTAL_PASSED
Certificate Chain: Testo Industrial
D-TRUST CA 5-22-
D-TRUST Root CA
On claimed time: 2025-07-31 07:14:38
Best signature time: 2025-09-14 13:40:18 (UTC)
<Certificate Id="CERTIFICATE_Testo-Industrial-Services-GmbH_20250120-1242">
<SubjectDistinguishedName Format="CANONICAL">2.5.4.5=#131944416b6b533030
<SubjectDistinguishedName Format="RFC2253">2.5.4.5=#131944416b6b5330302d
<IssuerDistinguishedName Format="CANONICAL">2.5.4.97=#130e4e545244452d48
<IssuerDistinguishedName Format="RFC2253">2.5.4.97=#130e4e545244452d4852
<SerialNumber>139447169879495309250663697157632878257</SerialNumber>
<SubjectSerialNumber>DAkkS00-DE-K0-15070-01-00</SubjectSerialNumber>
<CommonName>Testo Industrial Services GmbH</CommonName>
<Locality>Kirchzarten</Locality>
<CountryName>DE</CountryName>
<OrganizationIdentifier>DT:DE-1144693809</OrganizationIdentifier>
<OrganizationName>Testo Industrial Services GmbH</OrganizationName>
Signatures status: 1 valid signatures, out of 1
Document name: T254564_mit_sig.pdf
31.03.2026
Testo Industrial Services
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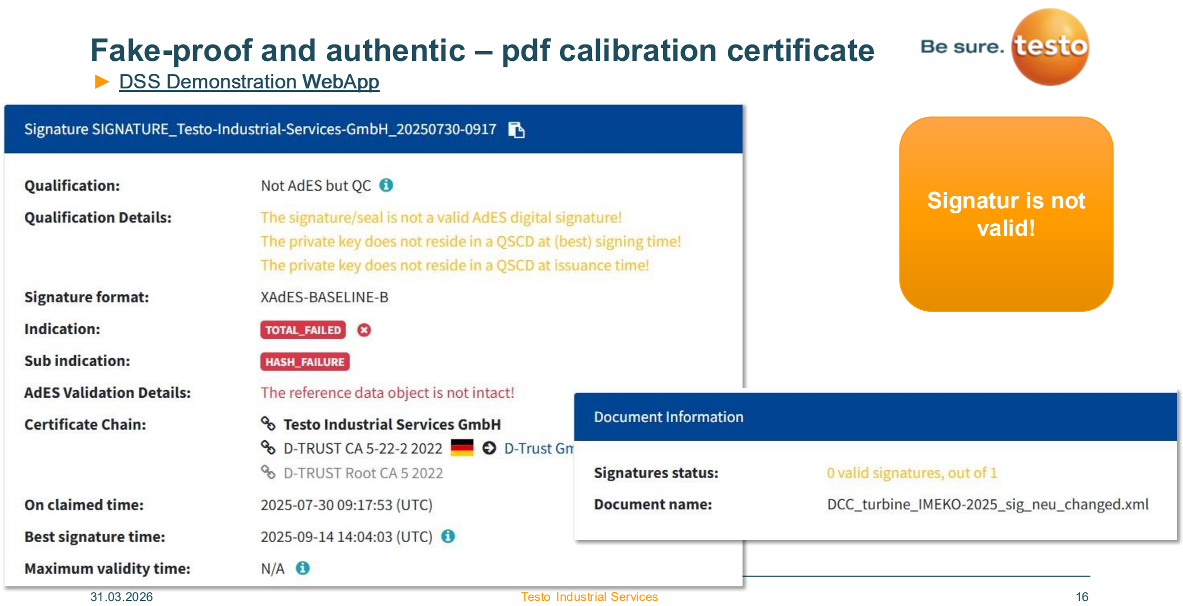
Fake-proof and authentic – pdf calibration certificate
DSS Demonstration WebApp
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Signature SIGNATURE_Testo-Industrial-Services-GmbH_20250730-0917
Qualification: Not AdES but QC
Qualification Details: The signature/seal is not a valid AdES digital signature!
The private key does not reside in a QSCD at (best) signing time!
The private key does not reside in a QSCD at issuance time!
Signature format: XAdES-BASELINE-B
Indication: TOTAL_FAILED
Sub indication: HASH_FAILURE
AdES Validation Details: The reference data object is not intact!
Certificate Chain: Testo Industrial Services GmbH
D-TRUST CA 5-22-2 2022
D-Trust Gm
D-TRUST Root CA 5 2022
On claimed time: 2025-07-30 09:17:53 (UTC)
Best signature time: 2025-09-14 14:04:03 (UTC)
Maximum validity time: N/A
Signatur is not valid!
Document Information
Signatures status: 0 valid signatures, out of 1
Document name: DCC_turbine_IMEKO-2025_sig_neu_changed.xml
31.03.2026
Testo Industrial Services
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Implementation and application of digital accreditation symbol

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- Application process has been running since April 2024 for all CABs at DAkkS
- Process duration approx. three months → Receipt of certificate and private-key
- Costs for certificate: approx. 500 € /year
- Works with all formats commonly used in conformity assessment (PDF, XML, etc.) → eAttestation

- Sealing process
  - By proprietary software in own IT development
    - Compliant WF / security and updates is personal responsibility !!
  - By third-party providers
    - Compliant WF guaranteed / monthly updates guaranteed

  - Typical Costs

10.000 sealing/year:	1.200 €/year	(0,12 €/seal)
100.000 sealing/year:	12.000 €/year	(0,05 €/seal)
1.000.000 sealing/year:	18.000 €/year	(0,018 €/seal)

Added value for accredited bodies and their customers

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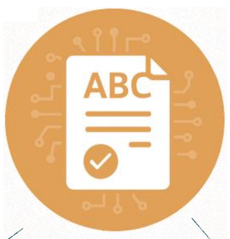
Protection of accreditation statements in the digital space

Acceleration of customer processes (purely mechanical processes)-> Time savings/cost savings

Real-time global validation of accreditation statements by third parties



Previous signatures can be replaced

Global validation of the authenticity and integrity of eAttestation in real time

Automated application (e.g., via LIMS, ERP, etc)

Enabling secure chains of evidence worldwide

DCC in Production Mode

Be sure. testo

beamex
A BETTER WAY TO CALIBRATE
E+H testo
PTB
SIEMENS
Boehringer Ingelheim

Meeting 24.10.2024 Ingelheim

Meeting 15.01.2025 Gerlingen

31.03.2026 Testo Industrial Services 19

Ihr Referent

Be sure. testo

Thank you for your attention

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31.03.2026 Testo Industrial Services 20

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P05 Gisa Foyer: A challenge to test interoperability of DCCs for weights

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Keywords: digital calibration certificate, interoperability, mass, weights

Abstract

The digital calibration certificate (DCC) was established for various reasons, one of them is to achieve interoperability of calibration certificates between laboratories. As a basis for the use of the DCC for weights, the Technical Committee on Mass and Weighing Instruments of the German Calibration Service (DKD) started working towards this aim in 2020. The result is an extensive expert report on how to write mass DCCs for weights, weight sets and mass standards [1], The logical consequence, after discussing rules for mass DCCs, was to validate XML files against those rules and also test the interoperability. For this purpose, the DCC mass Interoperability Challenge started in the beginning of 2025 [2],

The challenge was addressed to international mass calibration laboratories including mostly, but not solely, national metrology institutes. Three scenarios for mass calibrations with different complexities were created by listing the relevant data in an unstructured way. The laboratories were then asked to “translate” these into DCC format while considering all published rules and publications. Overall, seven laboratories participated with one or more example files. These were first tested against the expert report rules using Schematron and then evaluated against expected results to calculate an overall “interoperability score”.

The immediate result of the challenge was a list of questions and comments for the DCC Wiki, the DKD refType database and for the Expert report DKD-E 7-2 [1], These are very valuable as they identify errors in descriptions, existing contrary information and included suggestions for improving the documents to be more helpful for users.

The evaluation of the XML files revealed a wide range of possibilities to solve the given challenge. The overall “interoperability score” was 56 % for the single weight scenario meaning 56% of the interoperability relevant information such as serial number of weights and the conventional mass result were findable and correct (i.e. in accordance with the data given in the scenario description). The reasons for the remaining 44 % were caused mostly by typographical errors in the refType attributes or in measurement units, but also by (human) misinterpretation of the given scenarios which cannot be assigned to interoperability. With higher complexity of the scenarios the interoperability score got smaller. However, it can be pointed out

that most of these errors are 1) easily correctable and 2) detectable with a Schematron validation.

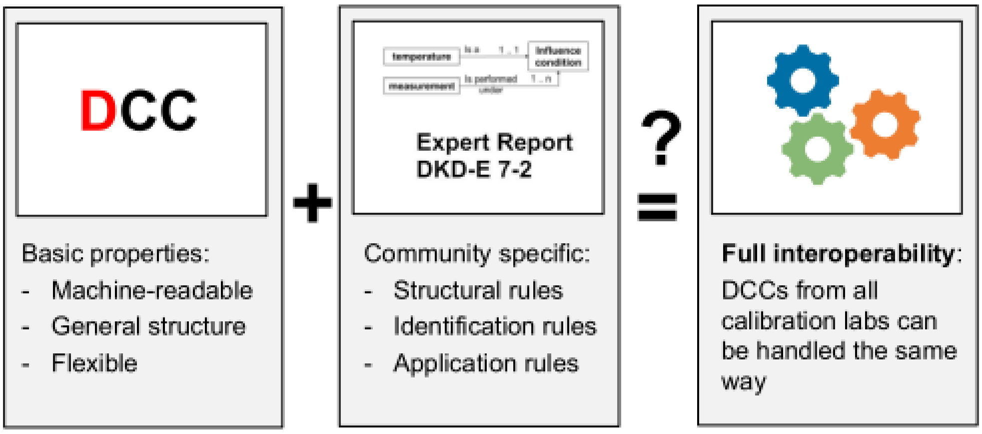

Figure 1. *Assumption of full interoperability when adhering to the DCC schema and community specific rules*

References:

[1] G. Foyer, M. Häfner, J. Haller, C. Müller-Schöll, S. Osang, and A. Scheibner, (2024): “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, Edition 01/2024, Revision 7,” https://oar.ptb.de/resources/show/10.7795/550.20240119B

[2] J. Haller and G. Foyer (2025), “Interoperability of DCCs for weights and weighing instruments through standardization f in IMEKO TC-6 International Conference on Metrology and Digital Transformation - M4DConf 2025, https://www.imeko.org/publications/tc6-2025/IMEKO-TC6-2025-009.pdf

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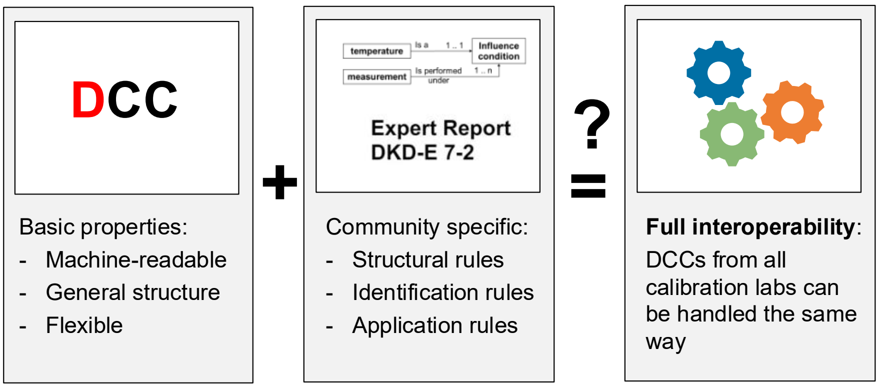
Presentation #P05 of Gisa Foyer

A challenge to test interoperability of DCCs for weights

Gisa Foyer, Julian Haller, Christian Müller-Schöll, Stuart Davidson
6th International DCC Conference

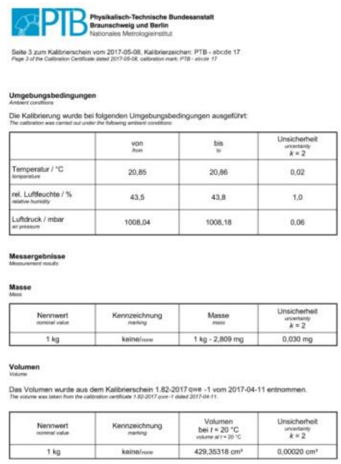
DCC Mass – Achieving Interoperability



Assessing interoperability of mass DCCs through comparison of test DCCs issued by different parties

DCC for mass/weights

- DKD expert report published in April 2022
  - Focus: weights
  - Instruction on how to fill the DCC template
  - Mostly applicable for mass standards as well
  - https://doi.org/10.7795/550.20220419B
    (English version)



Physikalisch-Technische Bundesanstalt
Braunschweig und Berlin
Nationales Metrologieinstitut

Seite 3 zum Kalibrierschein vom 2017-05-08, Kalibrierzeichen: PTB - abcde 17
Page 3 of the Calibration Certificate dated 2017-05-08, calibration mark: PTB - abcde 17

Umgebungsbedingungen
Ambient conditions

Die Kalibrierung wurde bei folgenden Umgebungsbedingungen ausgeführt:
The calibration was carried out under the following ambient conditions:

	von *from*	bis *to*	Unsicherheit *uncertainty* $k = 2$
Temperatur / °C *temperature*	20,85	20,86	0,02
rel. Luftfeuchte / % *relative humidity*	43,5	43,8	1,0
Luftdruck / mbar *air pressure*	1008,04	1008,18	0,06

Messergebnisse
Measurement results

Masse
Mass

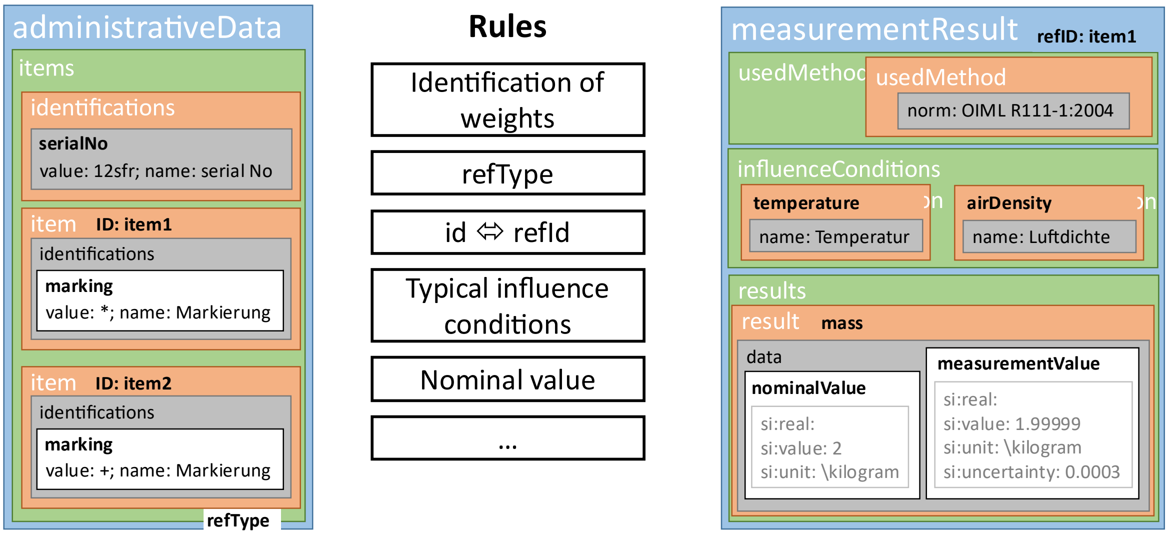
Nennwert *nominal value*	Kennzeichnung *marking*	Masse *mass*	Unsicherheit *uncertainty* $k = 2$
1 kg	keine/none	1 kg - 2,809 mg	0,030 mg

Volumen
Volume

Das Volumen wurde aus dem Kalibrierschein 1.82-2017 qwe -1 vom 2017-04-11 entnommen.
The volume was taken from the calibration certificate 1.82-2017 qwe-1 dated 2017-04-11.

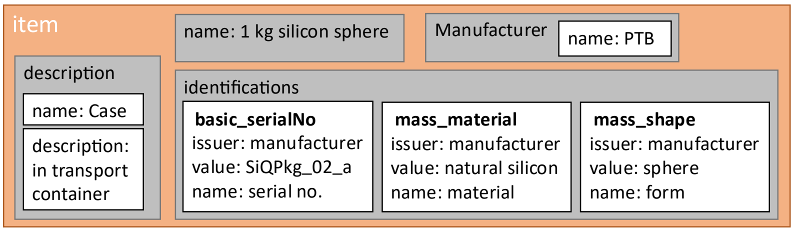
Nennwert *nominal value*	Kennzeichnung *marking*	Volumen bei t = 20 °C *volume at t = 20 °C*	Unsicherheit *uncertainty* $k = 2$
1 kg	keine/none	429,35318 cm³	0,00020 cm³

The DCC for weights ➔ rules in example



What happened next…

Expert group active again from September 2022 to January 2024



nominalValue

rounded or approximate value of a characterizing quantity of a measuring instrument or measuring system that provides guidance for its appropriate use

PREFIX:	mass_
NOTE 1:	VIM 4.6 „nominal quantity value"
NOTE 2:	nominal value can be a means of identification and part of a result
ELEMENT 1:	dcc:identification in dcc:item
ELEMENT 2:	dcc:quantity

DKD expert report revised in January 2024

- Focus: mass standards
- Includes sections on volume and density
- https://doi.org/10.7795/550.20240119B (English version)

What about interoperability?

Object of calibration:

1 kg

2 kg

End date of calibration: 2019-06-28

Issue date of calibration certificate: 2019-07-03

Nominal value (dcc:itemQuantity)

Nominal mass 1 \kilogram

Nominal mass 2 \kilogram

Nominal value (dcc:result)

Nominal value 2 \kilogram

Nominal value 1 \kilogram

Same request for 2 XML-files
➔ Not interoperable, because refTypes have been changed

Object of calibration:

1 kg

2 kg

End date of calibration: 2021-06-02

Issue date of calibration certificate:

Nominal value (dcc:itemQuantity)

Nominal value (dcc:result)

Expert report 2024
DOI: 10.7795/550.20240119B

Expert report 2022
DOI: 10.7795/550.20220419B

DCC Conference 2026

How we test interoperability

XML

<dcc:items>
<dcc:item>
…
</dcc:item>
</dcc:items>

➔ All elements must be closed in the correct order

<xs:element name="item“ type="dcc:itemType“ maxOccurs="unbounded"/>

➔ XML must have at least one item
➔ Item must be of itemType

Schema

Expert report

<sch:assert role="error" test="@id">
Id is missing
</sch:assert>

➔ Item must have an id

- Standardised name of item
- Additional identification
- Something we missed
- …

More?

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DCC_mass Interoperability Challenge

Expert report

What do we need?

1. Examples for testing **(Phase 1)**
   ➔ Create scenarios

Timeframe and information

1. Finished in February/March 2025
   ➔ 3(.5) scenarios

DCC_mass - Interoperability Challenge: Scenario 1

Topic	Single OIML weight
Number (for XML-filename)	Scenario1
Difficulty	easy
Reference examples (can be used and altered)	☐ Mass set ☒ Single mass

General information

- Fill one dcc:identification with mass_orderNo: Scenario1
- Calibration laboratory: Please provide the real data for your laboratory

Challenge contents

- Single weight F2
- Nominal value: 1 kg
- Conventional mass: 1 kg + 2.3 mg (U = 1.3 mg)
- Tolerance assessment against MPE acc. to OIML R111

		before adjustment				After adjustment or exchange			
No	Nominal weight	Marking	Shape	Conv. Value	U (k=2)	Marking	Shape	Conv. Value	U (k=2)
1	1 mg						Sheet	1 mg +0.001 mg	0.002 mg
2	2 mg		Sheet	2 mg+0.001 mg	0.002 mg				
3	2 mg	*bending*	Sheet	2 mg +0.003 mg	0.002 mg				
4	5 mg		Sheet	5 mg +0.001 mg	0.002 mg				
5	10 mg		Sheet	10 mg -0.001 mg	0.002 mg				
6	20 mg		Sheet	20 mg +0.002 mg	0.003 mg				
7	20 mg	*bending*	Sheet	20 mg -0.002 mg	0.003 mg				
8	50 mg		Sheet	50 mg +0.002 mg	0.004 mg				
9	100 mg		Wire	100 mg +0.021 mg	0.005 mg		Wire	100 mg +0.001 mg	0.005 mg
10	200 mg		Wire	200 mg -0.003 mg	0.006 mg				
11	200 mg	*bending*	Wire	200 mg +0.000 mg	0.006 mg				
12	500 mg		Wire	500 mg -0.008 mg	0.008 mg				
13	1 g	ABC	knob	1 g +0.001 mg	0.010 mg				
14	2 g		knob	2 g +0.032 mg	0.012 mg	LMN	knob	2 g +0.016 mg	0.012 mg
15	2 g	*dot*	knob	2 g +0.018 mg	0.012 mg				
16	5 g	DEF	knob	5 g -0.004 mg	0.016 mg				
17	10 g	EFG	knob	10 g +0.020 mg	0.020 mg				
18	20 g		knob	20 g +0.010 mg	0.025 mg				
19	20 g	*dot*	knob	20 g +0.027 mg	0.025 mg				
20	50 g	HIJ	knob	50 g -0.12 mg	0.03 mg	MNO	knob	50 g -0.06 mg	0.03 mg
21	100 g	IJK	knob	100 g -0.10 mg	0.05 mg				
22	200 g		knob	200 g +0.03 mg	0.10 mg				
23	200 g	*dot*	knob	200 g +0.03 mg	0.10 mg				

DCC Conference 2026

DCC_mass Interoperability Challenge

Expert report

What do we need?

1. Examples for testing **(Phase 1)**
   ➔ Create scenarios
2. Means to test interoperability **(Phase 2)**
   ➔ Create example XMLs
   ➔ Create XSLT and Schematron file to validate rules from the expert report
3. Check if it works **(Phase 3)**
   ➔ Test XSLT and Schematron and discuss results

Timeframe and information

1. Finished in February/March 2025
   ➔ 3 scenarios
2. Finished in August 2025
3. Started in September 2025 - ongoing

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Overview of the results

Several DCC examples from laboratories
→ 4 different examples
→ Partly integrated as scenario 0

6 participants for the scenarios
→ 23 examples for 3.5 scenario
→ 3 examples as “references”

Question list with more than 30 questions/comments
→ Typos and misleading information as wells as content questions
→ In the expert report, DCCWiki and refType database

Result at first glance
→ “typical” mistakes (unit error, misspelled refType, missing information, …)
→ Recurring questions (shape of weights, interventions, …)

Analysis with Schematron (scenario 1)

Many small mistakes

No interventions in this scenario!

No.	Overall	Errors	Warnings	Information	SI-units (error)	refType (warning)	Interv.
1	6	2	4	0	0	3	0
4	3	1	1	1	1	1	0
8	13	6	7	0	6	7	0
12	2	1	1	0	0	1	0
15	3	2	0	1	2	0	0
19	1	0	0	0	0	0	0
28	4	3	1	0	2	1	0
31	10	5	5	0	0	3	0

Analysis with Schematron (scenario 3)

Looks worse than it is!

There are more errors in interventions

No.	Overall	Errors	Warnings	Information	SI-units (error)	refType (warning)	Interv.
3	28	24	4	0	0	3	0
7	84	28	33	23	23	33	3
11	391	183	208	0	181	208	0
14	53	7	46	0	0	46	6
18	36	3	7	26	2	7	0
22	43	15	28	0	0	28	15
30	4	3	1	0	2	1	0

Quantification of interoperability

- For each information piece:
  - Score=100 % IF same as expected; 0 % OTHERWISE
  - Average interoperability score = 79 % for scenario1

	Interoperabilit	Participant 1	Participant 2	Participant 3	Participant 4	Participant 5	Participant 6	Participant 7	Overall	Us	Remark
order number	Scenario1	100%	---	100%	---	100%	---	100%	100%	X	
calibration start	45694	100%	100%	100%	100%	100%	100%	100%	100%	X	
issue date	45695	100%	100%	100%	---	100%	100%	100%	100%	X	
OIML class (set)	0	0%	---	0%	---	---	---	---	0%	X	To be clarified: Should the weight class in case of a single weight be given as well on the "set" level?
customer	Test Customer	100%	100%	100%	100%	100%	100%	100%	100%	X	
calibration end	45694	100%	100%	100%	100%	100%	100%	100%	100%	X	
serial number (set)	0	---	---	---	0%	---	---	---	0%	X	To be clarified: Should the serial number in case of a single weight be given as well on the "set" level?
OIML class (piece)	F2	---	---	100%	---	100%	100%	100%	100%	X	
nominal value	1	100%	---	100%	---	100%	100%	100%	100%	X	
unit	\kilogram	100%	---	100%	---	100%	100%	100%	100%	X	
marking	F 1	0%	---	---	---	---	0%	0%	0%	X	Was not explicitly given
shape	Cylinder	100%	---	100%	0%	100%	100%	100%	83%	X	To be improved:Referenceable taxonomy of weight shapes needed
unit	\kilogram\metre\	100%	---	0%	---	100%	---	0%	50%	X	"brackets and blanks in unit" (wrong in examples)
conventional mass	1,0000023	100%	---	0%	0%	100%	---	100%	60%	X	Not an interoperability issue: One participant confused "measurement error" and "measurement value"
unit	\kilogram	100%	---	0%	100%	100%	---	100%	80%	X	One participant used \mg instead of \miligram
exp. MU	0,0000013	100%	---	100%	0%	100%	---	100%	80%	X	Not an interoperability issue: One participant contributed different values
measurement error	0,0000023	---	---	100%	0%	---	---	100%	67%	X	Not an interoperability issue: One participant contributed different values
unit	\kilogram	---	---	0%	100%	---	---	100%	67%	X	One participant used \mg instead of \miligram
exp. MU	0,0000013	---	---	100%	---	---	---	100%	100%	X	
lower tolerance	0,999984	100%	---	---	---	100%	---	100%	100%	X	
unit	\kilogram	100%	---	---	---	100%	---	100%	100%	X	
upper tolerance	1,000016	100%	---	---	---	100%	---	100%	100%	X	
unit	\kilogram	100%	---	---	---	100%	---	100%	100%	X	
conformity	pass	100%	---	---	---	100%	---	100%	100%	X	
									79%	X	
		71%	17%	50%	21%	75%	33%	83%			

Quantification of interoperability (manual corrections)

- Correction of obvious mistakes that have nothing to do with interoperability: score reaches 82 %

	Interoperability	Participant 1	Participant 2	Participant 3	Participant 4	Participant 5	Participant 6	Participant 7	Overall	Use	Remark
order number	Scenario1	100%	---	100%	---	100%	---	100%	100%	X	
calibration start	45694	100%	100%	100%	100%	100%	100%	100%	100%	X	
issue date	45695	100%	100%	100%	---	100%	100%	100%	100%	X	
OIML class (set)	0	0%	---	0%	---	---	---	---	0%	X	To be clarified: Should the weight class in case of a single weight be given as well on the "set" level?
customer	Test Customer	100%	100%	100%	100%	100%	100%	100%	100%	X	
calibration end	45694	100%	100%	100%	100%	100%	100%	100%	100%	X	
serial number (set)	0	---	---	---	0%	---	---	---	0%	X	To be clarified: Should the serial number in case of a single weight be given as well on the "set" level?
OIML class (piece)	F2	---	---	100%	---	100%	100%	100%	100%	X	
nominal value	1	100%	---	100%	---	100%	100%	100%	100%	X	
unit	\kilogram	100%	---	100%	---	100%	100%	100%	100%	X	
marking	F 1	0%	---	---	---	---	0%	0%	0%	X	Was not explicitly given
shape	Cylinder	100%	---	100%	0%	100%	100%	100%	83%	X	To be improved:Referenceable taxonomy of weight shapes needed
unit	\kilogram\metre\	100%	---	0%	---	100%	---	0%	50%	X	"brackets and blanks in unit" (wrong in examples)
conventional mass	1,0000023	100%	---	0%	100%	100%	---	100%	80%	X	Not an interoperability issue: One participant confused "measurement error" and "measurement value"
unit	\kilogram	100%	---	0%	100%	100%	---	100%	80%	X	One participant used \mg instead of \miligram
exp. MU	0,0000013	100%	---	100%	100%	100%	---	100%	100%	X	Not an interoperability issue: One participant contributed different values
measurement error	0,0000023	---	---	100%	100%	---	---	100%	100%	X	Not an interoperability issue: One participant contributed different values
unit	\kilogram	---	---	0%	100%	---	---	100%	67%	X	One participant used \mg instead of \miligram
exp. MU	0,0000013	---	---	100%	---	---	---	100%	100%	X	
lower tolerance	0,999984	100%	---	---	---	100%	---	100%	100%	X	
unit	\kilogram	100%	---	---	---	100%	---	100%	100%	X	
upper tolerance	1,000016	100%	---	---	---	100%	---	100%	100%	X	
unit	\kilogram	100%	---	---	---	100%	---	100%	100%	X	
conformity	pass	100%	---	---	---	100%	---	100%	100%	X	
									82%	X	
		71%	17%	50%	33%	75%	33%	83%			

Correction of examples

- Why? To prove that you can "detect"/"forecast" interoperability
- What?
  - General structure issues
  - D-SI units
  - Correct and/or add essential refTypes
- Results: errors over all examples reduced from 476 to 45

Before corrections

No.	Errors	Warnings	SI-units (error)	refType (warning)
3	24	4	0	3
11	183	208	181	208

Reduction of errors

After corrections

No.	Errors	Warnings	SI-units (error)	refType (warning)
3	1	47	0	47
11	2	208	0	208

Also: detecting new errors

Correction of examples

- Results: errors over all examples reduced from 476 to 45
- Results: interoperability score raised from 79 % to 85 %

	Interoperabilit	Participant 1	Participant 2	Participant 3	Participant 4	Participant 5	Participant 6	Participant 7	Overall
order number	scenario1	100%	100%	100%	100%	100%	100%	100%	100%
calibration start	45694	100%	100%	100%	100%	100%	100%	100%	100%
issue date	45695	100%	100%	100%	100%	100%	100%	100%	100%
OIML class (set)	0	0%	---	0%	---	---	---	---	0%
customer	Test Customer	100%	100%	100%	100%	100%	100%	100%	100%
calibration end	45694	100%	100%	100%	100%	100%	100%	100%	100%
serial number (set)	0	---	---	---	0%	---	---	---	0%
OIML class (piece)	F2	---	---	100%	---	100%	100%	100%	100%
nominal value	1	100%	---	100%	---	100%	100%	100%	100%
unit	\kilogram	100%	---	100%	---	100%	100%	100%	100%
marking	F 1	0%	0%	---	---	---	0%	0%	0%
shape	Cylinder	100%	---	100%	0%	100%	100%	100%	83%
unit	\kilogram\metre\t	100%	---	100%	---	100%	---	100%	100%
conventional mass	1,0000023	100%	100%	100%	0%	100%	100%	100%	86%
unit	\kilogram	100%	100%	100%	100%	100%	100%	100%	100%
exp. MU	0,0000013	100%	100%	100%	0%	100%	100%	100%	86%
measurement error	0,0000023	---	100%	100%	0%	---	---	100%	75%
unit	\kilogram	---	100%	100%	100%	---	---	100%	100%
exp. MU	0,0000013	---	100%	100%	---	---	---	100%	100%
lower tolerance	0,999984	100%	---	---	---	100%	---	100%	100%
unit	\kilogram	100%	---	---	---	100%	---	100%	100%
upper tolerance	1,000016	100%	---	---	---	100%	---	100%	100%
unit	\kilogram	100%	---	---	---	100%	---	100%	100%
conformity	pass	100%	---	---	---	100%	---	100%	100%
									85%
		71%	46%	67%	29%	75%	50%	88%	

Summary and next steps

- Summary
  - Challenge to draft DCCs to test interoperability
  - Development of tools to test interoperability
  - Check for open topics
- More detailed analysis still needed
  - Define more error cases e.g. refType, …
  - Correct examples for each case
  - Check results again to test whether better schematron results give better interoperability (several iterations necessary)
  - Refine analysis
  - Some more discussions

Thanks to all the participants

https://www.imeko.org/publications/tc6-2025/IMEKO-TC6-2025-009.pdf

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Day 2 2026-02-25 Wednesday
Parallel Session “DCC Ecosystem”
Session Chair: Martin Koval

015 Bin Wang: Research and Application of Digital Reference Material Certificate System by NIM

Presenting author: Bin. Wang [1]
Email: wangbin@nim.ac.cn
Additional authors:

- Xiaohua. Lu [1]

Institute:
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Keywords: Digital Reference Material Certificate, Information system, Research and Application

Abstract

Reference material (RM) certificates are indispensable for proper use of reference materials, playing an important role in guiding users to store and use reference materials correctly. However, limitations have been found in paper certificates of reference materials, such as waiting long for their preparation, high risk of loss, and lack of security measures.

NIM has actively carried out the research on digital certificates of reference materials to explore more efficient technologies. NIM has studied bar codes for management of reference materials and has established a digital reference material certificate system with authority control, electronic seal, time stamp and other encryption mechanisms involved.

Based on the varieties and batches of reference materials, the coding rules for two-dimensional codes of reference materials are formulated and employed to uniquely manage each unit of reference materials. A complete process of certificate template making, review and release has been designed as part of the manufacturing process for reference materials. Using the interface development function of major social media platforms, the method of generating and previewing documents by scanning the QR code on the label of a reference material with a mobile phone is designed. Users may view and download all digital certificates generated by their scanning through the special certificate management website page. The system has been implemented and is currently in use.

In October 2020, NIM started the pilot project of the digital reference material certificate system. Up to December 23, 2025, it had provided more than 2400 reference materials and more than 901,000 copies of electronic documents for more than 90,000 users. The digital certificate system not only improves the efficiency of document query and use, but also greatly reduces the cost for document production and transportation. Through the user information provided by the end-users, the reference material producers may obtain the specific application fields of reference materials more accurately, establishing a more convenient communication channel between the reference material producers and users.

References:

[1] ISO 33401 (2024) Reference materials — Contents of certificates, labels and accom-

panying documentation
[2] ISO 17034 (2016) General requirements for the competence of reference material producers
[3] ISO/IEC 17025 (2017) General requirements for the competence of testing and calibration laboratories

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Presentation #015 of Bin Wang

Research and Application of Digital Reference Material Certificate System by NIM

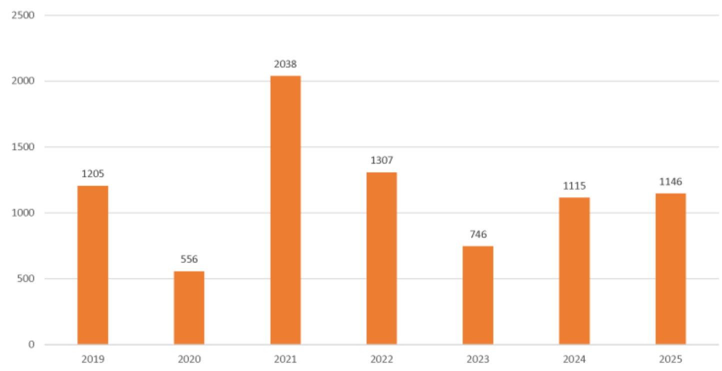
Bin Wang
National Institute of Metrology, China

25. Feb 2026

outline

1 Background

Certified Reference Materials in China



By the end of 2025, there are more than 19440 certified reference materials in China.

Technical requirements for reference material certificates

ISO 33401 (2024) Reference materials — Contents of certificates, labels and accompanying documentation

reference material certificate

- document containing the essential information for the use of a CRM, confirming that the necessary procedures have been carried out to ensure the validity and metrological traceability of the stated property values

RM document

- document containing all the information that is essential for using any RM

Disadvantages of paper certificates

1. Low production efficiency
2. Single anti-counterfeiting measures
3. Easy to lose
4. Easily damaged
5. Small amount of information
6. Easy to be tampered with

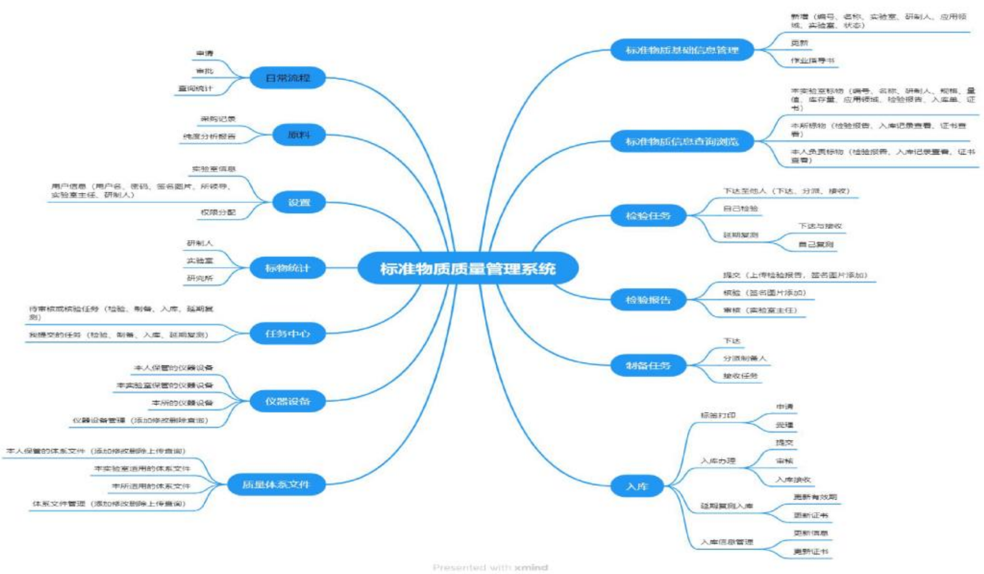
2 Research Content and Progress

Main research content

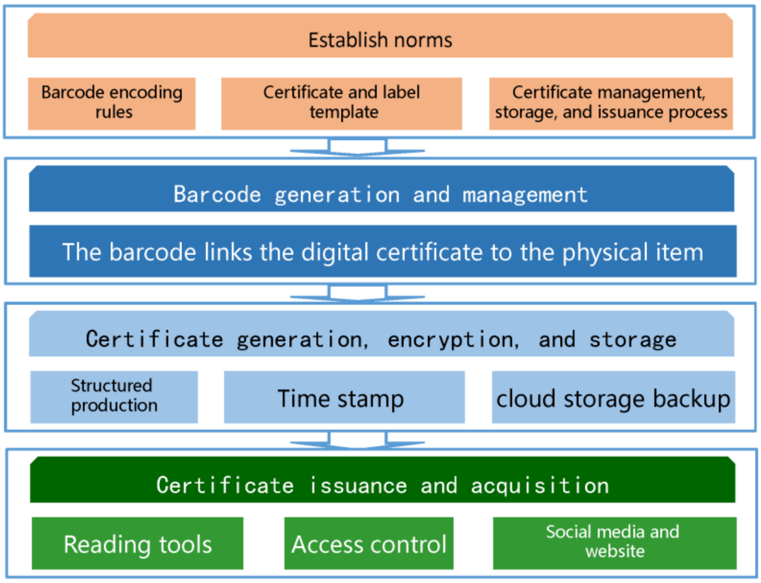
The digital transformation of reference material quality management

Digital reference material certificate

The digital transformation of reference material quality management



Main research content



Main research content

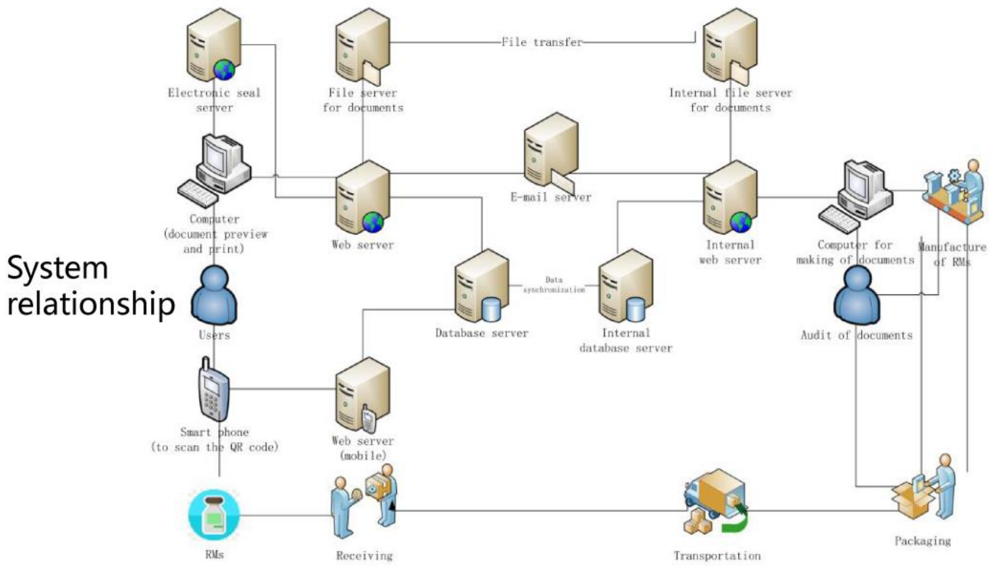
Barcode encoding rules

	Type code						sequence					Check code
Position index	12	11	10	9	8	7	6	5	4	3	2	1
code	2	0	1	8	1	8	0	0	0	0	1	X

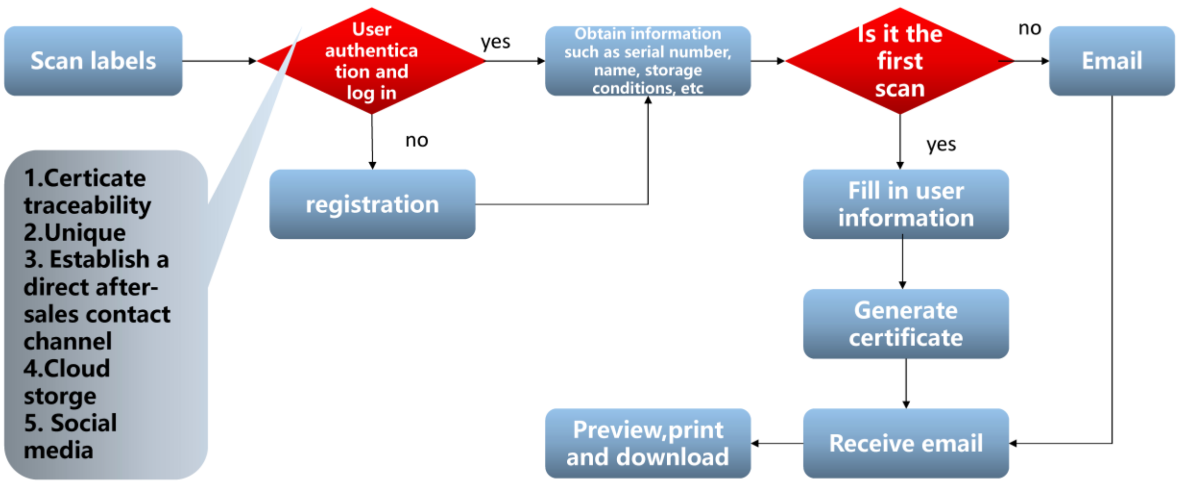
File format

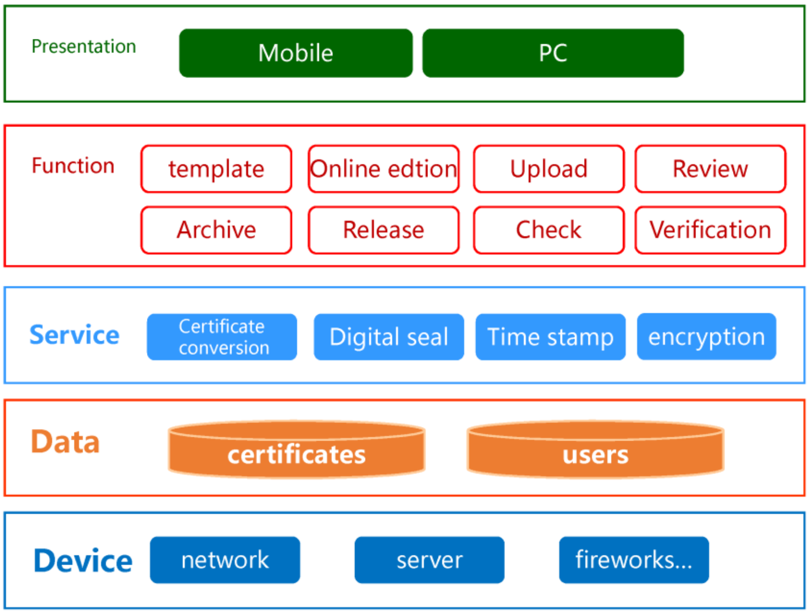
<RMCertificate>
<RMCode>**GBW08608**</RMCode>
<RMDescription>**trace elements in water**</RMDescription>
<BatchNo>**21011**</BatchNo>
<CertificationDate>**2021/10/11**</CertificationDate>
<PeriodOfValidity>**2022/10/10**</PeriodOfValidity>
<Producer>National Institute of Metrology, China</ Producer >
…
</RMCertificate>

Main research content



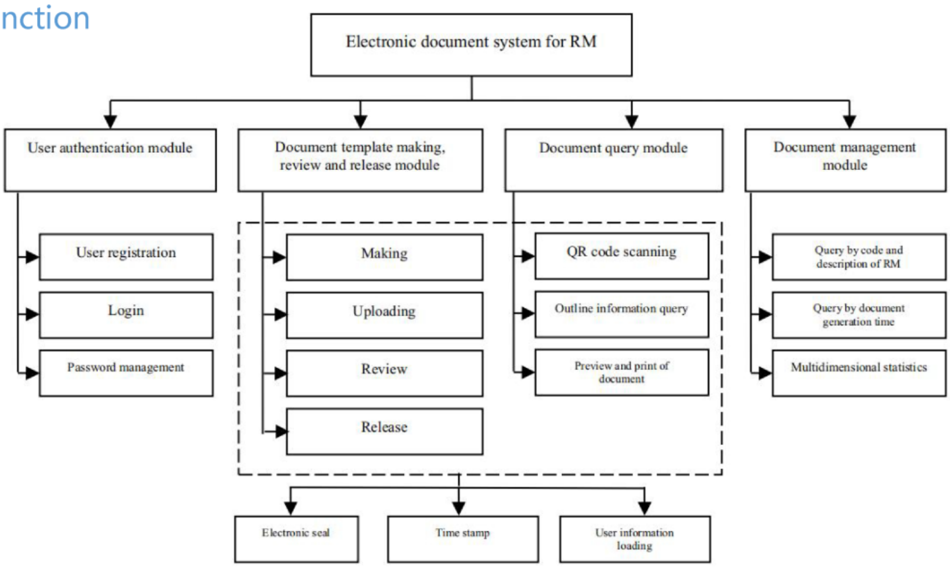
Main research content



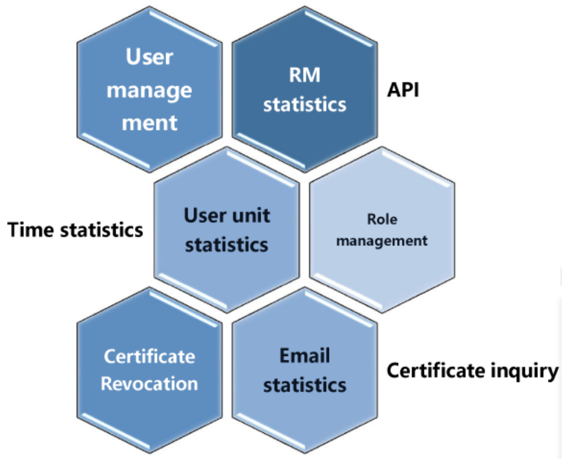


Main research content

Main Function



Current progress



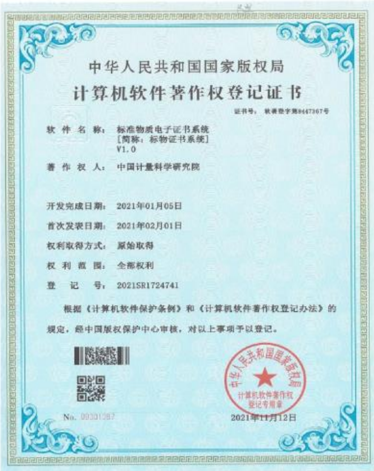
The certificates of 2512 types of labeled items have been digitized, with a digitization rate of 100%。 Over 931,000 digital certificates were provided to more than 92,000 users.

Current progress

- The digital certificate of the subject matter is associated one-to-one with the physical item
- Each unit of reference material has a unique identifier
- Obtaining the certificate is convenient and efficient
- The certificate information is more detailed
- It possesses uniqueness and enhanced anti-counterfeiting properties
- It is easier to manage and less prone to loss
- Energy conservation and emission reduction

Current progress

1 Software Copyright； 1 paper Accreditation and Quality Assurance



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著作权人： 中国计量科学研究院

开发完成日期： 2021年01月05日

首次发表日期： 2021年02月01日

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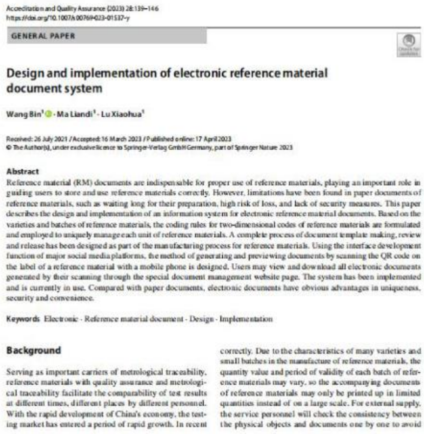

Accreditation and Quality Assurance (2023) 28:139–146
https://doi.org/10.1007/s00769-023-01537-y

GENERAL PAPER

Design and implementation of electronic reference material document system

Wang Bin[1] · Ma Liandi[1] · Lu Xiaohua[1]

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Abstract
Reference material (RM) documents are indispensable for proper use of reference materials, playing an important role in guiding users to store and use reference materials correctly. However, limitations have been found in paper documents of reference materials, such as waiting long for their preparation, high risk of loss, and lack of security measures. This paper describes the design and implementation of an information system for electronic reference material documents. Based on the varieties and batches of reference materials, the coding rules for two-dimensional codes of reference materials are formulated and employed to uniquely manage each unit of reference materials. A complete process of document template making, review and release has been designed as part of the manufacturing process for reference materials. Using the interface development function of major social media platforms, the method of generating and previewing documents by scanning the QR code on the label of a reference material with a mobile phone is designed. Users may view and download all electronic documents generated by their scanning through the special document management website page. The system has been implemented and is currently in use. Compared with paper documents, electronic documents have obvious advantages in uniqueness, security and convenience.

Keywords Electronic · Reference material document · Design · Implementation

Background

Serving as important carriers of metrological traceability, reference materials with quality assurance and metrological traceability facilitate the comparability of test results at different times, different places by different personnel. With the rapid development of China's economy, the testing market has entered a period of rapid growth. In recent correctly. Due to the characteristics of many varieties and small batches in the manufacture of reference materials, the quantity value and period of validity of each batch of reference materials may vary, so the accompanying documents of reference materials may only be printed up in limited quantities instead of on a large scale. For external supply, the service personnel will check the consistency between the physical objects and documents one by one to avoid

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016 Punith Durga Prasad Arumilli: The Digital Reference Material Document (DRMD): Transforming Static Certificates into Machine-Interpretable Quality Infrastructure

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Institute:
[1] Bundesanstalt für Materialforschung und -prüfung (BAM), Unter den Eichen 87, 12205, Berlin.
Keywords: Reference Materials, Digital Quality Infrastructure, ISO 33401, XML Schema, Vision Language Models, Industry 4.0

Abstract

Reference materials (RMs) serve as anchors of measurement reliability in analytical laboratories, yet their documentation currently remains trapped in static PDF formats creating a critical bottleneck for Industry 4.0 automation. While digitization has advanced for calibration through the Digital Calibration Certificate (DCC), RM certificates still require manual data entry, a time-consuming and error-prone process incompatible with modern quality infrastructure. This paper introduces the Digital Reference Material Document (DRMD), a standardized XML schema that transforms RM certificates into machine-interpretable assets aligned with ISO 33401.

Developed by BAM (German Federal Institute for Materials Research and Testing) within the QI- Digital initiative, the DRMD schema encodes essential metrological data through six structured containers: administrative metadata, material descriptions, property measurements with uncertainties, statements (e.g. on intended use and storage), comments, and digital signatures. By integrating the Digital System of Units (D-SI) and limiting document types to "referenceMaterialCertificate" or "productinformationSheet," the schema ensures semantic interoperability within federated data spaces like Quality-X and GAIA-X. Digital trust mechanisms including PKI infrastructure, DAkkS's digital accreditation symbol, and W3C verifiable credentials guarantee authenticity and data integrity throughout the document lifecycle.

To accelerate digitization of legacy certificates, we developed an AI-powered DRMD Generator leveraging state-of-the-art Vision Language Models (VLMs). This pipeline employs document layout analysis and LLM-based entity recognition to extract complex tabular data and relationships from PDFs, outputting validated XML through a human-in-the-loop workflow. Initial deployment on BAM's 400+ reference materials demonstrates high accuracy in extracting certified property values and metadata, enabling rapid integration into COMAR, the BAM-hosted international RM database.

DRMDs enable laboratories to automatically load RM information into analytical instruments, eliminating manual transcription while maintaining backward compatibility through dual PDF- XML export. Through international collaborations, and integration with Asset Administra-

tion Shells (AAS), the DRMD initiative will establish a cornerstone of digital quality infrastructure, enabling FAIR (Findable, Accessible, Interoperable, Reusable) metrological data for global Industry 4.0-compatible quality assurance systems.

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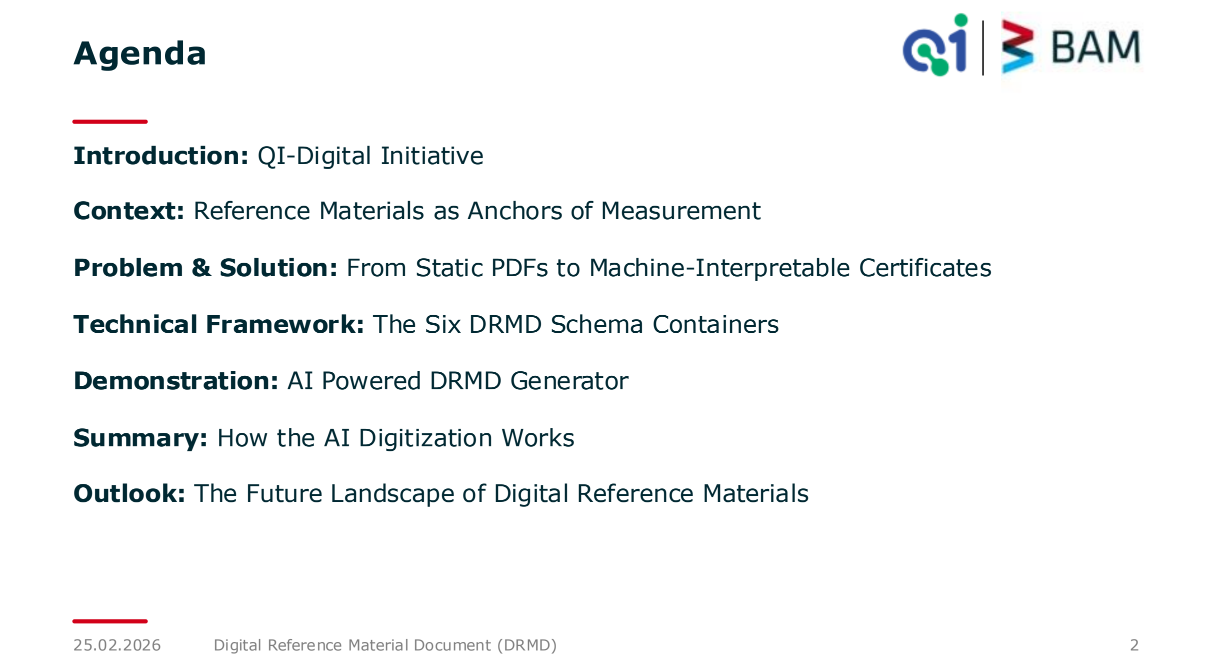
Presentation #016 of Punith Durga Prasad Arumilli



INTRODUCTION: QI-DIGITAL INITIATIVE

Ensuring quality smarter. With a digital quality infrastructure.

OUR VISION AND MISSION

The Vision: Establishing a modern, efficient Digital Quality Infrastructure (QI) that supports global value networks and the Green Transformation.

The Mission: Rethinking practice and regulation to ensure sustainability, resilience, and competitiveness for a modern global quality infrastructure.

CO-OPERATING ORGANISATIONS

BAM	DAkkS	DIN	DKE	PTB
Metrology & Materials Research	Accreditation	Standardization	Standardization	Metrology

BAM is driving the development of a DIGITAL ECOSYSTEM for QI

Digital QI-Tools
- SMART Standards
- Digital Calibration Certificate (DCC)
- Digital Conformity Certificate
- Dig. Reference Material Certificate
- Digital Accreditation Symbol

Modern Methods & Processes
- Data-/AI-driven Testing & Inspection Methods
- Remote Monitorings
- Predictive Maintenance
- Remote Calibration

Digital Ecosystem
- Standardized Data Sharing and Management
- Embedded in industrial digital ecosystems
- Integrating digital trust anchors

PILOT PROJECTS
With real-world test and R&D environments

Reliable Hydrogen Technology

Additive Manufacturing

CONTEXT:

REFERENCE MATERIALS AS ANCHORS OF MEASUREMENT

WHAT ARE REFERENCE MATERIALS?

- **Anchors of Reliability:** They serve as anchors of measurement reliability in analytical laboratories.
- **Calibration Essentials:** Crucial for calibration and ensuring global comparability of test results

BAM AS A RM PRODUCER

>100 Years of Experience
in RM production.

ISO 17034 Accredited
producer

400+ Specialized Products
available via the BAM webshop.

Hosting COMAR
The premier international database for reference materials.

PROBLEM & SOLUTION:

FROM STATIC PDFs TO MACHINE-INTERPRETABLE CERTIFICATES

PROBLEM

Locked Data: Static PDFs block automated workflows.

Inefficiency: Manual entry slows industrial processes.

Error Risks: Manual entry leads to inaccuracies.

System Gap: Legacy files do not support digital QI.

SOLUTION

Schema: DCC-based XML schema for ISO/IEC 17034 certificates, incorporating ISO 33401 content requirements.

Global Units: Seamless Digital SI integration.

Digital Trust: W3C credentials for Secure and verifiable eAttestations (e.g., DAkkS)

AI-Powered Generator: Converts PDFs to machine-readable data.

TECHNICAL FRAMEWORK:

THE SIX DRMD SCHEMA CONTAINERS

ADMINISTRATIVE DATA

- **Core Data:** Unique Identifier, Document Title (Cert/Sheet), Validity.
- **Producer:** Name, Contact, Electronic Seals.
- **Responsible Persons:** Roles, Signatures.

MATERIALS

- **Material List:** Name, Description, Material Class (ID, Reference).
- **Quantities:** Minimum Sample Size, Item Quantities.
- **Identifiers.**

MATERIAL PROPERTIES

- **Properties:** Name, Procedures (Method, Norm), Results (Value, Unit, Uncertainty - SI aligned).
- **Measurement Metadata.**
- **'isCertified'** attribute.

STATEMENTS

Intended Use, Storage Info, Handling & Use Instructions, Metrological Traceability, Health & Safety, Legal Notice, Certification Report Reference, Additional Statements.

COMMENTS & DOCUMENTS

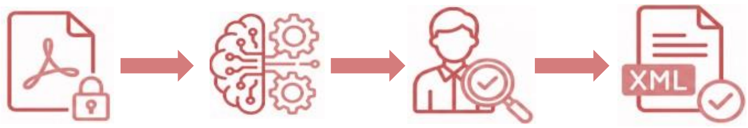
- **Comments:** Supporting notes and supplemental metrological data.
- **Documents:** Ability to embed or link external files (e.g., original PDF certificate)

DIGITAL SIGNATURE

XMLDSig elements ('ds:SignatureType') for cryptographic signatures, guaranteeing authenticity and integrity.

DEMONSTRATION:
AI-POWERED DRMD GENERATOR

SUMMARY:
HOW THE AI DIGITIZATION WORKS



Legacy PDF Certificates

Unstructured & non-machine-readable

Vision Language Model

Natively capture spatial layout and document context

Human - in - the - Loop Validation

Split-screen for integrity and auto-highlight its source on the PDF

Validated DRMD XML

Machine-ready data; single-click integration.

KEY CAPABILITIES

Visual AI Intelligence: Unlike old text scanners, the AI "sees" page layout like a human to place data accurately while capturing its **actual meaning and context**.

Verified Reliability: Achieves **95 – 100%** accuracy even on messy or complex certificate layouts.

Ready-to-Use Data: Automatically fixes units **(D-SI)** and **chemical identifiers (CAS)** so the data is ready for your lab software.

OUTLOOK:
THE FUTURE LANDSCAPE OF DIGITAL REFERENCE MATERIALS

ENABLING FAIR DATA & INDUSTRY 4.0 INTEROPERABILITY

- **Foundation for FAIR** metrological data in federated data spaces.
- **Enables automated loading** of RM information into analytical instruments.
- **Establishes a cornerstone** for a globally compatible digital quality infrastructure.

STRATEGIC COLLABORATION & NEXT STEPS

- **International Alignment**: Harmonization with major stakeholders
- **Digital Twins**: **Asset Administration Shell (AAS)** integration for manufacturing.
- **Scaling Up**: Digitizing pdf certificates and integrating into **databases such as COMAR**.

25.02.2026 Digital Reference Material Document (DRMD) 9

The Digital Reference Material Document (DRMD): Transforming Static Certificates into Machine-Interpretable Quality Infrastructure

Arumilli Punith Durga Prasad, M. Eng.
Research Associate – Digital Twins and AI
punith-durga-prasad.arumilli@bam.de

The Problem: Static PDFs create data silos, causing manual errors and blocking Industry 4.0 automation.

The Breakthrough: AI-powered VLM generator achieves 95–100% accuracy in converting PDF RM certificates into machine-interpretable XML.

The Impact: Enables direct integration into lab software of analytical instruments, ensuring FAIR data globally.

Call for Contributions: We are seeking your expertise for the upcoming modelling of the DRMD submodel for the Asset Administration Shell (AAS). Let's build the future of Digital Twins together.

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017 David Balslev-Harder: DCX in Practice: Workflow and Generation of Digital Calibration Requests

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Email: dbh@dfm.dk
Additional authors:

- Søren Kynde [1] srk@dfm.dk

Institute:
[1] Danish Fundamental Metrology – Danish National Metrology Institute (DFM), Kogle Allé, DK-2970 Hørsholm, Denmark
Keywords: DCC, DCR, cross-cutting, process-flow, standardisation

Abstract

The Digital Calibration Exchange (DCX) framework provides an emerging foundation for structuring calibration-related information in a machine-readable and domain-independent manner. In this contribution, we present practical experiences with applying DCX concepts to support the full workflow leading to a Digital Calibration Request (DCR).

We describe a generic process flow that starts from an informal calibration need and progresses toward a structured DCR. The workflow includes identifying relevant measurands, defining calibration points, uncertainties, and conditions, and preparing query expressions that formally describe the requested results. While the implementation details differ between domains, our experience suggests that the underlying approach is largely transferable across metrology fields such as mass, temperature, pressure, and others.

Particular attention is given to the preparation of queries within the DCX framework. We observe that many query structures show strong similarities across domains, even when the specific physical quantities differ. This observation may indicate that a shared conceptual basis for queries is feasible and could support harmonized digital requests without removing necessary domain-specific flexibility.

The presentation also reflects on the requirements and foundations needed for standardized DCRs and, by extension, Digital Calibration Certificates (DCCs). Rather than proposing a finalized or authoritative solution, we outline practical prerequisites such as consistent terminology, clear semantics, and alignment between request and result structures.

The aim of this contribution is to share lessons learned from early implementations, highlight

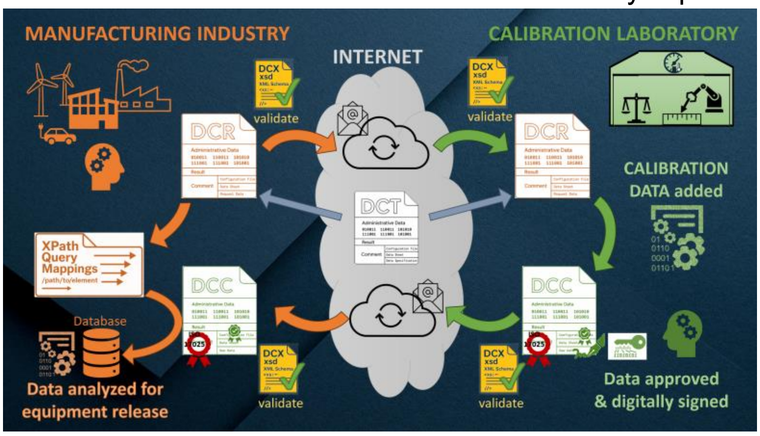

Figure 1. Illustration of the full DCX process flow, from generation of DCR and xpath-querries, to calibration lab conversion of received DCR into DCC and finally application of prepared xpath-querries to extract calibration data into client data-base.

both benefits and limitations, and invite discussion within the DCC community on how DCX-based workflows and standardized DCRs might gradually support more efficient, transparent, and interoperable digital calibration processes.

References:
[1] 5 minute video introduction to DCX: https://www.youtube.com/watch?v=AmXMWAHjakw
[2] Webpage (2025): https://github.com/TC-IM-1448/DCC-Tables

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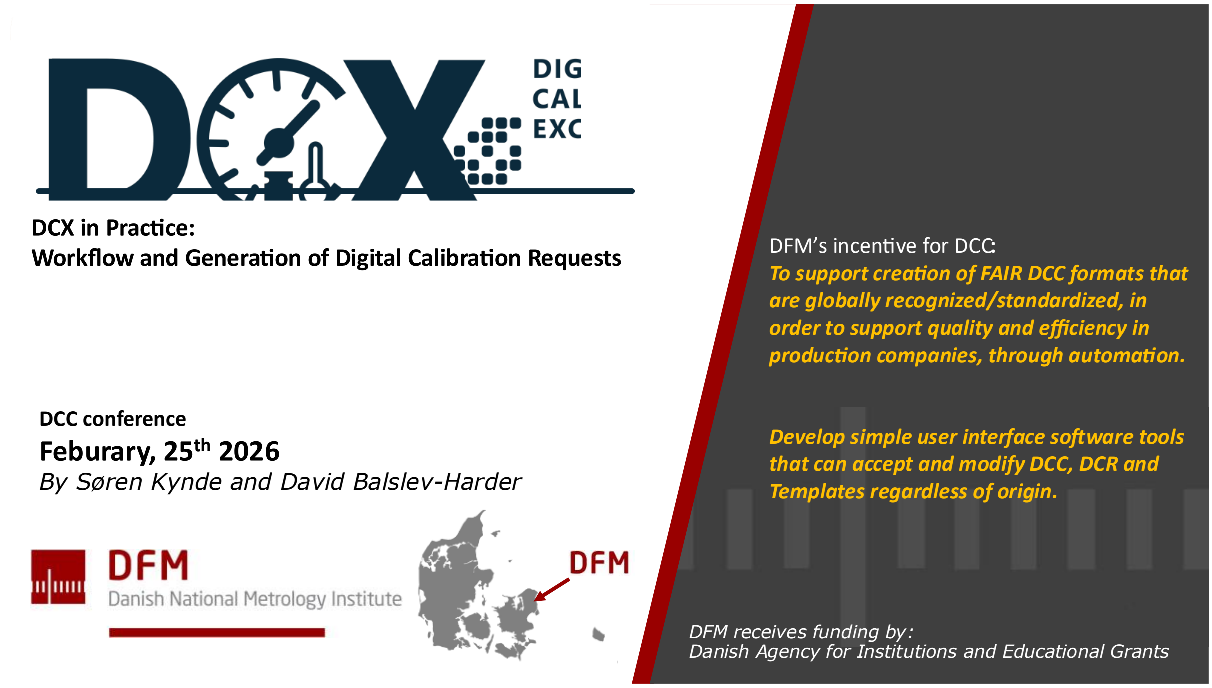
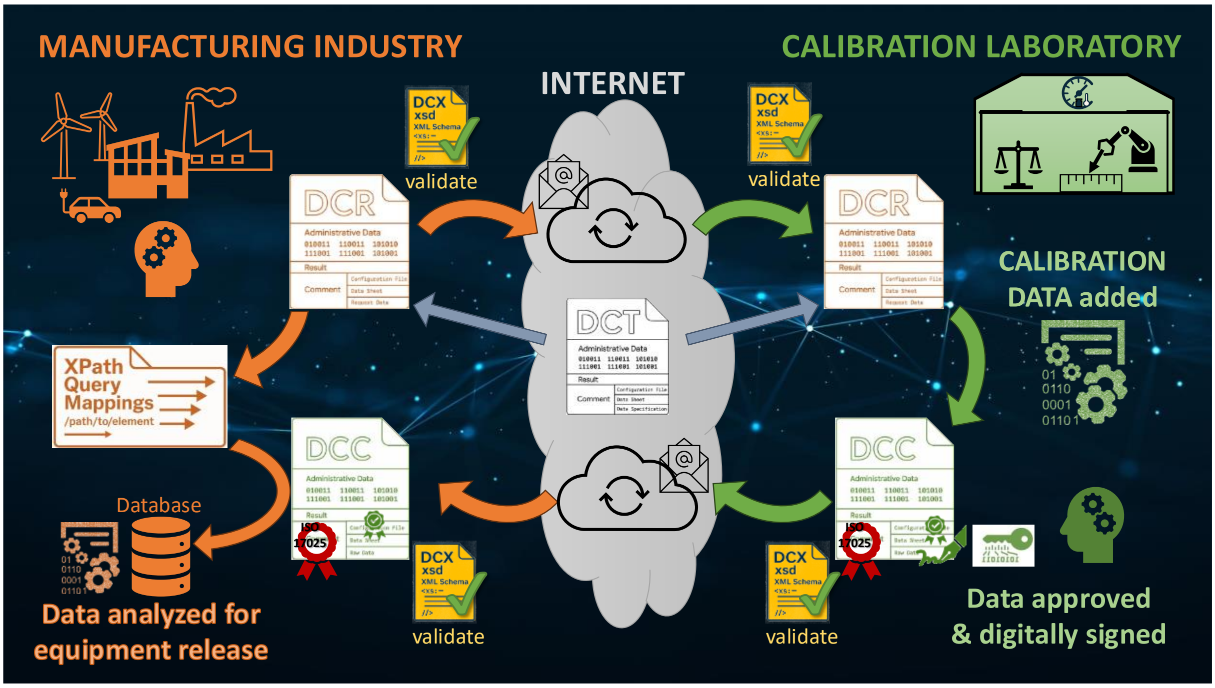
Presentation #017 of David Balslev-Harder





Result Table

DANAK [redacted]

[redacted]

Certificate no.: [redacted] **Page 2 of 3**

Result 1_P1

True mean value (Pa)	Object mean value (Pa)		Hysterese (Pa)	Repeat-ability (Pa)	Error (Pa)	Uncertainty of reading (Pa)	Measurement uncertainty (Pa)
-9,97	-10,57		0,00	0,20	-0,60	0,1	± 0,40
20,00	19,40		0,00	0,00	-0,60	0,1	± 0,38
49,95	49,50		-0,10	0,00	-0,45	0,1	± 0,39

Result Table

DANAK [redacted]

[redacted]

Certificate no.: [redacted] **Page 2 of 3**

Result 1_P1

True mean value (Pa)	Object mean value (Pa)		Hysterese (Pa)	Repeat-ability (Pa)	Error (Pa)	Uncertainty of reading (Pa)	Measurement uncertainty (Pa)
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20,00	19,40		0,00	0,00	-0,60	0,1	± 0,38
49,95	49,50		-0,10	0,00	-0,45	0,1	± 0,39

```
scope="reference"
quantity="4-14.2|gauge pressure|Pa"
unit="Pa"
datatype:<dcx:value>
```

Result Table

DANAK [redacted]

[redacted]

Certificate no.: [redacted] Page 2 of 3

Result 1_P1

True mean value (Pa)	Object mean value (Pa)		Hysterese (Pa)	Repeat-ability (Pa)	Error (Pa)	Uncertainty of reading (Pa)	Measurement uncertainty (Pa)
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20,00	19,40		0,00	0,00	-0,60	0,1	± 0,38
49,95	49,50		-0,10	0,00	-0,45	0,1	± 0,39

scope="indication"
quantity="4-14.2|gauge pressure|Pa"
unit="Pa"
datatype:<dcx:value>

Result Table

DANAK [redacted]

[redacted]

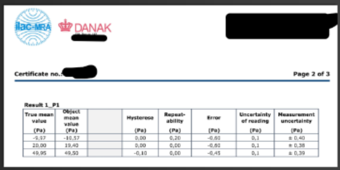
Certificate no.: [redacted] Page 2 of 3

Result 1_P1

True mean value (Pa)	Object mean value (Pa)		Hysterese (Pa)	Repeat-ability (Pa)	Error (Pa)	Uncertainty of reading (Pa)	Measurement uncertainty (Pa)
-9,97	-10,57		0,00	0,20	-0,60	0,1	± 0,40
20,00	19,40		0,00	0,00	-0,60	0,1	± 0,38
49,95	49,50		-0,10	0,00	-0,45	0,1	± 0,39

scope="bias"
quantity="4-14.2|gauge pressure|Pa"
unit="Pa"
datatype:<dcx:value>

Result Table




```xml
<dcx:calibrationResult tableId="calRes0" measurementConfigRef="config1" numRows="3" numCols=
<dcx:heading lang="en">Calibration of equipment ID015970</dcx:heading>
<dcx:column quantity="-" scope="-" unit="-">
    <dcx:heading lang="en">Customer Tags</dcx:heading>
    <dcx:rowTag>
        <dcx:row idx="1">01pnt-10</dcx:row>
        <dcx:row idx="2">02pnt20</dcx:row>
        <dcx:row idx="3">03pnt50</dcx:row>
    </dcx:rowTag>
</dcx:column>
<dcx:colmn quantity="4-14.2|gauge pressure|Pa" unit="Pa" scope="reference">
    <dcx:heading lang="en">Target value</dcx:heading>
    <dcx:targetValue>
        <dcx:row idx="1">-10</dcx:row>
        <dcx:row idx="2">20</dcx:row>
        <dcx:row idx="3">50</dcx:row>
    </dcx:targetValue>
</dcx:column>
<dcx:column quantity="4-14.2|gauge pressure|Pa" unit="Pa" scope="reference">
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    <dcx:value>
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        <dcx:row idx="2">20.00</dcx:row>
        <dcx:row idx="3">49.95</dcx:row>
    </dcx:value>
</dcx:column>
<dcx:column quantity="4-14.2|gauge pressure|Pa" unit="Pa" scope="indication">
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    <dcx:value>
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        <dcx:row idx="3">49.50</dcx:row>
    </dcx:value>
</dcx:column>
<dcx:column quantity="4-14.2|gauge pressure|Pa" unit="Pa" scope="bias">
```
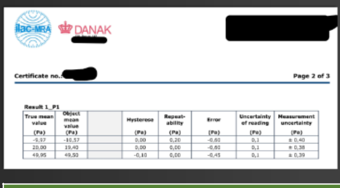


Result Table



Results : tableId='calRes0' measurementConfig='conf1'

Row tag	'targetValue' 'reference' '4-14.2|gauge pressure|Pa' 'Pa'	'value' 'reference' '4-14.2|gauge pressure|Pa' 'Pa'	'value' 'indication' '4-14.2|gauge pressure|Pa' 'Pa'	'value' 'bias' '4-14.2|gauge pressure|Pa' 'Pa'
01pnt-10	-10	-9.97	-10.57	-0.60
02pnt20	20	20.00	19.40	-0.60
03pnt50	50	49.95	49.50	-0.45

Xpath’sfor measurementdata

```
*//dcx:calibrationResult[@tableId="calRes0"]/*
    [@scope="reference"]
    [@quantity="4-14.2|gauge pressure|Pa"]
    [@unit="Pa"]
    /dcx:value
    /*[@idx="1"]
    /text()
```

Results : tableId=‘calRes0’
measurementConfig=‘conf1’

Row tag	‘reference’ ‘4-14.2|gauge pressure|Pa’ ‘Pa’ <dcx:value>	‘indication’ ‘4-14.2|gauge pressure|Pa’ ‘Pa’ <dcx:value>	‘bias’ ‘4-14.2|gauge pressure|Pa’ ‘Pa’ <dcx:value>	‘bias’ ‘4-14.2|gauge pressure|Pa’ ‘Pa’ <dcx:expanded Uncertainty>
01pnt-10	-9.97	-10.57	-0.60	0.40
02pnt20	20.00	19.40	-0.60	0.38
03pnt50	49.95	49.50	-0.45	0.39

dbh@dfm.dk

Xpath’sfor measurementdata

```
*//dcx:calibrationResult[@tableId="calRes0"]/*
    [@scope="reference"]
    [@quantity="4-14.2|gauge pressure|Pa"]
    [@unit="Pa"]
    /dcx:value
    /*[@idx="2"]
    /text()
```

Results : tableId=‘calRes0’
measurementConfig=‘conf1’

Row tag	‘reference’ ‘4-14.2|gauge pressure|Pa’ ‘Pa’ <dcx:value>	‘indication’ ‘4-14.2|gauge pressure|Pa’ ‘Pa’ <dcx:value>	‘bias’ ‘4-14.2|gauge pressure|Pa’ ‘Pa’ <dcx:value>	‘bias’ ‘4-14.2|gauge pressure|Pa’ ‘Pa’ <dcx:expanded Uncertainty>
01pnt-10	-9.97	-10.57	-0.60	0.40
02pnt20	20.00	19.40	-0.60	0.38
03pnt50	49.95	49.50	-0.45	0.39

dbh@dfm.dk

Xpath'sfor measurementdata

```
*//dcx:calibrationResult[@tableId="calRes0"]/*
        [@scope="reference"]
        [@quantity="4-14.2|gauge pressure|Pa"]
        [@unit="Pa"]
        /dcx:value
        /*[@idx="3"]
        /text()
```

Results : tableId='calRes0'
measurementConfig='conf1'

Row tag	'reference' '4-14.2|gauge pressure|Pa' 'Pa' <dcx:value>	'indication' '4-14.2|gauge pressure|Pa' 'Pa' <dcx:value>	'bias' '4-14.2|gauge pressure|Pa' 'Pa' <dcx:value>	'bias' '4-14.2|gauge pressure|Pa' 'Pa' <dcx:expanded Uncertainty>
01pnt-10	-9.97	-10.57	-0.60	0.40
02pnt20	20.00	19.40	-0.60	0.38
03pnt50	49.95	49.50	-0.45	0.39

dbh@dfm.dk

Xpath'sfor measurementdata

```
*//dcx:calibrationResult[@tableId="calRes0"]/*
        [@scope="indication"]
        [@quantity="4-14.2|gauge pressure|Pa"]
        [@unit="Pa"]
        /dcx:value
        /*[@idx="3"]
        /text()
```

Results : tableId='calRes0'
measurementConfig='conf1'

Row tag	'reference' '4-14.2|gauge pressure|Pa' 'Pa' <dcx:value>	'indication' '4-14.2|gauge pressure|Pa' 'Pa' <dcx:value>	'bias' '4-14.2|gauge pressure|Pa' 'Pa' <dcx:value>	'bias' '4-14.2|gauge pressure|Pa' 'Pa' <dcx:expanded Uncertainty>
01pnt-10	-9.97	-10.57	-0.60	0.40
02pnt20	20.00	19.40	-0.60	0.38
03pnt50	49.95	49.50	-0.45	0.39

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Xpath’sfor measurementdata

```
*//dcx:calibrationResult[@tableId="calRes0"]/*
        [@scope=“bias"]
        [@quantity="4-14.2|gauge pressure|Pa"]
        [@unit=”Pa"]
        /dcx:value
        /*[@idx=”3"]
        /text()
```

Results : tableId=‘calRes0’ measurementConfig=‘conf1’				
Row tag	‘reference’ ‘4-14.2|gauge pressure|Pa’ ‘Pa’ <dcx:value>	‘indication’ ‘4-14.2|gauge pressure|Pa’ ‘Pa’ <dcx:value>	‘bias’ ‘4-14.2|gauge pressure|Pa’ ‘Pa’ <dcx:value>	‘bias’ ‘4-14.2|gauge pressure|Pa’ ‘Pa’ <dcx:expanded Uncertainty>
01pnt-10	-9.97	-10.57	-0.60	0.40
02pnt20	20.00	19.40	-0.60	0.38
03pnt50	49.95	49.50	-0.45	0.39

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Xpath’sfor measurementdata

```
*//dcx:calibrationResult[@tableId="calRes0"]/*
        [@scope=“bias"]
        [@quantity="4-14.2|gauge pressure|Pa"]
        [@unit=”Pa"]
        /dcx:expandedUncertainty
        /*[@idx=”3"]
        /text()
```

Results : tableId=‘calRes0’ measurementConfig=‘conf1’				
Row tag	‘reference’ ‘4-14.2|gauge pressure|Pa’ ‘Pa’ <dcx:value>	‘indication’ ‘4-14.2|gauge pressure|Pa’ ‘Pa’ <dcx:value>	‘bias’ ‘4-14.2|gauge pressure|Pa’ ‘Pa’ <dcx:value>	‘bias’ ‘4-14.2|gauge pressure|Pa’ ‘Pa’ <dcx:expanded Uncertainty>
01pnt-10	-9.97	-10.57	-0.60	0.40
02pnt20	20.00	19.40	-0.60	0.38
03pnt50	49.95	49.50	-0.45	0.39

dbh@dfm.dk

Request

Equipment Description	Manufac-turer	Class	Set Id	Internal ref
Set of 6 weights of nominal weight 20 kg	Satorius	F1	030	item1
Set of 6 weights of nominal weight 10 kg	Satorius	F1	028	item2

Meas Config Description	Calibrated items	Internal ref
Set of weights, ID: 030	item1	conf1
Set of weights, ID: 028	item 2	conf2

Results
measurementConfig='conf2'

Row tag	'value' 'indication' '4-1|mass|kg' 'kg'	'value' 'bias' '4-1|mass|kg' 'mg'	'expandedUncertainty' 'bias' '4-1|mass|kg' 'mg'
Weight_no1	20		
Weight_no2	20		
Weight_no3	20		
Weight_no4	20		
Weight_no5	20		
Weight_no6	20		

Certificate

Equipment Description	Manufac-turer	Class	Set Id	Internal ref
Set of 6 weights of nominal weight 20 kg	Satorius	F1	030	item1
Set of 6 weights of nominal weight 10 kg	Satorius	F1	028	item2

Meas Config Description	Calibrated items	Setting refs	Internal ref	Method reerence
Set of weights, ID: 030	item1	setting1 setting2	conf1	meth1
Set of weights, ID: 028	item 2	setting3	conf2	meth1 meth2

Settings Description	Parameter	Value	Internal ref
Shape: cylindrical	MASS_shape	CYLINDRICAL	setting1
Material: Steel	MASS_material	STEEL	setting2
Shape: With knob	MASS_shape	KNOB	Setting3

Results
measurementConfig='conf1'

Row tag	'value' 'indication' '4-1|mass|kg' 'kg'	'value' 'bias' '4-1|mass|kg' 'mg'	'expandedUncertainty' 'bias' '4-1|mass|kg' 'mg'
Weight_no1	20	-27	53
Weight_no2	20	-21	53
Weight_no3	20	-25	53
Weight_no4	20	-22	53
Weight_no5	20	-23	53
Weight_no6	20	-20	53

Certificate

Equipment Description	Manufac-turer	Class	Set Id	Internal ref
Set of 6 weights of nominal weight 20 kg	Satorius	F1	030	item1
Set of 6 weights of nominal weight 10 kg	Satorius	F1	028	item2

Meas Config Description	Calibrated items	Setting refs	Internal ref
Set of weights, ID: 030	item1	setting1 setting2	conf1
Set of weights, ID: 028	item 2	setting3	conf2

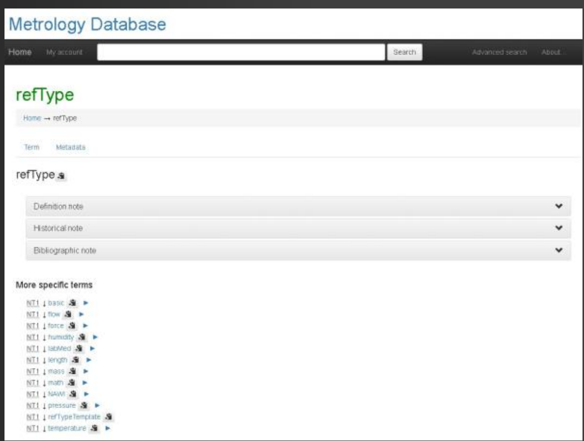
Settings Description	Parameter	Value	Internal ref
Shape: cylindrical	MASS_shape	CYLINDRICAL	setting1
Material: Steel	MASS_material	STEEL	setting2
Shape: With knob	MASS_shape	KNOB	Setting3

Results
measurementConfig='conf2'

Row tag	'value' 'indication' '4-1|mass|kg' 'kg'	'value' 'bias' '4-1|mass|kg' 'mg'	'expandedUncertainty' 'bias' '4-1|mass|kg' 'mg'
Weight_no1	10	-15	27
Weight_no2	10	-12	27
Weight_no3	10	-30	27
Weight_no4	10	-4	27
Weight_no5	10	8	26
Weight_no6	10	-10	26

Relation to refTypes

https://digilab.ptb.de/dkd/refType/vocab/index.php?tema=1&/reftype



Relation to refTypes

- acceptanceLimitLower
- acceptanceLimitUpper
- adjustment
- ambient
- appendix
- calibratedInterval
- calibrationMark
- calibrationMedium
- calibrationMethod
- calibrationMethodDeviation
- certificateNumber
- conformity

Special dataType for use in a column of a measurementResult

```
scope="bias"
quantity="4-14.2|gauge pressure|Pa"
unit="Pa"
datatype:<dcx:acceptanceLimitLower>
```

Data inside this element must be numbers

Relation to refTypes

- acceptanceLimitLower
- acceptanceLimitUpper
- adjustment
- ambient
- appendix
- calibratedInterval
- calibrationMark
- calibrationMedium
- calibrationMethod
- calibrationMethodDeviation
- certificateNumber
- conformity

Special dataType for use in a column of a measurementResult

```
scope="bias"
quantity="4-14.2|gauge pressure|Pa"
unit="Pa"
datatype:<dcx:acceptanceLimitUpper>
```

Data inside this element must be numbers

Relation to refTypes

- acceptanceLimitLower
- acceptanceLimitUpper
- adjustment
- ambient
- appendix
- calibratedInterval
- calibrationMark
- calibrationMedium
- calibrationMethod
- calibrationMethodDeviation
- certificateNumber
- conformity

Special dataType for use in a column of a measurementResult

```
scope="bias"
quantity="4-14.2|gauge pressure|Pa"
unit="Pa"
datatype:<dcx:conformity>
```

Data inside this element must be selected from the list:

```
pass
conditionalPass
noFail
noPass
```

Relation to refTypes

- acceptanceLimitLower
- acceptanceLimitUpper
- adjustment
- ambient
- appendix
- calibratedInterval
- calibrationMark
- calibrationMedium
- calibrationMethod
- calibrationMethodDeviation
- certificateNumber
- conformity

Special scope indicating that the result is not directly related to the calibration.

```
scope= "environment"
quantity="5-2|Celsius temperature|℃"
unit="℃"
datatype:<dcx:value>
```

Relation to refTypes

- acceptanceLimitLower
- acceptanceLimitUpper
- adjustment
- ambient
- appendix
- calibratedInterval
- calibrationMark
- calibrationMedium
- calibrationMethod
- calibrationMethodDeviation
- certificateNumber
- conformity

Unique element dcx:accredittionLabId in the unique dcx:accreditation section of the certificate

```
<dcx:accreditation imageRefs='acc.png'>
    <dcx:heading lang="en">Accreditation</dcx:heading>
    <dcx:accreditationLabId value="255">
        <dcx:heading lang="en">CAL Reg nr.</dcx:heading>
    </dcx:accreditationLabId>
    <dcx:accreditationBody value="DANAK">
        <dcx:heading lang="en">Accreditation body</dcx:heading>
    </dcx:accreditationBody>
    …
<dcx:accreditation>
```

Relation to refTypes

- acceptanceLimitLower
- acceptanceLimitUpper
- adjustment
- ambient
- appendix
- calibratedInterval
- calibrationMark
- calibrationMedium
- calibrationMethod
- calibrationMethodDeviation
- certificateNumber
- conformity

Unique element dcx:operationalStatus within a referenced dcx:measurementConfig

```
<dcx:measurementConfig id="config1">
  <dcx:devForMeasRefs>item1</dcx:devForMeasRefs>
   <dcx:devForMeasSettingRefs>
         setting1
   </dcx:devForMeasSettingRefs>
   <dcx:operationalStatus>
         as found
   </dcx:operationalStatus>
</dcx:measurementConfig>
```

Possible values are:

```
as found
after adjustment
after maintanence and adjustment
```

Relation to refTypes

- acceptanceLimitLower
- acceptanceLimitUpper
- adjustment
- ambient
- appendix
- calibratedInterval
- calibrationMark
- calibrationMedium
- calibrationMethod
- calibrationMethodDeviation
- certificateNumber
- conformity

Element dcx:statement of category method that can later be referenced

```
<dcx:statement id="meth01" category="method">
    <dcx:heading lang="en">Method</dcx:heading>
    <dcx:body lang="en">The masses of the weights have been determined by
weighing in air. The weighing in air including data analysis is performed
according to …
    </dcx:body>
    <dcx:externalReference>OIML D28, Conventional value of the result of
weighing in air, (2004).</dcx:externalReference>
</dcx:statement>
```

Possible values for the attribute category are:

general	accreditation
attention	accreditationException
method	decisionRule
equipment	norm
exception	traceability
comment	clientRequirement
	externalProvider

Relation to refTypes

- acceptanceLimitLower
- acceptanceLimitUpper
- adjustment
- ambient
- appendix
- calibratedInterval
- calibrationMark
- calibrationMedium
- calibrationMethod
- calibrationMethodDeviation
- certificateNumber
- conformity

Element dcx:statement of category method that can later be referenced

```
<dcx:statement id="excpt01" category="exception">
    <dcx:heading lang="en">Method</dcx:heading>
    <dcx:body lang="en">Measurements referring to this statement could
not be performed with the usual procedure due to…

    </dcx:body>


</dcx:statement>
```

Possible values for the attribute category are:

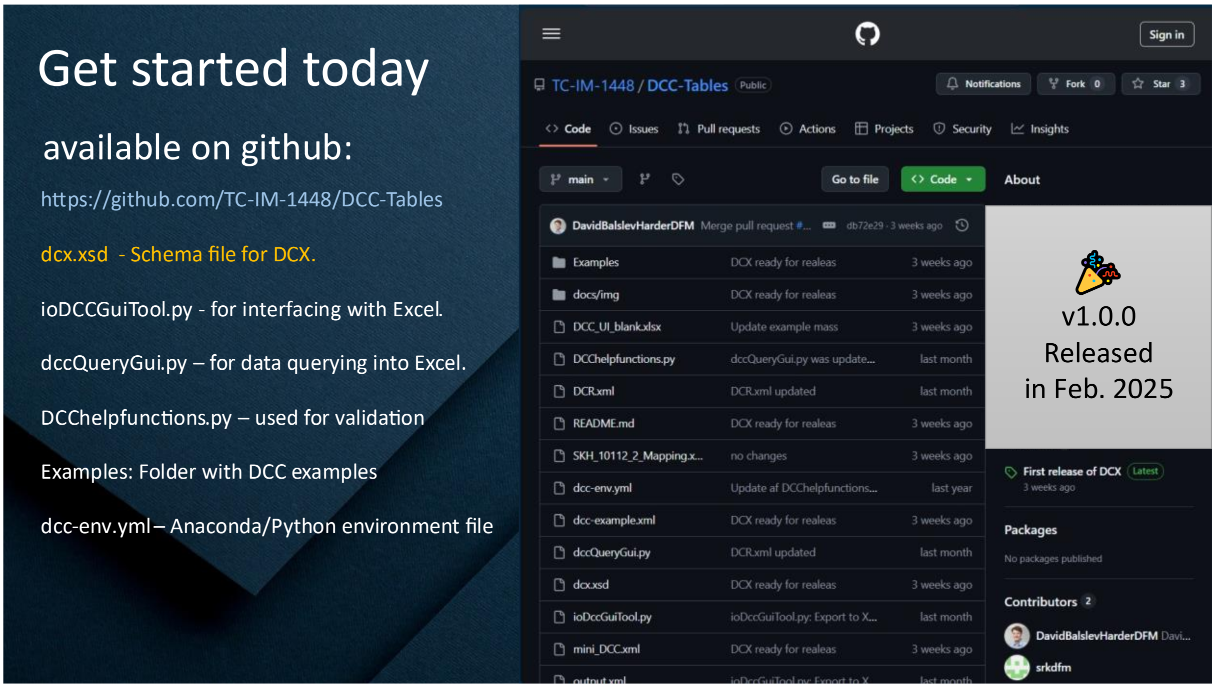
general	accreditation
attention	accreditationException
method	decisionRule
equipment	norm
exception	traceability
comment	clientRequirement
	externalProvider

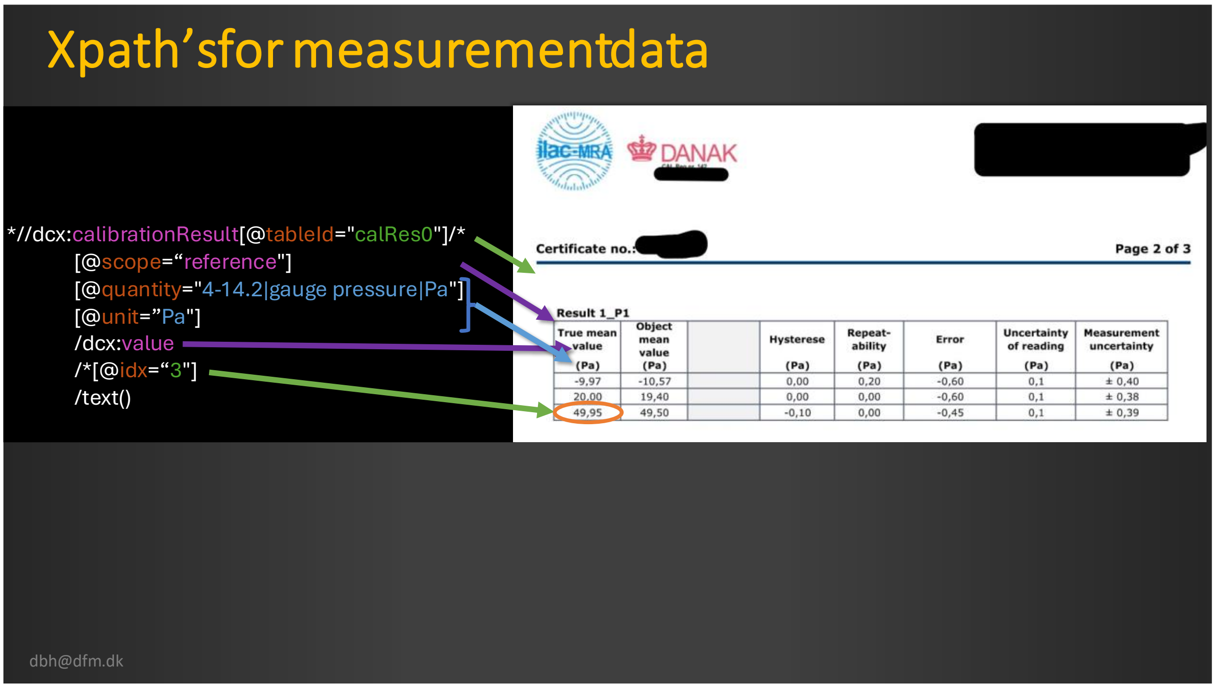
Relation to refTypes (further examples)

refType	Implementation (or surgested implemenataion) in DCX-schema
1. methodMeasurementUncertainty	1. Statement of category method
2. metrologicallyTraceableToSI	2. Statement of category traceability
3. nominalValue	3. Not used (nominal value is the same as indication of material measure)
4. orderNumber	4. Unique element in certificate
5. pressure	5. quantity
6. recalibrationDate	6. Unique element in certificate (not implemented)
7. referenceAirPressure	7. Special quantity?
8. referenceTemperature	8. Special quantity?
9. referenceValue	9. scope
10. resultScope	10. ?
11. revision	11. Unique element in certificate (not implemented)
12. serialNumber	12. Unique element for each calibration item
13. setPointValue	13. datatype (targetValue)

Conclusion

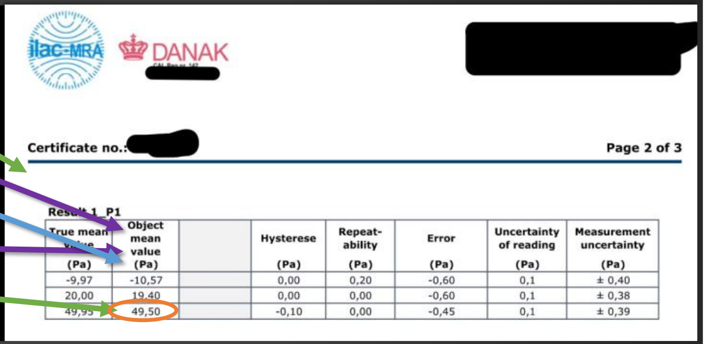
- The dcx-schema defines a language for tagging calibration data
- The schema confines the digital calibration document (request or certificate) thereby helping the user to obey the gramar and vocabulary of the language
- The basic vocabulary for common concepts is simple and very similar accross calibration areas
- The gramar is flexible enough to accomodate for advanced concepts pointed out by specialists in the DKD-working groups of various different calibration areas


Get started today
available on github:
https://github.com/TC-IM-1448/DCC-Tables
dcx.xsd - Schema file for DCX.
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
Sign in
TC-IM-1448 / DCC-Tables Public
Notifications
Fork 0
Star 3
Code
Issues
Pull requests
Actions
Projects
Security
Insights
main
Go to file
Code
About
DavidBalslevHarderDFM Merge pull request #...
Examples DCX ready for realeas 3 weeks ago
docs/img DCX ready for realeas 3 weeks ago
DCC_UI_blank.xlsx Update example mass 3 weeks ago
DCChelpfunctions.py dccQueryGui.py was update... last month
DCR.xml DCR.xml updated last month
README.md DCX ready for realeas 3 weeks ago
SKH_10112_2_Mapping.x... no changes 3 weeks ago
dcc-env.yml Update af DCChelpfunctions... last year
dcc-example.xml DCX ready for realeas 3 weeks ago
dccQueryGui.py DCR.xml updated last month
dcx.xsd DCX ready for realeas 3 weeks ago
ioDccGuiTool.py ioDccGuiTool.py: Export to X... last month
mini_DCC.xml DCX ready for realeas 3 weeks ago
v1.0.0
Released
in Feb. 2025
First release of DCX Latest
3 weeks ago
Packages
No packages published
Contributors 2
DavidBalslevHarderDFM
srkdfm


Xpath’sfor measurementdata
//dcx:calibrationResult[@tableId="calRes0"]/
[@scope=“reference"]
[@quantity="4-14.2|gauge pressure|Pa"]
[@unit=”Pa"]
/dcx:value
/*[@idx=“3"]
/text()
ilac-MRA
DANAK
Certificate no.: [redacted]
Page 2 of 3
Result 1_P1
True mean value (Pa) | Object mean value (Pa) | Hysterese (Pa) | Repeat-ability (Pa) | Error (Pa) | Uncertainty of reading (Pa) | Measurement uncertainty (Pa)
-9,97 | -10,57 | 0,00 | 0,20 | -0,60 | 0,1 | ± 0,40
20,00 | 19,40 | 0,00 | 0,00 | -0,60 | 0,1 | ± 0,38
49,95 | 49,50 | -0,10 | 0,00 | -0,45 | 0,1 | ± 0,39
dbh@dfm.dk

Xpath'sfor measurementdata

//dcx:calibrationResult[@tableId="calRes0"]/
[@scope="indication"]
[@quantity="4-14.2|gauge pressure|Pa"]
[@unit="Pa"]
/dcx:value
/*[@idx="3"]
/text()


ilac-MRA DANAK [redacted] [redacted]

Certificate no.: [redacted] **Page 2 of 3**

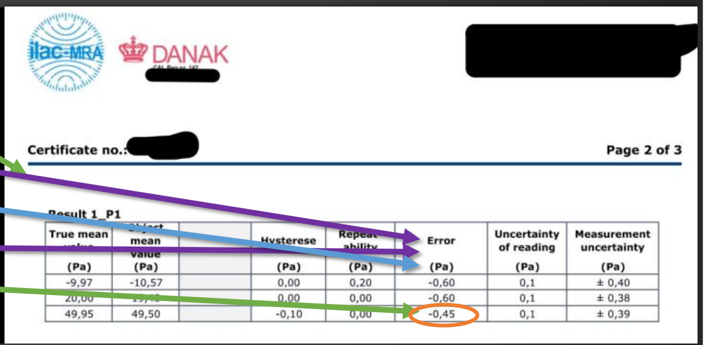
Result 1_P1

True mean value (Pa)	Object mean value (Pa)		Hysterese (Pa)	Repeat-ability (Pa)	Error (Pa)	Uncertainty of reading (Pa)	Measurement uncertainty (Pa)
-9,97	-10,57		0,00	0,20	-0,60	0,1	± 0,40
20,00	19,40		0,00	0,00	-0,60	0,1	± 0,38
49,95	49,50		-0,10	0,00	-0,45	0,1	± 0,39

dbh@dfm.dk

Xpath'sfor measurementdata

//dcx:calibrationResult[@tableId="calRes0"]/
[@scope="bias"]
[@quantity="4-14.2|gauge pressure|Pa"]
[@unit="Pa"]
/dcx:value
/*[@idx="3"]
/text()


ilac-MRA DANAK [redacted] [redacted]

Certificate no.: [redacted] **Page 2 of 3**

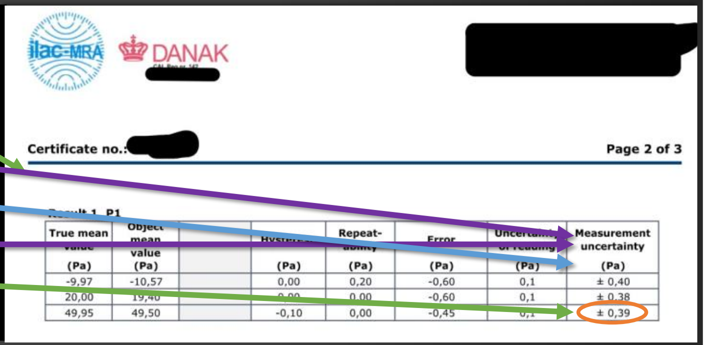
Result 1_P1

True mean value (Pa)	Object mean value (Pa)		Hysterese (Pa)	Repeat-ability (Pa)	Error (Pa)	Uncertainty of reading (Pa)	Measurement uncertainty (Pa)
-9,97	-10,57		0,00	0,20	-0,60	0,1	± 0,40
20,00	19,40		0,00	0,00	-0,60	0,1	± 0,38
49,95	49,50		-0,10	0,00	-0,45	0,1	± 0,39

dbh@dfm.dk

Xpath’sfor measurementdata

```
*//dcx:calibrationResult[@tableId="calResO"]/*
        [@scope=“bias"]
        [@quantity="4-14.2|gauge pressure|Pa"]
        [@unit=”Pa"]
        /dcx:expandedUncertainty
        /*[@idx="1"]
        /text()
```


ilac-MRA DANAK [redacted] [redacted]

Certificate no.: [redacted] Page 2 of 3

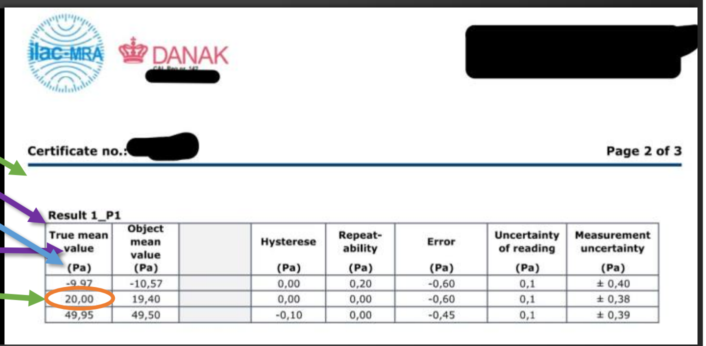
Result 1_P1

True mean value (Pa)	Object mean value (Pa)		Hysterese (Pa)	Repeat-ability (Pa)	Error (Pa)	Uncertainty of reading (Pa)	Measurement uncertainty (Pa)
-9,97	-10,57		0,00	0,20	-0,60	0,1	± 0,40
20,00	19,40		0,00	0,00	-0,60	0,1	± 0,38
49,95	49,50		-0,10	0,00	-0,45	0,1	± 0,39

dbh@dfm.dk

Xpath’sfor measurementdata

```
*//dcx:calibrationResult[@tableId="calResO"]/*
        [@scope=“reference"]
        [@quantity="4-14.2|gauge pressure|Pa"]
        [@unit=”Pa"]
        /dcx:value
        /*[@idx=“2"]
        /text()
```


ilac-MRA DANAK [redacted] [redacted]

Certificate no.: [redacted] Page 2 of 3

Result 1_P1

True mean value (Pa)	Object mean value (Pa)		Hysterese (Pa)	Repeat-ability (Pa)	Error (Pa)	Uncertainty of reading (Pa)	Measurement uncertainty (Pa)
-9,97	-10,57		0,00	0,20	-0,60	0,1	± 0,40
20,00	19,40		0,00	0,00	-0,60	0,1	± 0,38
49,95	49,50		-0,10	0,00	-0,45	0,1	± 0,39

dbh@dfm.dk

Result Table

//dcx:calibrationResult[@measurementConfigRef="conf1"]/[@scope="reference"][@quantity="4-14.2|gauge pressure|Pa"][@unit="Pa"]/dcx:value/*[@idx="1"]/text() => -9.97

Results : tableId='calRes0' measurementConfig='conf1'				
Row tag	'targetValue' 'reference' '4-14.2|gauge pressure|Pa' 'Pa'	'value' 'reference' '4-14.2|gauge pressure|Pa' 'Pa'	'value' 'indication' '4-14.2|gauge pressure|Pa' 'Pa'	'value' 'bias' '4-14.2|gauge pressure|Pa' 'Pa'
01 pnt -10(Pa)	-10	-9.97	-10.57	-0.60
02 pnt 20 (Pa)	20	20.00	19.40	-0.60
03 pnt 50 (Pa)	50	49.95	49.50	-0.45

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018 Martin Østerlund: Comparing the DCC with the DCX: Advantages, disadvantages and the tools developed

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Additional authors: Nil
Institute:
[1] Danish Technological Institute, Kongsvang Allé 29, 8000 Aarhus C, Denmark
Keywords: DCC, DCX, Tools

Abstract

The DCC project was started almost 10 years ago. In that time, calibration laboratories and metrology institutes all over the world have followed its development with keen interest, with the hopes of an internationally accepted standardized format.

The work with DCC has led to the development of the DCX (Digital Calibration Exchange) by the Danish National Metrology Institute DFM. The DCX format attempts to combine the DCC with the DCR (Digital Calibration Request) into a single format, where the act of creating a DCC corresponds to filling out the received DCR. Additionally, the tabular structure of the DCX allows for a simpler format, which comes at a cost of the customizability and freedom of the DCC tree structure.

In this presentation, we will be showing the main differences between the DCC and the DCX, namely the differences in how measurement data and results are presented. We will be discussing the main advantages and disadvantages of the respective formats.

We will also be presenting the tools we have developed at DTI to work with DCC and DCX. These tools are designed to help users visualize and build DCC and DCX, to gain a better understanding of the formats.

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Presentation #018 of Martin Østerlund

Agenda

- Getting started with DCX
- Machine readability and human readability
  - Structure
  - Developing for the different formats
- Learnings and challenges in working with DCX
- Tools developed
  - DCC and DCX interpreter
  - DCX Generation tool

Danish Agency for Higher Education and Science

Acknowledgement: This study was supported by a grant from Danish Technological Institutes performance contract 2025-2028, entered with the Danish Agency for Higher Education and Science, under The Ministry of Higher Education and Science Denmark. Collaborators are greatly acknowledged.

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Getting started with the DCX

- Where did we start?

XLS Schema

XLS

XML Example

XML

Documentation

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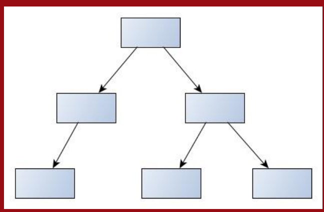
Machine readability and human readability

DCC

Tree structure



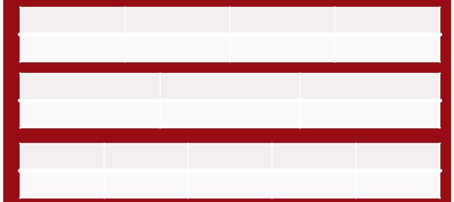
Good for organizing complex data

Designed with a lot of options in mind

Complex

DCX

Tabular structure



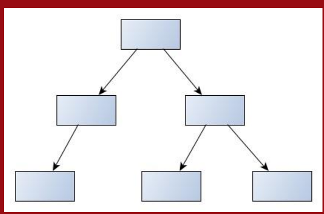
Well structured

More rigid

Simpler

Developing tools for each format

DCC



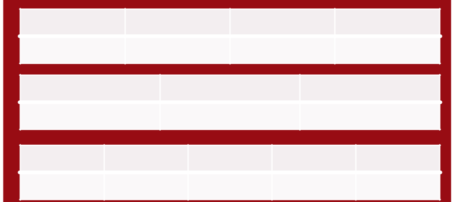
Good naming convention

Deep data structure

Lots of options

→Demands a lot of software

DCX



Good naming convention

Shallow data structure

More rigid

→Easier to build tools for

Learnings and challenges in working with DCX

DCX – DCR and DCC combined

documentIdentifier: ”customerDCR” documentIdentifier: ”laboratoryDCC”

Target value	Reference value	DUT value
10		
20		

Target value	Reference value	DUT value	Comment
10	10,02	9,91	Some comment
20	19,96	20,21	

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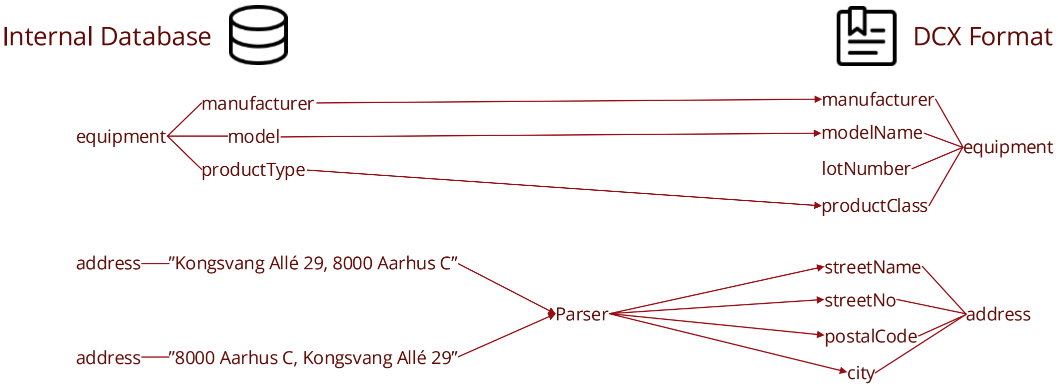
Learnings and challenges in working with DCX

- Reviewing how you save data
- Data you save vs data in the format
- Saving in the right format



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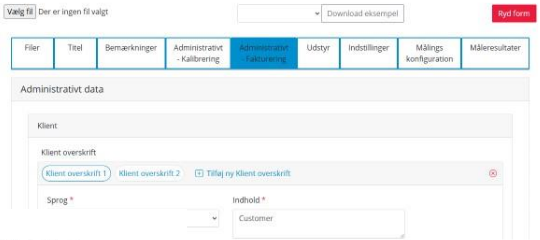
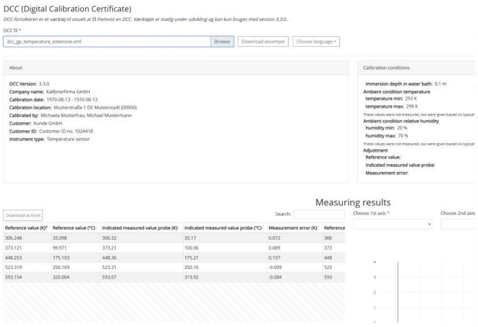
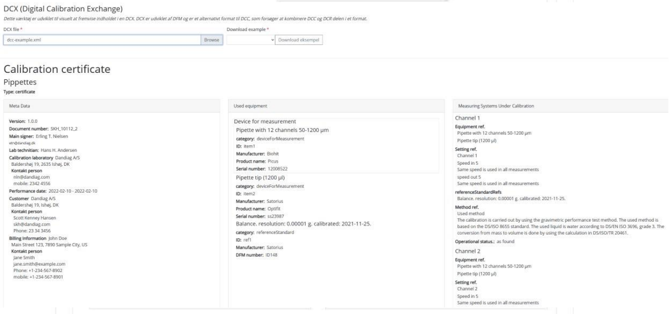
Tools developed

- DCC showcase tool
- DCX showcase tool
- DCX generator

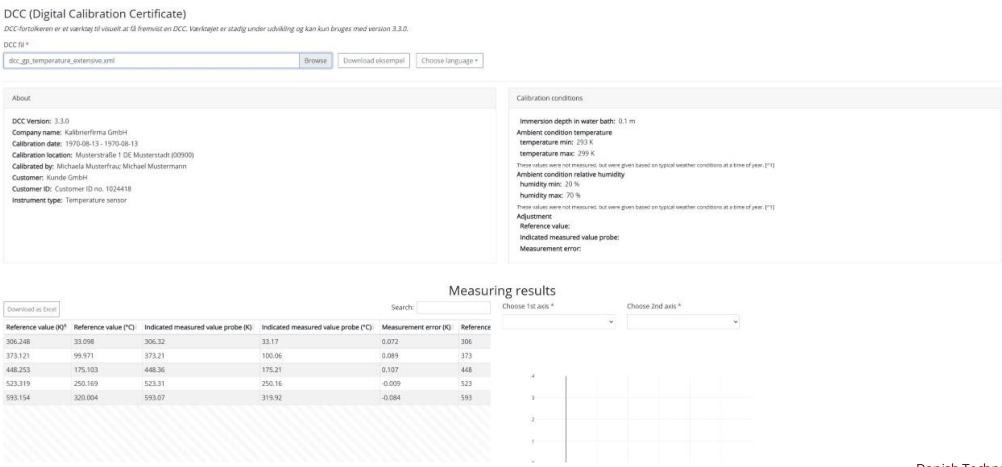






DCC Showcase tool

- Updated to support DCC V3.3.0



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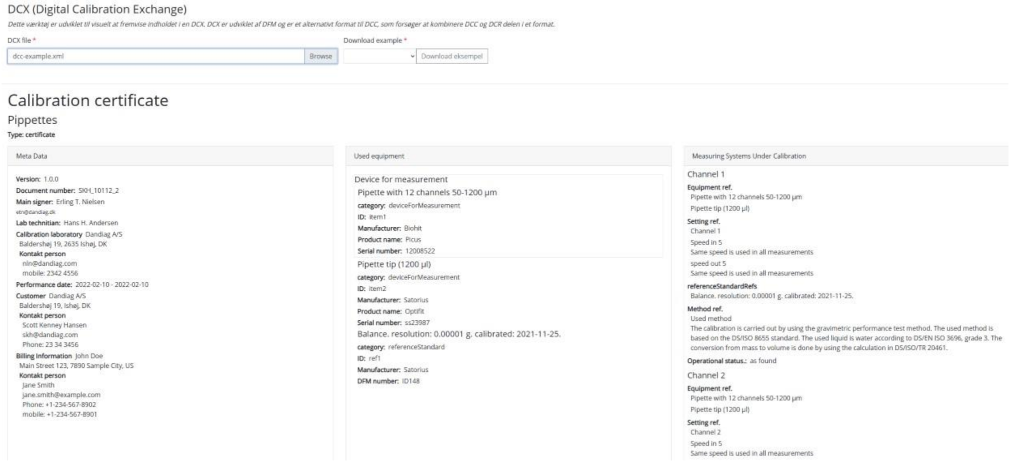
DCX Showcase tool

- New feature! DCX Showcase tool



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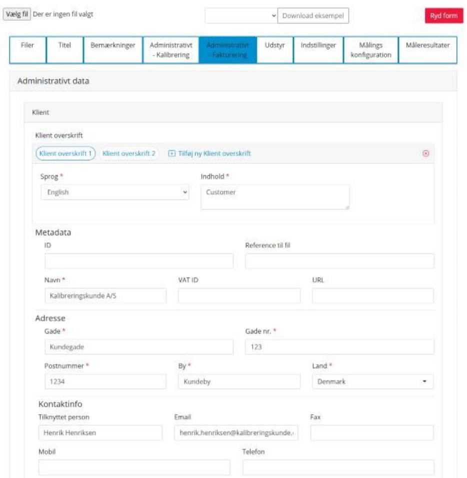
DCX Generator

- New feature: DCX Generator tool



- Get started with generating DCX
- Use examples to get a solid base
- Still Work-in-Progress – Some features have yet to be implemented

Try it now!

https://apps.teknologisk.dk/public/login/?redirectTo=%2Fdigital-kalibrering%2F

Link

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Contact

- Question or feedback regarding the tools? Want to collaborate on DCX?

- Contact us

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Thank you

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019 David Balslev-Harder: DCX from DCR to DCC: Digital Results and Round-Robin Evaluations

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Email: dbh@dfm.dk
Additional authors:

- Søren Kynde [1] srk@dfm.dk

Institute:
[1] Danish Fundamental Metrology – Danish National Metrology Institute (DFM), Kogle Allé, DK-2970 Hørsholm, Denmark
Keywords: Nil

Abstract

Building on structured Digital Calibration Requests (DCRs), similarly structured Digital Calibration Certificates (DCCs) offer the possibility of using calibration results directly in digital and automated processes. In this contribution, we share experiences with converting DCX-based DCRs into DCCs and applying the resulting method in implementation evaluations.

We describe a workflow in which a DCR serves as a common digital reference for multiple calibration laboratories. In a small round-robin exercise, three laboratories independently implemented their own DCCs based on the same received DCR and an equivalent traditional paper certificate. This setup allowed a comparison between laboratories' digital interpretations while maintaining established calibration practices.

A key aspect of the work is the reuse of DCX query expressions throughout the process. Queries defined at the request stage were applied to the resulting DCCs to extract and process calibration results in a consistent manner. This approach supported partial automation of data handling and helped reduce manual interpretation when comparing results across laboratories.

The contribution does not aim to demonstrate a fully automated or standardized solution. Instead, it focuses on practical insights gained from the round-robin activity, including differences in implementation, interpretation challenges, and areas where additional guidance or harmonization may be beneficial.

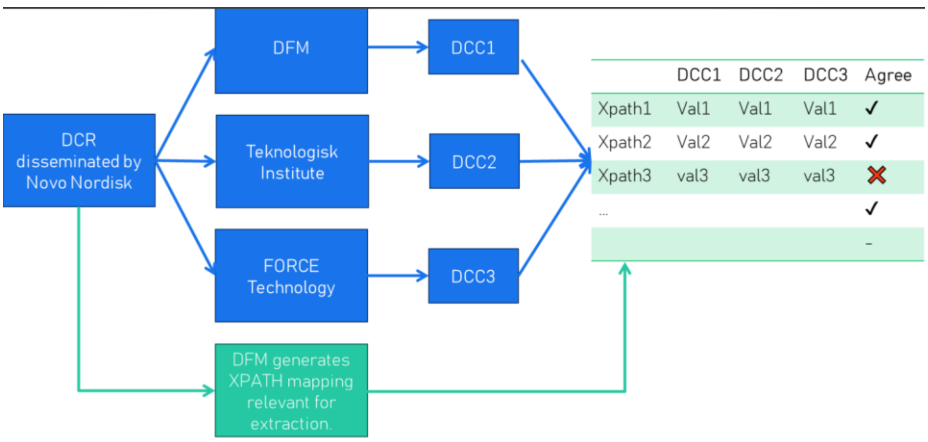

Figure 2. Process for the 2025 DCX round-robin, implementation comparison.

Overall, this presentation seeks to illustrate how DCX concepts can link DCRs, DCCs, and round-robin evaluations in a coherent digital workflow. By sharing early experiences rather than definitive answers, we hope to contribute constructively to the ongoing discussion on the role of digital certificates and structured queries in future calibration and comparison activities.

References:
[1] 5 minute video introduction to DCX: https://www.youtube.com/watch?v=AmXMWAHjakw
[2] Webpage (2025): https://github.com/TC-IM-1448/DCC-Tables

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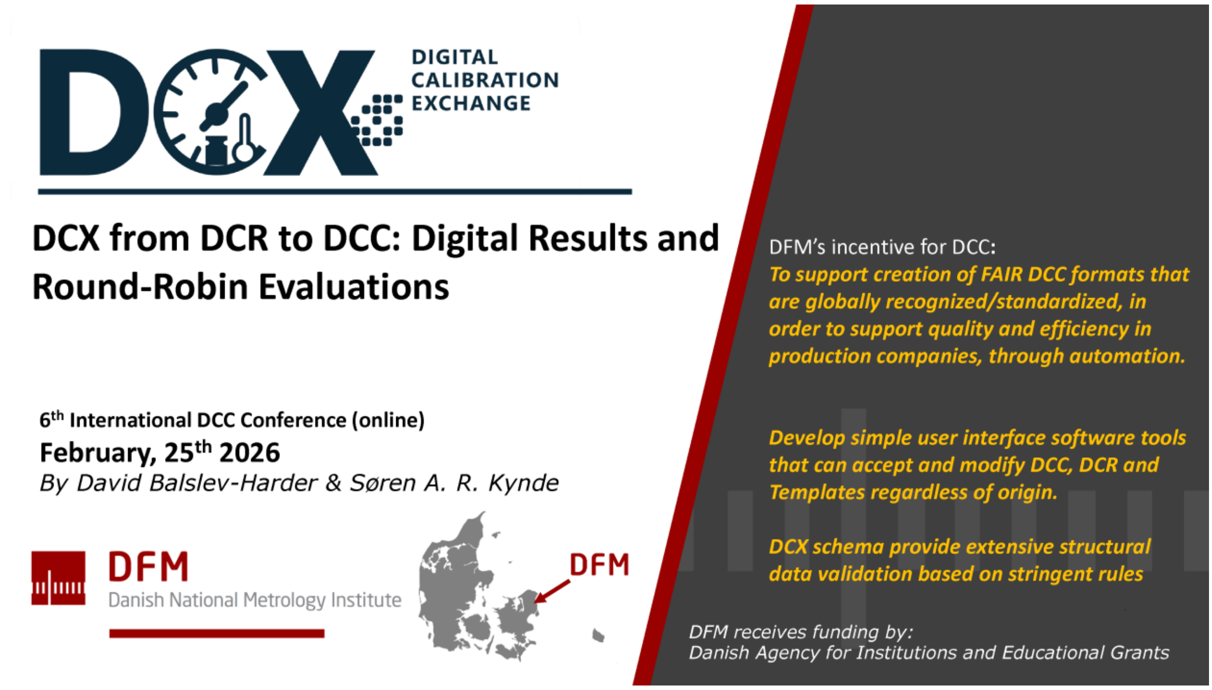
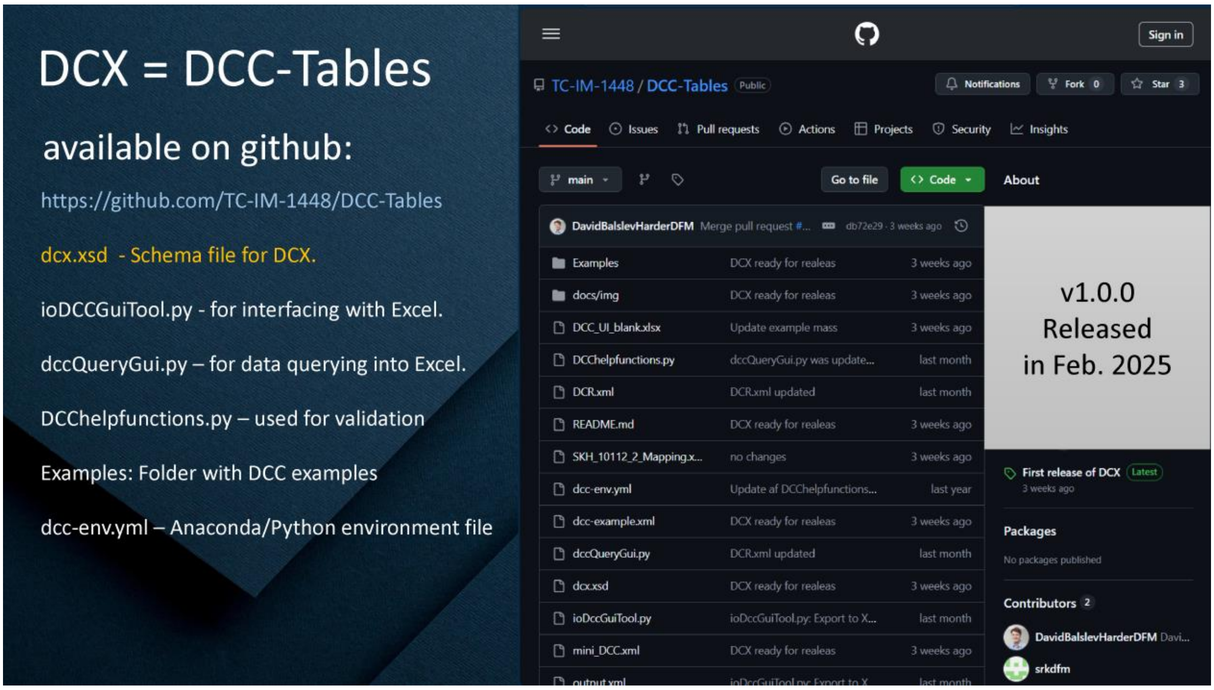
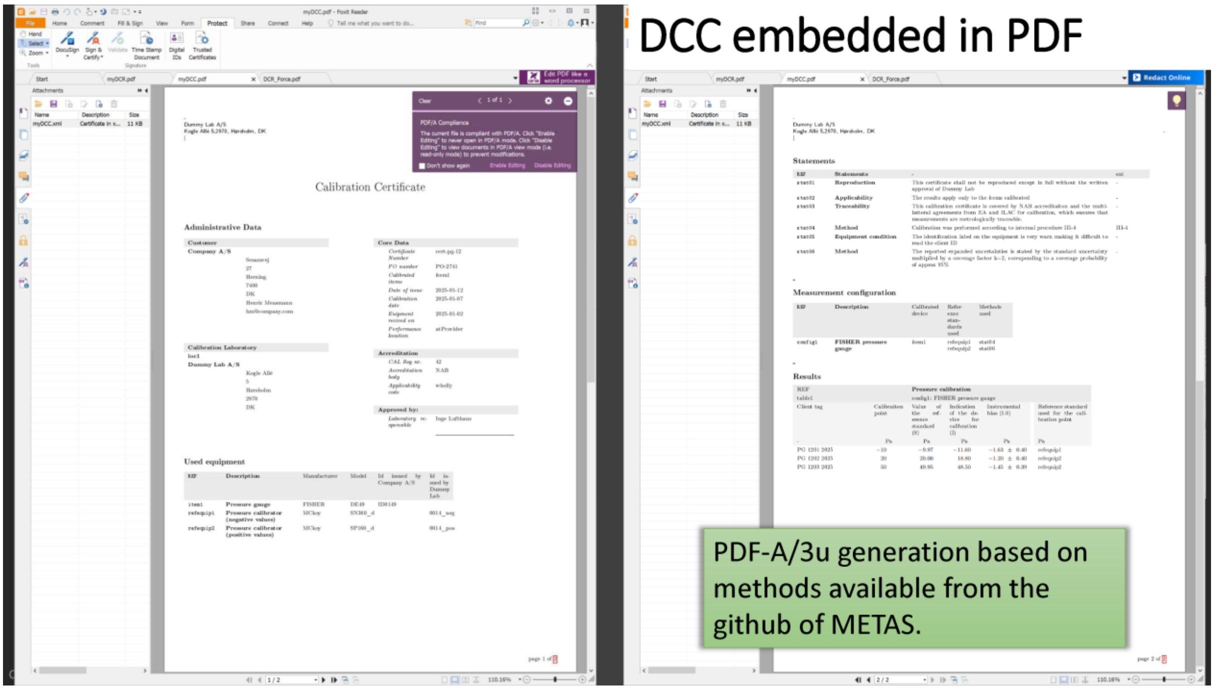
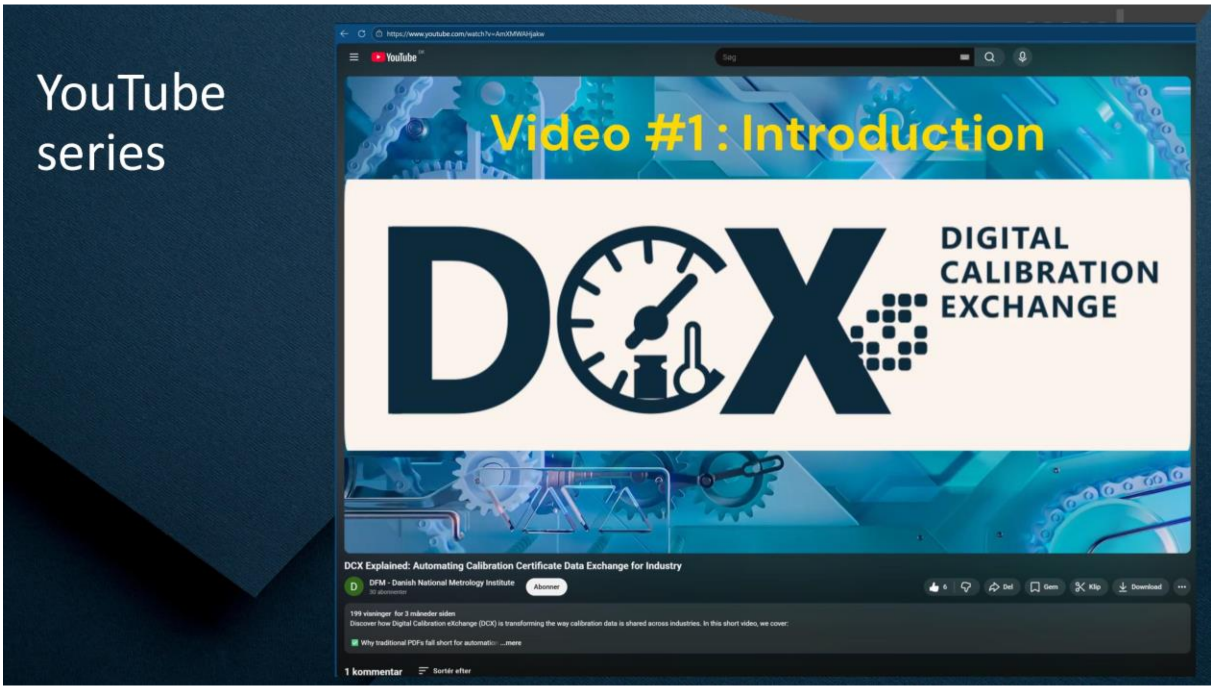
Presentation #019 of David Balslev-Harder



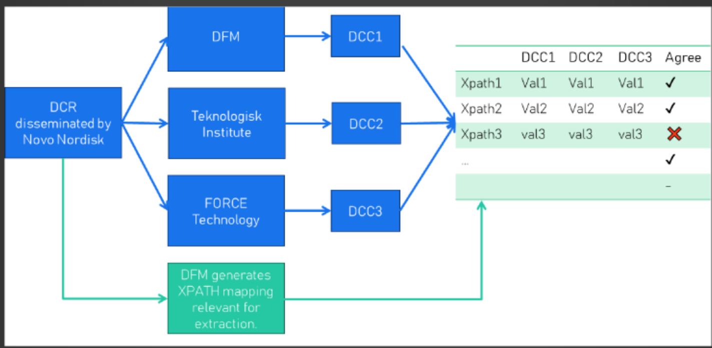



DCC embedded in PDF
Calibration Certificate
Administrative Data
Used equipment
Statements
Measurement configuration
Results
PDF-A/3u generation based on methods available from the github of METAS.


YouTube series
Video #1 : Introduction
DCX
DIGITAL CALIBRATION EXCHANGE
DCX Explained: Automating Calibration Certificate Data Exchange for Industry
DFM - Danish National Metrology Institute

Process for Pilot study of DCX v1.0.0

1. *Client map their data-base information needs to DCR format.*
2. *Prepare XPath mapping for extraction of data from DCC to client DB.*
3. *Certificates will be generated by several Service Providers to test if they return DCC's with equivalent content, structure and formats.*



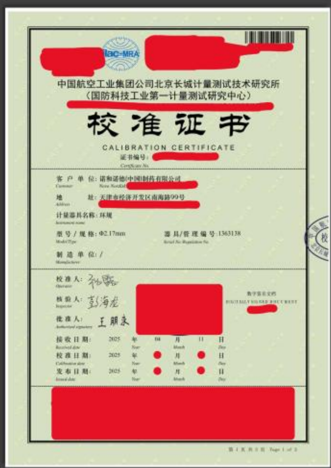
dbh@dfm.dk

Investigated 3 calibration scenarios

DK-DCX-RR-25-01
Pressure

DK-DCX-RR-25-02
Ring gauge geometry

DK-DCX-RR-25-03
Humidity



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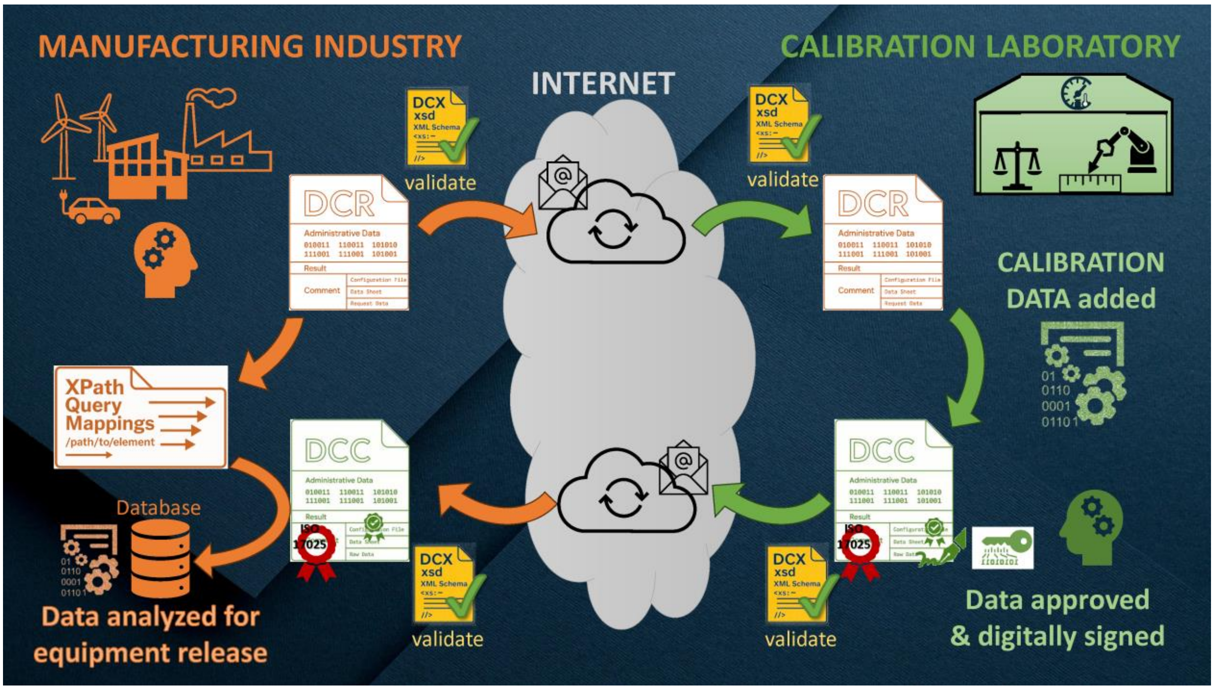
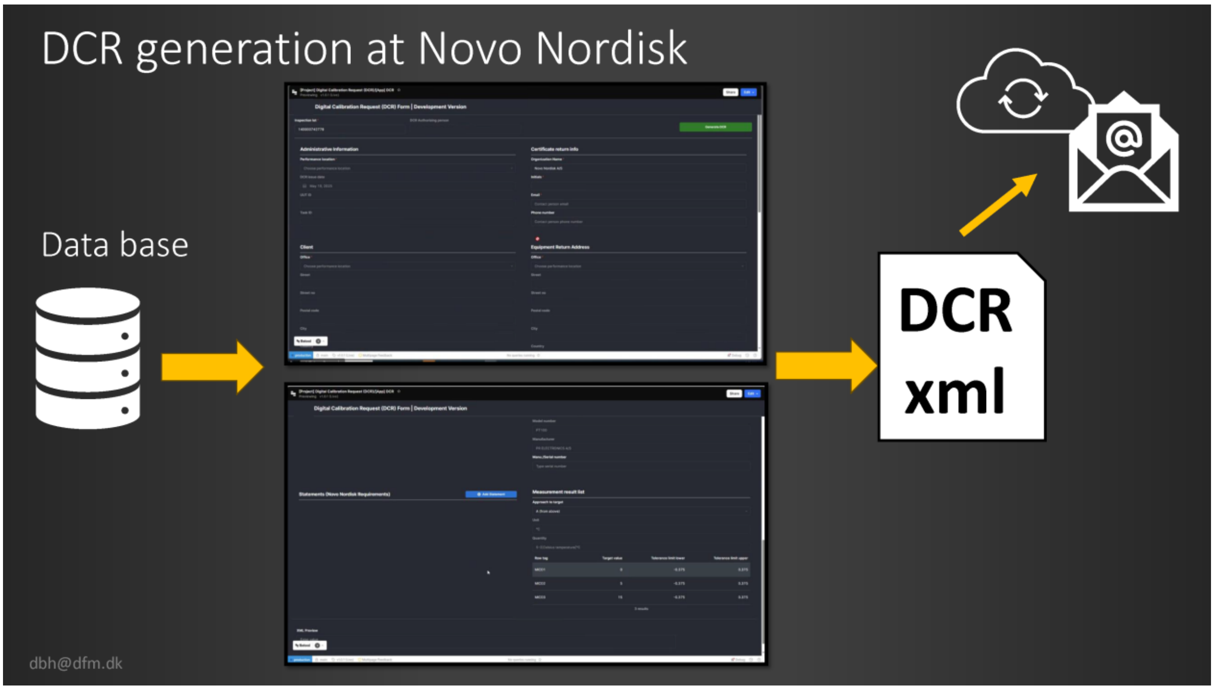
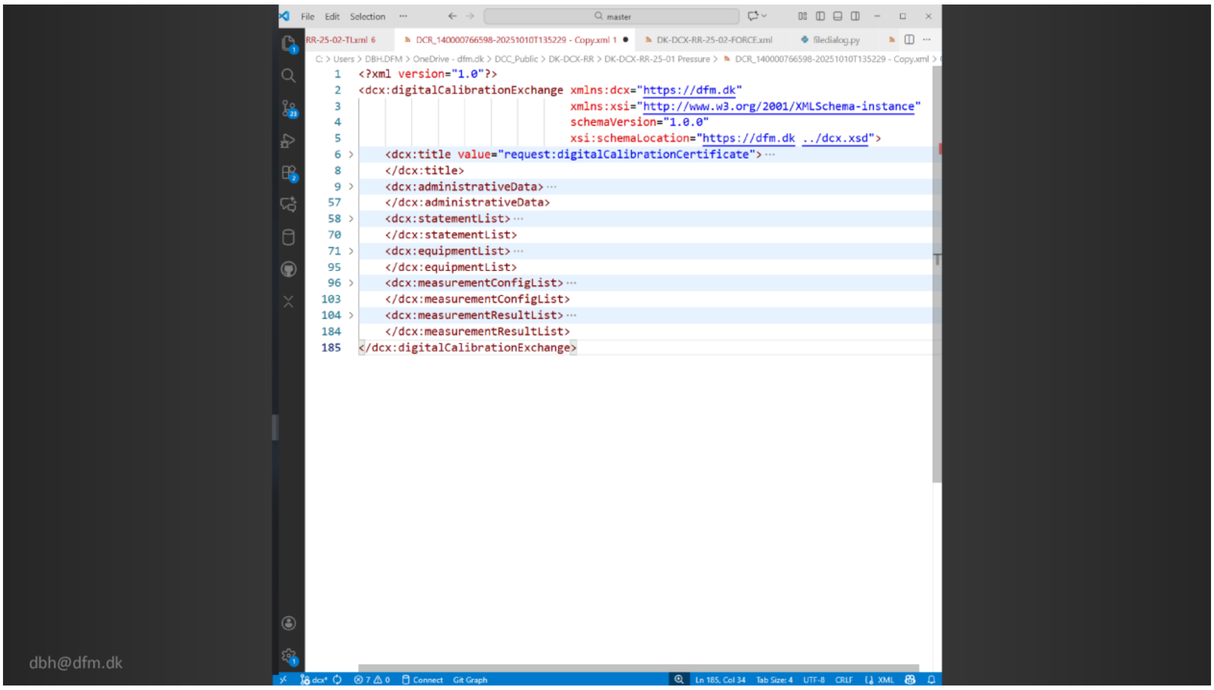

MANUFACTURING INDUSTRY
CALIBRATION LABORATORY
INTERNET
DCX xsd XML Schema
validate
DCR
Administrative Data
Result
Comment
XPath Query Mappings /path/to/element
Database
Data analyzed for equipment release
DCC
CALIBRATION DATA added
Data approved & digitally signed


MANUFACTURING INDUSTRY
CALIBRATION LABORATORY
DCX xsd XML Schema
validate
DCR
Administrative Data
Result
Comment
XPath Query Mappings /path/to/element
Preparation of Request and Data Query


DCR generation at Novo Nordisk
Data base
DCR
xml
dbh@dfm.dk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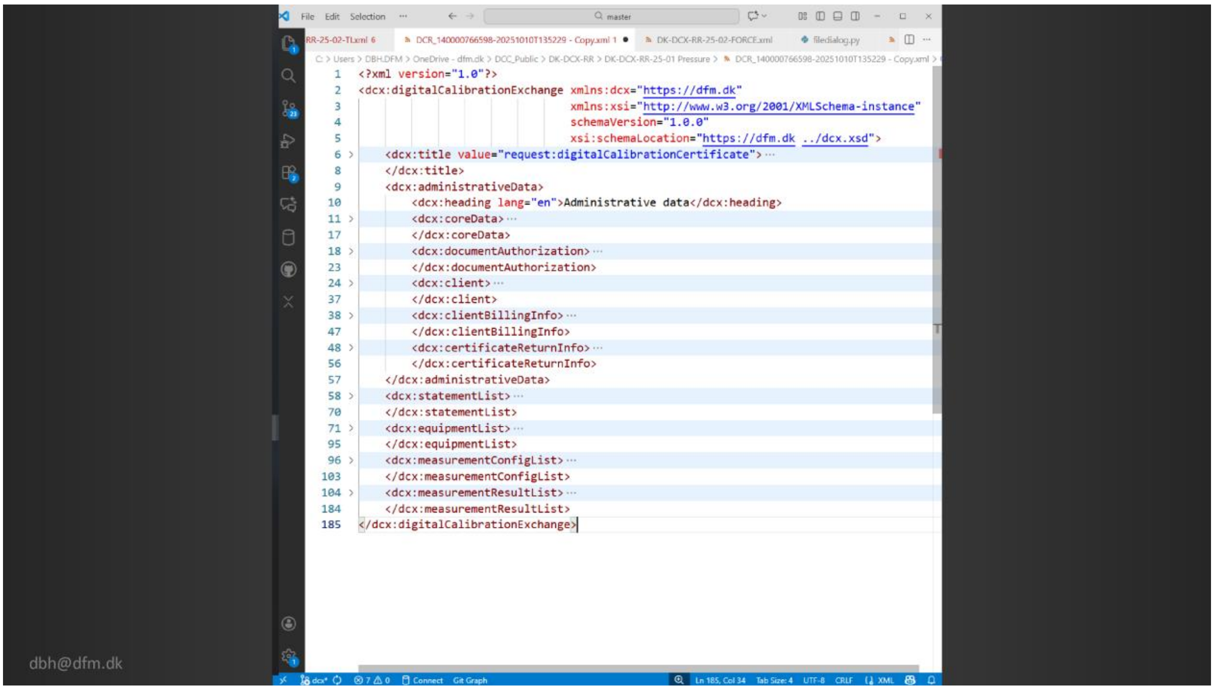
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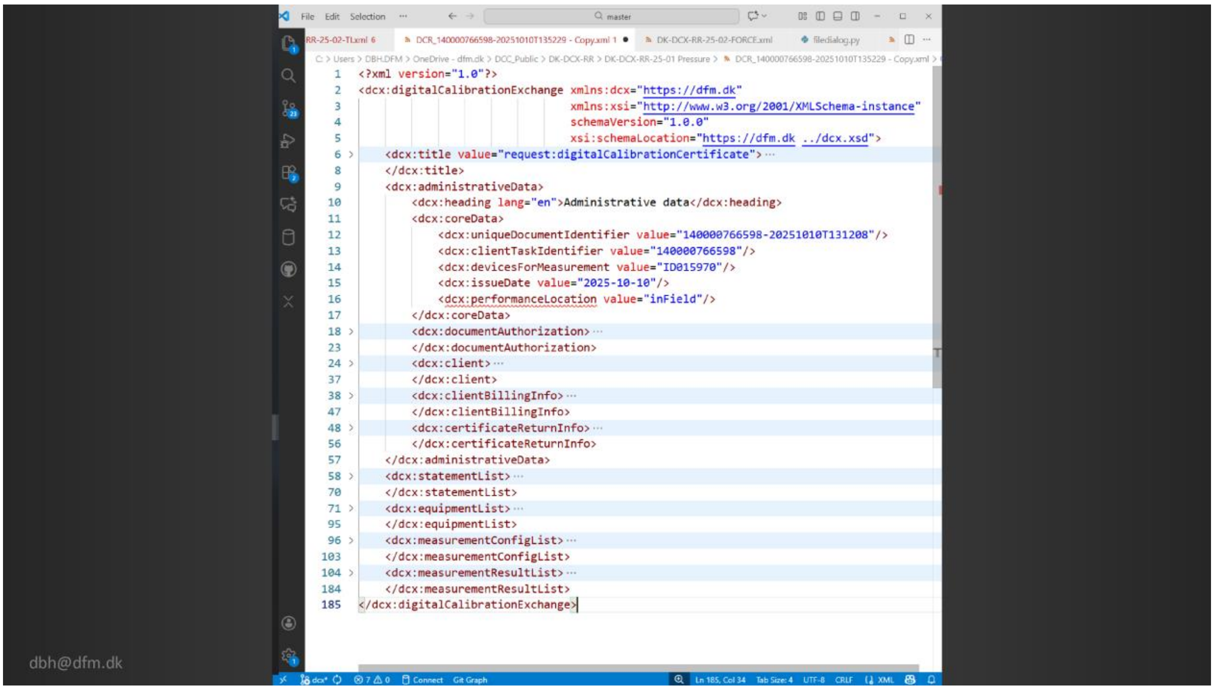
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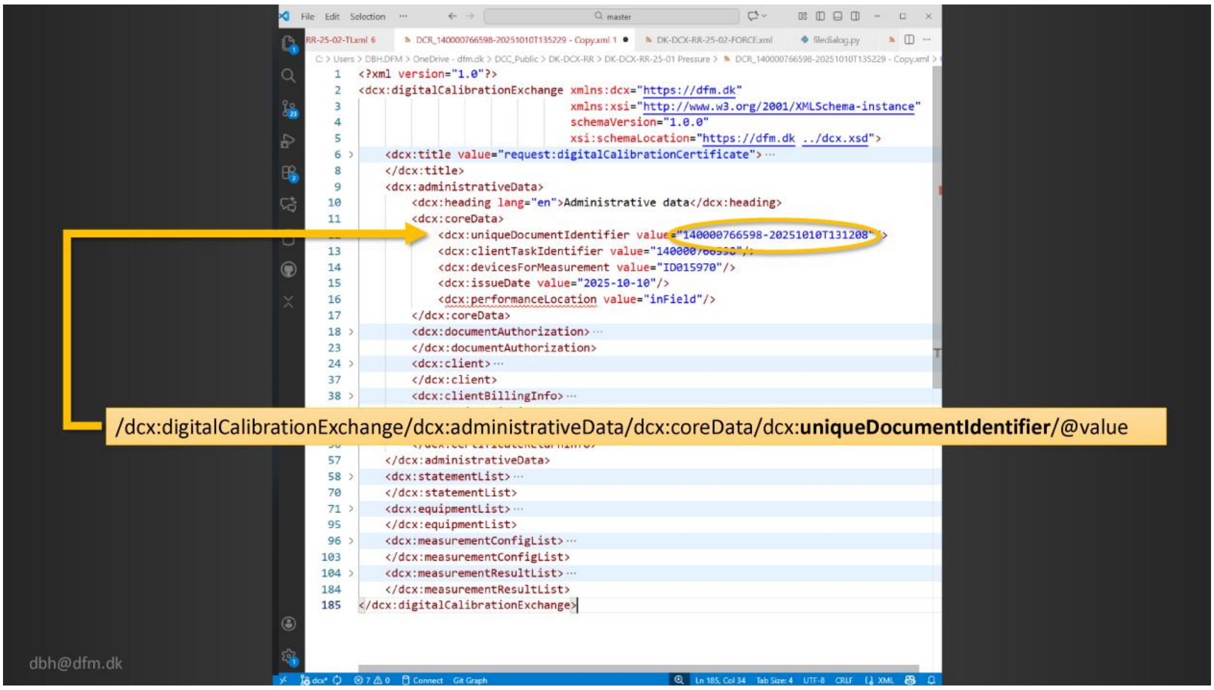

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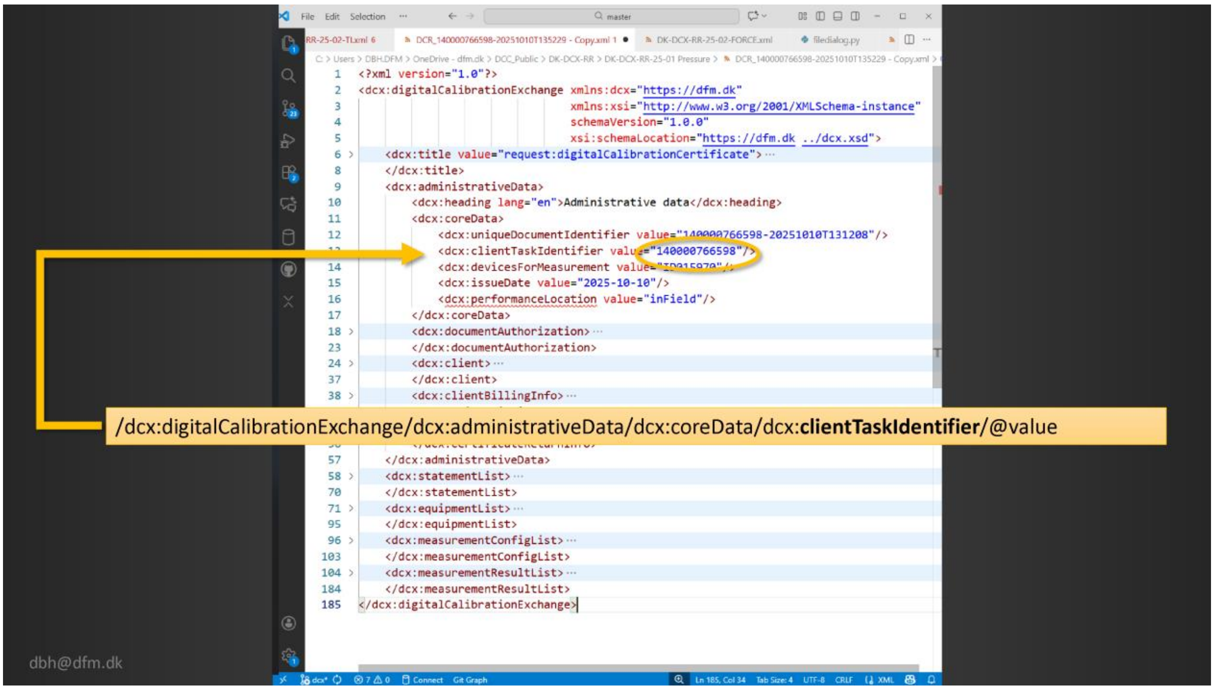

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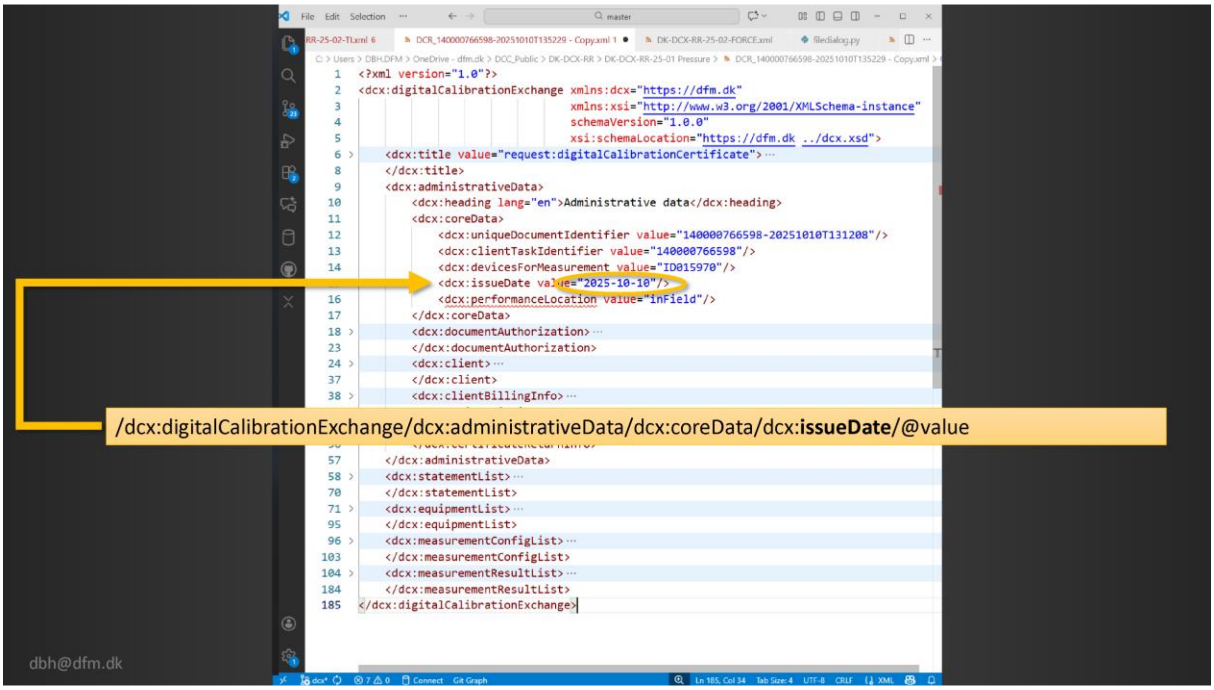
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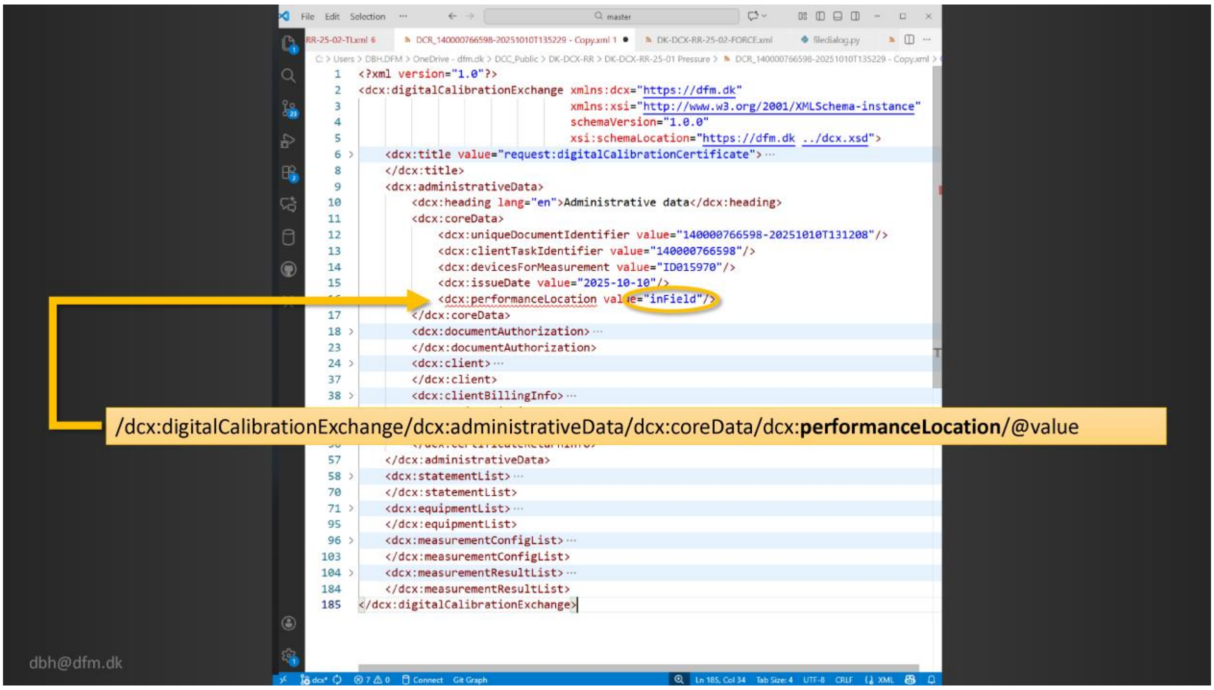
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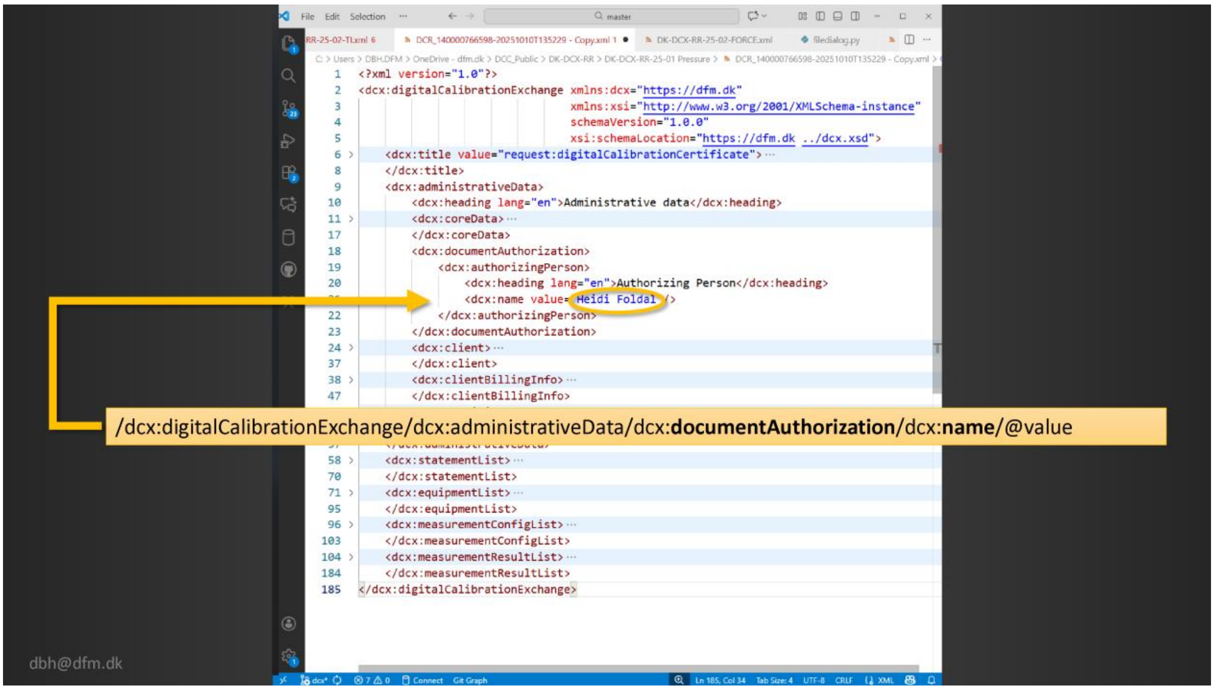
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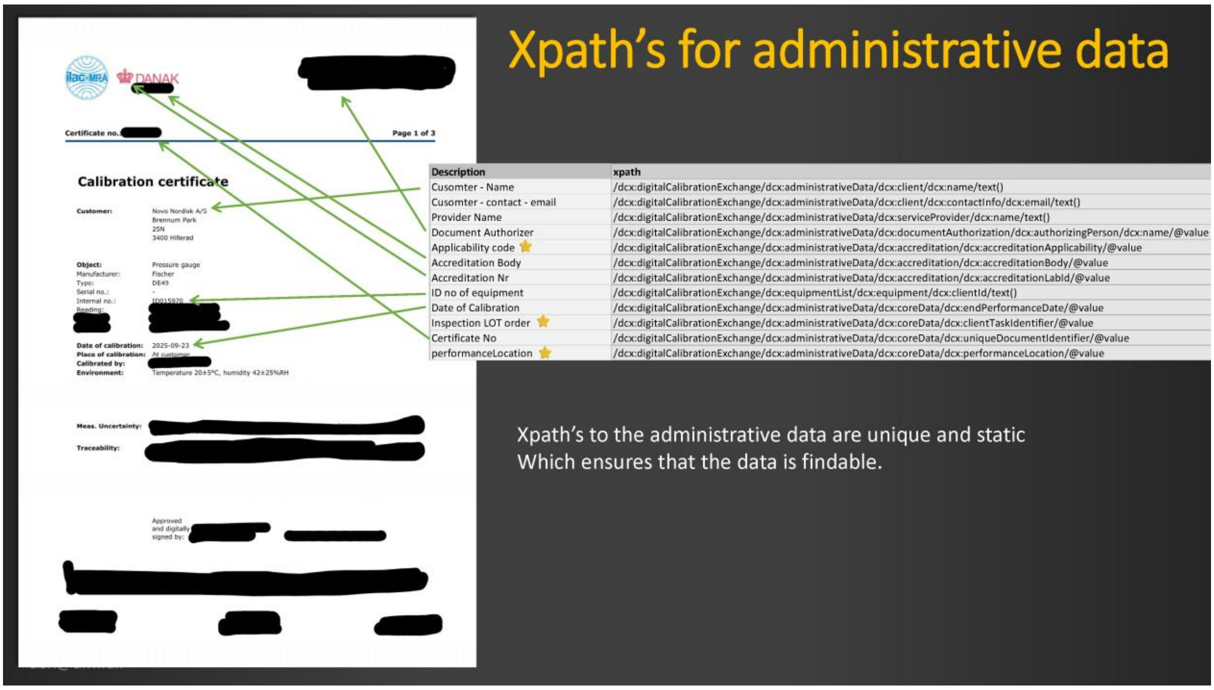
Xpath's for administrative data
Certificate no. [redacted]
Page 1 of 3
Calibration certificate
Customer: Novo Nordisk A/S
Object: Pressure gauge
Manufacturer: Fischer
Type: DE49
Date of calibration: 2025-09-23
Environment: Temperature 20±5ºC, humidity 42±25%RH
Meas. Uncertainty: [redacted]
Traceability: [redacted]
Approved and digitally signed by: [redacted]
Description | xpath
Cusomter - Name | /dcx:digitalCalibrationExchange/dcx:administrativeData/dcx:client/dcx:name/text()
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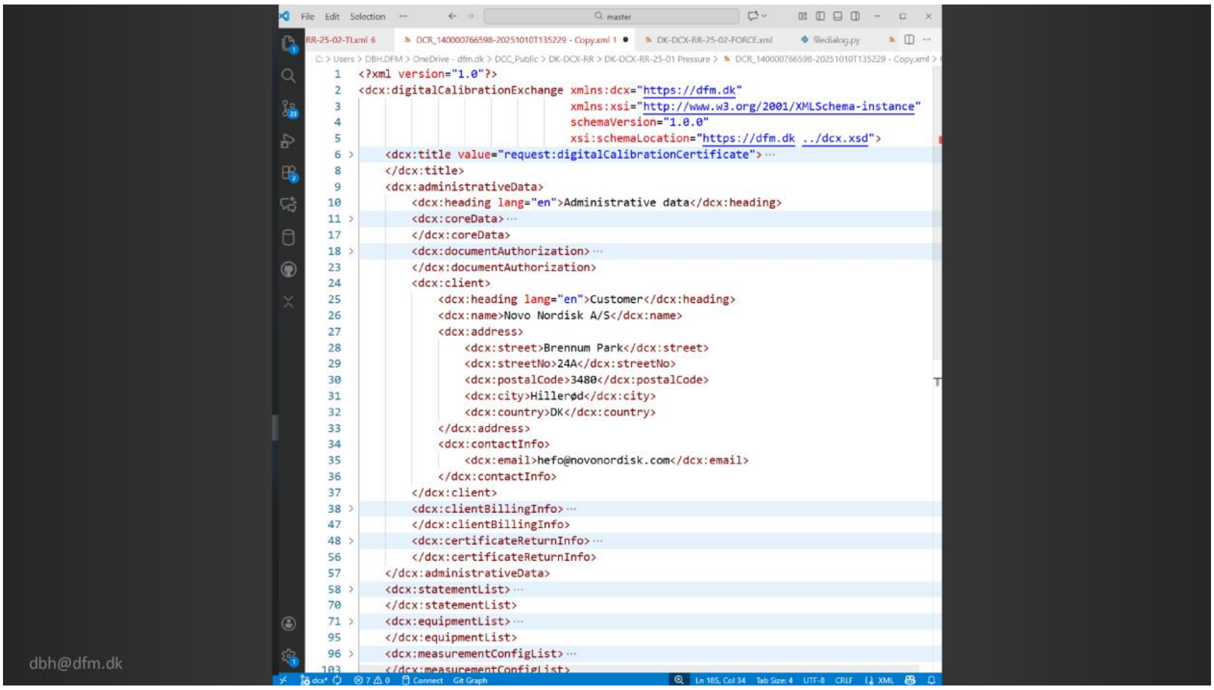
Accreditation Body | /dcx:digitalCalibrationExchange/dcx:administrativeData/dcx:accreditation/dcx:accreditationBody/@value
Accreditation Nr | /dcx:digitalCalibrationExchange/dcx:administrativeData/dcx:accreditation/dcx:accreditationLabId/@value
ID no of equipment | /dcx:digitalCalibrationExchange/dcx:equipmentList/dcx:equipment/dcx:clientId/text()
Date of Calibration | /dcx:digitalCalibrationExchange/dcx:administrativeData/dcx:coreData/dcx:endPerformanceDate/@value
Inspection LOT order | /dcx:digitalCalibrationExchange/dcx:administrativeData/dcx:coreData/dcx:clientTaskIdentifier/@value
Certificate No | /dcx:digitalCalibrationExchange/dcx:administrativeData/dcx:coreData/dcx:uniqueDocumentIdentifier/@value
performanceLocation | /dcx:digitalCalibrationExchange/dcx:administrativeData/dcx:coreData/dcx:performanceLocation/@value
Xpath's to the administrative data are unique and static
Which ensures that the data is findable.



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                                schemaVersion="1.0.0"
                                xsi:schemaLocation="https://dfm.dk ../dcx.xsd">
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        <dcx:coreData>···
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        <dcx:documentAuthorization>···
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            <dcx:heading lang="en">Customer</dcx:heading>
            <dcx:name>Novo Nordisk A/S</dcx:name>
            <dcx:address>
                <dcx:street>Brennum Park</dcx:street>
                <dcx:streetNo>24A</dcx:streetNo>
                <dcx:postalCode>3400</dcx:postalCode>
                <dcx:city>Hillerød</dcx:city>
                <dcx:country>DK</dcx:country>
            </dcx:address>
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                <dcx:email>hefo@novonordisk.com</dcx:email>
            </dcx:contactInfo>
        </dcx:client>
        <dcx:clientBillingInfo>···
        </dcx:clientBillingInfo>
        <dcx:certificateReturnInfo>···
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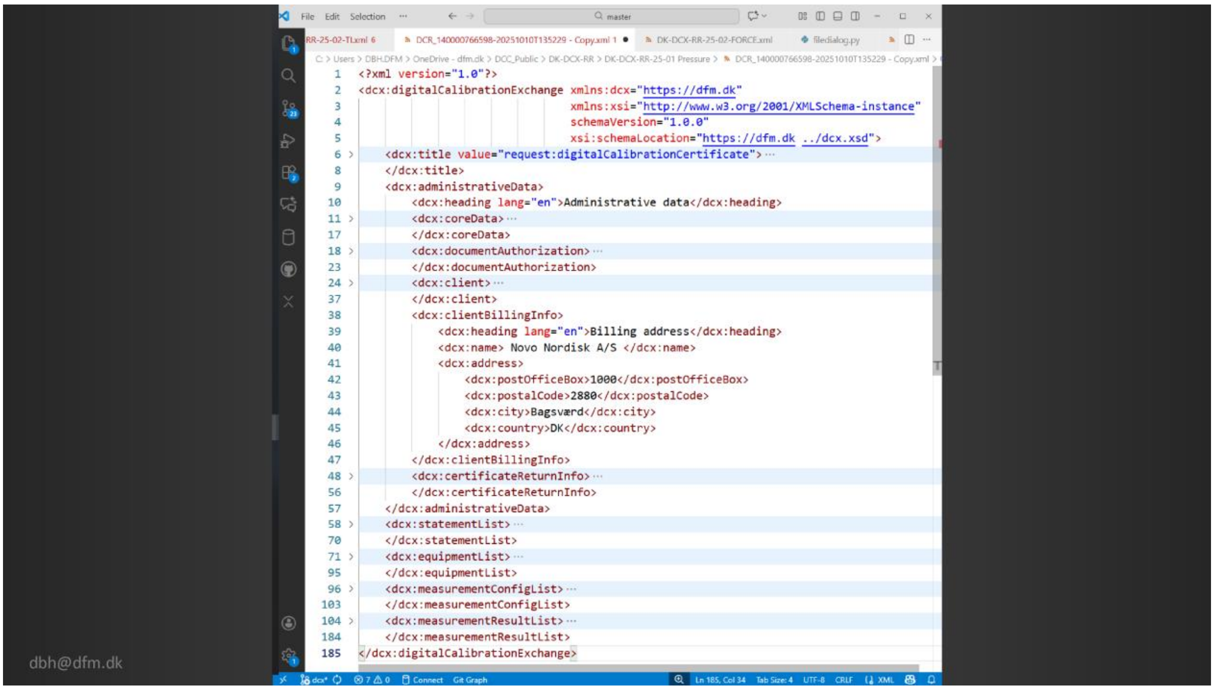
    </dcx:administrativeData>
    <dcx:statementList>···
    </dcx:statementList>
    <dcx:equipmentList>···
    </dcx:equipmentList>
    <dcx:measurementConfigList>···
```
dbh@dfm.dk



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                                xsi:schemaLocation="https://dfm.dk ../dcx.xsd">
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    </dcx:title>
    <dcx:administrativeData>
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        <dcx:coreData>···
        </dcx:coreData>
        <dcx:documentAuthorization>···
        </dcx:documentAuthorization>
        <dcx:client>···
        </dcx:client>
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            <dcx:heading lang="en">Billing address</dcx:heading>
            <dcx:name> Novo Nordisk A/S </dcx:name>
            <dcx:address>
                <dcx:postOfficeBox>1000</dcx:postOfficeBox>
                <dcx:postalCode>2880</dcx:postalCode>
                <dcx:city>Bagsværd</dcx:city>
                <dcx:country>DK</dcx:country>
            </dcx:address>
        </dcx:clientBillingInfo>
        <dcx:certificateReturnInfo>···
        </dcx:certificateReturnInfo>
    </dcx:administrativeData>
    <dcx:statementList>···
    </dcx:statementList>
    <dcx:equipmentList>···
    </dcx:equipmentList>
    <dcx:measurementConfigList>···
    </dcx:measurementConfigList>
    <dcx:measurementResultList>···
    </dcx:measurementResultList>
</dcx:digitalCalibrationExchange>
```
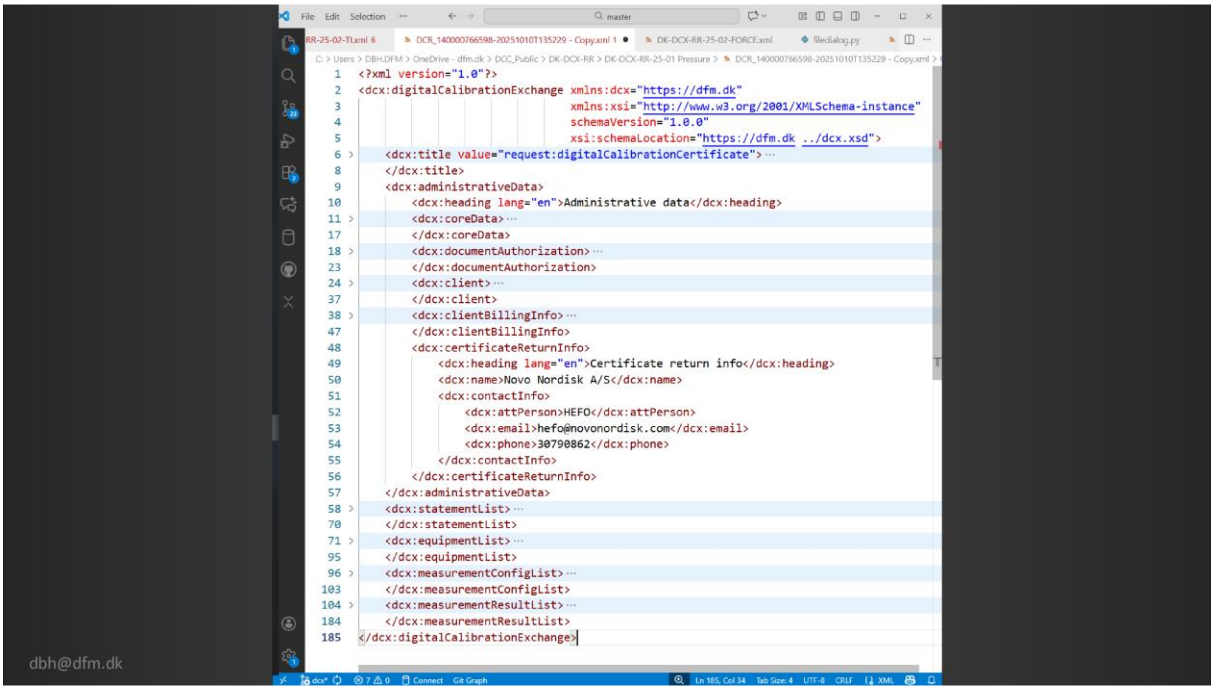
dbh@dfm.dk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xsi:schemaLocation="https://dfm.dk ../dcx.xsd">
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<dcx:contactInfo>
<dcx:attPerson>HEFO</dcx:attPerson>
<dcx:email>hefo@novonordisk.com</dcx:email>
<dcx:phone>30790862</dcx:phone>
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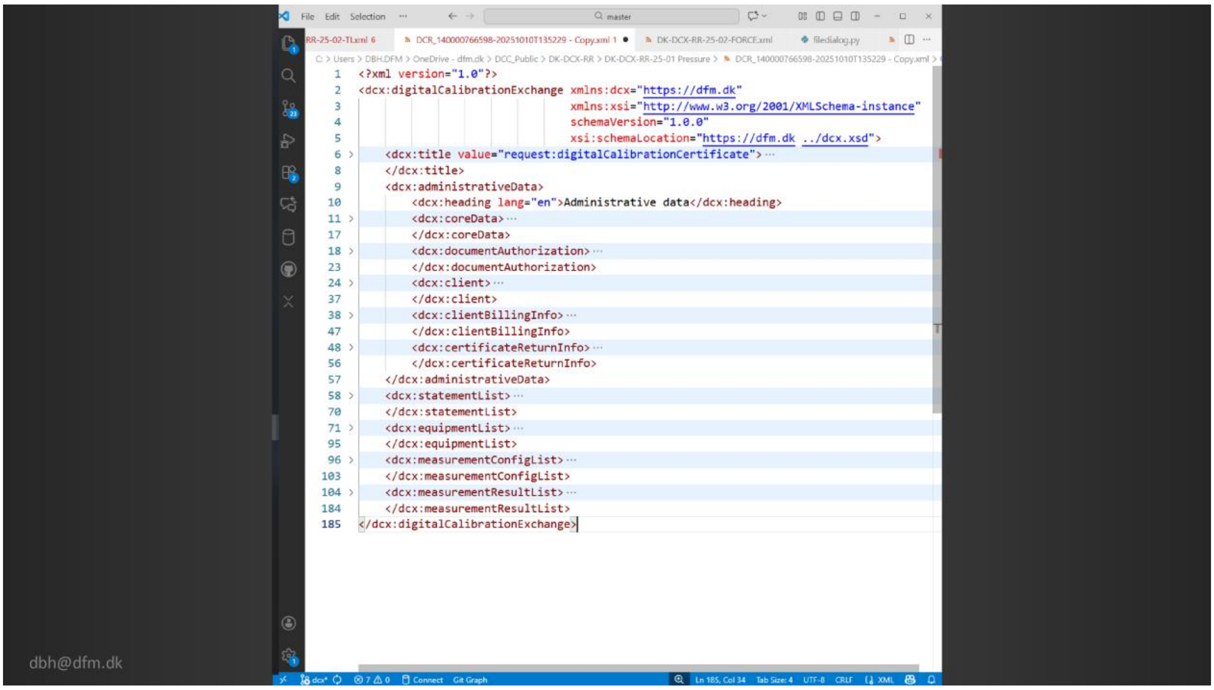
dbh@dfm.dk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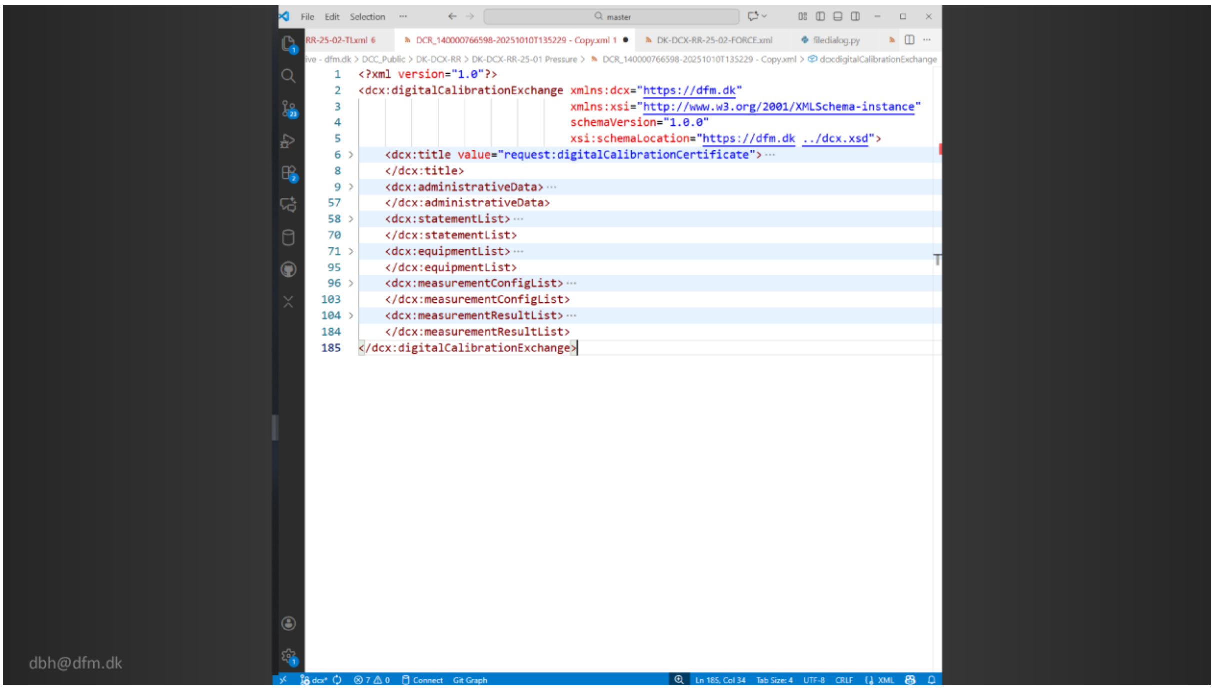
dbh@dfm.dk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</dcx:equipmentList>
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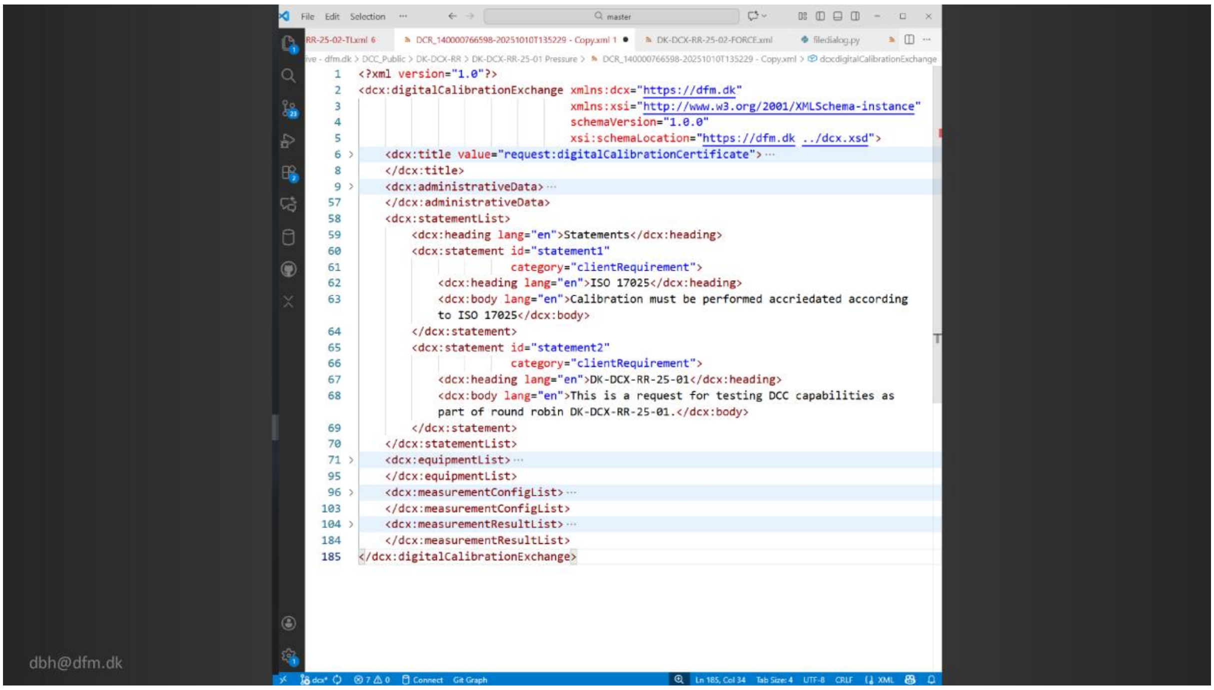
</dcx:measurementResultList>
</dcx:digitalCalibrationExchange>
dbh@dfm.dk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xsi:schemaLocation="https://dfm.dk ../dcx.xsd">
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</dcx:title>
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</dcx:administrativeData>
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category="clientRequirement">
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<dcx:body lang="en">Calibration must be performed accriedated according to ISO 17025</dcx:body>
</dcx:statement>
<dcx:statement id="statement2"
category="clientRequirement">
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<dcx:body lang="en">This is a request for testing DCC capabilities as part of round robin DK-DCX-RR-25-01.</dcx:body>
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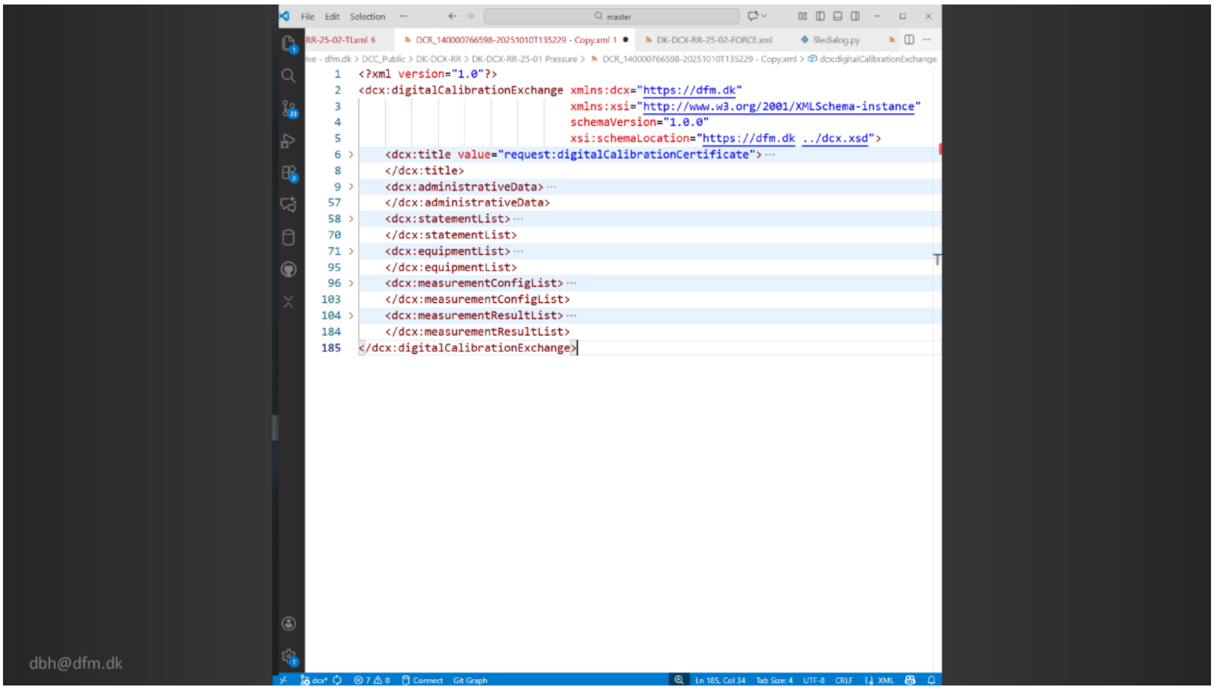
</dcx:digitalCalibrationExchange>
dbh@dfm.dk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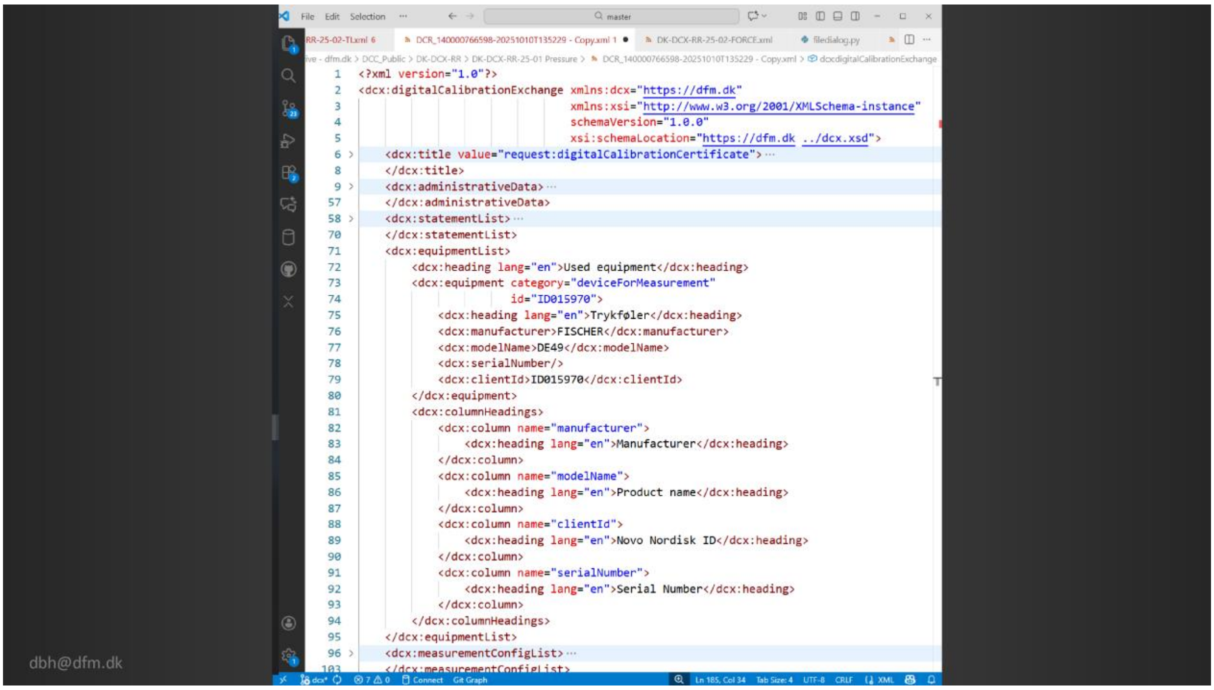
</dcx:digitalCalibrationExchange>
dbh@dfm.dk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xsi:schemaLocation="https://dfm.dk ../dcx.xsd">
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id="ID015970">
<dcx:heading lang="en">Trykføler</dcx:heading>
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<dcx:serialNumber/>
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</dcx:equipment>
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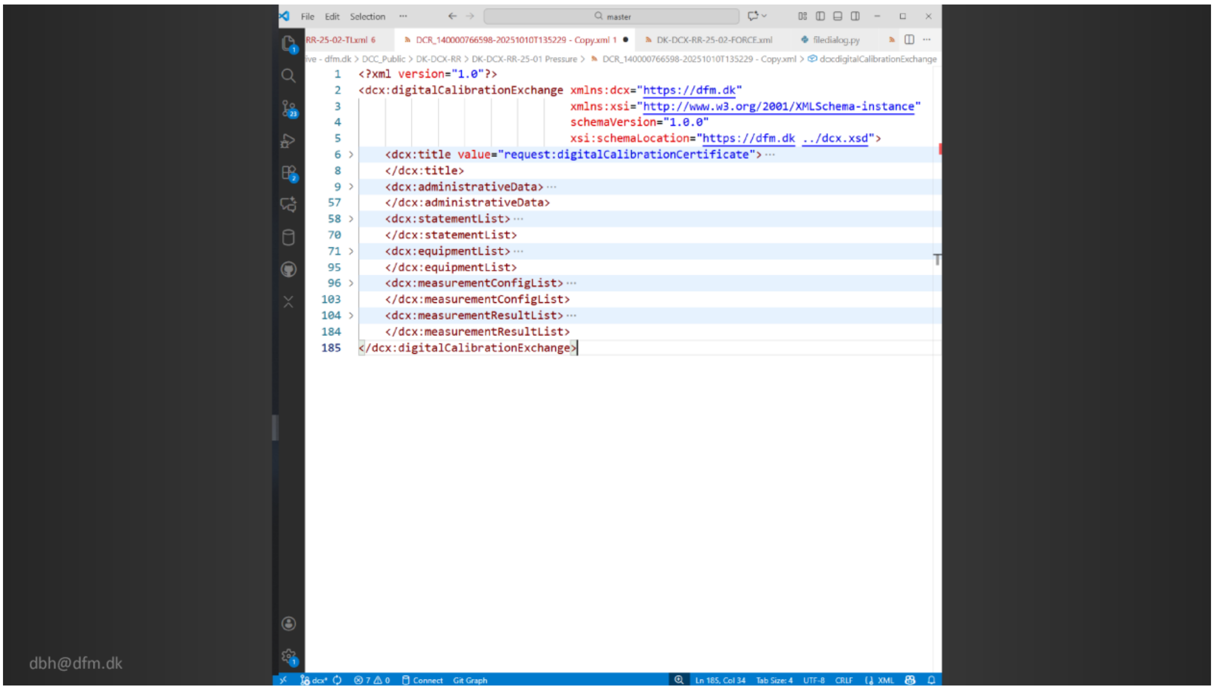
dbh@dfm.dk


File Edit Selection
master
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xsi:schemaLocation="https://dfm.dk ../dcx.xsd">
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<dcx:measurementConfigList>···
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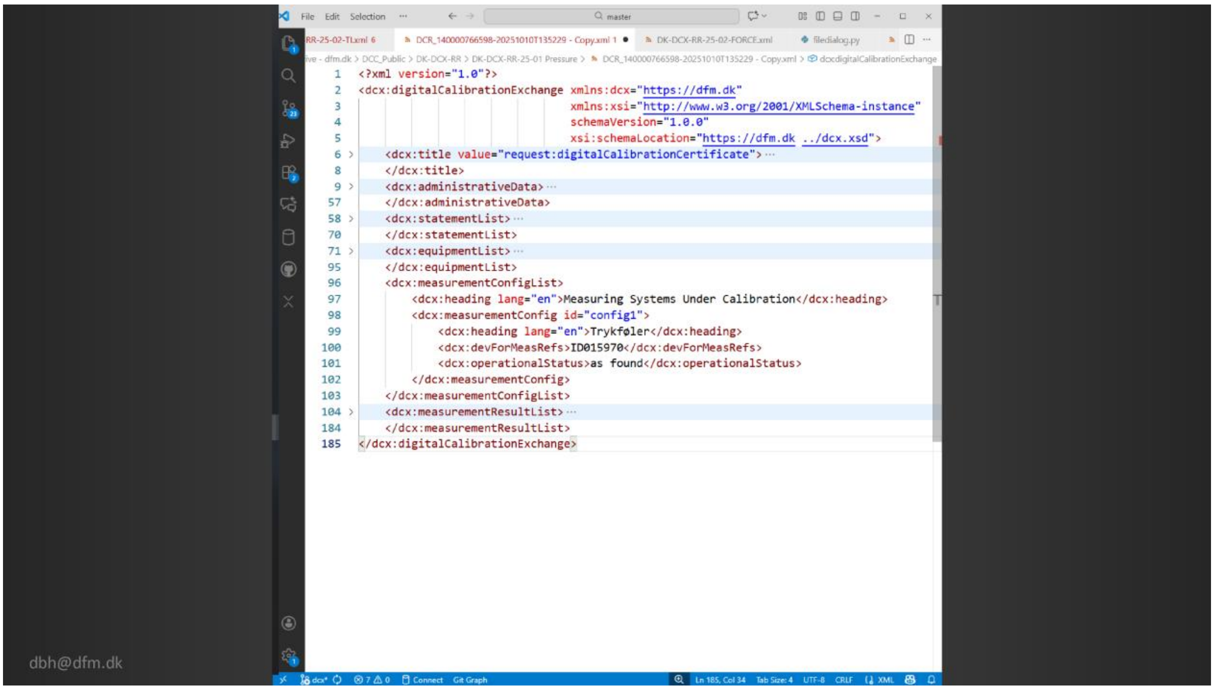
</dcx:digitalCalibrationExchange>
dbh@dfm.dk


File Edit Selection
master
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schemaVersion="1.0.0"
xsi:schemaLocation="https://dfm.dk ../dcx.xsd">
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</dcx:administrativeData>
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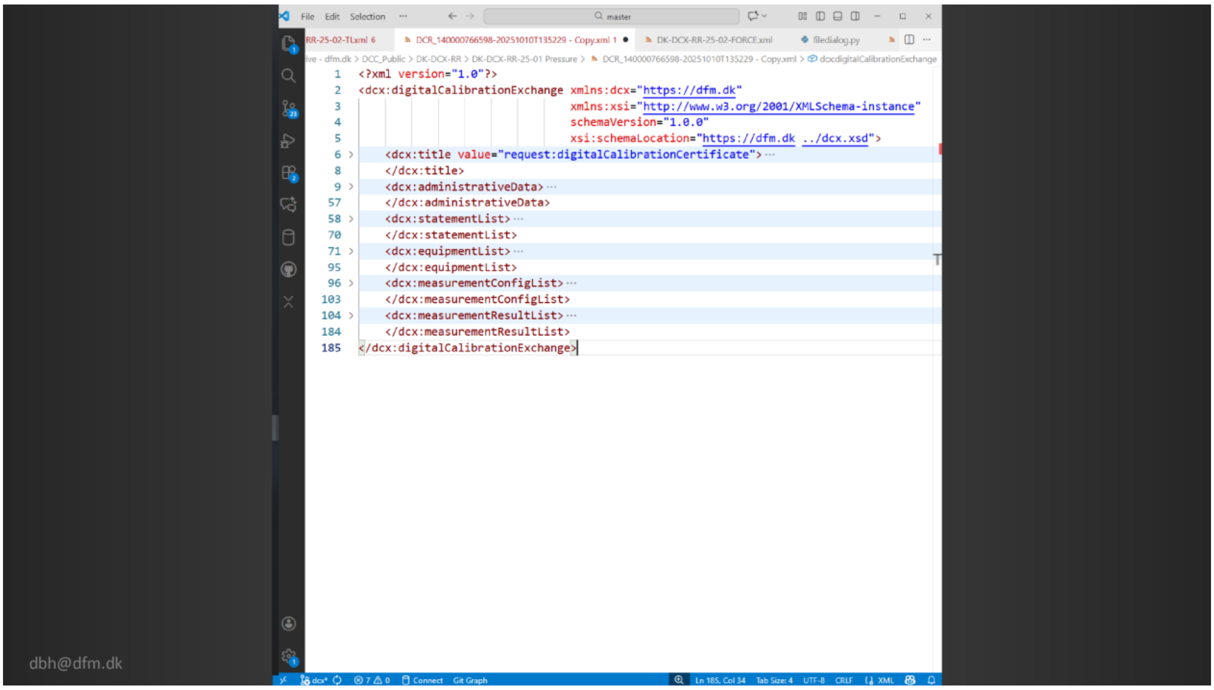
dbh@dfm.dk



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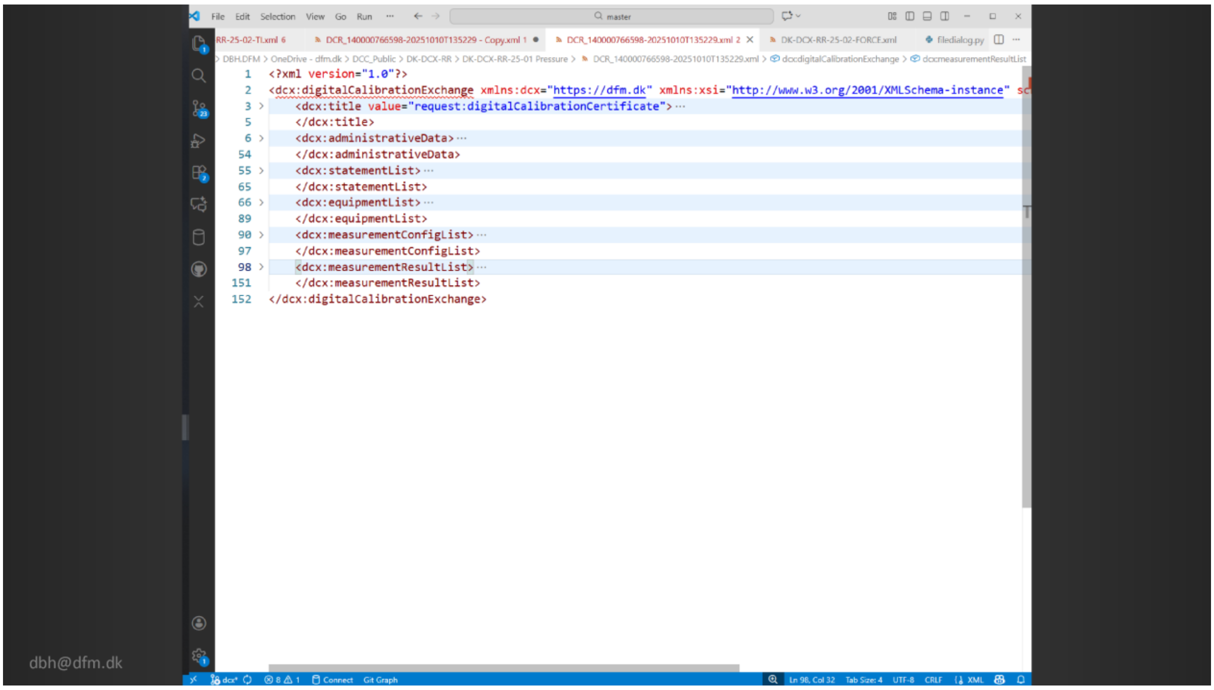
dbh@dfm.dk



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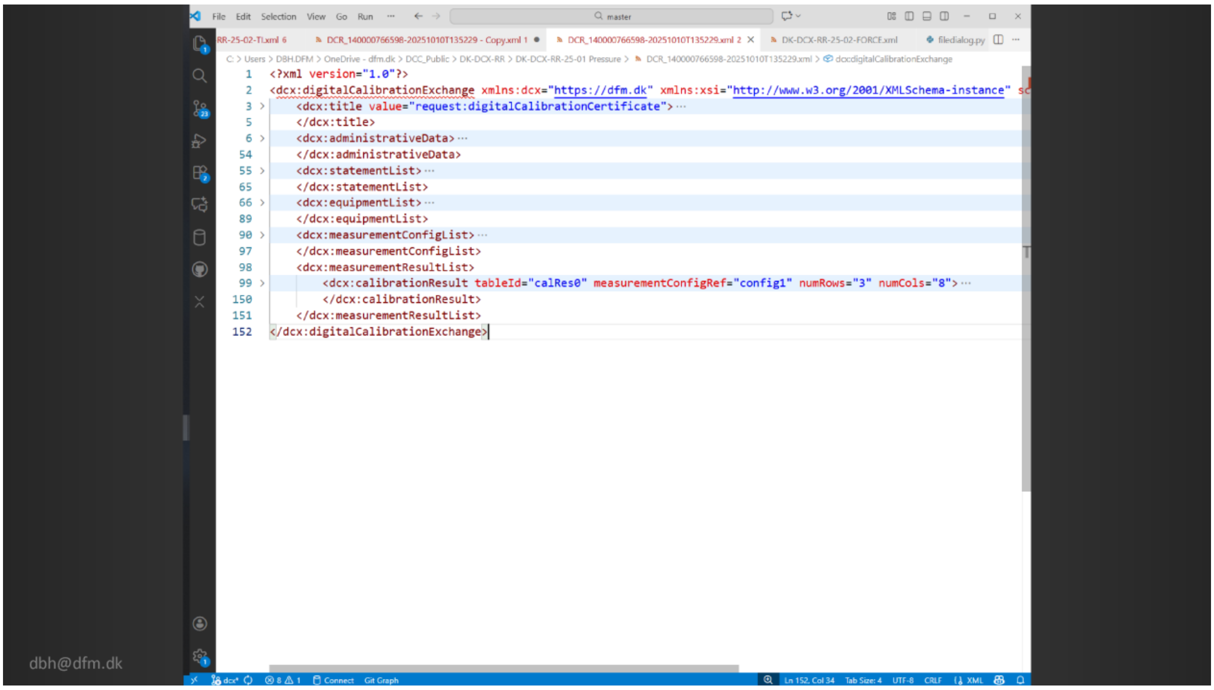
dbh@dfm.dk


master
DCR_140000766598-20251010T135229.xml 2
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</dcx:measurementConfigList>
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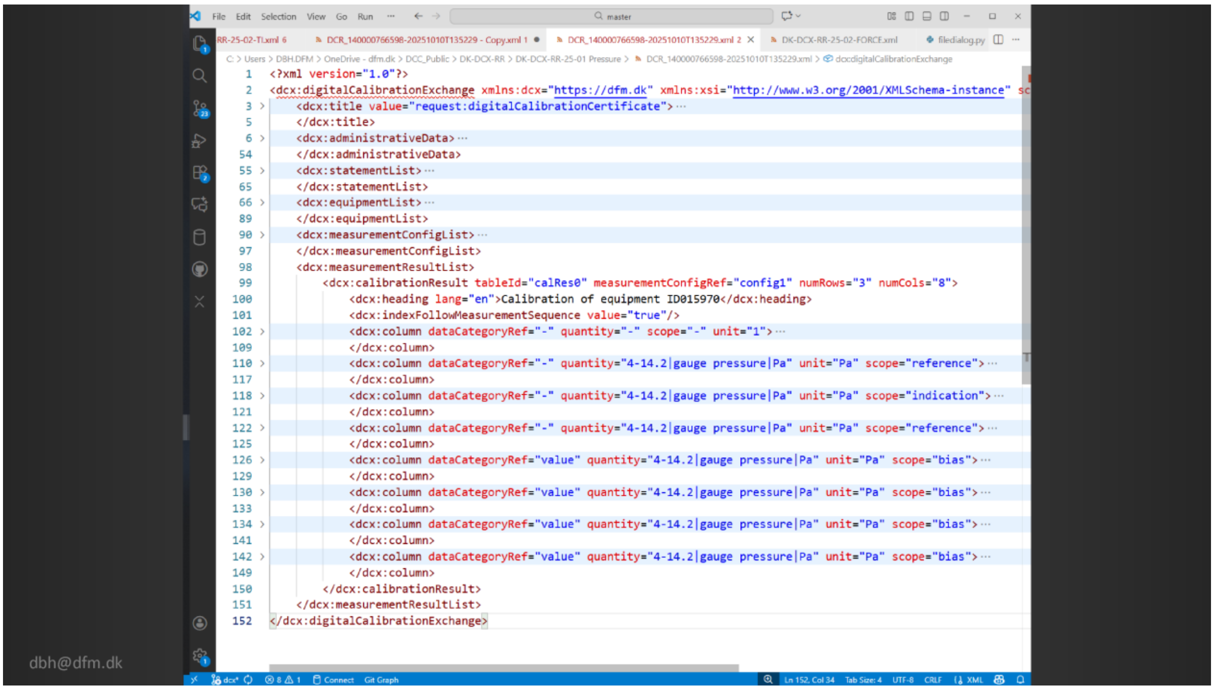
</dcx:calibrationResult>
</dcx:measurementResultList>
</dcx:digitalCalibrationExchange>
dbh@dfm.dk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<dcx:statementList>···
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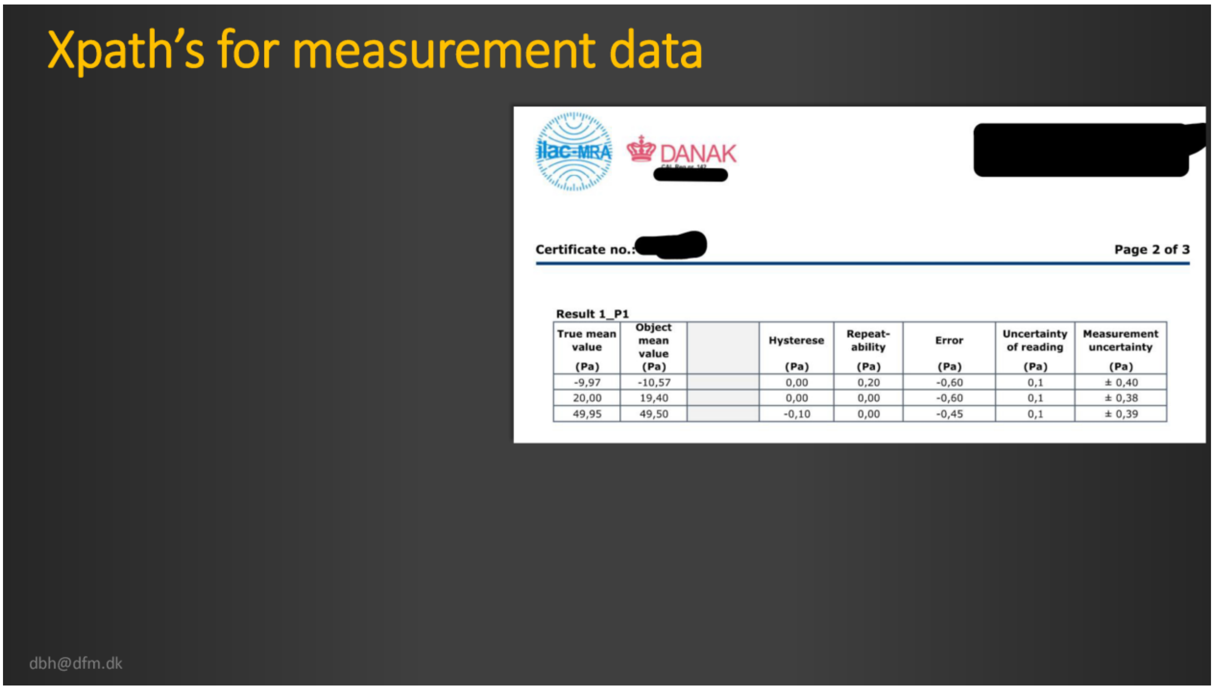
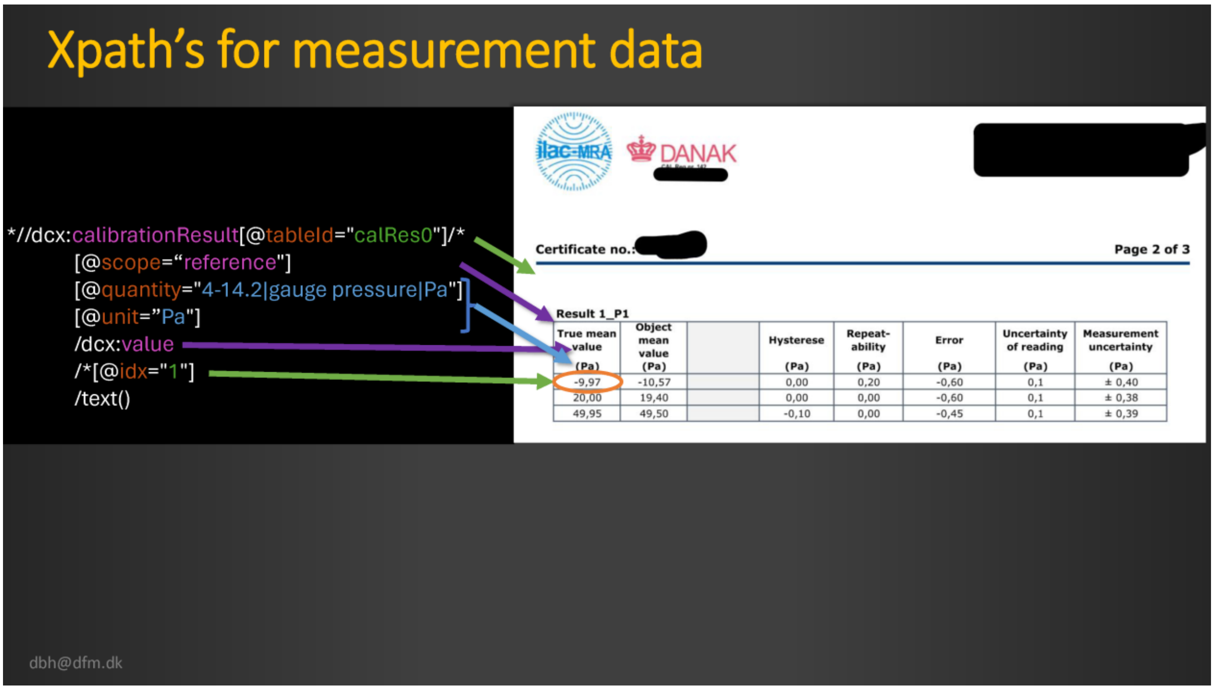
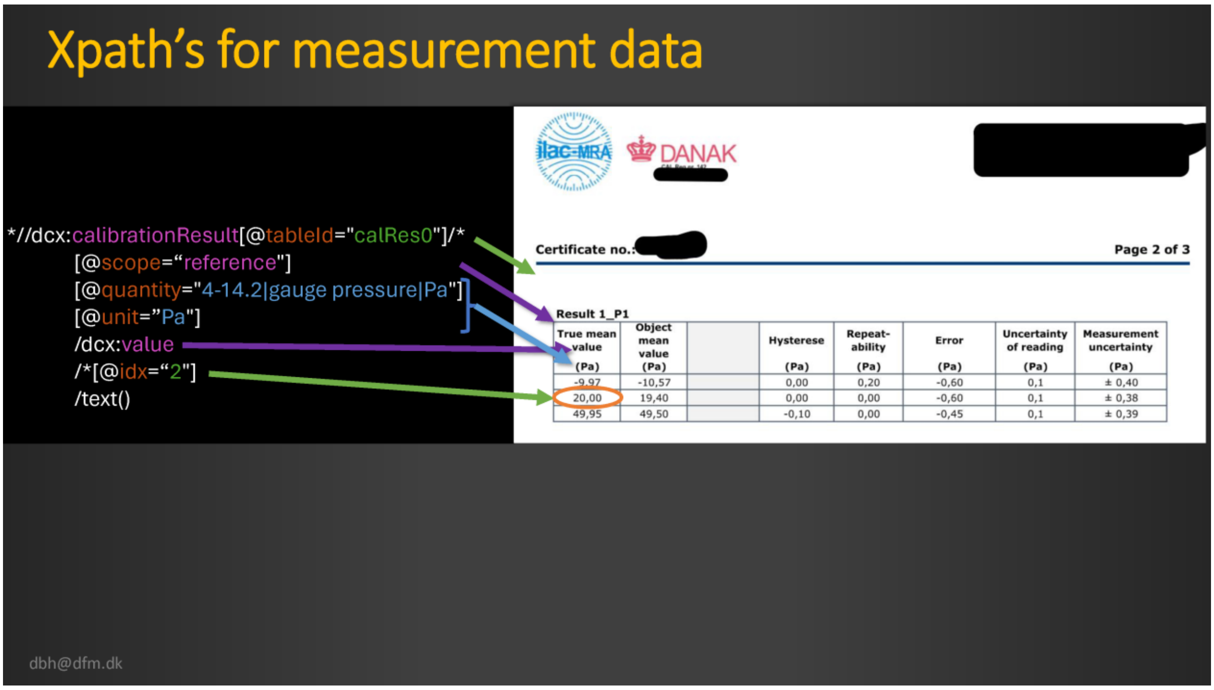
dbh@dfm.dk



True mean value (Pa)	Object mean value (Pa)		Hysterese (Pa)	Repeat-ability (Pa)	Error (Pa)	Uncertainty of reading (Pa)	Measurement uncertainty (Pa)
-9,97	-10,57		0,00	0,20	-0,60	0,1	± 0,40
20,00	19,40		0,00	0,00	-0,60	0,1	± 0,38
49,95	49,50		-0,10	0,00	-0,45	0,1	± 0,39



True mean value (Pa)	Object mean value (Pa)		Hysterese (Pa)	Repeat-ability (Pa)	Error (Pa)	Uncertainty of reading (Pa)	Measurement uncertainty (Pa)
-9,97	-10,57		0,00	0,20	-0,60	0,1	± 0,40
20,00	19,40		0,00	0,00	-0,60	0,1	± 0,38
49,95	49,50		-0,10	0,00	-0,45	0,1	± 0,39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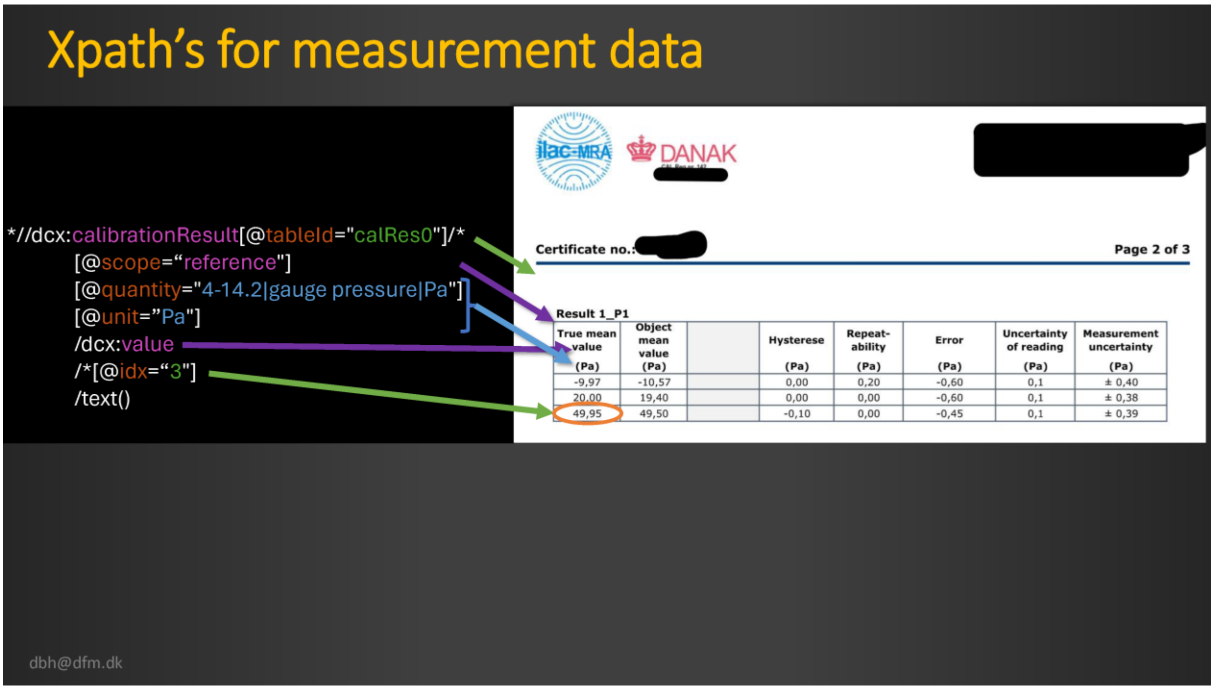
[@unit="Pa"]
/dcx:value
/*[@idx="2"]
/text()
ilac-MRA
DANAK
[redacted]
Certificate no.: [redacted]
Page 2 of 3
Result 1_P1
True mean value (Pa) | Object mean value (Pa) | Hysterese (Pa) | Repeat-ability (Pa) | Error (Pa) | Uncertainty of reading (Pa) | Measurement uncertainty (Pa)
-9,97 | -10,57 | 0,00 | 0,20 | -0,60 | 0,1 | ± 0,40
20,00 | 19,40 | 0,00 | 0,00 | -0,60 | 0,1 | ± 0,38
49,95 | 49,50 | -0,10 | 0,00 | -0,45 | 0,1 | ± 0,39
dbh@dfm.dk


Xpath's for measurement data
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/*[@idx="3"]
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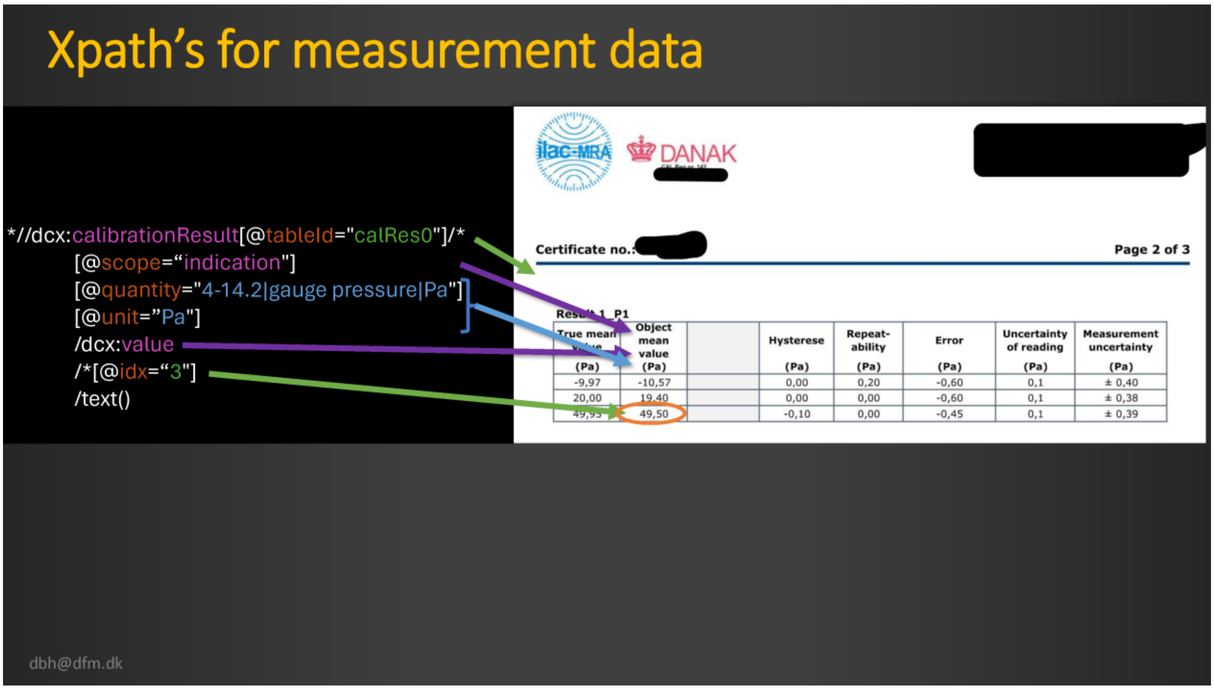
ilac-MRA
DANAK
[redacted]
Certificate no.: [redacted]
Page 2 of 3
Result 1_P1
True mean value (Pa) | Object mean value (Pa) | Hysterese (Pa) | Repeat-ability (Pa) | Error (Pa) | Uncertainty of reading (Pa) | Measurement uncertainty (Pa)
-9,97 | -10,57 | 0,00 | 0,20 | -0,60 | 0,1 | ± 0,40
20,00 | 19,40 | 0,00 | 0,00 | -0,60 | 0,1 | ± 0,38
49,95 | 49,50 | -0,10 | 0,00 | -0,45 | 0,1 | ± 0,39
dbh@dfm.dk


Xpath's for measurement data
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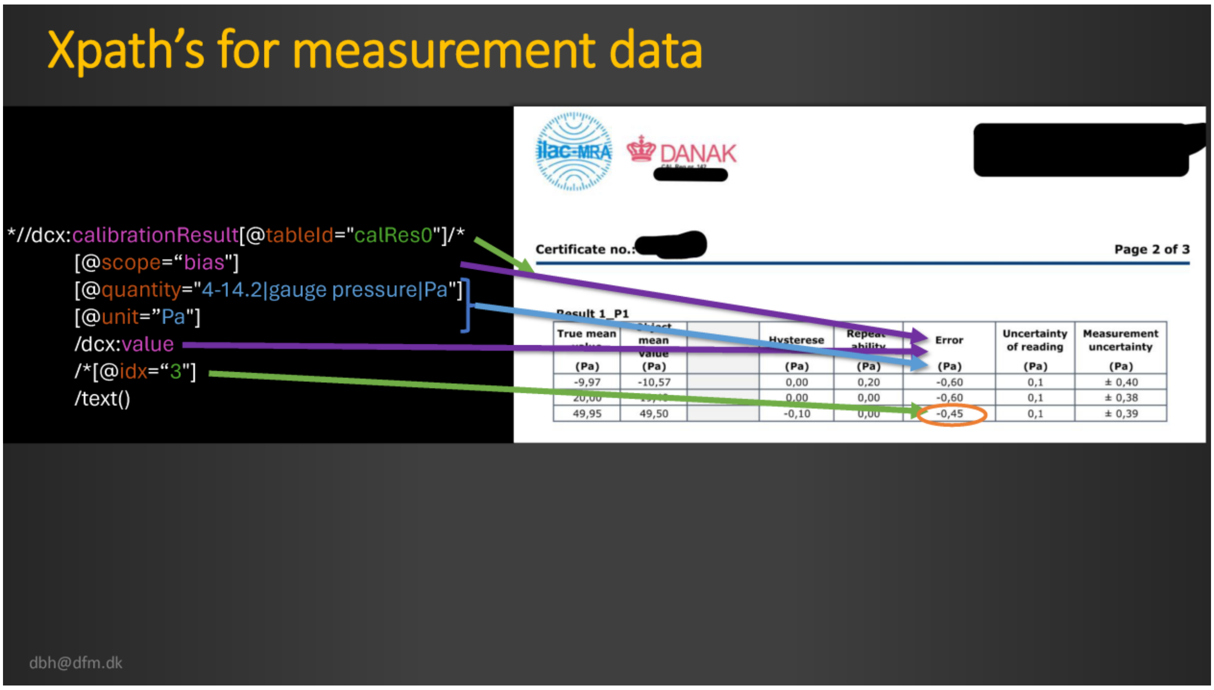
[@unit="Pa"]
/dcx:value
/*[@idx="3"]
/text()
ilac-MRA
DANAK
[redacted]
Certificate no.: [redacted]
Page 2 of 3
Result 1_P1
True mean value (Pa) | Object mean value (Pa) | | Hysterese (Pa) | Repeat-ability (Pa) | Error (Pa) | Uncertainty of reading (Pa) | Measurement uncertainty (Pa)
-9,97 | -10,57 | | 0,00 | 0,20 | -0,60 | 0,1 | ± 0,40
20,00 | 19,40 | | 0,00 | 0,00 | -0,60 | 0,1 | ± 0,38
49,95 | 49,50 | | -0,10 | 0,00 | -0,45 | 0,1 | ± 0,39
dbh@dfm.dk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DANAK
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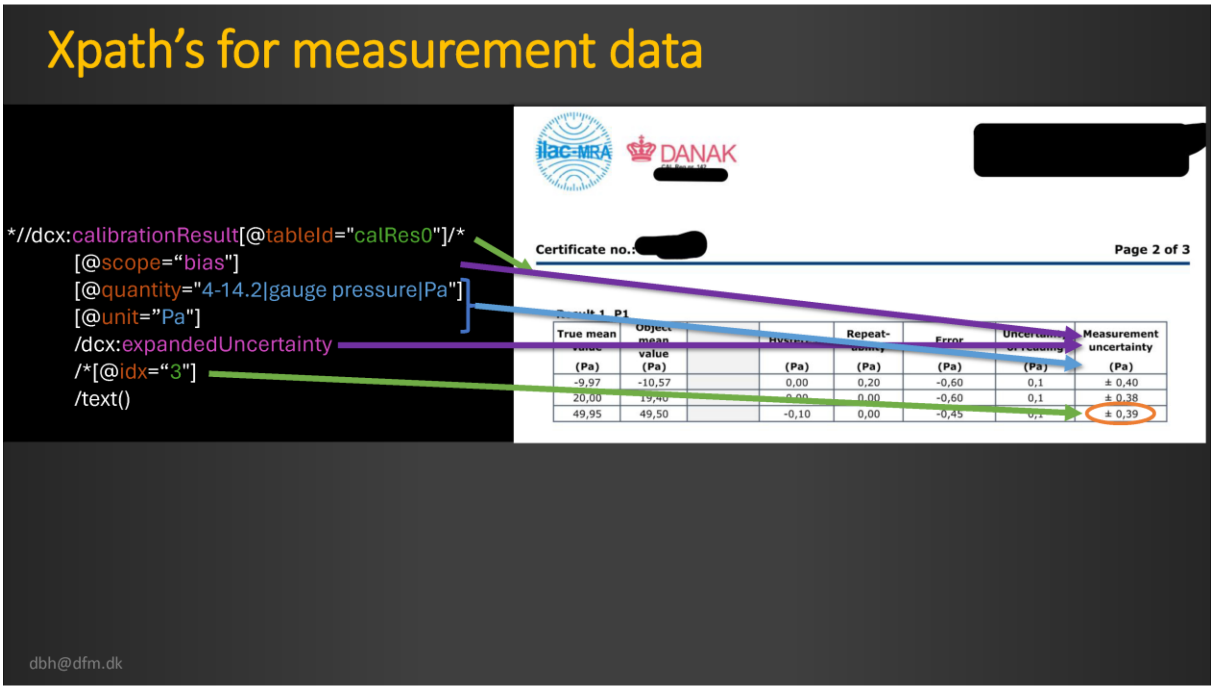
Page 2 of 3
Result 1_P1
True mean value (Pa) | Object mean value (Pa) | | Hysterese (Pa) | Repeat-ability (Pa) | Error (Pa) | Uncertainty of reading (Pa) | Measurement uncertainty (Pa)
-9,97 | -10,57 | | 0,00 | 0,20 | -0,60 | 0,1 | ± 0,40
20,00 | 19,40 | | 0,00 | 0,00 | -0,60 | 0,1 | ± 0,38
49,95 | 49,50 | | -0,10 | 0,00 | -0,45 | 0,1 | ± 0,39
dbh@dfm.dk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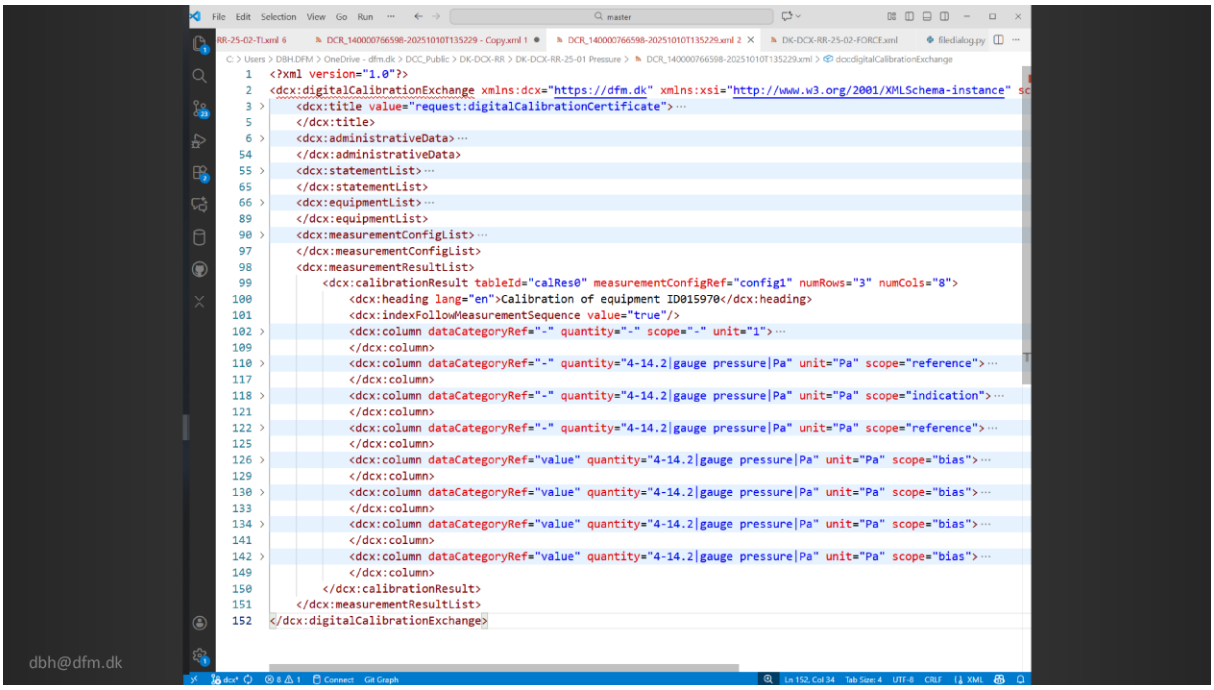
ilac-MRA
DANAK
[redacted]
Certificate no.: [redacted]
Page 2 of 3
True mean value (Pa)
Object mean value (Pa)
Repeat-ability (Pa)
Error (Pa)
Measurement uncertainty (Pa)
-9,97 -10,57 0,00 0,20 -0,60 0,1 ± 0,40
20,00 -0,60 0,1 ± 0,38
49,95 49,50 -0,10 0,00 -0,45 ± 0,39
dbh@dfm.dk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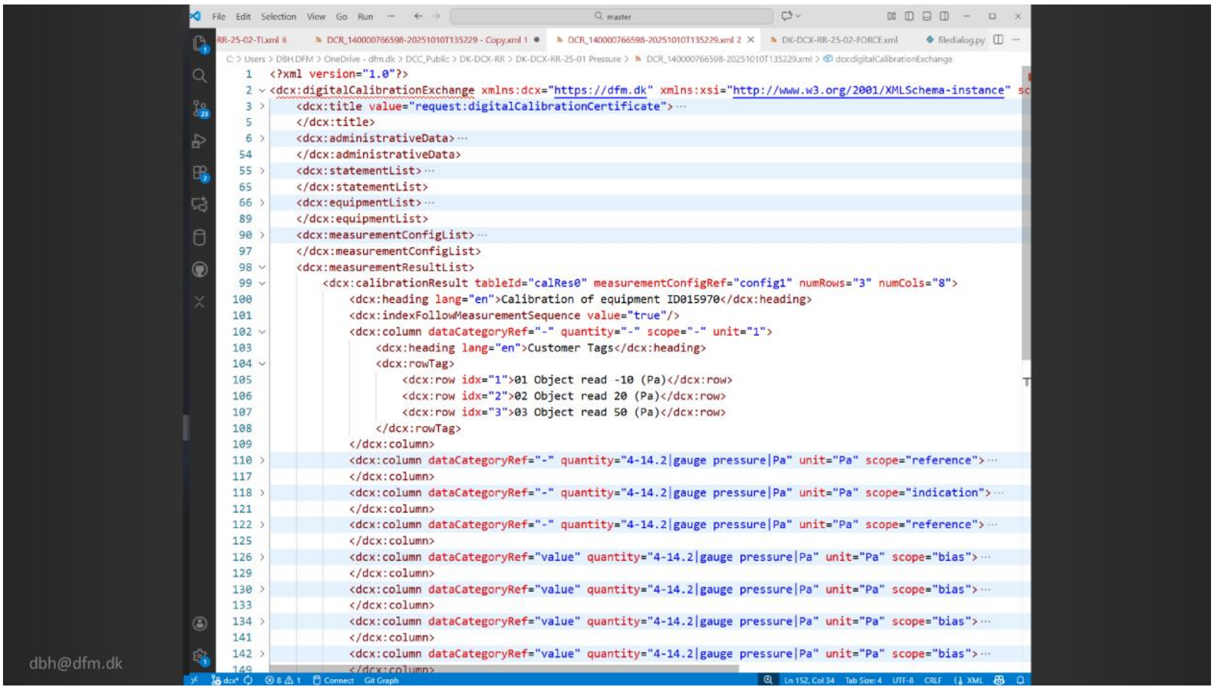
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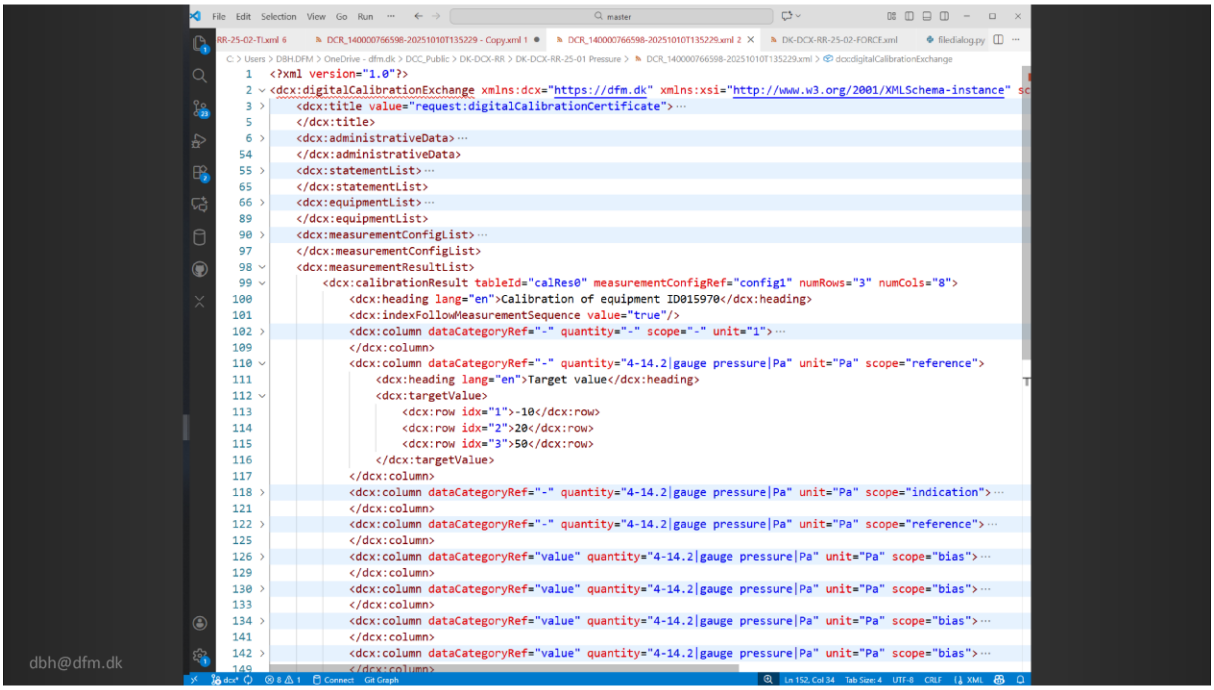
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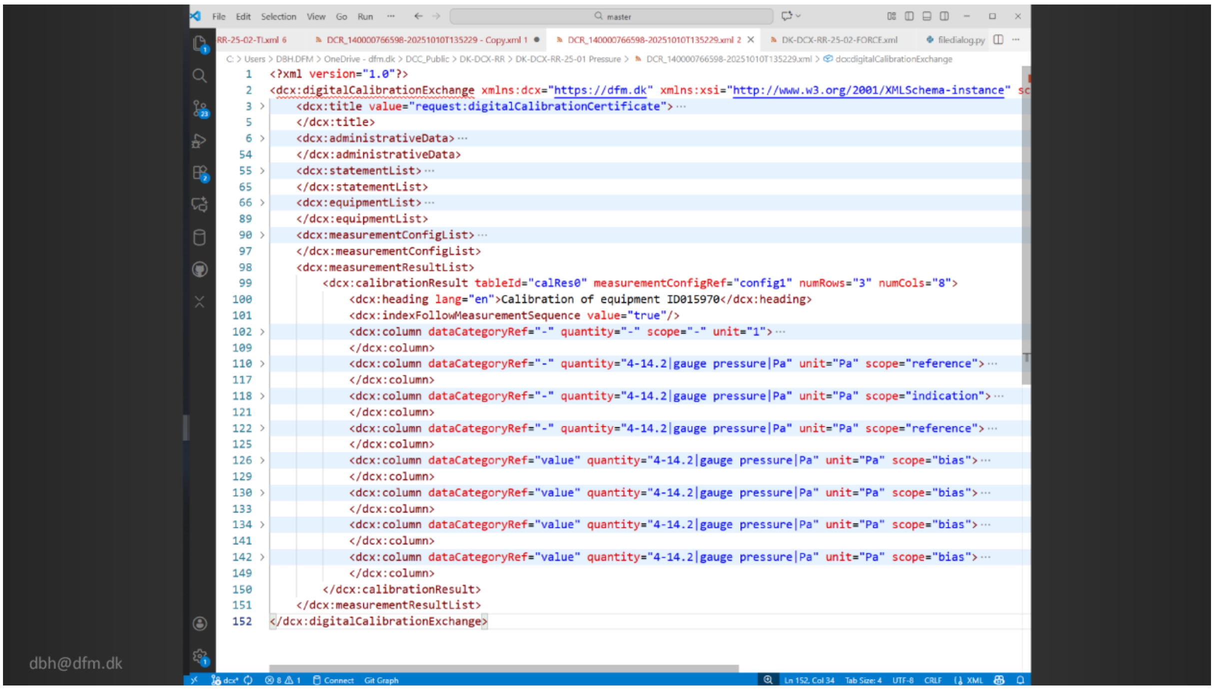

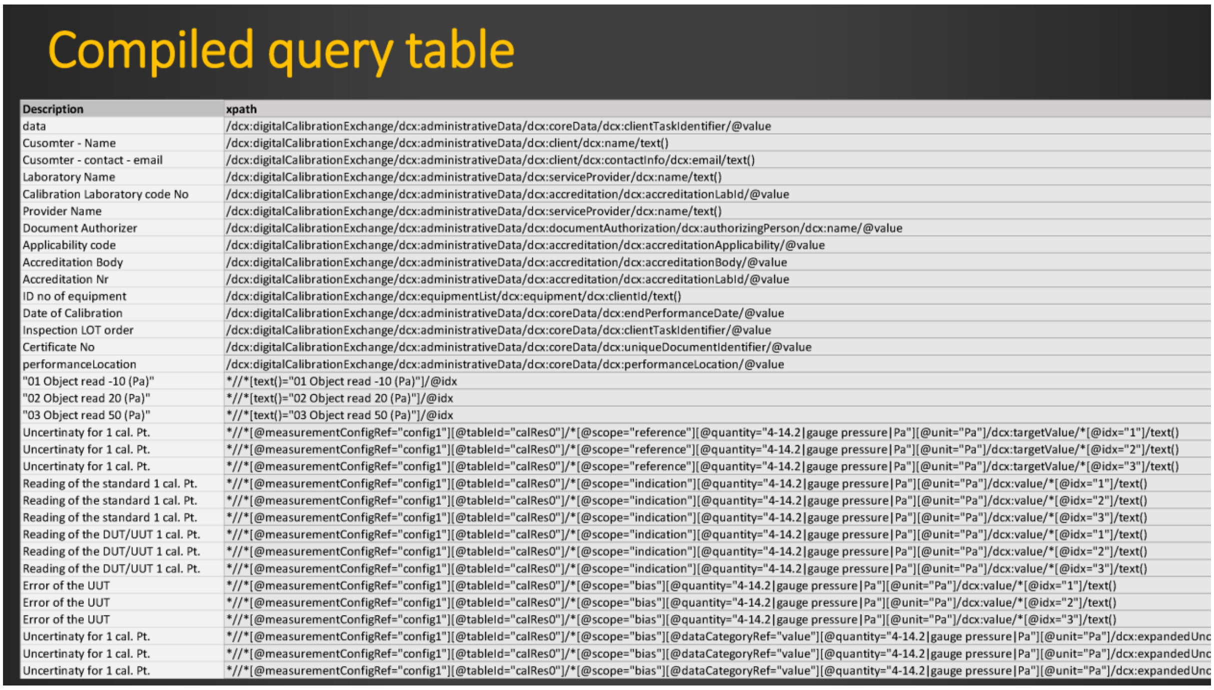

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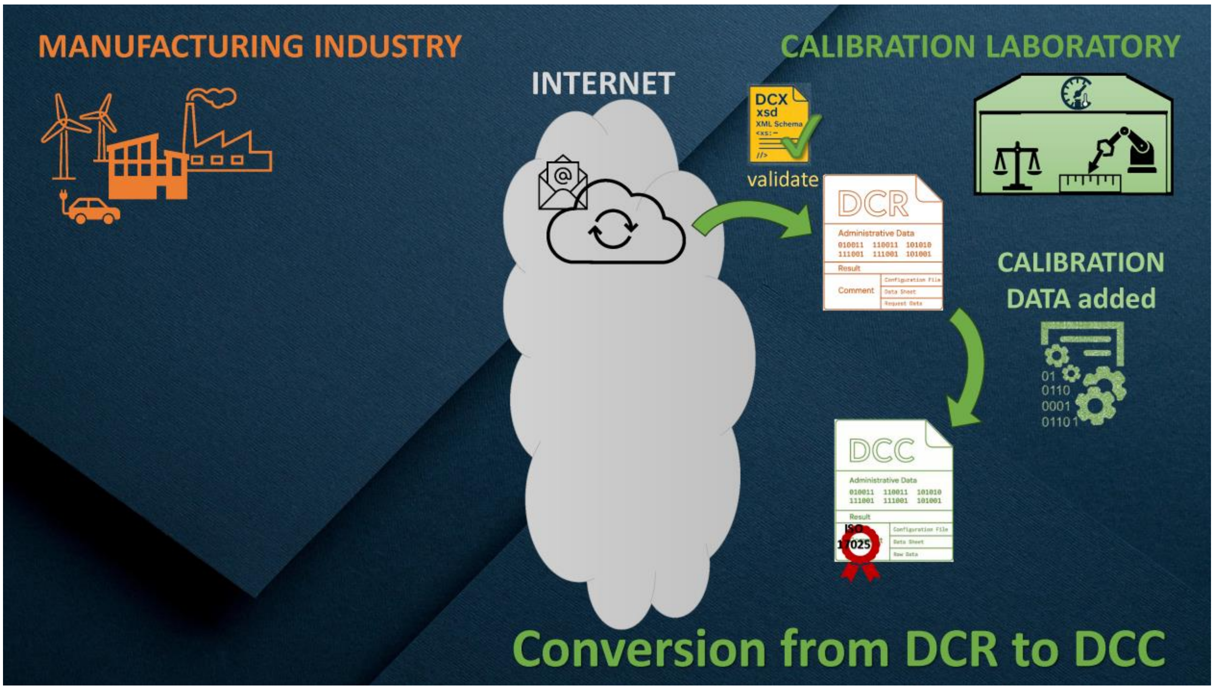
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INTERNET
CALIBRATION LABORATORY
DCX xsd XML Schema
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Result
ISO 17025
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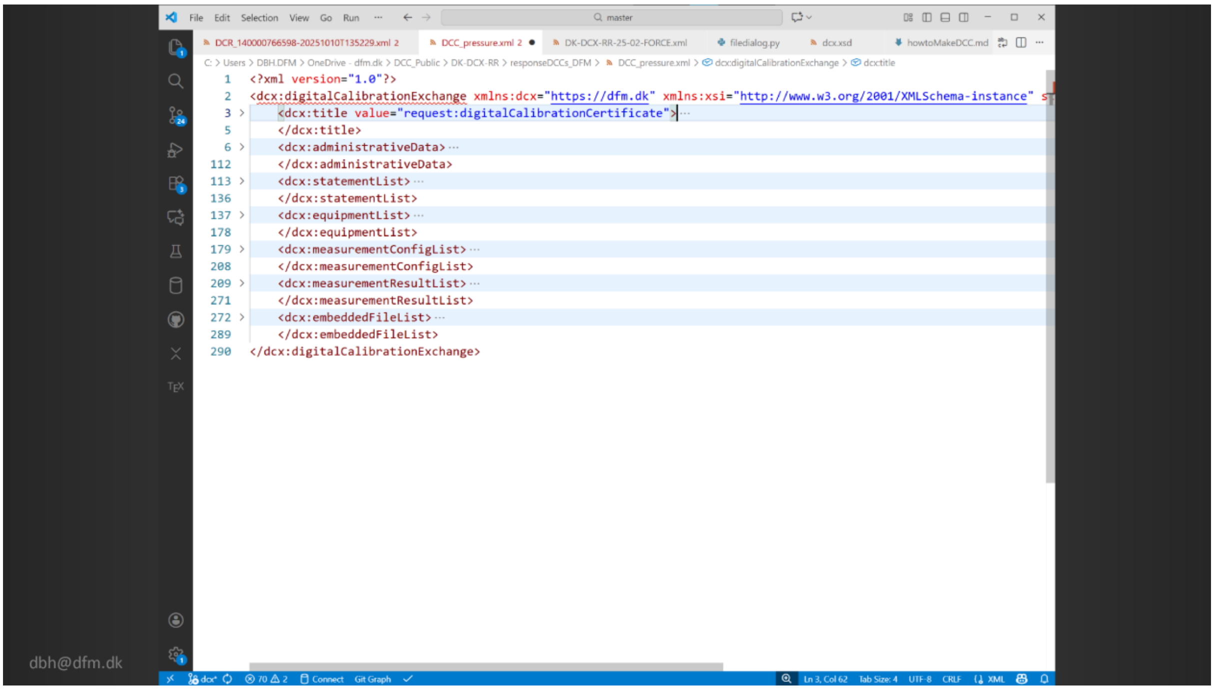
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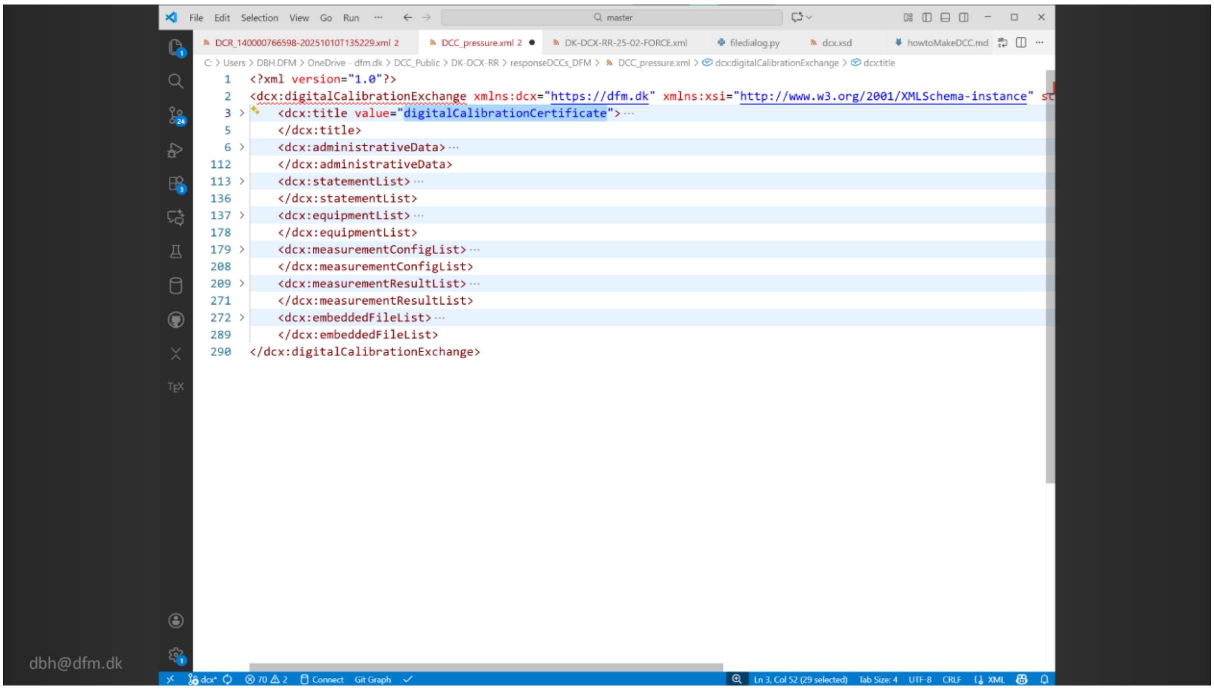
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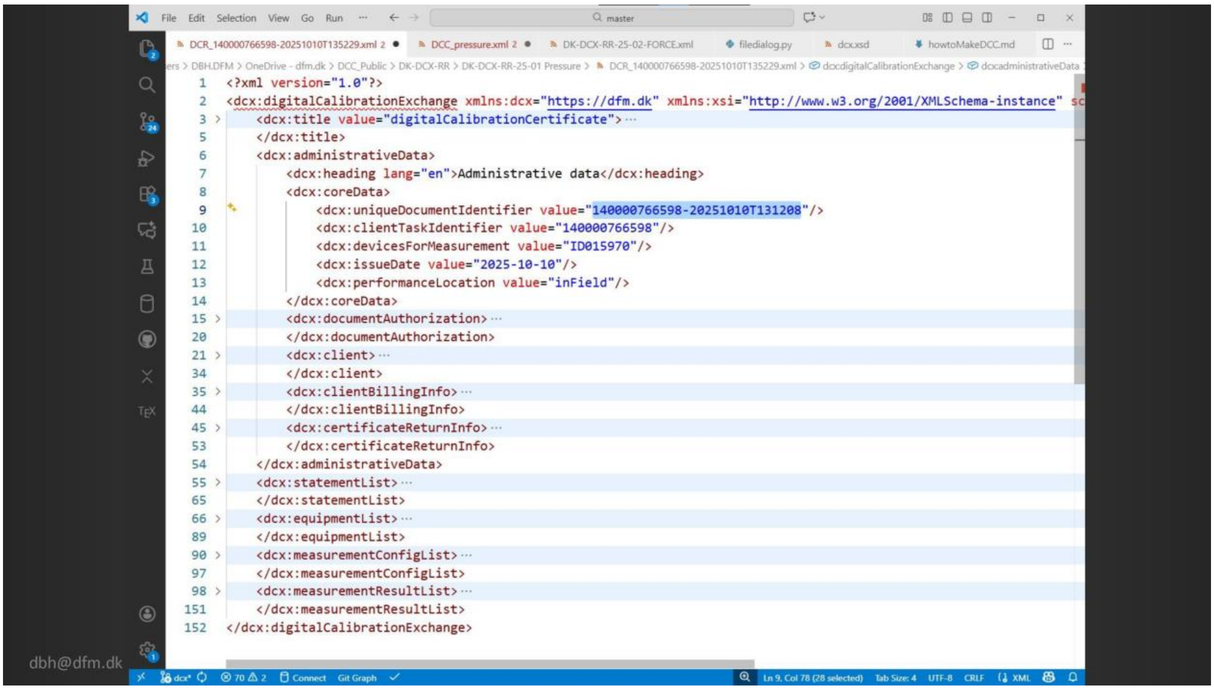
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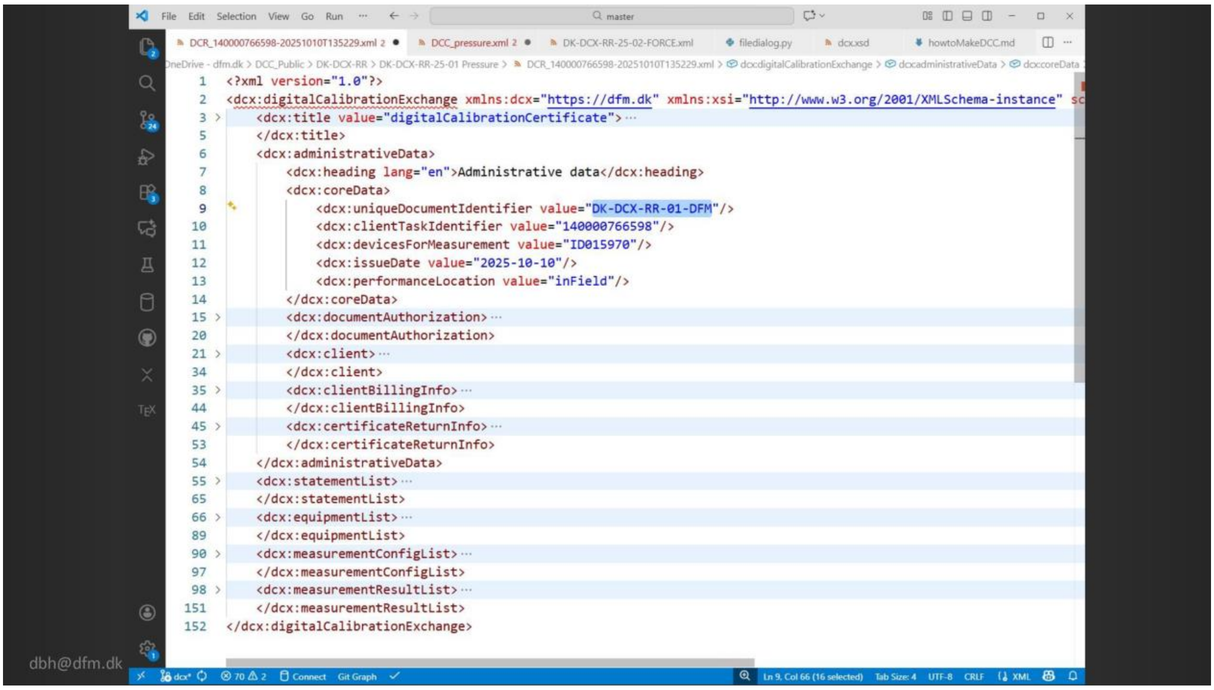
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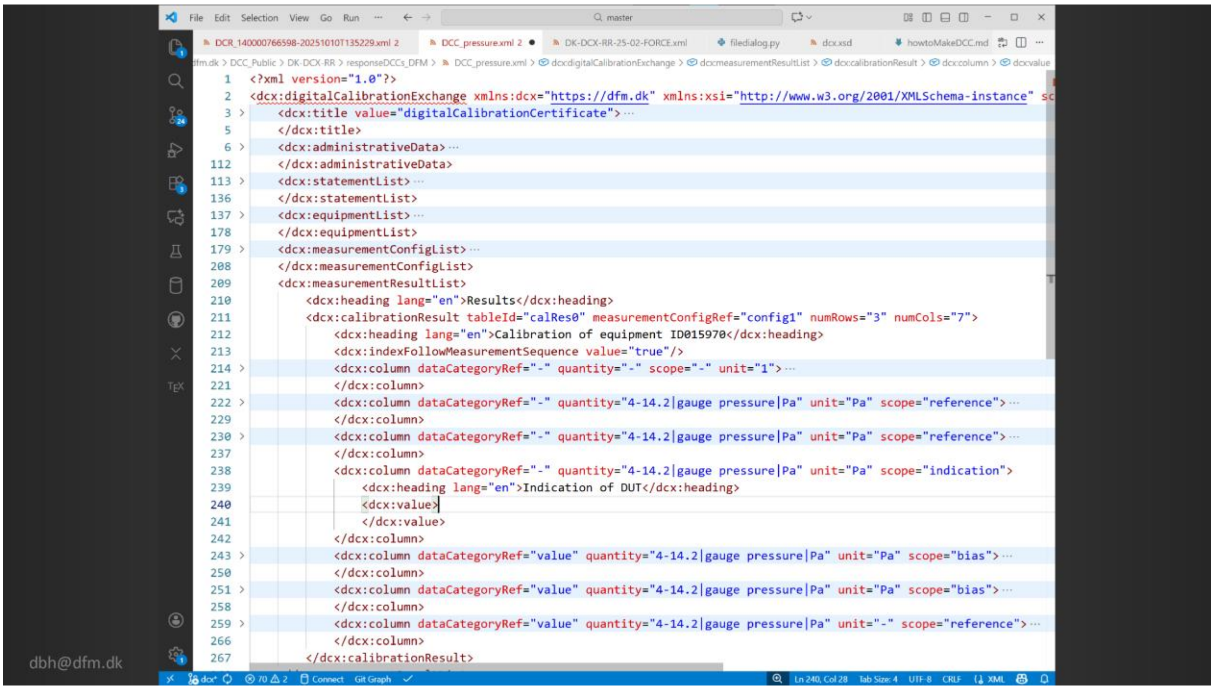
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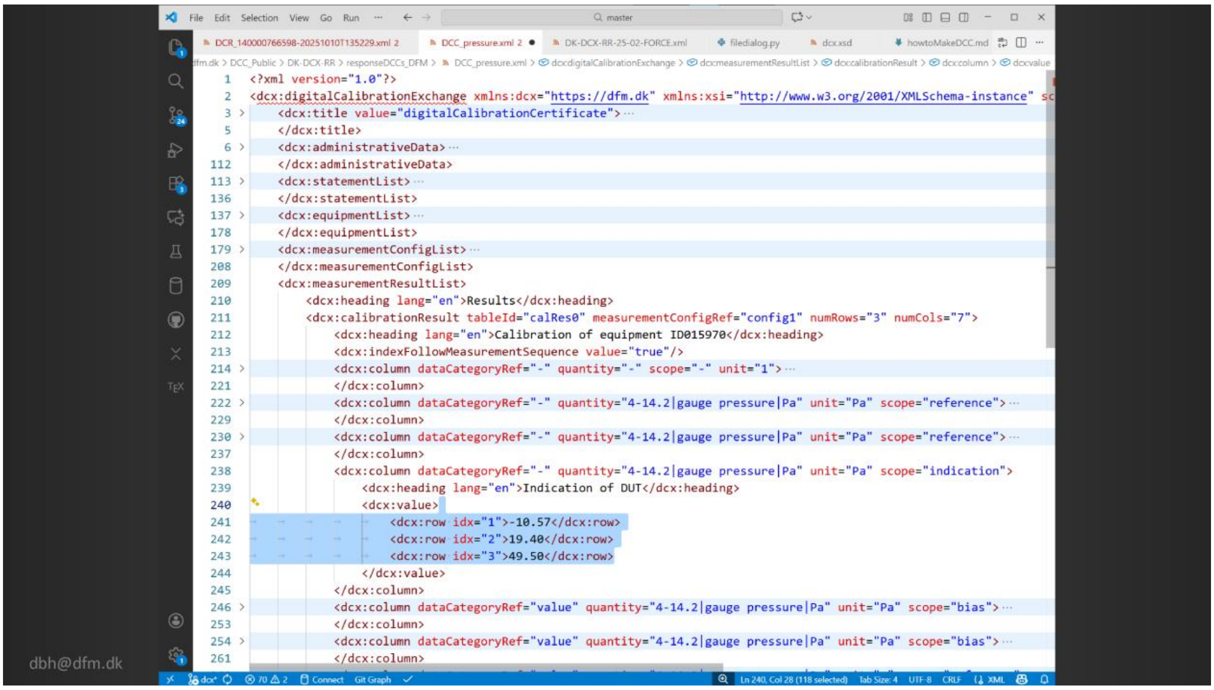
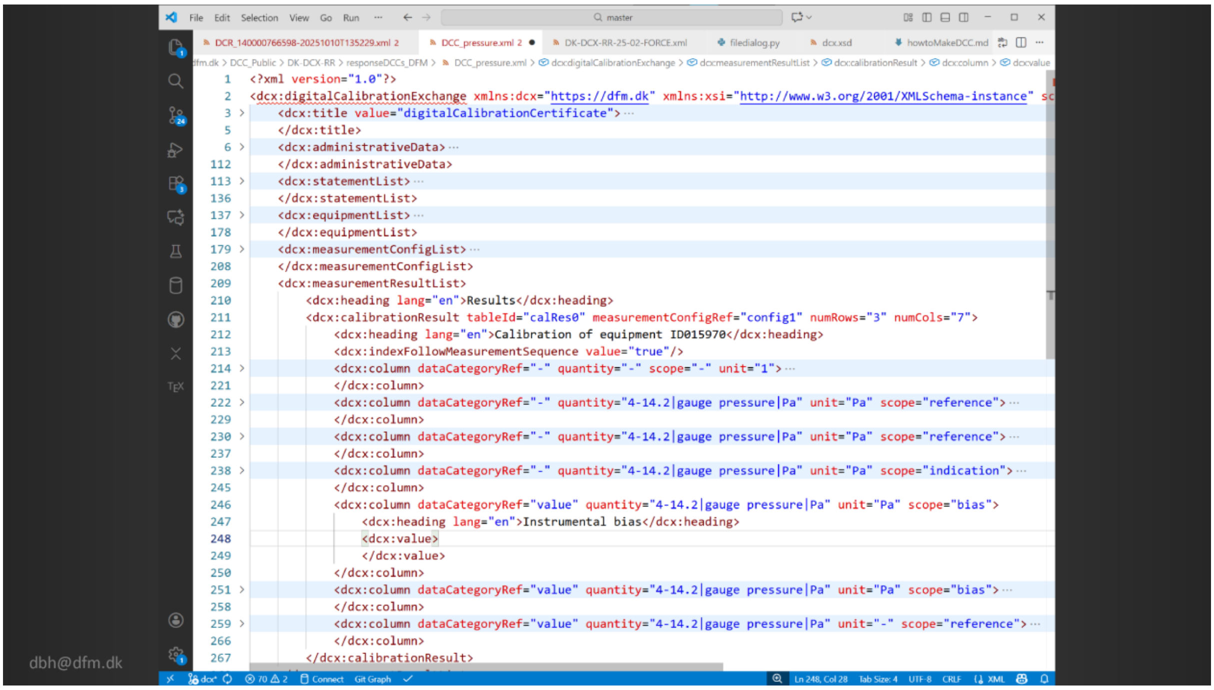
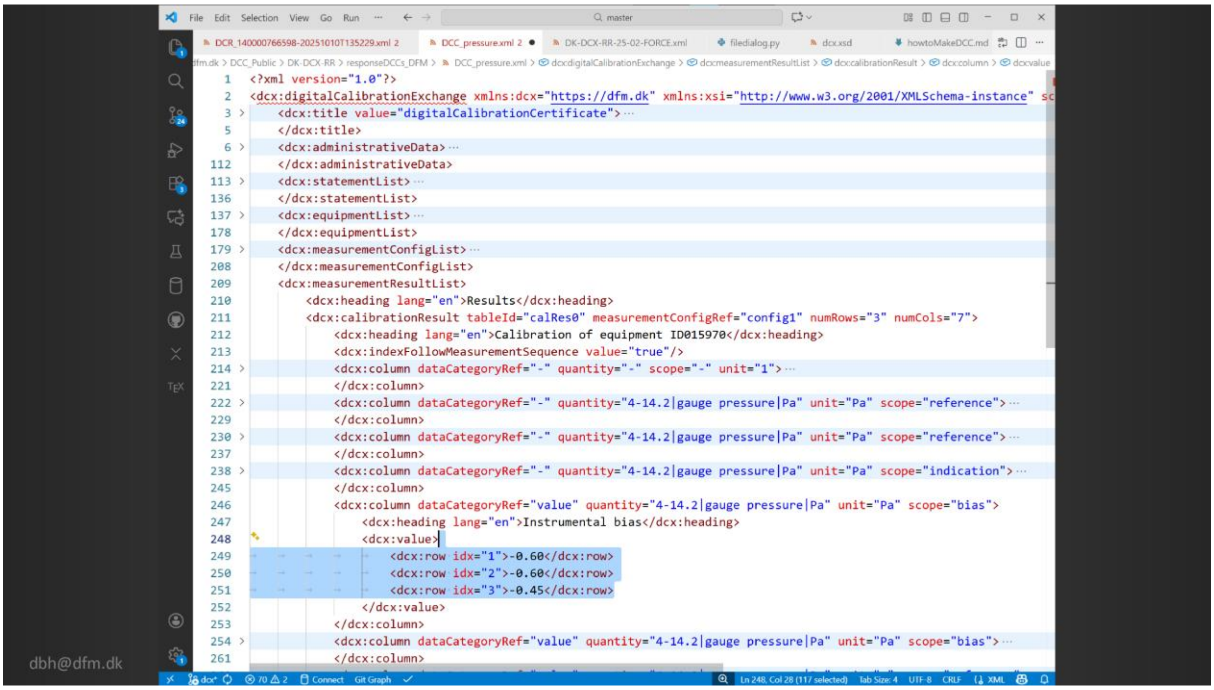
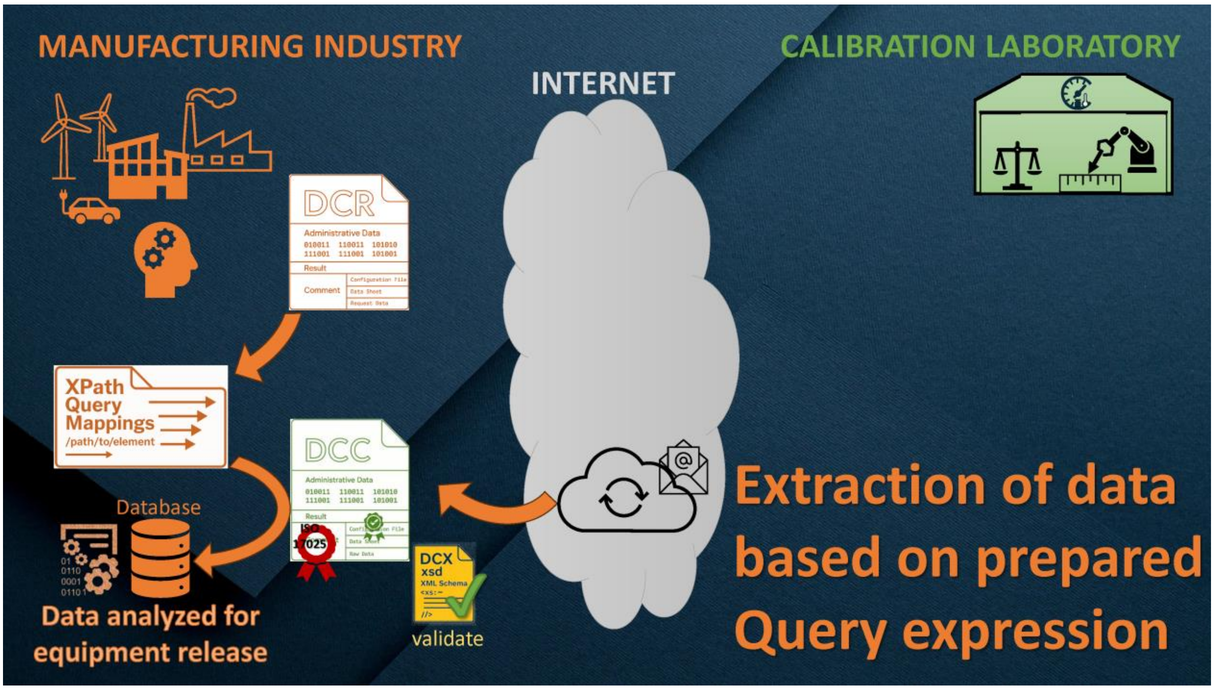
<dcx:column dataCategoryRef="value" quantity="4-14.2|gauge pressure|Pa" unit="-" scope="reference">···
</dcx:column>
</dcx:calibrationResult>
dbh@dfm.dk

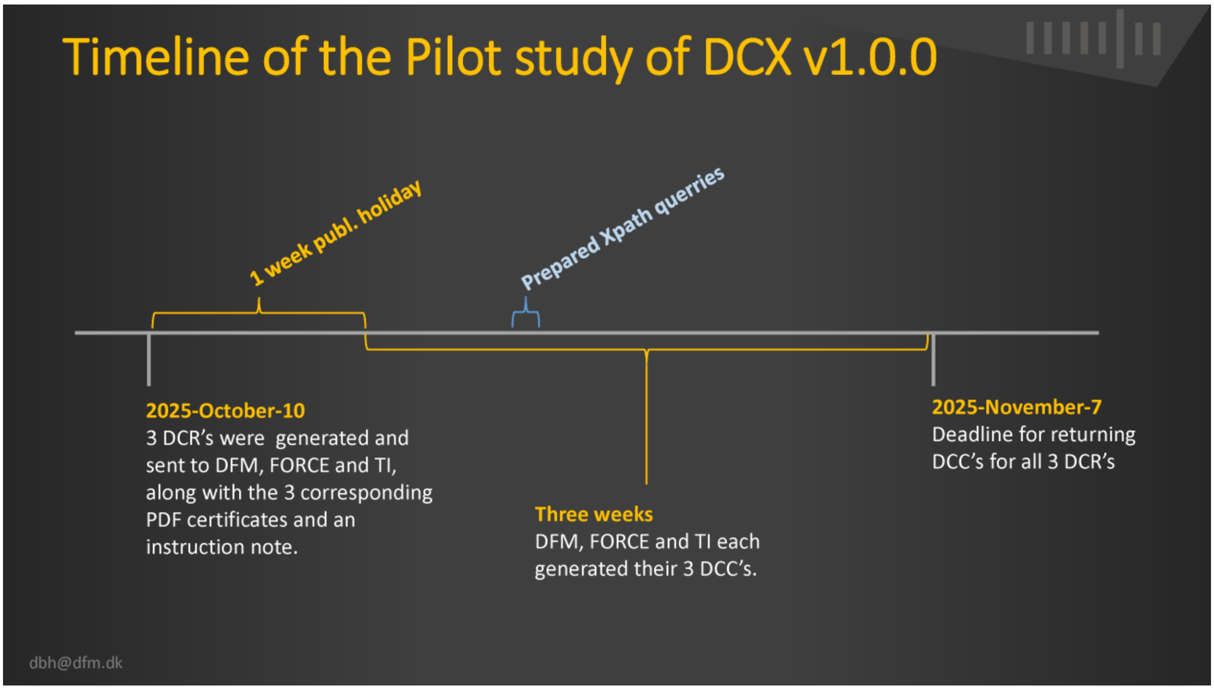

<?xml version="1.0"?>
<dcx:digitalCalibrationExchange xmlns:dcx="https://dfm.dk" xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance" sc
<dcx:title value="digitalCalibrationCertificate"> ···
</dcx:title>
<dcx:administrativeData> ···
</dcx:administrativeData>
<dcx:statementList> ···
</dcx:statementList>
<dcx:equipmentList> ···
</dcx:equipmentList>
<dcx:measurementConfigList> ···
</dcx:measurementConfigList>
<dcx:measurementResultList>
<dcx:heading lang="en">Results</dcx:heading>
<dcx:calibrationResult tableId="calRes0" measurementConfigRef="config1" numRows="3" numCols="7">
<dcx:heading lang="en">Calibration of equipment ID015970</dcx:heading>
<dcx:indexFollowMeasurementSequence value="true"/>
<dcx:column dataCategoryRef="-" quantity="-" scope="-" unit="1"> ···
</dcx:column>
<dcx:column dataCategoryRef="-" quantity="4-14.2|gauge pressure|Pa" unit="Pa" scope="reference"> ···
</dcx:column>
<dcx:column dataCategoryRef="-" quantity="4-14.2|gauge pressure|Pa" unit="Pa" scope="reference"> ···
</dcx:column>
<dcx:column dataCategoryRef="-" quantity="4-14.2|gauge pressure|Pa" unit="Pa" scope="indication">
<dcx:heading lang="en">Indication of DUT</dcx:heading>
<dcx:value>
<dcx:row idx="1">-10.57</dcx:row>
<dcx:row idx="2">19.40</dcx:row>
<dcx:row idx="3">49.50</dcx:row>
</dcx:value>
</dcx:column>
<dcx:column dataCategoryRef="value" quantity="4-14.2|gauge pressure|Pa" unit="Pa" scope="bias"> ···
</dcx:column>
<dcx:column dataCategoryRef="value" quantity="4-14.2|gauge pressure|Pa" unit="Pa" scope="bias"> ···
</dcx:column>
dbh@dfm.dk

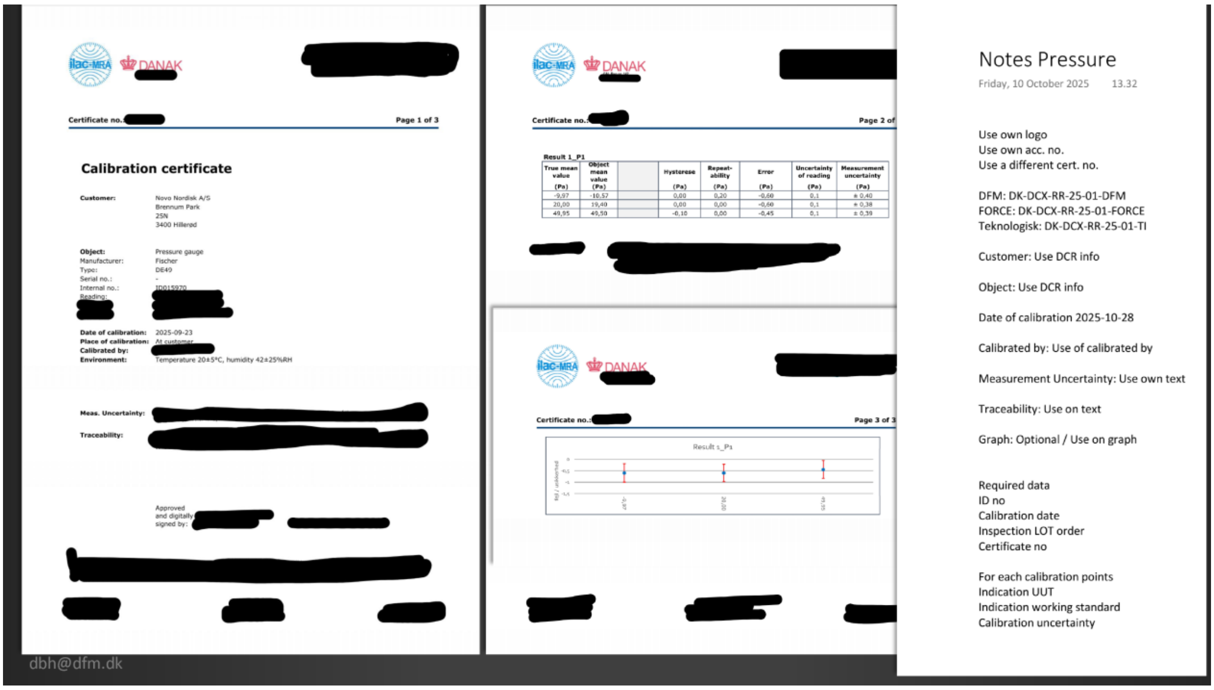

<?xml version="1.0"?>
<dcx:digitalCalibrationExchange xmlns:dcx="https://dfm.dk" xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance" sc
<dcx:title value="digitalCalibrationCertificate"> ···
</dcx:title>
<dcx:administrativeData> ···
</dcx:administrativeData>
<dcx:statementList> ···
</dcx:statementList>
<dcx:equipmentList> ···
</dcx:equipmentList>
<dcx:measurementConfigList> ···
</dcx:measurementConfigList>
<dcx:measurementResultList>
<dcx:heading lang="en">Results</dcx:heading>
<dcx:calibrationResult tableId="calRes0" measurementConfigRef="config1" numRows="3" numCols="7">
<dcx:heading lang="en">Calibration of equipment ID015970</dcx:heading>
<dcx:indexFollowMeasurementSequence value="true"/>
<dcx:column dataCategoryRef="-" quantity="-" scope="-" unit="1"> ···
</dcx:column>
<dcx:column dataCategoryRef="-" quantity="4-14.2|gauge pressure|Pa" unit="Pa" scope="reference"> ···
</dcx:column>
<dcx:column dataCategoryRef="-" quantity="4-14.2|gauge pressure|Pa" unit="Pa" scope="reference"> ···
</dcx:column>
<dcx:column dataCategoryRef="-" quantity="4-14.2|gauge pressure|Pa" unit="Pa" scope="indication"> ···
</dcx:column>
<dcx:column dataCategoryRef="value" quantity="4-14.2|gauge pressure|Pa" unit="Pa" scope="bias">
<dcx:heading lang="en">Instrumental bias</dcx:heading>
<dcx:value>
</dcx:value>
</dcx:column>
<dcx:column dataCategoryRef="value" quantity="4-14.2|gauge pressure|Pa" unit="Pa" scope="bias"> ···
</dcx:column>
<dcx:column dataCategoryRef="value" quantity="4-14.2|gauge pressure|Pa" unit="-" scope="reference"> ···
</dcx:column>
</dcx:calibrationResult>
dbh@dfm.dk

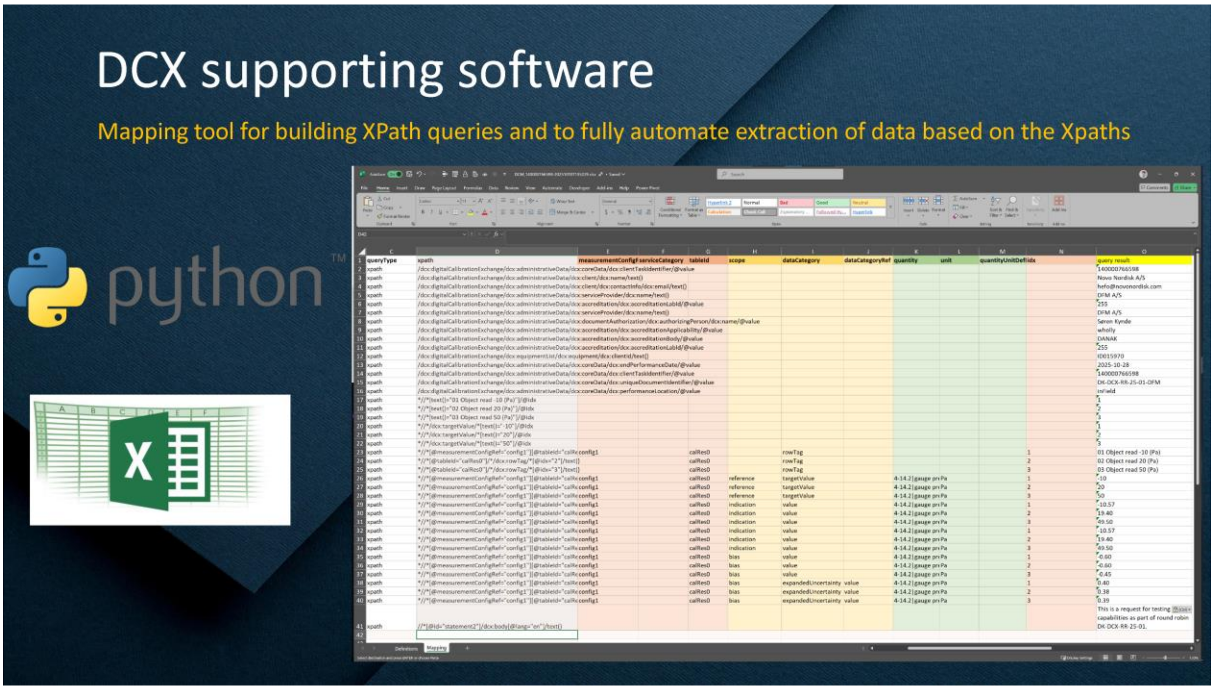

<?xml version="1.0"?>
<dcx:digitalCalibrationExchange xmlns:dcx="https://dfm.dk" xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
<dcx:title value="digitalCalibrationCertificate">
</dcx:title>
<dcx:administrativeData>
</dcx:administrativeData>
<dcx:statementList>
</dcx:statementList>
<dcx:equipmentList>
</dcx:equipmentList>
<dcx:measurementConfigList>
</dcx:measurementConfigList>
<dcx:measurementResultList>
<dcx:heading lang="en">Results</dcx:heading>
<dcx:calibrationResult tableId="calRes0" measurementConfigRef="config1" numRows="3" numCols="7">
<dcx:heading lang="en">Calibration of equipment ID015970</dcx:heading>
<dcx:indexFollowMeasurementSequence value="true"/>
<dcx:column dataCategoryRef="-" quantity="-" scope="-" unit="1">
</dcx:column>
<dcx:column dataCategoryRef="-" quantity="4-14.2|gauge pressure|Pa" unit="Pa" scope="reference">
</dcx:column>
<dcx:column dataCategoryRef="-" quantity="4-14.2|gauge pressure|Pa" unit="Pa" scope="reference">
</dcx:column>
<dcx:column dataCategoryRef="-" quantity="4-14.2|gauge pressure|Pa" unit="Pa" scope="indication">
</dcx:column>
<dcx:column dataCategoryRef="value" quantity="4-14.2|gauge pressure|Pa" unit="Pa" scope="bias">
<dcx:heading lang="en">Instrumental bias</dcx:heading>
<dcx:value>
<dcx:row idx="1">-0.60</dcx:row>
<dcx:row idx="2">-0.60</dcx:row>
<dcx:row idx="3">-0.45</dcx:row>
</dcx:value>
</dcx:column>
<dcx:column dataCategoryRef="value" quantity="4-14.2|gauge pressure|Pa" unit="Pa" scope="bias">
</dcx:column>
dbh@dfm.dk


MANUFACTURING INDUSTRY
INTERNET
CALIBRATION LABORATORY
DCR
XPath Query Mappings
/path/to/element
DCC
Database
DCX xsd
validate
Data analyzed for equipment release
Extraction of data based on prepared Query expression


DCR Round Robin testcase
Agile prototyping
transportation
improved control
bigger distance
motorised
practical & fun = convertible car!
dbh@dfm.dk


Timeline of the Pilot study of DCX v1.0.0
1 week publ. holiday
Prepared Xpath querries
2025-October-10
3 DCR's were generated and sent to DFM, FORCE and TI, along with the 3 corresponding PDF certificates and an instruction note.
Three weeks
DFM, FORCE and TI each generated their 3 DCC's.
2025-November-7
Deadline for returning DCC's for all 3 DCR's
dbh@dfm.dk


Certificate no. [redacted]
Page 1 of 3
Calibration certificate
Customer: Novo Nordisk A/S
Brennum Park
25N
3400 Hillerød
Object: Pressure gauge
Manufacturer: Fischer
Type: DE49
Internal no.: [redacted]
Date of calibration: 2025-09-23
Place of calibration: At customer
Calibrated by: [redacted]
Environment: Temperature 20±5°C, humidity 42±25%RH
Meas. Uncertainty: [redacted]
Traceability: [redacted]
Approved and digitally signed by: [redacted]
Page 2 of
Result 1_P1
True mean value (Pa)
Object mean value (Pa)
Hysterese (Pa)
Repeat-ability (Pa)
Error (Pa)
Uncertainty of reading (Pa)
Measurement uncertainty (Pa)
Page 3 of 3
Result 1_P1
dbh@dfm.dk
Notes Pressure
Friday, 10 October 2025 13.32
Use own logo
Use own acc. no.
Use a different cert. no.
DFM: DK-DCX-RR-25-01-DFM
FORCE: DK-DCX-RR-25-01-FORCE
Teknologisk: DK-DCX-RR-25-01-TI
Customer: Use DCR info
Object: Use DCR info
Date of calibration 2025-10-28
Calibrated by: Use of calibrated by
Measurement Uncertainty: Use own text
Traceability: Use on text
Graph: Optional / Use on graph
Required data
ID no
Calibration date
Inspection LOT order
Certificate no
For each calibration points
Indication UUT
Indication working standard
Calibration uncertainty


DCX supporting software
Mapping tool for building XPath queries and to fully automate extraction of data based on the Xpaths
python

DK-DCX-RR-25-01 Pressure

DTI:
email: Software error has subsequently been fixed.
Number of significant digits is not validated by the schema.

FORCE Technology :
Certificate number was not updated.
Renamed the rowTags and hindering mapping of data through these.
In this case mapping to the target values was the robust choice.

```xml
<dcx:rowTag>
  <dcx:row idx="1">01 Objekt aflæst -10 (Pa)</dcx:row>
  <dcx:row idx="2">02 Objekt aflæst 20 (Pa)</dcx:row>
  <dcx:row idx="3">03 Objekt aflæst 50 (Pa)</dcx:row>
</dcx:rowTag>
```

dbh@dfm.dk

Description	DCR - Novo Nordisk A/S	DCC - DFM A/S	DCC - FORCE Technology	DCC - DTI
Cusomter - Name	Novo Nordisk A/S	Novo Nordisk A/S	Novo Nordisk A/S	Novo Nordisk A/S
Cusomter - contact - email	hefo@novonordisk.com	hefo@novonordisk.com	hefo@novonordisk.com	ERROR not Found
Provider Name	n.a.	DFM A/S	FORCE Technology	Danish Technological Institute
Document Authorizer	Heidi Foldal	Søren Kynde	Andreas Lyndrup Jensen	Martin Østerlund
Applicability code	n.a.	wholly	wholly	wholly
Accreditation Body	n.a.	DANAK	DANAK	DANAK
Accreditation Nr	n.a.	255	9	200
ID no of equipment	ID015970	ID015970	ID015970	ID015970
Date of Calibration	n.a.	2025-10-28	2025-10-28	2025-10-28
Inspection LOT order	140000766598	140000766598	140000766598	140000766598
Certificate No	140000766598-20251010T131208	DK-DCX-RR-25-01-DFM	140000766598-20251010T131208	DK-DCX-RR-25-01-TI
performanceLocation	inField	inField	atProvider	inField
"01 Object read -10 (Pa)"	1	1	ERROR not Found	1
"02 Object read 20 (Pa)"	2	2	ERROR not Found	2
"03 Object read 50 (Pa)"	3	3	ERROR not Found	3
"-10"	1	1	1	1
"20"	2	2	2	2
"50"	3	3	3	3
	01 Object read -10 (Pa)	01 Object read -10 (Pa)	01 Objekt aflæst -10 (Pa)	01 Object read -10 (Pa)
	02 Object read 20 (Pa)	02 Object read 20 (Pa)	02 Objekt aflæst 20 (Pa)	02 Object read 20 (Pa)
	03 Object read 50 (Pa)	03 Object read 50 (Pa)	03 Objekt aflæst 50 (Pa)	03 Object read 50 (Pa)
Uncertinaty for 1 cal. Pt.	-10	-10	-10	-10
Uncertinaty for 1 cal. Pt.	20	20	20	20
Uncertinaty for 1 cal. Pt.	50	50	50	50
Reading of the standard 1 cal. Pt.	n.a.	-10.57	-10.57	-10.57
Reading of the standard 1 cal. Pt.	n.a.	19.40	19.40	19.4
Reading of the standard 1 cal. Pt.	n.a.	49.50	49.50	49.5
Reading of the DUT/UUT 1 cal. Pt.	n.a.	-10.57	-10.57	-10.57
Reading of the DUT/UUT 1 cal. Pt.	n.a.	19.40	19.40	19.4
Reading of the DUT/UUT 1 cal. Pt.	n.a.	49.50	49.50	49.5
Error of the UUT	n.a.	-0.60	-0.60	-0.6
Error of the UUT	n.a.	-0.60	-0.60	-0.6
Error of the UUT	n.a.	-0.45	-0.45	-0.45
Uncertinaty for 1 cal. Pt.	n.a.	0.40	0.40	0.4
Uncertinaty for 1 cal. Pt.	n.a.	0.38	0.38	0.38
Uncertinaty for 1 cal. Pt.	n.a.	0.39	0.39	0.39

Notes - Ring Gauge

Friday, 10 October 2025 14.26

Use own logo
Use own acc. no.

Use cert. no.
DFM: DK-DCX-RR-25-02-DFM
FORCE: DK-DCX-RR-25-02-FORCE
Teknologisk: DK-DCX-RR-25-02-TI

Customer: Use DCR info
Object: Use DCR info
Period (Received date): 2025-10-21
Date of calibration 2025-10-28
Calibrated by: Use own employee
Signatory: Use own employee
Measurement Uncertainty text: Use own text
Traceability: Use on text
Graph: Optional / Use on graph

Required data
ID no
Calibration date
Inspection LOT order
Certificate no

For each calibration points
Indication UUT: 2.17 mm <-- 2.17 mm added to no
Indication working standard
Calibration uncertainty

DK-DCX-RR-25-02 Ring gauge geometry

DTI:
rowTag was altered by removing “ “ in the tag.
In this case mapping was done on idx - number.
The reference and indication data was interchanged – human error.

FORCE Technology :
rowTags was altered by removing UUT.
In this case mapping was done on idx - number.
Unit was changed on half of the data → ERROR not Found

Description	DCR - Novo Nordisk A/S	DCC - DFM A/S	DCC - FORCE Technology	DCC - DTI
Cusomter - Name	Novo Nordisk A/S	Novo Nordisk A/S	Novo Nordisk A/S	Novo Nordisk A/S
Cusomter - contact - email	HEFO@novonordisk.com	HEFO@novonordisk.com	HEFO@novonordisk.com	ERROR not Found
Laboratory Name	n.a.	DFM A/S	FORCE Technology	Danish Technological Institute
Calibration Laboratory code No	n.a.	255	9	200
Document Authorizer	Heidi Foldal	Søren A.R. Kynde	Andreas Lyndrup Jensen	Martin Østerlund
Applicability code	n.a.	wholly	wholly	wholly
Accreditation Body	n.a.	DANAK	DANAK	DANAK
Accreditation Nr	n.a.	255	9	200
ID no of equipment	1363138	1363138	1363138	1363138
Date of Calibration	n.a.	2025-10-28	2025-10-09	2025-10-28
Inspection LOT order	140000785854	140000785854	140000785854	140000785854
Certificate No	140000785854-20251010T141146	DK-DCX-RR-25-02-DFM	140000785854-20251010T141146	DK-DCX-RR-25-02-TI
performanceLocation	atProvider	atProvider	atProvider	atProvider
idx1	1	1	1	1
idx2	2	2	2	2
idx3	3	3	3	3
idx4	4	4	4	4
idx5	5	5	5	5
idx6	6	6	6	6
T01	01 UUT reading at Diameter A 0°-180°	01 UUT reading at Diameter A 0°-180°	01 reading at Diameter A 0°–180°	01 UUT reading at Diameter A 0°-180°
T02	02 UUT reading at Diameter B 0°-180°	02 UUT reading at Diameter B 0°-180°	02 reading at Diameter B 0°–180°	02 UUT reading at Diameter B 0°-180°
T03	03 UUT reading at Diameter C 0°-180°	03 UUT reading at Diameter C 0°-180°	03 reading at Diameter C 0°–180°	03 UUT reading at Diameter C 0°-180°
T04	04 UUT reading at Diameter A 90°-270°	04 UUT reading at Diameter A 90°-270°	04 reading at Diameter A 90°–270°	04 UUT reading at Diameter A 90°-270°
T05	05 UUT reading at Diameter B 90°-270°	05 UUT reading at Diameter B 90°-270°	05 reading at Diameter B 90°–270°	05 UUT reading at Diameter B 90°-270°
T06	06 UUT reading at Diameter C 90°-270°	06 UUT reading at Diameter C 90°-270°	06 reading at Diameter C 90°–270°	06 UUT reading at Diameter C 90°-270°
01REF	2.1702	2.1702	2.1702	2.17
02REF	2.1701	2.1701	2.1701	2.17
03REF	2.1703	2.1703	2.1703	2.17
04REF	2.1702	2.1702	2.1702	2.17
05REF	2.1701	2.1701	2.1701	2.17
06REF	2.1703	2.1703	2.1703	2.17
01UUT	2.17	2.17	2.17	2.1702
02UUT	2.17	2.17	2.17	2.1701
03UUT	2.17	2.17	2.17	2.1703
04UUT	2.17	2.17	2.17	2.1702
05UUT	2.17	2.17	2.17	2.1701
06UUT	2.17	2.17	2.17	2.1703
01ERR	-0.0002	-0.0002	ERROR not Found	0.0002
02ERR	-0.0001	-0.0001	ERROR not Found	0.0001
03ERR	-0.0003	-0.0003	ERROR not Found	0.0003
04ERR	-0.0002	-0.0002	ERROR not Found	0.0002
05ERR	-0.0001	-0.0001	ERROR not Found	0.0001
06ERR	-0.0003	-0.0003	ERROR not Found	0.0003
01U	0.0008	0.0008	ERROR not Found	0.8
02U	0.0008	0.0008	ERROR not Found	0.8
03U	0.0008	0.0008	ERROR not Found	0.8
04U	0.0008	0.0008	ERROR not Found	0.8
05U	0.0008	0.0008	ERROR not Found	0.8
06U	0.0008	0.0008	ERROR not Found	0.8

dbh@dfm.dk

[redacted] Calibration Certificate ilac-MRA DANAK CAL+TEST Reg.Nr. [redacted]

Certificate No. [redacted]

Customer:
Company: Novo Nordisk A/S — *Certificate date:* 2025-06-12
Address: Brennum Park, 3400 Hillerød — *Version:* 1
Pages: 2
Requestor: Nicki Skaaning — *PO number:* N/A

Equipment ID:	Tag nr.:	Equipment Type:
1695520	N/A	Hygro Smart-Sensor

Comments:
Calibrated according to attached NN-doc. Q0877633

Method / Parameters:
[redacted]
Unit
MPE ±8,0%rH ±1,0°C
Receiving date: 2025-06-03
Calibration start date: 2025-06-10
Calibration end date: 2025-06-10
Calibration location: MS-lab

Environment:
Equipment Nr. MN-0139 — *Rel. Humidity:* n/a %rH
Temperature 24-25 °C — *Barom. Pressure:* 1011 hPa

Reference equipment - Calibration:

Equipment No.:	Description:	Traceability:	Calibration Date:
[redacted]	Rotronic HC2A-S	DANAK [redacted]	2025-02-28
	Fluke 5627A	DANAK [redacted]	2025-05-13
	Rotronic Hygrogen 2	N/A	

Author: [redacted] **Approved by:** [redacted]

Page 1 / 2

[redacted] Calibration Certificate ilac-MRA DANAK CAL+TEST Reg.Nr. [redacted]

Certificate No. [redacted]

As received

Point:	At:	True Value: [S]	Indicated: [I]	Error: [I-S]	Uncertainty: *)k=2 [±]	Error + Uncertainty: **)
%rH	°C	%rH	%rH	%rH	%rH	%rH
10	22	10,0	13,63	3,63	1,4	5,03
45	22	45,0	46,55	1,55	1,4	2,95
80	22	80,0	79,16	-0,84	1,4	-2,24
°C	%rH	°C	°C	°C	°C	°C
8	45	7,991	8,23	0,239	0,17	0,409
22	45	22,009	22,27	0,261	0,17	0,431
35	45	35,049	35,30	0,251	0,17	0,421

Comments: Parameter: A= 1,0000 | B= 0,000 , °C
Parameter: A= 1,0000 | B= 0,000 , %rH

*) The Uncertainty is multiplicated by a coverage factor = 2, providing a level of confidence of approximately 95% (EA-4/02)
**) By the calculation the same signs is used for Error and Uncertainty.
This certificate may not be reproduced other than in full, except with the prior written consent of Medico Support A/S.
The results only relate to listed equipment(s)

[redacted] Page 2 / 2

Notes - Hygro smart sensor

Tuesday, 14 October 2025 10.46

Use own logo
Use own acc. no.

Use cert. no.
DFM: DK-DCX-RR-25-03-DFM
FORCE: DK-DCX-RR-25-03-FORCE
Teknologisk: DK-DCX-RR-25-03-TI

Customer: Use DCR info
Object: Use DCR info
Period (Received date): 2025-10-21
Date of calibration 2025-10-28
Calibrated by: Use own employee
Signatory: Use own employee
Measurement Uncertainty text: Use own text
Traceability: Use on text
Graph: Optional / Use on graph

Required data
ID no
Calibration date
Inspection LOT order
Certificate no

For each calibration points
Indication UUT
Indication working standard
Calibration uncertainty

dbh@dfm.dk

DK-DCX-RR-25-03 Humidity

DFM:
Minor human error on data entry.

DTI:
Minor human error on data entry.

FORCE Technology :
Certificate number was not updated.
Minor human error on data entry.

Description	DCR - Novo Nordisk A/S	DCC - DFM A/S	DCC - FORCE Technology	DCC - DTI
Cusomter - Name	Novo Nordisk A/S	Novo Nordisk A/S	Novo Nordisk A/S	Novo Nordisk A/S
Cusomter - contact - email	HEFO@novonordisk.com	HEFO@novonordisk.com	HEFO@novonordisk.com	ERROR not Found
Laboratory Name	n.a.	DFM A/S	FORCE Technology	Danish Technological Institute
Calibration Laboratory code No	n.a.	255	9	200
Document Authorizer	Heidi Foldal	Søren Kynde	Andreas Lyndrup Jensen	Martin Østerlund
Applicability code	n.a.	wholly	wholly	wholly
Accreditation Body	n.a.	DANAK	DANAK	DANAK
Accreditation Nr	n.a.	255	9	200
ID no of equipment	1695520	1695520	1695520	1695520
Date of Calibration	n.a.	2025-10-28	2025-06-10	2025-10-28
Inspection LOT order	140000793877	140000766598	140000793877	140000793877
Certificate No	140000793877-20251010T145011	DK-DCX-RR-25-03-DFM	140000793877-20251010T145011	DK-DCX-RR-25-03-TI
performanceLocation	atProvider	atProvider	atProvider	atProvider
idx1	1	1	1	1
idx2	2	2	2	2
idx3	3	3	3	3
idx4	1	1	1	1
idx5	2	2	2	2
idx6	3	3	3	3
T01	01 Indicated [I]	01 Indicated [I]	01 Indicated [I]	01 Indicated [I]
T02	02 Indicated [I]	02 Indicated [I]	02 Indicated [I]	02 Indicated [I]
T03	03 Indicated [I]	03 Indicated [I]	03 Indicated [I]	03 Indicated [I]
01TV-RH	10	10	10	10
02TV-RH	45	45	45	45
03TV-RH	80	80	80	80
01TV-Temp	22	22	22	22
02TV-Temp	22	22	22	22
03TV-Temp	22	22	22	22
01REF	-	10.0	10.0	10
02REF	-	45.0	45.0	45
03REF	-	80.0	80.0	80
01UUT	-	13.63	13.63	13.63
02UUT	-	1.55	46.55	46.55
03UUT	-	79.16	79.16	79.16
01ERR	-	3.63	3.63	3.63
02ERR	-	1.55	1.55	1.55
03ERR	-	-0.84	0.84	-0.84
01U	-	1.4	1.4	1.4
02U	-	1.4	1.4	1.4
03U	-	1.4	1.4	1.4
T04	04 Indicated [I]	04 Indicated [I]	04 Indicated [I]	04 Indicated [I]
T05	05 Indicated [I]	05 Indicated [I]	05 Indicated [I]	05 Indicated [I]
T06	06 Indicated [I]	06 Indicated [I]	06 Indicated [I]	06 Indicated [I]
04TV-RH	45	45	45	45
05TV-RH	45	45	45	45
06TV-RH	45	45	45	45
04TV-Temp	8	8	8	8
05TV-Temp	22	22	22	22
06TV-Temp	35	35	35	35
04REF	-	7.991	7.991	7.991
05REF	-	22.009	22.009	22.009
06REF	-	35.049	35.049	35.049
04UUT	-	8.23	8.23	8.23
05UUT	-	22.27	22.27	22.27
06UUT	-	35.30	35.30	35.5
04ERR	-	0.24	0.239	0.239
05ERR	-	0.26	0.261	0.261
06ERR	-	0.25	0.251	0.251
04U	-	0.17	0.17	0.17
05U	-	0.17	0.17	0.17
06U	-	0.17	0.17	0.17

dbh@dfm.dk

Learnings from the Round Robin

1. ✓ Process for requesting and extracting of data was over all successful.

2. ÷ Challenges experienced:
   a. Not clear to laboratories that client's rowTag was not to be changed.
      a. On client side this resulted in inability to locate the corresponding row.

   b. One laboratory did not change dcx:uniqueDocumentIdentity, for certificate number

   c. One laboratory changed units in a certificate from mm → µm,
      i.e. data could not be found by xpath.

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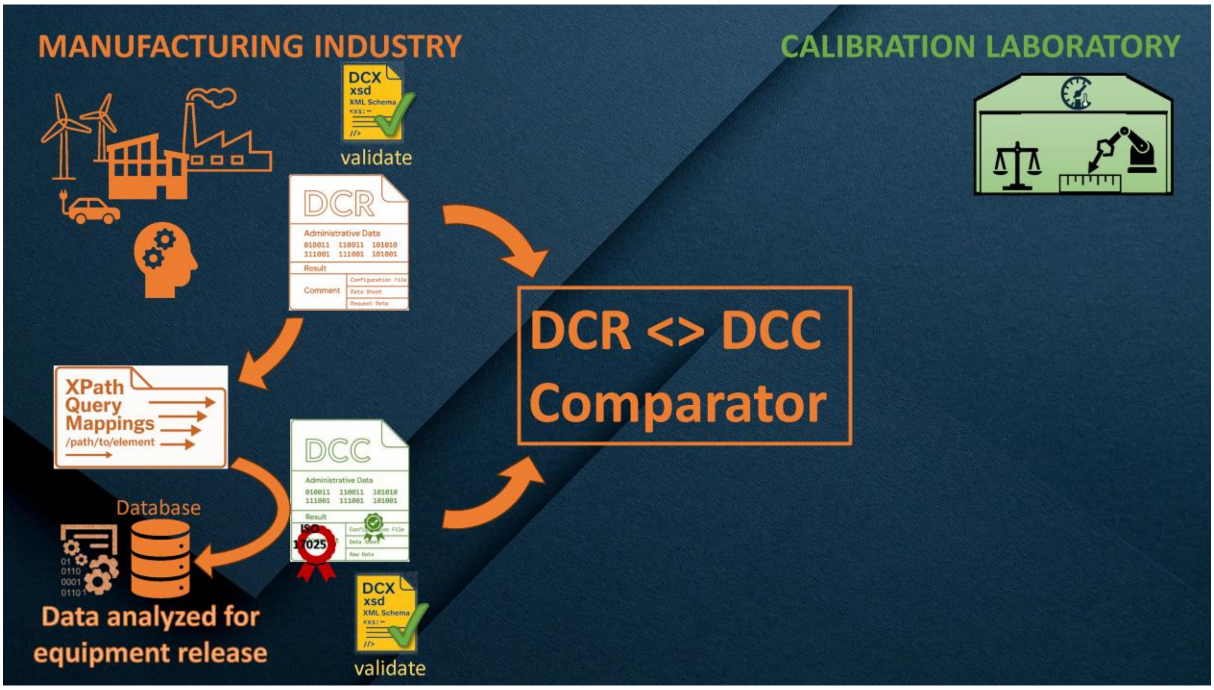

Conclusion & Outlook

DCR Round Robins are a good process for:

a. Gaining more experience
b. Strengthen the process e.g. generation: DCR and Xpath's
c. Test scalability: Increase number of areas, providers and clients
areas: more geometry, mass-balances, weights, flow, temperature, humidity, multimeter

DCX improvements:

a. Strengthening of schema validated internal IDREF pointers (ready for release)
b. Add attribute, describing action for an element :
@inDCC: 'edit', 'readOnly' or 'delete'

c. Develop DCR <> DCC comparator

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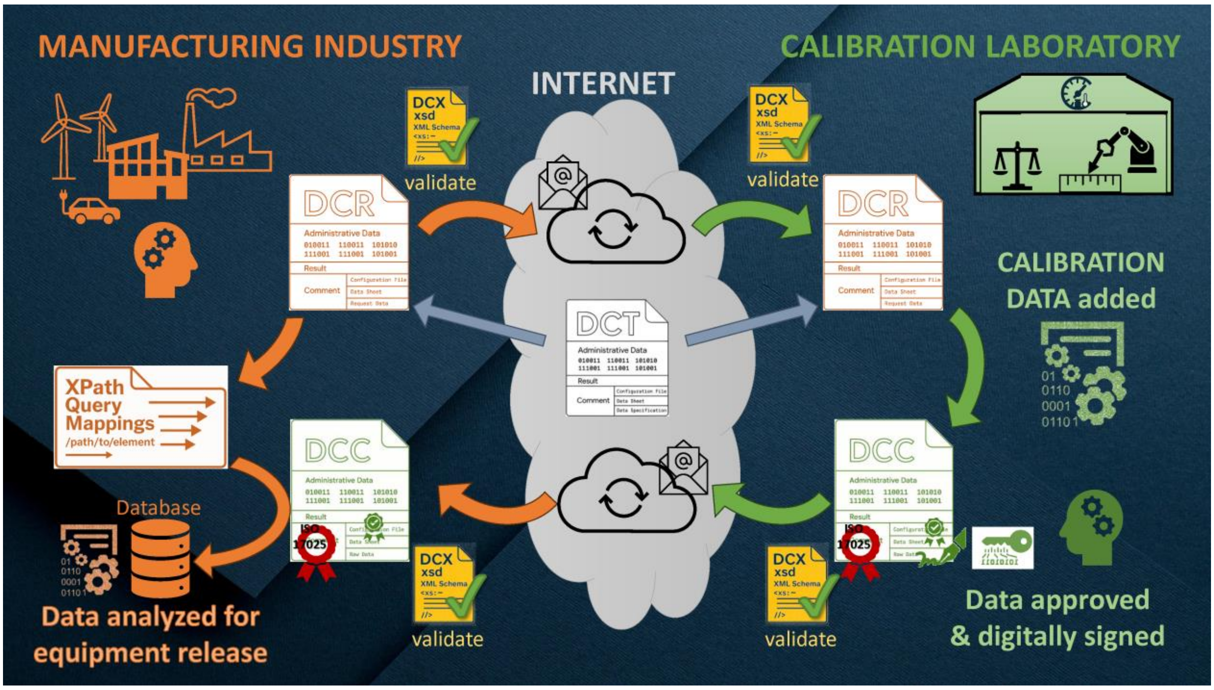


2nd DCR Round Robin
Running first half of 2026
(Expanding participants and certificate types, but single DCR provider)

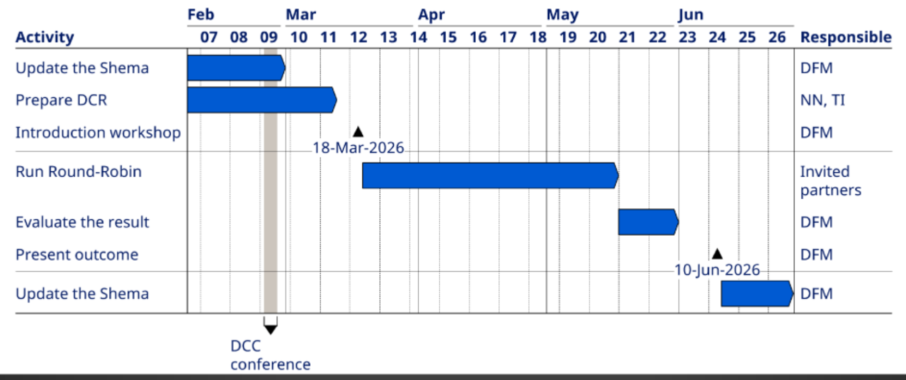
3rd DCR Round Robing
Running second half of 2026
(Expanding participants and DCR providers)

If interested write to
srk@dfm.dk | dbh@dfm.dk

dbh@dfm.dk

Timeline

Geometry, temp/humidity, pressure, flow, multimeter, balance, weight piece, geometry no. 2



dbh@dfm.dk

Thank You

Danish collaboration partners:

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

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

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

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

dbh@dfm.dk

Day 2 2026-02-25 Wednesday
Parallel Session “DCC Tools and Development I”
Session Chair: James Fedchak

020 Lisa Busser: Importing a DCC with the help of Globally Unique Identifers

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- M. Busser [1]

Institute:
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Keywords: Import, GUID, Automatization, Interoperability

Abstract

This presentation will focus primarily on the import of DCCs with the aim of further increasing the degree of automation.

Therefore, this presentation uses a brief demonstration in ScalesNet, a software for mass calibration, to show how the use of Globally Unique Identifiers (GUIDs) has significantly increased the efficiency and the degree of automation of the data import. To demonstrate the use case of GUIDs and the potential to further increase the degree of automation, thereby enabling faster data processing and reducing human interaction two different installations will be used for simulating the calibration laboratory and the customer to whom the DCC is send. The goal is to show a minimalistic easy-to-understand example within an existing application to demonstrate the benefits of GUIDs from the user's perspective.

Furthermore, the technical aspect is examined. It will be shown how the GUIDs were embedded into the existing XML-schema and what local management of the GUIDs is necessary to enable the decentralized chaining of database entries between different installations and even different software products to improve the interoperability whose positive effects were already shown in the initial demonstration. This approach does not explicitly concern the specific measured values, but rather the exchange and import of all other types of data that are also part of the DCC. In other words, the types of data for which text or numbers were entered manually into the local database at some point which applies not only to administrative details

such as customer names or addresses, but also to descriptions of individual test objects, such as their design or material.

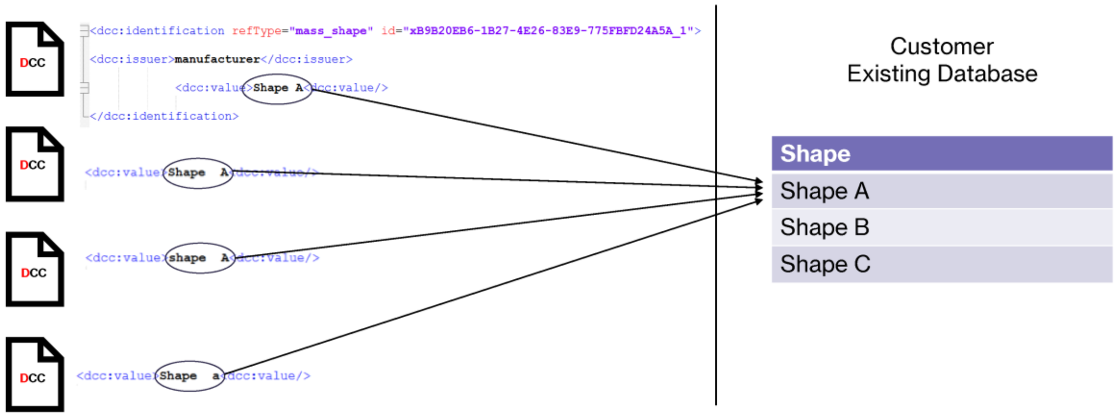
The examples and demonstration are tailored to mass metrology, as ScalesNet is a software for calibrating mass, but the approach and handling of GUIDs is analogous for all other types of DCCs.

Presentation #020 of Lisa Busser

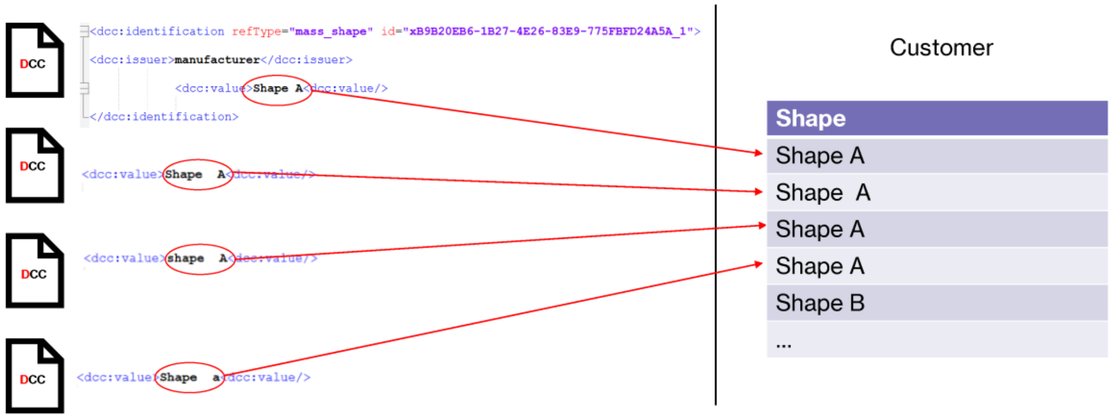
IMPORTING A DCC WITH THE HELP OF GLOBALLY UNIQUE IDENTIFIERS

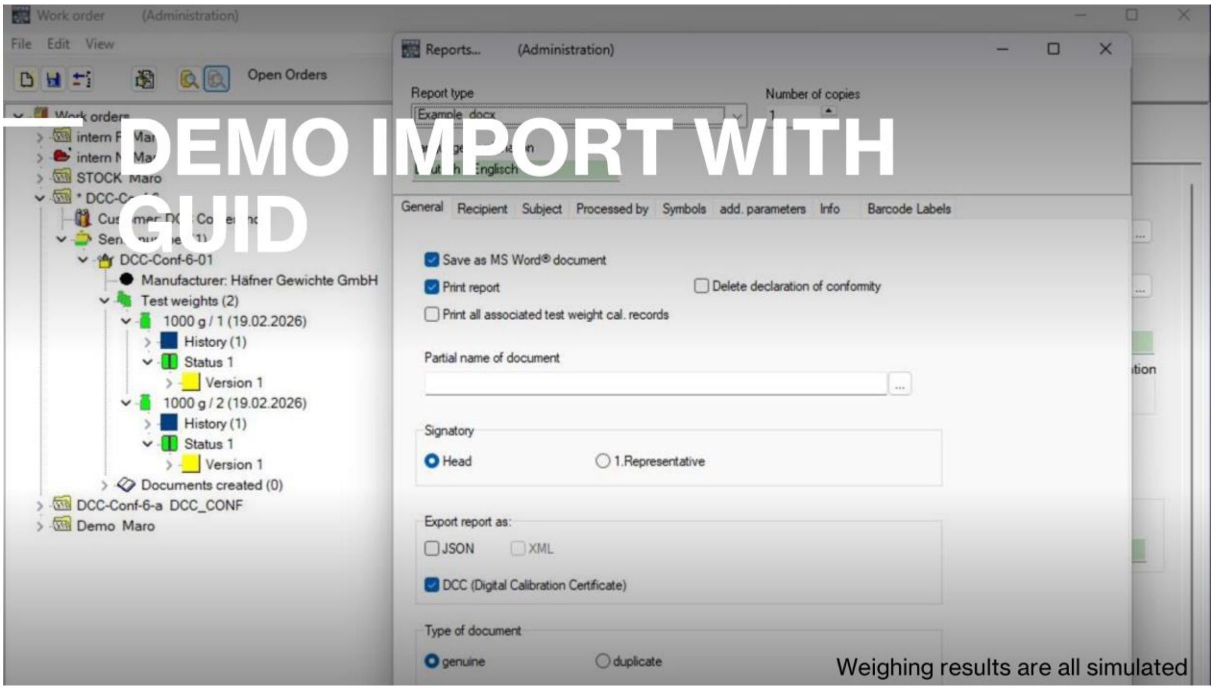
Lisa Busser, MARO Elektronik

Why is importing so difficult



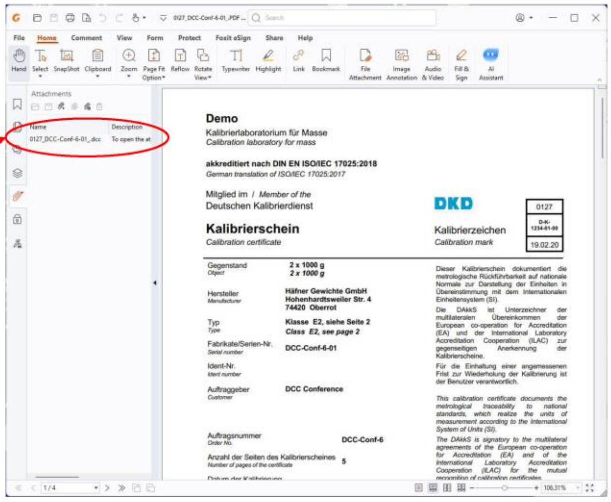
Why is importing so difficult





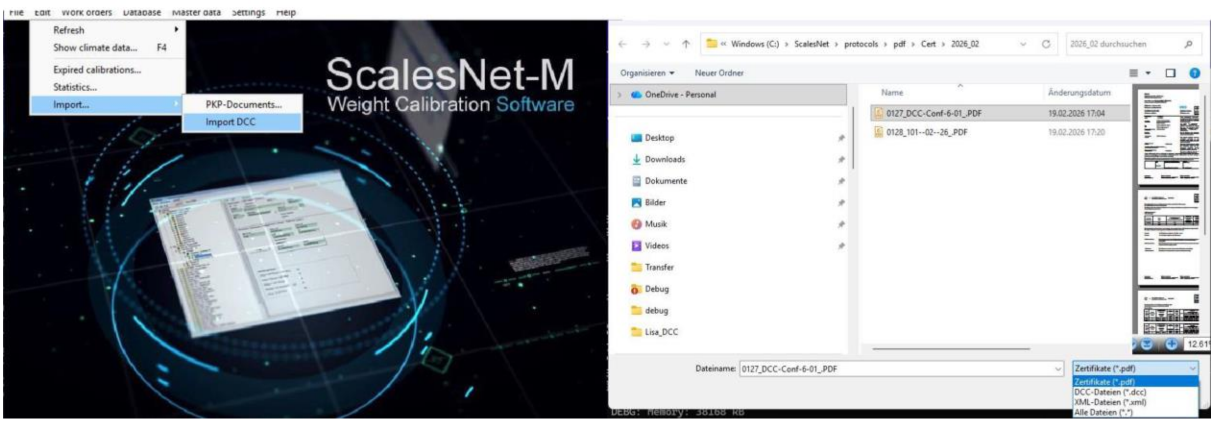
Callibration Certificate with attached DCC

Attached DCC

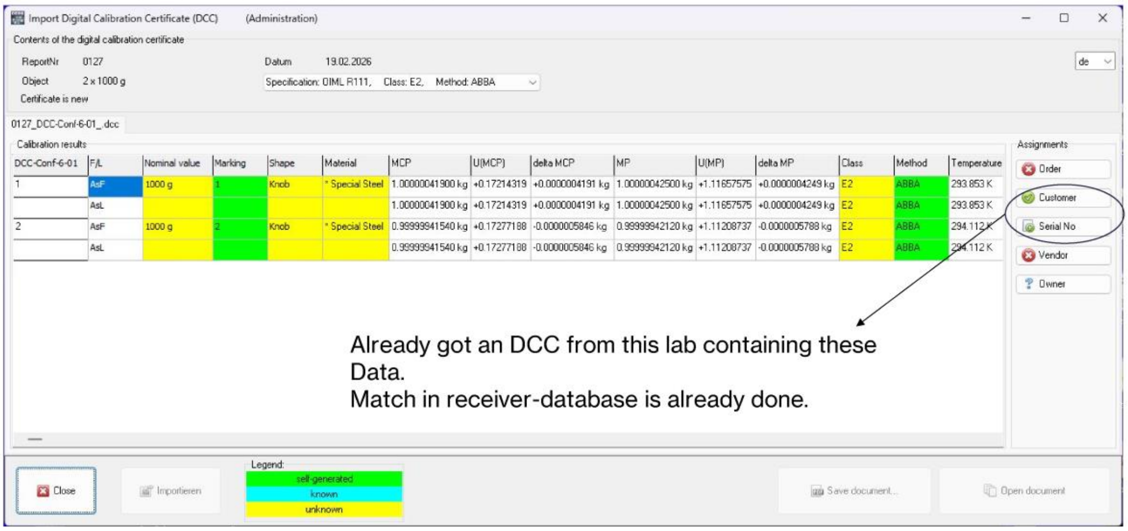


IMPORT DCC

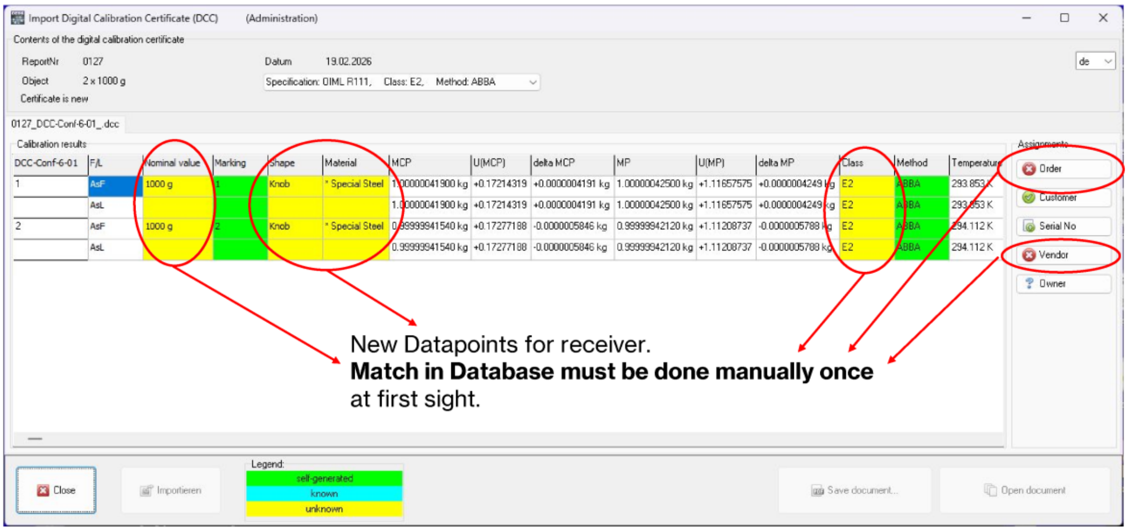
Receiver side



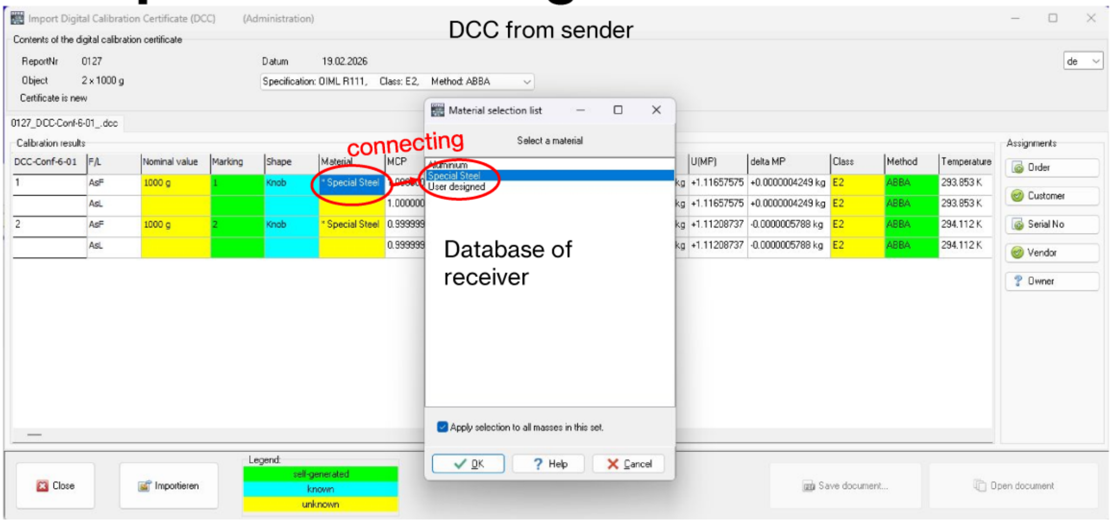
IMPORT DATA



IMPORT DATA

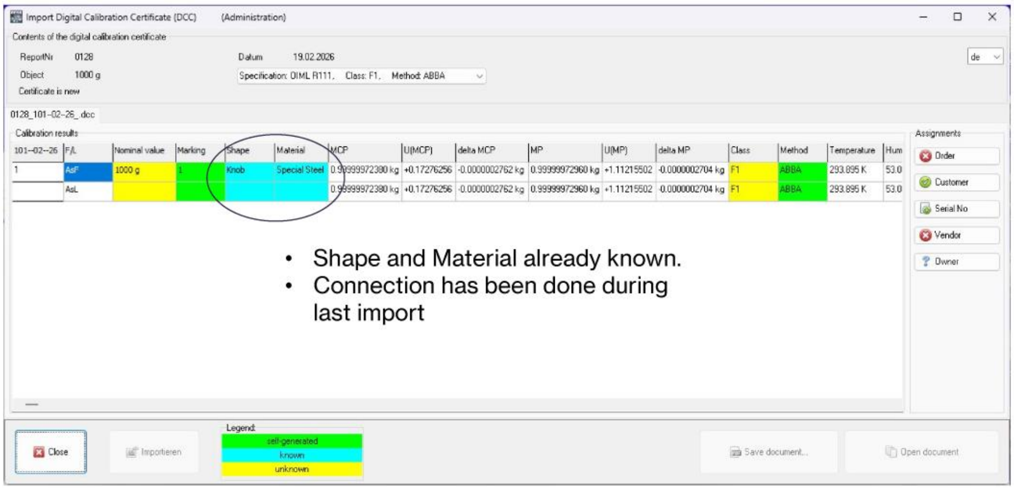


Import: connecting entries



Import: 2 DCC

From same lab to same customer



Benefits of using GUIDs

- Reduce duplications in Database
- Reduce human Interaction
- Higher grade of automatization
- Decentralised architecture
  - No central observer needed
  - No website for registration needed
  - No central resources or maintenance required
- Everyone can generate them

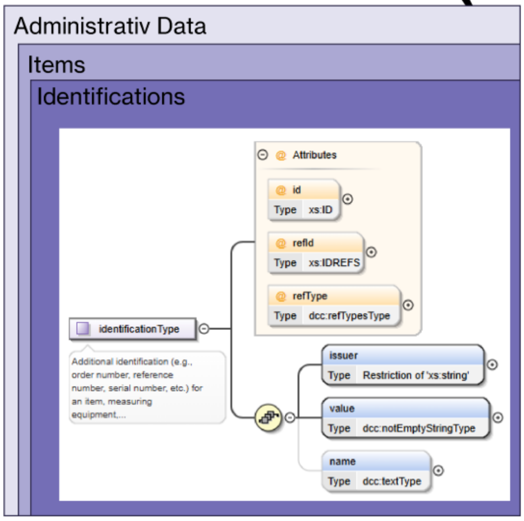
What is a GUID

- Globally Unique Identifier or Universally Unique Identifier
- UUIDv4: 128 bit [122 Bit are random]
- $2^{122} \approx 5{,}3 \times 10^{36}$ possibilities
- unique assignment

„It's more likely for e meteor to hit the computer running the program, blowing it up, than for a UUID to collide. So if you want 100% fail proof program you should solve the meteor defence problem before you start digging into handling UUID collisions"

Stackoverflow, gbtimmon, Jul,18 2018

XML schema (example: shape)



Constraints for Attribute „id“ in DCC
- Must begin with a letter
- Must be unique within one DCC

Modify GUIDs to fit into schema

<dcc:identification refType="mass_shape"

id="xF64656DA-5638-4A30-B910-9875309835BD_3">

Insert prefix “x”
✓ id must begin with letter

Suffix:
- Counting multiple use of same ID “_X”
- “af” = as found
- “al” = as left

✓ id must be unique
- ID can be used with different suffixes for multiple occurrences of same information e.g. same shape of multiple weights

GUIDs in use


```xml
        </dcc:coreData>
        <dcc:items>
            <dcc:name>···
            </dcc:name>
            <dcc:equipmentClass id="x3E32B73E-33B1-4F16-A053-F38BFAAF97EF">···
            </dcc:equipmentClass>
            <dcc:description>···
            </dcc:description>
            <dcc:manufacturer id="x1F024F95-9D3E-4404-AE7B-3E79785308D7">···
            </dcc:manufacturer>
            <dcc:identifications>
                <dcc:identification id="xF7203FE5-2EAA-4554-827F-C9AA77175BF4"···
                </dcc:identification>
            </dcc:identifications>
            <dcc:item id="x3349891E-FE2E-4247-892E-A6E9E6A7A92C">···
            </dcc:item>
        </dcc:items>
        <dcc:calibrationLaboratory>···
        </dcc:calibrationLaboratory>
        <dcc:respPersons>···
        </dcc:respPersons>
        <dcc:customer id="x374CA195-CBA6-4354-ADBD-9BFAED6E45EF">···
        </dcc:customer>
        <dcc:statements>···
        </dcc:statements>
    </dcc:administrativeData>
    <dcc:measurementResults>
        <dcc:measurementResult id="x0962395B-DCAE-4CBA-9CEF-6269FE9E7211af"
            refId="x3349891E-FE2E-4247-892E-A6E9E6A7A92C">
            <dcc:name>···
            </dcc:name>
            <dcc:usedMethods>
                <dcc:usedMethod id="x417833AC-9376-41E5-AD73-6181E935A8FF_1">···
                </dcc:usedMethod>
```


Local management of GUIDs

Shape	Own GUID	Other GUIDs
Shape A	Own_Guid_Shape_A	Other_GUID_Shape_A_01, Other_GUID_Shape_A_02, Other_GUID_Shape_A_03, Other_GUID_Shape_A_04, ...
Shape B	Own_Guid_Shape_B	Other_GUID_Shape_B_01, Other_GUID_Shape_B_02, Other_GUID_Shape_B_03, ...
Shape C	Own_Guid_Shape_C	Other_GUID_Shape_C_01, Other_GUID_Shape_C_02, Other_GUID_Shape_C_03, Other_GUID_Shape_C_04, Other_GUID_Shape_C_05, Other_GUID_Shape_C_06, ...
...	...	...

Outlook

- Further improving import and export of DCC
- Possible security vulnerabilities when importing data into the database (e.g. SQL-Injection)

Contact

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021 Moritz Jordan: Semantics of Digital Calibration Certificates: The DCCS and SIS Ontologies

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Institute:
[1] Physikalisch-Technische Bundesanstalt, Braunschweig, Germany
Keywords: Digital Calibration Certificate, Digital SI, Interoperability, Semantics

Abstract

This presentation provides an update on recent advancements in the development of the DCCS Ontology (Digital Calibration Certificate Semantics) and the SIS Ontology (SI Semantics, D-SI Ontology), two complementary semantic frameworks for digital metrology grounded in ISO/IEC 17025 and in the International Vocabulary of Metrology (VIM).

We report on the latest developments in the SIS Ontology, including its embedding and practical application within the Metadata4Ing Ontology, which demonstrates growing interest in shared Si-based measurement semantics. In parallel, we present the current state of the DCCS Ontology and its evolving support for interoperable Digital Calibration Certificates, covering certificate structure, metadata, stakeholders, instruments, and provenance.

The presentation also situates these developments with respect to related efforts such as the Ontology for Measurement Terminology (OMT) [1], clarifying differences in scope and design. Finally, we highlight how DCCS and SIS integrate with each other and align with established ontologies such as QUDT, the SI Reference Point, the Organization Ontology (ORG), the Provenance Ontology (PROV-O) and, Schema.org, and provide information on how to access and reuse both ontologies.

References:

[1] Wang S, Du M, Liu Z, Luo Y, Xiong X. Design and Implementation of an Ontology for Measurement Terminology in Digital Calibration Certificates. Sensors (Basel). 2024 Jun 19;24(12):3989. doi: 10.3390/s24123989. PMID: 38931773; PMCID: PMC11207306.

Presentation #021 of Moritz Jordan

Physikalisch-Technische Bundesanstalt
Braunschweig and Berlin
National Metrology Institute

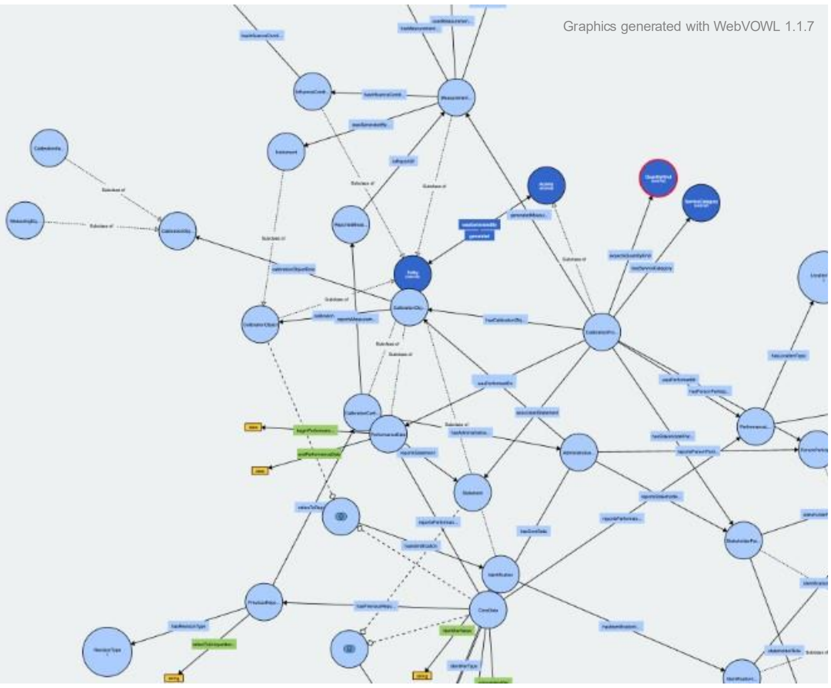
Semantics of Digital Calibration Certificates

The DCCS and SIS Ontologies

Moritz Jordan, WG 1.24, PTB
Giacomo Lanza, Z.5, PTB

Outline

- Motivation
- SIS Ontology
- DCCS Ontology
- Related work
- Usage scenarios



Graphics generated with WebVOWL 1.1.7

19.03.2026

From Structured Documents to Semantic Knowledge

- XML → structured documents
- Ontology → explicit semantics
- Enables reasoning & validation & interoperability

- Foundation for FAIR Digital Calibration Certificates

What is an Ontology?

based on a slide by Maximilian Gruber, PTB

Philosophy

→ Onto▪logy = study of being
What types of entities exist?
How do they relate to one another?

https://plato.stanford.edu/entries/logic-ontology/#DiffConcOnto

Semantic Web

W3C RDF

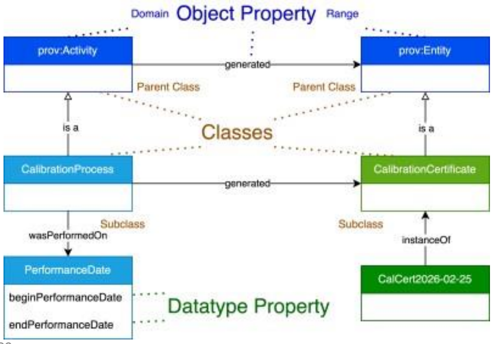
W3C OWL

Triples:
subject+predicate+object

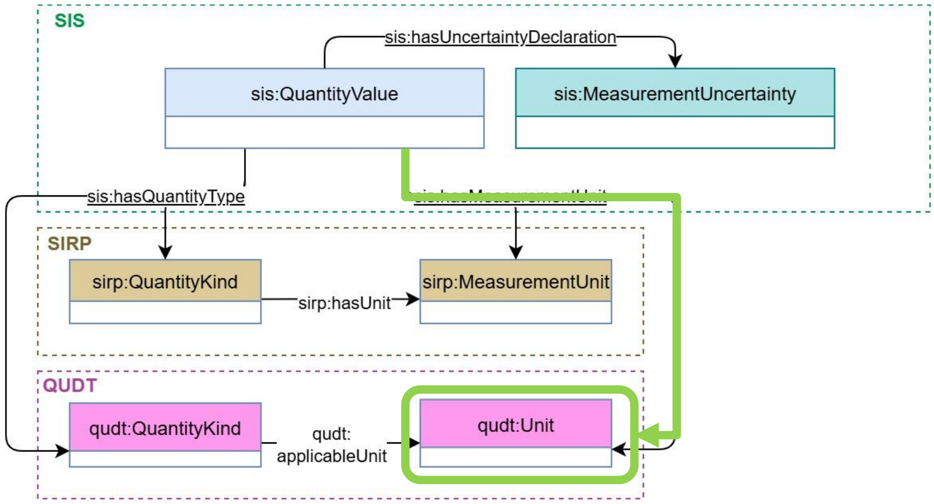
technical realization

Information Science

→ knowledge representation
represent concepts and relations
capture it in a formal way



Basic Structure of the Semantic SI Ontology



Alternative Use of QUDT:Unit

```
# QuantityValue for 1 kilogram
:massValue1 a sis:Real ;
  sis:hasQuantityType quantityKind:Mass ;
  sis:hasUnitIdentifier "\kilogram" ;
  sis:hasMeasurementUnit unit:KiloGM ;
  sis:hasValue "1.0"^^xsd:double .
```

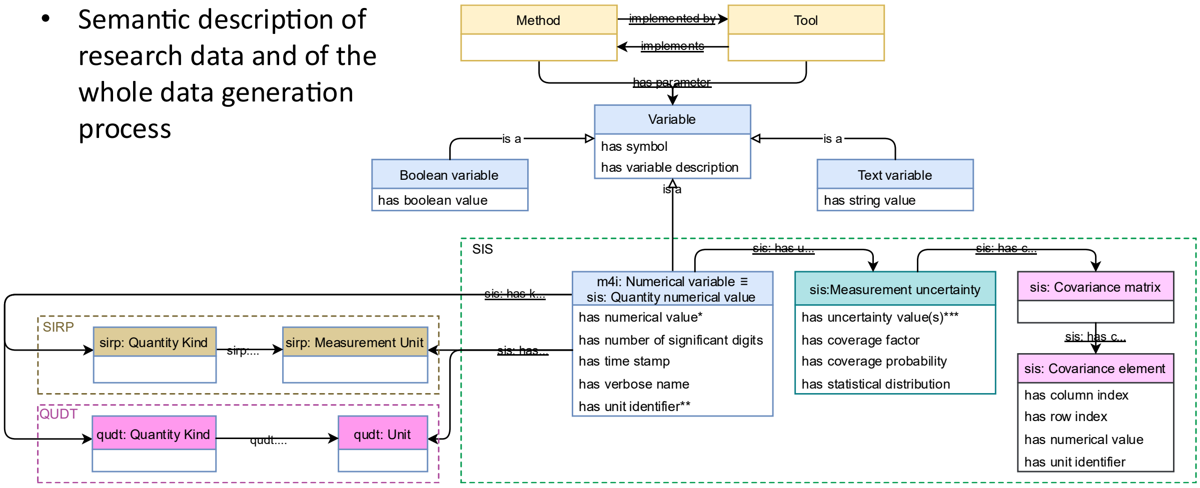
```
quantitykind:Mass a qudt:QuantityKind ;
  qudt:applicableUnit unit:KiloGM ;
  qudt:siExactMatch si-quantity:MASS ;
  qudt:symbol "m" .
```

```
unit:KiloGM a qudt:Unit ;
  qudt:siExactMatch si-unit:kilogram ;
  qudt:hasQuantityKind quantitykind:Mass;
  qudt:symbol "m" .
```

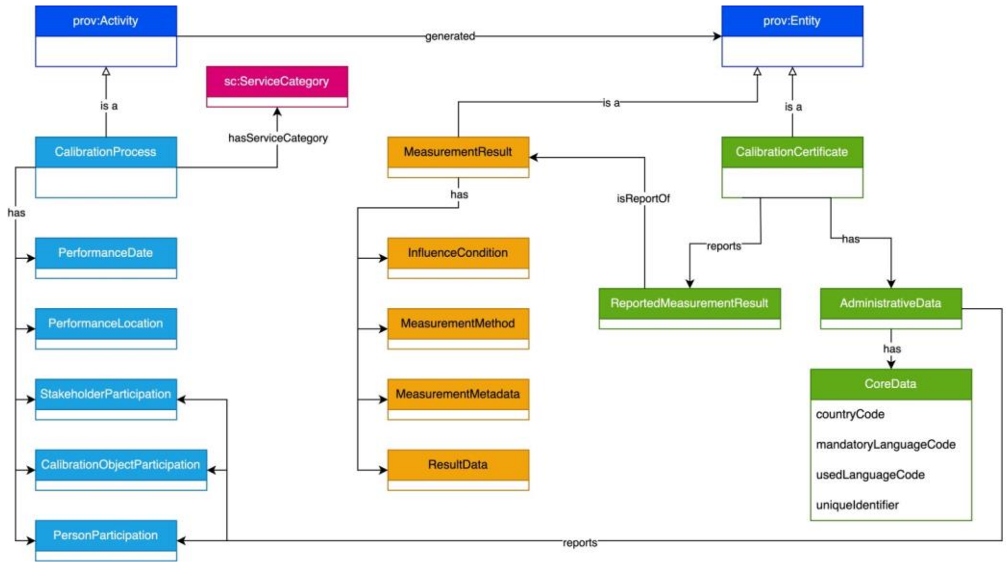
✔ Enables uncomplicated reasoning

Applications of SIS: Metadata4Ing

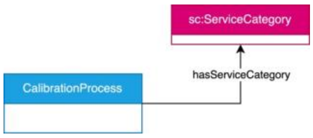
- Semantic description of research data and of the whole data generation process



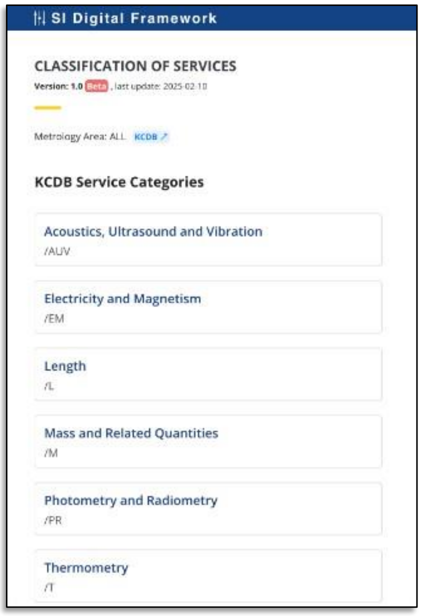
DCCS Ontology Basic Structure



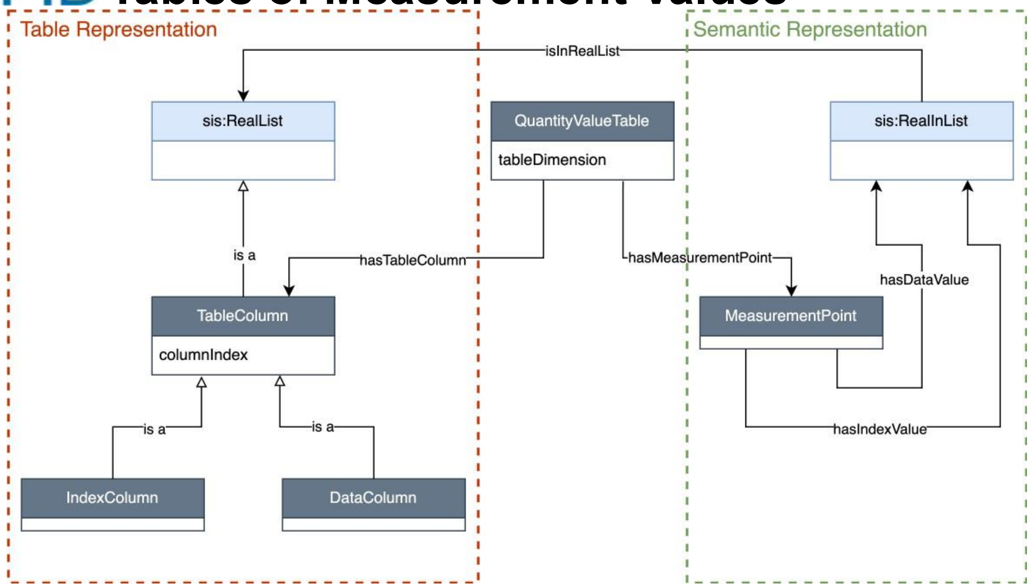
KCDB Service Category




```
# Example Calibration Process
:calibrationProcess1 a dccs:CalibrationProcess ;
  dccs:hasServiceCategory scm:Mass-1.1.1 ;
  dccs:generatesMeasurementResult :measurementResult1 .

# KCDB Service Category
scm:Mass-1.1.1 a sc:ServiceCategory ;
  sc:relatedSIQuantity quantities:MASS .

# Measurement Result
:measurementResult1 a dccs:MeasurementResult ;
  dccs:hasResultData :massValue1 .

# Quantity Value (real number)
:massValue1 a sis:Real ;
  sis:hasQuantityType quantities:MASS ;
  sis:hasValue "1.0"^^xsd:double ;
  sis:hasUnit "\kilogram" .
```



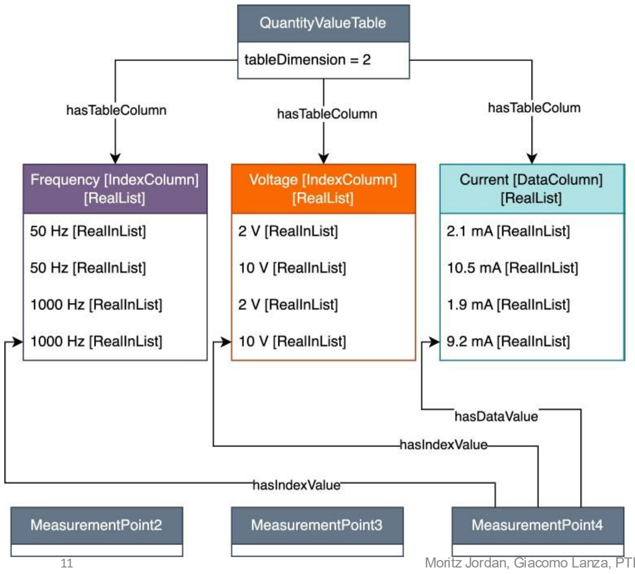
Tables of Measurement Values



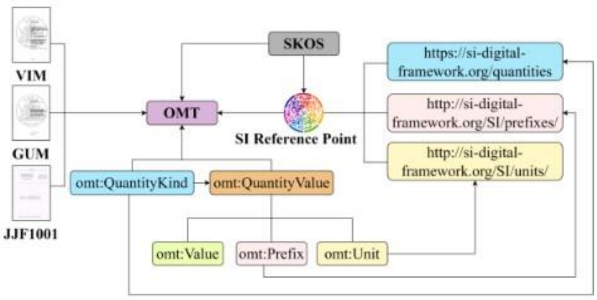
Tables Example: Volt-Meter AC Calibration

Frequency (Hz)	Voltage (V)	Current (mA)
50	2	2.1
50	10	10.5
1000	2	1.9
1000	10	9.2

based on an example by Vanessa Stehr, PTB



Related Work: OMT Ontology



Wang, S., Du, M., Liu, Z., Luo, Y., & Xiong, X. (2024). Design and Implementation of an Ontology for Measurement Terminology in Digital Calibration Certificates. *Sensors (Basel, Switzerland)*, *24*(12), 3989. https://doi.org/10.3390/s24123989

sensors MDPI

Article

Design and Implementation of an Ontology for Measurement Terminology in Digital Calibration Certificates

Shuaizhe Wang [1,2], Mingxin Du [3], Zilong Liu [1,2], Yuqi Luo [3] and Xingchuang Xiong [1,2,*]

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2 Key Laboratory of Metrology Digitalization and Digital Metrology for State Market Refulation, Beijing 100029, China
3 The College of Information Engineering, China Jiliang University, Hangzhou 310018, China; mingxin@cjlu.edu.cn (M.D.); s21040803026@cjlu.edu.cn (Y.L.)
* Correspondence: xiongxch@nim.ac.cn

Abstract: Digital Calibration Certificates (DCCs) are a key focus in metrology digitalization, necessitating that they satisfy the criteria for machine readability and understandability. Current DCCs are machine-readable, but they are still missing the essential semantic information required for machine understandability. This shortfall is particularly notable in the lack of a dedicated semantic ontology for measurement terminologies. This paper proposes a domain ontology for measurement terminologies named the OMT (Ontology for Measurement Terminology), using a foundation of metrological terms from standards like the International Vocabulary of Metrology (VIM), the Guide to the Expression of Uncertainty in Measurement (GUM), and JJF1001. It also incorporates insights from models such as the SI Reference Point, the Simple Knowledge Organization System (SKOS), and the DCC Schema. The methodology was guided by Stanford's Seven-Step Method, ensuring a systematic development process tailored to the needs of metrological semantics. Through semantic expression capability verification and SPARQL query validations, the OMT has been confirmed to possess essential machine readability and understandability features. It has been successfully integrated into version 3.2.1 of DCCs across ten representative domains. This integration demonstrates an effective method for ensuring that DCCs are machine-readable and capable of interoperating within digital environments, thereby advancing the research in metrology digitization.

Keywords: digital calibration certificate; ontology; terminology for measurement; SI reference point; metrology digitalization

check for updates

Citation: Wang, S.; Du, M.; Liu, Z.; Luo, Y.; Xiong, X. Design and Implementation of an Ontology for Measurement Terminology in Digital Calibration Certificates. Sensors 2024, 24, 3989. https://doi.org/10.3390/s24123989

1. Introduction

Comparison DCCS/SIS vs OMT

Feature	DCCS/SIS	OMT
Direct representation of XML DCC(easy mapping)	✓	✗
Alignment with Metrology Standards(VIM, GUM, SIRP)	✓	✓
Integrated provenance information	✓	✗
Single measurement result values	✓	✓
Complex measurement result tables	✓	✗
Extensive uncertainty representation	✓	✗
Measurement model representation	upcoming	✓
KCDB Service Categories	✓	✗

Usage Scenarios

- Machine-understandable DCCs
- Cross-laboratory interoperability
- Automated consistency checking
- Semantic search across calibration repositories
- Knowledge graph for metrology asset management
- Traceability chain representation
- Interlink calibration data with broader semantic ecosystems

How to access the ontologies?

SIS Ontology	DCCS Ontology
IRI https://ptb.de/sis/	IRI https://ptb.de/dccs/

About

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022 Jaime Gonzalez-Gomez: dccQuantities: A Python library for the Automated Evaluation and Uncertainty Propagation of Digital Calibration Certificates

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[1] Physikalisch-Technische Bundesanstalt, Braunschweig, Germany
Keywords: DCC tables, quantities, D-SI units, uncertainty propagation

Abstract

The Digital Calibration Certificate (DCC) provides a standardized XML schema for the exchange of structured calibration data. While the DCC format ensures machine-readability, the complexity of its nested structures — particularly regarding tabulated measurement results, like in analogue formats — presents significant integration challenges for developers for metrology software. The DCC data follows Physikalisch-Technische Bundesanstalt (PTB) policies for a good practice to store tabulated measurements with uncertainties [1][2], which will be briefly introduced in this contribution to define the bases and need for additional libraries.

As example for the latter, we present dccQuantities. This open-source Python library is designed to bridge the gap between the DCC data and functional metrological algorithms. By transforming static XML data into a dynamic object-oriented structure, dccQuantities simplifies data access and understanding while maintaining strict adherence to the DCC schema. A key feature of the framework is the seamless integration of the Metas UncLib package [3], The target is to allow access and subsequent calibration results through mathematical means, automatically carrying over the uncertainty propagation associated with the measurements.

The utility of dccQuantities is demonstrated through practical use cases, included reading DCC measurement data and generating calibration results. This contribution also outlines the library's documentation, intended to enable developers to use the library.

References:

[1] DCC - Wiki (2026): Tables in the DCC, [https://wiki.dcc.ptb.de/en/tables], last accessed: 08.01.2026

[2] Hutzschenreuter, D., et al. (2020): 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 Edition

[3] Wollensack, M. (2021): Introduction to Metas UncLib [https://www.metas.ch/dam/metas/en/data/fachbereiche/hochfrequenz/unclib/metas_unclib_intr o_3_fullprint-e.pdf]

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Presentation #022 of Jaime Gonzalez-Gomez

Physikalisch-Technische Bundesanstalt
Braunschweig and Berlin
National Metrology Institute

dccQuantities: A Python library for the Automated Evaluation and Uncertainty Propagation of Digital Calibration Certificates

6th DCC Conference

Jaime Gonzalez-Gomez, Benedikt Seeger, Vanessa Stehr, PTB, 1.73

DCC data in XML files

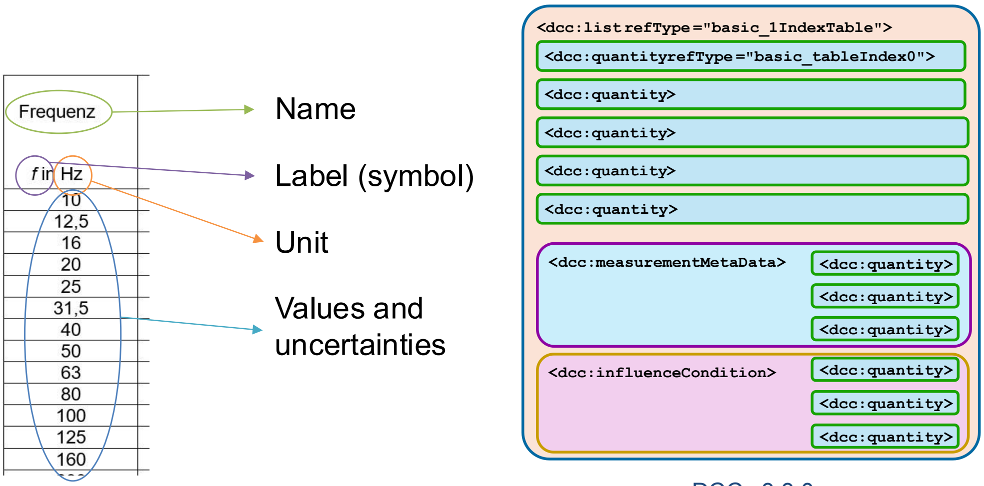
- DCC provides a standardized XML schema.
- Calibration data is stored in tables.
- Tables are composed by:
  - Index Quantities: independent input to the experiment.
  - Value Quantities: measured result, dependent to index quantities.
  - Other metadata

DCC Tables and Quantities

Index Quantities | Value Quantities

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

DCC Tables and Quantities



DCC v3.3.0

Where lies the problem?

Long Table representation

Frequency f (Hertz)	Acceleration $\hat{a}$ (m/s^2)	Transfer Coefficient S_{qa} $(\frac{\mathrm{pC}}{\mathrm{m}/s^2})$
10.0	5.0	0.13017
12.5	5.0	0.13017
16.0	5.0	0.13016
20.0	10.0	0.13016
25.0	10.0	0.13017
31.5	10.0	0.13017
…	…	…

Where lies the problem?

Long Table representation


```
<dcc:list tableDimension="1">
  <dcc:name><dcc:content lang="de">Ladungsübertragungskoeffizenten</dcc:content><dcc:content lang="en">Charge transfer coefficents</dcc:content></dcc:name>
  <dcc:quantity refType="vib_frequency vib_nominalFrequency" index="0"><dcc:name><dcc:content lang="en">Frequency</dcc:content><dcc:content lang="de">Frequenz</dcc:content><dcc:name><si:realListXMLList><si:valueXMLList>10.0 12.5 16.0 20.0 25.0 31.5 40.0 50.0 63.0 80.0 1.0e+02 1.25e+02 1.6e+02 2.0e+02 2.5e+02 …</si:valueXMLList><si:unitXMLList>\hertz</si:unitXMLList></si:realListXMLList></dcc:quantity>
  <dcc:quantity refType="vib_nominalAccelerationAmplitude vib_accelerationAmplitude"><dcc:name><dcc:content lang="en">Acceleration Amplitude</dcc:content><dcc:content lang="de">Beschleunigungsamplitude</dcc:content></dcc:name><si:realListXMLList> <si:valueXMLList>5.0 5.0 5.0 10.0 10.0 10.0 10.0 50.0 50.0 50.0 50.0 50.0 50.0 50.0 50.0 …</si:valueXMLList><si:unitXMLList>\metre\second\tothe{-2}</si:unitXMLList> </si:realListXMLList></dcc:quantity>
<dcc:quantity refType="vib_magnitudeTransferCoefCharge"><dcc:name><dcc:content lang="en">Charge transfer coefficient magnitude</dcc:content> <dcc:content lang="de">Ladungsübertragungskoeffizent Betrag</dcc:content></dcc:name><si:realListXMLList>
<si:valueXMLList>0.13017 0.13017 0.13016 0.13016 0.13017 0.13017 0.13017 0.13016 0.13013 0.13013 0.13012 0.13012 0.13012 0.13012 0.13014 …</si:valueXMLList> <si:unitXMLList>\pico\coulomb\per\metre\second\tothe{-2}</si:unitXMLList>
<si:expandedUncXMLList><si:uncertaintyXMLList>0.00026 0.00026 0.00026 0.00026 0.00026 0.00026 0.00026 0.00026 0.00026 0.00026 0.00026 0.00026 0.00026 0.00026 0.00026 …</si:uncertaintyXMLList> <si:coverageFactorXMLList>2.0</si:coverageFactorXMLList>
<si:coverageProbabilityXMLList>0.95</si:coverageProbabilityXMLList> </si:expandedUncXMLList> </si:realListXMLList>
<dcc:relativeUncertainty> <dcc:relativeUncertaintyXmlList> <si:valueXMLList>0.0020 0.0020 0.0020 0.0020 0.0020 0.0020 0.0020 0.0020 0.0020 0.0020 0.0020 0.0020 0.0020 0.0020 0.0020 …</si:valueXMLList> <si:unitXMLList>\one</si:unitXMLList> </dcc:relativeUncertaintyXmlList>
</dcc:relativeUncertainty> </dcc:quantity>
<dcc:quantity refType="vib_phase"> <dcc:name> <dcc:content lang="en">Phase delay</dcc:content> <dcc:content lang="de">Phasenverzögerung</dcc:content> </dcc:name> <si:realListXMLList> <si:valueXMLList>-0.0003 -0.0004 -0.0004 -0.0003 -0.0001 -0.0002 -0.0003 -0.0001 0.0000 0.0002 -0.0002 -0.0002 -0.0000 -0.0000 0.0001 …</si:valueXMLList> <si:unitXMLList>\radian</si:unitXMLList>
<si:expandedUncXMLList> <si:uncertaintyXMLList>0.0035 0.0035 0.0035 0.0035 0.0035 0.0035 0.0035 0.0035 0.0035 0.0035 0.0035 0.0035 0.0035 0.0035 0.0035 …</si:uncertaintyXMLList> <si:coverageFactorXMLList>2.0</si:coverageFactorXMLList>
<si:coverageProbabilityXMLList>0.95</si:coverageProbabilityXMLList> </si:expandedUncXMLList> </si:realListXMLList> </dcc:quantity>
<dcc:quantity refType="vib_phase"> <dcc:name> <dcc:content lang="en">Phase delay W Distribution given </dcc:content> <dcc:content lang="de">Phasenverzögerung</dcc:content> </dcc:name> <si:realListXMLList> <si:valueXMLList>-0.0003 -0.0004 -0.0004 -0.0003 -0.0001 -0.0002 -0.0003 -0.0001 0.0000 0.0002 -0.0002 -0.0002 -0.0000 -0.0000 0.0001 …</si:valueXMLList> <si:unitXMLList>\radian</si:unitXMLList>
<si:expandedUncXMLList> <si:uncertaintyXMLList>0.0035 0.0035 0.0035 0.0035 0.0035 0.0035 0.0035 0.0035 0.0035 0.0035 0.0035 0.0035 0.0035 0.0035 0.0035 …</si:uncertaintyXMLList> <si:coverageFactorXMLList>2.0</si:coverageFactorXMLList>
<si:coverageProbabilityXMLList>0.95</si:coverageProbabilityXMLList> <si:distributionXMLList>normal</si:distributionXMLList>
</si:expandedUncXMLList> </si:realListXMLList> </dcc:quantity>
</dcc:list>
```


DCC v3 4 0

What should you do?

Leave it to the software

dccQuantities – Python library

Already released at PyPI

https://pypi.org/project/dccQuantities/

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dccQuantities – Python library

dccQuantities 2.0.0

`pip install dccQuantities`

- Extract tables directly from XML files
- Create tables from existing data
- Apply math operation over Quantities
- Automatic D-SI unit handling*
- Automatic uncertainty propagation**
- Export table objects as XML strings

*Performed using *dsiUnits* Python package
**Performed by *metas_unclib* Python package

dccQuantities – Quantity serialization

```
from dcc_quantities import DccQuantityType
d = DccQuantityType.from_single_quantity_value (
    name="Distance", value=2.5, uncertainty=0.05, unit="\\metre"
)
t = DccQuantityType.from_single_quantity_value (
    name="Time", value=0.45, uncertainty=0.015, unit= "\\second"
)
v = d / t
v.set_label ("V")
v.set_name ("Velocity", "en")
print(v)
```

Velocity 'V': [5.555555555555555 ± 0.21596118129056666] \metre\per\second

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dccQuantities – Table initialization

```
from dcc_quantities import DccFlatTable, DccLongTable

index_quantities = {0: q_idx0, 1: q_idx1, ..., N:   q_idxN}
value_quantities = [q_val0, q_val1, ...,  q_valM]
```

Are the value quantities defined through all inputs for each index quantity?

Yes

```
flat_table = DccFlatTable(
    index_quantities, value_quantities, ...
)
```

No

```
long_table = DccLongTable(
    index_quantities, value_quantities, ...
)
```


dccQuantities – Read an XML file


```xml
<dcc:list tableDimension="1">
  <dcc:name><dcc:content lang="de">Ladungsübertragungskoeffizenten</dcc:content><dcc:content lang="en">Charge transfer coefficents</dcc:content></dcc:name>
  <dcc:quantity refType="vib_frequency vib_nominalFrequency" index="0"><dcc:name><dcc:content lang="en">Frequency</dcc:content><dcc:content lang="de">Frequenz</dcc:content><dcc:name><si:realListXMLList><si:valueXMLList>10.0 12.5 16.0 20.0 25.0 31.5 40.0 50.0 63.0 80.0 1.0e+02 1.25e+02 1.6e+02 2.0e+02 2.5e+02 …</si:valueXMLList><si:unitXMLList>\hertz</si:unitXMLList></si:realListXMLList></dcc:quantity>
```


```python
from dcc_quantities import extract_dcc_elements , DccQuantityTable

xml_tables = extract_dcc_elements (xml_file_path )
table = DccQuantityTable.from_dcc_data (xml_tables[0])

print("Loaded table of type: " , type(table))
```

Loaded table of type: DccLongTable

dccQuantities – Export as XML

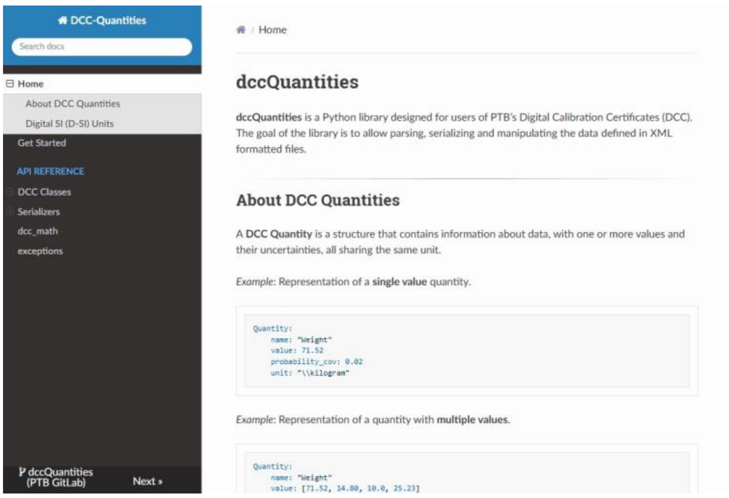
```python
from dcc_quantities import extract_dcc_elements , DccQuantityTable

# Both 'DccFlatTable' and 'DccLongTable' inherit from 'DccQuantityTable'
table: DccQuantityTable
table_xml_str = table.export_as_xml_structure ()

print(table_xml_str )
```

```xml
<dcc:list id="Ufa0553d7-866c-49b9-815b-335b3afaa038" refType="basic_1IndexTable">
  <dcc:name>
    <dcc:content lang="de">Ladungsübertragungskoeffizenten</dcc:content>
    <dcc:content lang="en">Charge transfer coefficents</dcc:content>
  </dcc:name>
  <dcc:quantity id="U929b2584-5989-45ed-b956-59adcae4e233" refType="vib_frequency vib_nominalFrequency
basic_tableIndex0" index="0">
  <dcc:name>
    …
```


User documentation



Upcoming features

SQL-like Quantity Access

```
table: DccQuantityTable
sliced_table = table.get_sliced_table (
   (“Frequency” < 50) “&&” (“Frequency” > 10)
)
```

Still not released!

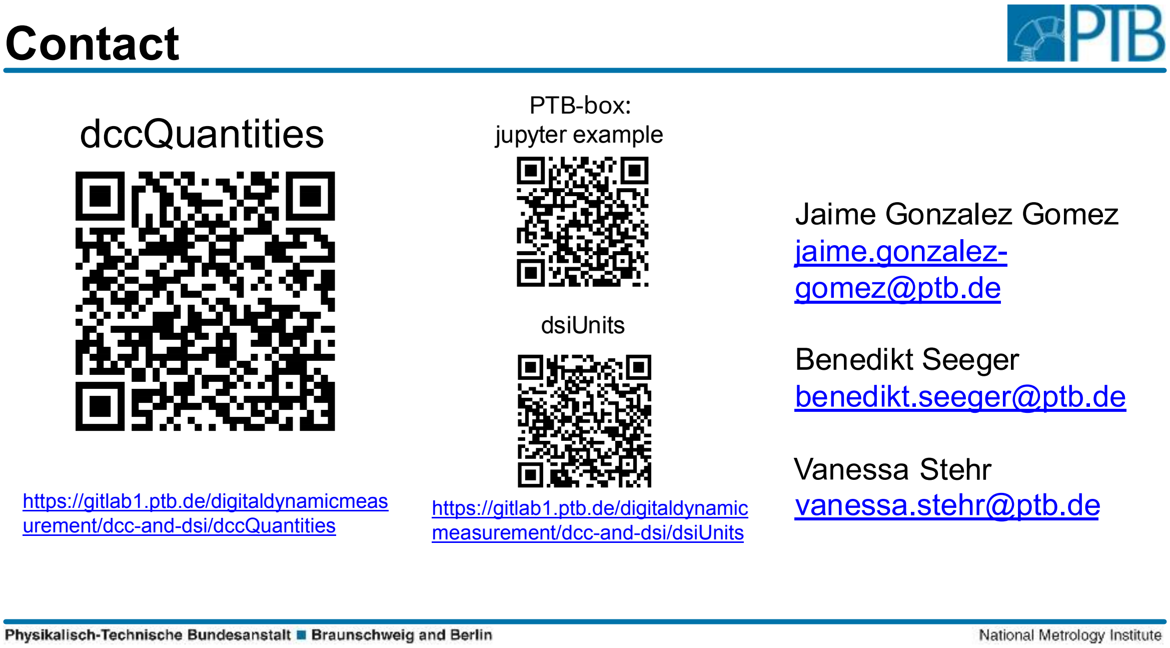
User requested feature: Math module

```
from dcc_quantities import DccQuantityType, dcc_math

# Trigonometry over angles
angle = DccQuantityType(..., unit=“\\radian”)
factor = dcc_math.sin(angle)

# Math over quantities
quantity = DccQuantityType(..., unit=“\\one” )
res = dcc_math.log10 (quantity)
```

All math functions are explained in the documentation



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023 Jan Loewe: dcclib - A Python Library for Automated DCC Processing

Presenting author: Jan Loewe [1]
Email: jan.loewe@ptb.de
Additional authors:

- Justin Jagieniak, justin.jagieniak@ptb.de [1]

Institute:
[1] Physikalisch-Technische Bundesanstalt (PTB), Bundesallee 100, Braunschweig, 38116, Germany
Keywords: dcclib, python, tools, automation, formulae

Abstract

The Digital Calibration Certificate (DCC) is an XML-based, machine-readable format for the standardised exchange of calibration results. Dedicated software tools are needed for the creation, validation, processing and evaluation of DCC content for use in automated and interoperable workflows.

This work continues and extends dcclib, a consolidated and modular Python library that unifies core DCC functionalities which were previously distributed across various tools, dcclib was first presented at the IMEKO TC-6 M4DConf on Digitalization [1], Its functionality is exposed through a public interface, a command line interface and a REST API so it can be integrated into scripts, CI/CD pipelines, and remote services across diverse environments. This architecture is shown in the component diagram in figure 1.

dcclib provides a standardised software interface for essential operations such as structural and content validation, attachment extraction, format conversion, digital signature handling, and DCC transformation into human-readable representations. Furthermore, it provides capabilities for the automated parsing and evaluation of formulae within DCCs. Content MathML [2] formulae are parsed into SymPy functions [3] and evaluated with quantities directly from the DCC. Uncertainty propagation and unit handling are ensured by the dccQuantities library [4], which itself is based on METAS UncLib [5],

Quality assurance is addressed through unit, integration and end-to-end tests, which are implemented with Pytest and executed within GitLab CVCD pipelines to ensure correct behaviour across modules and interfaces. Distribution via the Python Package Index (PyPI), container images and standalone executables enables deployment in a wide range of environments.

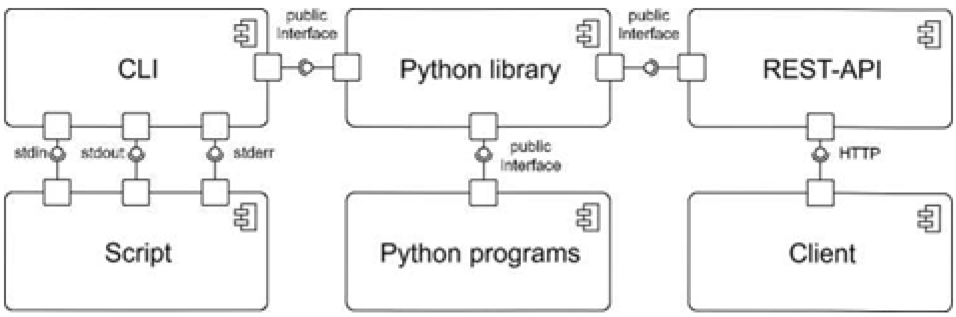

Figure 1. Component diagram showing the library and its interfaces

References:

[1] Loewe, Jan et al. (2025): dcclib - Consolidation of Digital Calibration Certificate (DCC) tools into a unified Python library, in: Proceedings of the IMEKO TC6 Conference on Digitalization - M4DConf

[2] Miner, Robert et al. (2014): Mathematical Markup Language (MathML) Version 3.0 2nd Edition, in W3C Recommendation

[3] Meurer, Aaron et al. (2017): SymPy: symbolic computing in Python, in PeerJ Computer Science

[4] gitlabl.ptb.de (2026): decQuantities, [https://gitlabl.ptb.de/digitaldynamicmeasurement/dcc- and-dsi/dccQuantities/], last accessed: 03.02.2026

[5] METAS (2026) UncLib, [https://www.metas.ch/metas/en/home/fabe/hochfrequenz/unclib.html], last accessed: 03.02.2026

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Presentation #023 of Jan Loewe


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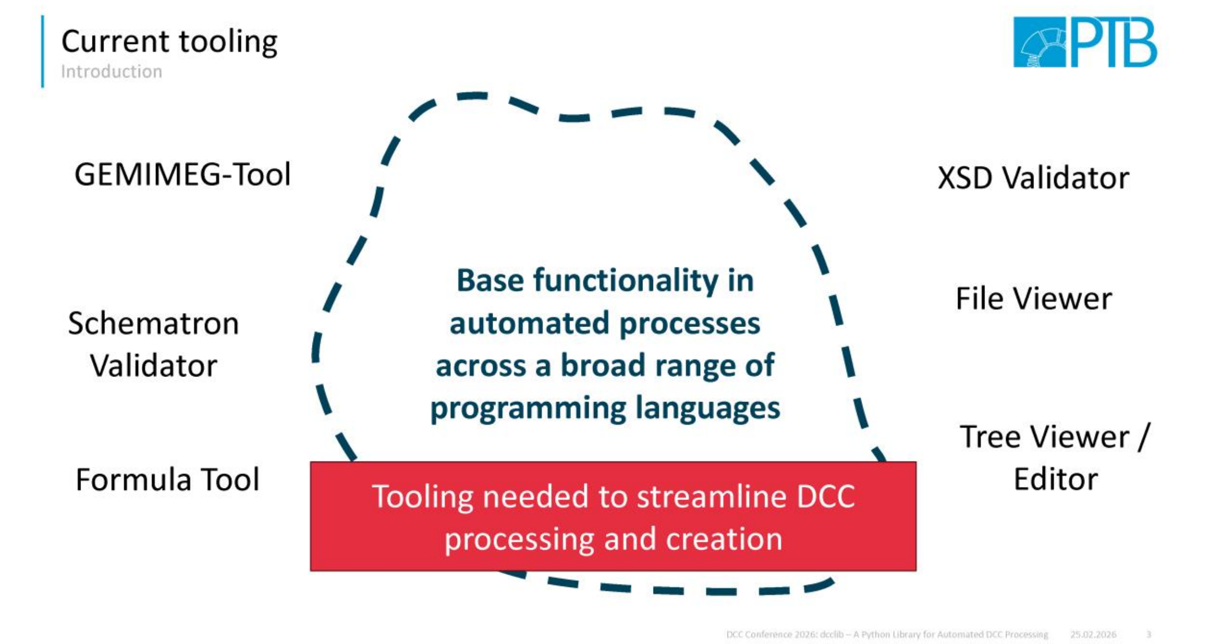
Introduction
Physikalisch-Technische Bundesanstalt
Bundesallee 1
6TH INTERNATIONAL DCC CONFERENCE
FEBRUARY 24–26, 2026


Current tooling
Introduction
GEMIMEG-Tool
Schematron Validator
Formula Tool
Base functionality in automated processes across a broad range of programming languages
Tooling needed to streamline DCC processing and creation
XSD Validator
File Viewer
Tree Viewer / Editor
DCC Conference 2026: dcclib – A Python Library for Automated DCC Processing
25.02.2026
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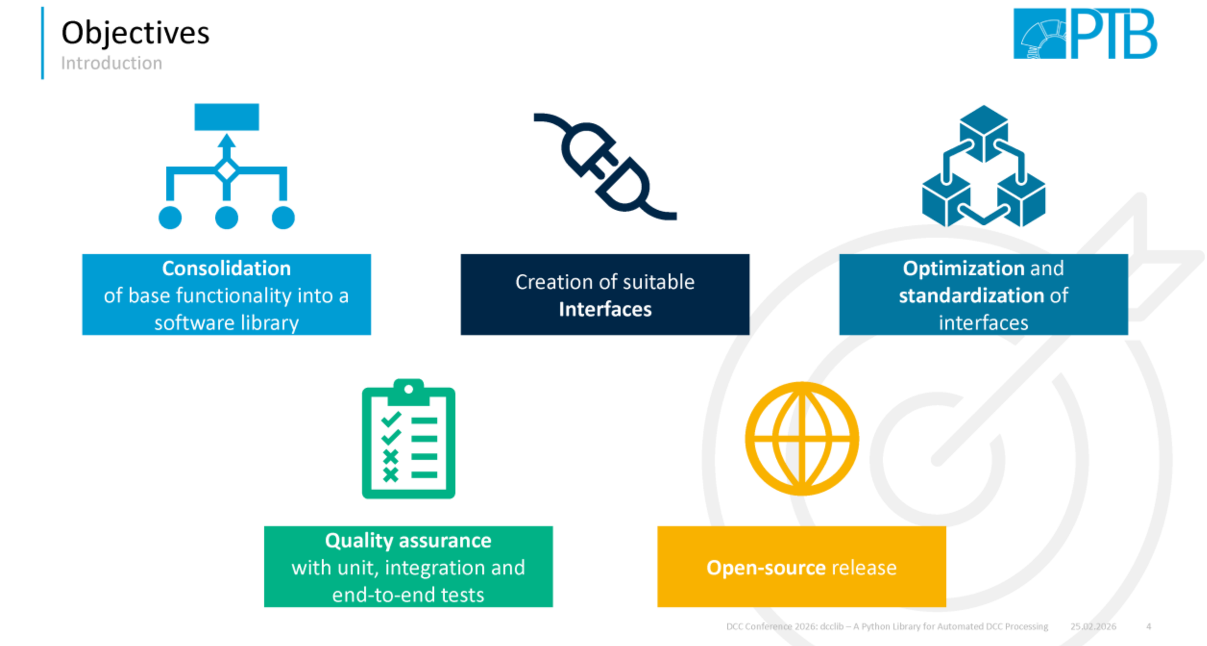
Objectives
Introduction
Consolidation of base functionality into a software library
Creation of suitable Interfaces
Optimization and standardization of interfaces
Quality assurance with unit, integration and end-to-end tests
Open-source release
DCC Conference 2026: dcclib – A Python Library for Automated DCC Processing
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2
Architecture and APIs
6TH INTERNATIONAL DCC CONFERENCE
FEBRUARY 24-26, 2026

Choosing a programming language
Architecture and APIs

Widely used in general and in the data science field

Widely used in **calibration laboratories**

Used in most of the **existing tooling**

Modules
Architecture and APIs

Validation
against the XSD and with Schematron

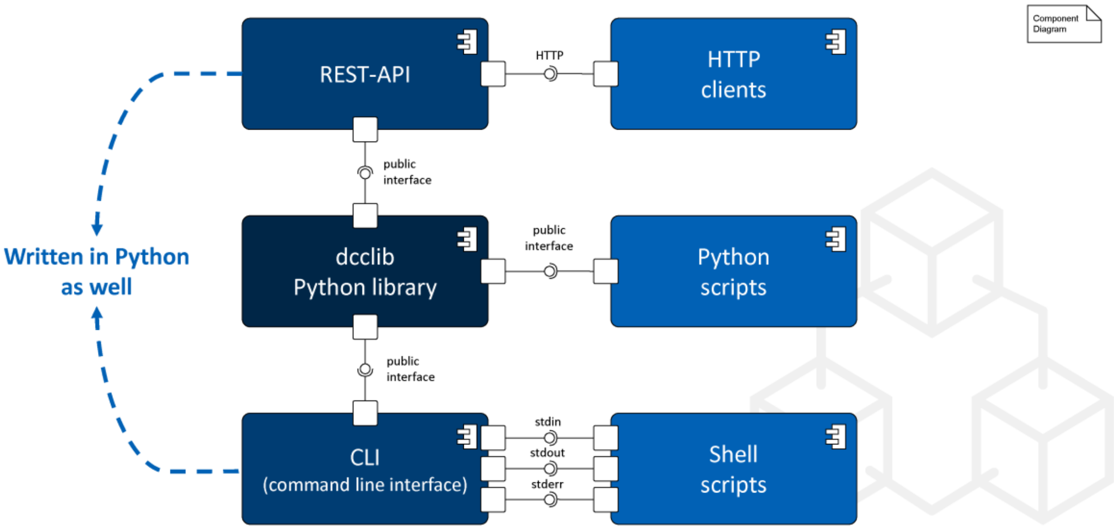
Conversion
into other formats like JSON

Extraction
of attachments and formulae

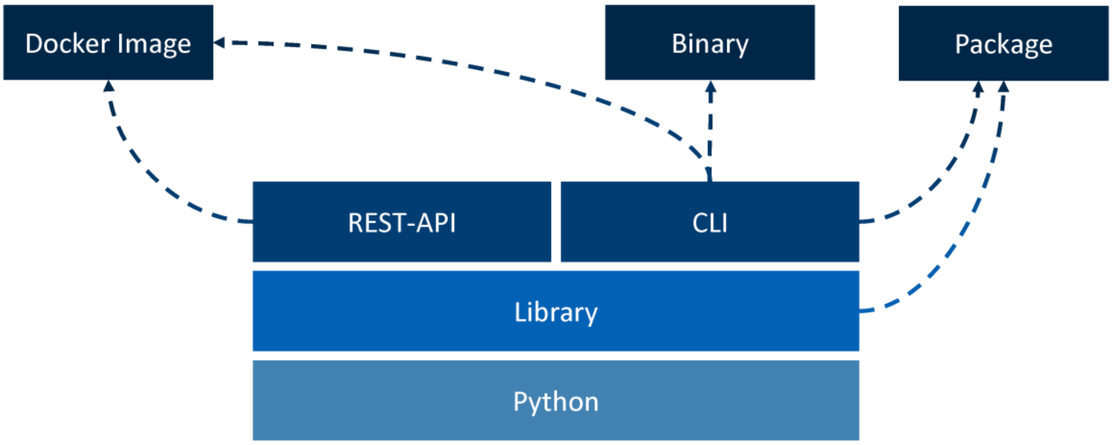
Transformation
into human-readable formats

Signature
verification and signing

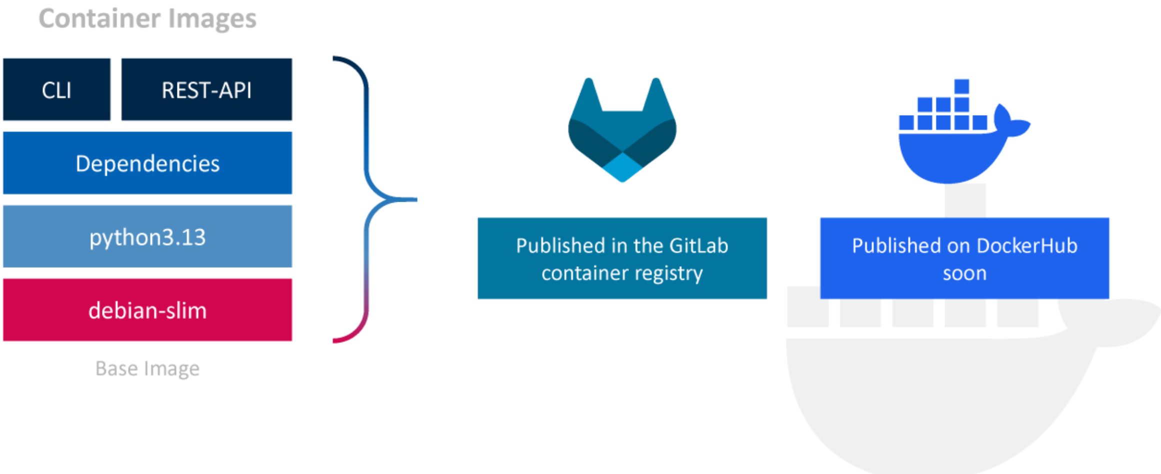
Architecture
Architecture and APIs



Overview of artifacts
Architecture and APIs



Containerization
Architecture and APIs



Installation of the Package via pip
Architecture and APIs

Installation for use as a library

Installation as a CLI tool

```
[jloewe@n251017] /tmp/cli [ v3.13.12(.venv)]
❯ pip install "dcclib"

[jloewe@n251017] /tmp/cli [ v3.13.12(.venv)]
❯ pip install "dcclib[cli]"

[jloewe@n251017] /tmp/cli [ v3.13.12(.venv)]
❯ dcclib --help
Usage: dcclib [OPTIONS] COMMAND [ARGS]...

Options:
  -v, --version  Show the version and exit.
  -h, --help     Show this message and exit.

Commands:
  convert    Convert DCC XML files to JSON.
  extract    Extract information like formulae and files from a DCC XML file.
  signature  Signs and verifies DCC XML files.
  transform  Transform an XML file with stylesheets.
  validate   Validate an DCC XML file against the DCC schema and schematron.
```

Validation with Schematron

Practical Use-Cases

```
[jloewe@n251017] /tmp [ v3.13.12(.venv)]
❯ dcclib validate schematron -s dcc.sch invalid_schematron.xml

ERROR: Schematron validation ended with 1 error(s), 0 warning(s) and 0 information message>
+---+-------+-----------------+-----------------------------------------------------------------
|   | Role  | Test            | Text
+---+-------+-----------------+-----------------------------------------------------------------
| 0 | error | $bDate le $eDate | The beginning date of the calibration must be earlier tha>
+---+-------+-----------------+-----------------------------------------------------------------
(END)
```

Use-Case

Performing semantic validations on DCCs e. g. for testing interoperability

- Custom Schematron can be supplied
- More output formats like CSV, JSON and JUnit reports planned for the future

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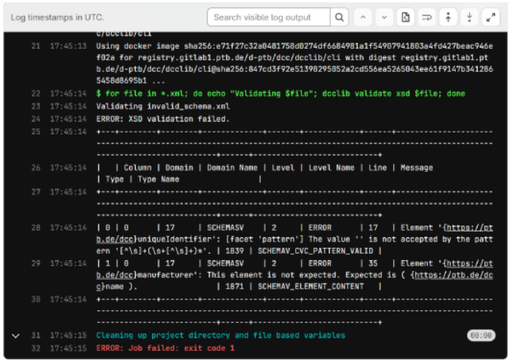
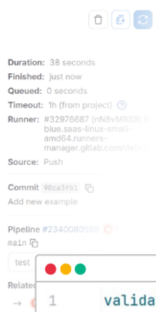
Validation in CI/CD Pipelines

Practical Use-Cases





Use-Case

Performing automated validation for good practice examples

- Automatically executed as a GitLab Pipeline for every change
- Accidental errors can be deteced and fixed faster

```yaml
validate_examples:
  image:
    name: registry.gitlab1.ptb.de/d-ptb/dcc/dcclib/cli
    entrypoint: [""]
  script:
    - for file in *.xml; do
        echo "Validating $file";
        dcclib validate xsd $file;
      done
```

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Creating Human-Readables from the CLI

Practical Use-Cases

```
[jloewe@n251017] /tmp
❯ dcclib transform xslt valid.xml custom.xsl | bat

STDIN
Size: -

<!DOCTYPE HTML>
<html>
    <body>
        <h1>Test XSLT</h1>
        <p>XSLT Version = 3.0</p>
        <p>XSLT Vendor = Saxonica</p>
        <p>XSLT Vendor URL = http://www.saxonica.com/</p>
    </body>
</html>
```

Use-Case

Human-Readables need to be created after creating the DCC in other software solutions

- Support for XSLT v3.0 using SaxonC
- No external dependencies needed, everything is packaged in the CLI

Output can be piped into other software or files

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Algorithm

Formula Evaluation

1. Parsing of the DCC
2. Identification of the MathML formulae
3. Conversion of MathML into SymPy expressions
4. Resolution of the quantity references and creation of dccQuantities objects
5. Output of the formulae for the user
6. Flexible evaluation with the resolved quantities or user-defined inputs
7. Automatic uncertainty propagation using dccQuantities based on METAS UncLib

Conversion of MathML into SymPy expressions

Formula Evaluation

```xml
<ml:math id="formula_02">
    <ml:declare type="fn">
        <ml:ci>R</ml:ci>
        <ml:lambda>
            <ml:bvar><ml:ci xref="T">T</ml:ci></ml:bvar>
            <ml:apply>
                <ml:times/>
                <ml:ci xref="R0">R0</ml:ci>
                <ml:apply>
                    <ml:plus/>
                    <ml:cn type="real">1</ml:cn>
                    <ml:apply>
                        <ml:times/>
                        <ml:ci xref="A">A</ml:ci>
                        <ml:ci>T</ml:ci>
                    </ml:apply>
                    <ml:apply>
                        <ml:times/>
                        <ml:ci xref="B">B</ml:ci>
                        <ml:apply>
                            <ml:power/>
                            <ml:ci>T</ml:ci>
                            <ml:cn>2</ml:cn>
                        </ml:apply>
                    </ml:apply>
                </ml:apply>
            </ml:apply>
        </ml:lambda>
    </ml:declare>
</ml:math>
```

$$\boxed{R(T)} = \boxed{R_0}(\boxed{1} \boxed{+} \boxed{AT} \boxed{+} \boxed{BT^2})$$

- MathML is parsed into SymPy expressions
- Bound variables are detected (*T* in this case)
- Unbound variables are detected (*A* and *B* in this case)

Resolution of References

Formula Evaluation

```xml
<ml:math id="formula_02">
    <ml:declare type="fn">
        <ml:ci>R</ml:ci>
        <ml:lambda>
            <ml:bvar><ml:ci xref="T">T</ml:ci></ml:bvar>
            <ml:apply>
                <ml:times/>
                <ml:ci xref="R0">R0</ml:ci>
                <ml:apply>
                    <ml:plus/>
                    <ml:cn type="real">1</ml:cn>
                    <ml:apply>
                        <ml:times/>
                        <ml:ci xref="A">A</ml:ci>
                        <ml:ci>T</ml:ci>
                    </ml:apply>
                    <ml:apply>
                        <ml:times/>
                        <ml:ci xref="B">B</ml:ci>
                        <ml:apply>
                            <ml:power/>
                            <ml:ci>T</ml:ci>
                            <ml:cn>2</ml:cn>
                        </ml:apply>
                    </ml:apply>
                </ml:apply>
            </ml:apply>
        </ml:lambda>
    </ml:declare>
</ml:math>
```

$$R(T) = R_0(1 + AT + BT^2)$$

```xml
<dcc:quantity id="R0">
  <si:real>
    <si:label>R0</si:label>
    <si:value>100.0225</si:value>
    <si:unit>\ohm</si:unit>
    <si:expandedUnc>
      <si:uncertainty>0.005</si:uncertainty>
      <si:coverageFactor>2</si:coverageFactor>
      <si:coverageProbability>0.95</si:coverageProbability>
    </si:expandedUnc>
  </si:real>
</dcc:quantity>
```

- References to quantities in the DCC are detected (*T*, R_0, *A* and *B* using *xref* references in this example)
- Other ways to reference quantities are under active discussion
- dccQuantities is used to process quantities

Variable Substitution and Evaluation

Formula Evaluation

```
[jloewe@n251017] /tmp [ v3.13.12(.venv)]
❯ dcclib extract formulae valid_formula.xml -v T=100
Variable: T = 100

R0*(A*T + B*T**2 + 1)

Variables: T, R0, A, B
Bound variables: T

Variables from DCC XML:
T = 0.0, 25.0, 50.0, 75.0, 100.0
R0 = 100.0225
A = 0.0039155
B = -0.0000006469

Results:
138.5392643225
```

Variable *T* is explicitly set to 100

- Output of the formula and the detected variables
- Calculation of the formula with the user-defined input

- Currently the CLI does not support uncertainties, but it will in the near future
- Formula evaluation is under heavy development and not stable for production use yet

Current State
Summary

Basic functionality needed to work with DCCs consolidated into modules

Usable via a Python library, REST API and CLI

Architecture open for future extensions

Open-source software under the LGPLv3 license

Look into the Future
Summary

$f(x)$

Further development of production-ready easy to use formula evaluation

Support for new output formats in the CLI

Further information

Summary

Source code on GitLab
https://gitlab1.ptb.de/d-ptb/dcc/dcclib

Packages on PyPI
https://pypi.org/project/dcclib

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Day 2 2026-02-25 Wednesday
Parallel Session “DCC Management”
Session Chair: Shanna Schönhals

024 Srijith Bangaru Thirumalairaj: A Framework for a Hybrid Digital Calibration Certificate Architecture at CSIR-NPL India

Presenting author: Srijith Bangaru Thirumalairaj [1]
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[1] Electrical & Electronics Metrology, CSIR-National Physical Laboratory, Dr KS Krishnan Marg, Delhi, 110012, India
Keywords: Digital Calibration Certificate (DCC), Hybrid architecture, Metrological traceability, Measurement uncertainty, Digital Quality Infrastructure

Abstract

The global transition toward digitalization of the quality infrastructure has accelerated the need for machine-readable, interoperable, and legally reliable calibration data. Digital Calibration Certificates (DCCs) represent a key enabler in this transformation by replacing conventional PDF-based certificates with structured, standardized digital data capable of supporting automated validation, data exchange, and long-term traceability. This contribution presents a structured framework for the adoption of DCCs at a National Metrology Institute (NMI), with specific reference to the ongoing digital modernization efforts at CSIR-National Physical Laboratory (CSIR-NPL), India.

The proposed framework addresses the complete digital lifecycle of calibration data, starting from measurement result acquisition and uncertainty evaluation to the generation, validation, storage, and dissemination of DCCs. Emphasis is placed on aligning DCC content with existing metrological requirements, including SI traceability, measurement uncertainty reporting, and compliance with ISO/IEC 17025. The framework is designed to be compatible with emerging international initiatives such as the SI Digital Framework and the D-SI model promoted by leading NMIs.

A modular architecture is proposed, wherein measurement data are captured in structured formats and mapped to a DCC schema using machine-readable representations such as XML or JSON. Schema validation, digital signatures, and metadata enrichment are incorporated to ensure authenticity, integrity, and long-term usability of the certificates. The approach enables seamless integration with laboratory information management systems (LIMS), calibration management software, and national quality infrastructure platforms, facilitating automation and reducing manual intervention.

The abstract further discusses practical challenges relevant to NMIs in developing economies, including legacy data migration, interoperability with industrial stakeholders, legal acceptance of digital certificates, and capacity building. Strategies for phased implementation

and pilot studies are outlined, highlighting how DCC adoption can improve efficiency, transparency, and international comparability of calibration services.

This work aims to contribute to the broader discussion on transitioning from good practice to standardized digital calibration services. By sharing the CSIR-NPL perspective, the paper seeks to support harmonized DCC adoption across NMIs and calibration laboratories, strengthening global metrological traceability in an increasingly digital ecosystem.

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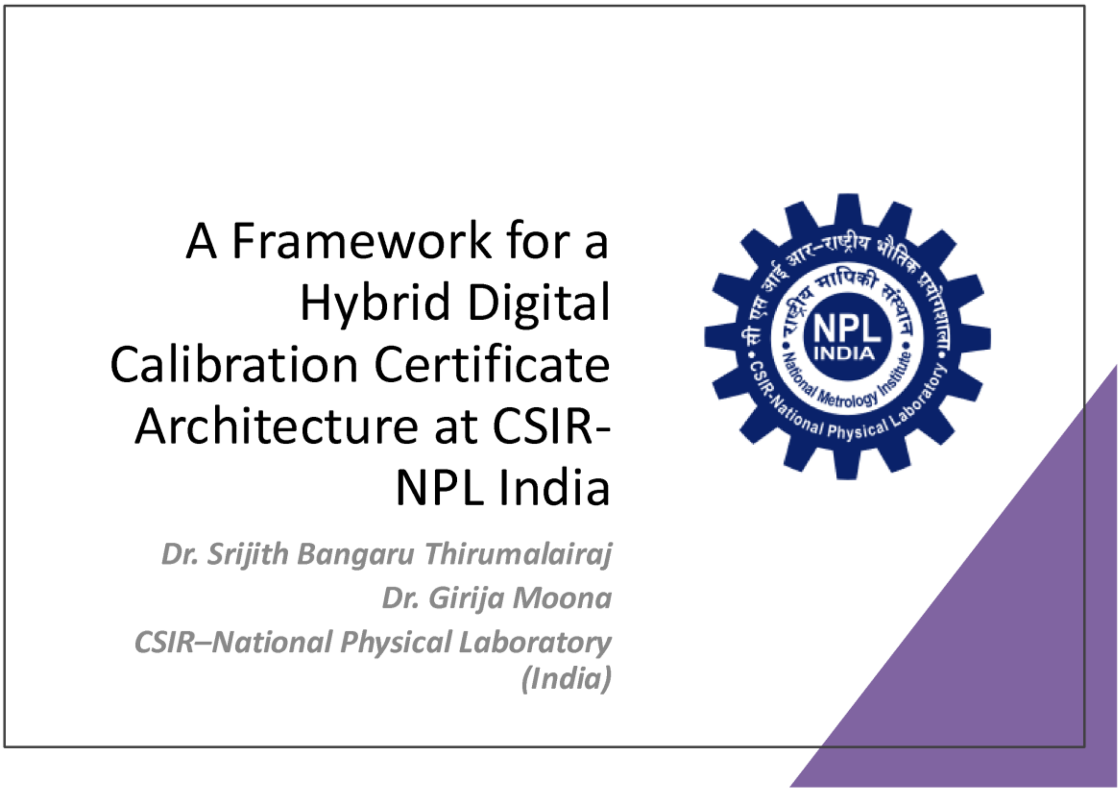
Presentation #024 of Srijith Bangaru Thirumalairaj



Global Digital Transformation in Metrology

- Metrology is undergoing structural digital evolution
  - Shift from PDF certificates to structured digital data
  - Demand for interoperability and automation
  - Automated traceability validation
  - Integration into Digital Quality Infrastructure (DQI)

Limitations of Conventional Calibration Certificates

- Traditional PDF certificates are human-readable but not machine-processable
  - Manual transcription errors
  - Limited automation capability
  - Traceability verification requires manual review
  - Limited integration with digital systems

Why DCC at the NMI Level?

- National Metrology Institutes must lead digital transition
  - Custodians of SI traceability
  - Responsibility for uncertainty integrity
  - International comparability requirements
  - Foundation for downstream calibration ecosystem

Institutional Objective at CSIR-NPL

- Develop a structured roadmap for DCC adoption
  - Preserve SI traceability and ISO/IEC 17025 compliance
  - Align with Digital SI initiatives
  - Enable interoperability with NMIs and industry
  - Adopt phased, risk-managed modernization

Hybrid Architecture Philosophy

- Coexistence of legacy and digital systems
  - Parallel PDF and DCC issuance
  - Gradual integration with LIMS
  - Minimizing disruption to accredited workflows
  - Scalable long-term transition model

Layered Institutional Architecture

- Three-Layer Model
  - Layer 1 – Measurement & Data Acquisition
  - Layer 2 – Digital Structuring & Processing
  - Layer 3 – Trust, Security & Dissemination

Layer 1 – Measurement & Data Acquisition

- Physical measurement infrastructure
  - Calibration benches and primary standards
  - Sensors and environmental monitoring
  - Data acquisition systems
  - Raw measurement data capture

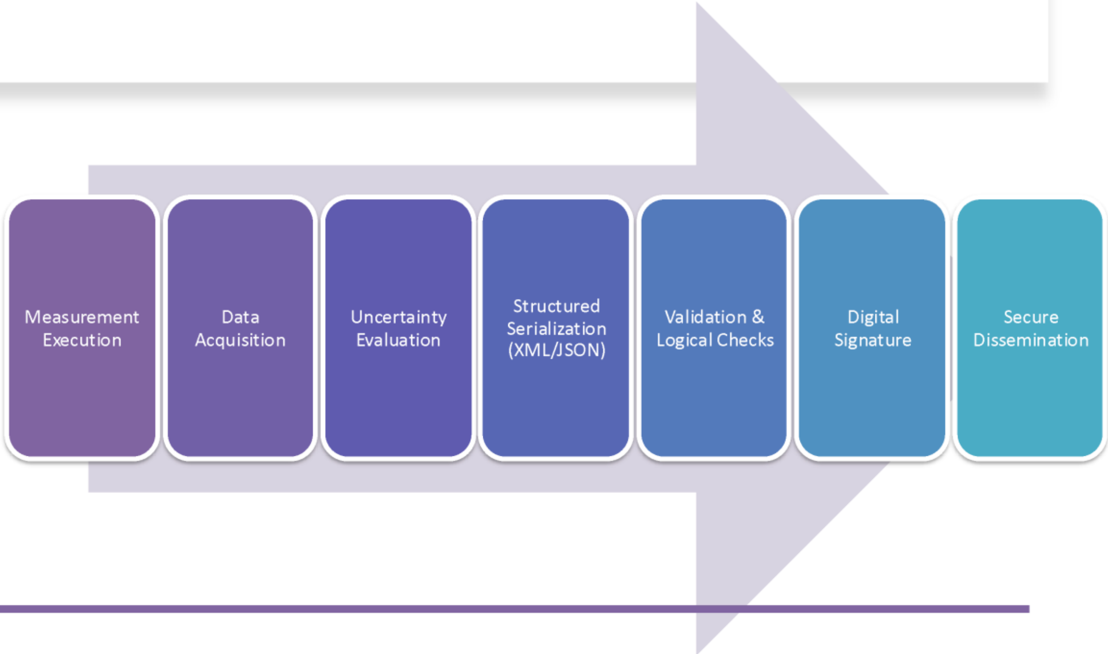
Layer 2 – Digital Structuring & Processing

- Core digital transformation layer
  - Standardized data formatting
  - Component-wise uncertainty evaluation
  - DCC schema mapping (XML / JSON)
  - Schema and logical validation mechanisms

Layer 3 – Trust, Security & Dissemination

- Ensuring authenticity and interoperability
  - PKI-based digital signature
  - Integrity hash and trusted time stamping
  - Secure repository management
  - Interoperability interfaces (NMI / Accreditation / Industry)

End-to-End Conceptual Workflow



Implementation Challenges

- Transition involves institutional considerations
  - Legacy data migration
  - LIMS interoperability constraints
  - Legal recognition of digital certificates
  - Capacity building and stakeholder readiness

Phased Institutional Roadmap

- Structured deployment strategy
  - Internal validation and stakeholder consultation
  - Prototype schema development
  - Pilot implementation in selected domains
  - Gradual scaling and harmonization

Strategic Impact for CSIR-NPL

- Long-term institutional benefits
  - Improved transparency and efficiency
  - Reduced manual handling risks
  - Enhanced international comparability
  - Strengthened role in global DCC harmonization

THANK YOU

QUESTIONS &
DISCUSSION

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025 Louis Wyss: A Robust Data Pipeline for Raw Measurement Processing and Uncertainty Propagation using METAS UncLib

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Additional authors:
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Institute:
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Keywords: UncLib, Traceability, Data Pipeline, Data Management

Abstract

The global transition toward a digital Quality Infrastructure (QI) depends not only on the standardization of Digital Calibration Certificates (DCC) but also on the reliability and automation of the data generation processes that feed them. As metrology institutes and laboratories move away from manual workflows, there is a critical need for software solutions that ensure machine-readable data is processed with rigorous metrological traceability. This work presents a comprehensive data pipeline designed to automate the lifecycle of measurement data—from raw acquisition to standardized storage—serving as a foundational engine for various digital products.

Our developed pipeline addresses the challenge of handling complex raw measurement data by establishing a streamlined, automated workflow. The system first ingests and parses raw measurement files, normalizing diverse input formats into a consistent internal structure. A defining feature of this architecture is the integration of METAS UncLib1, a Python library developed by the Federal Institute of Metrology (METAS) for automated uncertainty propagation. By utilizing multivariate uncertainty propagation objects rather than simple float values, the pipeline ensures that measurement uncertainties are calculated in strict accordance with the Guide to the Expression of Uncertainty in Measurement (GUM). Metrological traceability is integrated directly into the pipeline through METAS UncLib objects. These objects ensure that sensitivity coefficients and correlations are handled automatically.

Final processed results, including their associated uncertainty components, are persisted in a structured file storage system optimized for retrieval and interoperability. This architecture not only secures the integrity of the measurement data but also provides a data source that adheres to FAIR (Findable, Accessible, Interoperable, Reusable) principles. By decoupling data processing from certificate generation, our project demonstrates a scalable pathway for laboratories to modernize their operations, ensuring that the digital future of metrology is built upon accurate, transparent, and mathematically rigorous data.

References:

[1] M. Zeier, J. Hoffmann and M. Wollensack (2012): Metas. UncLib-a measurement uncertainty! calculator for advanced problems, in: Metrologia, Volume 49, Page 809

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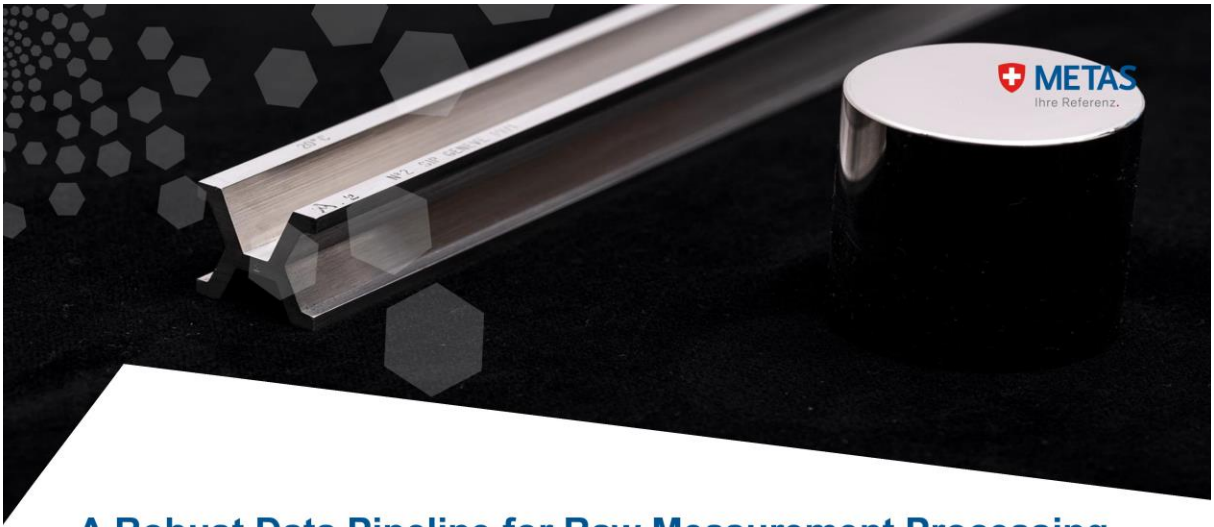
Presentation #025 of Louis Wyss



A Robust Data Pipeline for Raw Measurement Processing and Uncertainty Propagation using METAS UncLib

N. Mischler, L. Wyss, P. Blattner,

25.02.2026

Agenda

METAS

- Motivation
- Laboratory Data Management Framework
- METAS UncLib

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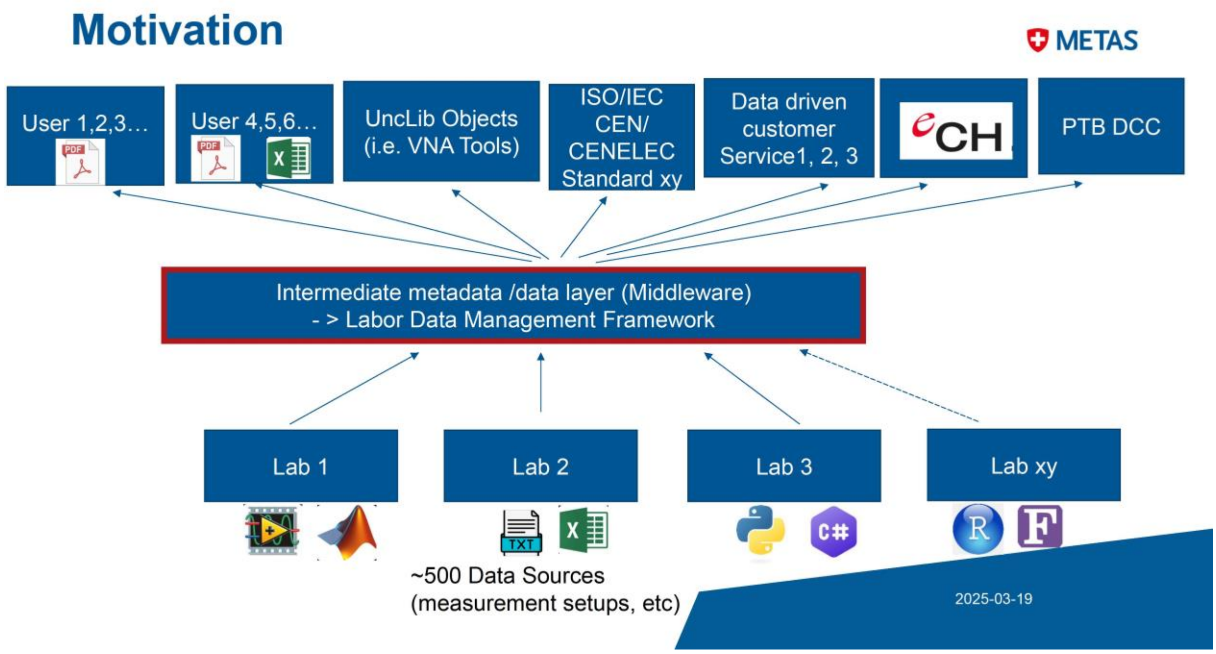
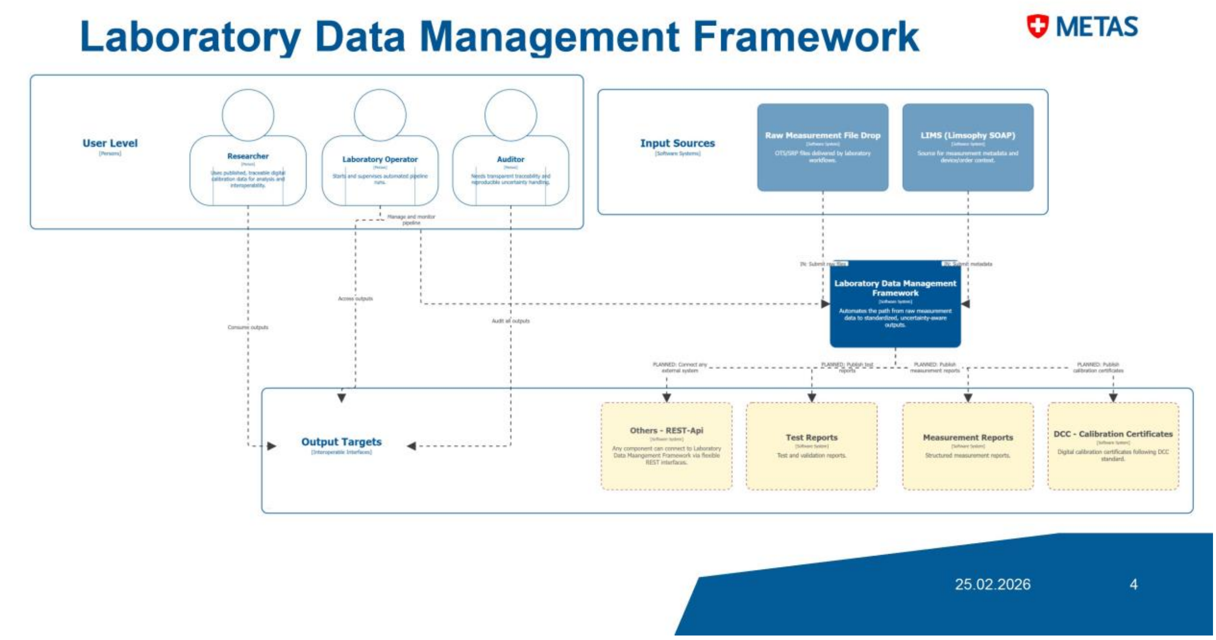

Motivation
METAS
User 1,2,3…
User 4,5,6…
UncLib Objects (i.e. VNA Tools)
ISO/IEC CEN/ CENELEC Standard xy
Data driven customer Service1, 2, 3
eCH
PTB DCC
Intermediate metadata /data layer (Middleware)
- > Labor Data Management Framework
Lab 1
Lab 2
Lab 3
Lab xy
~500 Data Sources (measurement setups, etc)
2025-03-19


Laboratory Data Management Framework
METAS
User Level
[Persons]
Researcher
Uses published, traceable digital calibration data for analysis and interoperability.
Laboratory Operator
Starts and supervises automated pipeline runs.
Auditor
Needs transparent traceability and reproducible uncertainty handling.
Input Sources
[Software Systems]
Raw Measurement File Drop
OTS/SRP files delivered by laboratory workflows.
LIMS (Limsophy SOAP)
Source for measurement metadata and device/order context.
Manage and monitor pipeline
Access outputs
Consume outputs
Audit all outputs
IN: Submit metadata
Laboratory Data Management Framework
Automates the path from raw measurement data to standardized, uncertainty-aware outputs.
PLANNED: Connect any external system
PLANNED: Publish test reports
PLANNED: Publish measurement reports
PLANNED: Publish calibration certificates
Output Targets
[Interoperable Interfaces]
Others - REST-Api
Any component can connect to Laboratory Data Maangement Framework via flexible REST interfaces.
Test Reports
Test and validation reports.
Measurement Reports
Structured measurement reports.
DCC - Calibration Certificates
Digital calibration certificates following DCC standard.
25.02.2026
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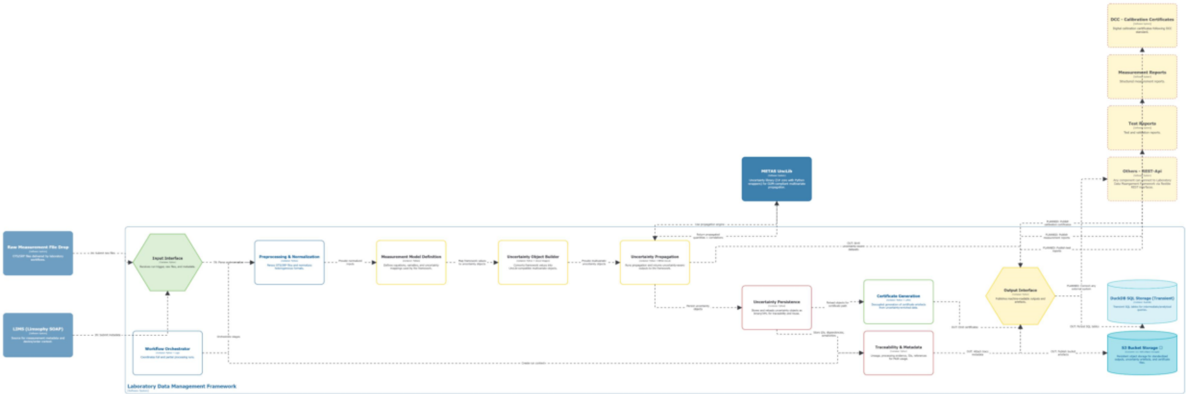
Laboratory Data Management Framework

Architecture Backbone: Decoupled, Traceable, Scalable

METAS



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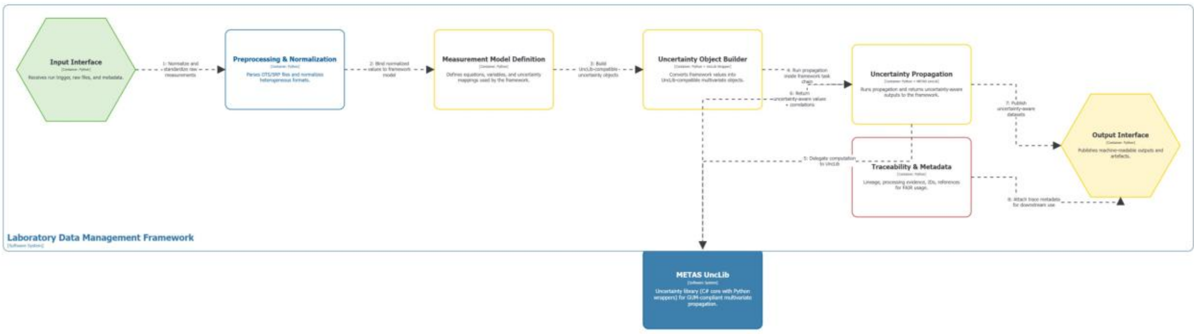
Laboratory Data Management Framework

UncLib Integrated into the Production Pipeline

METAS



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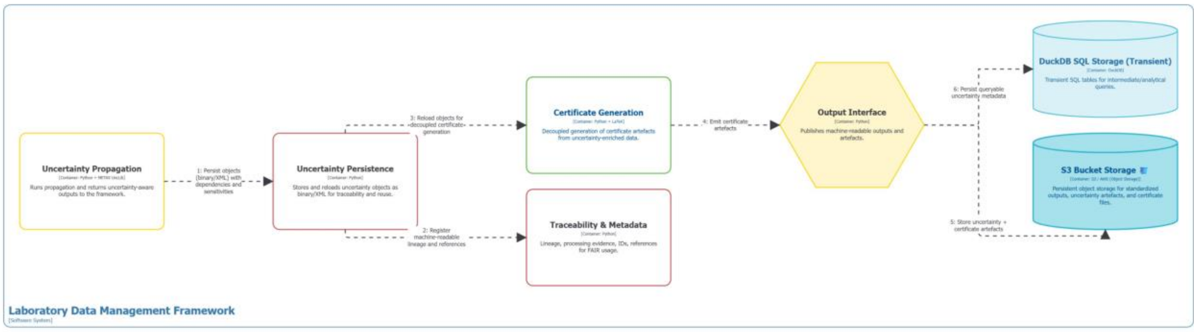
Laboratory Data Management Framework

Persist, Trace, Reuse: Operationalizing Metrological Traceability

METAS



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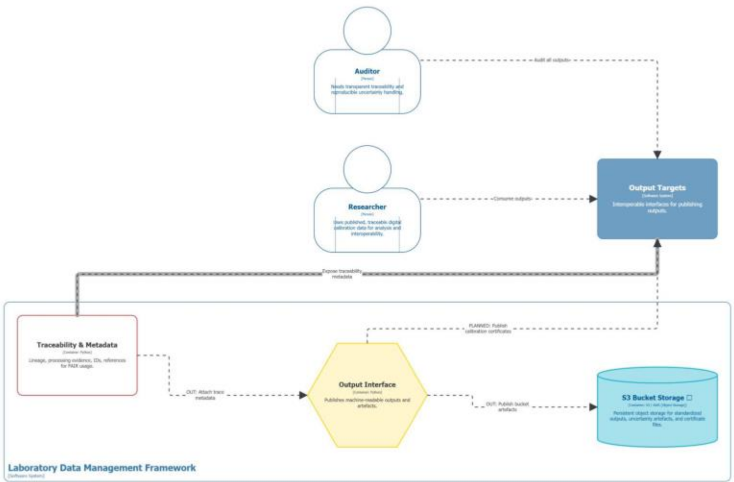
Laboratory Data Management Framework

FAIR, Traceable, and Ready for DCC Interoperability

METAS



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Metrological Traceability through UncLib[1]

METAS

- METAS UncLib is a C# software library
  - Provides Wrapper for Python and Matlab, freely available (https://www.metas.ch/unclib)
- Handles complex-valued and multivariate quantities
- Uses objected-oriented programming and overloads operators
  - Integrated with numpy in Python
- Offers three different propagation modes
  - LinProp: Linear uncertainty propagation
  - DistProp: Higher order uncertainty propagation
  - MCProp: Monte Carlo Propagation

[1] M. Zeier et al. (2012), Metas.UncLib - A measurement uncertainty calculator for advanced problems

Implementation of METAS UncLib

Define measurement model and uncertainties

METAS

$$X_{O_3} = -\frac{ln(D)}{\alpha_x \cdot L} \cdot \frac{T}{T_S} \cdot \frac{P_S}{P}$$

Component	Source	Distribution	Standard Uncertainty
Optical Pathlength, L	Measurement scale	Rectangular	0.0006 cm
	Variability	Normal	0.004 cm
	Divergence	Rectangular	0.115 cm
Pressure, P	Sensor calibration	Normal	0.015 kPa
	Cell Difference	Rectangular	0.018 kPa
Temperature, T	Sensor calibration	Normal	0.05 K
	Gradient over cells	Rectangular	0.115 K
Scaler, S	Resolution	Rectangular	0.5
Transmittance, D	Repeatability	Normal	$1.0 \cdot 10^{-5}$
Absorption coefficient, α_x	Conventional value	Normal	0.943609

Implementation of METAS UncLib

Define uncertainty objects in Python

METAS

- An uncertainty object has a *distribution* with *value and uncertainty*,
  description and an *ID*
  - unc_object = ufloatfromdistribution(*distribution(value, uncertainty), description, id*)
- *Distribution* defines how the uncertainty object is distributed (normal, rectangular, trapez etc.)
- Each input parameter has an unique *ID* which allows traceability
- *description* is a human readable string

```python
UNC_ALPHA = ufloatfromdistribution(
    distribution=NormalDistribution(ALPHA_VALUE, ALPHA_UNCERTAINTY),
    id=str(uuid.uuid4()),
    desc="Absorption coefficient [cm^-1]"
)

u_l1_geo= ufloatfromdistribution(
    distribution=NormalDistribution(L1_VALUE, L1_UNCERTAINTY),
    id=str(uuid.uuid4()),
    desc="Cell 1 geometrical length [cm]"
)

u_l2_geo = ufloatfromdistribution(
    distribution=NormalDistribution(L2_VALUE, L2_UNCERTAINTY),
    id=str(uuid.uuid4()),
    desc="Cell 2 geometrical length [cm]"
)

u_cal = ufloatfromdistribution(
    distribution=NormalDistribution(L_CALIBRATION_VALUE, L_CALIBRATION_UNCERTAINTY),
    id=str(uuid.uuid4()),
    desc="Length calibration factor"
)

u_div1 = ufloatfromdistribution(
    distribution=UniformDistribution(L_DIVERGENCE_MIN, L_DIVERGENCE_MAX),
    id=str(uuid.uuid4()),
    desc="Beam divergence Cell 1 [cm]"
)

u_div2 = ufloatfromdistribution(
    distribution=UniformDistribution(L_DIVERGENCE_MIN, L_DIVERGENCE_MAX),
    id=str(uuid.uuid4()),
    desc="Beam divergence Cell 2 [cm]"
)

UNC_OPTICAL_LENGTH = (u_l1_geo * u_cal + u_div1) + (u_l2_geo * u_cal + u_div2)
K = (1 / (UNC_ALPHA * UNC_OPTICAL_LENGTH)) * (P_S / T_S)
```


Implementation of METAS UncLib

Calculate uncertainty

METAS

- Beacuse UncLib overloads the operates and is compatible with numpy, calculations can be done simply as

```python
UNC_OPTICAL_LENGTH = (u_l1_geo * u_cal + u_div1) + (u_l2_geo * u_cal + u_div2)
K = (1 / (UNC_ALPHA * UNC_OPTICAL_LENGTH)) * (P_S / T_S)

print(f"Alpha: {UNC_ALPHA},\nOptical Length: {UNC_OPTICAL_LENGTH},\nK-Factor: {K}")
```

- And the output is

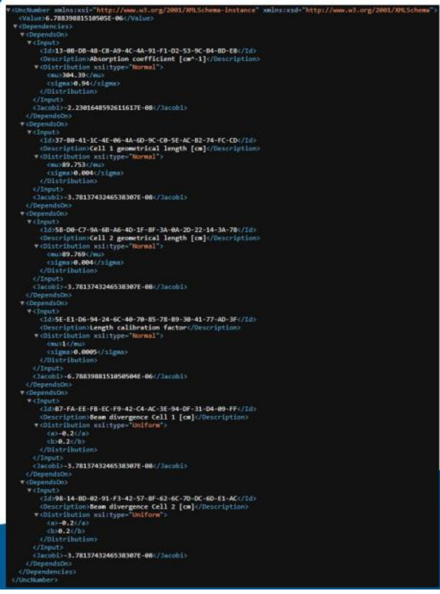
```
Alpha: 304.39 ± 0.94,
Optical Length: 179.522 ± 0.32870110767585037,
K-Factor: 6.78839881510505e-06 ± 3.339296896756227e-08
```

Implementation of METAS UncLib

Save uncertainty objects

METAS

- METAS UncLib offers two different methods to save uncertainty objects
  - Save as binary
  - Save as XML-File
- Stores all dependencies and sensitivties
  - Allows traceability
  - Correlations are seemlessly propagated through complex systems
- Can be loaded and used for further calculations
  - Can be part of a certificate -> added value for costumers!
  - Already implemented for VNA Tools since many years



Conclusion

METAS

- The new Laboratory Data Management Framework allows high degree of automation, respecting the FAIR principles.
- It allows high flexibility in respect to the output (including PTB DCC, PDF/A3, APIs,…)
- METAS UncLib is a software library that allows metrological traceability offering machine-readable objects pass to the customer

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Thank you

Nicolas Mischler
Louis Wyss
Peter Blattner

Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
Confederaziun svizra

Eidgenössisches Institut für Metrologie METAS

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026 Gean Marcos Geronymo: An End-to-End Framework for Electrical Metrology Digitalization: API-based DCC Integration, XSLT Visualization, and Workflow Automation

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Keywords: Digital Transformation, Digital Calibration Certificate, Automation, Database, Metrology 4.0

Abstract

Digital transformation in metrology is evolving from simple document dematerialization toward the creation of truly machine-readable Digital Calibration Certificates (DCCs). This paper presents recent advancements at the National Institute of Metrology, Quality and Technology (Inmetro) in implementing a robust ecosystem for the generation, visualization, and processing of DCCs within electrical metrology laboratories.

The methodology focuses on the development of a Python-based Application Programming Interface (API) that streamlines the creation of DCCs in XML format, in full compliance with the schema proposed by PTB. One of the primary challenges addressed is the inherent complexity of the XML schema for laboratories accustomed to analog processes. To bridge this gap, a simplified JSON structure was developed to map directly to the data fields of conventional certificates. This allows for data input via both JSON and Excel spreadsheets, making the process accessible to laboratory staff with basic IT skills while maintaining technical rigor.

A key contribution of this framework is the development of a custom DCC viewer using Extensible Stylesheet Language Transformations (XSLT). This tool addresses the need for human readability by rendering the complex XML data into a visual format that closely mirrors the official calibration certificate templates used by Inmetro. This ensures that, while the data is machine-optimized, it remains intuitive and verifiable for human end-users and quality managers, facilitating the transition from paper-based systems.

Furthermore, the study details the practical implementation of embedding the DCC XML within a PDF/A-3 file, providing a hybrid solution that combines familiar digital signatures with machine-readability. The effectiveness of the framework was validated through a pilot project involving Inmetro's LAMPE and LACEL laboratories. By utilizing tools such as NI Lab VIEW to extract data from DCCs and automatically update reference databases, a fully automated calibration workflow was demonstrated. The results indicate that the use of DCCs eliminates manual transcription errors and significantly reduces processing time for certificates with extensive data points.

The study concludes that the combination of modular APIs and standardized visualization tools is essential for global interoperability. This framework serves as a scalable model for

National Metrology Institutes transitioning into the Metrology 4.0 era, ensuring that digital certificates are both technologically advanced and practically accessible.

References:
[1] Geronymo, G.; Ventura, R. (2025): Recent advances in Inmetro's Digital Calibration Certificates (DCCs) implementation. XVI Congresso Intemcional de Metrologia Eletrica (Semetro).
[2] Geronymo, G. (2023): Enhancing Digital Calibration Certificate (DCC) Workflow: Python-based DCC Tools Development and Implementation. XV Congresso Intemacional de Metrologia Eletrica (Semetro).

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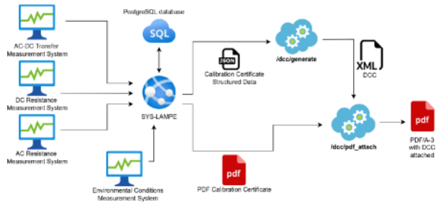
Presentation #026 of Gean Marcos Geronymo

Scope of this contribution (for a DCC-specialized audience)



This presentation focuses on implementation details and practical results, assuming prior familiarity with DCC concepts. **What is new since our previous report:**

- Consolidated Flask-based service architecture (Docker deployment)
- Expanded data model for multiple quantities and multi-index tables
- XSLT-based DCC visualization workflow integrated in the web app
- PDF/A-3 attachment pipeline with SHA256 integrity artifact
- Pilot-grade end-to-end integration in Inmetro laboratories (LAMPE and LACEL)

Technical contributions in this version

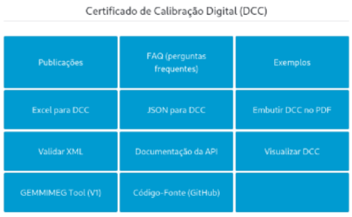
Main objective

Deliver an **operational end-to-end framework** for generation, visualization, validation, delivery, and downstream use of DCCs.

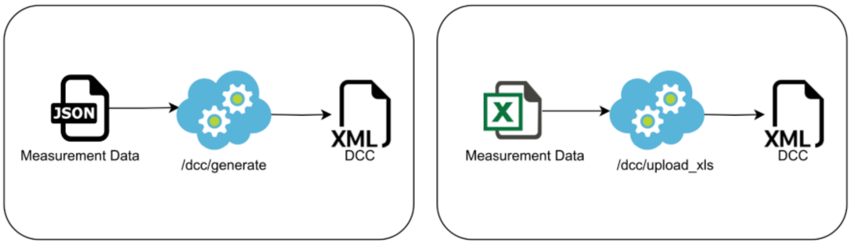
- Route `/dcc/generate`: JSON to DCC XML (schemaVersion `3.2.0`)
- Route `/dcc/upload_xls`: Excel workbook to JSON to DCC XML
- Route `/dcc/visualizar_dcc`: XML to HTML via XSLT template
- Route `/dcc/pdf_attach`: XML embedding in PDF/A-3 plus `SHA256SUM.txt`
- Route `/dcc/validate_xml`: XML schema validation with automatic XSD import/include loading

Implementation architecture and deployed stack

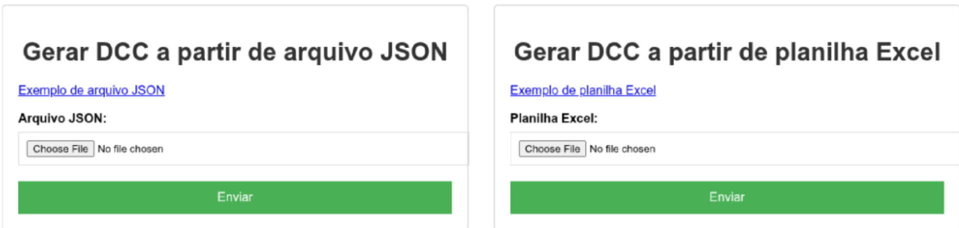
- Open-source implementation: `https://github.com/gmgeronymo/dcc_tools`
- Current production-oriented stack: Python Flask microservice
- Deployment model: Docker Compose (default service on port 9099)
- Core libraries: `lxml`, `pandas/openpyxl`, `pikepdf`
- Data input routes:
  - JSON for system-to-system automation
  - Excel for operator-assisted laboratory workflows
- Output: PTB DCC XML + optional visualization/validation/attachment services



Implemented API workflow and endpoints



`/dcc/generate`, `/dcc/upload_xls`, `/dcc/pdf_attach`, `/dcc/visualizar_dcc`, `/dcc/validate_xml`



Simplified JSON model: implementation decisions

- Administrative blocks mirror Inmetro certificate metadata fields
- `mensurando` supports multiple quantities with independent units and labels
- `indices` supports variable-dimensional indexing per quantity (range, voltage, frequency, ...)
- `resultados` stores value/uncertainty/coverage factor with quantity linkage
- Relative uncertainty mode (ppm) is converted to absolute uncertainty in generation stage

Input JSON example used by the API


```
{
  "mensurando": [
    {"label":"acdc","name":"AC-DC transfer difference",
     "col_name":"delta_u","unit":"\\micro\\volt\\volt\\tothe{-1}",
     "unc_relativa":false}
  ],
  "indices": [
    {"mensurando":"acdc","label":"range","unit":"\\volt"},
    {"mensurando":"acdc","label":"frequency","unit":"\\kilo\\hertz"}
  ],
  "resultados": [
    {"mensurando":"acdc","range":"0.022","frequency":"0.01",
     "value":"-280","unc":"44","k":"2.13"}
  ]
}
```


This structure is shared by `/dcc/generate` and `/dcc/upload_xls`.

Corresponding generated DCC XML (excerpt)

```
<dcc:result>
  <dcc:name><dcc:content lang="pt">AC-DC transfer difference</dcc:content></dcc:name>
  <dcc:data>
    <dcc:list>
      <dcc:quantity>...<si:valueXMLList>0.022</si:valueXMLList>
                       <si:unitXMLList>\volt</si:unitXMLList></dcc:quantity>
      <dcc:quantity>...<si:valueXMLList>-280</si:valueXMLList>
                       <si:unitXMLList>\micro\volt\volt\tothe{-1}</si:unitXMLList>
                       <si:uncertaintyXMLList>44</si:uncertaintyXMLList>
                       <si:coverageFactorXMLList>2.13</si:coverageFactorXMLList>
      </dcc:quantity>
    </dcc:list>
  </dcc:data>
</dcc:result>
```

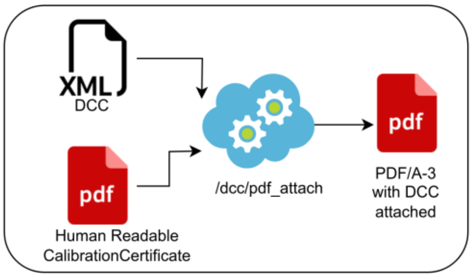
Generated by `/dcc/generate` from the previous JSON structure.

XSLT visualization pipeline (new module)

- Implemented at route `/dcc/visualizar_dcc`
- Transformation engine uses `lxml.etree.XSLT`
- Current template path: `static/examples/xslt/hr_template.xsl`
- Output is HTML rendered from the same DCC XML payload
- Improves verification without duplicating certificate data sources

XSLT rendering examples

PDF/A-3 attachment module: implementation details

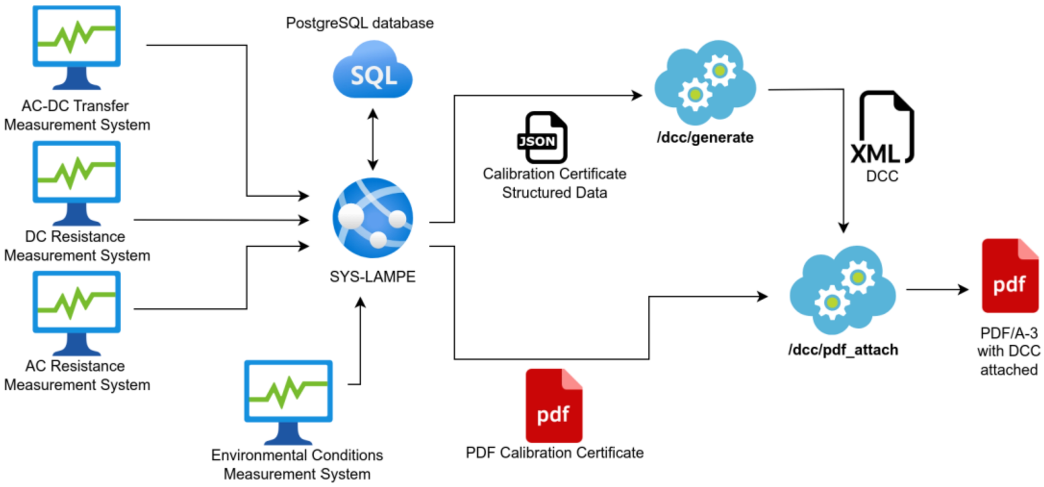


- Implemented at route `/dcc/pdf_attach`
- XML attached as EmbeddedFile with `AFRelationship=Alternative`
- Names tree updated for attachment navigation in common PDF readers
- Additional attached file: `SHA256SUM.txt` for integrity verification

Attachment accessibility in standard PDF readers

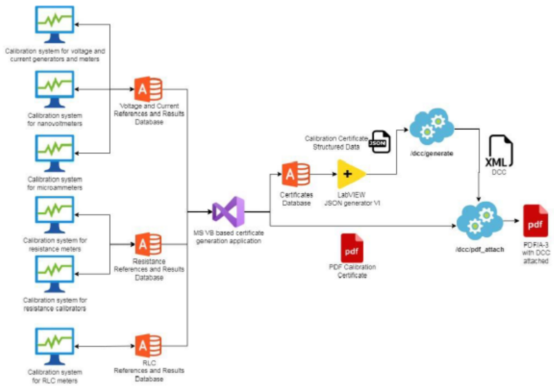
Operational behavior verified in common readers while preserving machine extraction of XML

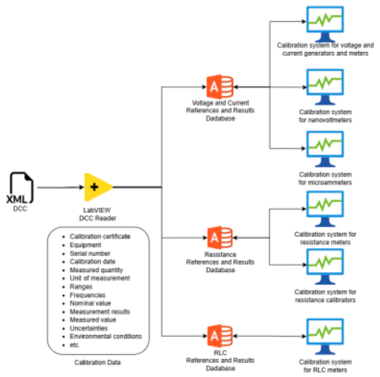
Pilot deployment: LAMPE and LACEL laboratories



SYS-LAMPE / LACEL databases → JSON → API → DCC XML → PDF/A-3 with attachment

Automated DCC processing in LabVIEW





DCC Reader VI extracts calibration data and updates reference databases automatically.

Observed impact and open technical points

Operational gains in the pilot

- Elimination of manual data transcription from certificates
- Reduced risk of transcription errors in high-point calibrations
- Faster update cycle for reference data in automation systems
- Stable interoperability between generation and LabVIEW processing workflow

Open points under active development

- Harmonized refType strategy and ontology/PID alignment
- Progressive adoption of multilingual fields and richer semantic tagging
- Expansion of validated integrations across additional laboratory stacks

Thank you

Thank you for your attention

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R V F Ventura – rvventura@inmetro.gov.br

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Day 3 2026-02-26 Thursday
Plenary Session
Session Chair: Hector Laiz

P06 Sami Koskinen: Live demonstration: how DCC is created by the vendor and utilized by the end user

Presenting author: Sami Koskinen [1]
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Keywords: Automation, DCC creation, DCC delivery, DCC import

Abstract

Digital Calibration Certificates (DCC) are reshaping the calibration landscape by enabling secure, structured, and machine-readable data exchange across the entire calibration chain. While the concept of DCC is rapidly gaining traction, industry stakeholders still ask a practical question: How can the DCC actually be used in practice? This presentation answers that question through a live end-to-end demonstration.

The first part of the demonstration shows an example how a calibration service provider or an instrument manufacturer can generate a DCC using modem calibration tools and software infrastructure. The demonstration walks through the process from the initial calibration execution at a production facility, through guided calibration execution, to the automatic creation of a DCC. The audience will see how structured, validated data flows seamlessly from reference standards and process instruments into the digital certificate.

The second part of the demonstration focuses on the end user's perspective. Participants will observe how a DCC is imported, interpreted, and utilized in the end user's on-premises calibration management system. This includes how end users can access key metadata, verify traceability, assess measurement results, and store calibration results securely as a part of the asset lifecycle management. The session highlights how structured digital data dramatically improves searchability, compliance management, and integration with broader digital ecosystems.

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Presentation #P06 of Sami Koskinen

Mr. Sami Koskinen presented a live demonstration.

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P07 Anjali Sharma: Assessing Feasibility of KCDB API–Driven Service Classification for NMI Service Catalogues: A Use Case from NPL India for Digital Calibration Requests

Presenting author: Anjali Sharma [1]
Email: anjali.nplindia@csir.res.in
Additional authors: Nil
Institute:
[1] Digital Transformation Working Group, CSIR-National Physical Laboratory, Dr K S Krishnan Marg, New Delhi, 110060, India.
Keywords: KCDB API, service classification, NMI service catalogue, Digital Calibration Request, Calibration Workflow Automation

Abstract

The digital transformation of calibration services requires not just the digitalization of certificates and workflows, but also a well-structured and interoperable representation of the calibration services themselves. In practice, service catalogues at National Metrology Institutes (NMIs) are frequently maintained as local lists with descriptions intended for customers to read [1], This may lead to inconsistencies in how services are understood, limited interoperability, and a significant reliance on human evaluation of customer requests [2],

This talk presents a service classification method evaluated as a practical use case to determine whether internationally defined services in the BIPM KCDB API [3] can serve as a basis for developing or aligning NMI-level service catalogues. Using NPL India as a case study, service definitions were extracted from the KCDB API and converted into service categories [4], which were then mapped to NPL India's specific calibration services, enabling a customer-facing Digital Calibration Request workflow.

The key contribution of this research is the development and assessment of KCDB API service descriptions [3] as reusable digital components for NMI service catalogues. The implementation revealed challenges in mapping, such as discrepancies in the level of detail between KCDB capability descriptors and customer-oriented service definitions, the management of laboratory specific constraints (e.g., ranges and turnaround times), semantic ambiguities in service naming, and the need for additional metadata to automate feasibility assessments.

This work is on-going; the mapping results are being refined and will undergo validation by domain experts and metrologists at NPL India before operational adoption. Our findings offer preliminary evidence that KCDB API-driven service classification can facilitate scalable harmonization and automation at the NMI level, while also identifying critical gaps for enabling a reliable end-to-end process.

References:

[1] Webpage (2026): Calibration & Testing - CSIR-NPL (Centre for Calibration & Testing - CFCT), https://www.nplindia.org/index.php/commercial-services/calibration-testing/, last accessed: 29.01.2026

[2] Webpage (n.d.): CSIR-NPL Centre for Calibration & Testing (CFCT) 'Calibration & Testing – NPL'. Accessed: Apr. 29, 2026. [Online]. Available: https://www.nplindia.in/index.php/commercial-services/calibration-testing/

Presentation #P07 of Anjali Sharma

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Assessing Feasibility of KCDB API–Driven Service Classification for NMI Service Catalogues: A Use Case from NPL India for Digital Calibration Requests

Dr. Anjali Sharma

Sr Principal Scientist & Assoc. Prof. AcSIR
Anjali.nplindia@csir.res.in

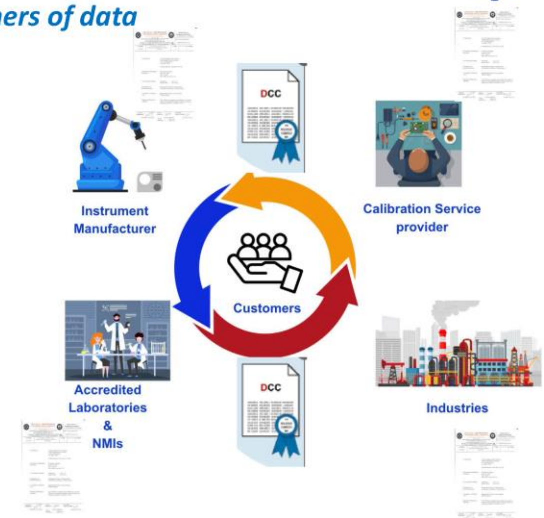
Introduction

Transactional viewpoint: producers and consumers of data

A **producer** will not know the requirements of (possibly many) consumers of data.

Consumers may need data for different purposes.

•Calibration ensures **measurement reliability and traceability**.



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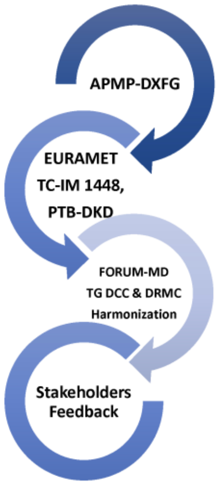
Why?

- 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



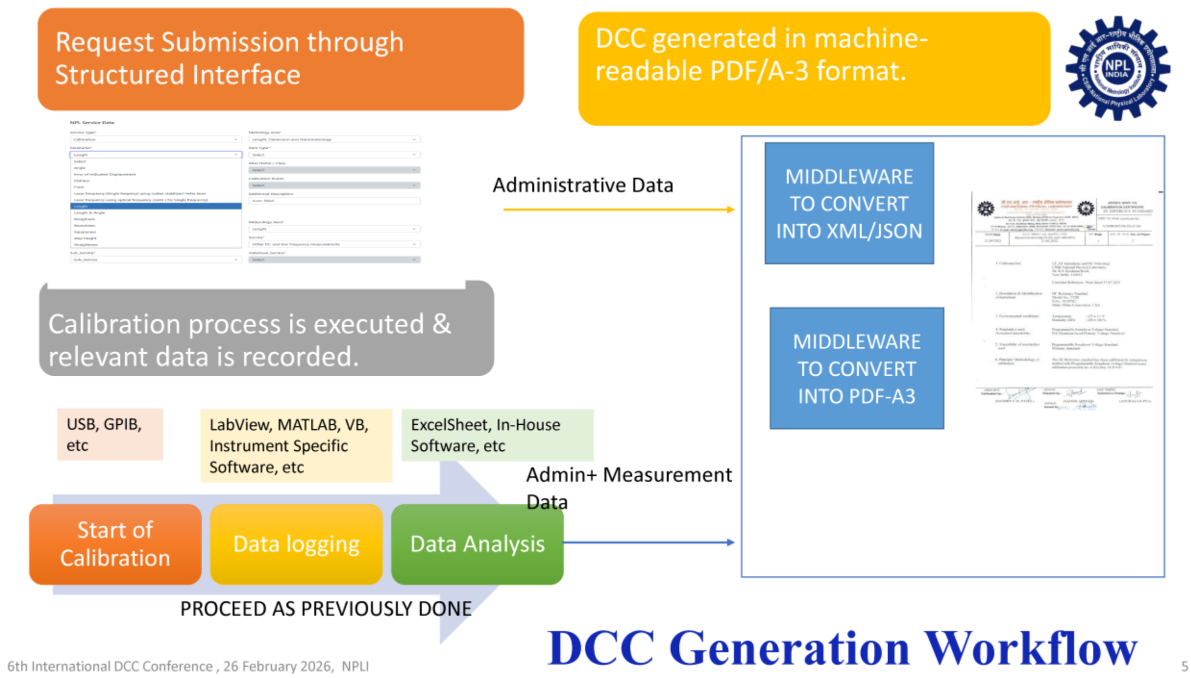
What?

- A unified, **machine-readable and interoperable format** for calibration certificates.
- Traceable measurement data
- Semantics & data
- Modelling

NMIs can Push but Pull from stakeholders is critical for DCC to be a success

How?

- How this PUSH-PULL may be achieved?
  - Showcase direct benefits
  - 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
- Support **interoperability and digital transformation** in metrology. Use BIPM SIDF and explore its feasability


Request Submission through Structured Interface
DCC generated in machine-readable PDF/A-3 format.
Administrative Data
MIDDLEWARE TO CONVERT INTO XML/JSON
MIDDLEWARE TO CONVERT INTO PDF-A3
Calibration process is executed & relevant data is recorded.
USB, GPIB, etc
LabView, MATLAB, VB, Instrument Specific Software, etc
ExcelSheet, In-House Software, etc
Admin+ Measurement Data
Start of Calibration
Data logging
Data Analysis
PROCEED AS PREVIOUSLY DONE
DCC Generation Workflow
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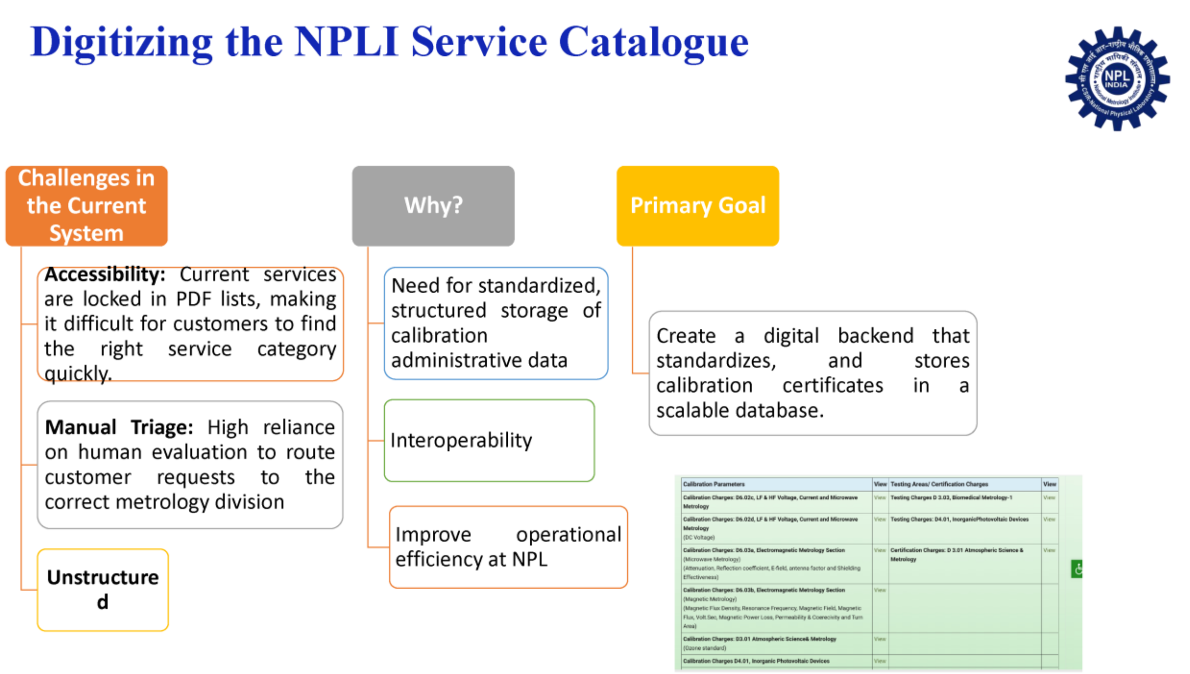
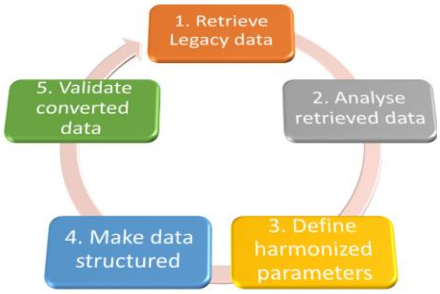
5


Digitizing the NPLI Service Catalogue
Challenges in the Current System
Accessibility: Current services are locked in PDF lists, making it difficult for customers to find the right service category quickly.
Manual Triage: High reliance on human evaluation to route customer requests to the correct metrology division
Unstructured
Why?
Need for standardized, structured storage of calibration administrative data
Interoperability
Improve operational efficiency at NPL
Primary Goal
Create a digital backend that standardizes, and stores calibration certificates in a scalable database.

Challenges to Address

- Legacy systems: No structured information
  NMI service catalogues are operational and customer-facing
- Resources may be limited so incremental adoption is often required
- KCDB provides internationally structured service taxonomy

Can we utilize the BIPM KCDB Service category APIs for automation and interoperability of identification of measurand through these metadata information?



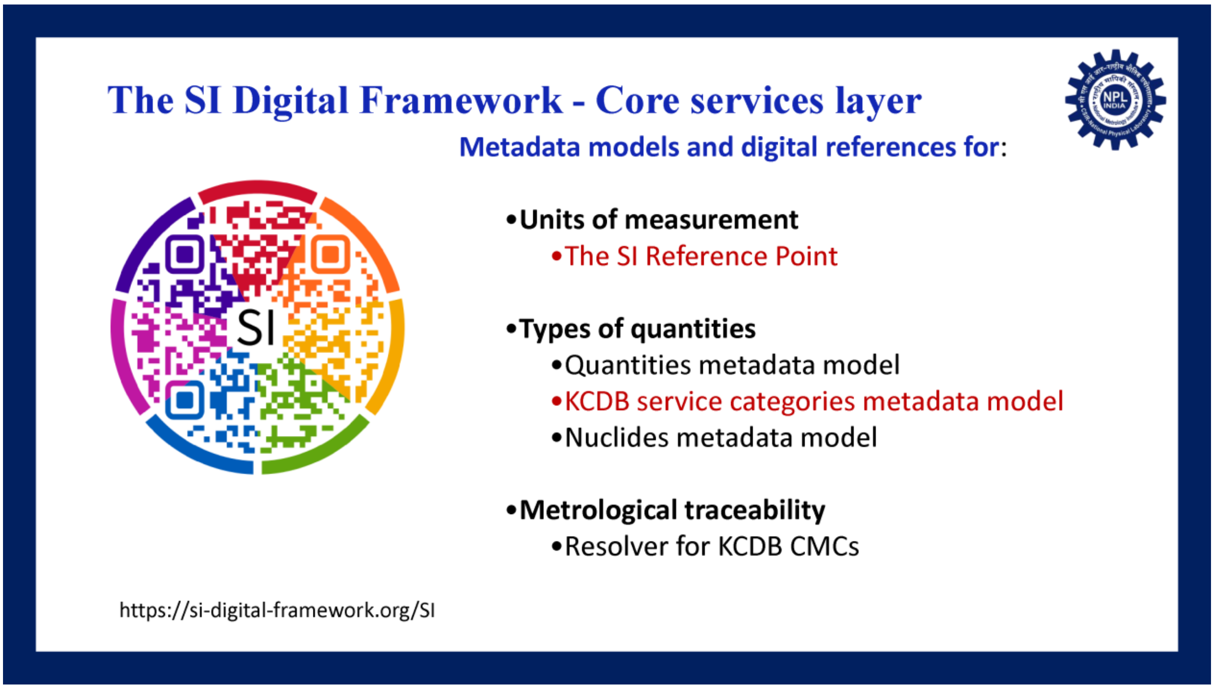
System Architecture Overview

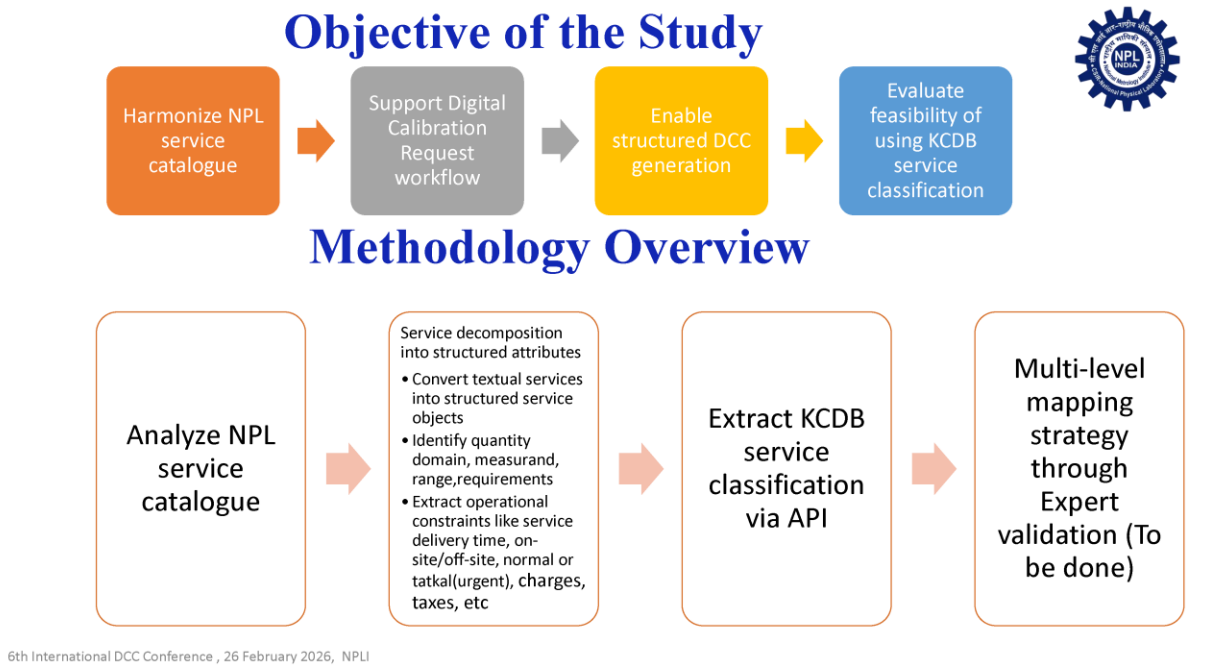
MODEL-VIEW-CONTROLLER (MVC) APPROACH

- **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
- **Flask** v3.0.3
- **PostgreSQL** v16.3
- **Python** v3.11.7
- **Pandas** v2.1.4
- **Miktex** v24.4 (Windows)


The SI Digital Framework - Core services layer
Metadata models and digital references for:
SI
•Units of measurement
•The SI Reference Point
•Types of quantities
•Quantities metadata model
•KCDB service categories metadata model
•Nuclides metadata model
•Metrological traceability
•Resolver for KCDB CMCs
https://si-digital-framework.org/SI


Objective of the Study
Harmonize NPL service catalogue
Support Digital Calibration Request workflow
Enable structured DCC generation
Evaluate feasibility of using KCDB service classification
Methodology Overview
Analyze NPL service catalogue
Service decomposition into structured attributes
• Convert textual services into structured service objects
• Identify quantity domain, measurand, range,requirements
• Extract operational constraints like service delivery time, on-site/off-site, normal or tatkal(urgent), charges, taxes, etc
Extract KCDB service classification via API
Multi-level mapping strategy through Expert validation (To be done)
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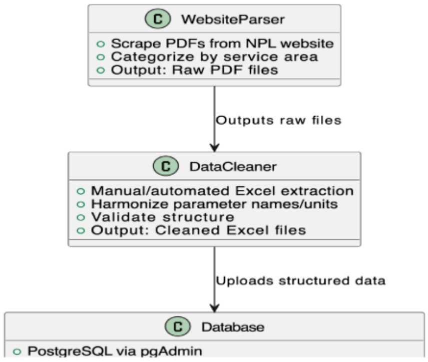
Digitizing the NPLI Service Catalogue

CALIBRATION	TESTING
Acoustics	Chemicals
Force	DC Metrology
Length	Energy materials
Mass	Fluid flow
Optical radiation	Gas Metrology
Pressure	In House BND
Temperature	Magnetic Metrology
AC high voltage	Microwave Metrology
AC power	Outreach
Atmospheric science	Photovoltaic Devices
Capacitance	Pressure
DC current	Quantum Hall
DC high voltage	Time and Frequency
Defibrillator	
Fluid flow	

- **Created a harmonised digital eService catalogue for NPL Calibration & Testing services using 45 Pdf files from NPL India website (Calibration Charges: 26 PDFs+ Testing Charge: 19 PDFs)**

Methodology Followed



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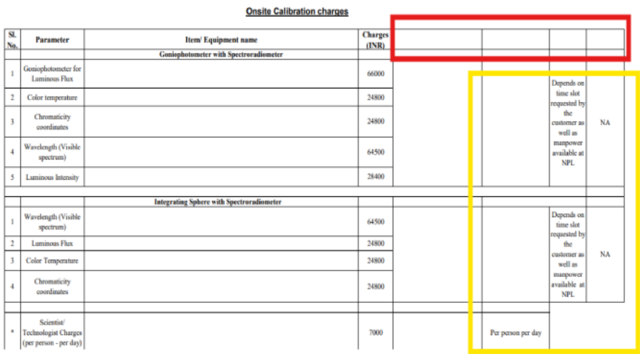
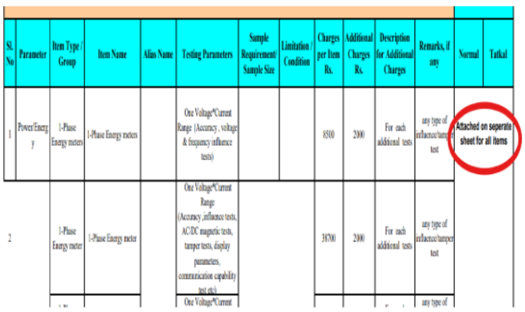
Challenges faced in digitizing the NPLI Service Catalogue

- Inconsistent & different PDF format (different terminologies, merged cells, line breaks, referencing separate sheets, missing or unclear column names, etc).
- Identified common data fields. Standardized column names and data types. Cleaned multi-line text and handled missing values.





HARMONIZATION OF PARAMETERS

UNIFIED LIST OF PARAMETERS FOR CALIBRATION

1 Parameter
2 Item Type / Group
3 Item Name
4 Alias Name
5 Range
6 No. of Points for Calibration / Procedure No.
7 Calibration Parameters (for metrology-specific cases)
8 Limitation / Condition
9 Sample Requirements (if any)
10 Charges per Item Rs.
11 Additional Charges Rs.
12 Description for Additional Charges
13 Remarks, if any
14 EDC (Normal, Tatkal) (where applicable)
15 Revised Charges as per CSIR Guidelines (where applicable)

The harmonized parameters list has been shared with CFCT department

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SYSTEM ARCHITECTURE

1. Website Parser

Technology Used: Python (requests, BeautifulSoup)

Purpose: Automates scraping and downloading of calibration/test files (typically PDFs) from nplindia.org.

Output: Raw PDF files stored in a structured local folder hierarchy, categorized by service area.

2. Data Cleaner / Preprocessor

Technology Used: Python (pandas, openpyxl), manual transformation via Excel
Purpose:
- Extracts tabular data from PDFs (converted to Excel).
- Standardizes units, headers, and parameter names for consistency.
- Resolves formatting issues and harmonizes missing/inconsistent values.

Output: Cleaned .xlsx files with a harmonized schema, ready for database insertion.

3. Database Layer (PostgreSQL via pgAdmin)

Schema Design:
- Tables: service, service_tarrifs, department_service mapping, Parameters,ranges, type of service, registration/admin_details, client_instrument_details, digital_calibration_request

Key Features:
- Foreign key relationships
- Timestamped entries for robust auditing
- ISO/IEC 17025-compliant schema design

Tools Used: pgAdmin for schema visualization and management; SQL scripts for DDL
Output: Structured, and queryable storage of service catalogue

4. Storage & Retrieval System

Purpose:
- Provides efficient access to stored calibration data
- Enables advanced search (e.g., by case number, customer, parameter)
- Supports auditing and reporting

Features:
- Query tools for inspection and verification
- Enables integration with front-end portals or APIs
- Preserves data integrity for long-term use

Output: Reliable access to historical service requests for stakeholders.

ACOUSTICS

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NPL Department

- npl_department
  - Columns (9)
    - department_id
    - department_code
    - department_name
    - head_of_department
    - email
    - is_active
    - created_at
    - parent_department_id
    - level

	department_id [PK] integer	department_code character varying (50)	department_name character varying (200)	parent_department_id integer	level integer
	55	1	Physical Metrology	[null]	1
	29	1.01	Mass Metrology	55	2
	39	1.02	Length, Dimension and Nanometrology	55	2
	28	1.03	Temperature & Humidity Metrology	55	2
	18	1.04	Optical Radiation Metrology	55	2
	40	1.05	Force & Hardness Metrology Section	55	2
	27	1.06	Pressure, Vacuum & Ultrasonic Metrology Section	55	2
	45	1.07	Acoustics and Vibration Metrology	55	2
	42	1.08	Fluid Flow Metrology	55	2
	43	1.08b	Fluid Flow Metrology (Gas Flow)	42	3
	21	1.08c	Fluid Flow Metrology (Water Flow)	42	3
12	56	2	Electrical Metrology	[null]	1
13	17	2.01	LF, HF Impedance and DC Metrology	56	2

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NPL Service Catalogue

- npl_service
  - Columns (8)
    - service_id
    - service_type
    - parameter_item
    - item_type
    - item_name
    - alias_name
    - is_active
    - created_at

Showing rows: 1 to 565 Page No: 1 of 1

	service_ [PK] inte	service_type text	parameter_item text	item_type text	item_name text	alias_name text
1	1	Calibration	AC Power / Energy	1/3-Phase Reference Po...	1/3-Phase Power & Energy Met...	1/3-Phase Reference P...
2	2	Calibration	Form	Instrument	Formtester	Formtester/Roundness ...
3	3	Calibration	Magnetic Flux Dens...	Magnetic Field Indicator	Magnetic Field Indicator	Residual Magnetic Gau...
4	4	Calibration	Gas Flow	Gas Meter	Mass Flow Controller (Laminar ...	High Precision Digital Fl...
5	5	Calibration	Color Temperature	Meters/ Detectors	Colorimeter/ Chromameter/ Co...	
6	6	Calibration	Density	Glass Hydrometer	High precision Hydrometer (Re...	
7	7	Calibration	Length	Instrument	Dial Gauge, Plunger /lever Type	
8	8	Calibration	Length	Accessory	Test Sieve	Sieve
9	9	Calibration	Viscosity	Viscometer	Glass Capillary Viscometer (Re...	
10	10	Calibration	Length	End Standard	Gauge Block Set	Slip Gauge By Comparis...
11	11	Calibration	Quantum Hall Resis...	1kOhm DC Resistor	1kOhm DC Resistor	
12	12	Calibration	Ultrasonic	Ultrasonic NDT Equipme...	Calibration Block A2 (IIW-VI)V1 ...	

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- npl_service_tariff
  - Columns (20)
    - tariff_id
    - service_id
    - calibration_range
    - calibration_points
    - testing_parameters
    - sample_requirement
    - limitation_condition
    - charge_per_item
    - additional_charges
    - additional_description
    - remarks
    - edc_normal
    - edc_tatkal
    - effective_from
    - effective_to
    - is_current
    - created_by
    - approved_by
    - approved_at
    - created_at

Data Output Messages Notifications

Showing rows: 1 to 1000 Page No: 1 of 3

	tariff_id [PK] inte	service_id integer	calibratio text	calibration_po text	testing_p text	sample_ text	limitatio text	charge_p numeric	additiona numeric	additiona text	remarks text
1	117	359		4	[null]	[null]		26950	6800	26950	Only one calibration parameter.
2	118	101		4	[null]	[null]		30800	7700	30800	Only one calibration parameter. (M
3	119	65		4	[null]	[null]		41800	10500	41800	Only one calibration parameter. (M
4	120	406		4	[null]	[null]		55000	13800	55000	Only one calibration parameter. (M
5	121	231		4	[null]	[null]		71500	17900	71500	Only one calibration parameter. (M
6	122	206		4	[null]	[null]		17050	4300	17050	Only one calibration parameter.
7	123	312		4	[null]	[null]		19800	5000	19800	Only one calibration parameter.
8	124	83		4	[null]	[null]		26950	6800	26950	Only one calibration parameter.
9	125	79		4	[null]	[null]		30800	7700	30800	Only one calibration parameter.
10	126	37	0.1 Ω/...	Single Fre...	[null]	[null]		24800	[null]	24800	Each Resistance Set
11	127	305	1 pF/...	Single Fre...	[null]	[null]		24800	[null]	24800	
12	128	343	1.0E-...		[null]	[null]		47700	[null]	47700	

Total rows: 2759 Query complete 00:00:00.385 CRLF Ln 1, Col 1

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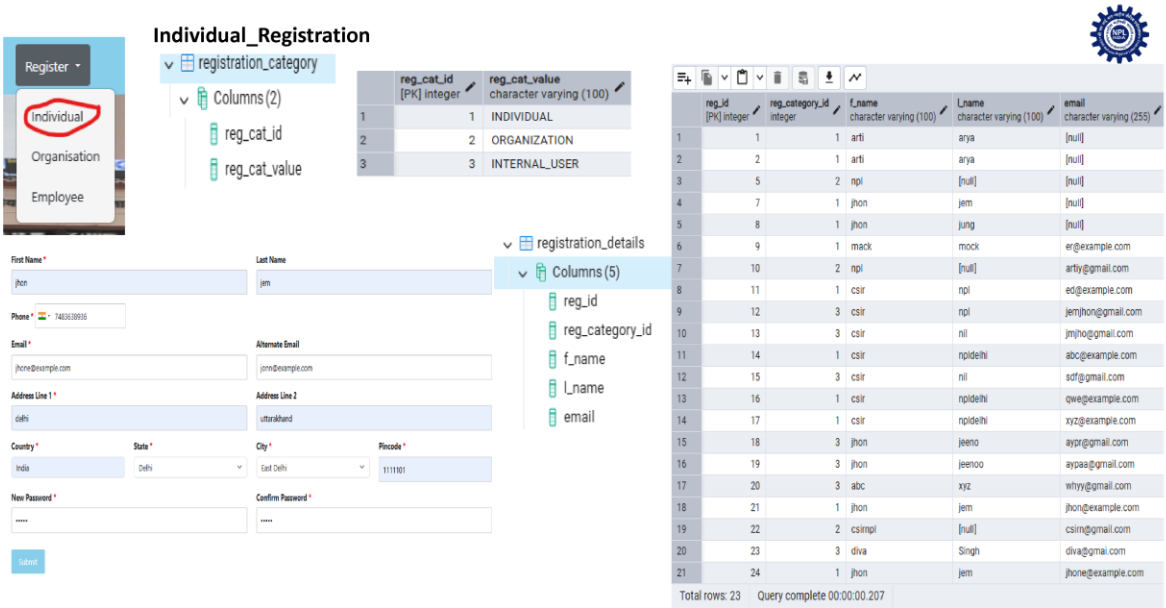

	reg_cat_id [PK] integer	reg_cat_value character varying (100)
1	1	INDIVIDUAL
2	2	ORGANIZATION
3	3	INTERNAL_USER

	reg_id [PK] integer	reg_category_id integer	f_name character varying (100)	l_name character varying (100)	email character varying (255)
1	1	1	arti	arya	[null]
2	2	1	arti	arya	[null]
3	5	2	npl	[null]	[null]
4	7	1	jhon	jem	[null]
5	8	1	jhon	jung	[null]
6	9	1	mack	mock	er@example.com
7	10	2	npl	[null]	artiy@gmail.com
8	11	1	csir	npl	ed@example.com
9	12	3	csir	npl	jemjhon@gmail.com
10	13	3	csir	nil	jmjho@gmail.com
11	14	1	csir	npldelhi	abc@example.com
12	15	3	csir	nil	sdf@gmail.com
13	16	1	csir	npldelhi	qwe@example.com
14	17	1	csir	npldelhi	xyz@example.com
15	18	3	jhon	jeeno	aypr@gmail.com
16	19	3	jhon	jeenoo	aypaa@gmail.com
17	20	3	abc	xyz	whyy@gmail.com
18	21	1	jhon	jem	jhon@example.com
19	22	2	csirnpl	[null]	csirn@gmail.com
20	23	3	diva	Singh	diva@gmai.com
21	24	1	jhon	jem	jhone@example.com

Total rows: 23 Query complete 00:00:00.207

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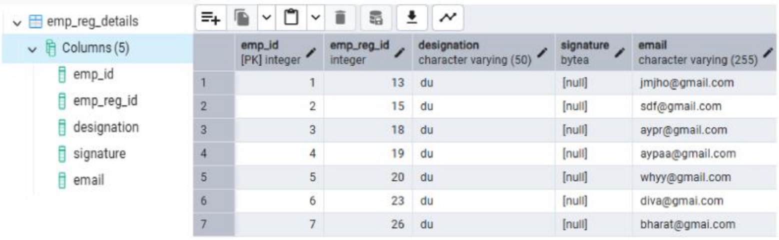

	emp_id [PK] integer	emp_reg_id integer	designation character varying (50)	signature bytea	email character varying (255)
1	1	13	du	[null]	jmjho@gmail.com
2	2	15	du	[null]	sdf@gmail.com
3	3	18	du	[null]	aypr@gmail.com
4	4	19	du	[null]	aypaa@gmail.com
5	5	20	du	[null]	whyy@gmail.com
6	6	23	du	[null]	diva@gmai.com
7	7	26	du	[null]	bharat@gmai.com

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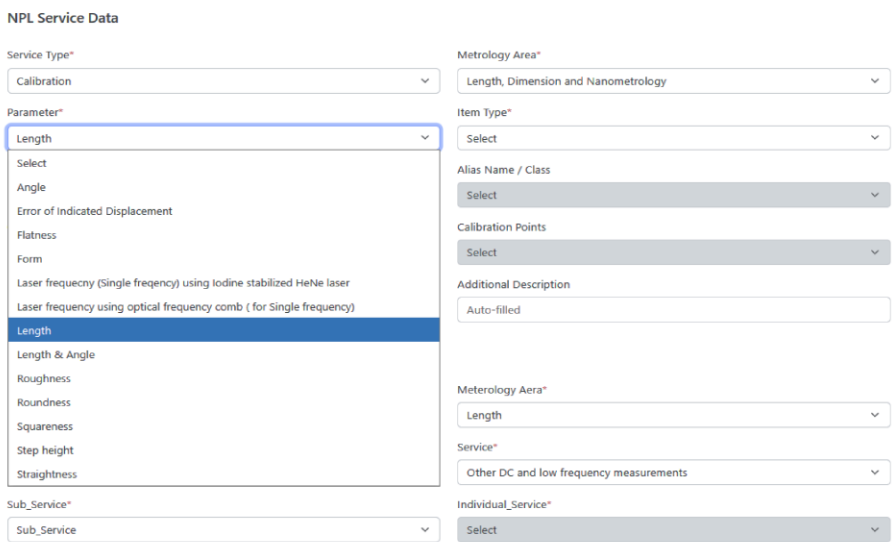
NPL Service Data

Service Type*
Calibration
Parameter*
Length
Select
Angle
Error of Indicated Displacement
Flatness
Form
Laser frequecny (Single freqency) using Iodine stabilized HeNe laser
Laser frequency using optical frequency comb (for Single frequency)
Length
Length & Angle
Roughness
Roundness
Squareness
Step height
Straightness
Sub_Service*
Sub_Service

Metrology Area*
Length, Dimension and Nanometrology
Item Type*
Select
Alias Name / Class
Select
Calibration Points
Select
Additional Description
Auto-filled
Meterology Aera*
Length
Service*
Other DC and low frequency measurements
Individual_Service*
Select

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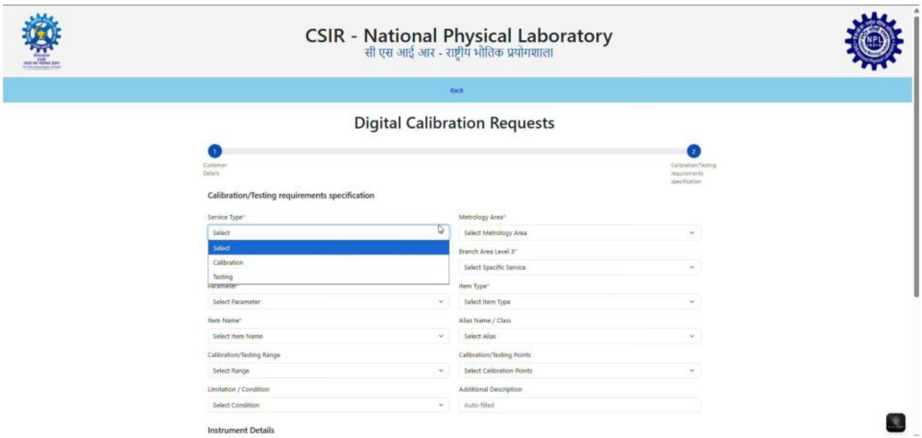
Present Status

- **Service-Level Extraction:** Used Python-based parsing to isolate service titles and category headers.
- **Schema Definition:** Created a standardized database schema focusing on Service_ID, Service_Name, Division, and Service and department Mapping.
- **Metrologist Review Pending:** They shall validate the service list to ensure no commercial offerings were missed or miscategorized.
- Working on the web-based intranet platform to enable this.

Service catalogues inclusion in DCR



The KCDB API for Classification

- The **BIPM KCDB API** provides the global blueprint for service classification.
- **Hierarchical Basis:** KCDB API uses "Branch" and "Service" hierarchy to group individual services.
- Extracted and analysed KCDB CMC service classification data using APIs
- Designed a hierarchical parent–child CMC classification model
- This is based on respective Consultative committees classification

```
select * from bipm_subservice
```

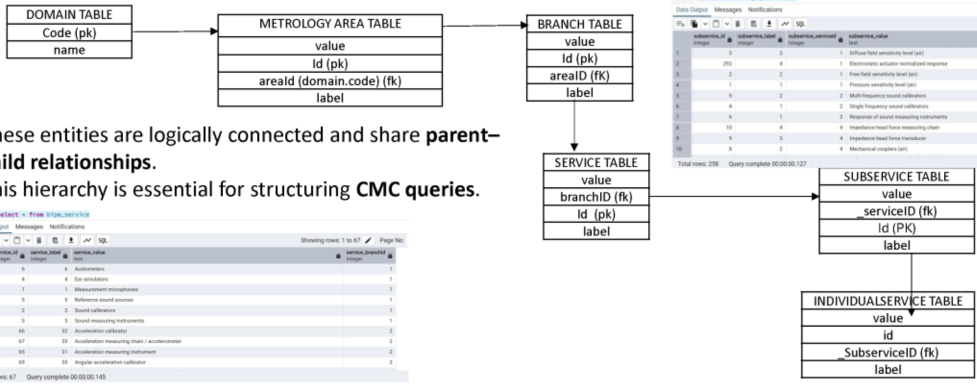
Data Output Messages Notifications

Showing rows: 1 to 258

	subservice_id integer	subservice_label integer	subservice_serviceid integer	subservice_value text
1	3	3	1	Diffuse field sensitivity level (air)
2	292	4	1	Electrostatic actuator normalized response
3	2	2	1	Free-field sensitivity level (air)
4	1	1	1	Pressure sensitivity level (air)
5	5	2	2	Multi-frequency sound calibrators
6	4	1	2	Single frequency sound calibrators
7	6	1	3	Response of sound measuring instruments
8	10	4	4	Impedance head force measuring chain
9	9	3	4	Impedance head force transducer
10	8	2	4	Mechanical couplers (air)

Total rows: 258 Query complete 00:00:00.127

✓ Successfully run. Total query



- These entities are logically connected and share **parent–child relationships**.
- This hierarchy is essential for structuring **CMC queries**.

```
select * from bipm_service
```

Data Output Messages Notifications

Showing rows: 1 to 67 Page No:

	service_id integer	service_label integer	service_value text	service_branchid integer
1	6	6	Audiometers	1
2	4	4	Ear simulators	1
3	1	1	Measurement microphones	1
4	5	5	Reference sound sources	1
5	2	2	Sound calibrators	1
6	3	3	Sound measuring instruments	1
7	66	32	Acceleration calibrator	2
8	67	33	Acceleration measuring chain / accelerometer	2
9	65	31	Acceleration measuring instrument	2
10	69	35	Angular acceleration calibrator	2

Total rows: 67 Query complete 00:00:00.145

Data Retrieval from KCDB API

A Python script was developed to fetch reference data from the **KCDB API**.
Link -https://www.bipm.org/api/kcdb/swagger-ui/index.html?configUrl=/api/kcdb/v3/api-docs/swagger-config#/reference-data-controller/getCategories

The script accesses **all reference-data-controller endpoints** required for **CMC queries**

API requests are executed iteratively to ensure complete data coverage.

The retrieved JSON responses are parsed and structured.

The processed data is stored in **Excel (.xlsx) files** for further analysis and mapping.

KCDB Reference Data APIs Used

The following reference-data-controller APIs were accessed to retrieve data required for CMC queries:

/referenceData/analyte – Analyte list **Request URL -https://www.bipm.org/api/kcdb/referenceData/analyte**

/referenceData/branch – Branch list **Request URL - https://www.bipm.org/api/kcdb/referenceData/branch**

/referenceData/category – Category list **Request URL - https://www.bipm.org/api/kcdb/referenceData/category**

/referenceData/country – Country list **Request URL - https://www.bipm.org/api/kcdb/referenceData/country**

/referenceData/domain – Domain list **Request URL - https://www.bipm.org/api/kcdb/referenceData/domain**

/referenceData/individualService – Individual service list **Request URL - https://www.bipm.org/api/kcdb/referenceData/individualService**

/referenceData/metrologyArea – Metrology area list **Request URL- https://www.bipm.org/api/kcdb/referenceData/metrologyArea**

/referenceData/nuclide – Nuclide list **Request URL- https://www.bipm.org/api/kcdb/referenceData/nuclide**

/referenceData/quantity – Quantity list **Request URL - https://www.bipm.org/api/kcdb/referenceData/quantity**

/referenceData/radiationMedium – Radiation medium list **Request URL - https://www.bipm.org/api/kcdb/referenceData/radiationMedium**

/referenceData/radiationSource – Radiation source list **Request URL - https://www.bipm.org/api/kcdb/referenceData/radiationSource**

/referenceData/service – Service list **Request URL - https://www.bipm.org/api/kcdb/referenceData/service**

/referenceData/subService – Sub-service list **Request URL- https://www.bipm.org/api/kcdb/referenceData/subService**

Mapping Structure of KCDB Reference Data

Mapped (Hierarchical) Reference Data

The following reference data entities form a **hierarchical relationship** and were **successfully mapped**:

Domain

→ Metrology Area

→ Branch Area

→ Service

→ Sub-Service

→ Individual Service

Explanation:

These entities are logically connected and share **parent–child relationships.**

Each level references the next level through unique identifiers.

This hierarchy is essential for structuring **CMC queries**.

```
15 select * from bipm_domain
```

	domain_code character varying (255)	domain_name text
1	CHEM-BIO	Chemistry and Biology
2	PHYSICS	General physics
3	RADIATION	Ionizing radiation

```
15 select * from bipm_metrologyarea
```

	metrologyarea_value text	metrologyarea_id integer	metrologyarea_areaid text	metrologyarea_label text
1	Acoustics, Ultrasound, Vibration	1	PHYSICS	AUV
2	Electricity and Magnetism	2	PHYSICS	EM
3	Length	3	PHYSICS	L
4	Mass and related quantities	4	PHYSICS	M
5	Photometry and Radiometry	5	PHYSICS	PR
6	Thermometry	6	PHYSICS	T
7	Time and Frequency	7	PHYSICS	TF
8	Chemistry and Biology	8	CHEM-BIO	QM
9	Ionizing Radiation	9	RADIATION	RI

```
15 select * from bipm_individualservice
```

Showing rows: 1 to 615 Page No: 1

	individualservice_value text	individualservice_id integer	individualservice_subserviceid integer	individualservice_label integer
1	Modulus	1	1	1
2	Phase	2	1	2
3	Directivity	5	2	3
4	Modulus	3	2	1
5	Phase	4	2	2
6	Modulus	6	3	1
7	Phase	7	3	2
8	Sound pressure level	8	4	1
9	Sound pressure level	9	5	1
10	Diffuse field response level	12	6	3

Total rows: 615 Query complete 00:00:00.692

Non-Mapped (Independent) Reference Data

The following reference data entities **do not follow a direct hierarchical mapping** with the above structure:

- **Quantity**
- **Category**
- **Country**
- **Analyte**
- **Nuclide**
- **Radiation Medium**
- **Radiation Source**

```
15 select * from bipm_branch
```

Data Output | Messages | Notifications

	branch_value text	branch_id integer	branch_areaid integer	branch_label text
1	Sound in air	1	1	AUV/A
2	Sound in water	3	1	AUV/W
3	Vibration	2	1	AUV/V
4	AC voltage, current, and power	4	2	EM/AC
5	DC voltage, current, and resistance	5	2	EM/DC
6	Electric and magnetic fields	6	2	EM/Field
7	High voltage and current	7	2	EM/HV
8	Impedance up to the MHz range	8	2	EM/Imped
9	Materials	9	2	EM/Mater
10	Other DC and low frequency measurements	10	2	EM/OtherDC

Total rows: 35 Query complete 00:00:00.183

Explanation:

These datasets are **standalone reference lists**.

They are used as **attributes or filters** in CMC data but **do not have direct parent–child links**.

Hence, they were stored separately and not merged into the main hierarchy.

bipm_domain

bipm_domain
- Columns (2)
  - domain_code
  - domain_name

	domain_code character varying (255)	domain_name text
1	CHEM-BIO	Chemistry and Biolo...
2	PHYSICS	General physics
3	RADIATION	Ionizing radiation

bipm_metrologyarea_value

bipm_metrologyarea
- Columns (4)
  - metrologyarea_value
  - metrologyarea_id
  - metrologyarea_areaid
  - metrologyarea_label

Data Output | Messages | Notifications

	metrologyarea_value text	metrologyarea_id integer	metrologyarea_areaid text	metrologyarea_label text
1	Acoustics, Ultrasound, Vibration	1	PHYSICS	AUV
2	Electricity and Magnetism	2	PHYSICS	EM
3	Length	3	PHYSICS	L
4	Mass and related quantities	4	PHYSICS	M
5	Photometry and Radiometry	5	PHYSICS	PR
6	Thermometry	6	PHYSICS	T
7	Time and Frequency	7	PHYSICS	TF
8	Chemistry and Biology	8	CHEM-BIO	QM
9	Ionizing Radiation	9	RADIATION	RI

bipm_branch

- bipm_branch
  - Columns (4)
    - branch_value
    - branch_id
    - branch_areaid
    - branch_label

	branch_value text	branch_id integer	branch_areaid integer	branch_label text
1	Sound in air	1	1	AUV/A
2	Sound in water	3	1	AUV/W
3	Vibration	2	1	AUV/V
4	AC voltage, current, and power	4	2	EM/AC
5	DC voltage, current, and resistance	5	2	EM/DC
6	Electric and magnetic fields	6	2	EM/Field
7	High voltage and current	7	2	EM/HV
8	Impedance up to the MHz range	8	2	EM/Imped
9	Materials	9	2	EM/Mater

Total rows: 35 Query complete 00:00:00.128

bipm_service

- bipm_service
  - Columns (4)
    - service_id
    - service_label
    - service_value
    - service_branchid

Data Output Messages Notifications

	service_id integer	service_label integer	service_value text	service_branchid integer
1	6	6	Audiometers	1
2	4	4	Ear simulators	1
3	1	1	Measurement microphones	1
4	5	5	Reference sound sources	1
5	2	2	Sound calibrators	1
6	3	3	Sound measuring instruments	1
7	66	32	Acceleration calibrator	2
8	67	33	Acceleration measuring chain / accelerometer	2
9	65	31	Acceleration measuring instrument	2
10	69	35	Angular acceleration calibrator	2
11	70	36	Angular acceleration measuring chain / accelerometer	2
12	68	34	Angular acceleration measuring instrument	2
13	8	22	Angular vibration	2
14	10	30	AUV auxiliary instruments and/or services	2
15	9	23	Dynamic force	2
16	72	38	Force measuring chain or force transducer for mechanical impedance and mobility measurements or modal testing	2
17	71	37	Force measuring instrument for mechanical impedance and mobility measurements or modal testing	2
18	7	21	Linear vibration	2
19	73	45	Vibration signal conditioner	2
20	11	11	Hydrophones (medical ultrasonic)	3

Total rows: 67 Query complete 00:00:00.117

bipm_subservice

- bipm_subservice
  - Columns (4)
    - subservice_id
    - subservice_label
    - subservice_serviceid
    - subservice_value

	subservice_id integer	subservice_label integer	subservice_serviceid integer	subservice_value text
1	3	3	1	Diffuse field sensitivity level (air)
2	292	4	1	Electrostatic actuator normalized response
3	2	2	1	Free-field sensitivity level (air)
4	1	1	1	Pressure sensitivity level (air)
5	5	2	2	Multi-frequency sound calibrators
6	4	1	2	Single frequency sound calibrators
7	6	1	3	Response of sound measuring instruments
8	10	4	4	Impedance head force measuring chain
9	9	3	4	Impedance head force transducer
10	8	2	4	Mechanical couplers (air)
11	7	1	4	Reference couplers or artificial ears (air)

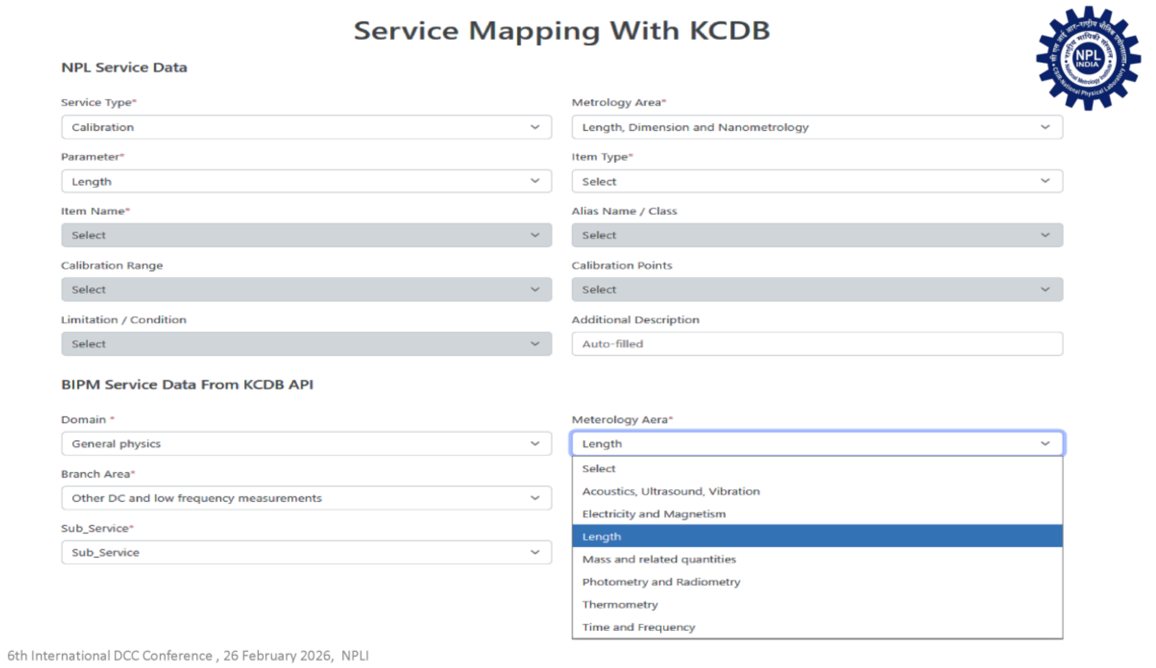
Total rows: 258 Query complete 00:00:00.171

bipm_individualservice

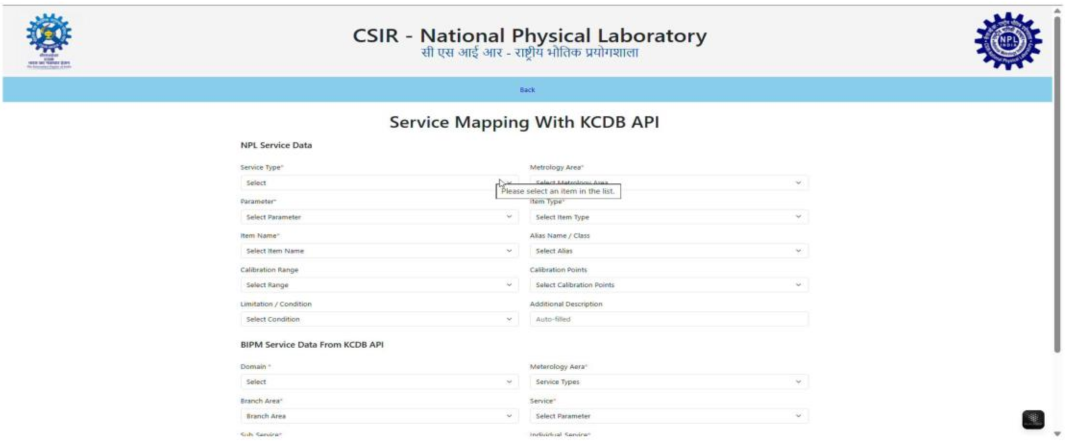
- bipm_individualservice
  - Columns (4)
    - individualservice_value
    - individualservice_id
    - individualservice_subserviceid
    - individualservice_label

	individualservice_value text	individualservice_id integer	individualservice_subserviceid integer	individualservice_label integer
1	Modulus	1	1	1
2	Phase	2	1	2
3	Directivity	5	2	3
4	Modulus	3	2	1
5	Phase	4	2	2
6	Modulus	6	3	1
7	Phase	7	3	2
8	Sound pressure level	8	4	1
9	Sound pressure level	9	5	1
10	Diffuse field response level	12	6	3
11	Free-field response level	11	6	2

Total rows: 615 Query complete 00:00:00.113



KCDB Mapping

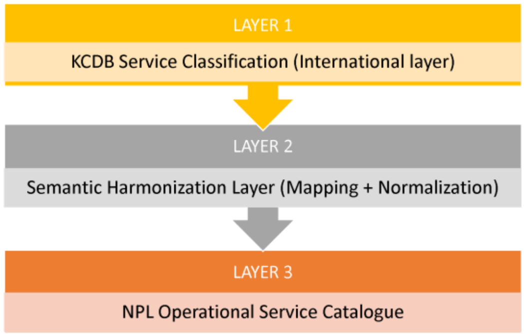


Mapping Strategy

- Align Individual services
- Classify mapping type: Exact / Broader / Narrower / Composite / No match
- Avoid forced 1:1 alignment

Key Issues Identified

Unstructured catalogue → Manual interpretation	Service decomposition
Capability vs operational gap → Structural divergence	Semantic harmonization layer
Granularity mismatch → Many-to-many mapping	Multi-level mapping categories
Terminology differences → Ambiguity	Controlled vocabulary



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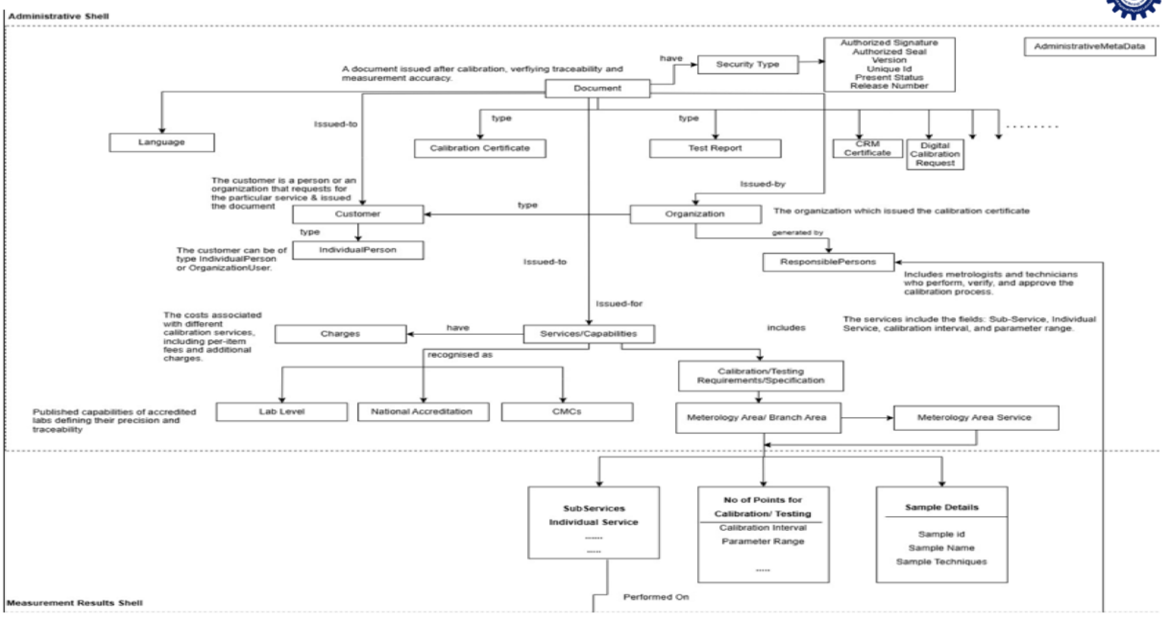
How this fits in DCC



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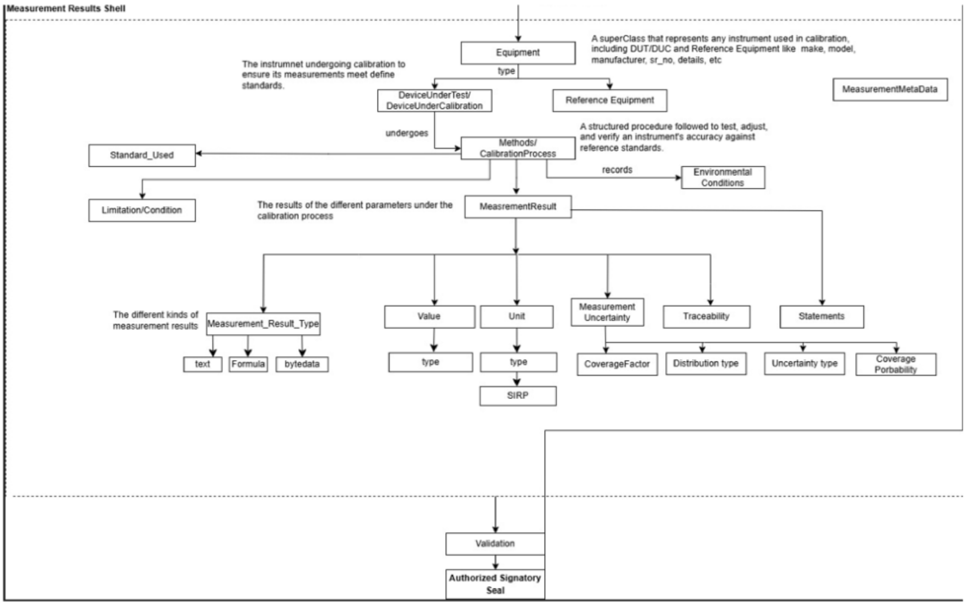
How this fits in DCC



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Summary

- DCR through structured measurement service representation
- Feasibility evaluation of KCDB service classification at NMI level
  - Direct 1:1 mapping not feasible
  - Semantic harmonization layer required
  - Expert validation essential
- Step towards FAIR DCC ecosystems
  - Findable: Service class identifiers enable indexing
  - Accessible: API-driven structured taxonomy
  - Interoperable: Harmonized services
  - Reusable: Clear service scope and metadata

Future Work

Extend toward CMC-level linkage

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References

ISO/IEC (2017): ISO/IEC 17025:2017 — General requirements for the competence of testing and calibration laboratories, International Organization for Standardization (ISO), Geneva.

Webpage (2024): KCDB API (API KCDB), https://www.bipm.org/en/cipm-mra/kcdb-api, last accessed: 29.01.2026

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Webpage (2024): Key Comparison Database (KCDB), https://www.bipm.org/kcdb/, last accessed: 29.01.2026

Webpage (2026): Calibration & Testing – CSIR-NPL (Centre for Calibration & Testing – CFCT), https://www.nplindia.org/index.php/commercial-services/calibration-testing/, last accessed: 29.01.2026

Webpage (n.d.): CSIR-NPL Centre for Calibration & Testing (CFCT): Calibration/Testing/BND Request (CTBR) Form (PDF), https://www.nplindia.org/sites/default/files/ctbr.pdf, last accessed: 29.01.2026

SI Digital Framework (SIDF): https://si-digital-framework.org/SI?lang=en

M-layer: https://www.mlayer.org/

Acknowledgements

- **This research was supported by CSIR-NPL India (HCP-55 Project).**
- **Director CSIR-NPL, HCP-55 PI and Co-PI, CSIR-NPL Staff**
- **Special thanks to Dr Ryan White.**

THANK YOU

💡 **Any Questions?**

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Anjali.nplindia@csir.res.in

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P08 Daniel Hutzschenreuter: Units of measurement at its best

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Keywords: Units of Measurement (UoM), Common Data Dictionary (CDD), IEC, SI Reference Point, Digital-SI

Abstract

Standard repositories for units of measurement with high relevance for digital services and tools of laboratories are moving closer together in April 2026. The IEC/SC 3D "Classes, Properties and Identification of products - Common Data Dictionary (CDD)" is maintaining the Common Data Dictionary (IEC CDD) [1], All units of measurement are represented with concise and complete information to enable seamless digital interoperability when converting the metrological unit of a measurand. Users are provided with a validated and machine- readable framework to trace measurement data to the definitions from the International System of Units (SI). Conversion metadata will provide the digital links to BIPM's SI Reference Point (SIRP) [2], the international backbone for the SI in a digital era coming from metrology. In addition, revised numerical data will bring conversion between over 1700 units of measurement and the SI to the next level of numerical accuracy.

These benefits will directly be accessible to developers and users of Digital Calibration Certificates (DCC) [3] through the cross-linking with SIRP as shown in Figure 1. We present details of the upcoming IEC-CDD update and practical use-cases for the application of highly accurate conversion of metrological units for DCC measurands.

Figure 1. IEC-CDD, BIPM-SIRP and DCC units of measure at its best.

References:

[1] I EC TC 3 SCD Webpage (2016), Common Data Dictionary - CDI). https://tc3.iec.ch/tc-activity/common-data-dictionary-cdd/, last accessed: 22.01.2026
[2] BIPM SIRP Webpage (2026): SI Digital Framework - SI Reference Point, https://si-digi-tal- framework.org/SI, last accessed: 22.01.2026
[3] DCC Webpage (2026): Digital Calibration Certificate, https://www.ptb.de/dcc/, last accessed: 22.01.2026

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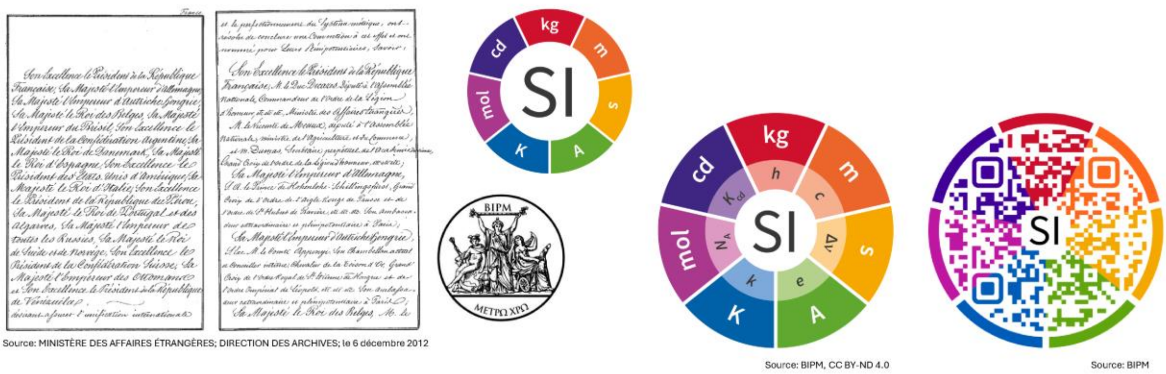
Presentation #P08 of Daniel Hutzschenreuter

Units of measurement at its best

Report on work in progress of connecting the
IEC CDD Units of measurement to the
BIPM SI Reference Point.

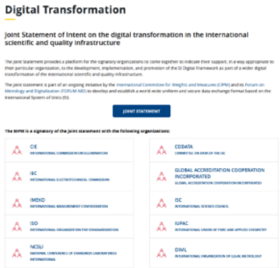
The Motivation behind this endeavor

The international (digital) Units of Measurement



2026-02-26 DCC Conference 2026: Units of measurement at its best 2

The Motivation behind this endeavor (cont.)



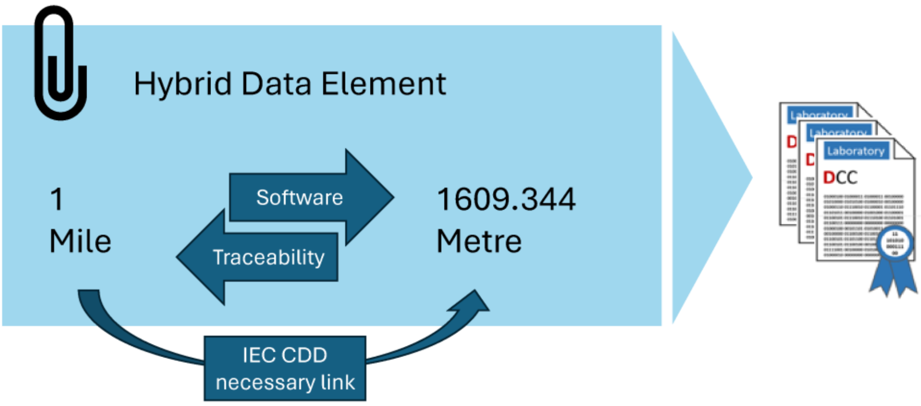
7 base units

“semantic traceability” of concepts to a trusted source

2150+ industry-relevant variations

The Motivation with regard to DCC

Anchor of trust for data beyond SI



Where it all began :-)

QI Digital Forum in October 2024

The Team

G. Rossi
IEC/SC 3D

R. Sporer
Siemens / IEC SMB

K. Dickmann
Siemens / IEC/SC 65E

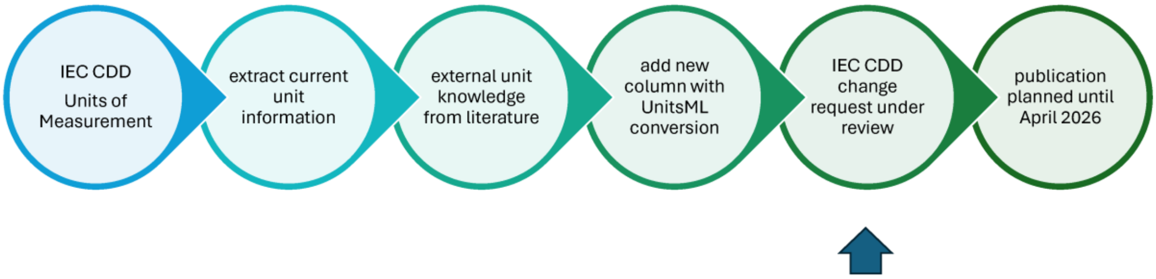
T. Engel
Siemens

S. Westerkamp
Siemens

D. Hutzschenreuter
PTB

M. Gruber
PTB

The Plan



We are here :-)

Highlights for the April 2026 update

IEC CDD unit (2168 total)	internal conversion	no internal conversion
SIRP conversion	2080	0
no SIRP conversion	24	64

IEC CDD unit	exact	approximation
SIRP conversion	1488	592
internal conversion	1644	460

- calculations use 40-digits precision
- output with (up to) 28 relevant digits
- often exact numerator + denominator

Example 1: gram (UAA465)

```
<Float64ConversionFrom
xml:id="UAA594_from_UAA465"
initialUnit="0112/2///62720#UAA465"
multiplicand="0.001" divisor="1"
exact="true" />
```

Highlights for the April 2026 update (examples)

Example 1: **gram** (UAA465)

```
<Float64ConversionFrom
xml:id="UAA594_from_UAA465"
initialUnit="0112/2///62720#UAA465"
multiplicand="0.001" divisor="1"
exact="true" />
```

Example 2: **mile per hour** (UAB111)

```
<Float64ConversionFrom
xml:id="SI::metre.second-1_from_UAB111"
initialUnit="0112/2///62720#UAB111"
multiplicand="1609.344" divisor="3600"
exact="true" />
```

Example 3: **newton metre per degree** (UAB308)

```
<Float64ConversionFrom
xml:id="UAB309_from_UAB308"
initialUnit="0112/2///62720#UAB308"
multiplicand="180"
divisor="3.141592653589793238462643383" />
```

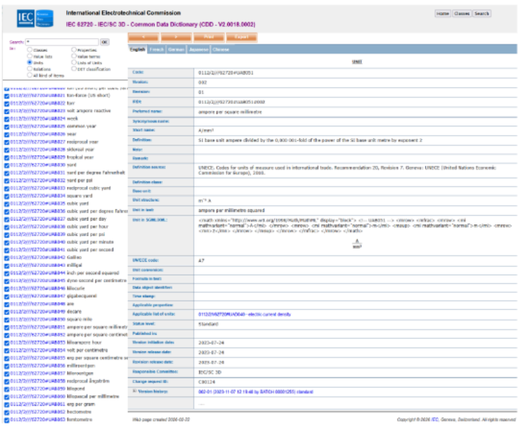
Example 4: **degree Fahrenheit** (UAA039)

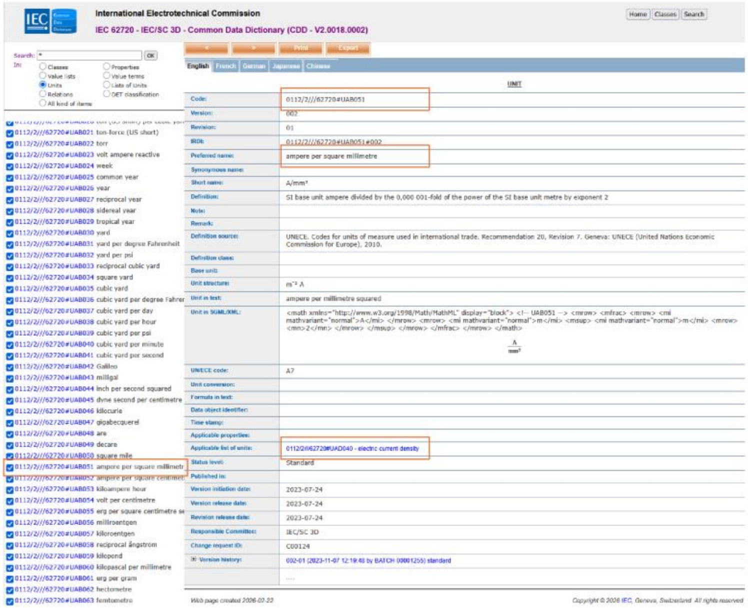
```
<Float64ConversionFrom
xml:id="SI::kelvin_from_UAA039"
initialUnit="0112/2///62720#UAA039"
initialAddend="459.67" multiplicand="5"
divisor="9" exact="true" />
```

... of course, these are just the main parts of a full UnitsML string.

The IEC CDD Units

- IEC 62720 - IEC/SC 3D - Common Data Dictionary
- online, public, re-useable unit repository (free attribute according to EULA)
- https://cdd.iec.ch/cdd/iec62720/iec62720.nsf





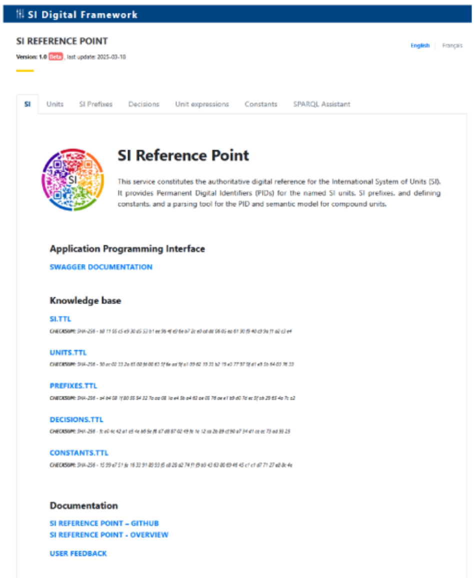
id

structured description

link to a quantity kind with related common unit

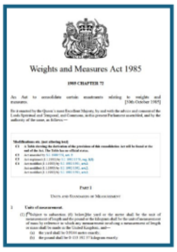
The SI Reference Point

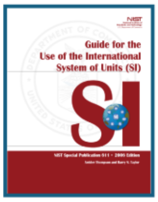
- ontology to capture the knowledge of the SI Brochure
- online, public, re-useable, beta stage
- https://si-digital-framework.org/SI/
- dynamic PIDs, e.g.: https://si-digital-framework.org/SI/units/ampere.millimetre-2

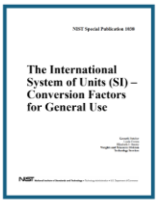


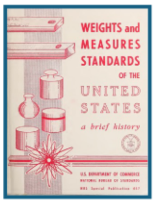
Where to get information on units?

D-SI documentation









→ a lot of consolidation work!

- getting exact conversion factors was sometimes supported by relying on less official references available on platforms like wikipedia:
- E.g.: barrel (US dry)
  - sometimes said to be 7056 cubic inch
  - however, following to logic of the US customary units:
  - 1 barrel (US dry) = 105 quart = 105 * (1/4 gallon) = 105/4 * (1/8 bushel) = 105/32 bushel = 105/32 * 2150.42 cubic inch = 7056.065625 cubic inch

Conversion to SI base units

- parse the IEC CDD structured name
- regex automatically constructed from consolidated unit information
- convert to SI base units (no special named units, no prefixes, no per)
- example: UAD883

parse unit "atoms": [factor, prefix, unit, exponent, per]

- "ampere hour per cubic decimetre"
- [1.0, '', ampere, 1.0, ''] [1.0, '', hour, 1.0, ''] ['', '', '', '', per] [1.0, deci, metre, 3.0, ''']
- [3600.0, '', second, 1.0, ''][1.0, '', ampere, 1.0, ''][1E+3, '', metre, -3.0, '']
- 3.6E+6, https://si-digital-framework.org/SI/units/second.ampere.metre-3

equiv. ops., e.g.:
- replace units
- replace prefixes
- remove per

prepare
UnitsML

UnitsML output strings

a : initialAddend
b : multiplicand
c : divisor
d : finalAddend

```
<UnitsML xmlns="https://schema.unitsml.org/unitsml/1.0">

<Unit xml:id="0112/2///62720#UAA135">
    <Conversions>
        <Float64ConversionFrom
        xml:id="UAA135_from_UAD883"
        initialUnit="0112/2///62720#UAD883"
        multiplicand="3.6E+6"
        divisor="1"
        exact="true" />
    </Conversions>
</Unit>

<Unit xml:id="https://si-digital-framework.org/SI/units/second.ampere.metre-3">
    <Conversions>
        <Float64ConversionFrom
        xml:id="SI::second.ampere.metre-3_from_UAD883"
        initialUnit="0112/2///62720#UAD883"
        multiplicand="3.6E+6"
        divisor="1"
        exact="true" />
    </Conversions>
</Unit>

</UnitsML>
```

$$y = \left((x + a) * \frac{b}{c}\right) + d$$

https://schema.unitsml.org/docs/unitsml/unitsml-v1.0/

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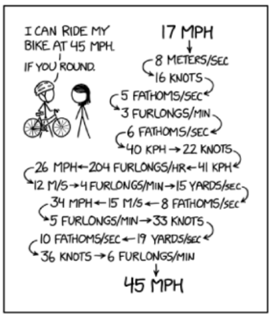
Calculations and datatypes



https://xkcd.com/2585

- initially: float calculations
- but: e.g., convert µS/cm (UAA075) to S/m (UAA279)
  - float: 1E-6 / 1E-2 S/m = 9.999999999999999e-5 S/m
  - decimal: 1E-6 / 1E-2 S/m = 1E-4 S/m

- calculations of conversion coefficients with 40-digit decimal precision
- includes high precision π, log and power
- output (at most) 28 decimal digits to adjust for accuracy loss during calculations
- UnitsML-strings store numbers as strings to preserve higher accuracy than possible with double datatype

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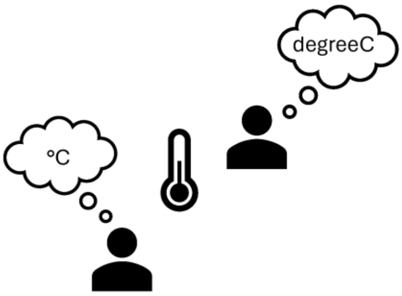
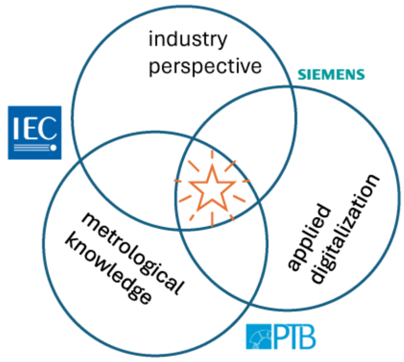
Lessons learned / applied



It is essential to have a shared understanding and terminology of the subject at hand, i.e. one common semantics are fundamental for interoperable knowledge exchange.

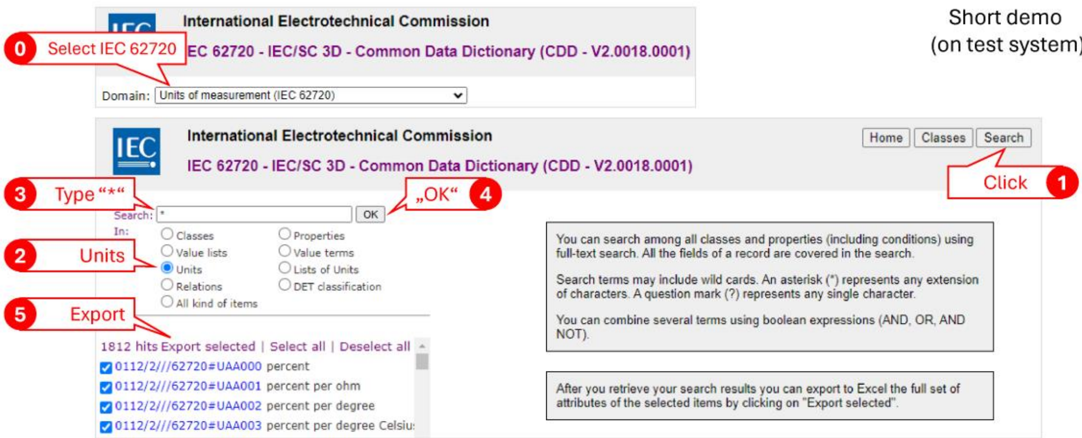
- Consolidate and quality check by hand
- Automate the repetitive and error-prone tasks



It is essential to have the relevant perspectives in place and let the right people work together as a motivated team

Accessing the IEC CDD

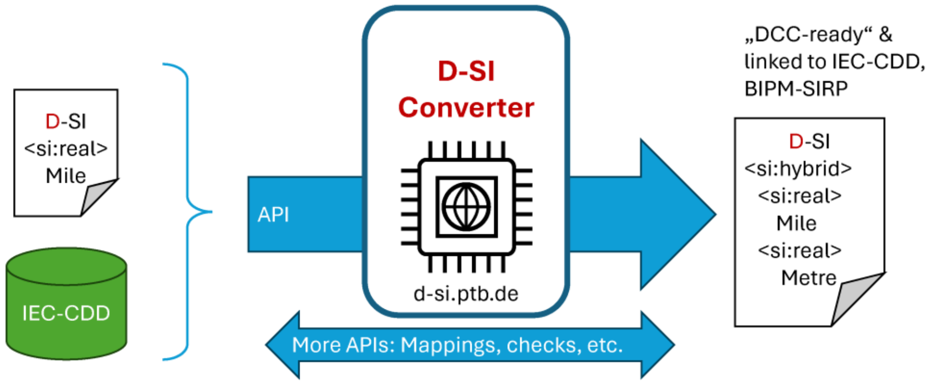
Start IEC CDD (https://cdd.iec.ch) and perform the following
6 STEPS to visualize (or export) the UNITS of MEASUREMENT:



Short demo
(on test system)

Applications for the presented work

Project: D-SI converter for quality infrastructure applications



The Summary

- link IEC CDD UoM to SIRP for many (95.9%) of all entries
- links are given as UnitsML conversions to base units (often exact factors)

And what's next?

- Release schedule / process
- How to access the results?
- Plans for the future (SI converter)

References

- https://www.bipm.org/en/liaison/digital-transformation
- https://cdd.iec.ch/cdd/iec62720/iec62720.nsf
- https://si-digital-framework.org/SI/

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Day 3 2026-02-26 Thursday
Parallel Session: “DCC Tool and Development II”
Session Chair: Hugo Gasca Aragon

028 Muhammed-Ali Demir: Current developments for the next DCC schema version

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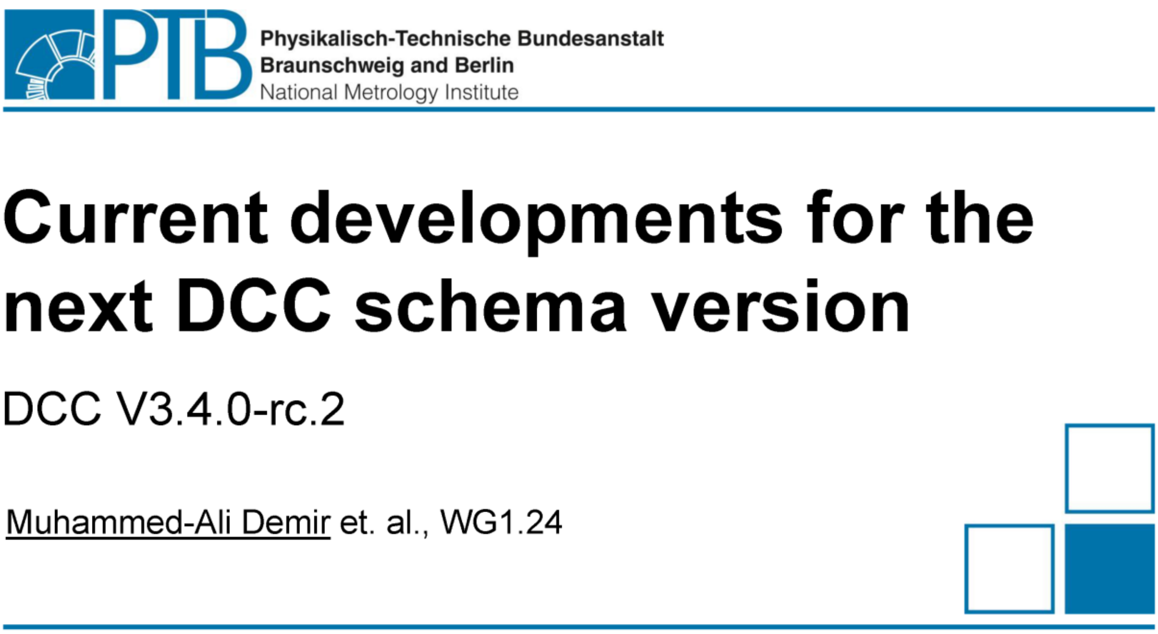
Keywords: DCC

Abstract

In this presentation we will talk about the current developments on the road to release of the DCC schema V3.4.0. Currently we are working on release candidates. We will show how the release candidate can be used for tests. The release candidate is for testing only and can change during further development.

Presentation #028 of Muhammed-Ali Demir

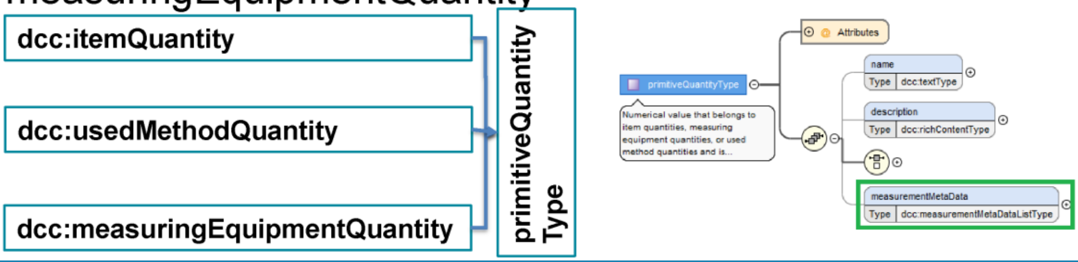


Introduction

- Current DCC Version (stable)
  - Version: DCC V3.3.0
  - Release date: 29th October of 2024
- Current Release Candidate (development):
  - Version: V3.4.0-rc.2
  - Available since 30th of October 2025
  - Use only for testing new features, changes will occur until release

Meta data in primitive quantities

- Requirement: meta data in item quantities, used method quantities and measuring equipment quantities
- Change: new optional element dcc:measurmentMetaData in dcc:itemQuantity, dcc:usedMethodQuantity and measuringEquipmentQuantity



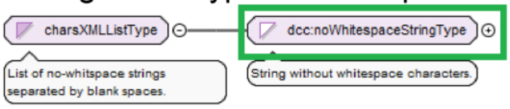
No whitespaced strings in lists

- Requirement: avoiding misinterpretation between whitespace as a separator and string with whitespace characters in string list type
- Example: <dcc:charsXMLList>A B C</dcc:charsXMLList>

Before: Is this one string containing space or …?

Now: These are 3 strings separated by space!

- Change: new type noWhitespaceStringType (string without any whitespace)



- Modifications: dcc:charsXMLList and Attribute refType are now lists of noWhitespaceStringType

dcc:content trimmed at start/ end

- Modified dcc:content – is now notEmptyStringType, it is neither allowed to be an empty string nor to start or end with a space, spaces in between are allowed
- Now:
  <dcc:content/>

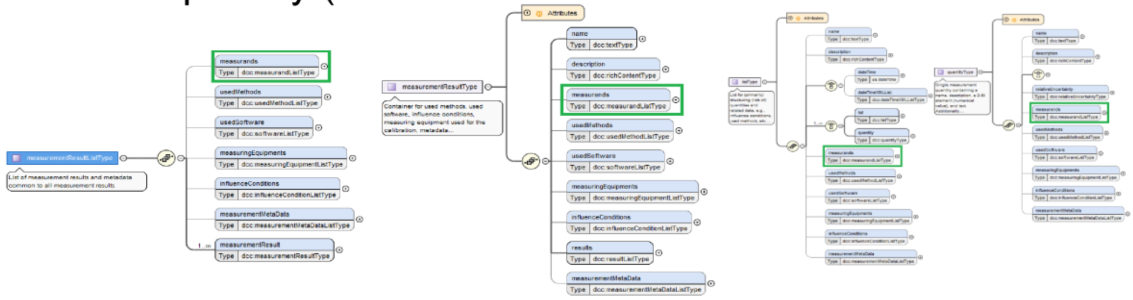
<dcc:content lang="en">Abc   </dcc:content>

<dcc:content lang="en">Abc</dcc:content>

<dcc:content lang="en">Abc def</dcc:content>

Measurands (1)

- [VIM3] 2.3: measurand = ‘quantity intended to be measured’
- Change: new type dcc:measurands in dcc:measurementResults, dcc:measurementResult, dcc:list and dcc:quantity (further sub types)



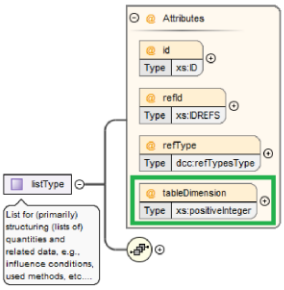
Measurands (2)

- Example

```
<dcc:measurands>
  <dcc:measurand>
    <dcc:name>
      <dcc:content lang="de">Gleichspannungsverhältnis</dcc:content>
      <dcc:content lang="en">Direct voltage ratio</dcc:content>
    </dcc:name>
    <dcc:description>
      <dcc:content lang="de">Verhältnis der Ausgangsgleichspannung zur Eingangsgleichspannung eines
      <dcc:content lang="en">For a multi-terminal device, ratio of the DC output voltage to the DC i
    </dcc:description>
    <dcc:informationSources>
      <dcc:informationSource>
        <dcc:reference>DKD TemaTres for measurands</dcc:reference>
        <dcc:referenceID>EM.Voltage.DC.Ratio</dcc:referenceID>
        <dcc:link>https://digilab.ptb.de/dkd/refType/vocab/index.php?tema=1</dcc:link>
      </dcc:informationSource>
      <dcc:informationSource>
        <dcc:reference>Electropedia</dcc:reference>
        <dcc:referenceID>431-02-06</dcc:referenceID>
        <dcc:link>https://www.electropedia.org/iev/iev.nsf/display?openform&amp;ievref=431-02-06</d
      </dcc:informationSource>
    </dcc:informationSources>
    <dcc:measurandSpecifications>
      <dcc:measurandSpecification>
        ...
      </dcc:measurandSpecification>
    </dcc:measurandSpecifications>
  </dcc:measurand>
</dcc:measurands>
```

Tables (1)

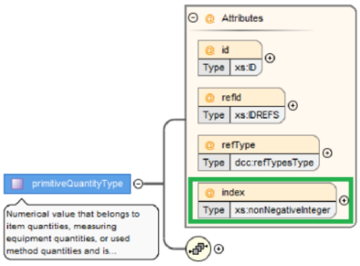
- Requirement: for table structures – specification of how many independent quantities are in a list
- Change: new attribute tableDimension in dcc:list

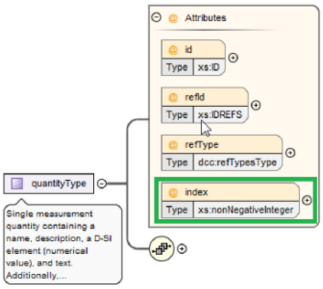


- Example – list has two independent columns: <dcc:list tableDimension="2">

Tables (2)

- Requirement: for table structures – zero based index of independent quantities
- Change: New attribute index in dcc:itemQuantity, dcc:usedMethodQuantity and measuringEquipmentQuantity and dcc:quantity





- Example - first independent quantity in list: <dcc:list tableDimension="1" >
  <dcc:quantity index="0"> …

Tables (3)

- For details please see corresponding presentations from last years DCC Conference

See also #014 Consistent Representation and Usage of Tabulated Data in the DCC by Benedikt Seeger (5th DCC Conference)

Tables (4)

- Also have a look at the presentation hereafter

See also #029 dccviewer-js: A solution to view and explore measurement data from DCCs by Jendrik Wenke (6th DCC Conference)

How to use the current release candidate

- If you want to use the DCC V3.4.0-rc.2, you have to edit the schemaLocation and the schemaVersion in the DCC XML

```
<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/v3.3.0/dcc.xsd"
+  xsi:schemaLocation="https://ptb.de/dcc https://ptb.de/dcc/v3.4.0-rc.2/dcc.xsd"
-  schemaVersion="3.3.0">
+  schemaVersion="3.4.0-rc.2">
   ...
```

- Caution: V3.4.0-rc.2 can change, not all features may end up in the final schema version, only use it if you want to test some features
- See also: https://wiki.dcc.ptb.de/en/release-candidate

Contributors

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About

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From: 02/26

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029 Jendrik Wenke: dccviewer-js: A solution to view and explore measurement data from DCCs

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Jaime Gonzalez-Gomez [1] jaime.gonzalez-gomez@ptb.de
Institution:
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Keywords: Graph, Plot, Quantities, Tables, Visualization

Abstract

The ongoing digitalization in metrology comes with many advantages, including the DCC as a data interchange format defined by an XML schema [1]. However, the raw XML is not readily accessible by humans. Instead, it structures data so that relationships can be interpreted by machines. Custom tooling can help humans in understanding and exploring the data [2].

These considerations resulted in the development of a JavaScript library dccviewer-js that is used in a web-based tool [3] to display administrative data and interactively plot measurement results of a DCC. The web tool consists of a single self-contained HTML file that works in any browser, without the need of internet access. This makes it possible to use dccviewer-js in a restricted lab network and ensures that no sensitive data is exposed. Additionally, the tool is fully open-source and freely available under the MIT license [4], allowing laboratories and institutions to customize the design and add their own specialized functionality.

While the tool theoretically works with any valid DCC using schema version 3.3.0 or later, interactive visualizations can only be made if the data follows the good practice table format [5], [6]. Only conformance to the good practices enables the software to rely on implicit relationships defined by the XML structure, like consistent units in the implemented list types. In turn, one gets an intuitive understanding of the data, its uncertainties and potential outliers.

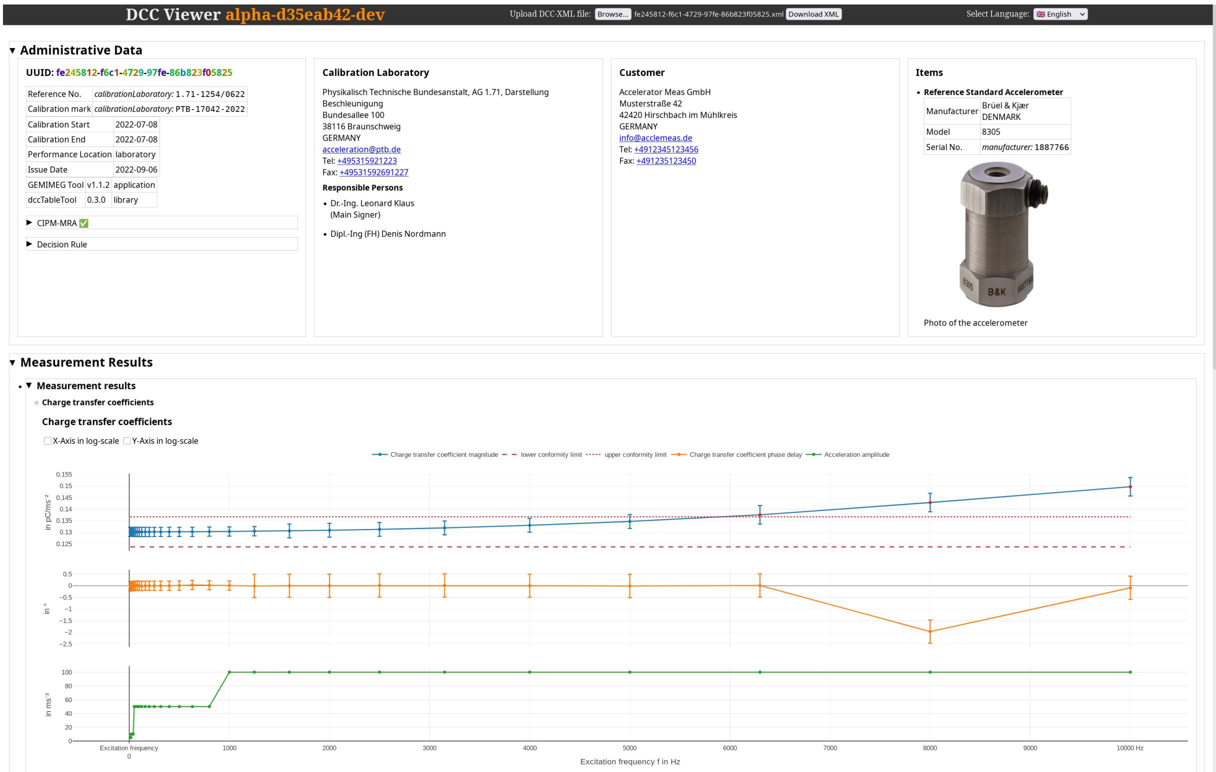

***Figure 1**. Screenshot of the application showing calibration results of an accelerometer*

References:

[1] xsd-dcc (2026): xsd-dcc [https://gitlab1.ptb.de/d-ptb/dcc/xsd-dcc], last accessed: 21.01.2026

[2] Schönhals, Shanna; Jordan, Moritz; Melzer, Michael; Röske, Dirk (2025): Ideas for the transition from paper-based force and torque calibration certificates to machine-readable XML data, in: Proceedings of the XXIV IMEKO World Congress, https://doi.org/10.1016/j.measen.2024.101334

[3] dccviewer-js (2026): DCC Viewer JavaScript "dccviewer-js", [https://gitlab1.ptb.de/digitaldynamicmeasurement/dccviewer-js], last accessed: 21.01.2026

[4] The System Package Data Exchange™ (SPDX®) (2018): MIT License, [https://spdx.org/licenses/MIT.html], last accessed: 21.01.2026

[5] Seeger, Benedikt; Stehr, Vanessa (2025): Consistent Representation and Usage of Tabulated Data in the DCC. Enable Easy-To-Use Computer-Aided Processing and Visualization of Your Data, in: 5th International DCC-Conference, page 215, https://doi.org/10.7795/810.20250619

[6] Digital Calibration Certificate - Wiki (2026): Tables in the DCC, [https://wiki.dcc.ptb.de/en/tables], last accessed: 21.01.2026

Presentation #029 of Jendrik Wenke

Physikalisch-Technische Bundesanstalt
Braunschweig and Berlin
National Metrology Institute

dccviewer-js: A solution to view and explore measurement data from DCCs

Jendrik Wenke Benedikt Seeger
Vanessa Stehr Jaime Gonzalez-Gomez

2026-02-26

Readability

```xml
<dcc:list tableDimension="1">
  <dcc:name><dcc:content lang="en">Charge transfer coefficients</dcc:content><dcc:name>
  <dcc:quantity refType="vibration_frequency basic_nominalValue" index="0">
    <dcc:name><dcc:content lang="en">Excitation frequency</dcc:content></dcc:name>
    <si:realListXMLList>
      <si:valueXMLList>10.0 12.5 16.0 20.0 25.0 31.5 40.0 50.0 63.0 80.0 1.0e+02 1.25e+02 1.6e+02 2.0e+02 2.5e+02 3.15e+02
      <si:unitXMLList>\hertz</si:unitXMLList>
    </si:realListXMLList>
  </dcc:quantity>
  <dcc:quantity refType="vibration_magnitudeTransferCoefCharge vibration_magnitude" >
    <dcc:name><dcc:content lang="en">Charge transfer coefficient magnitude</dcc:content></dcc:name>
    <si:realListXMLList>
      <si:valueXMLList>0.13017 0.13017 0.13016 0.13016 0.13017 0.13017 0.13017 0.13016 0.13013 0.13013 0.13012 0.13012 0.13
      <si:unitXMLList>\pico\coulomb\per\metre\second\tothe{-2} </si:unitXMLList>
      <si:measurementUncertaintyUnivariateXMLList><si:expandedMUXMLList>
          <si:valueExpandedMUXMLList>0.00026 0.00026 0.00026 0.00026 0.00026 0.00026 0.00026 0.00026 0.00026 0.00026 0.0002
          <si:coverageFactorXMLList>2.0</si:coverageFactorXMLList><si:coverageProbabilityXMLList> 0.95</si:coverageProbabili
      </si:expandedMUXMLList></si:measurementUncertaintyUnivariateXMLList>
    </si:realListXMLList>
    <dcc:measurementMetaData>
      <dcc:metaData refType="basic_conformity">
        <dcc:name><dcc:content lang="en">Conformity</dcc:content></dcc:name>
        <dcc:conformityXMLList>pass pass pass pass pass pass pass pass pass pass pass pass pass pass pass pass pass pass pa
        <dcc:data>
          <dcc:quantity refType="basic_toleranceLimitLower">
            <dcc:name><dcc:content lang="en">Lower conformity limit for Charge transfer coefficient magnitude</dcc:content>
            <si:realListXMLList><si:valueXMLList> 0.1236615</si:valueXMLList><si:unitXMLList> \pico\coulomb\per\metre\second\
          </dcc:quantity>
          <dcc:quantity refType="basic_toleranceLimitUpper">
            <dcc:name><dcc:content lang="en">Upper conformity limit for Charge transfer coefficient magnitude</dcc:content>
            <si:realListXMLList><si:valueXMLList> 0.1366785</si:valueXMLList><si:unitXMLList> \pico\coulomb\per\metre\second\
          </dcc:quantity>
        </dcc:data>
      </dcc:metaData>
    </dcc:measurementMetaData>
  </dcc:quantity>
</dcc:list>
```

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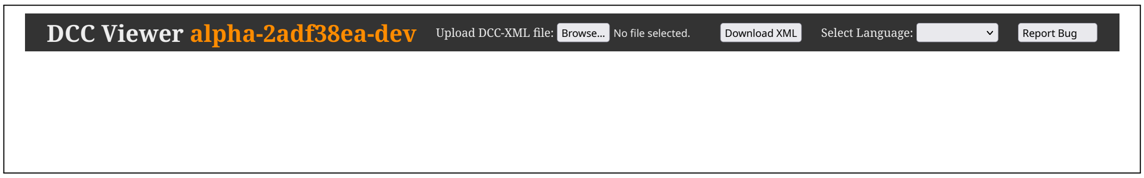
What is dccviewer-js?



- self-contained HTML file: no installation, works offline
- make *any* DCC human readable
- interactive plots for tabular data

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Plots

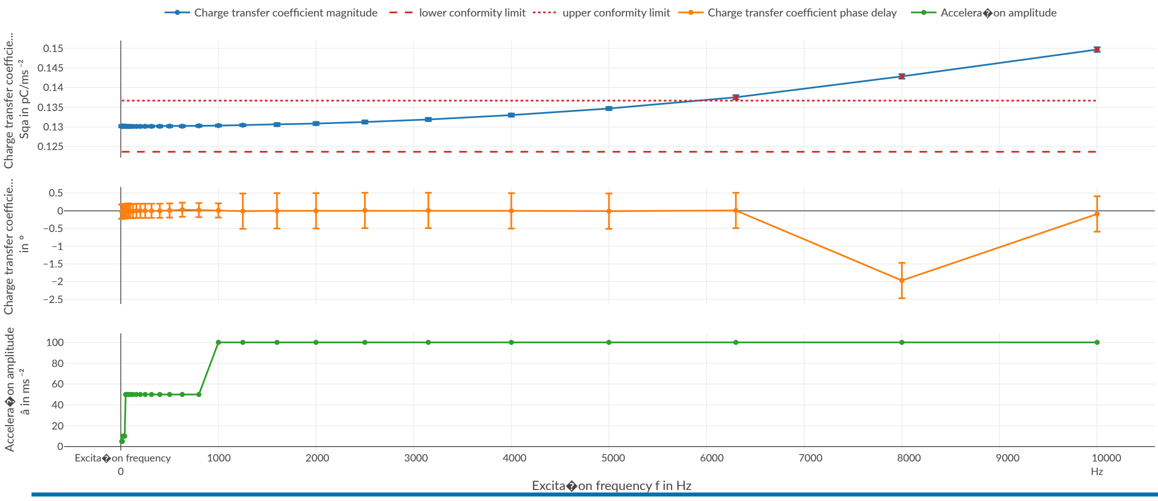
Charge transfer coefficient magnitude
lower conformity limit
upper conformity limit
Charge transfer coefficient phase delay
Accelera�on amplitude
Charge transfer coefficie... Sqa in pC/ms⁻²
Charge transfer coefficie... in °
Accelera�on amplitude â in ms⁻²
Excita�on frequency
Excita�on frequency f in Hz
Hz

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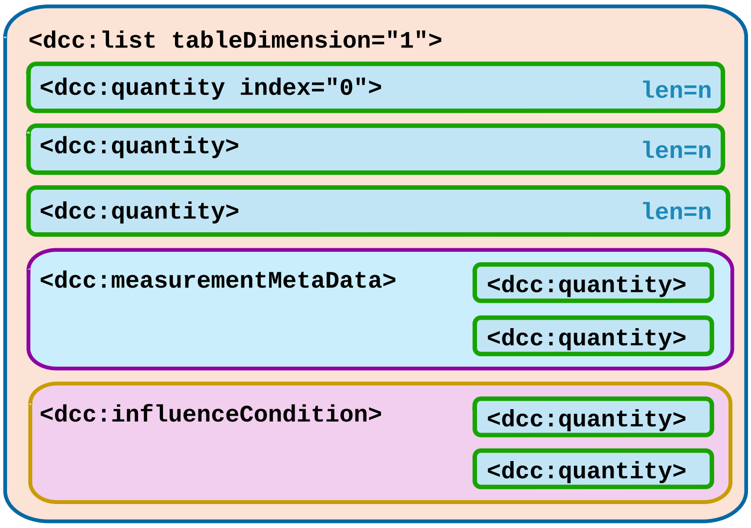
Table Structure

excitation frequency in Hz	magnitude in pC/(m/s^2)	phase delay in degrees
2500	0.13124(39)	0.01(50)
3150	0.13188(40)	0.01(50)
4000	0.13300(40)	0.00(50)
5000	0.13467(40)	−0.01(50)
6300	0.13753(55)	0.01(50)
8000	0.14285(57)	−1.97(50)
10000	0.14968(60)	−0.09(50)

`index="0"`

Tabular Data



https://wiki.dcc.ptb.de/en/tables

Live Demo

https://unpkg.com/dccviewer-js/dist/index.html#dccUrl=https://raw.githubusercontent.com/BeSeeTek/DCCView/refs/heads/main/dccs/6b7f3863-fc45-11f0-ad5c-88aedda88e32.xml

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Fallback for non-tabular data

▼ Measurement results Range 1 First Measurement (before adjustment)

▼ Repeatability

Repeatability Measurement at 100 g

	0.100 kg	Testload (nominal value)				
Measured values	0.10000006 kg	0.10000003 kg	0.10000005 kg	0.10000004 kg	0.10000005 kg	Measured values for repeated loading
	0.000000011 kg	Standard deviation of the repeatability measurement				

▼ Eccentricity Außermittige Belastung

Position1: Front left Position2: Back left Position3: Back right Position4: Front right
Eccentricity measurement at 100 g

	0.100 kg	Testload (nominal value) Testlast (Nennwert)			
Reference value	0.10000006 kg	Measured value at center position			
Measured values	Position1 = 0.10000004 kg	Position2 = 0.10000005 kg	Position3 = 0.10000007 kg	Position4 = 0.10000005 kg	Measured values at eccentric positions
Errors	Position1 = -0.00000002 kg	Position2 = -0.00000001 kg	Position3 = 0.00000001 kg	Position4 = -0.00000001 kg	Deviations from measured value at centric loading

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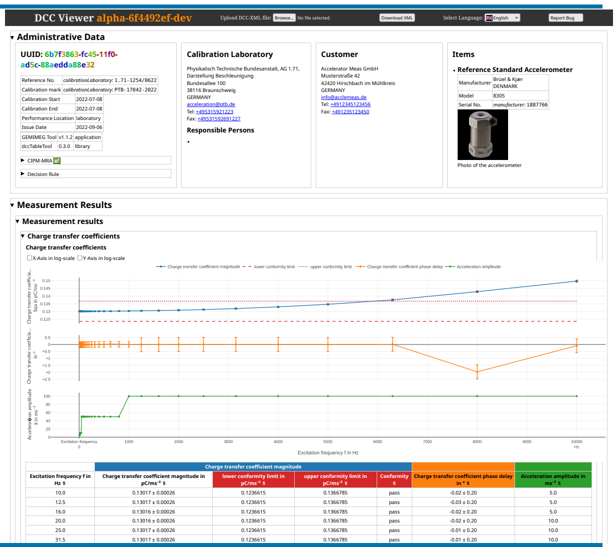
Summary

- self-contained HTML file
- no installation, works offline
- all data is displayed
- interactive
- open source: MIT-licensed
- customizable



Source code and issue tracker:
https://gitlab1.ptb.de/digitaldynamicmeasurement/dccviewer-js

Physikalisch-Technische Bundesanstalt (PTB), WG 1.73
Bundesallee 100
38106 Braunschweig
Jendrik Wenke, Benedikt Seeger, Vanessa Stehr, Jaime Gonzalez-Gomez
jendrik.wenke@ptb.de
www.ptb.de

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030 Daniel Hutzschenreuter: Application of DCCs in the Digital Metrological Expert software tool for interlaboratory comparison data analysis

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Keywords: key comparison, Digital Metrological Expert, DCC, data model

Abstract

The Digital Metrological Expert (DME) is a digital standard enabling an automated data analysis for evaluating interlaboratory comparisons [1]. It utilizes Digital Calibration Certificates [2] as universal data exchange format for reporting measurement results of participants within a comparison. A comprehensive analysis and modelling of a data structure for results of international comparisons was conducted including use-cases from metrological areas of mass, temperature, length, and chemistry. It led to a framework for providing outcomes of generic comparison data analysis within the DCC structure of measurement results.

This data structure represents an important addition to the generic architecture of the DME for interlaboratory comparison [3]. It underpins the universal useability of elements within the DCC data structure beyond calibration.

Our presentation gives an overview on the key structures for generic comparison data and a proposal of semantics for generic comparison which could be included as controlled vocabulary, e.g., “refTypes”, into DCCs.

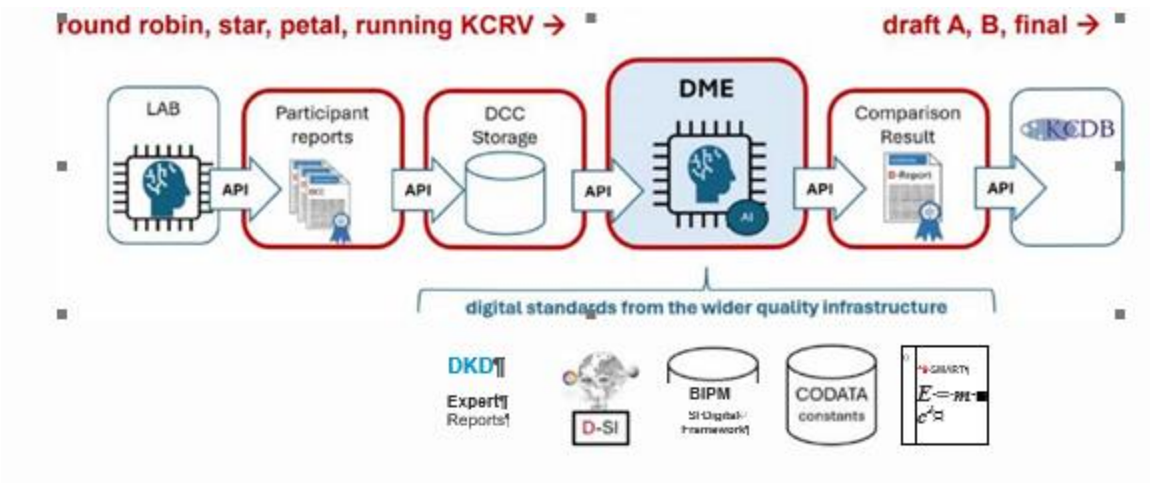

Figure 1. DME workflow for automated comparison data analysis with DCCs.

References:
[1] Brown, C., et al. (2025): A digital expert for a digital key comparison report processor, in: Measurement: Sensors, Volume 38, Supplement, May 2025, 101463
[2] DCC Webpage (2026): Digital Calibration Certificate, https://www.ptb.de/dcc/, last accessed: 26.01.2026
[3] Hutzschenreuter, D., et al. (2025): Digital Metrological Expert - design of a software for automated key comparison data analysis in a digital world, in: 2025 IMEKO TC-6 International Conference on Metrology and Digital Transformation - M4DConf 2025 Proceedings, Benevento, Italy, September 3-5, 2025

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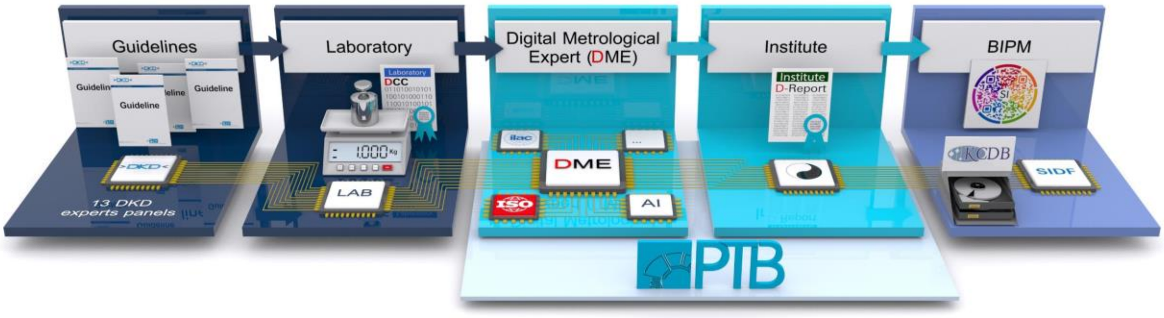
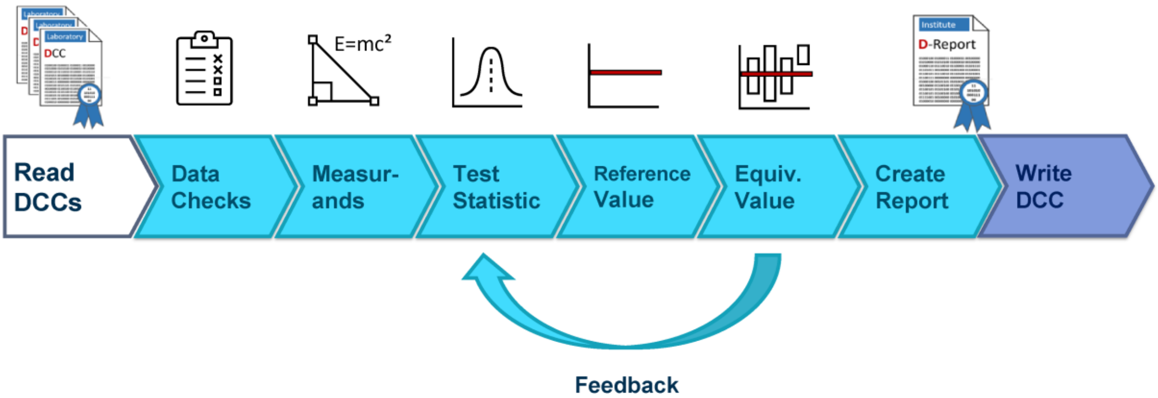
Presentation #030 of Daniel Hutzschenreuter

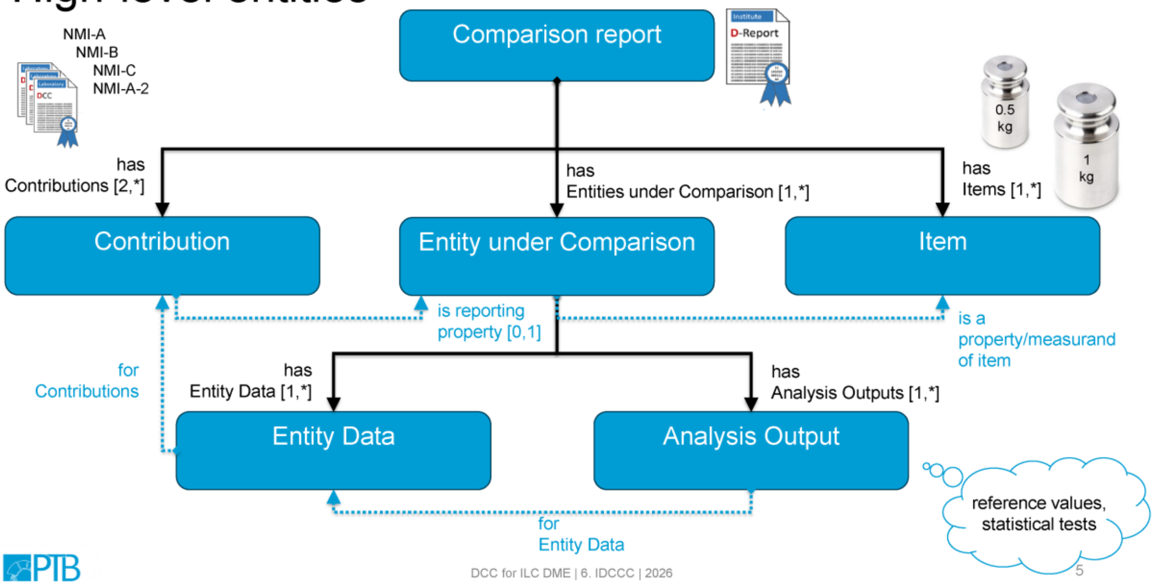
DCC used for evaluating interlaboratory comparison



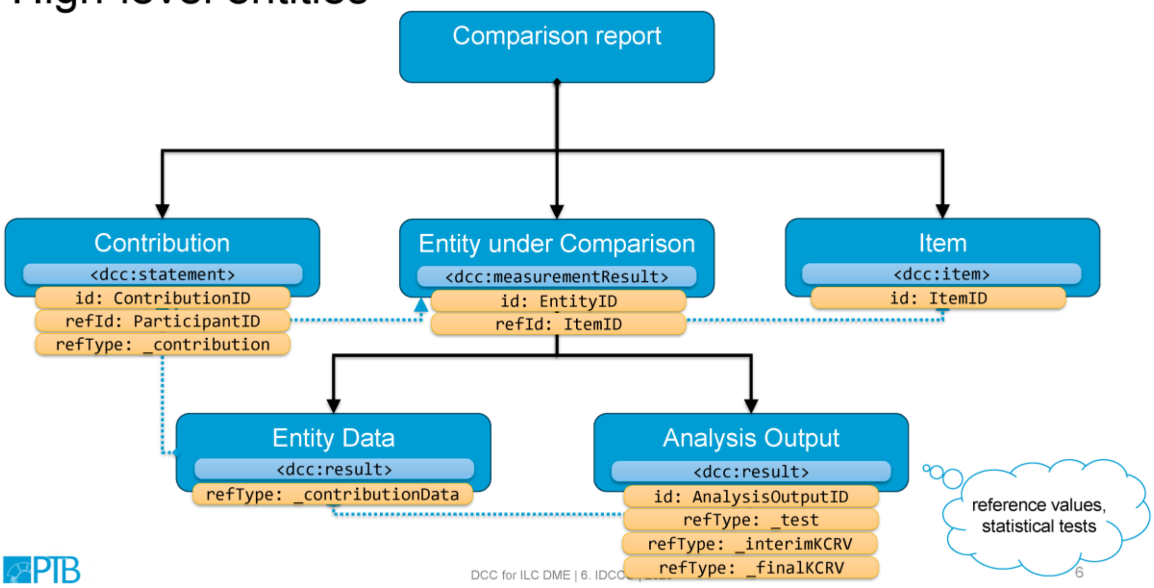
Data along comparison analysis process



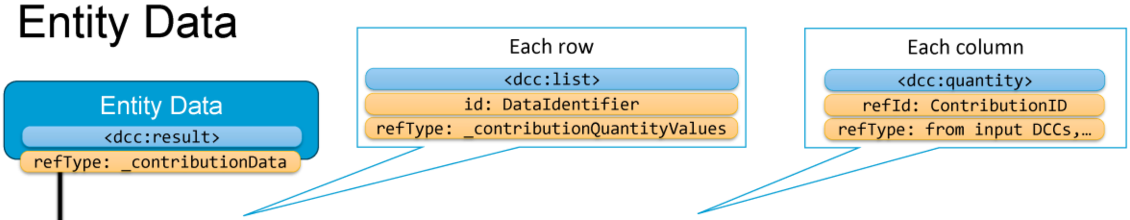
High-level entities



High-level entities

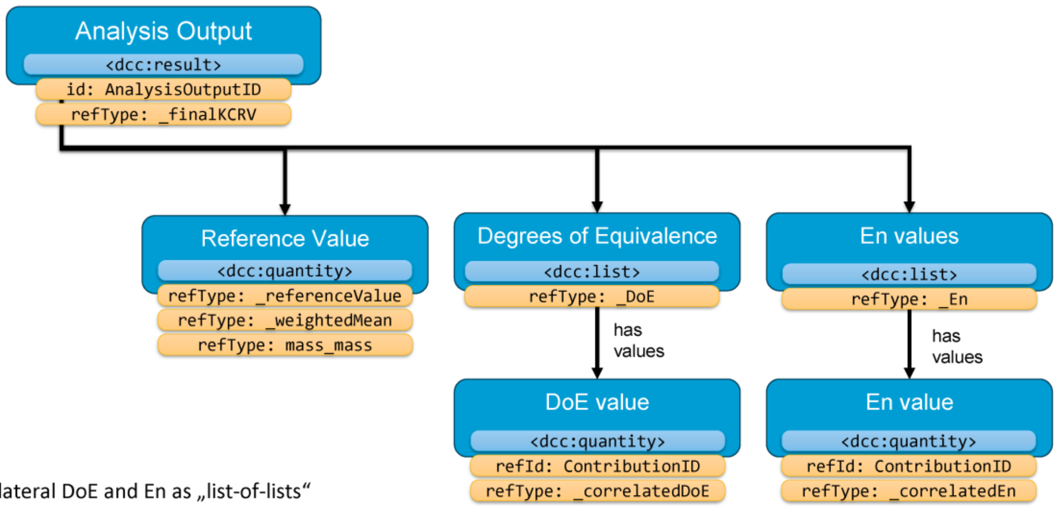


Entity Data



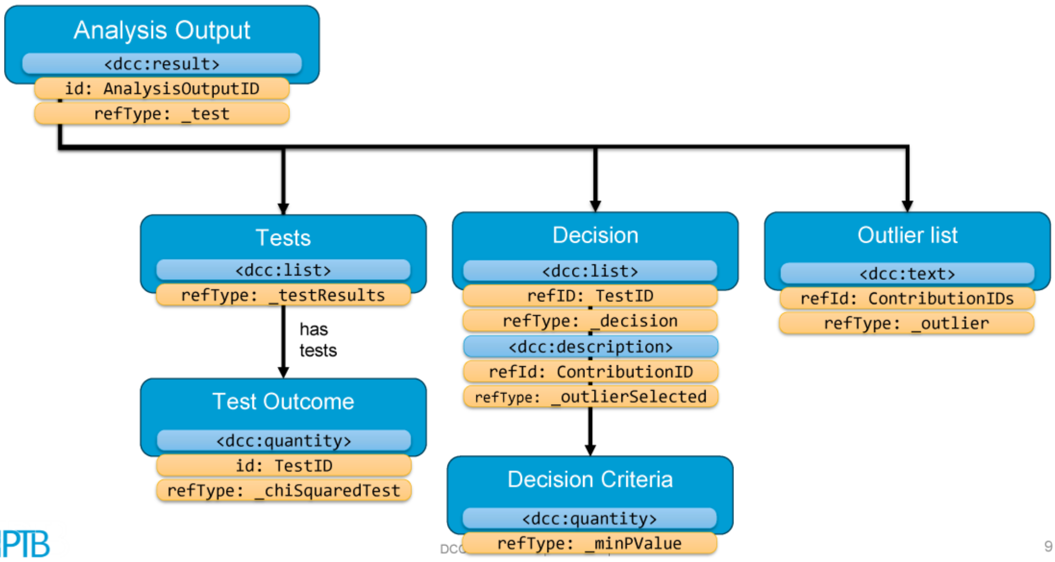
Data	Contribution 1 (pilot)	Contribution 2	Contribution 3	…	Contribution N
measured value	1.0010 kg	0.9995 kg	1.0011 kg		1.0002 kg
ambient temperature	20.01 °C	19.95 °C	19.98 °C		20.55 °C
density (some reference)	10 g/cm³	-	-		-
Difference to 1 kg	0.0015 kg	-0.0002 kg	0.0016 kg		0.0004 kg

Analysis Output – Key Comparison Reference Value (KCRV)



bilateral DoE and En as „list-of-lists“

Analysis Output – Hypothesis tests



Summary of semantics

Vocabulary in Namespace „comparison“

Entities, Classes
- _contribution, _contributionData
- _finalKCRV, interimKCRV
- _test, _testResults
- _outlier

Kinds of quantities
- _DoE
- _En

Calculated measurands, Methods
- _referenceValue, _weightedMean
- _correlatedDoE
- _chiSquaredTest, _minPValue

Relations between data

Defining “id” to identify
- participants and contributions
- items and entities under comparison
- input data measurands
- test outcomes

Using “refID” to associated
- Results to items, measurands, contributions
- Decisions to outcomes of tests
- Contributions to lists of outliers

XML hierarchy
- Express “has” relations

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031 Vashti Galpin: Digital calibration certificates for X-ray Photoelectron Spectroscopy

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[1] University of Edinburgh, United Kingdom
Additional authors: Nil
Keywords: DCC, XPS, XML, GEMIMEG, temporal databases

Abstract

This presentation will report on work done in collaboration with NPL, the UK's national metrology institute, on the use of digital calibration certificates (DCCs). The DCC XML schema developed by PTB and others in the DCC initiative [1], has been applied to X-ray Photoelectron Spectroscopy (XPS) calibration. This calibration process involves taking measurements using reference materials (gold, silver and copper). These measurements are used to fit a response function, called the calibration function, which can be applied for intensity correction in the operation of the instrument [2],

NPL has recently launched an online portal to provide this service [3], Measurements of the reference materials are submitted in VAMAS format, and the appropriate calculations are made to generate the response function. This function is reported both as (i) a collection of coefficients for use in a standard equation, and (ii) as a set of measurements in VAMAS format that can be used by supported spectrometers as correction data. A PDF calibration certificate can also be issued which includes information about the input measurements (such as pass energy and anode details), and output measurements (such as expanded measurement uncertainty, divergence measures for each reference material and scatter).

This presentation will describe the outcomes of the investigation into XPS DCCs, specifically:

- Using illustrative data from the portal database, examples of DCC use for XPS were generated with the support of the GEMIMEG tool [4] and will be demonstrated.
- A web application [5] was developed using the Links programming language and temporal database technology, extending earlier work on this approach [6],
    - The application can generate XPS DCCs from portal data.
    - The application shows data changes that have occurred within a DCC.
    - The application allows for the comparison of DCCs across instruments, including (over multiple DCCs for an instrument, and over a specific instrument type/brand. The differences are tabulated, and temporal changes to the data are noted.

To the best of our knowledge, digital calibration certificates have not been previously used in this area of metrology, and the XPS calibration process is very different to those of the existing good-practice DCCs for temperature, humidity and gauge blocks. Hence, this investigation and its related software development have broadened the use of DCCs within metrology and contributed to ongoing digitalisation efforts.

Acknowledgements: Vashti Galpin was funded by a Royal Society Short Industry Fellowship (2022 Round 2: SIF\R2\222052) awarded to James Cheney.

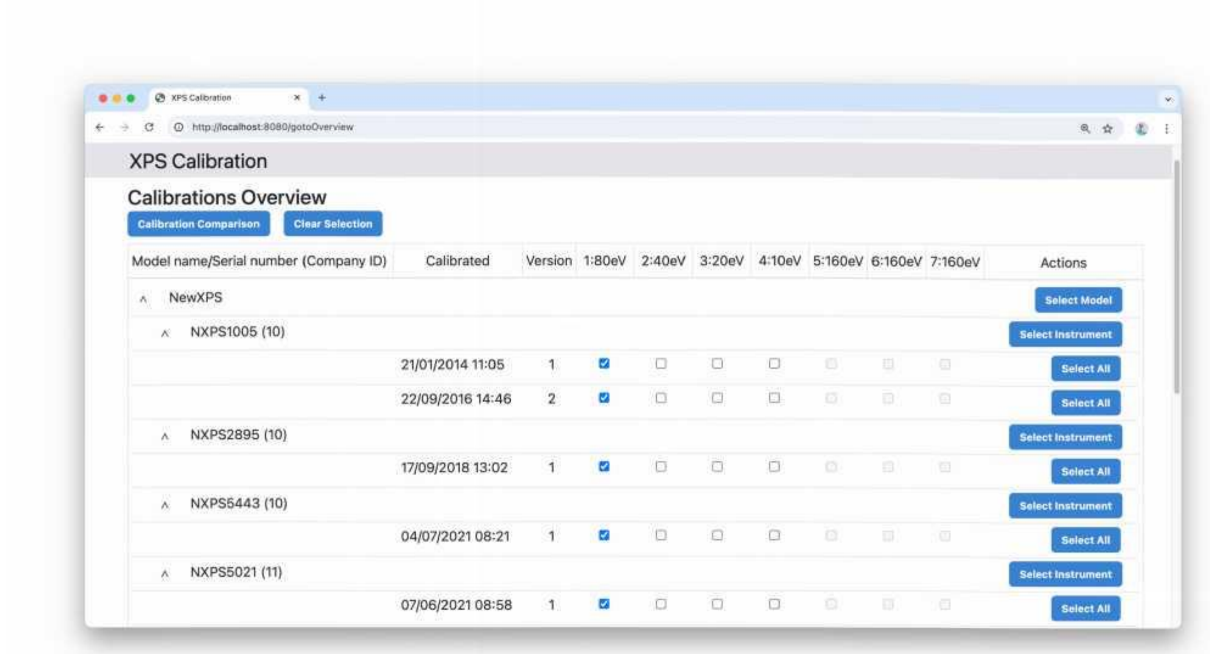

Figure 1. Choosing calibrations for comparison

References:

[1] PTB (2026): Digital Calibration Certificate, [https://www.ptb.de/dcc/], last accessed: 04.02.2026
[2] Seah, M.P. (1995): A system for the intensity calibration of electron spectrometers, in: Journal of Electron Spectroscopy and Related Phenomena 71, 191-204, [https://doi.org/10.1016/0368-2048(94)02275-5]
[3] NPL (2026): XPS Intensity Calibration, [https://xps.npl.co.uk/about/general1, last accessed: 03.02.2026
[4] PTB (2026): GEMIMEGv 1.5.0. [https://gemimeg-tool.ptb.de/vl1, last accessed: 03.02.2026
[5] vcgalpin (2026): xps-dcc-app, [https://github.com/vcgalpin/xps_dcc_app], last accessed: 04.02.2026
[6] Galpin, V., Smith, I., Hippolyte, J.-L. (2023): Tracking and viewing modifications in digital calibration certificates, in: ActaIMEKO 12(1), [https ://doi.org/l 0.21014/actaimeko.vl 2i 1.1407]

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Presentation #031 of Vashti Galpin

Digital calibration certificates (DCCs) for X-ray Photoelectron Spectroscopy (XPS)

Vashti Galpin
University of Edinburgh

6th International DCC Conference 2026
From Good Practice to Standardization: DCC for a Reliable Future

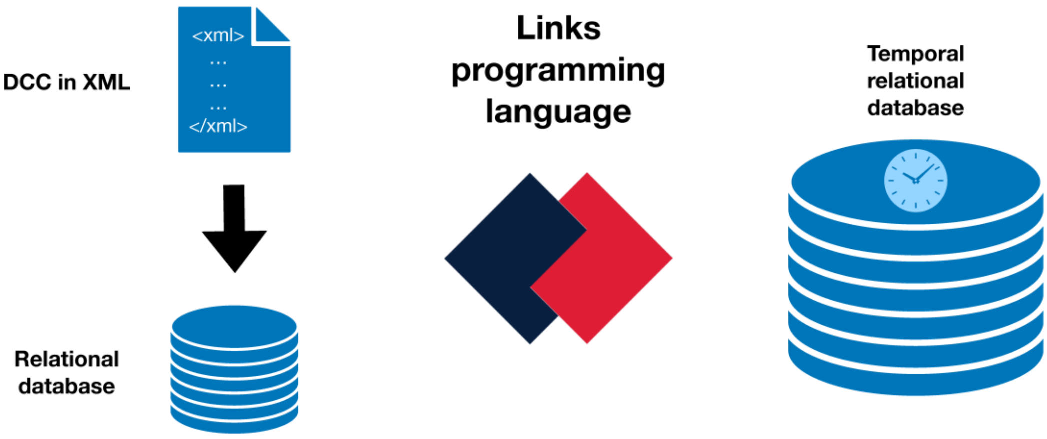
2

Introduction, motivation and background

- Recent funding from the Royal Society to work with NPL
  - Digital calibration certificates as XML document
  - Temporal databases for tracking changes in XML documents
  - Extends earlier work on DCCs in this context
- Case study: X-ray Photoelectron Spectroscopy
  - NPL's new online system for XPS calibration
- Contributions
  - Application of XML DCC schema to XPS calibration data
  - Open source demo web application for interacting with XPS DCCs

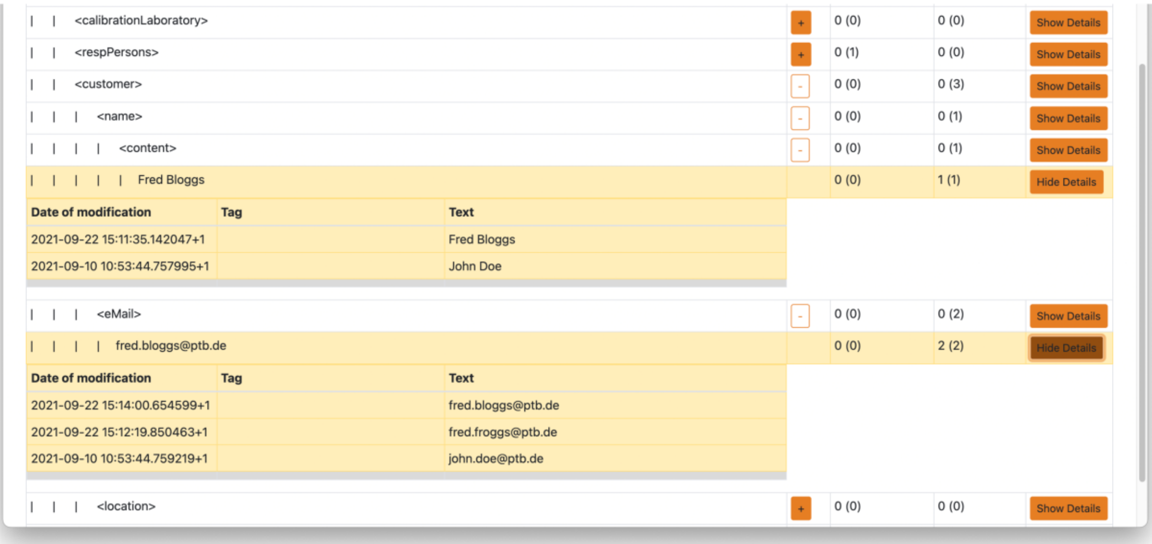
3

Previous work with DCCs: single DCC demo



https://github.com/vcgalpin/dcc-xml-temporal

Certificate comparison — details of changes



<calibrationLaboratory>	+	0 (0)	0 (0)	Show Details
<respPersons>	+	0 (1)	0 (0)	Show Details
<customer>	-	0 (0)	0 (3)	Show Details
<name>	-	0 (0)	0 (1)	Show Details
<content>	-	0 (0)	0 (1)	Show Details
Fred Bloggs		0 (0)	1 (1)	Hide Details

Date of modification	Tag	Text
2021-09-22 15:11:35.142047+1		Fred Bloggs
2021-09-10 10:53:44.757995+1		John Doe

<eMail>	-	0 (0)	0 (2)	Show Details
fred.bloggs@ptb.de		0 (0)	2 (2)	Hide Details

Date of modification	Tag	Text
2021-09-22 15:14:00.654599+1		fred.bloggs@ptb.de
2021-09-22 15:12:19.850463+1		fred.froggs@ptb.de
2021-09-10 10:53:44.759219+1		john.doe@ptb.de

<location>	+	0 (0)	0 (0)	Show Details

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Online intensity calibration: xps.npl.co.uk

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XPS calibration process

- The customer generates measurements from reference materials: copper, silver, gold.
- The data is submitted via the online portal using the VAMAS data format.
- The NPL software performs appropriate calculations that provide uncertainty measurements together with a response function Q(E), both as points and coefficients for an equation.
- The customer can download a PDF calibration certificate and details of the response function, along with other information.
- The response function can then be used with the equipment to ensure accurate measurement
- There are substantial amounts of data to be stored

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Application of DCC schema: overview

- The data involved differs substantially the existing good practice examples at https://wiki.dcc.ptb.de/en/gp_home and is stored in an SQL database.
- Differences include providing a function as a result (rather than a small number of scalar values), datasets as input (rather than a few values), and multiple materials.
- Working with GEMIMEG, I made a number of decisions on how to store this data in the DCC schema, specifically in the measurement results. This did not include the use of refTypes. Dummy data was generated from a few examples.
- A specific reason to use GEMIMEG is that it can output a human-readable calibration certificate, allowing for comparison with an actual calibration certificate.
- The GEMIMEG interface provided guidance for the decisions about the data and how it should be organised but the process was still challenging and is only a starting point.

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Application of DCC schema: usage

```
<dcc:digitalCalibrationCertificate>
  <dcc:administrativeData>
     . . .
  <dcc:measurementResults>
     <dcc:measurementResult>

       <dcc:name> Pass Energy:10.0

      <dcc:usedMethods >
         <dcc:usedMethod> Intensity/energy response function Q(E), reference to original paper, DOI
         <dcc:usedMethod> Analyser mode
         <dcc:usedMethod> Anode material

     <dcc: influenceConditions>
         <dcc:influenceCondition> Pass energy
         <dcc:influenceCondition> Gamma angle
         <dcc:influenceCondition> Xi angle
         <dcc:influenceCondition> Anode voltage
         <dcc:influenceCondition> Anode emission
```

```
<dcc:name>
   <dcc:content> . . .
<dcc:data>
    <dcc:quantity>
       <si:real>
          <si:value> . . .
          <si:unit> . . .
```

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Application of DCC schema: usage

<dcc:Results >

<dcc:Result> Copper
<dcc:Result> Silver
<dcc:Result> Gold
<dcc:Result> Pointwise representation of Q(E)

Each of the above are a list of pairs, representing an input energy value and the related output value

<dcc:name><dcc:content> • • •
<dcc:description><dcc:content> • • •
<dcc:data>
<dcc:list>
<dcc:quantity><dcc:name><dcc:content>
<si:realListXMLList> • • •
<dcc:quantity><dcc:name><dcc:content>
<si:realListXMLList> • • •

<dcc:Result> Co-efficients for Q(E), LaTeX formula for Q(E)
<dcc:Result> Additional results (various values that appear in the calibration certificate)

<dcc:Result> Uncertainty results

<dcc:data><dcc:quantity>
<dcc:name ><dcc:content> • • •
<si:real><si:value><si:unit><si:expandedUnc>
<si:uncertainty> • • •
<si:coverageFactor> • • •
<si:coverageProbability> • • •

<dcc:measurementMetaData> Repetition of influence conditions

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GEMIMEG human-readable output

Measurement Results

Measurement Result PE20

Used Methods

- Used Method 1

  Name Intensity/Energy response function Q(E)
  Description The Intensity/Energy response function Q(E) is derived using TBC Software Release 9/99 (see J. Elec. Spectrosc. 71, referred to the Fermi Level. This calibration is for XPS data recorded in accordance with Spectrum Acquisition Guide
  Reference https://doi.org/10.1016/0368-2048(94)02275-5
- Used Method 2

  Name Analyser mode
  Description FAT
- Used Method 3

  Name Anode material
  Description Aluminium Mono

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GEMIMEG human-readable output

Influence Conditions

- Influence Condition 1

Name Pass energy
Description electronvolt (eV) is not an SI unit and could be converted to \Joule at 1eV = 1.602176634×10−19 \Joule

Label	PE
Unit	
Value	20

- Influence Condition 2

Name Gamma angle

Unit	°
Value	54.7

- Influence Condition 3

Name Xi angle

Unit	°
Value	0

- Influence Condition 4

Name Anode voltage

Unit	kV
Value	15

- Influence Condition 5

Name Anode emission

Unit	mA
Value	3

Results

Copper

Smoothed data

X-axis	Y-axis
1.0	4.0
2.0	8.0

Incomplete

Silver

Smoothed data

X-axis	Y-axis
1.0	4.0
2.0	8.0

Incomplete

Gold

Smoothed data

X-axis	Y-axis
1.0	4.0
2.0	8.0

Incomplete

Q(E)

Pointwise representation of response function (derived from Copper, Silver and Gold data)

X-axis	Y-axis
1.0	4.0
2.0	8.0

Incomplete

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GEMIMEG human-readable output

Q(E)

Equational representation of response function

$Q(E) = \frac{a_0+a_1\varepsilon+a_2\varepsilon^2+a_3\varepsilon^3+a_4\varepsilon^4}{1+b_1\varepsilon+b_2\varepsilon^2+b_3\varepsilon^3+b_4\varepsilon^4} X_0 \text{ units where } \varepsilon = \frac{E-1000 \text{ eV}}{1000 \text{ eV}}$

a_0	a_1	a_3	a_4	b_1	b_2	b_3	b_4
2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0

$$\boxed{Q(E) = \frac{a_0+a_1\varepsilon+a_2\varepsilon^2+a_3\varepsilon^3+a_4\varepsilon^4}{1+b_1\varepsilon+b_2\varepsilon^2+b_3\varepsilon^3+b_4\varepsilon^4} X_0 \text{ units where } \varepsilon = \frac{E-1000 \text{ eV}}{1000 \text{ eV}}}$$

Q(E)

Additional results

Minimum valid calibration energy: E_{min}	Maximum valid calibration energy: E_{max}	Label	Percentage rms scatter	Energy calibration shift indicated: E_{ind}	Er
2.0	2.0	r	2.0	0.0	0.(

U_r

Relative uncertainty in the energy independence of Q(E), ignoring the uncertainty of the method

Uncertainty of response function
0

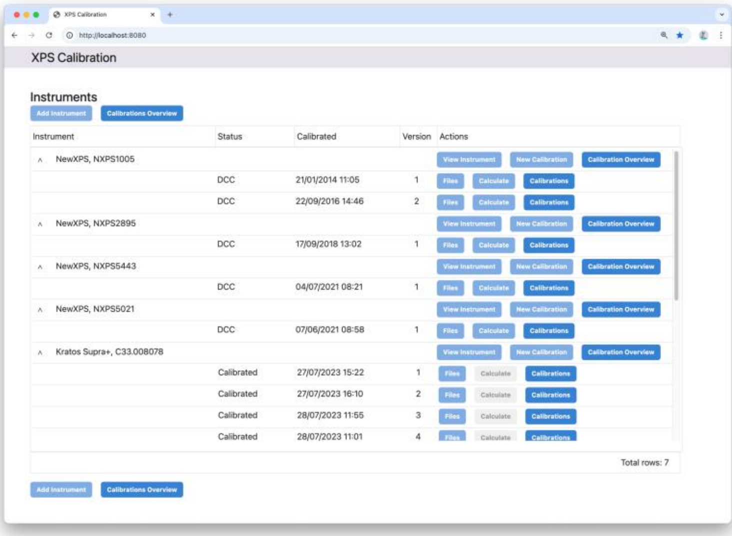
Expanded Measurement Uncertainty

Unit	Uncertainty	Coverage Factor	Coverage Probability
	4.2	2	0.95

Demo web application for XPS DCCs

- This uses the database schema for the NPL software plus additional relational tables (both temporal and non-temporal) for storing and working with DCCs.
- Given the data provided for a calibration, and assuming that the required calculations have been done, the app creates a DCC from the data in the database.
- The app provides a list of instruments (mimicking the NPL software).
- The DCCs for each instrument can be generated and inspected.
- The app has a page providing an overview of all calibrations and allows selection for comparison.
- Once calibrations have been selected, the items in the DCC for comparison can be chosen and the comparison performed.
- In the comparison, data changes within a single DCC are highlighted.

Web app: instruments overview



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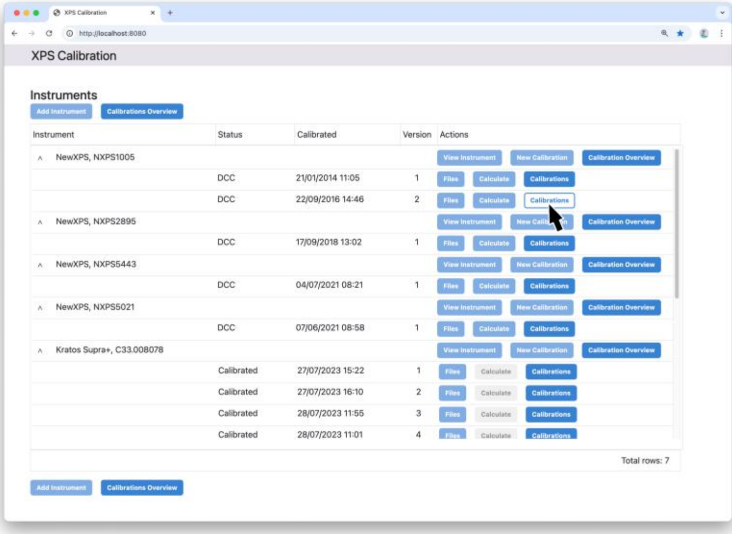
Web app: selecting a calibration



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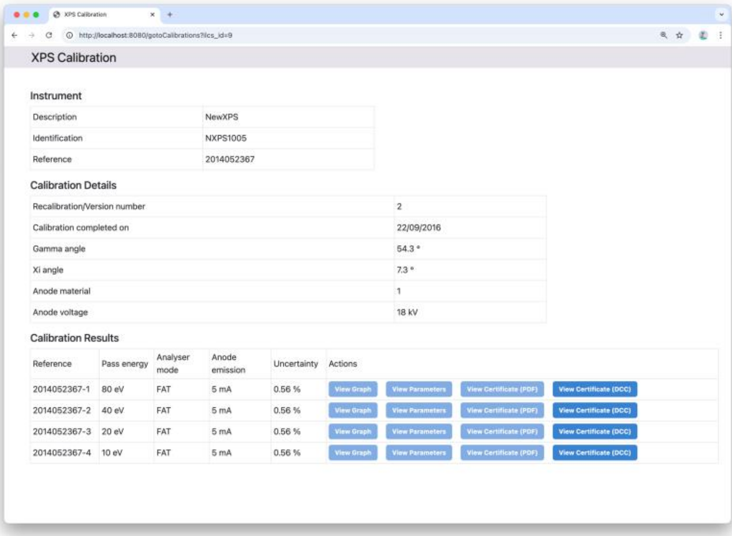
Web app: selecting a calibration



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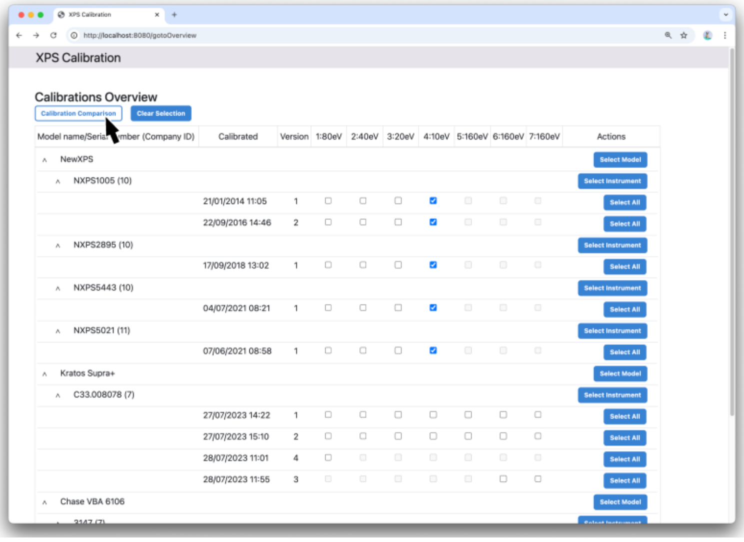
Web app: calibrations overview/selection



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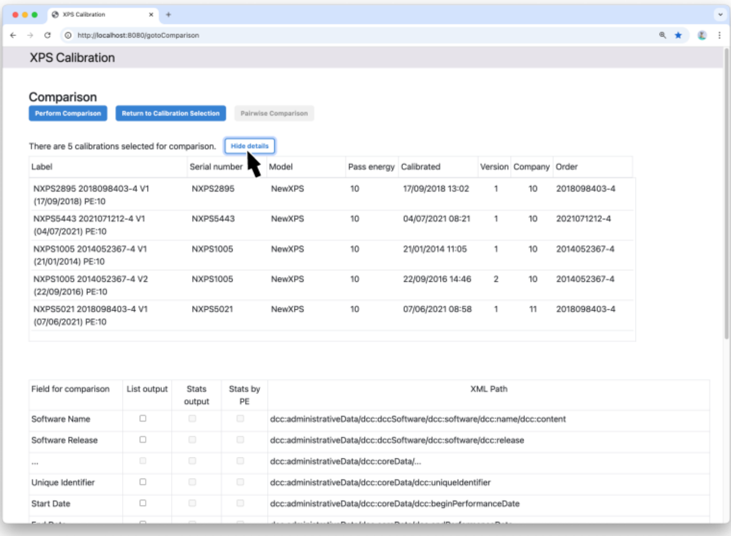
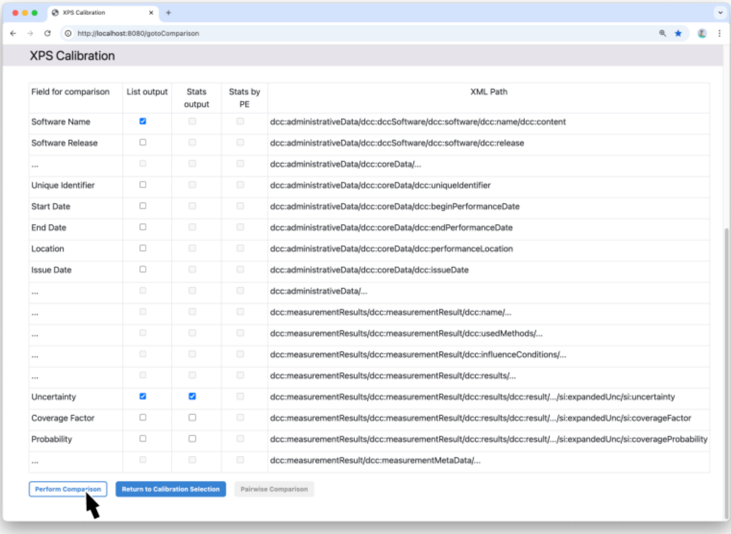
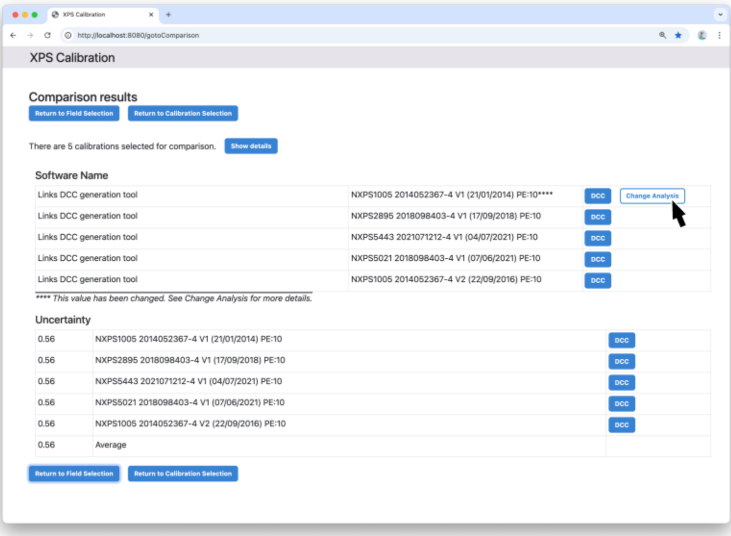
Web app: data selection for comparison



Web app: data selection for comparison



Web app: results of comparison



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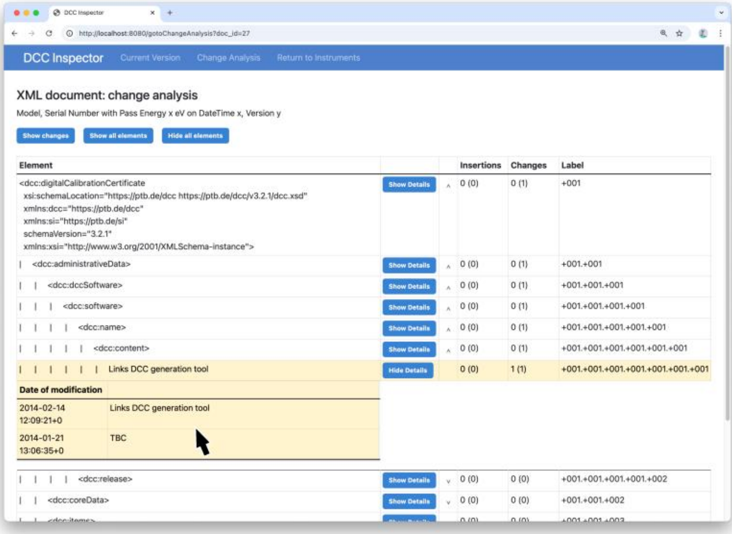
Web app: change in DCC values



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Conclusions

- The XML DCC schema has been applied to XPS calibration.
- The web app originally written to deal with a single DCC has now been expanded to deal with multiple DCCs and comparison between them.
- The software and DCC examples are open source, written in Links and can be found at https://github.com/vcgalpin/xps_dcc_app.
- Currently, there is very little documentation but this will be improved over the next few months.
- The documentation aims to provide information about the general approach taken so that the concepts used in this work will be available to the metrology community.

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References

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- **PTB** (2026): Digital Calibration Certificate, https://www.ptb.de/dcc/
- **PTB** (2026): GEMIMEG v1.5.0, https://gemimeg-tool.ptb.de/v1
- **vcgalpin** (2026): xps-dcc-app, https://github.com/vcgalpin/xps_dcc_app
- **vcgalpin** (2023): Update provenance of digital calibration certificates using Links and temporal databases, https://github.com/vcgalpin/dcc-xml-temporal
- **Galpin, V., Smith, I., Hippolyte, J.-L.** (2023): Tracking and viewing modifications in digital calibration certificates, Acta IMEKO 12(1), https://doi.org/10.21014/actaimeko.v12i1.1407
- **Seah, M.P.** (1995): A system for the intensity calibration of electron spectrometers, Journal of Electron Spectroscopy and Related Phenomena 71, 191-204, https://doi.org/10.1016/0368-2048(94)02275-5

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https://homepages.inf.ed.ac.uk/vgalpin1 **https://github.com/vcgalpin**

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Acknowledgments

Royal Society Short Industry Fellowship (2022 Round 2: SIF\R2\222052) awarded to **James Cheney**.

The people at NPL with whom I worked with during my secondment

Thank you for your attention

Any questions, comments or feedback?

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Day 3 2026-02-26 Thursday
Parallel Session “DCC Use Case”
Session Chair: David Balslev-Harder

032 Wiebke Heeren: DCC to Industry - Processes in a Practical Use-Case

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- Jens Schüür [2], j.schueuer@elmtec.de
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[2] ELMTEC Ingenieurgesellschaft mbH, Kattreppeln 28, Königslutter am Elm, 38154, Germany.
Keywords: DCC, Good Practice, Software Integration, Use Case, Workflow

Abstract

The BMFTR-funded “DCC2Ind” (Digital Calibration Certificate to Industry [1]) project - a substantial use case exploring end-to-end digital traceability from the national metrology institute through an accredited calibration laboratory to the industrial customer - highlights both the possibilities and inherent challenges of generating and integrating Digital Calibration Certificates (DCCs) into practical measurement workflows. This project, centered on gas humidity, demonstrates a phased approach involving template development, workflow establishment, and software integration, directly addressing the need for automated traceability chains.

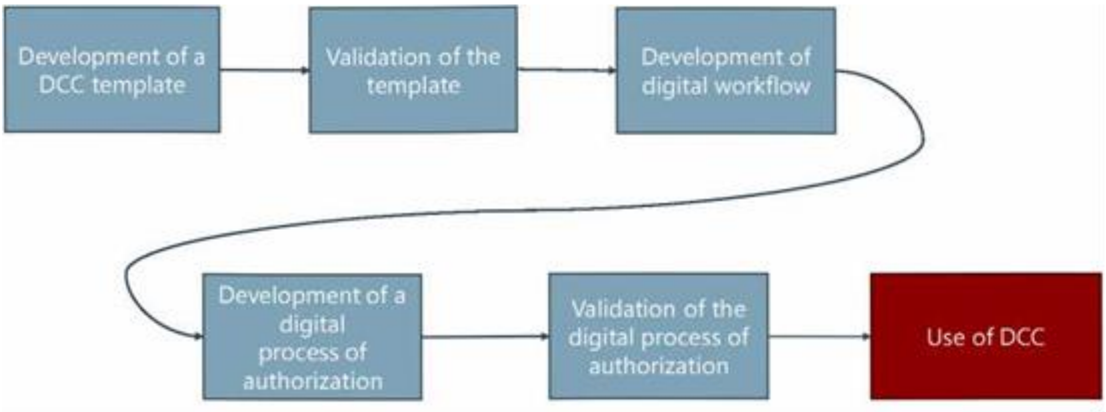
On the part of the NMI, the first step of the integration process is the provision of an aligned and harmonized DCC template. Relevant content for the template is established in coordination with multiple stakeholders including DKD subcommittees and incorporating internal quality management processes. This iterative process is complemented by integrating a digital workflow designed for DCC generation, validation, and processing into the existing laboratory software environment.

A key practical implementation involves the accredited calibration laboratory’s development of a dedicated software solution capable of verifying DCCs, performing plausibility checks, and storing essential metrological and administrative data within a calibration management system. This system amongst others incorporates machine-interpretable data export for drift control - facilitating seamless data transfer to the end customer.

The project's overarching goal is to automate the entire process, mirroring the conventional analogue traceability chain but with enhanced digital efficiency. This includes automated dispatching and synchronization of data alongside a web database for redundancy and verification. Furthermore, the development incorporates features like defining a user interface for writing and reading key DCC data, enabling real-time status verification and implementation on a webserver for revision control [2],

Ultimately, this project seeks to enable industries to request, receive, and verify DCCs, extracting essential information required in subsequent manufacturing processes. The presenta-

tion will focus on establishing the DCC within an NMI laboratory, covering template preparation and incorporation into existing processes, while also addressing potential challenges and positive outcomes associated with this digital transformation.



References:

[1] www.ptb.de (2025): Home-DCC 2 Industry, [https://www.ptb.de/dcc2ind/home/], last accessed: 03.02.2026

[2] Schüür, Jens (2026): *A web based revision validation system for (digital) calibration certificates,* at: DCC Conference 2026

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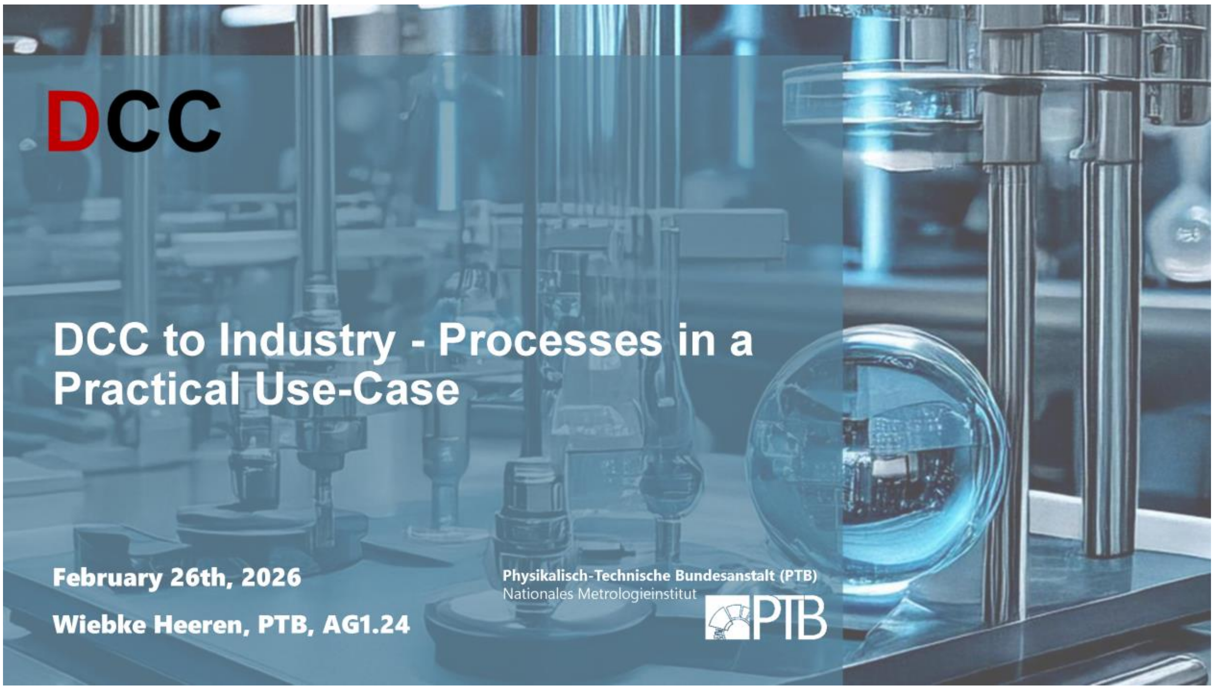
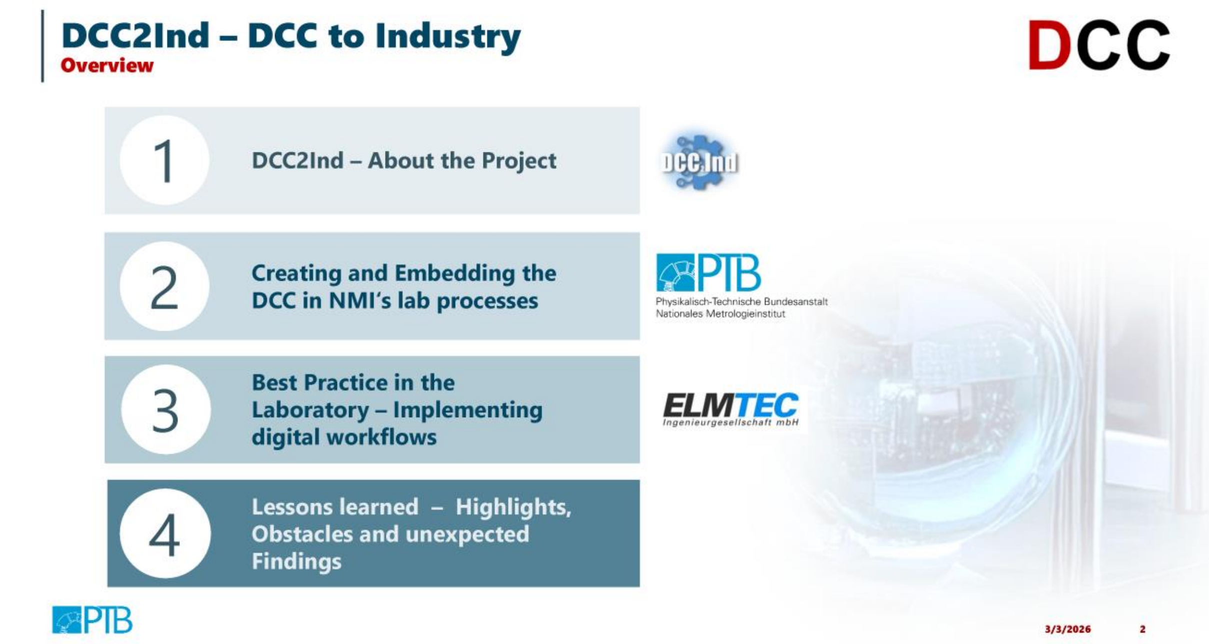
Presentation #032 of Wiebke Heeren




DCC2Ind – DCC to Industry
Overview
DCC
1
DCC2Ind – About the Project
DCC2Ind
2
Creating and Embedding the DCC in NMI's lab processes
PTB
Physikalisch-Technische Bundesanstalt
Nationales Metrologieinstitut
3
Best Practice in the Laboratory – Implementing digital workflows
ELMTEC
Ingenieurgesellschaft mbH
4
Lessons learned – Highlights, Obstacles and unexpected Findings
PTB
3/3/2026
2


DCC
DCC2Ind
–
About the Project
DCC2Ind


Project
Goals
DCC
DCC2Ind: Vollständig digitale Rückführungskette vom nationalen Metrologieinstitut in die Industrie
Beteiligte
Dr.-Ing. Shanna Schönhals,
Physikalisch-Technische Bundesanstalt PTB
Jens Schüür,
ELMTEC Ingenieurgesellschaft mbH
Art der Innovation
vorwiegend sozial
vorwiegend technisch
INTERNATIONALER STANDARD IN DER KALIBRIERUNG VON MESSMITTELN
MESSTECHNIK IST ÜBERALL
DOKUMENTATION
ENTWICKLUNG VON WERKZEUGEN UND LÖSUNGEN
KALIBRIER-SCHEIN
Project Goals:
Creation, Processing and Transfer of a DCC
Good Practice Example/ Template
Demonstrator
From the NMI via an accredited calibration laboratory through to the industrial customer
Creation of a specialized good practice template and integration in the existing NMI's laboratory settings
Reading and providing of data from a DCC.
Creation and Transmission of a DCC using existing measurement data.
PTB
Bundesministerium für Bildung und Forschung
DATIpilot
3/3/2026
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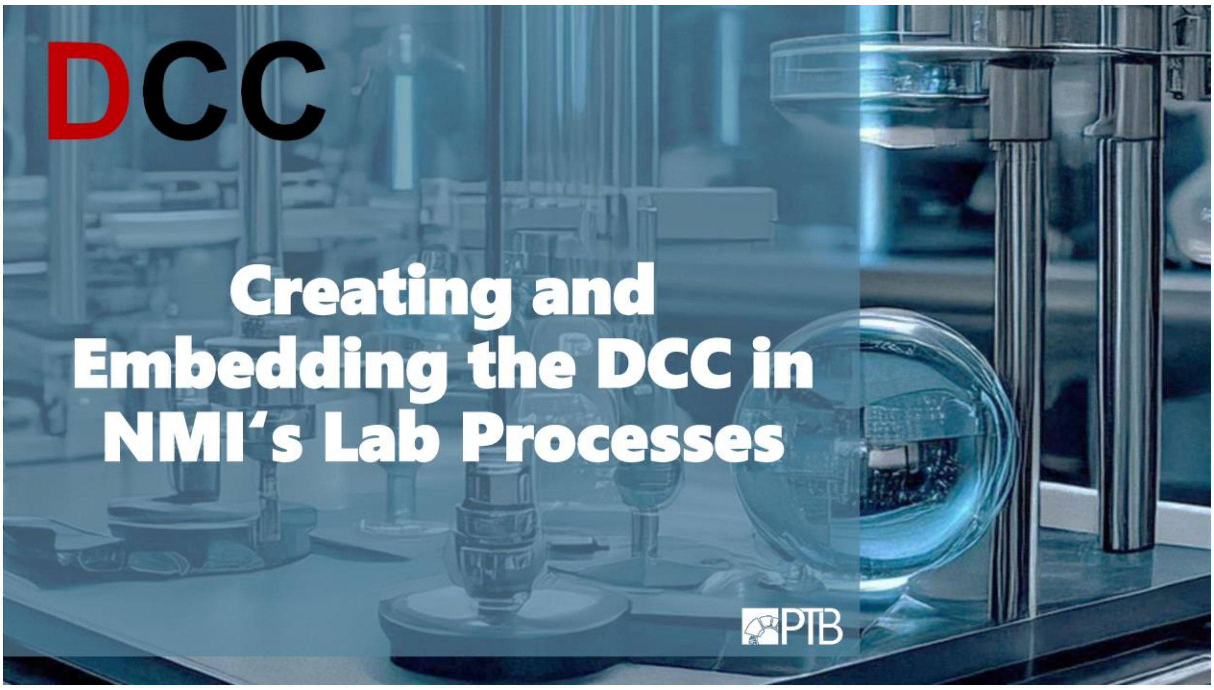
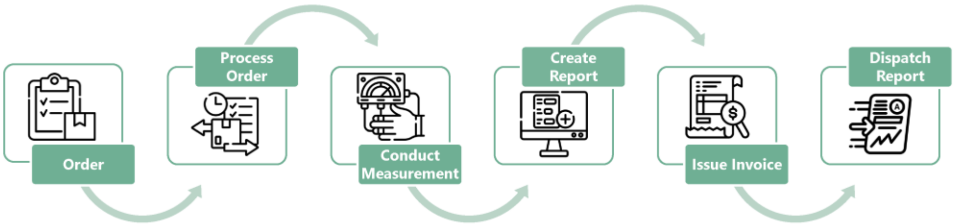

DCC
Creating and Embedding the DCC in NMI´s Lab Processes
PTB

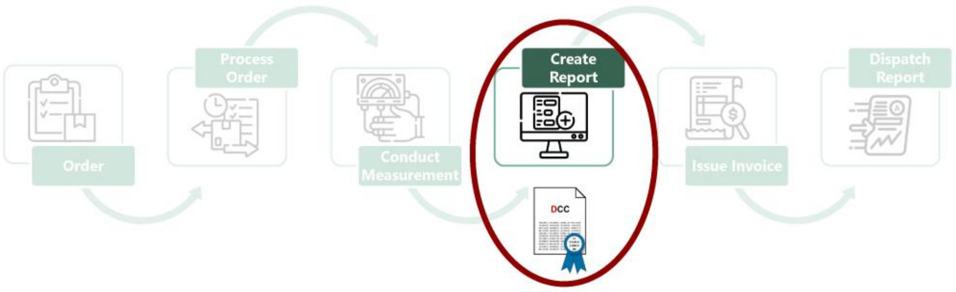
Context of the DCC
Digital Workflow

DCC



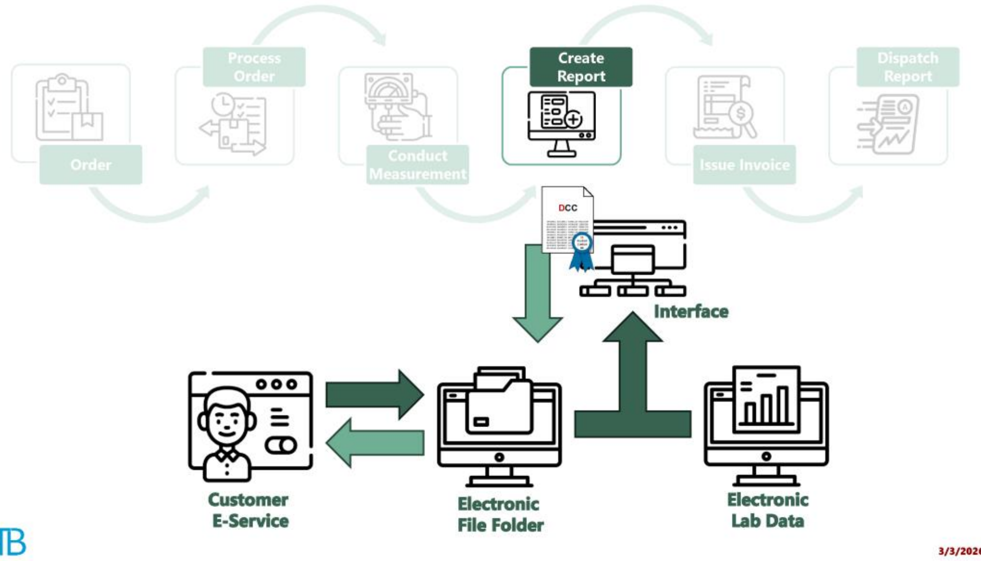
Context of the DCC
Digital Workflow

DCC



Context of the DCC
Digital Workflow

DCC



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En Route to DCC
Required Steps

DCC

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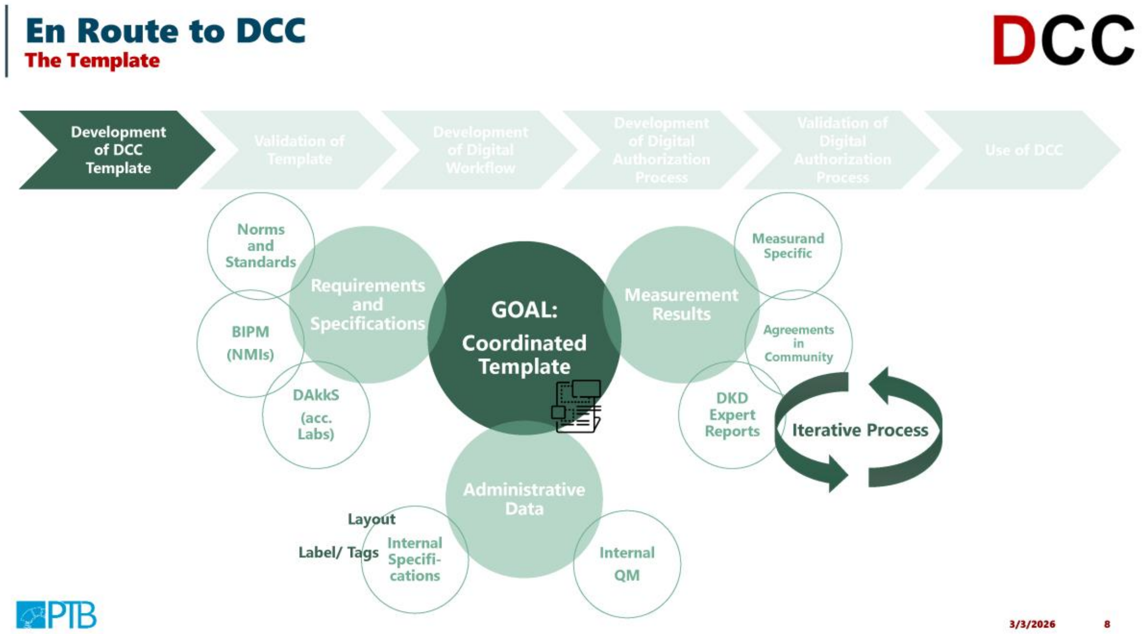
En Route to DCC
The Template
DCC
Development of DCC Template
Validation of Template
Development of Digital Workflow
Development of Digital Authorization Process
Validation of Digital Authorization Process
Use of DCC
Norms and Standards
Requirements and Specifications
BIPM (NMIs)
DAkkS (acc. Labs)
GOAL: Coordinated Template
Measurement Results
Measurand Specific
Agreements in Community
DKD Expert Reports
Iterative Process
Administrative Data
Layout
Label/ Tags
Internal Specifi-cations
Internal QM
3/3/2026
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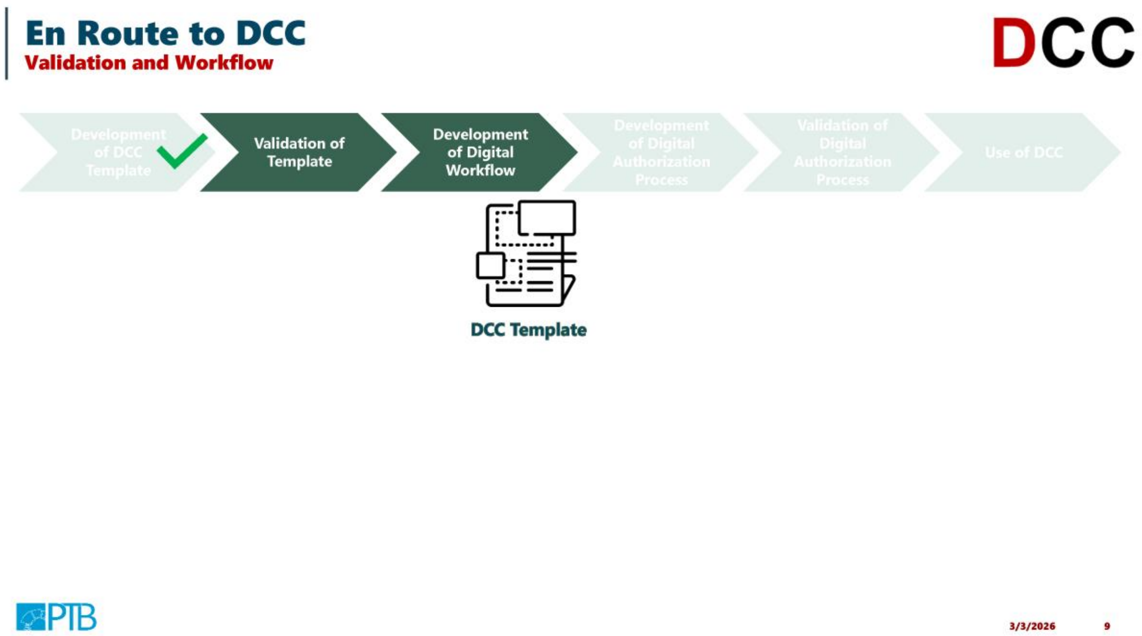
En Route to DCC
Validation and Workflow
DCC
Development of DCC Template
Validation of Template
Development of Digital Workflow
Development of Digital Authorization Process
Validation of Digital Authorization Process
Use of DCC
DCC Template
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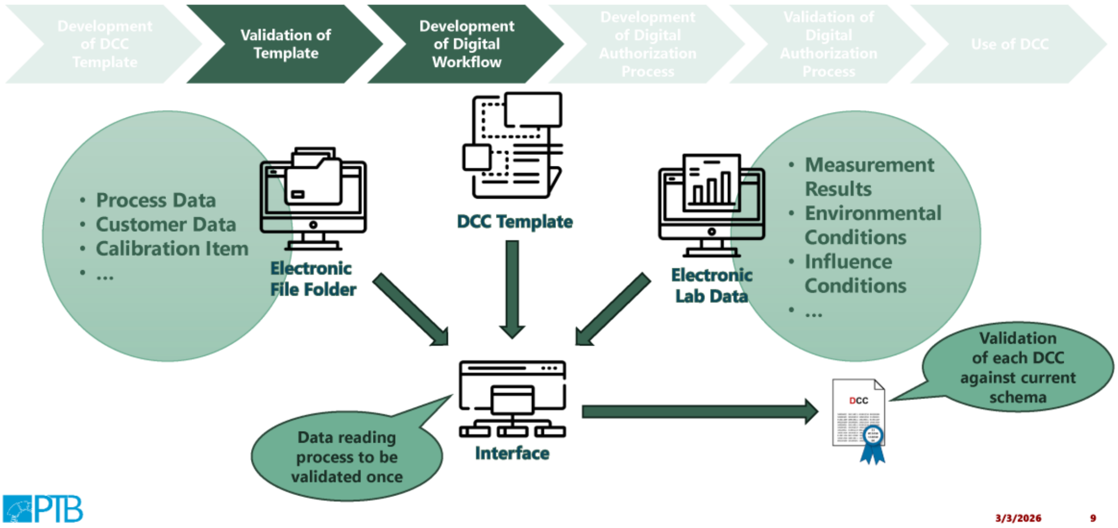
En Route to DCC
Validation and Workflow

DCC



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En Route to DCC
Digital Authorization Process

DCC

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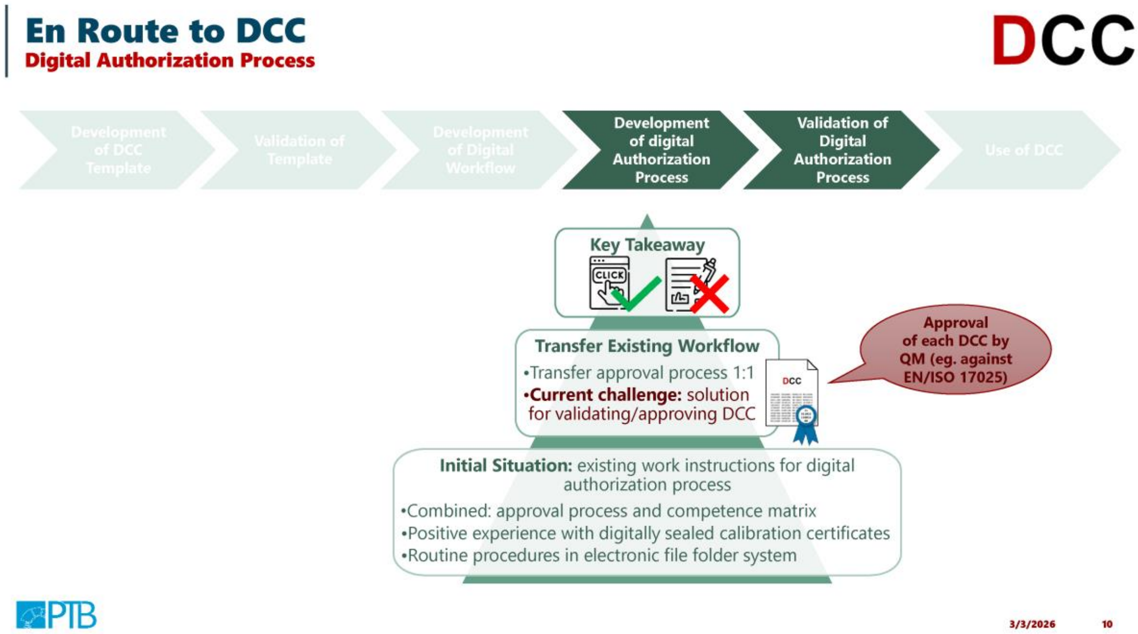
En Route to DCC
Digital Authorization Process
DCC
Development of DCC Template
Validation of Template
Development of Digital Workflow
Development of digital Authorization Process
Validation of Digital Authorization Process
Use of DCC
Key Takeaway
CLICK
Transfer Existing Workflow
•Transfer approval process 1:1
•Current challenge: solution for validating/approving DCC
DCC
Approval of each DCC by QM (eg. against EN/ISO 17025)
Initial Situation: existing work instructions for digital authorization process
•Combined: approval process and competence matrix
•Positive experience with digitally sealed calibration certificates
•Routine procedures in electronic file folder system
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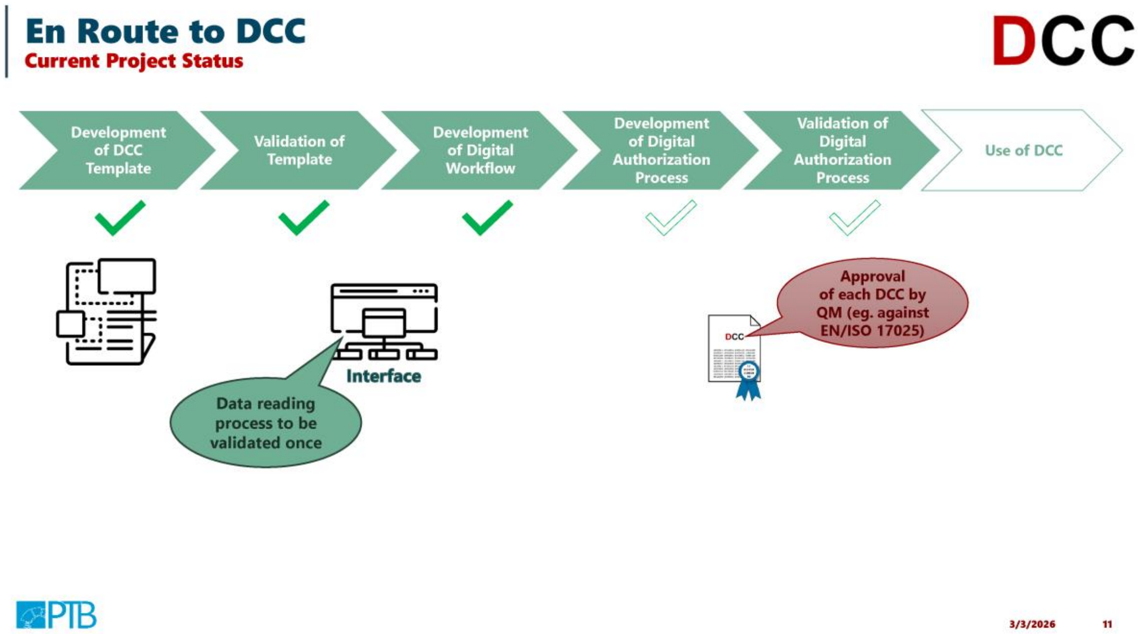
En Route to DCC
Current Project Status
DCC
Development of DCC Template
Validation of Template
Development of Digital Workflow
Development of Digital Authorization Process
Validation of Digital Authorization Process
Use of DCC
Interface
Data reading process to be validated once
DCC
Approval of each DCC by QM (eg. against EN/ISO 17025)
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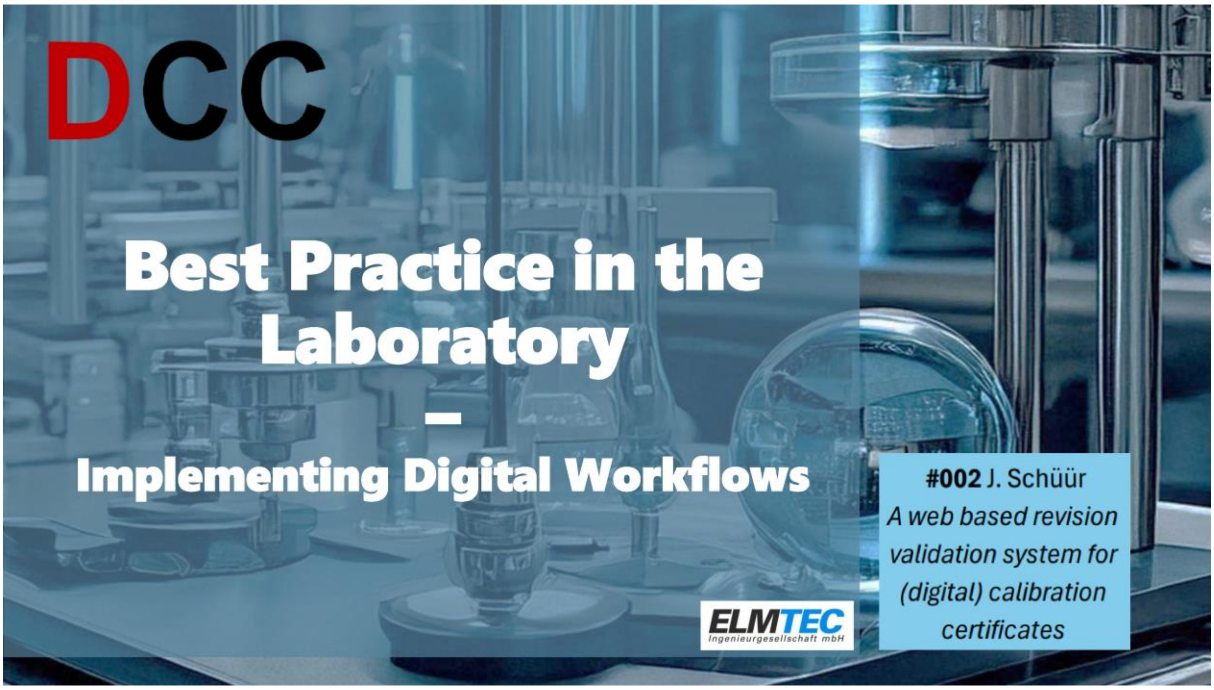
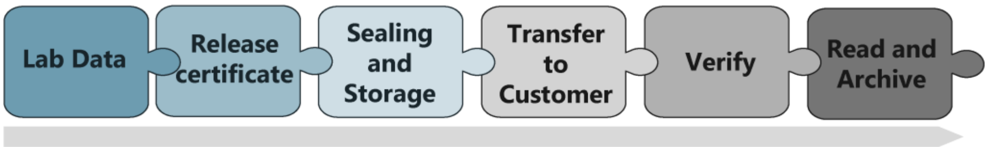


General Workflow in/with the Accredited Laboratory

DCC



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Digital Workflow in/with the Accredited Laboratory

Lab Data

DCC

Lab Data

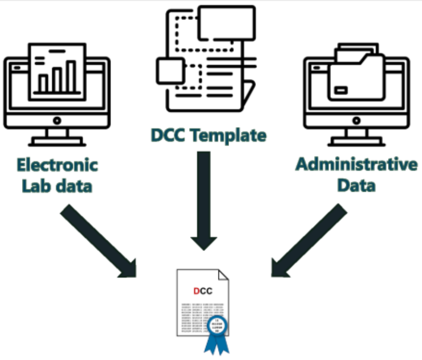
Digital Data Acquisition in the Laboratory

Digital Workflow in/with the Accredited Laboratory

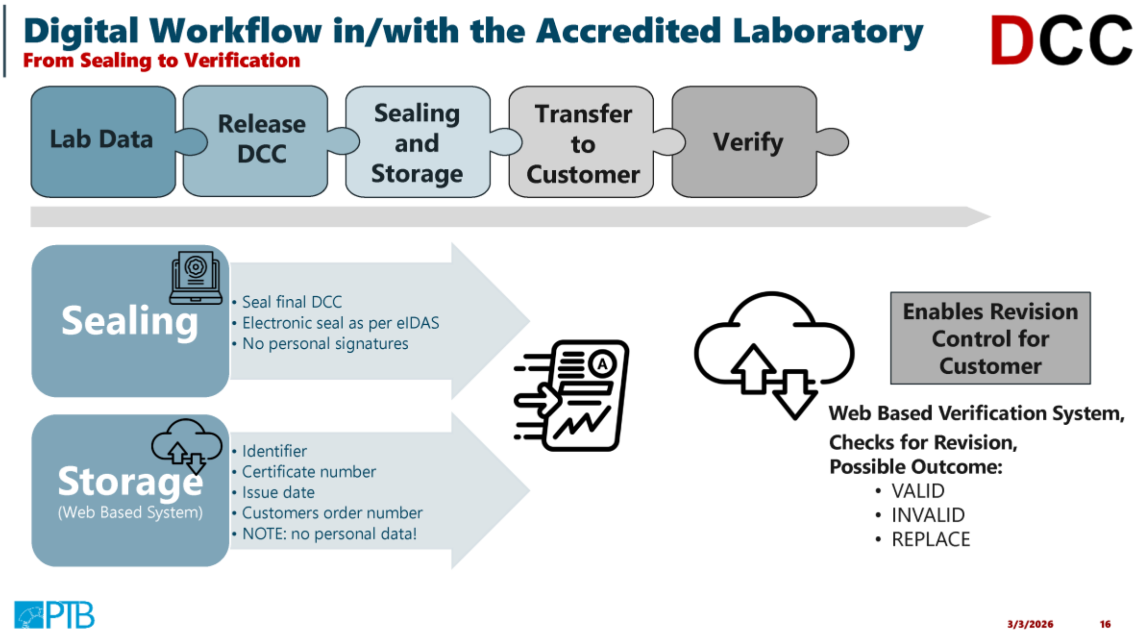
Digital Certificate and Release

DCC

Lab Data | Release DCC



Implementation depends on
- Existing Structures
- Existing Data Storage
- Existing Software Solutions


Digital Workflow in/with the Accredited Laboratory
From Sealing to Verification
DCC
Lab Data
Release DCC
Sealing and Storage
Transfer to Customer
Verify
Sealing
• Seal final DCC
• Electronic seal as per eIDAS
• No personal signatures
Storage
(Web Based System)
• Identifier
• Certificate number
• Issue date
• Customers order number
• NOTE: no personal data!
Enables Revision Control for Customer
Web Based Verification System,
Checks for Revision,
Possible Outcome:
• VALID
• INVALID
• REPLACE
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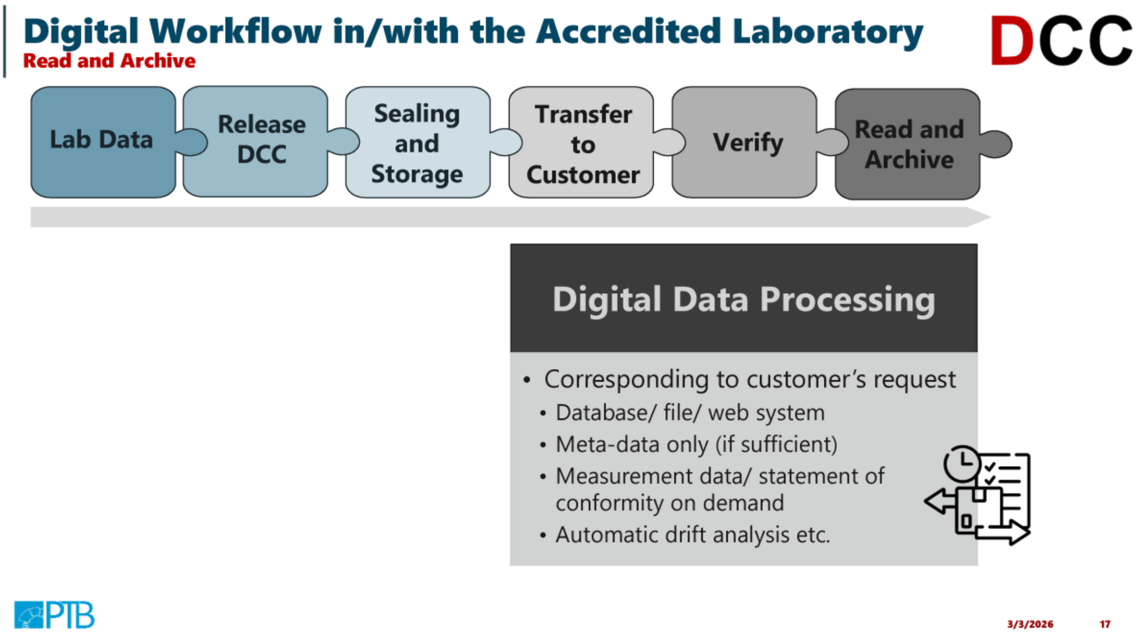
Digital Workflow in/with the Accredited Laboratory
Read and Archive
DCC
Lab Data
Release DCC
Sealing and Storage
Transfer to Customer
Verify
Read and Archive
Digital Data Processing
• Corresponding to customer's request
• Database/ file/ web system
• Meta-data only (if sufficient)
• Measurement data/ statement of conformity on demand
• Automatic drift analysis etc.
PTB
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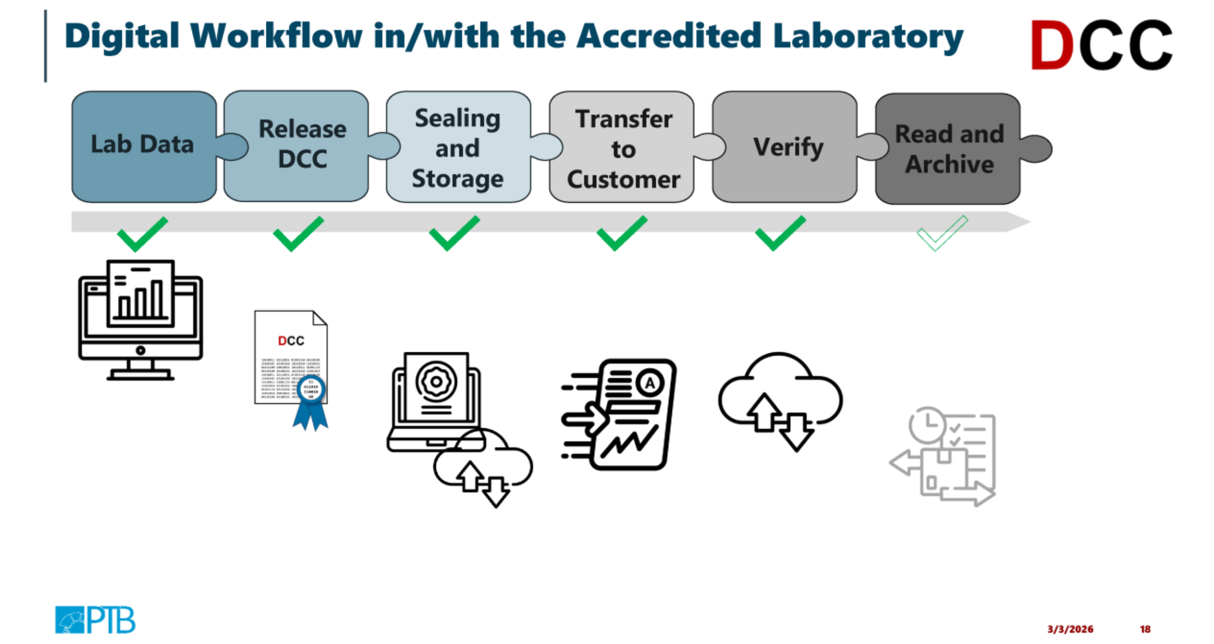
Digital Workflow in/with the Accredited Laboratory
DCC
Lab Data
Release DCC
Sealing and Storage
Transfer to Customer
Verify
Read and Archive
DCC
3/3/2026
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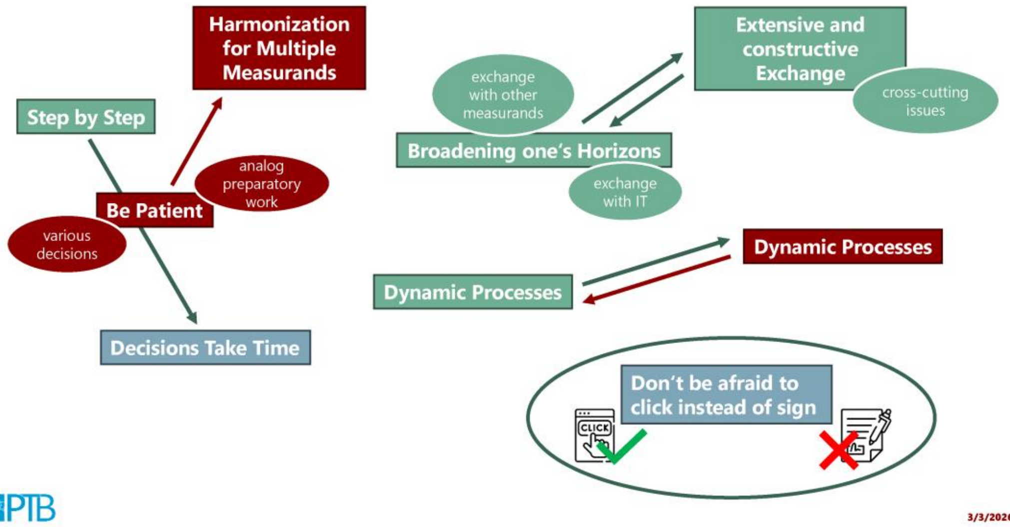
DCC
Lessons Learned
–
Highlights, Obstacles and Unexpected Findings

Lessons Learned
Upsides and Downsides (Challenges)

DCC



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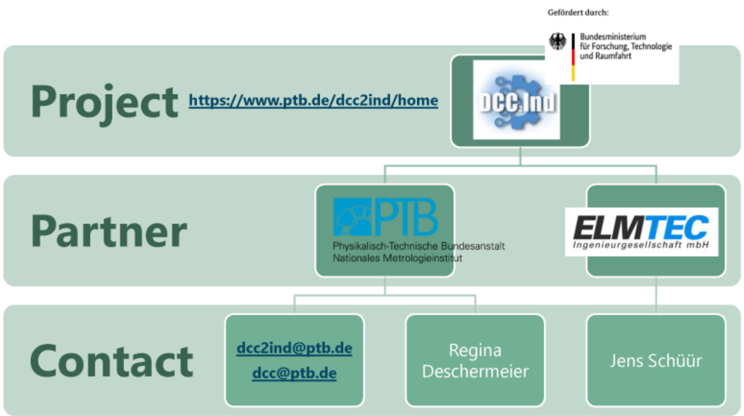
Thank-You Note
to the Project Team

DCC



NOTE: all icons in this presentation were taken from https://de.freepik.com/icons#from_element=stock-subhome

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033 Donny Taipe: Dynamic characterization of comparators for weight calibration through DCC integration

Presenting author: Donny Taipe [1]
Email: dtaipe@inacal.gob.pe
Additional authors: Rubén Dario Gil Chacaltana [1], rgil@inacal.gob.pe
Institution:
[1] INACAL, 150 La Prosa Street, San Boija, Lima, 15034, Peru
Keywords: DCC, mass laboratory, characterization, weight calibration

Abstract

The digital transformation of the quality infrastructure requires calibration data to be digital and compliant with the FAIR principles (Findable, Accessible, Interoperable, and Reusable). In this context, Digital Calibration Certificates (DCC) enable the automated exchange, processing, and structured reuse of metrological information.

In weight calibration, comparators are critical instruments whose performance must be assessed through the statistical characterization of repeatability. Traditionally, this characterization is carried out retrospectively, based on the manual compilation of standard deviations over long operational periods. This approach limits early detection of performance deviations and reduces the effectiveness of statistical control of the measurement process.

This work presents a system for the dynamic characterization of comparators by automatically integrating structured calibration data in XML format, compliant with the DCC schema. Each calibration generates an XML file containing measurement results, including repeatability parameters and relevant process metadata. These files are processed using XML-reading software that automatically extracts the statistical values associated with the comparator.

From the extracted data, the software calculates the population standard deviation, which is incorporated into the calibration software. Each new calibration is evaluated using statistical consistency tests, such as Fisher's F-test, enabling real-time verification of whether the current comparator performance is consistent with its historical behavior. This allows immediate detection of anomalies related to instrumental failures, environmental influences, or operational inconsistencies.

The proposed workflow establishes a continuous, automated, and statistically controlled characterization process based on digital data, ensuring interoperability with laboratory management systems and improving metrological reliability, traceability, and responsiveness in mass laboratories.

References:

[1] DCC -PTB (2026): Digital Calibration Certificates (DCC), in: Physikalisch-Technische Bundesanstalt, https://www.ptb.de/dcc/, last accessed: 16.01.2026

[2] International Organization of Legal Metrology (2004): OIML R 111-1:2004 (E) Weights of classes El, E2, Fl, F2, Ml, Ml-2, M2, M2-3 and M3 - Part 1: Metrological and technical requirements, Paris: OIML. [https://www.oiml.org/en/files/pdf r/rl H-l-e04.pdf].

[3] National Institute for Quality - Peru (2015): PC-016 Procedure for the calibration of precision weights, Edition 2, April 2015, Lima, Peru.

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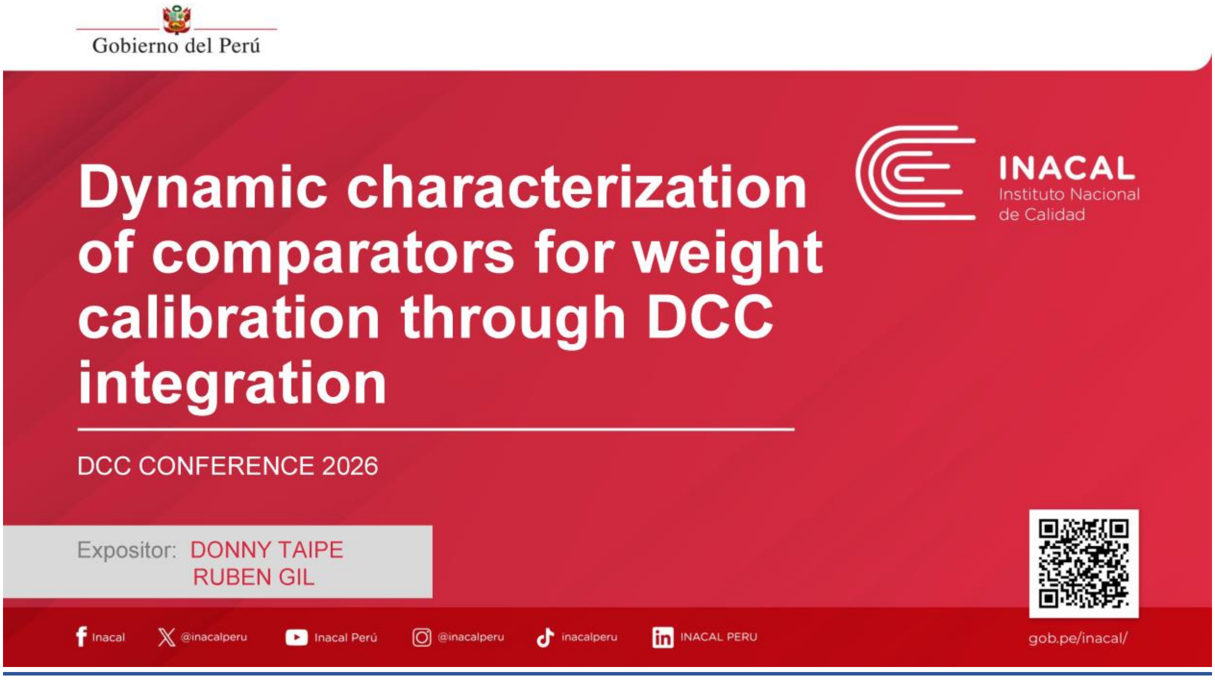
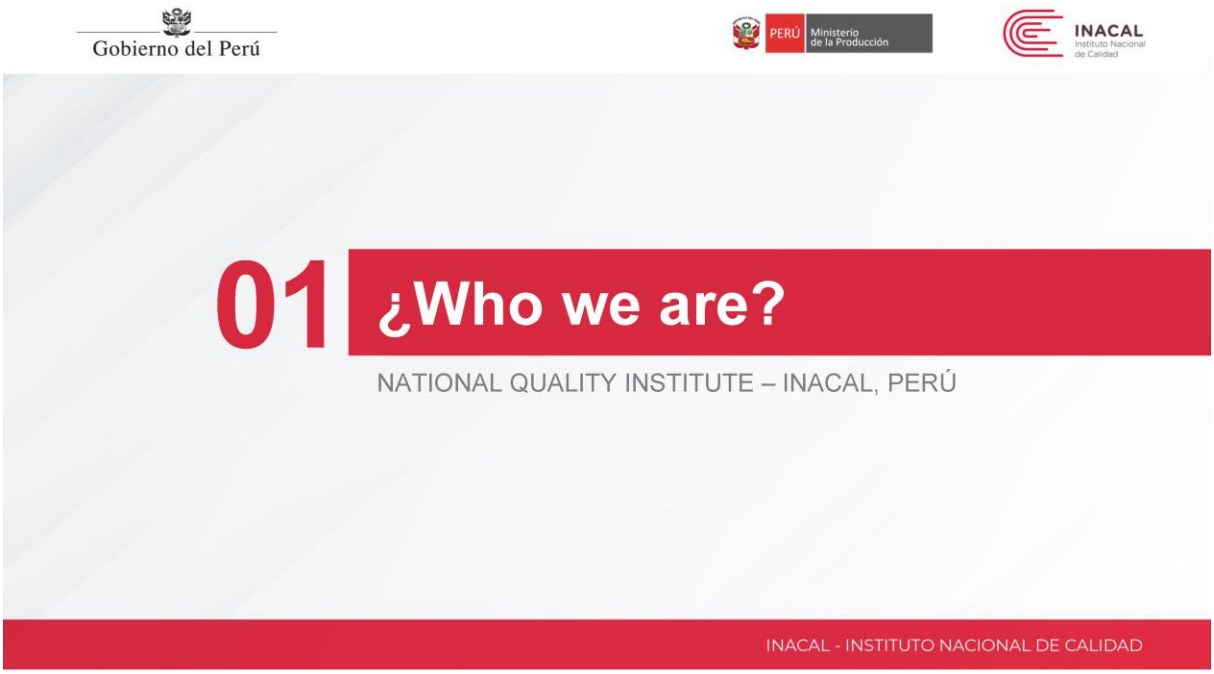
Presentation #033 of Donny Taipe





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INACAL

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What we do?
We provide national services in:
- Metrology
- Accreditation
- Standardization

Our impact
Supporting:
- Industrial competitiveness
- Public safety
- International trade

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Key Facts

- 19 specialized laboratories
- ~600 calibration services/month
- Mechanical | Electrical | Thermometry & Chemistry

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INACAL - Mass Laboratory

Calibration Services with CMC registered in the KCDB

- Mass Calibration:
  - OIML Class E1: 1 mg to 5 kg
  - OIML Class E2: 10 kg to 50 kg
- Mass Density and Volume Determination (1 g to 5 kg)

Additional Services

- Calibration of Non-Automatic Weighing Instruments (NAWI) (Class I & II)
- Determination of magnetic properties of weights.

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02 Background and Technical Challenge

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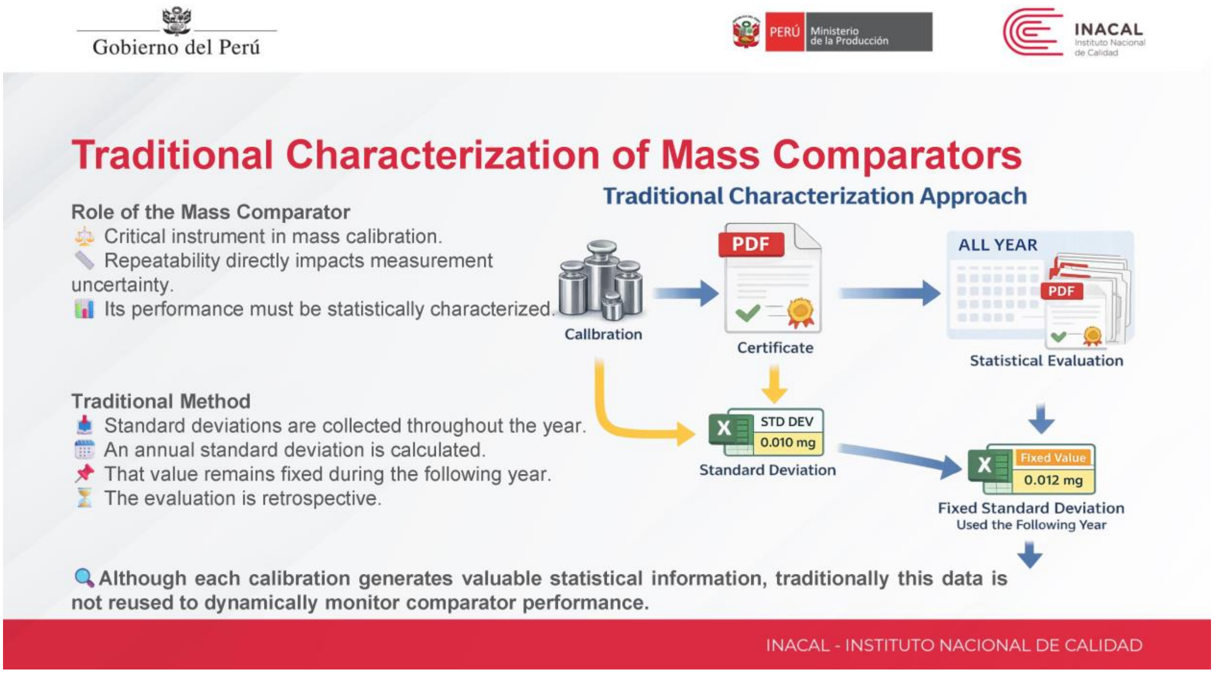
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Traditional Characterization of Mass Comparators
Role of the Mass Comparator
Critical instrument in mass calibration.
Repeatability directly impacts measurement uncertainty.
Its performance must be statistically characterized.
Traditional Method
Standard deviations are collected throughout the year.
An annual standard deviation is calculated.
That value remains fixed during the following year.
The evaluation is retrospective.
Traditional Characterization Approach
Calibration
PDF
Certificate
ALL YEAR
PDF
Statistical Evaluation
STD DEV
0.010 mg
Standard Deviation
Fixed Value
0.012 mg
Fixed Standard Deviation
Used the Following Year
Although each calibration generates valuable statistical information, traditionally this data is not reused to dynamically monitor comparator performance.
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03
OBJECTIVE AND PROPOSED APPROACH
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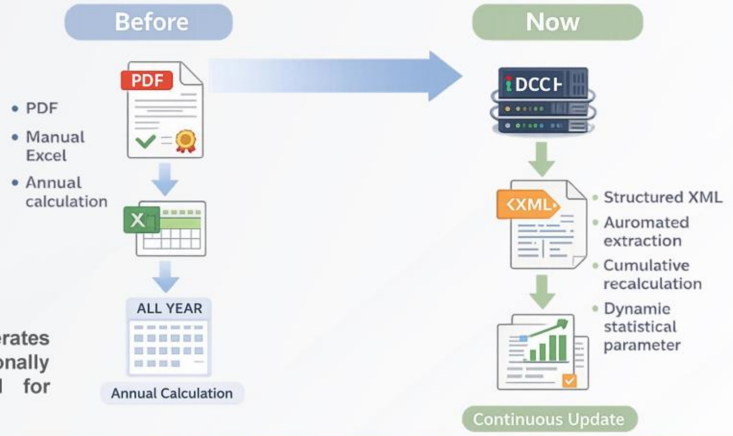
DCC-Based Dynamic Characterization of Mass Comparators



Each calibration generates statistical data, but traditionally this data is not reused for continuous monitoring.

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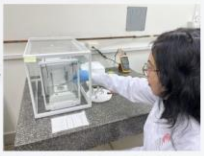
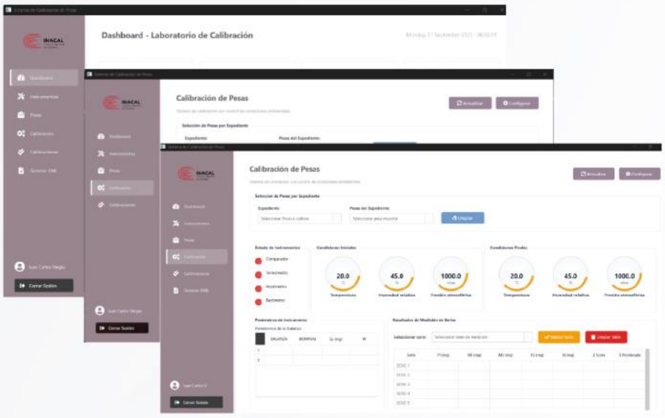
PROPOSED ARCHITECTURE

Measurement System



Python Application (PyQt6, Python 3.11, SQLite3, Matplotlib, SciPy, PySerial, OpenPyXL, PyDCC, ReportLab)

- Real-time data acquisition
- Management of auxiliary instruments, reference weights, and weights under calibration
- Complete calibration workflow
- Statistical analysis, correction calculation, and uncertainty estimation
- Automatic reporting in PDF and XML formats



The DCC-compatible structured data allows us to transform comparator characterization into a cumulative and continuously updated process.

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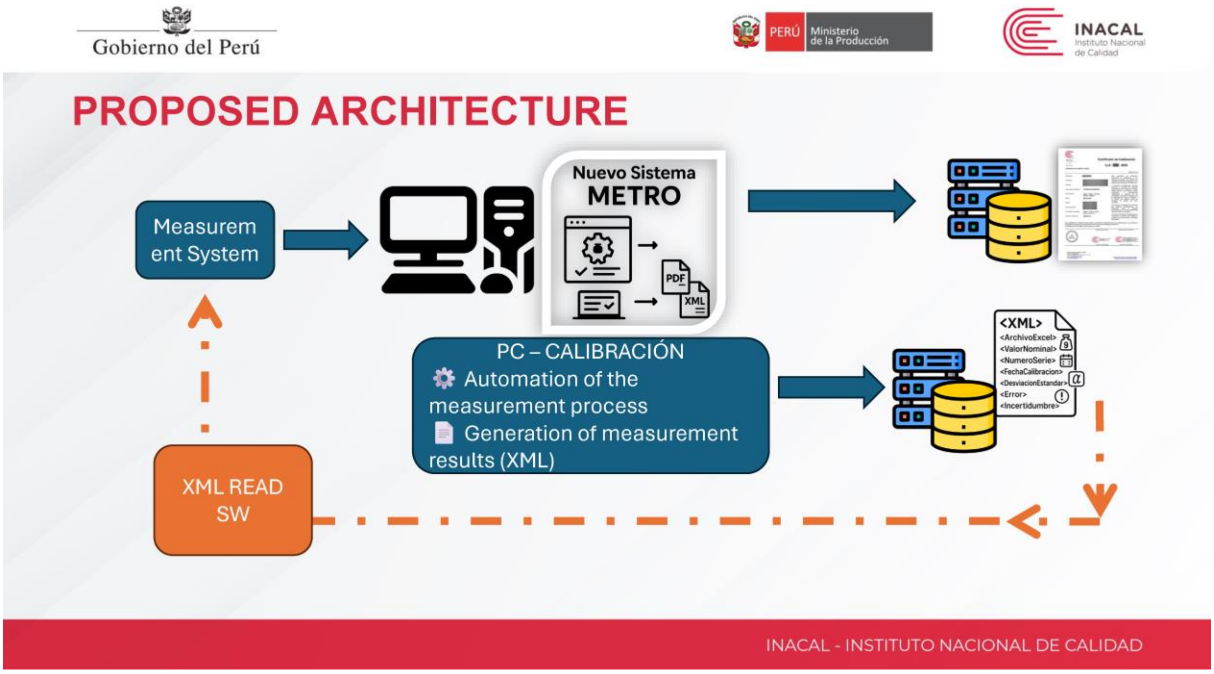
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PROPOSED ARCHITECTURE
Measurement System
Nuevo Sistema
METRO
PDF
XML
PC – CALIBRACIÓN
Automation of the measurement process
Generation of measurement results (XML)
<XML>
XML READ SW
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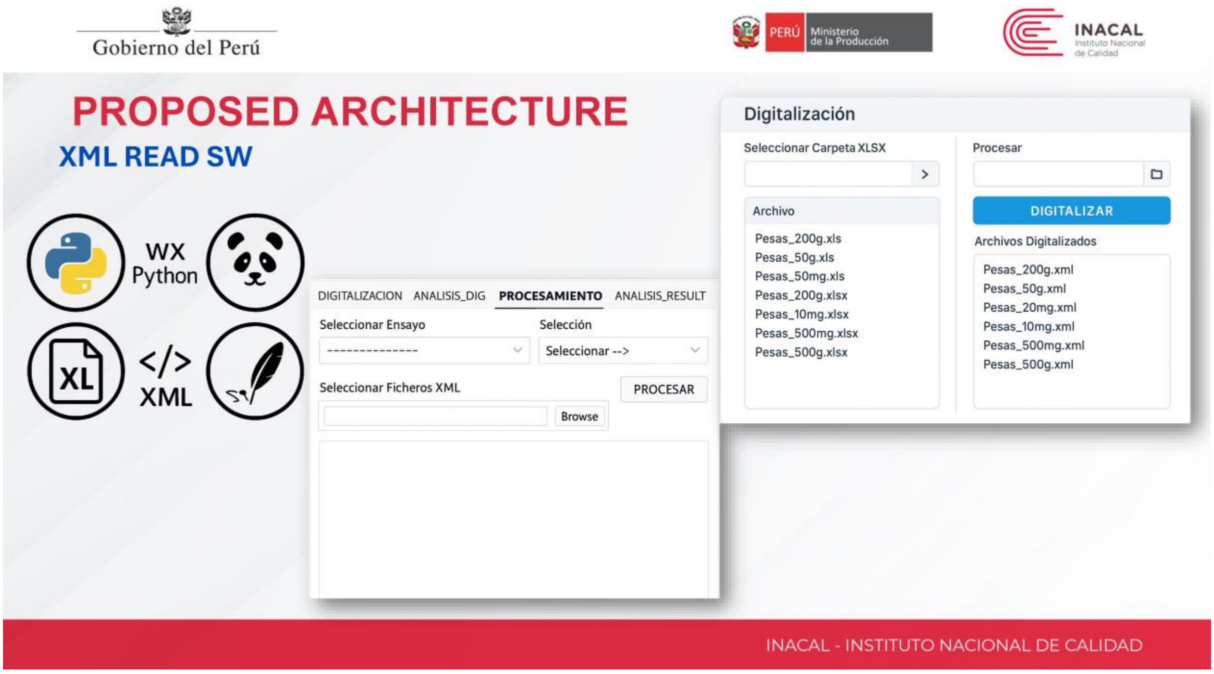
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PROPOSED ARCHITECTURE
XML READ SW
WX Python
XL
</> XML
DIGITALIZACION ANALISIS_DIG PROCESAMIENTO ANALISIS_RESULT
Seleccionar Ensayo
Selección
Seleccionar -->
Seleccionar Ficheros XML
PROCESAR
Browse
Digitalización
Seleccionar Carpeta XLSX
Procesar
Archivo
DIGITALIZAR
Archivos Digitalizados
Pesas_200g.xls
Pesas_50g.xls
Pesas_50mg.xls
Pesas_200g.xlsx
Pesas_10mg.xlsx
Pesas_500mg.xlsx
Pesas_500g.xlsx
Pesas_200g.xml
Pesas_50g.xml
Pesas_20mg.xml
Pesas_10mg.xml
Pesas_500mg.xml
Pesas_500g.xml
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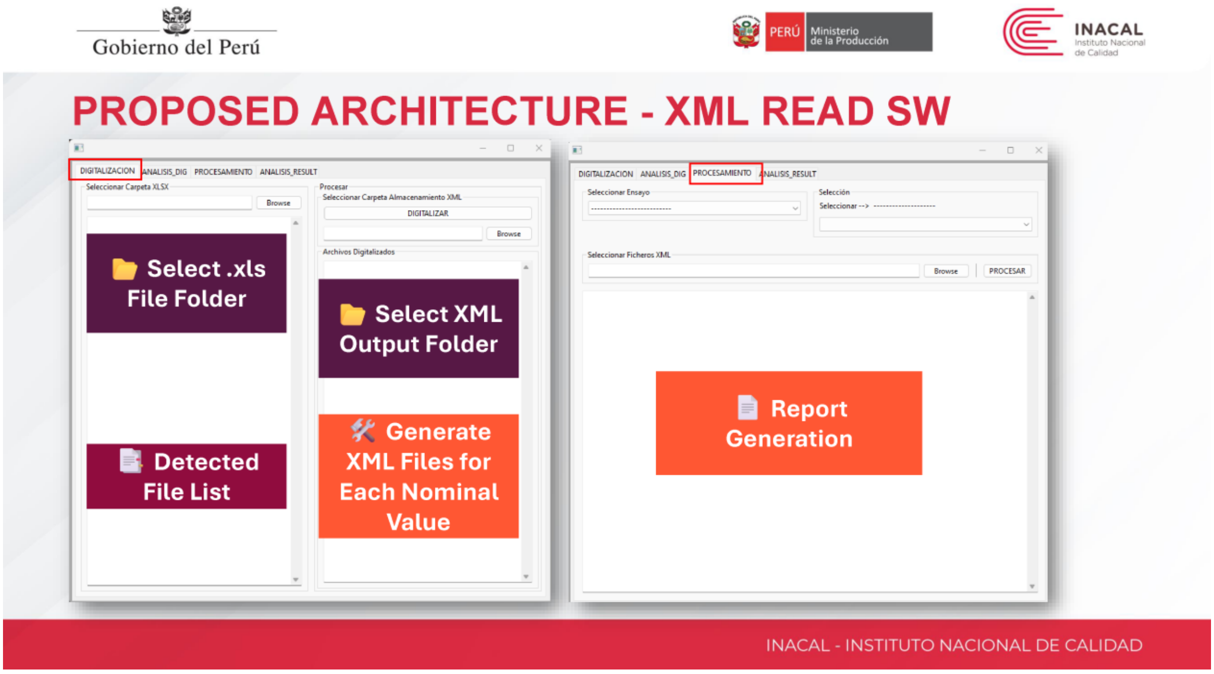
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PROPOSED ARCHITECTURE - XML READ SW
DIGITALIZACION ANALISIS_DIG PROCESAMIENTO ANALISIS_RESULT
Seleccionar Carpeta XLSX
Browse
Select .xls File Folder
Detected File List
Procesar
Seleccionar Carpeta Almacenamiento XML
DIGITALIZAR
Browse
Archivos Digitalizados
Select XML Output Folder
Generate XML Files for Each Nominal Value
Seleccionar Ensayo
Selección
Seleccionar -->
Seleccionar Ficheros XML
Browse
PROCESAR
Report Generation
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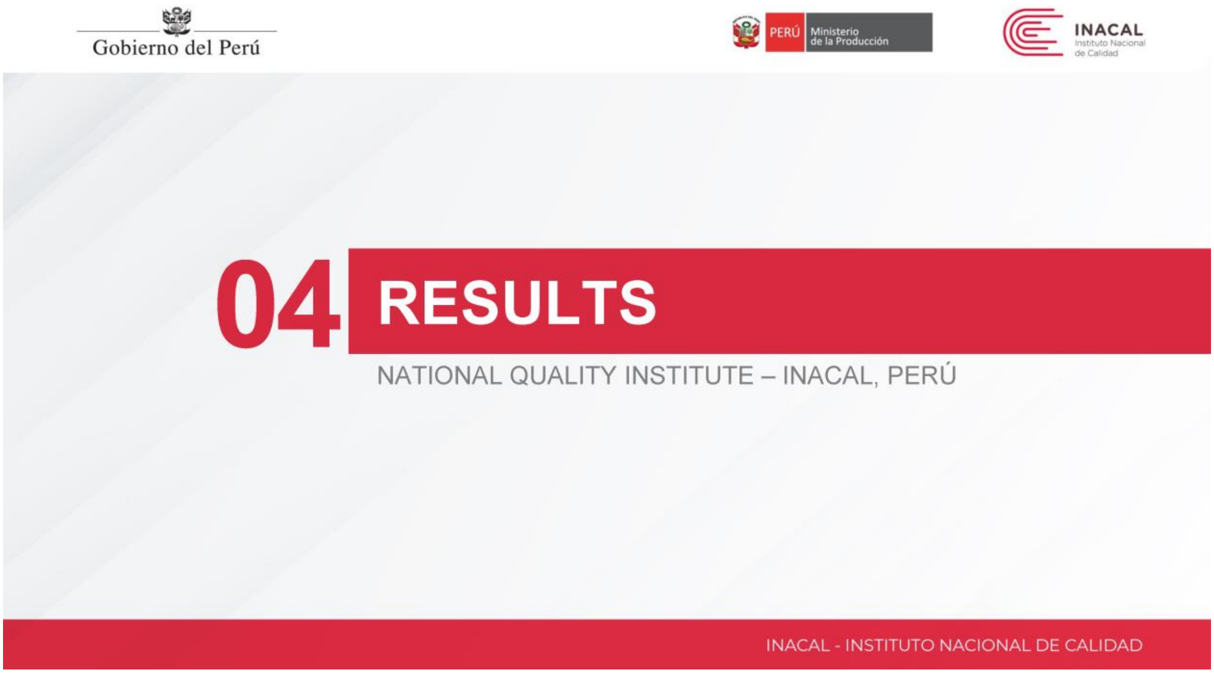
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04 RESULTS
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RESULTS

Dynamic Characterization Parameter

The comparator characterization parameter is no longer a fixed annual value. It is recalculated cumulatively before each calibration using historical XML data.

Automated Statistical Extraction

The XML Reader software filters calibrations by nominal value and date, reads stored standard deviations, and computes an updated population standard deviation in seconds.

Digital Traceability Through Structured XML

Each calibration generates a DCC-compatible XML file containing measurement results and statistical information, enabling consistent digital traceability and reuse.

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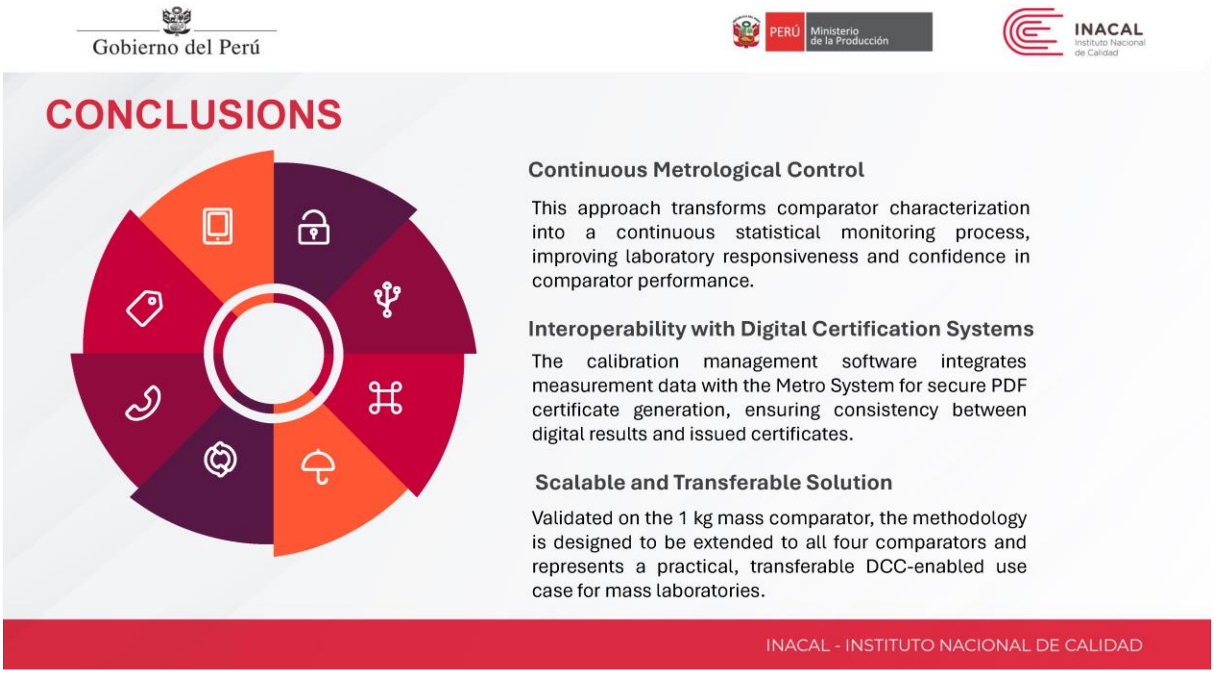
05 CONCLUSIONS

NATIONAL QUALITY INSTITUTE – INACAL, PERÚ

INACAL - INSTITUTO NACIONAL DE CALIDAD



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034 Ciro Alberto Sánchez: From Good Practice to Standardization: Advancing Digital Calibration Certificates at the Instituto Nacional de Metrología de Colombia (INM)

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Email: csanchez@inm.gov.co
Additional authors: C. Sánchez [1], J. Monroy [1], Y. Alonso [1], J. Barreto [1], A. Bohórquez
Institution(s):
[1] Subdirección de Metrología Física, Instituto Nacional de Metrología de Colombia (INM), AK 50 # 26 – 55, Int. 2, Bogotá, D.C., 111321, Colombia
Keywords: Digital Calibration Certificates (DCC), Digital Quality Infrastructure, Metrology Digital Transformation, Machine-Readable Calibration Data, Interoperability and FAIR Data

Abstract

The ongoing digital transformation of quality infrastructure requires calibration information to be machine-readable, interoperable, and trustworthy across institutional and national boundaries. Digital Calibration Certificates (DCC) are increasingly recognized as a key enabler of this transformation, moving beyond digitised documents toward fully machine-actionable and FAIR- compliant calibration data.

This work presents the experience of the Instituto Nacional de Metrología de Colombia (INM) in the progressive adoption of DCC within a strategic digital transformation framework. The approach emphasizes institutional planning and early-stage laboratory prototyping, with particular focus on the Temperature and Humidity Laboratory. DCC development is addressed as an analytical and preparatory process, aligned with international good practices and anticipated harmonization needs, rather than as an operational deployment.

In 2025, the Temperature and Humidity Laboratory implemented internal DCC prototypes for temperature and relative humidity, intended exclusively for internal use. These prototypes support workflow evaluation, data consistency analysis, and the improvement of laboratory environmental monitoring. Beyond their primary laboratory scope, the generated DCC data have been identified as a reusable digital asset for other internal laboratories. In particular, pressure calibration activities have explored the generation of DCC based on the institutional prototype, while viscosity and volume laboratories have assessed the use of DCC-derived temperature, relative humidity, and pressure data to support environmental condition corrections within their measurement workflows.

The technical implementation has been supported by the Oficina de Información y Desarrollo Tecnológico (OIDT), ensuring coherence with the institutional digital infrastructure. Enterprise architecture considerations are discussed, including a layered architecture model covering data acquisition, measurement data validation, and data interoperability, as well as software aspects based on a web application. This includes the use of XML-based schemas promoted within the international metrology community, in relation to interoperability and the growing demand from industry for standardized, machine-readable calibration data. Finally, lessons learned and future perspectives are presented, positioning DCC as a practical bridge between good practice and the gradual transition toward a digital quality infrastructure.

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Presentation #034 of Ciro Alberto Sánchez

Instituto Nacional de
Metrología de Colombia

From Good Practice to Standardization: Advancing Digital Calibration Certificates at the Instituto Nacional de Metrología de Colombia (INM)

C. Sánchez, J. Monroy, Y. Alonso, J. Barreto, A. Bohórquez, W. Contreras, J. Culma, C. Peña

Instituto Nacional de Metrología de Colombia (INM)

2026-02-26

Instituto Nacional de Metrología de Colombia

Context: Why DCC?

- Digital transformation is redefining metrology.
- Industry increasingly demands machine-readable calibration data.
- Interoperability and traceability must evolve beyond PDF certificates.
- Digital Calibration Certificates (DCC) enable structured, reusable data.

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Institutional Vision

INM Strategic Perspective:

- Strengthening national quality infrastructure.
- Preparing laboratories for digital interoperability.
- Aligning with international developments in digital metrology.

The DCC initiative at INM is conceived as a progressive institutional effort, not an isolated IT project.

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Implementation Scope at INM

Current Status: Prototype Phase

• Led by Temperature & Humidity Laboratory.

• Technical collaboration with Office of Information Technology and Technological Development (OIDT).

• Exploratory institutional interest from other technical laboratories.

Nature of the system:

Analytical and preparatory prototype — not yet an operational production system.

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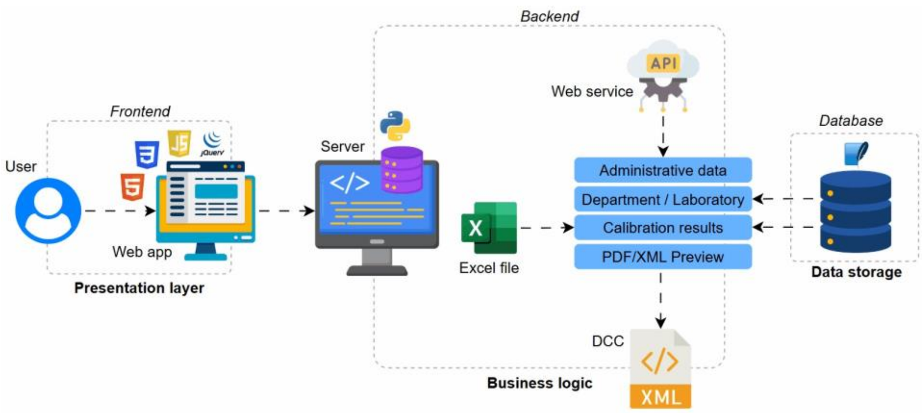
Functional Architecture of the INM DCC Prototype



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1. **Presentation Layer (Web Application)**
   - User authentication and controlled access.
   - Entry of administrative and calibration data.
   - Upload of structured calibration input (Excel template).
   - PDF/XML preview before final generation.

2. Application & Business Logic Layer
   - Python-based processing engine.
   - Data validation and structural checks.
   - PTB-aligned XML schema generation.
   - Internal API-style architecture.

3. Persistence Layer
   - Relational database structure.
   - Laboratory–service configuration.
   - Historical certificate registry.

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Deployment:

- Linux server environment.
- Accessible within secure institutional network.

Core Architectural Principle:
Clear separation of Presentation – Processing – Persistence.

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Data Flow and Interoperability Logic

Database interactions:
- Controlled read/write operations.
- Traceable storage of generated certificates.

Interoperability Enablers:
- Structured XML schema.
- Machine-readable calibration results.
- Future API integration potential.

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Strategic Impact

Institutional Impact:
- Reinforces digital traceability under ISO/IEC 17025.
- Strengthens structured data governance.
- Enhances institutional digital readiness.

Technical Impact:
- Reduces transcription risks.
- Improves structural consistency.
- Enables future automated data exchange.

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Regional Projection:
• Contributes to digital metrology capacity in Latin America.
• Positions INM as an active participant in DCC implementation dialogue.

Key Message:
The prototype acts as a structured transition mechanism toward digital quality infrastructure.

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Lessons Learned

• Early IT–metrology collaboration is essential.

• Data structure standardization is more complex than format conversion.

• Institutional alignment improves technical robustness.

• Prototype approach reduces implementation risk.

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Future Perspectives

• Gradual extension to additional laboratories.

• Strengthening XML validation processes.

• Exploring secure external interoperability.

• Evaluating pathway from prototype to institutional deployment.

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Conclusion

Digital Calibration Certificates represent:

• A structural transformation in calibration data management.

• An opportunity to modernize metrological infrastructure.
• A strategic step toward scalable digital quality systems.

INM's approach:
Structured, cautious, and aligned with international digital metrology developments.

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Thank You & Q&A

Thank you for your attention.

Questions and discussion.

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035 Aldo Adrián García González: Digitization of laboratories for the automation of measurement processes by implementing DCC

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José Hugo Arellano Pérez [1], josehugoarellanoperez@gmail.com
Institution:
[1] Centro Nacional de Metrología: Physics Sound and Vibration, Carretera a los Cues, Km 4.5, El Marqués, Querétaro.
Keywords: DCC, Automation, Interoperability, Integration, Digitalization, Laboratory, API.

Abstract

The digitization of calibration laboratories is emerging as a transformative approach to modernizing measurement processes and strengthening the reliability of metrological infrastructures. This work focuses on the implementation of Digital Calibration Certificates (DCC) to automate and streamline the generation, management, and dissemination of calibration results. By moving beyond traditional paper or PDF certificates, DCCs enable laboratories to ensure interoperability, enhance data integrity, and reinforce traceability across the calibration chain.

The proposed implementation begins with the digitalization of existing calibration certificates, applying best practices to guarantee consistency and accuracy. In parallel, new design proposals for certificates in the field of physical metrology—specifically vibration measurements—are introduced. These designs are tailored to meet the needs of laboratories working with alternating acceleration standards and transfer standards, two critical areas where precision and reliability are paramount. The initiative integrates administrative information and measurement results into a centralized database, which is accessed through a web application developed to automatically generate DCCs. This architecture not only reduces manual intervention but also ensures that data flows seamlessly from acquisition to certification.

The case studies presented highlight the role of the primary laboratory for alternating acceleration and the transfer standards laboratory. In both contexts, the adoption of DCCs demonstrates how digital solutions can unify operational processes, reduce redundancy, and provide transparent access to calibration data. The web application serves as a bridge between laboratory operations and end users, offering certificates that are machine-readable, verifiable, and compatible with international standards. This interoperability is essential for laboratories seeking to align with global initiatives in digital metrology and to participate in broader ecosystems of trust.

The benefits of this approach are multifold. Interoperability ensures that certificates can be integrated into diverse digital environments, while data reliability minimizes the risk of human error and strengthens confidence in calibration outcomes. Traceability is enhanced by embedding structured data directly into the certificates, thereby reinforcing the integrity of the calibration chain. Ultimately, the implementation of DCCs illustrates how digital transformation can elevate laboratory practices, providing a scalable model that can be replicated across other domains of physical metrology.

This work underscores the importance of adopting digital infrastructures in calibration laboratories, positioning DCCs as a cornerstone for future developments in measurement science.

By demonstrating practical applications and tangible benefits, it invites laboratories and stakeholders to embrace digitalization as a pathway toward more efficient, transparent, and globally connected metrological systems.

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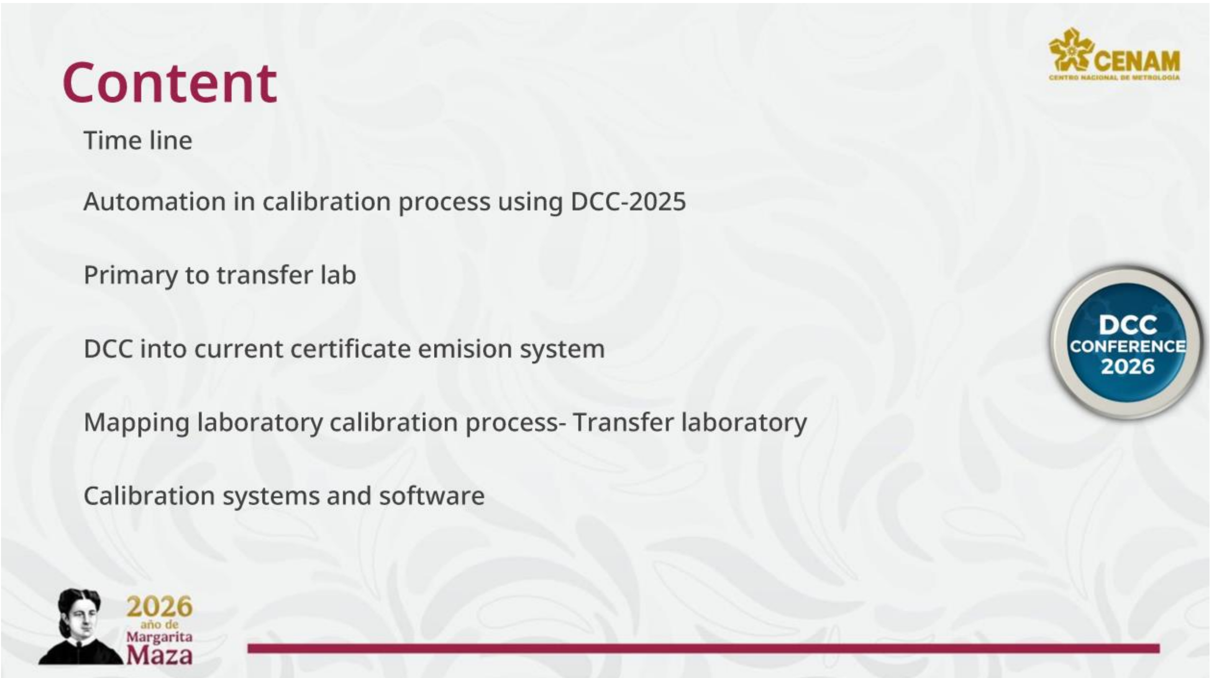
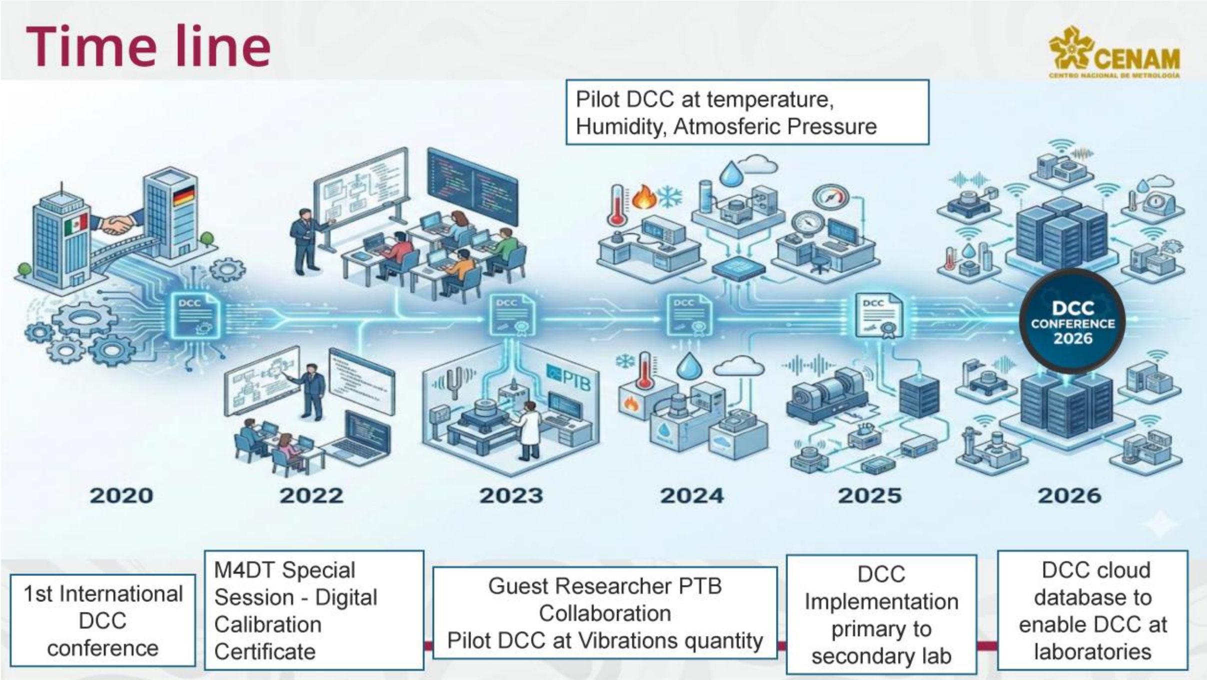
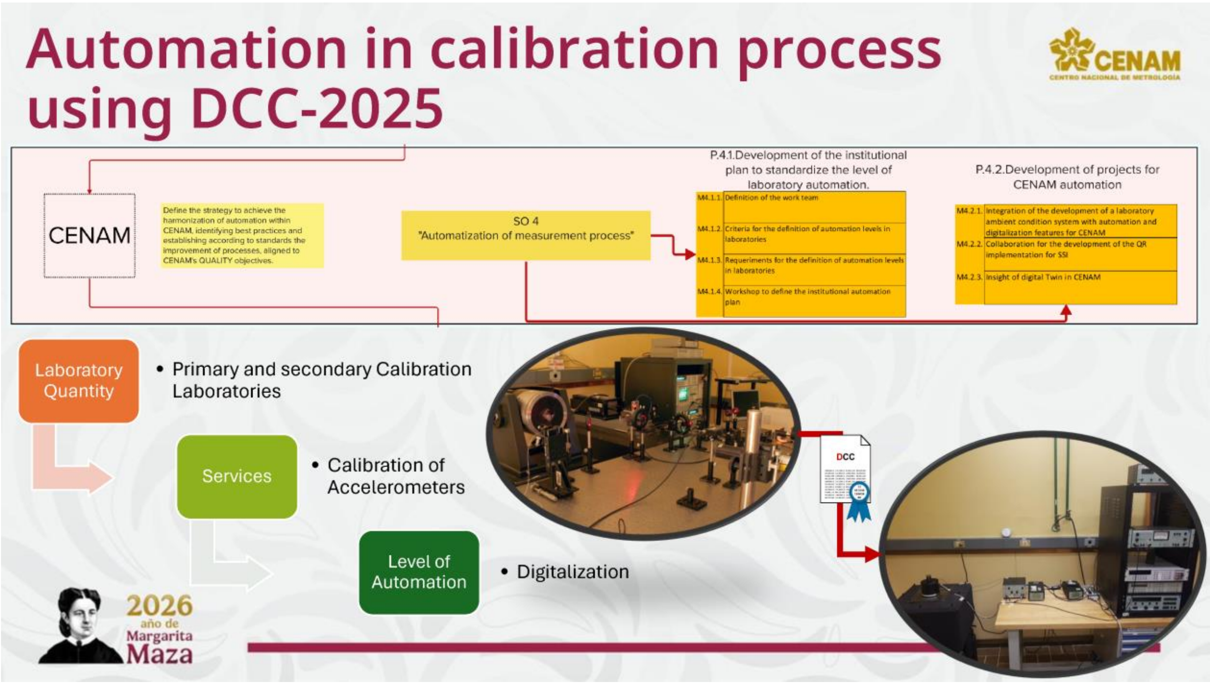
Presentation #035 of Aldo AdriánGarcía González




Time line
CENAM
CENTRO NACIONAL DE METROLOGÍA
Pilot DCC at temperature, Humidity, Atmosferic Pressure
DCC CONFERENCE 2026
PTB
2020
2022
2023
2024
2025
2026
1st International DCC conference
M4DT Special Session - Digital Calibration Certificate
Guest Researcher PTB Collaboration
Pilot DCC at Vibrations quantity
DCC Implementation primary to secondary lab
DCC cloud database to enable DCC at laboratories


Automation in calibration process using DCC-2025
CENAM
CENTRO NACIONAL DE METROLOGÍA
CENAM
Define the strategy to achieve the harmonization of automation within CENAM, identifying best practices and establishing according to standards the improvement of processes, aligned to CENAM's QUALITY objectives.
SO 4
"Automatization of measurement process"
P.4.1.Development of the institutional plan to standardize the level of laboratory automation.
M4.1.1. Definition of the work team
M4.1.2. Criteria for the definition of automation levels in laboratories
M4.1.3. Requeriments for the definition of automation levels in laboratories
M4.1.4. Workshop to define the institutional automation plan
P.4.2.Development of projects for CENAM automation
M4.2.1. Integration of the development of a laboratory ambient condition system with automation and digitalization features for CENAM
M4.2.2. Collaboration for the development of the QR implementation for SSI
M4.2.3. Insight of digital Twin in CENAM
Laboratory Quantity
Primary and secondary Calibration Laboratories
Services
Calibration of Accelerometers
Level of Automation
Digitalization
DCC
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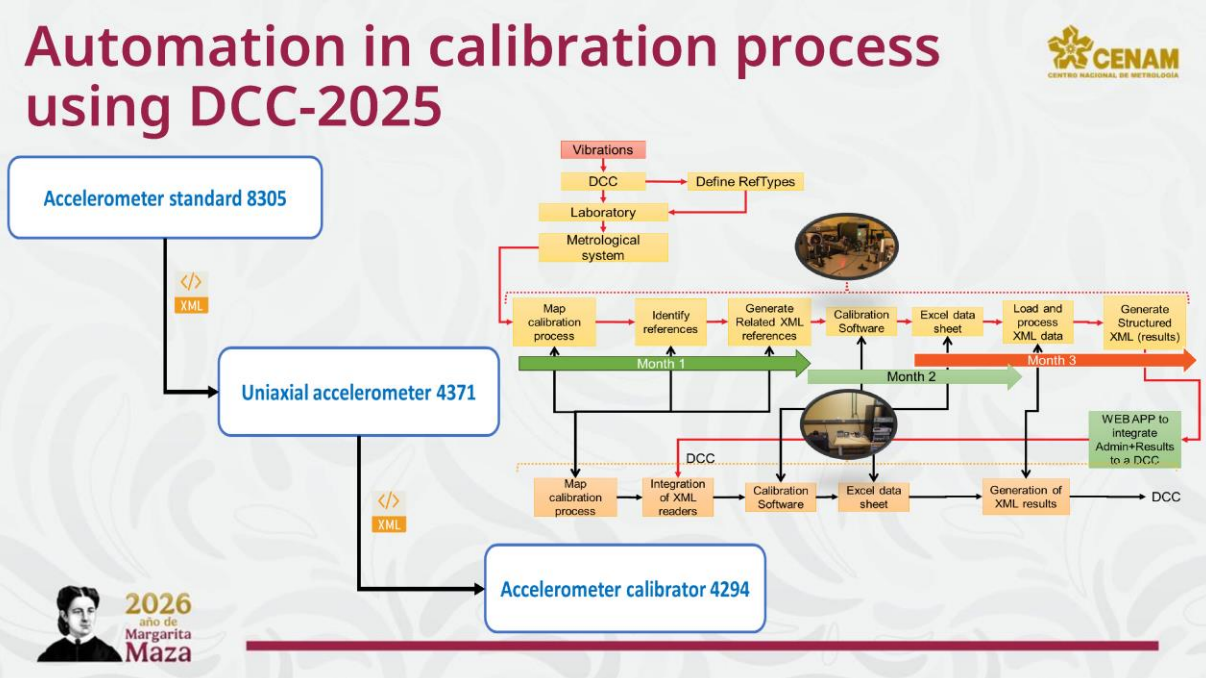
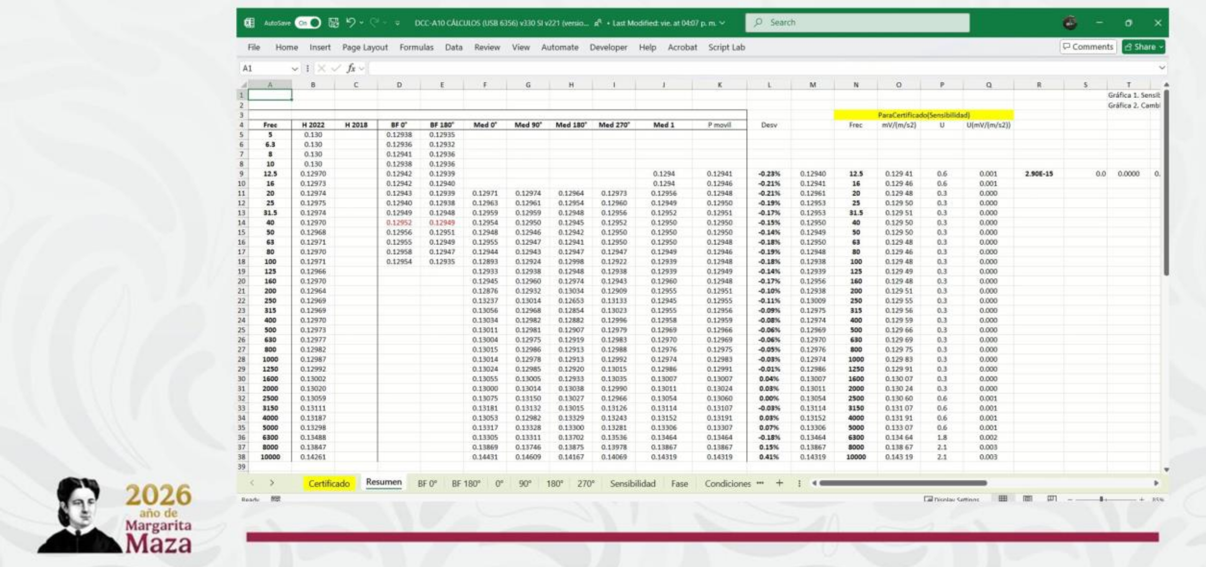
Automation in calibration process using DCC-2025

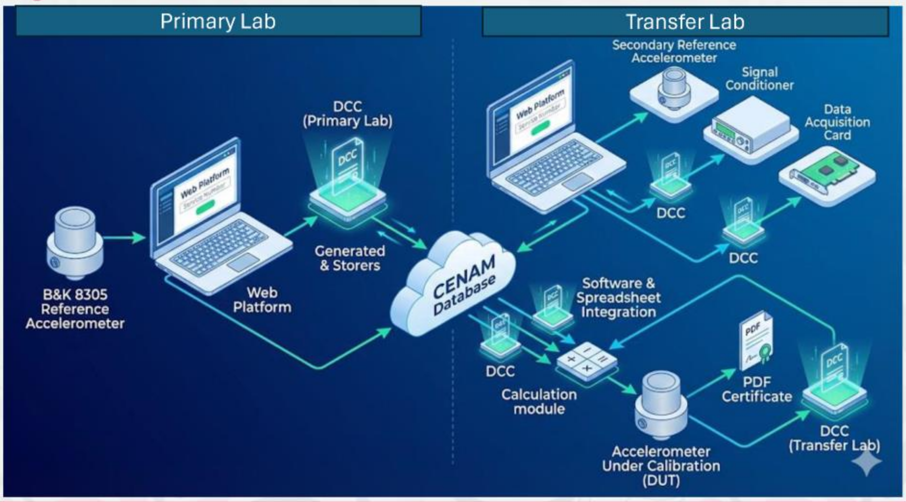


Primary to transfer lab



	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	
1																				Gráfica 1. Sensit	
2																				Gráfica 2. Cambi	
3														ParaCertificado(Sensibilidad)							
4	Frec	H 2022	H 2018	BF 0°	BF 180°	Med 0°	Med 90°	Med 180°	Med 270°	Med 1	P movil	Desv		Frec	mV/(m/s2)	U	U(mV/(m/s2))				
5	5	0.130		0.12938	0.12935																
6	6.3	0.130		0.12936	0.12932																
7	8	0.130		0.12941	0.12936																
8	10	0.130		0.12938	0.12936																
9	12.5	0.12970		0.12942	0.12939					0.1294	0.12941	-0.23%	0.12940	12.5	0.129 41	0.6	0.001	2.90E-15	0.0	0.0000	0.
10	16	0.12973		0.12942	0.12940					0.1294	0.12946	-0.21%	0.12941	16	0.129 46	0.6	0.001				
11	20	0.12974		0.12943	0.12939	0.12971	0.12974	0.12964	0.12973	0.12956	0.12948	-0.21%	0.12961	20	0.129 48	0.3	0.000				
12	25	0.12975		0.12940	0.12938	0.12963	0.12961	0.12954	0.12960	0.12949	0.12950	-0.19%	0.12953	25	0.129 50	0.3	0.000				
13	31.5	0.12974		0.12949	0.12948	0.12959	0.12959	0.12948	0.12956	0.12952	0.12951	-0.17%	0.12953	31.5	0.129 51	0.3	0.000				
14	40	0.12970		0.12952	0.12949	0.12954	0.12950	0.12945	0.12952	0.12950	0.12950	-0.15%	0.12950	40	0.129 50	0.3	0.000				
15	50	0.12968		0.12956	0.12951	0.12948	0.12946	0.12942	0.12950	0.12950	0.12950	-0.14%	0.12949	50	0.129 50	0.3	0.000				
16	63	0.12971		0.12955	0.12949	0.12955	0.12947	0.12941	0.12950	0.12950	0.12948	-0.18%	0.12950	63	0.129 48	0.3	0.000				
17	80	0.12970		0.12958	0.12947	0.12944	0.12943	0.12947	0.12947	0.12949	0.12946	-0.19%	0.12948	80	0.129 46	0.3	0.000				
18	100	0.12971		0.12954	0.12935	0.12893	0.12924	0.12998	0.12922	0.12939	0.12948	-0.18%	0.12938	100	0.129 48	0.3	0.000				
19	125	0.12966				0.12933	0.12938	0.12948	0.12938	0.12939	0.12949	-0.14%	0.12939	125	0.129 49	0.3	0.000				
20	160	0.12970				0.12945	0.12960	0.12974	0.12943	0.12960	0.12948	-0.17%	0.12956	160	0.129 48	0.3	0.000				
21	200	0.12964				0.12876	0.12932	0.13034	0.12909	0.12955	0.12951	-0.10%	0.12938	200	0.129 51	0.3	0.000				
22	250	0.12969				0.13237	0.13014	0.12653	0.13133	0.12945	0.12955	-0.11%	0.13009	250	0.129 55	0.3	0.000				
23	315	0.12969				0.13056	0.12968	0.12854	0.13023	0.12955	0.12956	-0.09%	0.12975	315	0.129 56	0.3	0.000				
24	400	0.12970				0.13034	0.12982	0.12882	0.12996	0.12958	0.12959	-0.08%	0.12974	400	0.129 59	0.3	0.000				
25	500	0.12973				0.13011	0.12981	0.12907	0.12979	0.12969	0.12966	-0.06%	0.12969	500	0.129 66	0.3	0.000				
26	630	0.12977				0.13004	0.12975	0.12919	0.12983	0.12970	0.12969	-0.06%	0.12970	630	0.129 69	0.3	0.000				
27	800	0.12982				0.13015	0.12986	0.12913	0.12988	0.12976	0.12975	-0.05%	0.12976	800	0.129 75	0.3	0.000				
28	1000	0.12987				0.13014	0.12978	0.12913	0.12992	0.12974	0.12983	-0.03%	0.12974	1000	0.129 83	0.3	0.000				
29	1250	0.12992				0.13024	0.12985	0.12920	0.13015	0.12986	0.12991	-0.01%	0.12986	1250	0.129 91	0.3	0.000				
30	1600	0.13002				0.13055	0.13005	0.12933	0.13035	0.13007	0.13007	0.04%	0.13007	1600	0.130 07	0.3	0.000				
31	2000	0.13020				0.13000	0.13014	0.13038	0.12990	0.13011	0.13024	0.03%	0.13011	2000	0.130 24	0.3	0.000				
32	2500	0.13059				0.13075	0.13150	0.13027	0.12966	0.13054	0.13060	0.00%	0.13054	2500	0.130 60	0.6	0.001				
33	3150	0.13111				0.13181	0.13132	0.13015	0.13126	0.13114	0.13107	-0.03%	0.13114	3150	0.131 07	0.6	0.001				
34	4000	0.13187				0.13053	0.12982	0.13329	0.13243	0.13152	0.13191	0.03%	0.13152	4000	0.131 91	0.6	0.001				
35	5000	0.13298				0.13317	0.13328	0.13300	0.13281	0.13306	0.13307	0.07%	0.13306	5000	0.133 07	0.6	0.001				
36	6300	0.13488				0.13305	0.13311	0.13702	0.13536	0.13464	0.13464	-0.18%	0.13464	6300	0.134 64	1.8	0.002				
37	8000	0.13847				0.13869	0.13746	0.13875	0.13978	0.13867	0.13867	0.15%	0.13867	8000	0.138 67	2.1	0.003				
38	10000	0.14261				0.14431	0.14609	0.14167	0.14069	0.14319	0.14319	0.41%	0.14319	10000	0.143 19	2.1	0.003				

DCC into current certificate emision system



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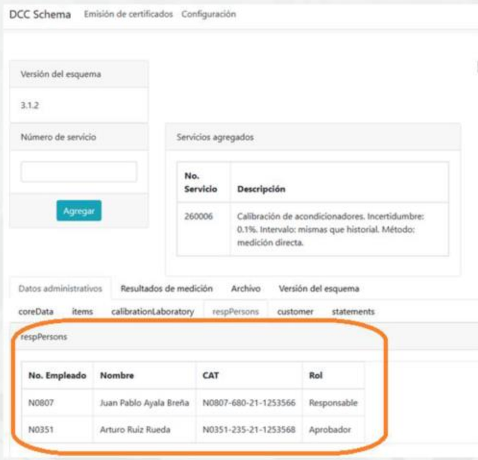
DCC into current certificate emision system



DCC Schema · Emisión de certificados · Configuración

Versión del esquema: 3.1.2

Número de servicio

Agregar

Servicios agregados

No. Servicio	Descripción
260006	Calibración de acondicionadores. Incertidumbre: 0.1%. Intervalo: mismas que historial. Método: medición directa.

Datos administrativos · Resultados de medición · Archivo · Versión del esquema

coreData · items · calibrationLaboratory · respPersons · customer · statements

respPersons

No. Empleado	Nombre	CAT	Rol
N0807	Juan Pablo Ayala Breña	N0807-680-21-1253566	Responsable
N0351	Arturo Ruiz Rueda	N0351-235-21-1253568	Aprobador

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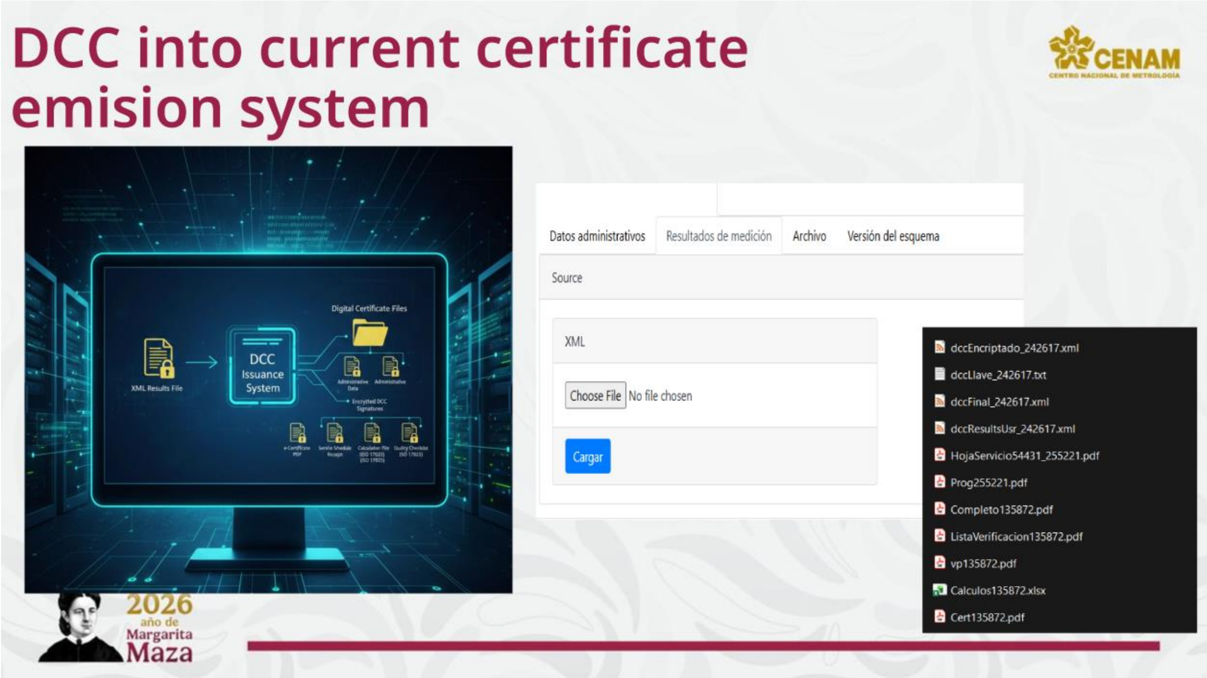
DCC into current certificate emision system
CENAM
CENTRO NACIONAL DE METROLOGÍA
XML Results File
DCC Issuance System
Digital Certificate Files
Datos administrativos
Resultados de medición
Archivo
Versión del esquema
Source
XML
Choose File
No file chosen
Cargar
dccEncriptado_242617.xml
dccLlave_242617.txt
dccFinal_242617.xml
dccResultsUsr_242617.xml
HojaServicio54431_255221.pdf
Prog255221.pdf
Completo135872.pdf
ListaVerificacion135872.pdf
vp135872.pdf
Calculos135872.xlsx
Cert135872.pdf
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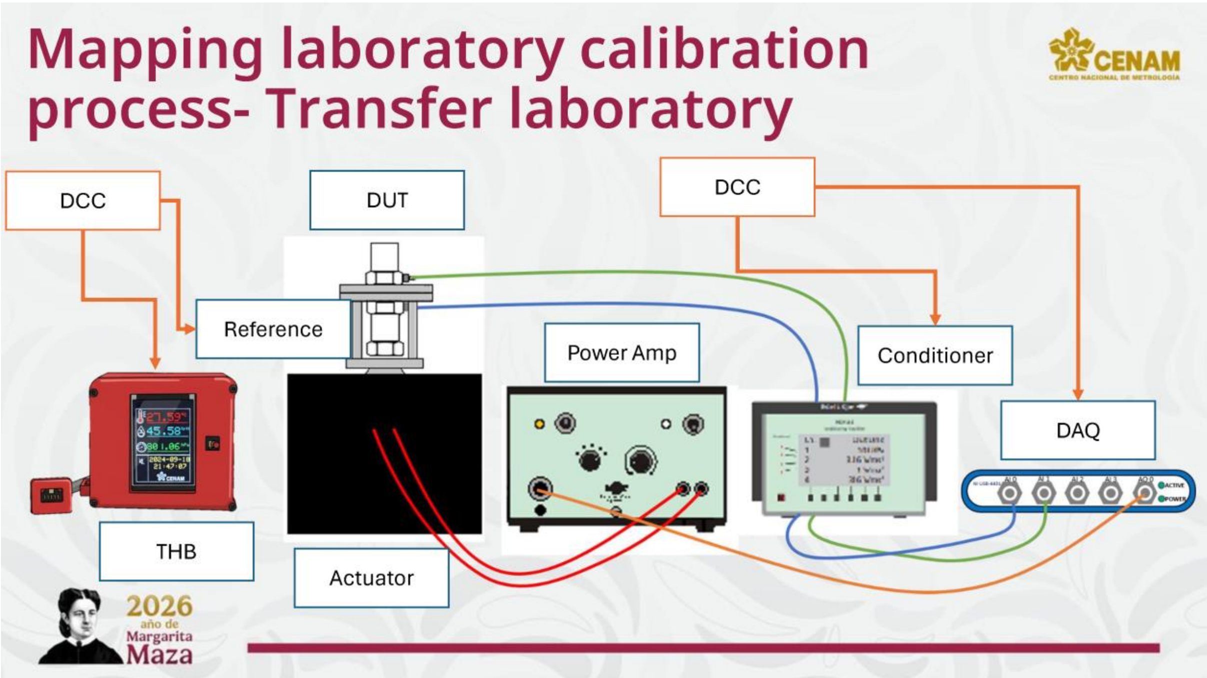
Mapping laboratory calibration process- Transfer laboratory
CENAM
CENTRO NACIONAL DE METROLOGÍA
DCC
DUT
DCC
Reference
Power Amp
Conditioner
DAQ
THB
Actuator
2026
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Maza

Calibration systems and software

Instrument	Calibration certificate	Brand/Model
Accelerometer Standard	CENAM—Primary Alternating Acceleration Laboratory.	B&K/XXXX
DAQ	CENAM-Secondary Alternating Acceleration Laboratory.	NI-USB/XXXX
Signal conditioner	CENAM-Secondary Alternating Acceleration Laboratory.	B&K/XXXX
THB	CENAM-Thermometry and Pressure Laboratory	CENAM DEVELOPMENT

Software/Version/Name	Process description	Producer
LabVIEW/14/Accelerometer calibrator calibration program	Input: Measurement readings Process: Corrections, adjustments, inclusion of environmental conditions Output: Data in table processed in LVM format for Excel	CENAM/XXXX
Excel/W10/CA Spreadsheet	Input: Data in LVM measurement format, CC reference information, environmental conditions.Process: Data loading, environmental conditions, uncertainty calculation, voltage corrections, graphs, etc.Output: Results sheet to transfer to WORD.	CENAM/XXXX
WORD/W10/CNM-XXX-XXX-2023	Input: Excel dataProcess: document formatting, inclusion of results and graphsOutput: Certificate without cover page in PDF format	CENAM/XXXX

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Findings & Future Work

- Implement at CENAM level
- Transfer the knowledge to other NMI´s and users
- Integrate a complex sensor network to measure different quantities inside a laboratory
- Integrate AI to enable new aplitacions using Machine Learning

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Day 3 2026-02-26 Thursday
Parallel Session “DCC Production II”
Session Chair: Thomas Krah

036 Julian Haller:
Expert Report DKD-E 7-3 on how to use the DCC schema for weighing instruments - content and first months of experience

Presenting author: Julian Haller
Email: julian.haller@sartorius.com
Additional authors: Nil
Institution:
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Keywords: DKD, NAWI, Weighing Instruments

Abstract

In March 2025, the DKD published the 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” [1]. Within this document several recommendations are given how DCCs for weighing instruments should be created in a harmonized way to achieve interoperability and vendor-independent compatibility.

In detail, the expert report contains some general remarks, guidance on structuring the information in the DCC schema, particular application rules for weighing instruments in DCCs, a list of applicable refType identifiers, guidance on reading information from a DCC for weighing instruments as well as three example DCCs.

In this presentation, the content of the expert report will be presented in detail and how interoperability is intended to be achieved through the content.

Sartorius issues respective DCCs in several countries under several accreditations since more than 6 months. Therefore, in addition, experiences will be shared from the Sartorius implementation, as well as perception and acceptance by customers and accreditation bodies.

References:
[1] 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 03/2025, Physikalisch- Technische Bundesanstalt, Braunschweig and Berlin. DOI: 10.7795/550.20250325

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Presentation #036 of Julian Haller

Expert Report DKD-E 7-3 on how to use the DCC schema for weighing instruments - content and first months of experience

Dr. Julian Haller, Sartorius Lab Instruments GmbH & Co. KG, 27.02.2024

DKD Working Group „DCC NAWIs“

D. Knopf (PTB)
S. Hackel (PTB)
K. Fritsch (Mettler-Toledo)
M. Häfner (Häfner)
P. Straubinger (Bizerba)
S. Osang (Minebea, DKD-FA)
M. Turino (Kern)
Z. Zelenka (BEV, EURAMET TC-M)
J. Haller (Sartorius)

Goals:

- 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!

DKD Working Group „DCC NAWIs“

Timeline:

- Kickoff meeting 03/2022
- First draft 06/2024
- Final publication 03/2025

Challenges:

- Parallel development of general conventions/rules
- NO interpretation of the calibration guide
- Clarification what is really needed in a machine-readable (or –identifiable) way

Content of the expert report DKD-E 7-3

Editorial Note:
Chapters 1 and 2 of this expert report were taken from an equivalent expert report concerning DCCs for weights and mass [1] and were only adapted to NAWIs, where applicable.

These two chapters concern rather general topics about DCCs and it is to be expected that their content will be published in another overarching expert report [2] in the future.

When this overarching expert report is available, the content of these two chapters will be significantly reduced accordingly in upcoming revisions of this report and this editorial note will be omitted.

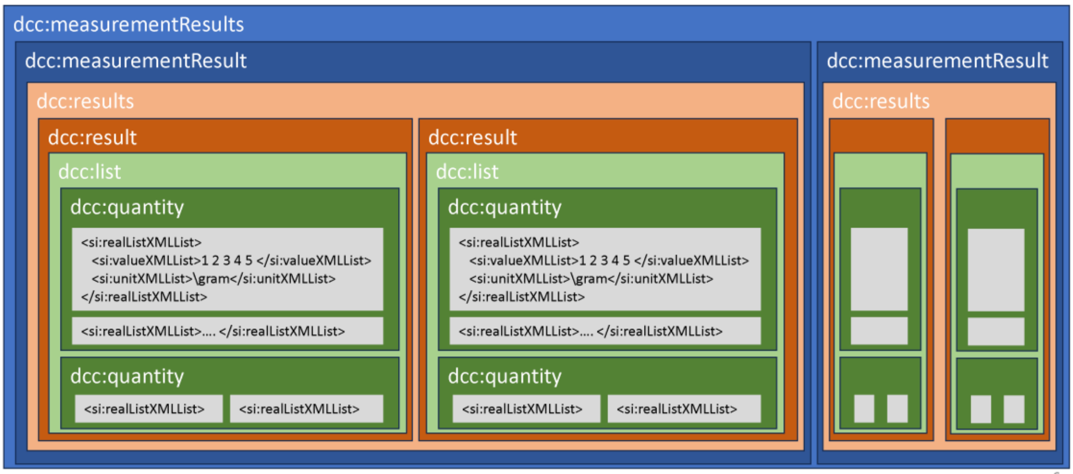
Content of the expert report DKD-E 7-3

Using the DCC elements for calibrations of NAWIs:

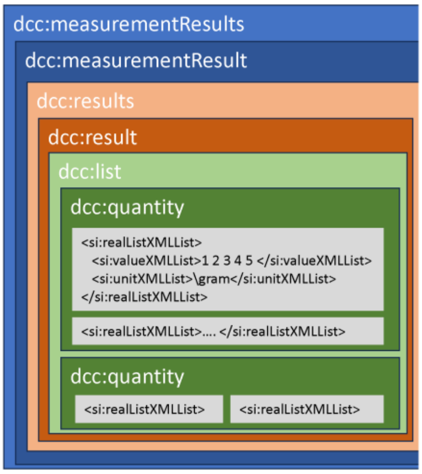
***Where** do I find particular information?*

Content of the expert report DKD-E 7-3

Given structure of the DCC schema: > 5 „nested“, hierarchical layers for results:



Content of the expert report DKD-E 7-3



How shall the given structure be applied to the specific data structure of a particular kind of calibration objects?

General:
- Multiple measurements (e.g. before/after adjustment)

Weighing Instruments:
- Ranges
- Individual measurements (repeatability, eccentricity, error of indication and optionally auxiliary measurements)
- Nominal values, single indications, calculated values (standard deviation)

Content of the expert report DKD-E 7-3

Application rules for NAWIs in DCCs:

*How do I handle **certain particularities**?*

- Several calibrations (“as found/as left”)
- Repair and adjustment status
- Multiple range and multi-interval instruments

Expert Report DKD-E 7-3 on how to use the DCC schema for weighing instruments - content and first months of experience

Content of the expert report DKD-E 7-3

List of refType identifiers for calibrations of NAWIs:

***How** do I find particular information?*

Expert Report DKD-E 7-3 on how to use the DCC schema for weighing instruments - content and first months of experience

Content of the expert report DKD-E 7-3

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:name>
      <dcc:content>Repeatability</dcc:content>
   </dcc:name>
   <dcc:data>
      <dcc:quantity>
         <si:realListXMLList>
            <si:valueXMLList>0.1000001 0.0999999 0.1000002 0.0999999 0.999998</si:valueXMLList>
            <si:unitXMLList>\kilogram</si:unitXMLList>
         </si:realListXMLList>
      </dcc:quantity>
   </dcc:data>
</dcc:result>
<dcc:result  refType=„NAWI_eccentricityMeasurement“>
 <dcc:name>
      <dcc:content>Eccentricity</dcc:content>
   </dcc:name>
   <dcc:data>
      <dcc:quantity>
         <si:realListXMLList>
            <si:valueXMLList>0.0999999 0.1000002 0.999997 0.1000000 0.999999</si:valu
            <si:unitXMLList>\kilogram</si:unitXMLList>
         </si:realListXMLList>
      </dcc:quantity>
   </dcc:data>
</dcc:result>
```

Full Interoperability
(Search for refType=„NAWI_repeatabilityMeasurement“ will work for every issuer that follows this convention)

Needed: 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>	

Expert Report DKD-E 7-3 on how to use the DCC schema for weighing instruments - content and first months of experience

Content of the expert report DKD-E 7-3

Guidance on reading information from a DCC for a NAWI:

e.g. date of calibration:

6.1 Date of calibration

This is a single entry in the format YYYY-MM-DD in the DCC.

Procedure:

1. Go to dcc:endPerformanceDate
2. Output value

XSLT example:

```
<xsl:value-of select="//dcc:endPerformanceDate"/>
```

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Expert Report DKD-E 7-3 on how to use the DCC schema for weighing instruments - content and first months of experience

Content of the expert report DKD-E 7-3

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Three example DCCs:

Appendix A Example of a digital calibration certificate for a single range balance with two measurements (before/after adjustment)

The example matches the example given in Annex H1 of EURAMET cg-18, concerning the instrument and the results (Option 1 for both measurements).

Maximum capacity Max=220 g
Scale interval d=0.1 mg

Note: According to the example in H1.2/B, the measurements of repeatability and eccentricity have not been performed after adjustment and are thus not denoted in the second dcc:measurementResult block.

Appendix B Example of a digital calibration certificate for a multiple range balance

Appendix C Example of a digital calibration certificate for a multi-interval balance consisting of two identifiable parts (indicator and platform)

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Expert Report DKD-E 7-3 on how to use the DCC schema for weighing instruments - content and first months of experience

First months of experience

- Since 07/2025, Sartorius issues DCCs (as attachment to the PDF) in ~15 countries
- >30 000 DCCs issued so far
- 5 audits successfully passed since then
- Hardly any customer interest yet
- Applications for DCCs urgently needed to foster the distribution of DCCs!

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Expert Report DKD-E 7-3 on how to use the DCC schema for weighing instruments - content and first months of experience

Outlook

- Revision of the expert report will start soon in order to
  - adapt schema changes
  - adapt cross-sectional conventions
  - add missing parts ("uncertainty in use", "minimum weight")
  - correct small mistakes
  - include international partners to include international views and increase international acceptance
    - Interest has been expressed from CN, CO, TH, GM and UA – if other countries (NMIs) are interested to participate, please contact me!

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Thank you.

Scan or click on QR Code for the DKD Expert report:

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037 Michael Melzer: Recommendations for DCCs for the ISO 376 calibration of uniaxial force measuring devices

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Keywords: Force calibration, Digital metrology, DCC good practice, Mechanical quantities

Abstract

ISO 376 is a globally established calibration standard for uniaxial force transducers. It regulates the handling, measuring procedure, raw data processing, calibration function determination as well as the assessment of measurement uncertainty and item classification. The DCC task group of the DKD's technical committees for force, acceleration and acoustics and for torque defined good practice rules for DCCs in the scope of ISO 376 [1] to enable interoperable certificates in force metrology. This talk introduces a specific DCC realization for a 1,000 kN tensile force transducer, highlighting several advanced features that are hardly covered by other model implementations so far, i.e. multiple measurement series with varying loading sequences and mounting positions, embedded balancing functions and coefficients, solitary relative measurement uncertainties and load-specific item classifications. Many of those aspects are also relevant for DCCs from other metrological communities, that may adopt the approaches that are recently harmonized for the quantity of force.

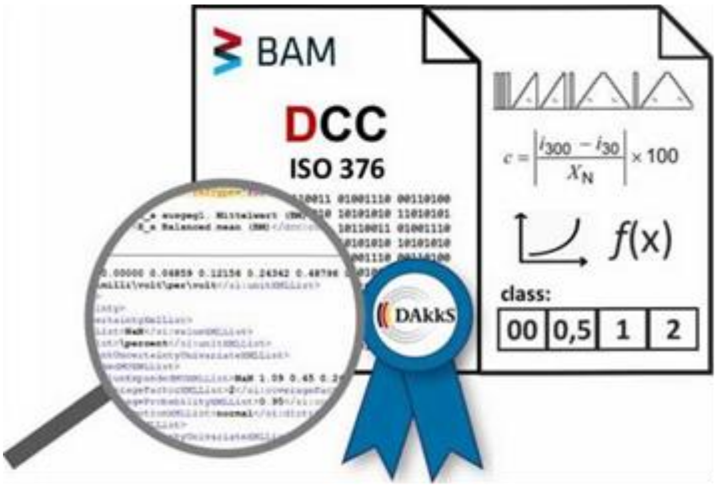

Figure 1. Deep dive into DCC for an ISO 376 calibration covering aspects like multiple measurement series, results from processed measurement data, calibration functions, and classification

Reference:

[1] S. Schönhals, M. Jordan, M. Melzer, D. Röske (2025): Ideas for the transition from paper-based force and torque calibration certificates to machine-readable XML data, Measurement: Sensors 38, 101334; DOI: 10.1016/j.measen.2024.101334

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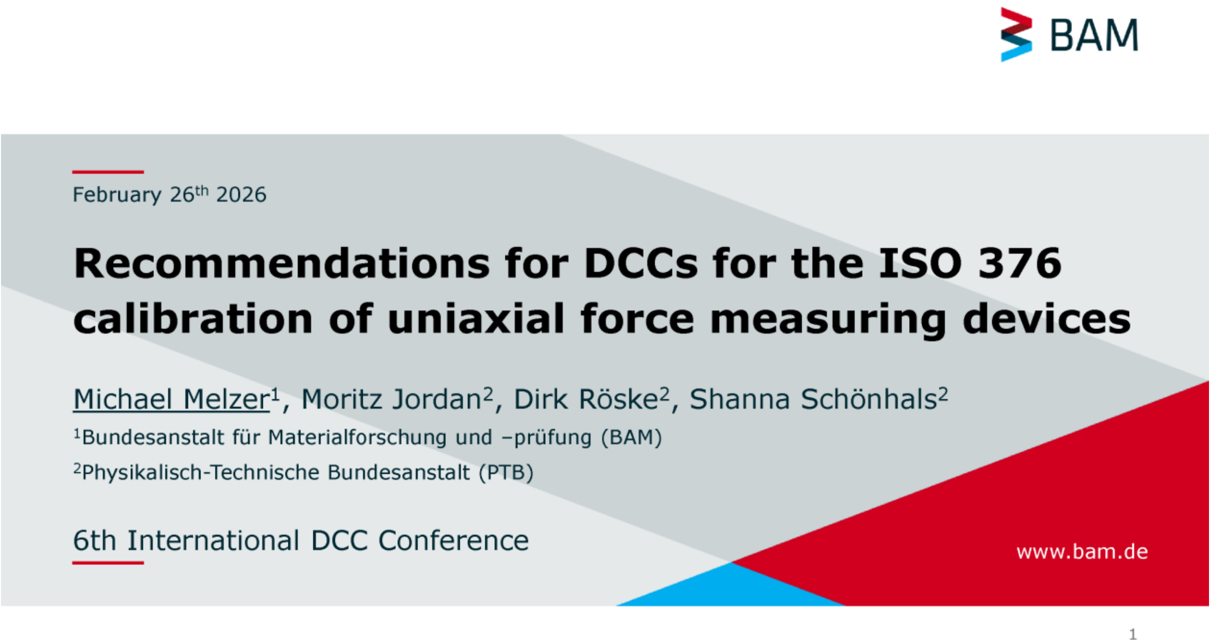
Presentation #037 of Michael Melzer



The BAM Calibration Lab - CMCs

DAkkS – accreditation D-K-11075-08

- **Force quantity:** uniaxial force transducers
  ISO 376 and DKD-R 3-3
  Range: 10 N to 5 MN (compressive: up to 21 MN possible)
  BMC: down to 0.01 % / class 0.5 or 00
- **Temperature quantity:** resistance thermometers, thermocouples and simulation (DKD-R 5-1, 5-3 and 5-5)
  Temperature range: -50 °C to 160 °C
  BMC: down to 30 mK
- **Electrical quantities:** DCU, DCI, DCR, charge voltage ratio (full-, half- and quarterbridges)
  BMC: DCU 1 µV, DCR 4 ppm, DCI 0,8 nA, U/U 0,03 µV/V
- **Total staff: 3, about 200 certificates p.a.** (99% accredited)

Calibration of electrical quantities (left), force transducer in the 5 MN force calibration machine (right)

- Establishment of DCCs in the scope of accreditation
- Pilot lab for eAttestations
- Contributing to DCC good practice definitions (via DKD)

Feb 26th 2026 https://rrr.bam.de/RRR/Navigation/EN/Calibration-Laboratory/calibration-lab.html 3

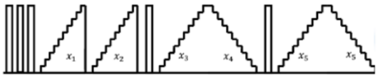
Content

1. **Scope of the ISO 376 standard**
2. **Calibration facilities and items**
3. **Peculiarities of calibration certificates according to ISO 376**
4. **Realization of requirements in a DCC**

Feb 26th 2026 DCC for ISO 376 – Force transducers 4

ISO 376:2011
Scope

- **Process of calibration**



- **Evaluation of measured data**

$$c = \left| \frac{i_{300} - i_{30}}{X_N} \right| \times 100$$

- **How to obtain the calibration function**

$f(x)$

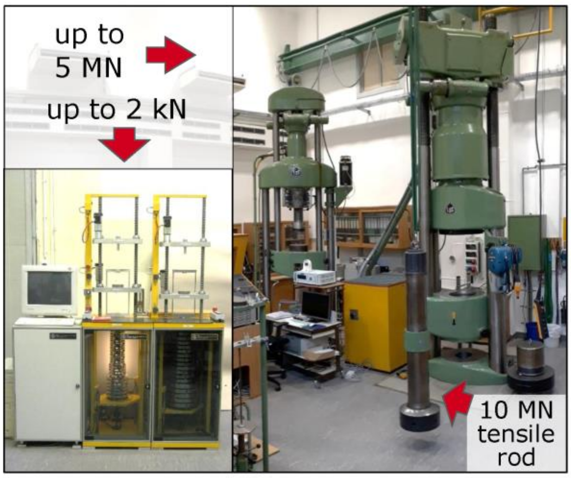
- **Determination of measurement uncertainty**

$$w_2 = \frac{1}{|\bar{X}_r|} \times \sqrt{\frac{1}{6} \times \sum_{i=1,3,5} (X_i - \bar{X}_r)^2}$$

- **Classifications**

Klasse	b	b'	f_c	f_0	v	c	%
00	0,05	0,0 25	±0,025	±0,012	0,07	0,025	±0,01
0,5	0,10	0,05	±0,05	±0,025	0,15	0,05	±0,02
1	0,20	0,10	±0,10	±0,050	0,30	0,10	±0,05
2	0,40	0,20	±0,20	±0,10	0,50	0,20	±0,10

ISO 376:2011
Calibration facilities and items



- **Compressive or tensile loading**
- **Acquisition of electrical signal (typically mV/V)**
- **Single transducer or measurement chain**

ISO 376:2011
Calibration certificate

Bundesanstalt für Materialforschung und -prüfung (BAM)
Fachbereich 8.1 Sensorik, mess- und prüftechnische Verfahren

Unter den Eichen 87
12205 Berlin
T: +49 30 8104 - 1919
F: +49 30 8104 - 1917
www.bam.de

BAM
Bundesanstalt für Materialforschung und -prüfung

DAkkS
Deutsche Akkreditierungsstelle
D-K-11075-08-00

Kalibrierschein / Calibration Certificate

erstellt durch das Kalibrierlaboratorium
issued by the calibration laboratory

Mitglied im / a member of the
Deutschen Kalibrierdienst

DKD

Kalibrierzeichen *Calibration mark*	2000 D-K- 11075-08-00 2023-08

Gegenstand *Object*: Zug-Kraftaufnehmer 1 MN

Hersteller *Manufacturer*: interface

Dieser Kalibrierschein dokumentiert die metrologische Rückführbarkeit auf nationale Normale zur Darstellung der Einheiten in Übereinstimmung mit dem Internationalen Einheitensystem (SI).
Die DAkkS ist Unterzeichner der multilateralen

Peculiarities

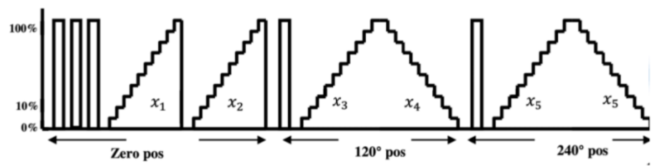
In general:

- Well structured
  - High similarity of certificates
- High in content
  - Typically 5-8 pages (for one loading direction)
- 4 subroutines possible (case A-D)

ISO 376:2011
Calibration certificate

Tabelle 1: Messergebnisse
Table 1: Results

Kraft in kN *force*	Messreihen *measuring runs* Unveränderte Einbaustellung *Unchanged mounting position*		Veränderte Einbaustellung *Rotated mounting position*			
	1 (0°)	2 (0°)	3 (120°)	4 (120°)	5 (240°)	6 (240°)
20	0,04866	0,04866	0,04862	0,04868	0,04863	0,04873
50	0,12160	0,12160	0,12156	0,12173	0,12171	0,12193
100	0,24336	0,24337	0,24340	0,24377	0,24371	0,24412
200	0,48753	0,48753	0,48751	0,48821	0,48808	0,48880
300	0,73286	0,73286	0,73275	0,73390	0,73357	0,73473
400	0,97959	0,97961	0,97942	0,98067	0,98039	0,98165
500	1,22651	1,22649	1,22624	1,22748	1,22732	1,22853
600	1,47346	1,47347	1,47316	1,47420	1,47433	1,47538
700	1,72051	1,72050	1,72012	1,72089	1,72137	1,72216
800	1,96756	1,96758	1,96715	1,96749	1,96846	1,96888
900	2,21465	2,21462	2,21422	2,21425	2,21558	2,21565
1000	2,46170	2,46175	2,46134		2,46275	
0	-0,00016	-0,00012	-0,00006		-0,00007	



Peculiarities

- Multiple series of measurement
  - Increasing and decreasing loads
  - Varying mounting positions

ISO 376:2011
Calibration certificate

Tabelle 2: Arithmetische Mittelwerte, rel. Wiederholpräzision, rel. erweiterte Vergleichspräzision, rel. Umkehrspanne, rel. Interpolationsabweichung
Table 2: Average values, rel. repeatability error, rel. reproducibility error, rel. reversibility error, rel. interpolation error

Kraft in *force*	Messreihen 1 und 2 *measuring runs* Einbaustellung 0° *Unchanged mounting position 0°*		Messreihen 1, 3, 5 *measuring runs* Einbaustellungen 0°, 120°, 240° *Rotated positions 0°, 120°, 240°*			Wert Xa nach Ausgleichs-kurve in	rel. Interpolations-abweichung *rel. interpolation error*
kN	arithm. Mittelwert in *average value* mV/V	rel. Wiederhol-präzision* *rel. repeatability error* b' (%)	arithm. Mittelwert in *average value* mV/V	rel. erweit. Vergleichs-präzision* *rel. reproducibility error* b (%)	rel. Umkehr-spanne *rel. reversibility error* v (%)	*value Xa calculated (fitted curve)* mV/V	f_c (%)
20	0,04866	0,000	0,04864	0,082	0,165	0,04859	0,103
50	0,12160	0,000	0,12162	0,123	0,160	0,12156	0,051
100	0,24337	0,004	0,24349	0,144	0,160	0,24342	0,028
200	0,48753	0,000	0,48771	0,117	0,146	0,48796	-0,051
300	0,73286	0,000	0,73306	0,112	0,158	0,73342	-0,048
400	0,97960	0,002	0,97980	0,099	0,128	0,97961	0,020
500	1,22650	0,002	1,22669	0,088	0,100	1,22635	0,028
600	1,47347	0,001	1,47365	0,079	0,071	1,47345	0,013
700	1,72051	0,001	1,72067	0,073	0,045	1,72073	-0,003
800	1,96757	0,001	1,96772	0,067	0,019	1,96798	-0,013
900	2,21464	0,001	2,21482	0,061	0,002	2,21504	-0,010
1000	2,46173	0,002	2,46193	0,057		2,46170	0,009

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Peculiarities

- Multiple series of measurement
  - Increasing and decreasing loads
  - Varying mounting positions
- Various processed data

ISO 376:2011
Calibration certificate

Tabelle 4: Klassifizierungen nach DIN EN ISO 376 Fall D mit Umkehrspanne. Erweiterte relative Messunsicherheit der Kalibrierung (zu- und abnehmende Kräfte)
Table 4: Classification according to DIN EN ISO 376 case D with reversibility. Relative expanded uncertainty of calibration (increasing forces and increasing/decreasing forces).

Kraftstufe *force level*	eingestuft in Geräteklasse von Kraftstufe bis Kalibrierhöchstkraft *class from the force level up to maximum calibration force*	erweiterte relative Messunsicherheit (%) für *expanded uncertainty of calibration (%) for* zunehmende Kräfte *increasing forces*	zu/abnehmende Kräfte *in/decreasing forces*
20 kN	2	1,09	1,11
50 kN	1	0,45	0,49
100 kN	1	0,24	0,31
200 kN	1	0,14	0,22
300 kN	1	0,11	0,21
400 kN	0,5	0,087	0,18
500 kN	0,5	0,077	0,14
600 kN	0,5	0,070	0,11
700 kN	0,5	0,065	0,084
800 kN	0,5	0,062	0,066
900 kN	0,5	0,059	0,059
1000 kN	0,5	0,057	0,057

Klasse	b	b'	f_c	f_0	v	c	%
00	0,05	0,0 25	±0,025	±0,012	0,07	0,025	±0,01
0,5	0,10	0,05	±0,05	±0,025	0,15	0,05	±0,02
1	0,20	0,10	±0,10	±0,050	0,30	0,10	±0,05
2	0,40	0,20	±0,20	±0,10	0,50	0,20	±0,10

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Peculiarities

- Multiple series of measurement
  - Increasing and decreasing loads
  - Varying mounting positions
- Various processed data
- Classifications
  - Based on 7 criteria
- Relative uncertainties
  - For in-/decreasing forces

ISO 376:2011
Calibration certificate

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Gleichung für die Interpolation
Equation of the interpolation

Anhand der Messergebnisse wurden für die Mittelwerte (unterschiedliche Einbaustellungen) die Koeffizienten der folgenden Funktionen durch Ausgleichsrechnung bestimmt. Die Werte X_a nach Ausgleichskurve, Tabelle 2, sind die mit der Funktion $X_a = a\,F + b\,F^2 + c\,F^3$ berechneten Werte.

According to the results listed above, the parameters of the following functions were calculated from averaged values (rotated positions) using the least squares method. The values X_a, calculated, table 2, have been obtained using the best fit function $X_a = a\,F + b\,F^2 + c\,F^3$.

Kraft F [kN] in Anzeige X_a [mV/V] umrechnen
force F [kN] into indication X_a [mV/V]

$X_a = a\,F + b\,F^2 + c\,F^3$

a = 2,428048E-3
b = 6,495637E-8
c = -3,130240E-11

Anzeige X [mV/V] in Kraft F [kN] umrechnen
indication X [mV/V] into force F [kN]

$F = a'\,X + b'\,X^2 + c'\,X^3$

a' = 4,117998E+2
b' = -4,385429E+0
c' = 8,614265E-1

› **How to represent this data in a DCC?**

>DKD<

Joint DCC working group
for force and torque
of DKD-TCs 3 and 10

› **DCC good practice**

Peculiarities

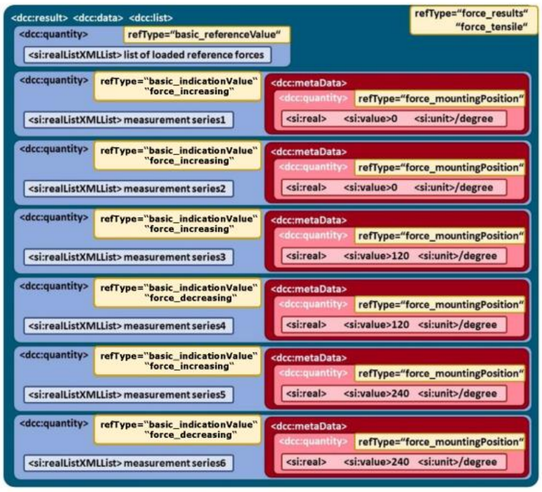
- Multiple series of measurement
  - › Increasing and decreasing loads
  - › Varying mounting positions
- Various processed data
- Classifications
  - › Based on 7 criteria
- Relative uncertainties
  - › For in-/decreasing forces
- Balancing functions
  - › Coefficients

DCC: ISO 376:2011
Measured data

BAM

Tabelle 1: Messergebnisse
Table 1: Results

Kraft in kN *force*	Messreihen		
	Unveränderte Einbaustellung *Unchanged mounting position*		
	1 (0°)	2 (0°)	3 (120°)
20	0,04866	0,04866	0,04862
50	0,12160	0,12160	0,12156
100	0,24336	0,24337	0,24340
200	0,48753	0,48753	0,48751
300	0,73286	0,73286	0,73275
400	0,97959	0,97961	0,97942
500	1,22651	1,22649	1,22624
600	1,47346	1,47347	1,47316
700	1,72051	1,72050	1,72012
800	1,96756	1,96758	1,96715
900	2,21465	2,21462	2,21422
1000	2,46170	2,46175	2,46134
0	-0,00016	-0,00012	-0,00006



DCC: ISO 376:2011
Measured data

BAM

Tabelle 1: Messergebnisse
Table 1: Results

Kraft in kN *force*	Messreihen *measuring runs*					
	Unveränderte Einbaustellung *Unchanged mounting position*		Veränderte Einbaustellung *Rotated mounting position*			
	1 (0°)	2 (0°)	3 (120°)	4 (120°)	5 (240°)	6 (240°)
20	0,04866	0,04866	0,04862	0,04868	0,04863	0,04873
50	0,12160	0,12160	0,12156	0,12173	0,12171	0,12193
100	0,24336	0,24337	0,24340	0,24377	0,24371	0,24412
200	0,48753	0,48753	0,48751	0,48821	0,48808	0,48880
300	0,73286	0,73286	0,73275	0,73390	0,73357	0,73473
400	0,97959	0,97961	0,97942	0,98067	0,98039	0,98165
500	1,22651	1,22649	1,22624	1,22748	1,22732	1,22853
600	1,47346	1,47347	1,47316	1,47420	1,47433	1,47538
700	1,72051	1,72050	1,72012	1,72089	1,72137	1,72216
800	1,96756	1,96758	1,96715	1,96749	1,96846	1,96888
900	2,21465	2,21462	2,21422	2,21425	2,21558	2,21565
1000	2,46170	2,46175	2,46134		2,46275	
0	-0,00016	-0,00012	-0,00006		-0,00007	

DCC: ISO 376:2011
Measured data

BAM

```
<dcc:result refType="force_results">
    <dcc:name>
    <dcc:data>
        <dcc:list refType="basic_1IndexTable">
            <dcc:quantity refType="basic_referenceValue basic_tableIndex0" id="referenceValue">
                <dcc:name>
                <si:realListXMLList>
                    <si:valueXMLList>0 20 50 100 200 300 400 500 600 700 800 900 1000 0</si:valueXMLList>
                    <si:unitXMLList>\kilo\newton</si:unitXMLList>
                </si:realListXMLList>
            </dcc:quantity>
            <dcc:quantity id="measurementSeries1" refType="basic_indicationValue force_increasing force_zeroReduced">
            <dcc:quantity id="measurementSeries2" refType="basic_indicationValue force_increasing force_zeroReduced">
            <dcc:quantity id="measurementSeries3" refType="basic_indicationValue force_increasing force_zeroReduced">
            <dcc:quantity id="measurementSeries4" refType="basic_indicationValue force_decreasing force_zeroReduced">
            <dcc:quantity id="measurementSeries5" refType="basic_indicationValue force_increasing force_zeroReduced">
            <dcc:quantity id="measurementSeries6" refType="basic_indicationValue force_decreasing force_zeroReduced">
                <dcc:name>
                    <dcc:content lang="de">Messreihe 6</dcc:content>
                    <dcc:content lang="en">Measurement series 6</dcc:content>
                </dcc:name>
                <si:realListXMLList>
                    <si:valueXMLList>-0.00007 0.04873 0.12193 0.24412 0.48880 0.73473 0.98165 1.22853 1.47538 1.72216 1.96888 2.21565 NaN NaN</si:valueXMLList>
                    <si:unitXMLList>\milli\volt\per\volt</si:unitXMLList>
                </si:realListXMLList>
                <dcc:measurementMetaData>
                    <dcc:metaData>
                        <dcc:data>
                            <dcc:quantity refType="force_mountingPosition">
                                <dcc:name>
                                    <dcc:content lang="de">Einbaustellung</dcc:content>
                                    <dcc:content lang="en">Mounting position</dcc:content>
                                </dcc:name>
                                <si:real>
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                                    <si:unit>\degree</si:unit>
                                </si:real>
                            </dcc:quantity>
                        </dcc:data>
                    </dcc:metaData>
                </dcc:measurementMetaData>
```

"NaN": not a number

(available since DCC-Schema v3.3.0)

DCC: ISO 376:2011

Processed data, classifications and uncertainties

BAM

Tabelle 2: Arithmetische Mittelwerte, rel. Wiederholpräzision, rel. erweiterte Vergleichspräzision, rel. Umkehrspanne, rel. Interpolationsabweichung
Table 2: Average values, rel. repeatability error, rel. reproducibility error, rel. reversibility error, rel. interpolation error

Kraft in *force* kN	Messreihen 1 und 2 *measuring runs* Einbaustellung 0° *Unchanged mounting position 0°*		Messreihen 1, 3, 5 *measuring runs* Einbaustellungen 0°, 120°, 240° *Rotated positions 0°, 120°, 240°*			Wert Xa nach Ausgleichs-kurve in *value Xa calculated (fitted curve)* mV/V	rel. Interpolations-abweichung *rel. interpolation error* f_c (%)
	arithm. Mittelwert in *average value* mV/V	rel. Wiederhol-präzision* *rel. repeatability error* b' (%)	arithm. Mittelwert in *average value* mV/V	rel. erweit. Vergleichs-präzision* *rel. reproducibility error* b (%)	rel. Umkehr-spanne *rel. reversibility error* v (%)		
20	0,04866	0,000	0,04864	0,082	0,165	0,04859	0,103
50	0,12160	0,000	0,12162	0,123	0,160	0,12156	0,051
100	0,24337	0,004	0,24349	0,144	0,160	0,24342	0,028
200	0,48753	0,000	0,48771	0,117	0,146	0,48796	-0,051
300	0,73286	0,000	0,73306	0,112	0,158	0,73342	-0,048
400	0,97960	0,002	0,97980	0,099	0,128	0,97961	0,020
500	1,22650	0,002	1,22669	0,088	0,100	1,22635	0,028
600	1,47347	0,001	1,47365	0,079	0,071	1,47345	0,013
700	1,72051	0,001	1,72067	0,073	0,045	1,72073	-0,003
800	1,96757	0,001	1,96772	0,067	0,019	1,96798	-0,013
900	2,21464	0,001	2,21482	0,061	0,002	2,21504	-0,010
1000	2,46173	0,002	2,46193	0,057		2,46170	0,009

Tabelle 4: Klassifizierungen nach DIN EN ISO 376 Fall D mit Umkehrspanne. Erweiterte relative Messunsicherheit der Kalibrierung (zu- und abnehmende Kräfte)
Table 4: Classification according to DIN EN ISO 376 case D with reversibility. Relative expanded uncertainty of calibration (increasing forces and increasing/decreasing forces).

Kraftstufe *force level*	eingestuft in Geräteklasse von Kraftstufe bis Kalibrierhöchstkraft *class from the force level up to maximum calibration force*	erweiterte relative Messunsicherheit (%) für *expanded uncertainty of calibration (%) for*	
		zunehmende Kräfte *increasing forces*	zu/abnehmende Kräfte *in/decreasing forces*
20 kN	2	1,09	1,11
50 kN	1	0,45	0,49
100 kN	1	0,24	0,31
200 kN	1	0,14	0,22
300 kN	1	0,11	0,21
400 kN	0,5	0,087	0,18
500 kN	0,5	0,077	0,14
600 kN	0,5	0,070	0,11
700 kN	0,5	0,065	0,084
800 kN	0,5	0,062	0,066
900 kN	0,5	0,059	0,059
1000 kN	0,5	0,057	0,057

- All data (columns) have the same reference as the measured data (loaded force)
  - Can be merged in the same <dcc:list>-element (table) in a DCC

DCC: ISO 376:2011

Processed data, classifications and uncertainties

BAM

```
<dcc:result refType="force_results">
    <dcc:name>
    <dcc:data>
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            <dcc:quantity id="measurementSeries2" refType="basic_indicationValue force_increasing force_zeroReduced">
            <dcc:quantity id="measurementSeries3" refType="basic_indicationValue force_increasing force_zeroReduced">
            <dcc:quantity id="measurementSeries4" refType="basic_indicationValue force_decreasing force_zeroReduced">
            <dcc:quantity id="measurementSeries5" refType="basic_indicationValue force_increasing force_zeroReduced">
            <dcc:quantity id="measurementSeries6" refType="basic_indicationValue force_decreasing force_zeroReduced">
            <dcc:quantity refId="measurementSeries1 measurementSeries2" refType="math_arithmeticMean force_withoutRotation">
            <dcc:quantity refId="measurementSeries1 measurementSeries2" refType="force_relativeRepeatabilityError">
            <dcc:quantity refId="measurementSeries1 measurementSeries3 measurementSeries5" refType="math_arithmeticMean force_withRotation">
            <dcc:quantity refId="measurementSeries1 measurementSeries3 measurementSeries5" refType="force_relativeReproducibilityError">
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                    <dcc:content lang="de">rel. Vergleichspräzision</dcc:content>
                    <dcc:content lang="en">rel. reproducibility error</dcc:content>
                </dcc:name>
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                    <si:unitXMLList>\percent</si:unitXMLList>
                </si:realListXMLList>
            </dcc:quantity>
            <dcc:quantity refId="measurementSeries3 measurementSeries4 measurementSeries5 measurementSeries6" refType="force_relativeReversibilityError">
            <dcc:quantity refId="balancingFunction" refType="force_balancedMean force_caseC force_increasing">
            <dcc:quantity refId="balancingFunction" refType="force_balancedMean force_caseD force_increasing force_decreasing">
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            <dcc:quantity refType="force_classification force_caseD">
            <dcc:usedMethods>
            <dcc:measurementMetaData>
        </dcc:list>
    </dcc:data>
</dcc:result>
```

DCC: ISO 376:2011

Processed data, classifications and uncertainties

BAM

```xml
<dcc:result refType="force_results">
    <dcc:name>
    <dcc:data>
        <dcc:list refType="basic_1IndexTable">
            <dcc:quantity refType="basic_referenceValue basic_tableIndex0" id="referenceValue">
            <dcc:quantity id="measurementSeries1" refType="basic_indicationValue force_increasing force_zeroReduced">
            <dcc:quantity id="measurementSeries2" refType="basic_indicationValue force_increasing force_zeroReduced">
            <dcc:quantity id="measurementSeries3" refType="basic_indicationValue force_increasing force_zeroReduced">
            <dcc:quantity id="measurementSeries4" refType="basic_indicationValue force_decreasing force_zeroReduced">
            <dcc:quantity id="measurementSeries5" refType="basic_indicationValue force_increasing force_zeroReduced">
            <dcc:quantity id="measurementSeries6" refType="basic_indicationValue force_decreasing force_zeroReduced">
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            <dcc:quantity refId="measurementSeries3 measurementSeries4 measurementSeries5 measurementSeries6" refType="force_relativeReversibilityError">
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            <dcc:quantity refType="force_classification force_caseD">
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                    <dcc:content lang="en">Classification according to DIN EN ISO 376 case D with reversibility</dcc:content>
                </dcc:name>
                <dcc:description>
                    <dcc:content lang="de">Der kalibrierte Kraftaufnehmer wird für die Verwendung von der jeweiligen Kraftstufe bis zur Kalibrierhöchstkraft
                    <dcc:content lang="en">The calibrated force transducer is classified from the respective force level up to the maximum calibration force
                </dcc:description>
                <dcc:charsXMLList>undefined 2 1 1 1 1 0,5 0,5 0,5 0,5 0,5 0,5 0,5 undefined</dcc:charsXMLList>
            </dcc:quantity>
            <dcc:usedMethods>
            <dcc:measurementMetaData>
        </dcc:list>
    </dcc:data>
</dcc:result>
```


DCC: ISO 376:2011

Processed data, classifications and uncertainties

BAM

```xml
<dcc:quantity refId="balancingFunction" refType="force_balancedMean force_caseC force_increasing">
    <dcc:name>
        <dcc:content lang="de">X_a ausgegl. Mittelwert (BM), zunehmend</dcc:content>
        <dcc:content lang="en">X_a Balanced mean (BM)</dcc:content>
    </dcc:name>
    <dcc:description>
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        <si:valueXMLList>0.00000 0.04859 0.12156 0.24342 0.48796 0.73342 0.97961 1.22635 1.47345 1.72073 1.96798 2.21504 2.46170 NaN</si:valueXMLList>
        <si:unitXMLList>\milli\volt\per\volt</si:unitXMLList>
    </si:realListXMLList>
    <dcc:relativeUncertainty>
        <dcc:relativeUncertaintyXmlList>
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            <si:unitXMLList>\percent</si:unitXMLList>
            <si:measurementUncertaintyUnivariateXMLList>
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                    <si:valueExpandedMUXMLList>NaN</si:valueExpandedMUXMLList>
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                    <si:coverageProbabilityXMLList>0.95</si:coverageProbabilityXMLList>
                    <si:distributionXMLList>normal</si:distributionXMLList>
                </si:expandedMUXMLList>
            </si:measurementUncertaintyUnivariateXMLList>
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    </dcc:relativeUncertainty>
</dcc:quantity>
<dcc:quantity refId="balancingFunction" refType="force_balancedMean force_caseD force_increasing force_decreasing">
```

- Statement of relative expanded measurement uncertainties without stating the respective absolute uncertainties (DCC-schema v3.3.0)

DCC: ISO 376:2011

Regression analysis (balanced mean)

Gleichung für die Interpolation
Equation of the interpolation

Anhand der Messergebnisse wurden für die Mittelwerte (unterschiedliche Einbaustellungen) die Koeffizienten der folgenden Funktionen durch Ausgleichsrechnung bestimmt. Die Werte X_a nach Ausgleichskurve, Tabelle 2, sind die mit der Funktion $X_a = a\,F + b\,F^2 + c\,F^3$ berechneten Werte.

According to the results listed above, the parameters of the following functions were calculated from averaged values (rotated positions) using the least squares method. The values X_a, calculated, table 2, have been obtained using the best fit function $X_a = a\,F + b\,F^2 + c\,F^3$.

Kraft F [kN] in Anzeige X_a [mV/V] umrechnen
force F [kN] into indication X_a [mV/V]

$$\boxed{X_a = a\,F + b\,F^2 + c\,F^3}$$

a = 2,428048E-3
b = 6,495637E-8
c = -3,130240E-11

Anzeige X [mV/V] in Kraft F [kN] umrechnen
indication X [mV/V] into force F [kN]

$$F = a'\,X + b'\,X^2 + c'\,X^3$$

a' = 4,117998E+2
b' = -4,385429E+0
c' = 8,614265E-1

- Formula as <dcc:result> using MathML (content type)
  - Representation of polynomial (3rd degree)
  - id-attributes for coefficients

```xml
<dcc:result refType="force_fittingFunction force_balancedMean">
  <dcc:name>
  <dcc:description>
  <dcc:data>
    <dcc:formula refType="force_function">
      <dcc:mathml>
        <ml:math>
          <ml:declare type="fn">
            <ml:ci id="balancingFunction">X_a</ml:ci>
            <ml:lambda>
              <ml:bvar>
                <ml:ci>F</ml:ci>
              </ml:bvar>
              <ml:apply>
                <ml:plus />
                <ml:apply>
                  <ml:times/>
                  <ml:ci id="linearBalanceCoefficient_a">a</ml:ci>
                  <ml:ci>F</ml:ci>
                </ml:apply>
                <ml:apply>
                  <ml:times/>
                  <ml:ci id="quadraticBalanceCoefficient_b">b</ml:ci>
                  <ml:apply>
                    <ml:power />
                    <ml:ci>F</ml:ci>
                    <ml:cn>2</ml:cn>
                  </ml:apply>
                </ml:apply>
                <ml:apply>
                  <ml:times/>
                    <ml:ci id="cubicBalanceCoefficient_c">c</ml:ci>
                    <ml:apply>
                      <ml:power />
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                      <ml:cn>3</ml:cn>
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                </ml:apply>
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          </ml:declare>
        </ml:math>
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    </dcc:formula>
```

Mar 30th 2026 DCC for ISO 376 – Force transducers 10a

DCC: ISO 376:2011

Regression analysis (balanced mean)

Gleichung für die Interpolation
Equation of the interpolation

Anhand der Messergebnisse wurden für die Mittelwerte (unterschiedliche Einbaustellungen) die Koeffizienten der folgenden Funktionen durch Ausgleichsrechnung bestimmt. Die Werte X_a nach Ausgleichskurve, Tabelle 2, sind die mit der Funktion $X_a = a\,F + b\,F^2 + c\,F^3$ berechneten Werte.

According to the results listed above, the parameters of the following functions were calculated from averaged values (rotated positions) using the least squares method. The values X_a, calculated, table 2, have been obtained using the best fit function $X_a = a\,F + b\,F^2 + c\,F^3$.

Kraft F [kN] in Anzeige X_a [mV/V] umrechnen
force F [kN] into indication X_a [mV/V]

$$X_a = a\,F + b\,F^2 + c\,F^3$$

a = 2,428048E-3
b = 6,495637E-8
c = -3,130240E-11

Anzeige X [mV/V] in Kraft F [kN] umrechnen
indication X [mV/V] into force F [kN]

$$F = a'\,X + b'\,X^2 + c'\,X^3$$

a' = 4,117998E+2
b' = -4,385429E+0
c' = 8,614265E-1

- Formula as <dcc:result> using MathML (content type)
- Likewise for the reverse function (and uncertainty envelope)

Coefficients

- Given separately with linkage to the formula
- Can be directly and individually addressed via refTypes

```xml
<dcc:list refType="force_functionParameters">
    <dcc:name>
    <dcc:quantity refType="force_coefficient force_linear" refId="linearBalanceCoefficient_a">
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            <si:unit>\milli\volt\volt\tothe(-1)\kilo\newton\tothe(-1)</si:unit>
        </si:real>
    </dcc:quantity>
    <dcc:quantity refType="force_coefficient force_quadratic" refId="quadraticBalanceCoefficient_b">
        <si:real>
            <si:value>1.99e-10</si:value>
            <si:unit>\milli\volt\volt\tothe(-1)\kilo\newton\tothe(-2)</si:unit>
        </si:real>
    </dcc:quantity>
    <dcc:quantity refType="force_coefficient force_cubic" refId="cubicBalanceCoefficient_c">
        <si:real>
            <si:value>1e-13</si:value>
            <si:unit>\milli\volt\volt\tothe(-1)\kilo\newton\tothe(-3)</si:unit>
        </si:real>
    </dcc:quantity>
</dcc:list>
```

Mar 30th 2026 DCC for ISO 376 – Force transducers 10b

DKD Expert Report for force DCC (ISO 376)
(final editing)

Content

- Description of the data structure with XML-snippets
- Definitions of refTypes → TemaTres
- XML templates (minimal and NMI)
  → Good Practice
- Open access (Englisch language)
- Hosted by DKD

www.ptb.de/cms/en/metrological-services/dkd/publications.html

→ Harmonization for enhanced interoperability and robust IT developments

Acknowledgements and contact

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Michael Fischer

DCC-core team
Muhammed-Ali Demir
Benedikt Seeger

German Calibration Service (DKD)
DCC-WG for force and torque
Torsten Hahn, Shan Lin, Co-authors
DCC-WG for overarching issues

QUALITÄTS INFRASTRUKTUR DIGITAL

Federal Ministry for Economic Affairs and Energy

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038 Erkan Danaci: From Fragmented Practices to Harmonized and Interoperable Models: Designing Common Templates for Measurement Results in Digital Calibration Certificates

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Institute:
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Keywords: Digital Calibration Certificate (DCC), Harmonized Data Models, XML-Based Data Models, Interoperability, Digitalization in Metrology

Abstract

The transition from conventional calibration certificates to Digital Calibration Certificates (DCC) requires more than digital document formats; it demands harmonized data models that ensure machine-readability, interoperability, and long-term scalability across laboratories and digital quality infrastructures. While international initiatives led by PTB and EURAMET have established reference DCC schemas and validation mechanisms, significant variability in laboratory specific data structures continues to impede systematic adoption and standardization of DCC.

This study presents a template-driven approach for structuring measurement results as a foundational layer between laboratory practices and emerging international DCC standards. Building upon TS EN ISO/IEC 17025:2017 requirements, National Metrology Institute of Germany (PTB)'s XML-based DCC schemas, and FAIR data principles, common templates were designed to unify the representation of administrative information, measurement conditions, results, uncertainties, and contextual metadata across diverse laboratory domains.

The proposed measurement result templates were developed through an analysis of existing miscellaneous calibration certificates carried out by various laboratories within a national metrology institute, followed by the definition of a shared semantic and structural model aligned with European DCC initiatives. The framework enables the systematic transformation of heterogeneous laboratory data into harmonized digital representations, supporting both human-readable certificates and machine-actionable DCC outputs. Interoperability was evaluated by validating generated DCC instances against international reference models, demonstrating compatibility with current DCC schema specifications.

The results indicate that common templates constitute a critical layer between laboratory specific practices and emerging international standards. By reducing structural variability, enhancing semantic consistency, and enabling automated data exchange, the proposed approach contributes to the harmonization of digital calibration practices and supports the evolution from good practice to standardization within digital quality infrastructures. The study provides practical insights for national metrology institutes and calibration laboratories aiming to align their DCC implementations with international frameworks and future standardization efforts.

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Presentation #038 of Erkan Danaci

From Fragmented Practices to Harmonized and Interoperable Models: Designing Common Templates for Measurement Results in Digital Calibration Certificates

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Presented by Dr. Erkan DANACI
TÜBİTAK UME
Digitalization Working Group

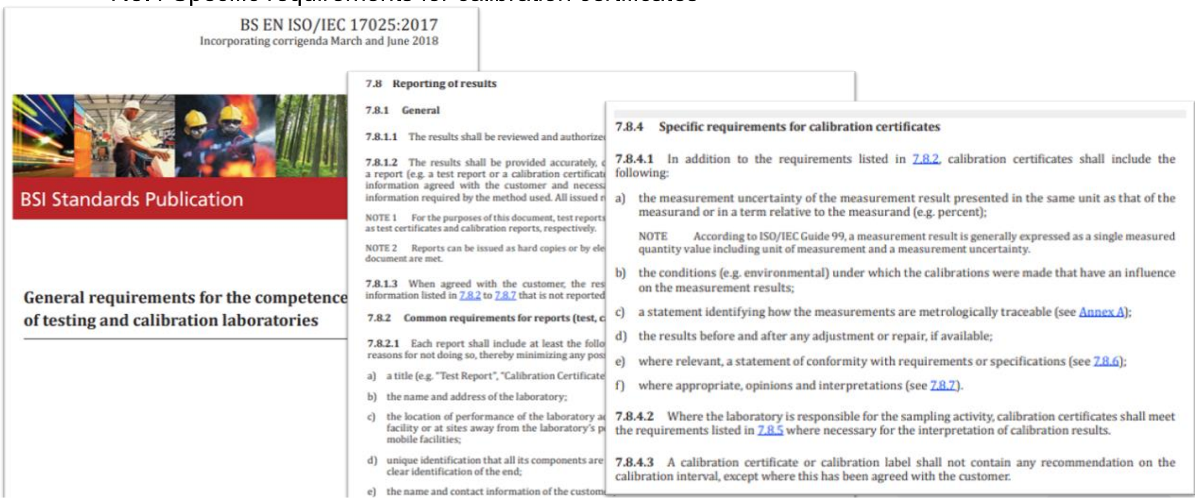
6th DCC Conference
February 26, 2026

Contents

- ISO/IEC 17025 Context
- Structure of the Calibration Certificate
- Obtaining the ADD, CON and COM data
- RoM Complexity and Cross-Domain Variability
- Transferring the Inputs to DCC (DC3 Software)
- RoM Transferring Rules to DCC
- Advantages of DC3 Software
- Conclusion

ISO/IEC 17025 Context for Certification

- EN ISO / IEC 17025 Standard Sections related to calibration certificates
  - 7.8 Reporting of results
  - 7.8.4 Specific requirements for calibration certificates



BS EN ISO/IEC 17025:2017
Incorporating corrigenda March and June 2018

BSI Standards Publication

General requirements for the competence of testing and calibration laboratories

7.8 Reporting of results

7.8.1 General

7.8.1.1 The results shall be reviewed and authorize[d]

7.8.1.2 The results shall be provided accurately, c[…] a report (e.g. a test report or a calibration certificat[e …] information agreed with the customer and necess[…] information required by the method used. All issued r[…]

NOTE 1 For the purposes of this document, test report[s …] as test certificates and calibration reports, respectively.

NOTE 2 Reports can be issued as hard copies or by ele[…] document are met.

7.8.1.3 When agreed with the customer, the res[…] information listed in 7.8.2 to 7.8.7 that is not reported[…]

7.8.2 Common requirements for reports (test, c[…]

7.8.2.1 Each report shall include at least the follo[…] reasons for not doing so, thereby minimizing any pos[…]

a) a title (e.g. "Test Report", "Calibration Certificate[…]

b) the name and address of the laboratory;

c) the location of performance of the laboratory a[…] facility or at sites away from the laboratory's p[…] mobile facilities;

d) unique identification that all its components are[…] clear identification of the end;

e) the name and contact information of the custom[…]

7.8.4 Specific requirements for calibration certificates

7.8.4.1 In addition to the requirements listed in 7.8.2, calibration certificates shall include the following:

a) the measurement uncertainty of the measurement result presented in the same unit as that of the measurand or in a term relative to the measurand (e.g. percent);

NOTE According to ISO/IEC Guide 99, a measurement result is generally expressed as a single measured quantity value including unit of measurement and a measurement uncertainty.

b) the conditions (e.g. environmental) under which the calibrations were made that have an influence on the measurement results;

c) a statement identifying how the measurements are metrologically traceable (see Annex A);

d) the results before and after any adjustment or repair, if available;

e) where relevant, a statement of conformity with requirements or specifications (see 7.8.6);

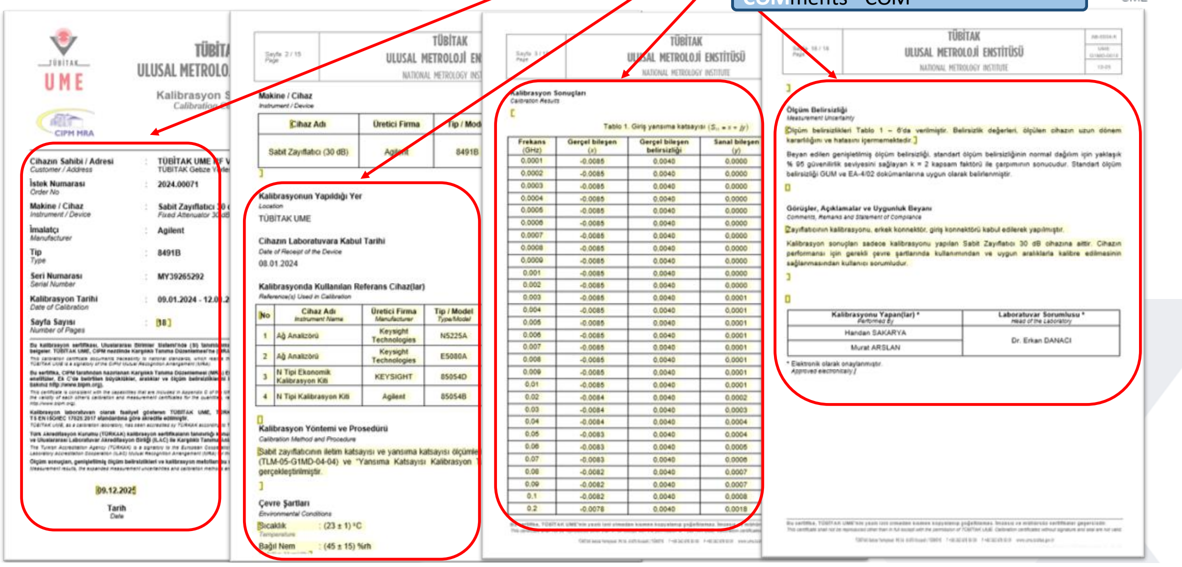
f) where appropriate, opinions and interpretations (see 7.8.7).

7.8.4.2 Where the laboratory is responsible for the sampling activity, calibration certificates shall meet the requirements listed in 7.8.5 where necessary for the interpretation of calibration results.

7.8.4.3 A calibration certificate or calibration label shall not contain any recommendation on the calibration interval, except where this has been agreed with the customer.

Structure of the Calibration Certificate

- ADministrative Data - ADD
- CONditions - CON
- Result of Measurement - RoM
- COMments - COM



Structure of the Calibration Certificate

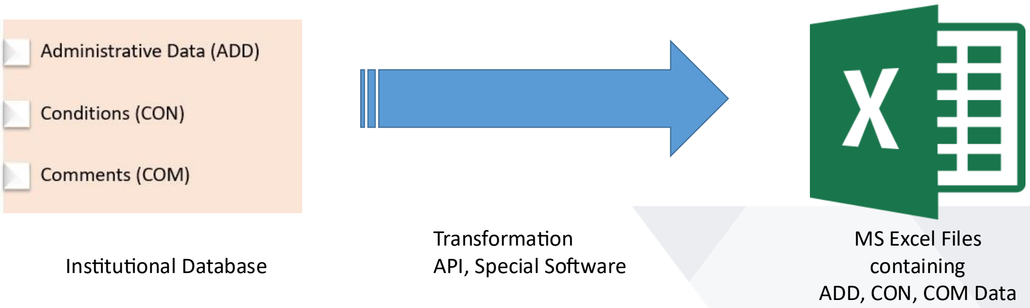
TÜBİTAK UME

Calibration Certificate Content

- Administrative Data (ADD)
- Conditions (CON)
- Comments (COM)
- Result of Measurement (RoM)

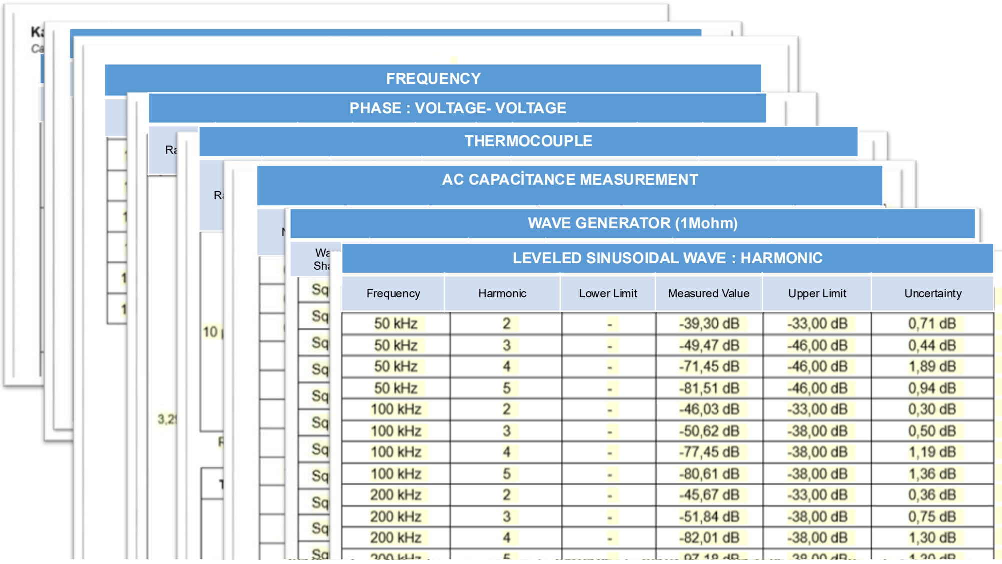
Obtaining the ADD, CON, COM

TÜBİTAK UME



RoM Complexity of Calibration Certificates

Harmonization of RoM Table Structures



Frequency	Harmonic	Lower Limit	Measured Value	Upper Limit	Uncertainty
50 kHz	2	-	-39,30 dB	-33,00 dB	0,71 dB
50 kHz	3	-	-49,47 dB	-46,00 dB	0,44 dB
50 kHz	4	-	-71,45 dB	-46,00 dB	1,89 dB
50 kHz	5	-	-81,51 dB	-46,00 dB	0,94 dB
100 kHz	2	-	-46,03 dB	-33,00 dB	0,30 dB
100 kHz	3	-	-50,62 dB	-38,00 dB	0,50 dB
100 kHz	4	-	-77,45 dB	-38,00 dB	1,19 dB
100 kHz	5	-	-80,61 dB	-38,00 dB	1,36 dB
200 kHz	2	-	-45,67 dB	-33,00 dB	0,36 dB
200 kHz	3	-	-51,84 dB	-38,00 dB	0,75 dB
200 kHz	4	-	-82,01 dB	-38,00 dB	1,30 dB

Examples of the Measurement Result Tables

Harmonization of RoM Table Structures

RF Çıkış Gücü Seviye Doğruluğu Testi RF Output Power Linearity Test		
Frekans	Ölçülen Güç	Belirsizliği
Frequency	Measured Output Power	Uncertainty
(MHz)	(dBm)	(dB)

RF Çıkış Gücü Seviye Doğruluğu Testi RF Output Power Linearity Test			
Frekans	Çıkış Gücü	Ölçülen Güç	Belirsizliği
Frequency	Output Power	Measured Output Power	Uncertainty
(MHz)	(dBm)	(dBm)	(dB)

RF Çıkış Gücü Seviye Doğruluğu Testi RF Output Power Linearity Test				
Frekans	Çıkış Gücü	Ölçülen Güç	Fark	Belirsizliği
Frequency	Output Power	Measured Output Power	Difference	Uncertainty
(MHz)	(dBm)	(dBm)	(dB)	(dB)

Yansıma Katsayısının Lineer Genliği ve Fazı (|S11|<Θ) The Linear Magnitude and Phase of The Reflection Coefficient (|S11|<Θ)				
Frekans	Büyüklük (|S11|)	Büyüklük Belirsizliği	Faz (θ)	Faz Belirsizliği
Frequency	Magnitude (|S11|)	Magnitude uncertainty	Phase(Q)	Phase uncertainty
(GHz)			(°)	(°)

Commonalized ROM Tables

Harmonization of ROM Table Structures

Old Templates

RF Çıkış Gücü Seviye Doğruluğu Testi
RF Output Power Linearity Test

Frekans Frequency (MHz)	Ölçülen Güç Measured Output Power (dBm)	Belirsizliği Uncertainty (dB)

RF Çıkış Gücü Seviye Doğruluğu Testi
RF Output Power Linearity Test

Frekans Frequency (MHz)	Çıkış Gücü Output Power (dBm)	Ölçülen Güç Measured Output Power (dBm)	Belirsizliği Uncertainty (dB)

RF Çıkış Gücü Seviye Doğruluğu Testi
RF Output Power Linearity Test

Frekans Frequency (MHz)	Çıkış Gücü Output Power (dBm)	Ölçülen Güç Measured Output Power (dBm)	Fark Difference (dB)	Belirsizliği Uncertainty (dB)

Yansıma Katsayısının Lineer Genliği ve Fazı (\|S11\|<Θ)
The Linear Magnitude and Phase of The Reflection Coefficient (\|S11\|<Θ)

Frekans Frequency (GHz)	Büyüklük (|S11|) Magnitude (|S11|)	Büyüklük Belirsizliği Magnitude uncertainty	Faz (θ) Phase(Q) (°)	Faz Belirsizliği Phase uncertainty (°)

New Templates

RF Çıkış Gücü Seviye Doğruluğu Testi
RF Output Power Linearity Test

Frekans Frequency (GHz)	Alt Limit Lower Limit (dB)	Ölçülen Güç Measured Output Power (dBm)	Üst Limit Upper Limit (dB)	Belirsizliği uncertainty (dB)

RF Çıkış Gücü Seviye Doğruluğu Testi
RF Output Power Linearity Test

Frekans Frequency (MHz)	Çıkış Gücü Output Power (dBm)	Alt Limit Lower Limit (dB)	Ölçülen Güç Measured Output Power (dBm)	Üst Limit Upper Limit (dB)	Belirsizliği Uncertainty (dB)

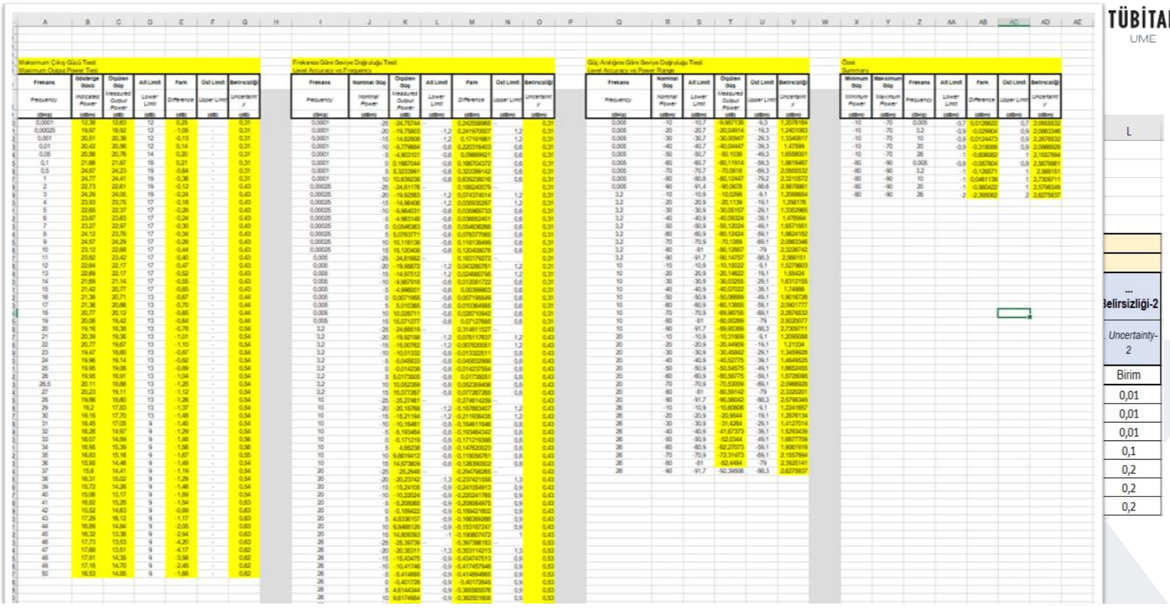
RF Çıkış Gücü Seviye Doğruluğu Testi
RF Output Power Linearity Test

Frekans Frequency (MHz)	Çıkış Gücü Output Power (dBm)	Ölçülen Güç Measured Output Power (dBm)	Alt Limit Lower Limit (dB)	Fark Difference (dB)	Üst Limit Upper Limit (dB)	Belirsizliği Uncertainty (dB)

Yansıma Katsayısının Lineer Genliği ve Fazı (\|S11\|<Θ)
The Linear Magnitude and Phase of The Reflection Coefficient (\|S11\|<Θ)

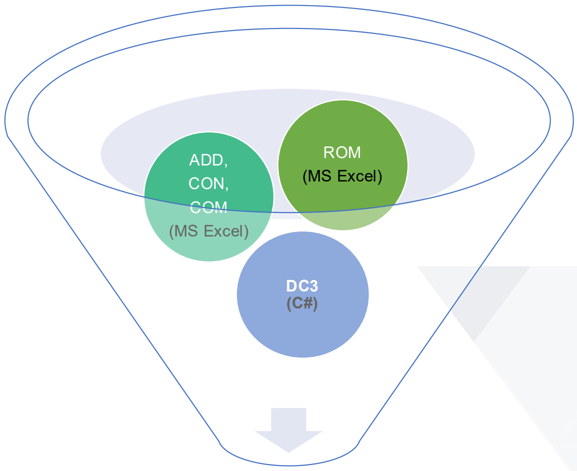
Frekans Frequency (GHz)	Büyüklük Alt Limit Magnitude Lower Limit	Büyüklük (|S11|) Magnitude (|S11|)	Büyüklük Üst Limit Magnitude Upper Limit	Büyüklük Belirsizliği Magnitude uncertainty	Faz Alt Limit Phase Lower Limit (°)	Faz (θ) Phase(Q) (°)	Faz Üst Limit Phase Upper Limit (°)	Faz Belirsizliği Phase uncertainty (°)

Commonalized RoM Table Examples



Transfer of the Input Data to DCC

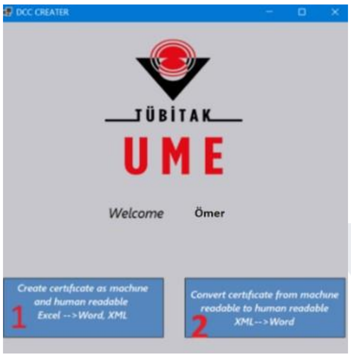
INPUTS: ADD; CON, COM, ROM



OUTPUT: DCC (XML based PTB DCC Schema)

Transfer of the Input Data to DCC

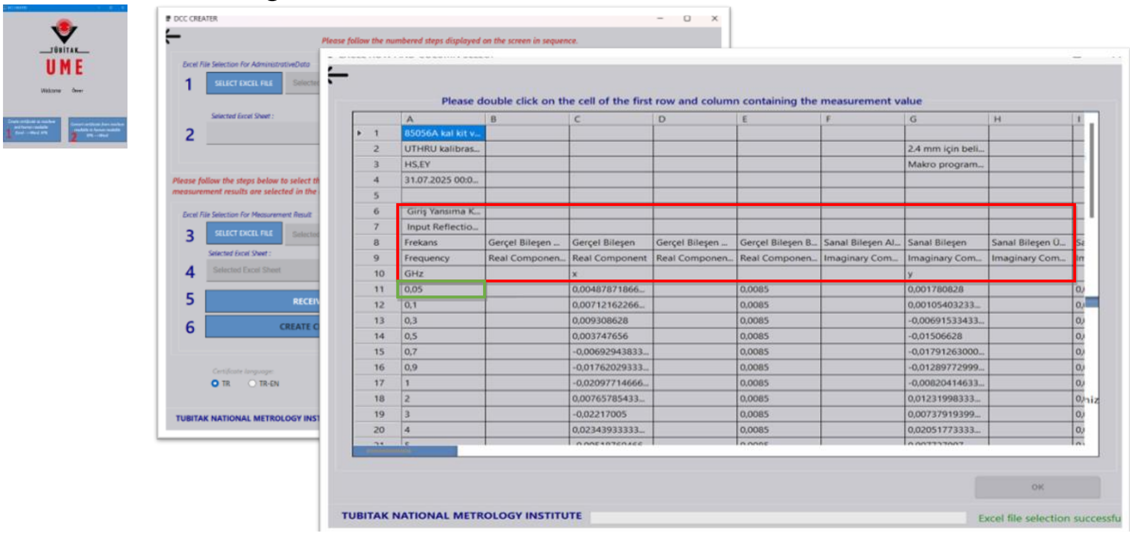
Digital Calibration Certificate Creater - **DC3**



DC3 application

Transfer of the Input Data to DCC

Digital **C**alibration **C**ertificate **C**reater - **DC3**



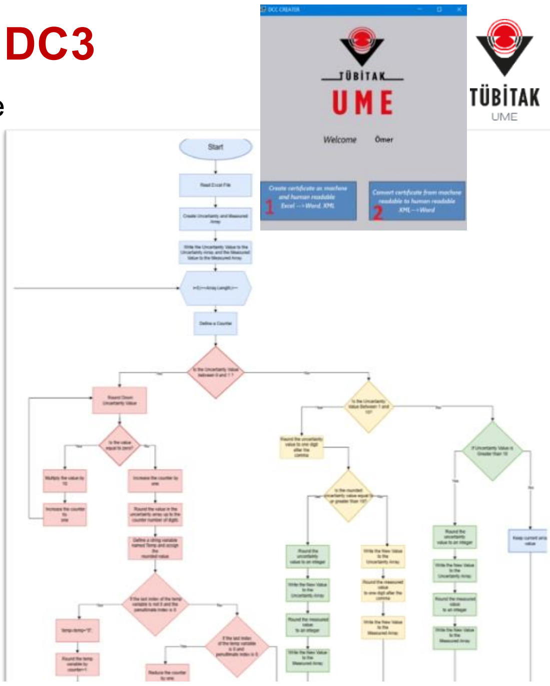
RoM Table Transfer Rules with DC3

- Ordering columns in the RoM tables must be placed on the left side of the table in MS Excel; multiple ordering columns may be added if needed.
- Lower and upper limit columns must always be present, even if no limit values are provided in MS Excel. If the column is left empty, they will not appear in the generated certificate.
- DC3 application automatically detects columns containing the term “Uncertainty”. Measurement tables in MS Excel must use “Uncertainty” as the column header in accordance with the quality system.
- DC3 can transfer multiple tables from Excel at once.
- Tables intended as input for DC3 can be positioned side by side in MS Excel with one column space.
- DC3 automatically removes unused columns (upper / lower limit) in a RoM table during the DCC transfer.
- Measurement tables with different row counts are all processed and structured correctly.

The Advantages Provided by DC3

- Contributions to the Existing Human-Readable Calibration Certificate Process
  - Simplified handling of two significant figures issues
  - Improved and standardized tabulation structure

Frekans (GHz) *Frequency (GHz)*	Reel Bileşen (x) *Real Component (x)*	Reel Bileşen Belirsizliği *Real Component Uncertainty*
0,0001	0,0028	0,0055
0,0002	0,0028	0,0055
0,0003	0,0028	0,0055
0,0004	0,0028	0,0055
0,0005	0,0028	0,0055
0,0006	0,0028	0,0055
0,0007	0,0028	0,0055



The Advantages Provided by DC3

- Contributions to the Existing Human-Readable Calibration Certificate Process
  - Simplified handling of ambiguous digit issues
  - Improved and standardized tabulation structure

TÜBİTAK
ULUSAL METROLOJİ ENSTİTÜSÜ
NATIONAL METROLOGY INSTITUTE

Tablo 1. 8494H_0001_4dB Giriş Yansıma Katsayısı (S11=x+jy)
Table 1. 8494H_0001_4dB Input Reflection Coefficient (S11=x+jy)

Frekans (GHz) *Frequency (GHz)*	Reel Bileşen (x) *Real Component (x)*	Reel Bileşen Belirsizliği *Real Component Uncertainty*	İmajiner Bileşen (y) *Imaginary Component (y)*	İmajiner Bileşen Belirsizliği *Imaginary Component Uncertainty*
0,0001	0,0028	0,0055	0,0001	0,0055
0,0002	0,0028	0,0055	0,0001	0,0055
0,0003	0,0028	0,0055	0,0001	0,0055
0,0004	0,0028	0,0055	0,0001	0,0055
0,0005	0,0028	0,0055	0,0001	0,0055
0,0006	0,0028	0,0055	0,0001	0,0055
0,0007	0,0028	0,0055	0,0001	0,0055
0,0008	0,0028	0,0055	0,0001	0,0055
0,0009	0,0028	0,0055	0,0001	0,0055
0,001	0,0028	0,0055	0,0001	0,0055
0,002	0,0029	0,0055	0,0002	0,0055
0,003	0,0030	0,0055	0,0002	0,0055
0,004	0,0032	0,0055	0,0003	0,0055
0,005	0,0032	0,0055	0,0003	0,0055
0,006	0,0033	0,0041	0,0004	0,0041
0,007	0,0033	0,0041	0,0003	0,0041
0,008	0,0034	0,0041	0,0003	0,0041

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Frekans (GHz) *Frequency (GHz)*	Reel Bileşen (x) *Real Component (x)*	Reel Bileşen Belirsizliği *Real Component Uncertainty*	İmajiner Bileşen (y) *Imaginary Component (y)*	İmajiner Bileşen Belirsizliği *Imaginary Component Uncertainty*
1,2	0,0029	0,0054	0,0041	0,0054
1,5	-0,0039	0,0042	0,0082	0,0042
2	0,0130	0,0041	0,0114	0,0041
2,4	0,0126	0,0052	-0,0016	0,0052
2,6	0,0115	0,0049	-0,0025	0,0049
3	0,0144	0,0049	-0,0106	0,0049
4	-0,0195	0,0041	-0,0031	0,0041
4,2	-0,0184	0,0051	-0,0086	0,0051
4,8	-0,0404	0,0048	0,0361	0,0048
5	-0,0159	0,0052	0,0448	0,0052
6	0,0408	0,0045	0,0396	0,0045
7	0,0266	0,0041	-0,0170	0,0041
8	-0,0371	0,0045	0,0031	0,0045
8,2	-0,0327	0,0041	0,0166	0,0041
8,4	-0,0290	0,0042	0,0272	0,0042
9	0,0167	0,0050	0,0467	0,0050
10	0,0429	0,0041	-0,0082	0,0041

Conclusion

- Measurement result tables in various formats have been transformed to a single / common format.
- The DC3 software enables the transfer of the measurement result tables to XML based DCC by performing rule based / deterministic parsing.
- The support of the DC3 software has facilitated the challenging tasks of table numbering and determining two significant figures when creating a human-readable format.

Thank you for your attention

Questions

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erkan.danaci@tubitak.gov.tr

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039 Serhii Kursin: Peculiarities of Data Representation in Digital Calibration Certificates for Measuring Antennas

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Email: skursin@ukrcsm.kiev.ua, kursin@gmail.com
Additional authors: Oleh Velychko [1]
Institute:
[1] State Enterprise «State Research and Production Centre of Standardization, Metrology, Certification and Consumers' Rights Protection» (SE «UKRMETRTESTSTANDART»), Metrologichna str. 4, 03143 Kyiv, Ukraine
Keywords: Measuring antennas, DCCs, hybrid units

Abstract

Digital Calibration Certificates (DCCs) enable automated data exchange, traceability, and reduction of human errors compared to traditional PDF or paper-based certificates. Antennas widely used in electromagnetic compatibility and radiated emission measurements must be calibrated to ensure traceable and accurate determination of the electromagnetic field strength in test laboratories.

The electric field strength is expressed in volts per meter (V/m), and the magnetic field strength in amperes per meter (A/m). For measuring antennas, the antenna factor (AF) is the primary calibration quantity, since measuring antennas act as field-to-voltage transducers converting electromagnetic field quantities into electrical signals. AF is typically expressed in logarithmic units such as dB/m for electric antennas and dB(A/m)/V for magnetic antennas.

Antenna calibration results are frequency-dependent, and logarithmic units (dB) are commonly used in Radio Frequency metrology. Hybrid data structures in DCCs allow representation in both SI and logarithmic units (see Figure 1) [1], while list-based structures are recommended for frequency-dependent calibration data [2], For measuring antennas, DCCs must include antenna factor, reflection coefficients, and expanded uncertainty over a frequency range.

```
<dcc:quantity refType="basic_measuredValue">
<dcc:name><dcc:content lang="en">Antenna Factor</dcc:content></dcc:name>
<si:hybrid>
<si:realListXMLList>
<si:valueXMLList>1.2 1.5 1.3 1.4</si:valueXMLList>
<si:unitXMLList>\metre\tothe{-1}</si:unitXMLList>
</si:realListXMLList>
<si:realListXMLList>
<si:valueXMLList>1.58 3.52 2.28 2.92</si:valueXMLList>
<si:unitXMLList>\decibel\metre\tothe{-1}</si:unitXMLList>
</si:realListXMLList>
</si:hybrid>
</dcc:quantity>
```

Figure 1. XML hybrid structure for the Antenna Factor example

References:

[1] Digital System of Units D-SI, [https://zenodo.org/records/3522631], last accessed: 31.01.2026
[2] Digital Calibration Certificate (DCC) - Wiki, [https://wiki.dcc.ptb.de], last accessed 31.01.2026

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Presentation #039 of Serhii Kursin

6th International DCC Conference

From Good Practice to Standardization: DCC for a Reliable Future

Peculiarities of Data Representation in DCC for Measuring Antennas

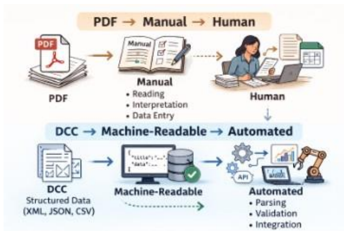
Serhii Kursin, Oleh Velychko
State Enterprise "UKRMETRTESTSTANDART", Ukraine
Speaker: Serhii Kursin

1

Motivation

From PDF Certificates to Digital Calibration Certificates

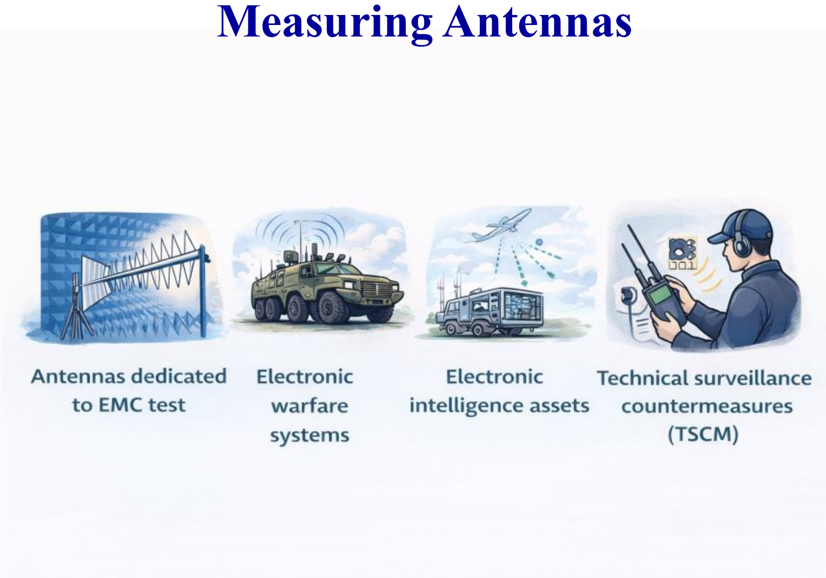
- Digital transformation is reshaping modern metrology
- Industry 4.0 requires machine-readable calibration data
- Traditional PDF certificates are human-readable only
- Limited support for automation and interoperability
- Digital Calibration Certificates (DCC) address these limitations



Digital Calibration Certificates enable machine-actionable metrology

2

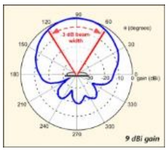
Measuring Antennas

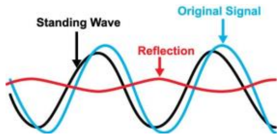


Укрметртест стандарт

3

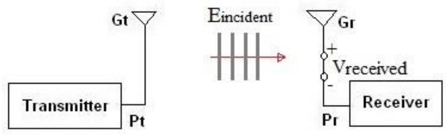
Why Antenna Factor Instead of Gain





Gain → radiation efficiency

VSWR → matching quality



$$\text{Antenna Factor} = \frac{E_{incident}}{V_{received}}$$

Antenna Factor → metrological transfer function

Only the antenna factor provides traceable field strength evaluation

Укрметртест стандарт

4

Units in Antenna Metrology

Electric field strength — V/m

$$AF_E(f) = \frac{E(f)}{V(f)}$$

linear units: **1/m**

$$AF_E(f) = 20\log_{10}\left(\frac{E(f)}{V(f)}\right)$$

logarithmic units: **dB/m**

Magnetic field strength — A/m

$$AF_H(f) = \frac{H(f)}{V(f)}$$

linear units: **(A/m)/V**

$$AF_H(f) = 20\log_{10}\left(\frac{H(f)}{V(f)}\right)$$

logarithmic units: **dB(A/m)/V**

$$E(f) = AF(f) \cdot V(f)$$

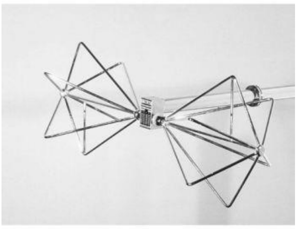
$$E_{dB\mu V/m} = V_{dB\mu V} + AF_{dB/m}$$

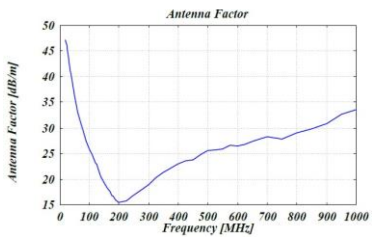
SI and logarithmic units must coexist in DCC representation

Укрметртест стандарт

5

Frequency-Dependent Nature





Calibration must be provided over the full frequency range

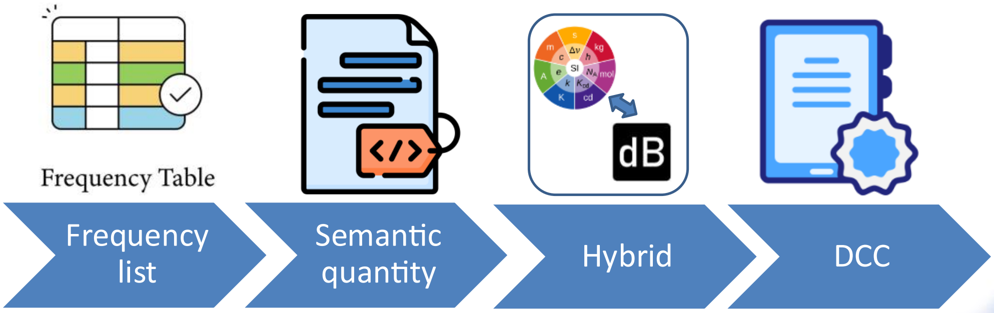
$$AF = \{AF_1, AF_2, \ldots, A\downarrow\}, \quad f = \{f_1, f_2, \ldots, f_N\}$$

Antenna factor is strongly frequency-dependent

Укрметртест стандарт

6

Digital Calibration Certificates and Data Representation Challenges



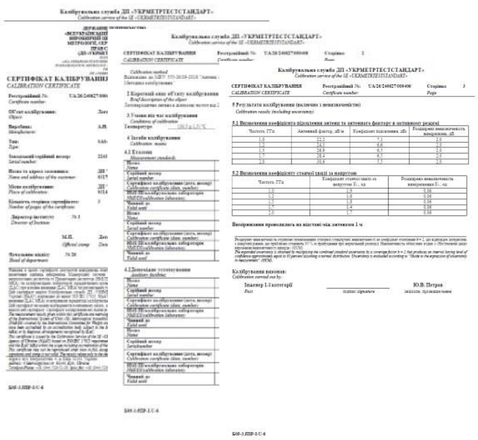
Structured semantic representation of frequency-dependent antenna data

Hybrid semantic representation ensures machine-actionable antenna calibration data.

7

Real Calibration Example

Model: SAS-510-2 **Log Periodic Antenna** 290 MHz - 2 GHz

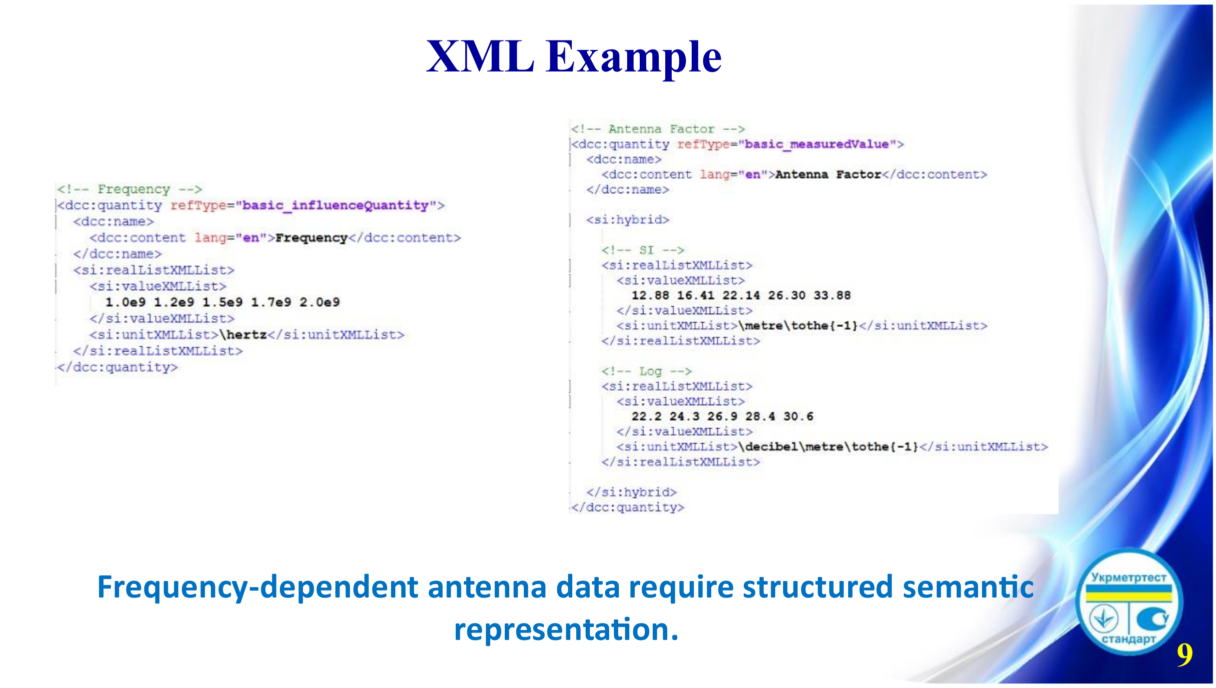


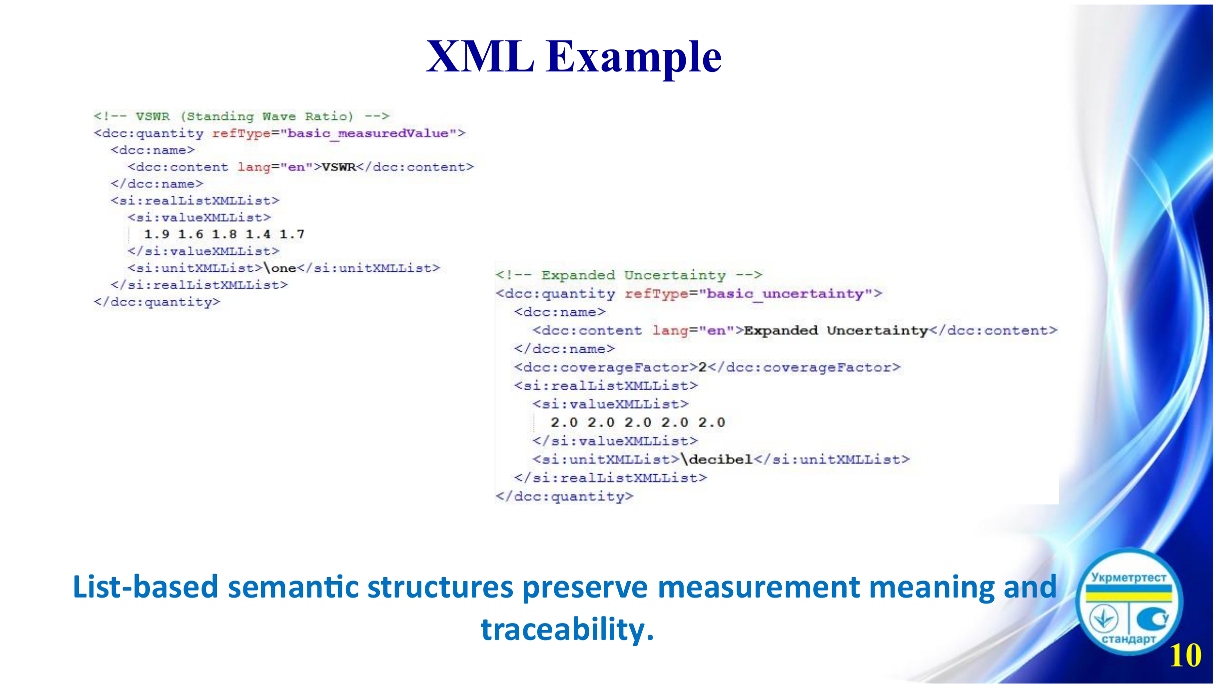
Log-periodic antenna calibration
Frequency range: 1–2 GHz

f (GHz)	AF (dB/m)	Gain (dBi)	U (dB)
1.0	22.2	7.1	2.0
1.2	24.3	6.6	2.0
1.5	26.9	6.5	2.0
1.7	28.4	6.5	2.0
2.0	30.6	5.5	2.0

Hybrid semantic representation ensures machine-actionable antenna calibration data.

8


XML Example
<!-- Frequency -->
<dcc:quantity refType="basic_influenceQuantity">
<dcc:name>
<dcc:content lang="en">Frequency</dcc:content>
</dcc:name>
<si:realListXMLList>
<si:valueXMLList>
1.0e9 1.2e9 1.5e9 1.7e9 2.0e9
</si:valueXMLList>
<si:unitXMLList>\hertz</si:unitXMLList>
</si:realListXMLList>
</dcc:quantity>
<!-- Antenna Factor -->
<dcc:quantity refType="basic_measuredValue">
<dcc:name>
<dcc:content lang="en">Antenna Factor</dcc:content>
</dcc:name>
<si:hybrid>
<!-- SI -->
<si:realListXMLList>
<si:valueXMLList>
12.88 16.41 22.14 26.30 33.88
</si:valueXMLList>
<si:unitXMLList>\metre\tothe{-1}</si:unitXMLList>
</si:realListXMLList>
<!-- Log -->
<si:realListXMLList>
<si:valueXMLList>
22.2 24.3 26.9 28.4 30.6
</si:valueXMLList>
<si:unitXMLList>\decibel\metre\tothe{-1}</si:unitXMLList>
</si:realListXMLList>
</si:hybrid>
</dcc:quantity>
Frequency-dependent antenna data require structured semantic representation.
Укрметртест
стандарт
9


XML Example
<!-- VSWR (Standing Wave Ratio) -->
<dcc:quantity refType="basic_measuredValue">
<dcc:name>
<dcc:content lang="en">VSWR</dcc:content>
</dcc:name>
<si:realListXMLList>
<si:valueXMLList>
1.9 1.6 1.8 1.4 1.7
</si:valueXMLList>
<si:unitXMLList>\one</si:unitXMLList>
</si:realListXMLList>
</dcc:quantity>
<!-- Expanded Uncertainty -->
<dcc:quantity refType="basic_uncertainty">
<dcc:name>
<dcc:content lang="en">Expanded Uncertainty</dcc:content>
</dcc:name>
<dcc:coverageFactor>2</dcc:coverageFactor>
<si:realListXMLList>
<si:valueXMLList>
2.0 2.0 2.0 2.0 2.0
</si:valueXMLList>
<si:unitXMLList>\decibel</si:unitXMLList>
</si:realListXMLList>
</dcc:quantity>
List-based semantic structures preserve measurement meaning and traceability.
Укрметртест
стандарт
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Conclusions

- Real antenna calibration certificates include multiple parameters (gain, VSWR, antenna factor)
- Antenna factor remains the key metrological quantity for traceable field-to-voltage conversion
- Antenna calibration results are inherently frequency-dependent
- Structured list representations are required in Digital Calibration Certificates
- Hybrid and list-based data structures enable machine-readable antenna metrology

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Thank you for your attention

Serhii Kursin, Ph.D., Senior researcher
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Укрметртест стандарт

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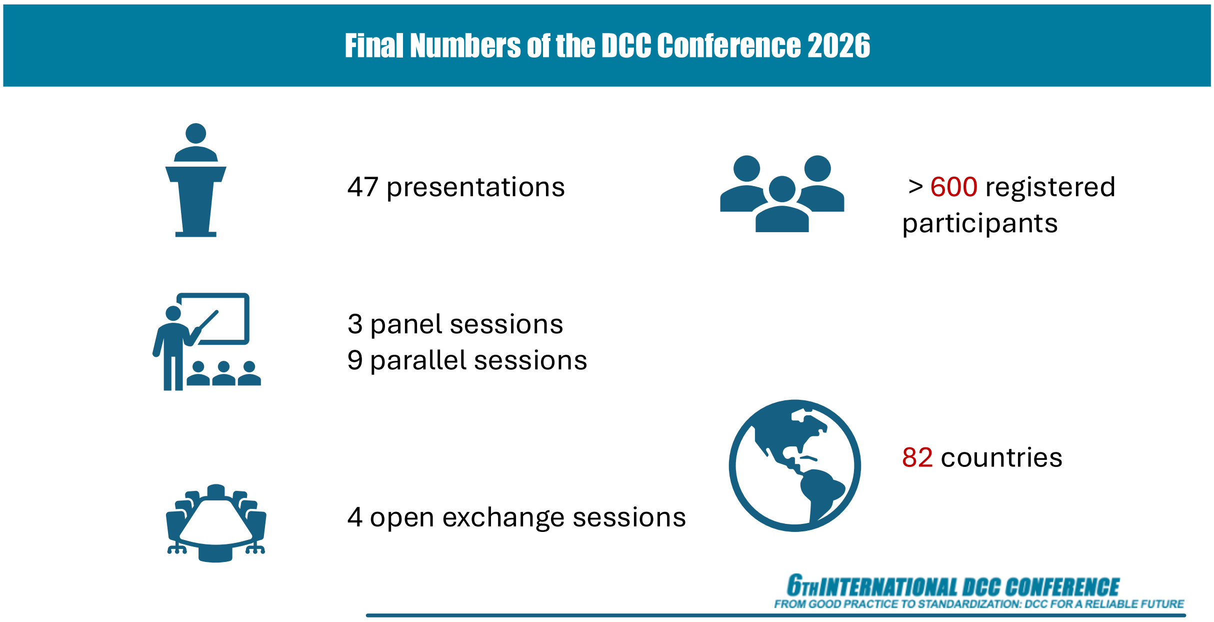
Closing Session:

Summary of the 2026 conference and outlook for the 2027 DCC conference



A huge Thank You to the Conference Chairs

Session	Chairs
DAY 1	
Plenary Session	Jariya Buajarern
DCC in digital QI	Brett Hyland
DCC Production I	Carlos Galván
Digitalization to enable DCC	Mark Kuster
DAY 2	
Plenary Session	Anjali Sharma
DCC Ecosystem	Martin Koval
DCC Tools and Development I	James Fedchak
DCC Management	Shanna Schönhals
DAY 3	
Plenary Session	Hector Laiz
DCC Tools and Development II	Hugo Gasca Aragon
DCC Use Case	David Balslev-Harder
DCC Production II	Thomas Krah

6TH INTERNATIONAL DCC CONFERENCE
FROM GOOD PRACTICE TO STANDARDIZATION: DCC FOR A RELIABLE FUTURE

A huge Thank You to the Conference Team

Oksana Baer
Franziska Decker
Lutz Doering
Muhammed-Ali Demir
Wiebke Heeren
Justin Jagieniak
Moritz Jordan
Jan Loewe

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Conference Proceedings and Recordings

- All presenters will be requested to provide updated slides and Author‘s License Agreement until end of March 2026
- Conference Proceedings will be published directly afterwards, open access and free of charge for presenters
- Recordings will be available on the conference website beginning of March 2026 for registered participants
- https://www.dcc-conference-2026.ptb.de/6th-international-dcc-conference

6TH INTERNATIONAL DCC CONFERENCE
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Be part of the Community!

- IMEKO TC6 SC "International Cooperation (M4DX)“ newly established
- More information and contact via https://www.imeko.org/index.php/tc6-homepage

6TH INTERNATIONAL DCC CONFERENCE
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See you at the DCC Conference 2027

- 2027 will be special: 10 years of DCC
- Hybrid conference – in PTB Berlin and online
- 22. – 24. March 2027
- Looking forward to meeting you again!

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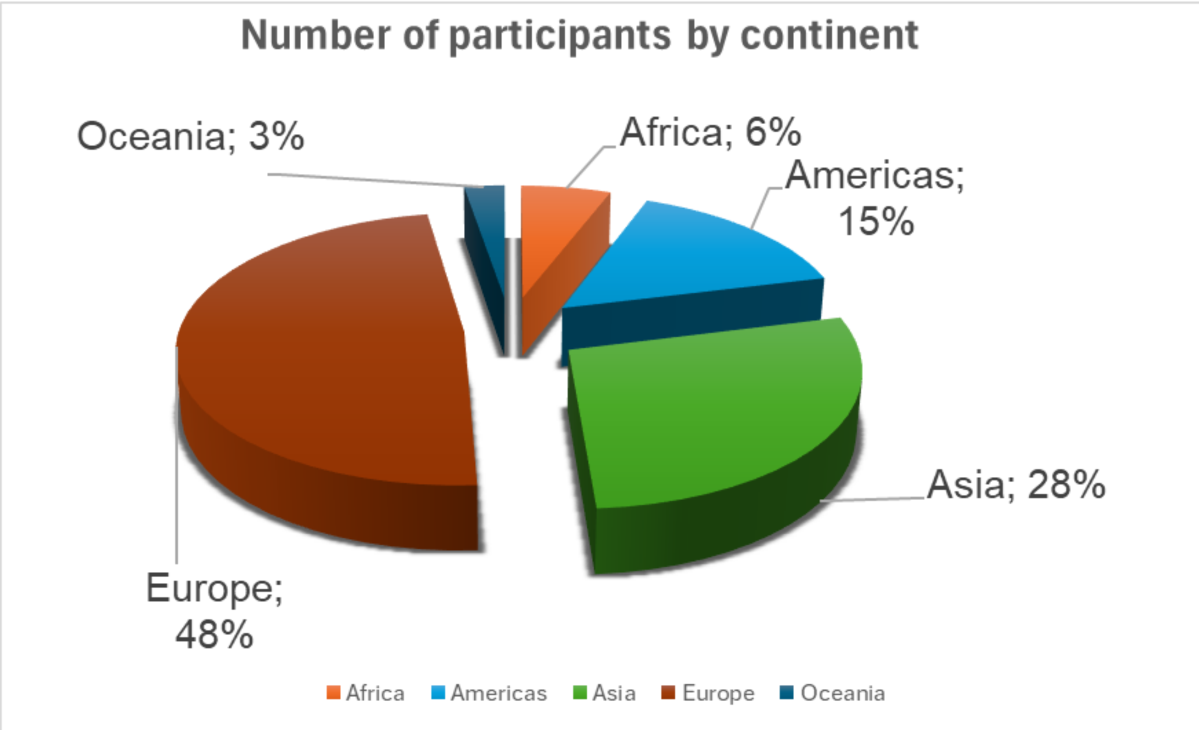
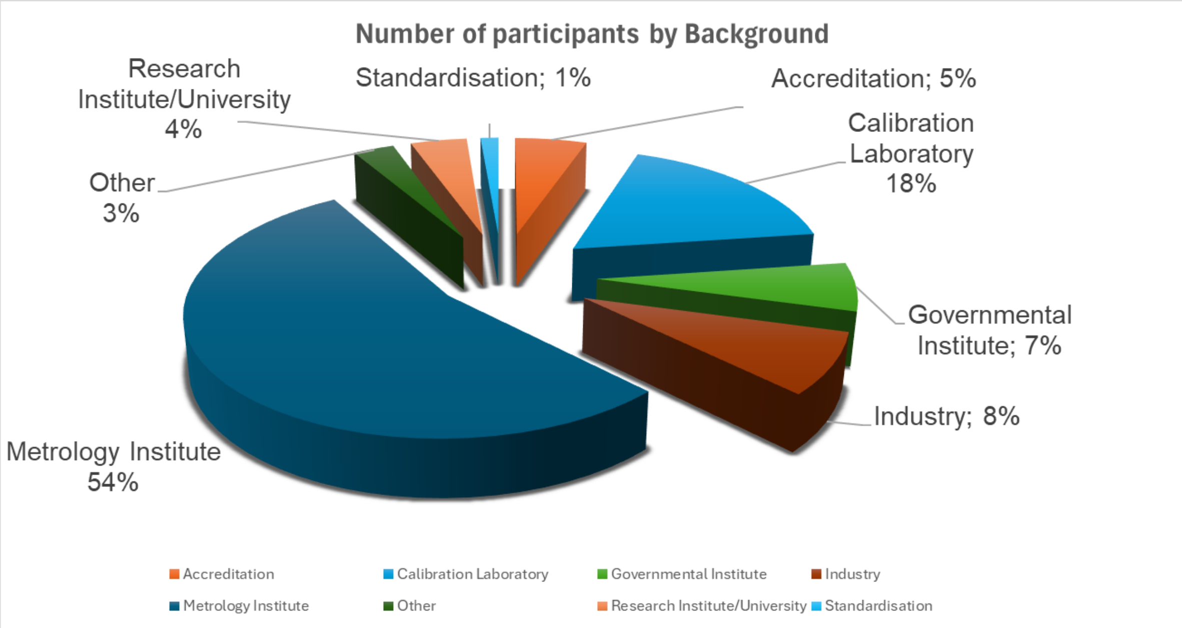
Statistical information:

Number of participants by continent



Number of participants by Background



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