

SMART INFRASTRUCTURE FOR DEVELOPING DIGITAL CALIBRATION CERTIFICATES AT SASO-NMCC

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Abstract – Nowadays, digital solutions are dominant in almost all industry related activities and applications, especially in the metrology domain. Digital Calibration Certificates (DCCs) will soon replace both paper and electronic calibration certificates. This is due to the fact that electronic files can be communicated instantly and securely to the customer and are machine readable. However, DCCs require a digital security and software infrastructure to fulfill the current ‘analogue’ processes of authentication and validation that secures traceability of the measurements. In this work, we present the efforts at SASO-NMCC of Saudi Arabia towards modifying its work processes for replacing analog calibration certificates with the modern DCCs. A smart e-infrastructure for issuing DCCs is proposed. The system communicates with customers and national standards communities via metrology clouds (e.g. SASO Cloud and GULFMET cloud). Our proposed system is also able to be compatible with recent artificial intelligence applications, the Internet of Things (IoT) and future completely digital metrology.

Keywords: DCC, Digital Transformation, Metrology Cloud, Digital SI, Machine-readable, AI, Digital metrological services

1. MOTIVATION

The introduction of increasingly affordable processing power and memory, as well as interconnected networks, has ushered in a huge change in how information technology affects our lives over the last decades [1-4]. A secure and thriving economy and society are built on innovation and trust in a high-quality infrastructure. Metrology is the science and practice of measurement, hence the ability to gather correct data based on high-precision measurements is one of the objectives of metrology, is the foundation of an effective quality infrastructure. The economy and society of the 21st century are undergoing a comprehensive digital transformation, with the goal of securely establishing the foundation for success in the digital arena, which is the cornerstone for the economy and society's progress in the digital era. The process of digitization has been ongoing for several years [5-6]. The exponential growth of computing and storage capacities, as well as the increasing speed of data exchange and the affordable availability of versatile sensors that can be used flexibly, have opened up completely new

possibilities for creating networks between objects and exploitation of the data and information stored [7-12].

The increased number of measuring equipment, sensors, and sensor systems and networks, as well as the restricted time available for doing metrological work, necessitate a large rise in metrological activity efficiency. Calibration of measuring instruments is one of metrology's most significant duties [13-14]. Currently, the method for calibrating measuring equipment concludes with the issue of a calibration certificate, which is normally in the form of a paper certificate or a PDF file certified by an electronic digital signature. In response to the problems of the digital economy, the Digital Calibration Certificate (DCC) idea is being developed alongside the Digital International System of Units (D-SI) paradigm [12]. As previously stated, the significant increase in the number of calibrations necessitates automation of both the calibration technique and machine-readability for automatic analysis of issued calibration certificates [13, 15-18].

On the other hand, through a variety of recognized protocols, legal metrology relies on a set of tests, calibrations, and method assurances. Calibrations are sometimes done by hand. A type evaluation authority, or in some situations, a manufacturer, conducts in-house tests and subsequently submits a data set to a type approval authority for certification [3-4]. The type evaluation authority then stores the certificates in digital form and makes them publicly available through online access. When a legal metrology instrument is modified, the type evaluation may be revised as well. State agencies or registered service groups conduct field tests, with the results reported in a variety of ways that differ from country to another. Paper documents, hard copy files, file scans, and digital files saved locally or remotely on a cloud-like system are all examples. Overall, there is a lot of variation in how data is acquired, stored, preserved, and managed. In conclusion, switching to the DCC becomes crucial, and the above mentioned changes motive the NMIs to work on setting optimum software protocols for data storage, manipulation, and secure transfer of those data as well as planning and implementation steps for issuing DCCs, which should be a step-forward of the current available facilities and electronic management systems that currently available, to save the efforts while keeping the compatibility with the electronic management systems in hand. The following are the most frequently mentioned benefits of switching to DCC, among others:

1. DCC enables simultaneous access and use in several locations at the same time.

2. DCC's machine-readability enables for the automated verification of certificate availability, validity duration, and content information.

3. Data from the DCC can be instantly downloaded to the instrument without the need for human interaction. This reduces errors caused by manual data entry.

4. As instruments get increasingly complicated, the amount of information required in a calibration certificate grows. Because this data is available in digital form, it is easier to interact with it both manually and automatically during the measurement process.

5. The application of DCCs in practice will allow machine learning methods in artificial intelligence and IoT systems to analyze calibration data.

A digital calibration certificate (DCC) is used for electronic storage, authentication, encryption, and signing of calibration findings, as well as standard interpretation. Because the data gathered during calibration is time-consuming and error-prone, the analogue calibration certificate has rarely provided a surplus value for a corporation. The DCC compensates for this important flaw in its analog cousin. Digitally assisted manufacturing and quality monitoring processes benefit substantially from its machine readability. For a corporation that uses the DCC, this adds significant value. In addition to the DCC's structure, unique framework constraints for its transfer must be established. Cryptographic protection measures are among them. They ensure the integrity and authenticity of the DCC's contents, as well as their electronic transmission. Metrology institutes do not have the fundamental capability for acceptable processes. Previous results and outside knowledge will be utilized for this. The framework criteria, on the other hand, are set by metrology institutions, taking legislative requirements into account. The goal is to produce a DCC format that is universally recognized. In the entire field of metrology, this will be established as an exchange format. Exchange formats in legal metrology, for digital type evaluation, and for the "digital twin" (DT) should be established based on the DCC.

The general structure of a DCC is subdivided into four layers: first, Administrative data that contains information of central interest; usually found in the first page of any analogue calibration certificate. Second, measurements and calibration results. Third, any additional comments. Finally; optional version of the calibration certificate stored in PDF format, as shown in figure 1. Figure 2 also presents a demonstration to show worked example of analogue calibration certificate versus its DCC counterpart excerpt. Figure shows that the mistakes that might happen in the analogue certificate, e.g. due to OCR, is all impossible to be happened in the DCC

2. AVAILABLE E-INFRASTRUCTURE

Current e-infrastructure for processing and managing the calibration process until the issuance of the paper based and PDF calibration certificate at SASO-NMCC is based on Laboratory Information Management System (LIMS) software. The work on developing an electronic system for the creation and storage of electronic calibration certificates was carried out at NMCC (NMI of Saudi Arabia), including

the development of a program that was developed as a java-applet running in a browser, with the purpose of creating an electronic calibration certificate with LIMS software e-infrastructure. The program's certificate satisfies all of the standard "ISO/IEC 17025:2017".

The brief of the steps of processing of calibration request since it is placed by the customer until the issuance of the paper certificate or PDF version is shown in figure 3(a).

Currently, the method for calibrating a measuring equipment concludes with the issue of a calibration certificate, which is normally in the form of a paper certificate or a PDF file certified by an electronic digital signature and recently with added unique QR code (figure 3 b). There are several methods for putting such files, sometimes known as electronic calibration certificates, into action. The need to adopt the so-called DCC is considered with the usage of the paper certificate as a standard and the gradual introduction of electronic calibration certificates towards developing the DCC.

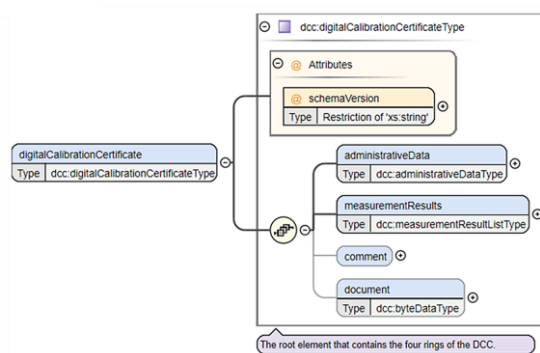


Figure 1. DCC structure, layers and type as concluded by PTB (Source: <https://ptb.de/dcc>) [13]

3. SASO-NMCC METHODOLOGY FOR ISSUANCE OF DCC

3.1. International reference standards for DCC

Many efforts are pushing today towards a unified structure for the DCC. The international standard ISO/IEC 17025, which deals with the general requirements for calibration laboratories, is the reference document used by reference laboratories around the world, like the Physikalisch-Technische Bundesanstalt (PTB), the Instituto Nacional de Metrologia, Qualidade e Tecnologia (INMETRO), and the National Institute of Standards and Technology (NIST), among others [1-6, 14, 15]. The items 7.8.2 and 7.8.4 - titled "Common requirements for reports (test, calibration or sampling)" and "Specific requirements for calibration certificates" - are objective in defining what is required on a calibration certificate, and item 8 adds minimal requirements for management system for assuring the quality of the laboratory results. The ISO GUM, Guides to the Expression of Uncertainty in Measurement, defines, among other references and standards, the vocabulary to be used in documents that deals with expressing uncertainty in measurement [1-3, 8, 12, 14]. Such documents are used to guide the requirements for what needs to be implemented in our software tools.

VDI/VDE-2623 establishes a rigid Extensible Markup Language (XML) data structure with both required and

3.5. Worked example

In Figure 4, an example of the calibration section of a digital certificate in a XML format, with information regarding calibration result, ambient conditions, traceability, used technical procedure, among others. This piece of code is used to produce the PDF file without reducing the quality of figures, even for high quality printouts.

```
<calibration>
  <inspection_plan>
    <id>PP1234</id>
    <description>Bleco Padrão 150 mm</description>
    <calibration_procedure>PTB10011501</calibration_procedure>
  </inspection_plan>
  <characteristics>
    <character>
      <supplier_character_id>A17300</supplier_character_id>
      <buyer_character_id>B1</buyer_character_id>
      <class>000</class>
      <designation>Erro de medição</designation>
      <type>002</type>
      <nominal_value>0</nominal_value>
      <upper_limit>10.2</upper_limit>
      <lower_limit>-30.5</lower_limit>
      <unit>mm</unit>
      <result_value>28</result_value>
      <uncertainty>10</uncertainty>
      <unit_uncertainty>mm</unit_uncertainty>
      <compliance>001</compliance>
      <remarks>48 código comum para jmc/remark</remarks>
    </character>
    <attributes>
      <attribute>
        <class>001</class>
        <designation>temperatura ambiente</designation>
        <value>20.5</value>
        <upper_limit>22.5</upper_limit>
        <lower_limit>19.2</lower_limit>
        <unit>C</unit>
        <remarks>C1 código comum para temperatura em graus Celsius</remarks>
      </attribute>
      <attribute>
        <class>001</class>
        <value>22</value>
      </attribute>
    </attributes>
    <traceability>
      <tracesability>
        <id_number>V00056782</id_number>
        <test_equipment_notation>Conjunto de 10 partes</test_equipment_notation>
        <last_calibration_date>2018-02-28</last_calibration_date>
        <last_calibration_certificate_number>K5987720</last_calibration_certificate_number>
      </tracesability>
    </traceability>
  </characteristics>
</calibration>
```

Figure 4. Example of a digital certificate in a XML format.

We believe that all calibration labs should use standard capabilities and tools from PTB [1] as well as the programming environment of Excel for the visual generation of a DCC in an Excel workbook [2]. The basic structure schema of the Excel tool supported by PTB is shown in figure 5. Moreover, the first lines of the dcc.xsd file, version 2.3.0. is shown in figure 6 [2].

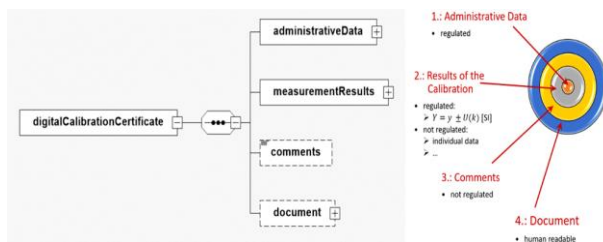


Figure 5. The basic structure of the DCC generation tool (Source: <https://dccwiki.ptb.de/en/root/>).

```
<?xml version="1.0" encoding="UTF-8"?>
<xs:schema version="2.3.0" xmlns:xs="http://www.w3.org/2001/XMLSchema"
  xmlns:dcc="https://ptb.de/dcc"
  xmlns:si="https://ptb.de/si"
  targetNamespace="https://ptb.de/dcc"
  elementFormDefault="qualified">

  <xs:import
    namespace="https://ptb.de/si"
    schemaLocation="https://ptb.de/si/v1.3.0/SI_Format.xsd"/>

  ...

  <xs:complexType name="digitalCalibrationCertificateType">
    <xs:sequence>
      <xs:element name="administrativeData" type="
        dcc:administrativeDataType"/>
      <xs:element name="measurementResults" type="
        dcc:measurementResultListType"/>
    </xs:sequence>
  </xs:complexType>
```

Figure 6. the first lines of the dcc.xsd file, version 2.3.0. as represented by [10].

4. CONCLUSIONS

The transformation towards digital metrological services starts with a DCC. In this work, we described the proposed system for issuing DCC at SASO-NMCC. Our system gets its basic information from our e-certificate infrastructure which was built based on LIMS software. The system communicates with customers and national standards communities via metrology clouds (SASO Cloud and GULFMET cloud). Moreover, the system can communicate with recent artificial intelligence applications and Internet of Things (IoT). We believe that there are many other steps required for complete digital metrological activities. we also believe that additional standardization discussions regarding the formatting and representation of measurement data and metadata are required towards machine actionable DCCs.

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