IMEKO TC6 International Conference on Metrology and Digital Transformation
September 19 – September 21, 2022, Berlin, Germany

INTEGRATING A CALIBRATION LABORATORY WORKFLOW INTO A METROLOGICAL DIGITAL ECOSYSTEM: A CASE STUDY

Samuel Eickelberg [a,*], *Thomas Bock* [a], *Matthias Bernien* [a], *Alexander Oppermann* [a]

[a]Physikalisch-Technische Bundesanstalt (PTB), Abbestr. 2-12, 10587 Berlin, Germany
[*]Corresponding author. E-mail address: samuel.eickelberg@ptb.de

Abstract – This paper is a case study describing the integration of a digitally transformed calibration workflow into a metrological service ecosystem. The integration on both sides is described in detail at workflow level. Transparency of workflows is a major goal and is supported by introducing status updates. Furthermore, providing a fast and easy information interchange is paramount, and is achieved by focusing on Open Source, standardized and secure communications, like REST interfaces. This case study serves as a blueprint for future-proof IT integration tasks and can be put into a general context with similar projects.

Keywords: Digital transformation; Metrological processes; Administrative shell; Digital Calibration Certificate; DCC; Distributed software architecture

1. INTRODUCTION

Digital transformation is a driving factor for successful processes in businesses, as well as in public administration. A major milestone in driving digital transformation of processes is to overcome procedural automation gaps in productively used systems. This paper presents a case study of attaching a highly specialized laboratory software for handling calibration requests to an agnostic, process-centric service hub, which has been prototypically developed as part of the project described in section 1.1. The integration of both systems using standardized interfaces, the process flow, and the process transparency form a complete use case.

The rest of the paper is structured as follows: Section 1.2 gives an overview of the Vacuum Laboratory at PTB and their digital workflow; section 1.3 describes the Digital Calibration Certificate. Section 2 elaborates how the integration has been developed in both systems. Sections 3 and 4 then conclude the paper by providing the case study's key findings, and provide an outlook to future related projects.

1.1. AnGeWaNt Project

AnGeWaNt is a research project funded by the German Federal Ministry of Education and Research (BMBF), and encompasses representatives from the weighing and construction industries, and scientific institutions. These are the National Metrology Institute of Germany "PTB" (Physikalisch-Technische Bundesanstalt), a regional agency for innovation and European affairs, and the Institute for applied labour science "IfaA" (Institut für angewandte Arbeitswissenschaft). The IfaA is responsible for socio-economics and human factors within the project (see [1]).

The project's goal is to streamline and innovate metrological processes for measuring instruments under legal control, and to fulfill PTB's digital key objectives [2], such as a holistic approach for measuring instruments and data, as well as the efficient and secure use of digital technologies. The project provides a distributed modular platform for digitally transformed procedures, which has been extensively described in [3] and [4].

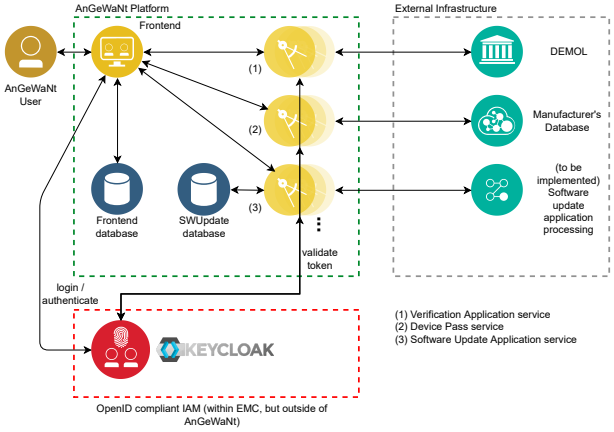

Fig. 1: Overview of the AnGeWaNt Platform

Each service is implemented as its own application container, which can also be updated independently, avoiding the need to update the whole platform at once. It consequently uses the Digital Calibration Certificate (DCC) (see section 1.3) as part of the Vacuum Laboratory integration. This shows the benefit of the modular approach of the AnGeWaNt platform, its independent service architecture and rapid prototyping capabilities. Fig. 1 gives an overview of the AnGeWaNt platform. The upper left section shows the core platform (web frontend and use-case specific backend services). The upper right section shows external third-party systems, communicating with respective AnGeWaNt backend services. The bottom section shows the user authentication and authorization component (OAuth 2.0 Framework-based "Keycloak" Identity Access Management solution, see [5], [6] and [7]).

1.2. Vacuum Laboratory

The Vacuum Metrology Group of PTB disseminates the pressure scale from 1×10^{-9} Pa to 1 kPa [8, 9]. To realize this range of pressures, several primary standards are maintained and operated. They are used to carry out research and calibrations of vacuum gauges for customers ranging from industry, calibration laboratories to other metrology institutes. Automation of both of the calibration workflow and the operation of primary standards [10, 11] soon became obvious. Since 2020 the generation of Digital Calibration Certificates (DCCs) has been integrated into the calibration workflow.

A calibration request specifies the type and the number of devices as well as the target pressures. Within the database, the available target pressures (*tdo*) and customers (*cus*) are stored. The relevant data sets are selected via a user interface and stored in a planning document (*pla*). These planning documents are used to generate an offer for the customer via LaTeX and block a certain time slot for calibration. Once the offer is accepted, a bureaucracy document (*bur*) and a corresponding number of calibration documents (*cal1, cal2, ...*) are generated based on the planning document. During the calibration, measurement data is written into the appropriate subsection of the calibration document (*cal1*) and an online analysis is performed after each measurement point. For the latter, information on equipment that is used during the calibration is obtained from calibration object documents (*cob1, cob2, ...*) and included in the calibration document (*cal1*). Once the measurement is finished, a certificate document (*cer1*) is derived from the calibration document (*cal1*). and corresponding DCCs are generated.

1.3. Digital Calibration Certificate

The Digital Calibration Certificate (DCC) [12] is a unified way of transferring calibration results from machine (issuing authority) to machine (calibration customer) in XML (Extensible Markup Language) format. The DCC provides metrological traceability, and it ensures reliability of measuring equipment in industrial as well as administrative processes. The conventional, paper-based certificates are physically signed, and manually transcribed into the processing system that uses the device or artefact that has been calibrated. This manual transcription of the calibration data is an error prone procedure. XML-based calibration certificates are machine readable and can be sent instantly and securely to customers. Thus, data-handling is significantly simplified and can be further automated by software. The calibration data is automatically imported and transferred to relevant systems without the need for manual transcription.

This paper provides a precedence use case for the DCC, in which the certificate generation is performed by the laboratory application and then fetched and verified by the service hub platform to provide fully standardized availability. This scenario shows how digital calibration certificates can be automatically processed across different application domains without human interference, thus enhancing trust in such documents.

2. IMPLEMENTATION

The main goal is to create a seamless integration of digital calibration requests and digital calibration certificates into one harmonized, digitally transformed process. The adaptations on both the AnGeWaNt and the Vacuum laboratory sides are reviewed in this section.

2.1. AnGeWaNt

The interface integration of Vacuum laboratory and AnGeWaNt is entirely implemented as REST interfaces, using JSON as data exchange structure. The sequence of interactions taking place is depicted in figure 2.

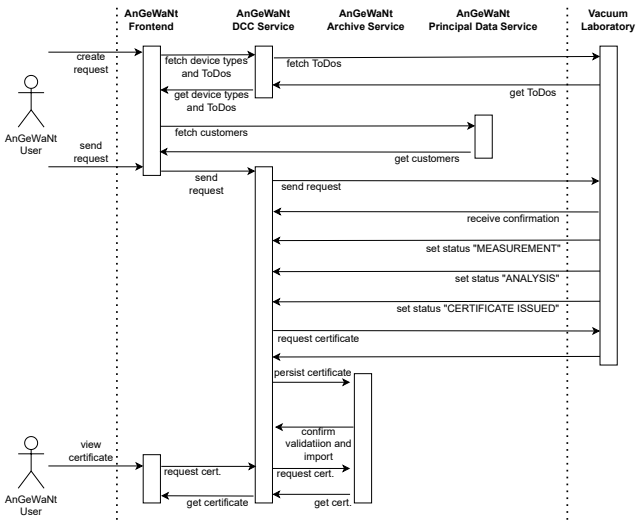

Fig. 2: Sequence diagram of the interface integration to enable communication between Vacuum Metrology Group, and the AnGeWaNt platform.

When the graphical user interface (GUI) for creating calibration requests is initiated, the DCC service first pulls a list of "ToDo" items from the Vacuum laboratory via GET requests through REST endpoints. A ToDo item is a unique piece of information which holds the task to be performed for calibration. The DCC service also provides a generated set of unique device types, generated form the list of ToDo items. Each unique string starts with the device type's name. Both sets of information are passed to AnGeWaNt's web frontend to be conveniently selectable by the user.

Once a calibration request is completed and submitted, the DCC service transfers the request to Vacuum laboratory via a POST request through a REST enpoint. The Vacuum laboratory confirms the recipience by sending the submitted JSON structure back with an additional external UUID generated by the laboratory and a status message 20 ("SUB-

MITTED"). While processing the request, Vacuum laboratory updates the status of the request by issuing status 30 ("MEASUREMENT"), 40 ("ANALYSIS"), and finally either 50 ("CERTIFICATE ISSUED"), or 51 ("CALIBRATION ERROR"). When the status 50 ("CERTIFICATE ISSUED") is received, the DCC service pulls and stores the assigned DCCs according to section 2.2. The DCC service then sets the status 60 ("CERTIFICATE ARCHIVED") for the calibration request, for which the certificates have been retrieved.

2.2. *Vacuum laboratory*

The workflow within Vacuum laboratory is displayed in figure 3. When a calibration request is received as JSON via POST, the process is initiated. Vacuum laboratory updates the status towards AnGeWaNt according to and subsequently, at which stage in a calibration process which status message is delivered via PUT method from Vacuum laboratory to the DCC service of AnGeWaNt: NEW (10), SUBMITTED (20), MEASUREMENT (30), ANALYSIS (40), CERTIFICATE ISSUED (50), and CALIBRATION ERROR (51).

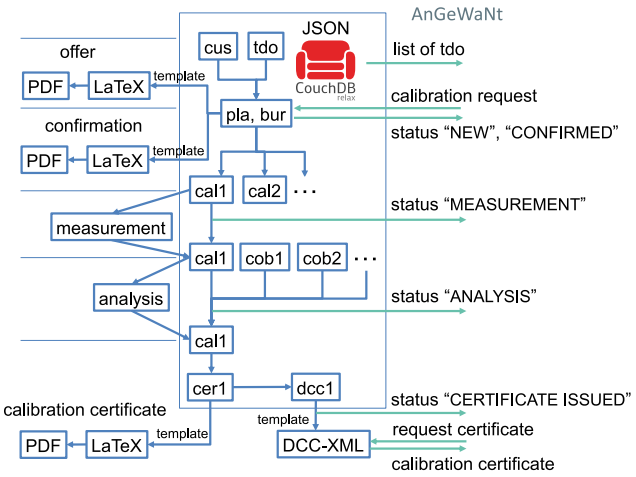

Fig. 3: Workflow of calibration application in the Vacuum Metrology Group, and its integration with AnGeWaNt by sending status codes via PUT to the specified REST endpoint of AnGeWaNt's DCC service.

The implementation of the calibration workflow is built with the NoSQL database CouchDB [13] at its centre. CouchDB is a document store and supports a master-master replication mechanism to keep the database instances synchronized. Data is stored in self-contained JSON [14] documents accessible via REST interfaces. The modelling of the processes in the laboratory is achieved with the help of these documents. The flow of documents generated within the calibration workflow is shown in figure 3.

The current status of each request is displayed in the list of calibration requests within the web frontend of the AnGeWaNt platform. Once the status 50 ("CERTIFICATE ISSUED") has been issued, the DCC service retrieves the issued certificates from the Vacuum laboratory, validates them according to section 1.3 and stores them permanently via the Archive service.

3. CONCLUSION

In this paper, the digital transformation of the calibration workflow and its integration into a digital metrological ecosystem has been extensively described. The previously disjoint information systems are representative for many digital transformation projects. The identified automation challenges lead to the following key findings:

1. A seamless *integration* and consistent communication flow is important, especially across different departments.
2. The *transparency* of process flows is paramount and was achieved by introducing status messages for long running processes.
3. A well documented and standardized *process flow* supports the integration and digital transformation of the process.
4. *Standardized interfaces* and uniform exchange formats enable loosely coupled and seamless communication.
5. To significantly improve *tamper proof information flow*, well-implemented security standards and norms were employed.

The above key findings serve as requirements for this case study to be a blueprint for future systems integration in the field of metrology. Harmonized interfaces support a seamless integration of information interchange without media discontinuity. It is therefore advised to use state of the art, widespread and well-known standards. Furthermore, transparency in the process as well as secure communications lead to greater acceptance and trust. For the involved departments, a clear and precise documentation of the process flow is key to its successful implementation. By following the key findings, the feasibility of a successful digital transformation is increased.

4. FUTURE WORK

Many laboratories within PTB employ highly specialized software solutions without being integrated into an automated process flow. This lack leads to information sinks and silos, which inhibits seamless communication across departments. The AnGeWaNt platform serves as a showcase for a cloud-native service architecture. The presented case study shows how existing laboratory information systems can be integrated and embedded into a harmonized and automated process flow while increasing security at the same time. Many concepts and design decision made

within AnGeWaNt will be further used and deployed in a follow-up project called "Operation Layer (OP-Layer)".

ACKNOWLEDGEMENTS

The presented case study was conducted within the project "AnGeWaNt - Arbeit an geeichten Waagen für hybride Wiegeleistungen an Nutzfahrzeugen" (FKZ: 02L17B050). We would like to thank the German Federal Ministry of Education and Research (BMBF) and the European Social Fund (ESF) for funding this research project. Both projects are implemented by the Project Management Agency Karlsruhe (PTKA). The authors would like to acknowledge funding of the presented research within the European Metrology Programme for Innovation and Research (EMPIR) as well as the European Association of National Metrology Institutes (Euramet) in the Joint Research Project 17IND02 SmartCom. The authors are responsible for the content of this publication.

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