Building a Radionuclide Metrology Algorithm Comparison Platform (NuCodeComP): Insights from Rapid Integration with Microsoft PowerApps

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Abstract. An essential step in radionuclide activity measurement comparisons is the counting signal processing performed by laboratory-specific software. This has led to initiatives comparing software performance using a unique dataset from a list-mode data structure, as defined in IEC 63047:2021. A virtual Radionuclide Metrology Algorithm Comparison Platform was developed at BIPM to ensure a FAIR approach and facilitate broader laboratory participation. Beyond presenting the final product, this work highlights key insights from its development. The platform was designed to be reliable, adaptable, and future-proof, aligning with the D-SI framework to ensure machine-readable, structured, and interoperable data. A strategic decision was made to investigate Microsoft 365, leveraging its infrastructure to real-test software operations before investing in scalability. However, scalability limitations arise, requiring Azure solutions like SQL Server for big data applications. The drag-and-drop interface simplifies the platform's development in interface design while utilizing SharePoint tables for data structuring and access control. However, performance constraints exist, particularly with SharePoint's row-number limitation. Furthermore, non-M365 users face access barriers mitigated through basic M365 plans or per-app licensing. This case study serves as a model for digital metrology projects, balancing cost-effective IT solutions with scalability and accessibility challenges while ensuring alignment with SI Digital transformation.

1 Introduction

The digital transformation of metrology is changing how measurement data is generated, processed, and compared. In radionuclide metrology, interlaboratory comparisons have traditionally relied on the physical exchange of radioactive samples, posing logistical, regulatory, and reproducibility challenges [1]. Moreover, data analysis is a key aspect of any comparison—understanding how different laboratories process measurement data [2].

Unlike conventional approaches, where activity of radioactive samples using is estimated by primary measurement techniques, a code comparison framework focuses on the validation of downstream part of the measurement, the software, enable thanks to standardized structured list-mode data (IEC 63047:2021) generated by the measurement device [1–3].

Based on that demand, a project was started to develop a platform that manages that code comparison, a digital-first approach, leveraging structured list-mode data and FAIR (Findable, Accessible, Interoperable, Reusable) principles, offers a solution that aligns with the SI Digital Framework, as stated by the CIPM [4–6].

The Radionuclide Metrology Algorithm Comparison Platform (NuCodeComP) was developed at the BIPM to facilitate an interlaboratory assessment of data processing algorithms. The platform leverages BIPM's existing Microsoft 365 (M365) infrastructure to minimize deployment costs and ensure ease of access [7]. However, before committing to scalability investments, the platform was tested under real-use conditions, revealing both advantages and constraints.

The Consultative Committee for Ionizing Radiation (CCRI(II)), which oversees international comparisons of radionuclide activity measurements, recognizes the potential of software-based comparisons in complementing traditional methods [8].

This paper presents the insights gained during the platform's development and technical implementation, as well as lessons learned regarding the feasibility of adopting a digital-first approach in radionuclide metrology. By integrating FAIR principles and the D-SI framework, the platform may serve as a model for future digital comparison initiatives in metrology. However, challenges such as scalability, access management, compliance with the CIPM MRA, and long-term sustainability must be considered to ensure its adoption.

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2 Radionuclide Activity Comparisons and Code Comparison

Interlaboratory comparisons are fundamental to ensuring measurement equivalence across National Metrology Institutes (NMIs), with the CCRI(II) coordinating their implementation in radionuclide metrology. The comparison process follows a structured flow (see Fig. 1) to maintain traceability to the International System of Units (SI) and adherence to the CIPM Mutual Recognition Arrangement (CIPM MRA) [8].

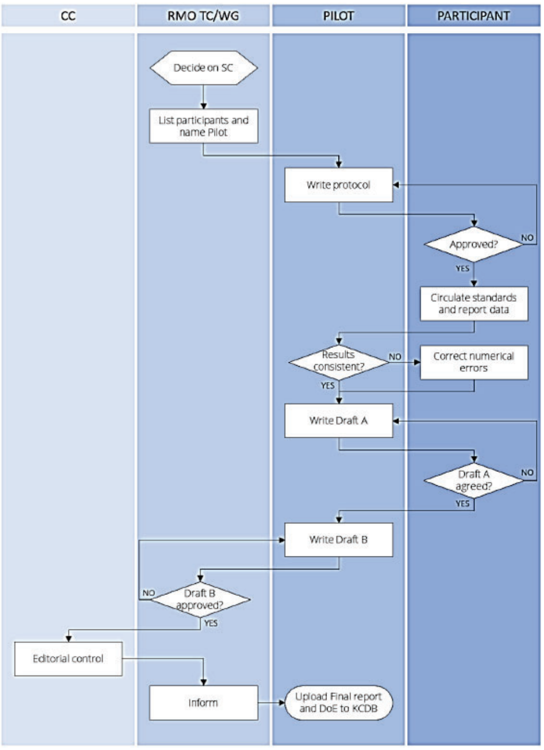


Fig. 1. Flowchart of CIPM and RMO key comparisons [8]**.**

The comparison begins with the designation of a pilot laboratory, such as the BIPM or other NMI, responsible for defining the technical protocol. This document outlines the measurement methods, reporting formats, and uncertainty evaluation requirements governing the exercise. Participants receive a reference sample, such as an aqueous solution of technetium-99 (Tc-99), or sent a standard solution to the BIPM on-demand key comparison services (the SIR, SIRTI, and ESIR) [1].

Upon receipt of the test material, each participating laboratory conducts measurements according to its established methodologies. The results, including activity values and associated uncertainties, are submitted to the pilot laboratory for centralized analysis. The initial collation of data is compiled into Draft A, a preliminary report that presents individual laboratory results while maintaining confidentiality regarding deviations. At this stage, laboratories are permitted to review their own data for numerical or procedural inconsistencies, but no information is provided on the magnitude or direction of potential discrepancies, ensuring an unbiased reassessment [8].

Following participant feedback, the pilot laboratory refines the dataset, incorporating validated corrections and performing statistical analyses to establish the Key Comparison Reference Value (KCRV). The revised document, Draft B, undergoes further scrutiny by CCRI(II) (and/or KCWG(II)) before final approval. The degrees of equivalence, quantifying each participant's alignment with the KCRV, are determined and presented alongside the final results. Upon acceptance, the findings are published in the Key Comparison Database (KCDB), providing a globally accessible benchmark for radionuclide metrology.

While effective, this approach presents several challenges, such as regulatory constraints (international transport of radioactive sources), measurement variability (differences in laboratory setups, detector types, and measurement protocols), and focus on activity estimation, not data processing (traditional comparisons primarily assess measurement accuracy but do not systematically evaluate how different laboratories process list-mode data, which is a critical aspect of radionuclide metrology) [9,10].

2.1 The Code Comparison

In radionuclide metrology, while activity estimation typically follows data acquisition and analysis, specific investigations focus on the "data analysis" step, evaluating signal processing methodologies and their influencing parameters. A complementary to conventional comparisons is the code comparison approach, wherein laboratories analyze a common dataset rather than handling physical radioactive materials. This method establishes a controlled and reproducible framework for assessing the performance of signal processing algorithms and activity estimation techniques [2].

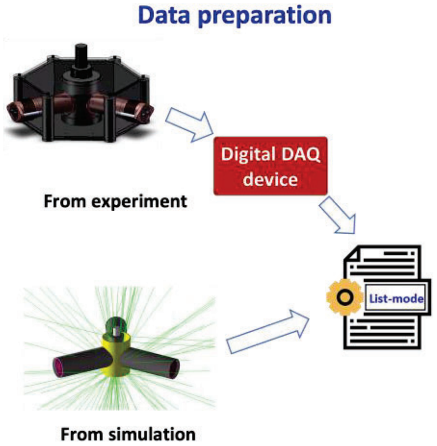


Fig. 2. Data preparation of Code Comparison [2]**.**

The overall comparison structure follows the framework outlined in the CIPM MRA, with a key modification in the "Circulate standards and report data" phase. Instead of distributing radioactive sources, the pilot laboratory provides a list-mode dataset from either an experimentally validated measurement comparison, a prior algorithm comparison, or an unvalidated dataset from a volunteer laboratory using a proper digitizer (see Fig. 2). Alternatively, the dataset may be generated through Monte Carlo simulations, allowing evaluation under various processing conditions [2,3,8,11].

Each participating laboratory processes the list-mode dataset using its proprietary software and submits the results accordingly (see Fig. 3). Subsequent steps remain unchanged, ensuring alignment with the standard comparison procedures while adapting the methodology to software-based evaluations.

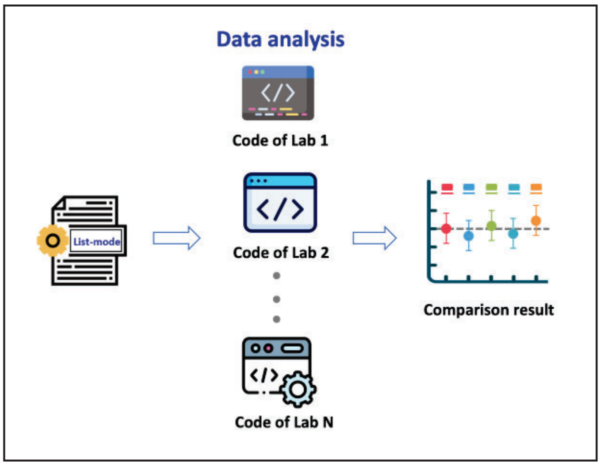


Fig. 3. Data analysis of Code Comparison [2].

3 Development of the Code Comparison Platform (NuCodeComP) for Radionuclide Metrology

3.1 Key Requirements and Design Principles

The NuCodeComP was developed at BIPM to provide a standardized environment for evaluating the performance of signal processing and activity estimation [2]. The objective was to create a FAIR-compliant system that supports structured, machine-readable, and interoperable data processing in line with the D-SI framework [5,12].

3.1.1 Design Requirements

The platform was designed based on the following principles:

- **Reliability and Data Integrity:** Ensuring a secure and auditable framework that maintains traceability of processed data back to the original list-mode dataset, in compliance with metrological standards [8].
- **Interoperability:** Compatibility with list-mode data formats, adhering to IEC 63047:2021 for radionuclide activity measurements [3].
- **Scalability and Future-Proofing**: Handle increasing data volumes and evolving metrological requirements, integrating cloud-based solutions.

3.1.2 Technology Stack

The M365 ecosystem was chosen for rapid deployment and cost efficiency, leveraging the BIPM inside it and using the following tools [7,13]:

- **PowerApps:** For building the user interface with drag-and-drop simplicity.
- **SharePoint**: Used as the primary database for structured storage of list-mode datasets and analysis results.
- **Power BI**: For data visualization and reporting, ensuring clear insights into software performance across laboratories.
- **Power Automate**: For future automation, such as sending e-mails automatically after each comparison step.

3.2 Insights from the Development Process

The development and implementation of the platform provided some insights that shaped its functionality and guided future improvements. A critical observation was the importance of real-world software testing at zero cost before investing in scalability. The initial prototype was developed within an already available M365 environment, leveraging PowerApps without additional expenses for infrastructure, database management, or hosting services. This approach allows the team to assess usability, identify performance bottlenecks, and evaluate access limitations using existing organizational resources.

Following initial validation, NuCodeComP can operate as the primary application for managing algorithm comparisons in radionuclide metrology, supporting this role within its current structure. The platform facilitates processing and validating final results while also tracking intermediate subset values throughout the comparison workflow [14]. This feature allows laboratories to evaluate specific processing steps, detect anomalies, and improve consistency before final reporting. These enhancements align with CIPM MRA guidelines, ensuring traceability in software-based radionuclide metrology comparisons [8].

The platform is accessed via a web browser using M365 accounts, with development simplified through PowerApps' drag-and-drop interface. Users familiar with Microsoft PowerPoint can adapt quickly to the PowerApps environment, enabling efficient development. SharePoint tables serve as the database, integrating pre-configured elements such as forms and galleries for structured data management.

Power BI is used for data visualization and structuring comparison results into interactive dashboards. Power Automate handles automated notifications and updates, supporting communication tasks such as comparison status alerts [13].

4 Implementation and Technical Considerations

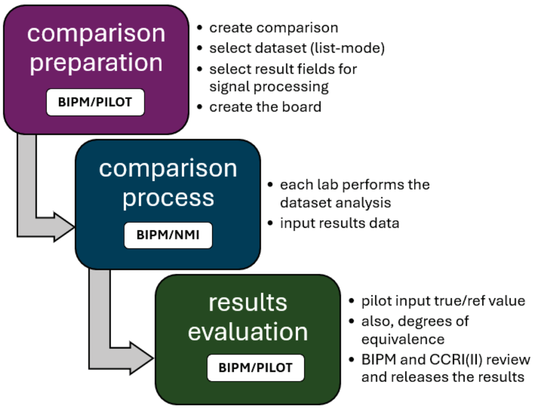


Fig. 4. Workflow Overview.

4.1 Platform Workflow and Data Processing

The NuCodeComP operates as a structured digital environment for interlaboratory evaluations, analyzing the results of those software-based activity estimations. The workflow (see Fig. 4) shows a general sequence of data submission, processing, and evaluation aligned with metrological standards and the D-SI Framework.

In the **Comparison Preparation** phase:

- In that phase, the Comparison Protocol was accepted by the comparison board members and the CCRI(II);
- BIPM or the Pilot Lab submits list-mode datasets following the protocol and IEC 63047:2021 specifications.
- Files are uploaded to SharePoint, where metadata (e.g., measurement conditions, equipment parameters) are registered.
- The necessary and optional fields for participants to input their results are configured.
- The comparison board is created and called to join in the comparison on the NuCodeComP.

In the **Comparison Process** phase:

- Participating laboratories download the dataset (including the list-mode data) and process it using their own software.
- Output files include processed activity results, uncertainty estimations, applied corrections, and rich metadata (parameters of digital measurement model) currently not considered in conventional comparisons.
- Processed results are re-uploaded to the platform.

In the **Results Evaluation** phase:

- Pilot Lab analyses and validates/corrects the pre-calculated evaluation parameters, such as true/reference value and the degrees of equivalence.
- A semi-automated validation script checks for format compliance and consistency with input parameters, reinforcing compliance with ISO/IEC 17025 [15].
- BIPM and CCRI(II) review and release the results.

For the visualization of comparison data:

- Power BI generates comparison charts.
- Users access a dashboard that highlights systematic deviations among laboratories according to access rules.

4.2 Scalability and Performance Limitations

Adopting an M365-based architecture provides a cost-effective and deployable solution for managing comparisons, but certain scalability constraints must be considered for long-term sustainability. A key limitation is SharePoint's data management, particularly the 20,000-row restriction per table for a fluid operation [16]. Based on projected data growth rates, NuCodeComP can operate within this limit for over 50 years. However, potential future expansions for additional applications should be evaluated before adopting M365 as the software platform.

Several scalability strategies are under consideration. One approach is migration to an SQL-based cloud storage solution, such as Azure SQL Server, which would enhance data handling efficiency and optimize query execution. While this transition involves additional costs, it ensures long-term scalability and faster data retrieval, supporting platform expansion. Alternatively, a hybrid model could be implemented, where metadata remains in SharePoint while large datasets are transferred to a cloud SQL database. This approach maintains SharePoint's cost efficiency while leveraging SQL for performance-intensive tasks, improving both accessibility and computational efficiency [17].

Another factor is user access and licensing limitations, particularly for non-M365 users. Currently, laboratories without M365 subscriptions face restricted access, limiting participation for institutions outside the Microsoft ecosystem. Possible solutions include institutional M365 subscriptions or per-app licensing plans (~$5–$6 per user/month). Additionally, Azure B2B authentication presents an alternative that allows external institutions to participate without requiring full M365 integration [18].

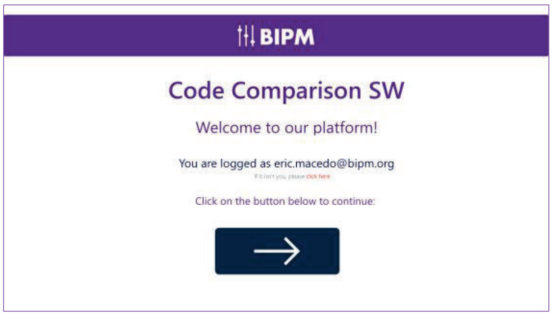
When scalability demands exceed expectations, migrating SharePoint data to an SQL-based system would be straightforward. Since data is already structured with defined types (e.g., CHAR, VARCHAR, FLOAT, INTEGER), transferring to cloud-based SQL storage would require minimal effort while maintaining data integrity and accessibility [19].

5 Impact on Digital Metrology and Future Developments

5.1 A Model for Other Metrology Applications

The NuCodeComP (see Fig. 5) applies a digital-first approach to radionuclide metrology comparisons, enhancing activity estimation algorithm evaluation by introducing a more detailed data processing analysis. This enables a comprehensive assessment of software performance and methodological consistency throughout the measurement process.

This approach supports the digitalization of metrology, aligning with the D-SI framework to promote the use of structured, machine-readable, and interoperable datasets. The platform's architecture can also be adapted to other metrology fields that rely on digital signal processing, broadening its applicability beyond radionuclide metrology.



Code Comparison SW

Welcome to our platform!

You are logged as eric.macedo@bipm.org

If it isn't you, please click here

Click on the button below to continue:

Fig. 5. NuCodeComP start page.

5.2 Future Improvements and Expansion

The NuCodeComP is advancing toward its first full version, with ongoing efforts to refine its functionalities and align with modern metrology frameworks. Current priorities include implementing Power BI dashboards for dynamic visualization and analysis of comparison results and integrating Power Automate into streamline communication workflows among participants. Additionally, the platform will be integrated with the D-SI framework, ensuring structured, interoperable, and machine-readable data principles through its reports. The platform's measurement data format will be interoperable with the recently developed machine-readable format for key comparisons in radionuclide metrology [20,21]. Expanding participant engagement will further validate usability, adaptability, and effectiveness in interlaboratory comparisons.

Beyond the initial deployment, future developments will aim to enhance automation, scalability, and real-time data processing capabilities. One possible envisioned expansion is the integration of measurement systems with the platform, enabling real-time data acquisition for quality control purposes.

The need for scaling computational and access management features will be assessed, identifying solutions for handling larger datasets and improving accessibility for laboratories outside the Microsoft 365 ecosystem.

Further iterations of the platform will incorporate advanced analytics and AI-driven automation to optimize data processing. Key enhancements include automated data quality checks and AI-driven detection of anomalies in submitted datasets.

In alignment with CIPM MRA, CCRI(II), and D-SI objectives, the long-term vision for NuCodeComP is to establish it as a reference model for software-based interlaboratory comparisons, extending its impact beyond radionuclide metrology [5,6,14]. This evolution will emphasize:

- FAIR Data Implementation, ensuring full compliance with Findable, Accessible, Interoperable, and Reusable principles [4].
- Interconnectivity with Global Metrology Networks, facilitating data exchange among BIPM, NMIs, and scientific repositories.

6 Conclusion

The Radionuclide Metrology Algorithm Comparison Platform (NuCodeComP) marks a significant step in the digital transformation of metrology, aligning with the CIPM Vision for Transforming the SI for a Digital World. The platform enables software-based comparisons and introduces a structured approach to interlaboratory comparisons, improving traceability, reproducibility, and efficiency.

Unlike traditional interlaboratory comparisons that focus solely on final activity estimations, NuCodeComP integrates intermediary processing steps, providing detailed insights into software performance and measurement methodologies. By structuring signal processing and activity estimation workflows, the platform ensures that each stage is documented, auditable, and reproducible, reinforcing the SI Digital Framework (D-SI).

The use of the Microsoft 365 ecosystem enabled rapid deployment without additional infrastructure costs, leveraging existing tools for data processing, access control, and interlaboratory collaboration. However, scalability and accessibility challenges—including SharePoint performance limitations and restricted access for non-M365 users—need future exploration of cloud-based SQL solutions and alternative authentication models to expand participation.

Despite these constraints, NuCodeComP's implementation has been effective, providing insights into software-based activity estimations and establishing a digital reference model for metrology. Future developments will focus on full D-SI framework integration, automated data validation, and AI-driven anomaly detection. Additionally, the platform will support machine-readable metrology reports, ensuring compliance with FAIR data principles and interoperability with global metrology networks, including BIPM and NMIs.

As metrology transitions to digital infrastructure, NuCodeComP demonstrates the feasibility of software-driven comparisons, contributing to cost-effective, scalable, and globally interoperable solutions for the future of measurement science.

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