Provenance in the context of metrological traceability

Ryan M White | Digital Metrology | SIM M4DT Annual Conference

Introduction

Provenance and metrological traceability are properties of a measurement result.

- What is provenance metadata?

- What is metrological traceability?

- Why distinguish these concepts?

- Improving current practice with provenance metadata

Provenance

"The fact of coming from some particular source or quarter; source, derivation," initially applied to works of art or historical objects.

Wikipedia, Provenance, Oxford English Dictionary.
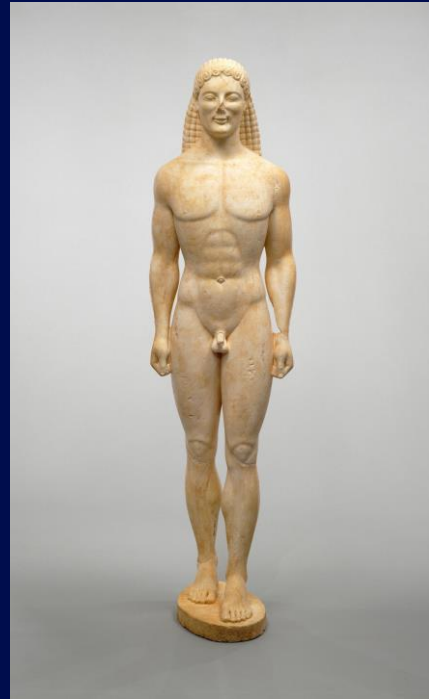
By J. Paul Getty Museum - The Getty Center, Object 103VNP, Getty kouros

Provenance of data and information

Database provenance

Characterizing and computing the provenance of a query result. Information about how and why certain data items has become part of a result.

Process provenance

Data dependencies that account for the generation of a piece of data as a result of a sequence of process transformations.

Provenance – domain-agnostic concept

Provenance is **information** about entities, activities, people, and institutions involved in producing, influencing, or delivering a piece of data or thing, which can be used to form assessments about its **quality, reliability or trustworthiness**. *W3C definition of the term provenance.*

No universally accepted definition, best to define provenance in its appropriate context, it is necessary to know what the information is to be used for.

PROV-N: The Provenance Notation (w3.org)

Provenance content (W3C)

- **Object:** Artifact the provenance statement is about (e.g., the measurement result).
- **Attribution:** Sources or entities contributing to the artifact (e.g., authorized staff, measurement system, reference standards, laboratory).
- **Process:** Activities or steps to generate the artifact (e.g., calibration, measurement methods).
- **Justification:** Documentation of decisions (e.g., authorization of reports).
- **Entailment:** Explanations of derivation of facts (e.g., supporting documents for uncertainty statements).

Metrological Traceability

Property of a measurement result whereby the result can be related to a reference through a **documented** unbroken chain of calibrations, each contributing to the measurement uncertainty. *Vocabulary of Metrology 3rd edition*
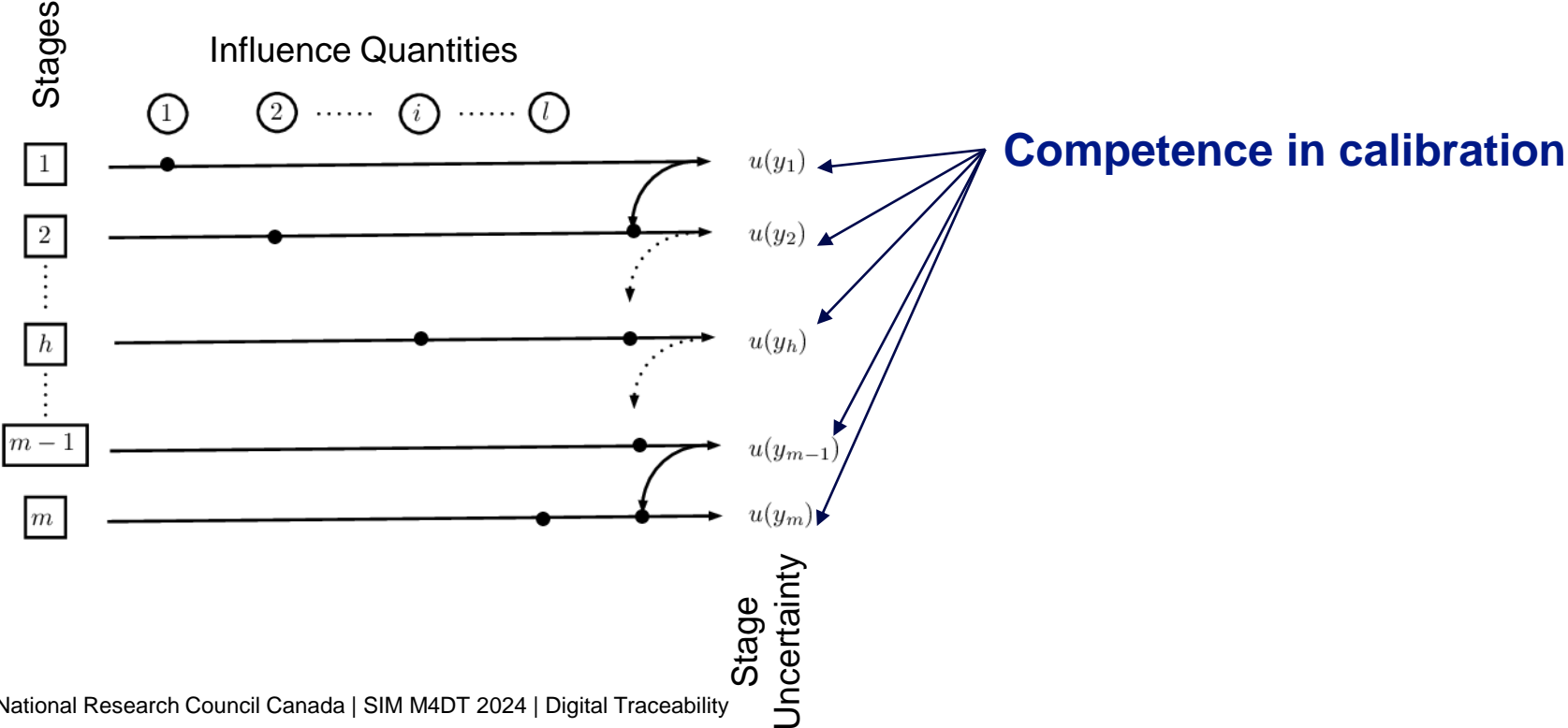
Metrological Traceability

Property of a measurement result whereby the result can be related to a reference through a **documented** unbroken chain of calibrations, each contributing to the measurement uncertainty. *Vocabulary of Metrology 3rd edition*

"traceability only exists when scientifically rigorous evidence is collected on a continuing basis showing that the measurement is producing documented results for which the total measurement uncertainty is quantified." *Dr Robert Hebner, the Acting Deputy Director of NIST*
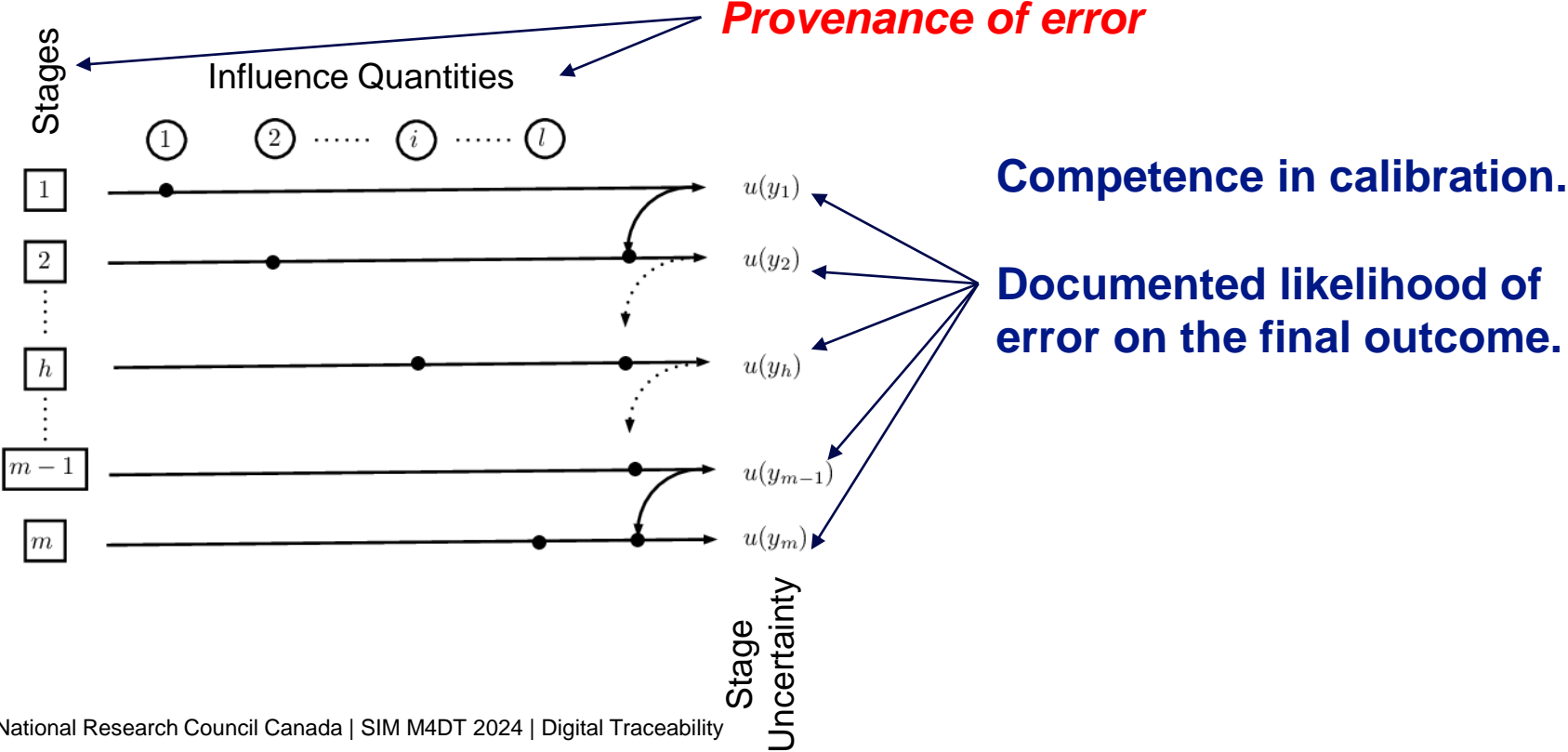
Metrological Traceability

Value of metrological traceability is its **assurance and quantification of measurement accuracy** through which the role of national **measurement standards** is realized.

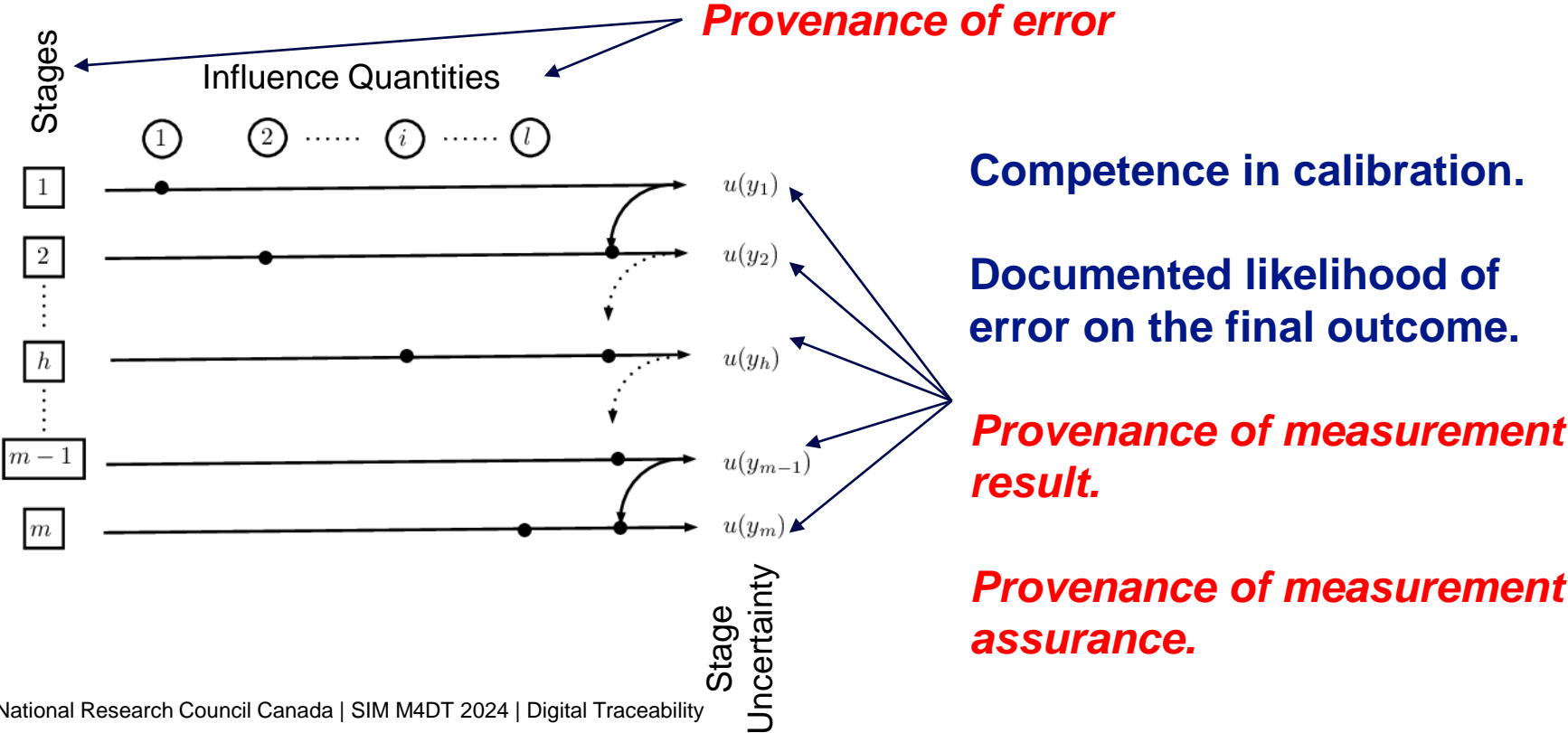# Metrological Traceability | Conceptual Model

Competence in calibration

Metrological Traceability | Conceptual Model

Provenance of error

Influence Quantities

Competence in calibration.

Documented likelihood of error on the final outcome.

Metrological Traceability | Conceptual Model

Provenance of error

Influence Quantities

Stages

Competence in calibration.

Documented likelihood of error on the final outcome.

Provenance of measurement result.

Provenance of measurement assurance.

Stage Uncertainty

How do we assess quality of measurement?

Demonstrate competence in calibration – *provenance of measurement error*.

Total quantification of measurement accuracy – *provenance of measurement result*.

Evidence that support claims of metrological traceability – *provenance of measurement assurance*.

Provenance

Metrological Traceability

Data's origin & history.

Entities, agents, activities.

Domain agnostic.

Assess data quality.

Documentation
Quality Assurance
Integrity
Trustworthiness

Measurement accuracy.

Measurement results, standards.

Specific to metrology.

Likelihood of error.

Provenance and traceable measurement

(1) Complete picture of the measurement process detailing the **provenance of measurement errors** in traceable chain of measurements, each stage contributing to a likelihood of error. *Benefits for the consumer of measurement.*

(2) **Provenance of documented measurement assurance** that support claims of measurement traceability at each stage in a traceable measurement chain. *Benefits for quality infrastructure.*

Provenance data model (PROV-DM)

Entities: Real-world or informational (e.g., a measurement result, standard).

**Activities**: Processes generating or changing entities. (e.g. a calibration)

Agents: People or organizations responsible for activities. (e.g. a calibration lab)

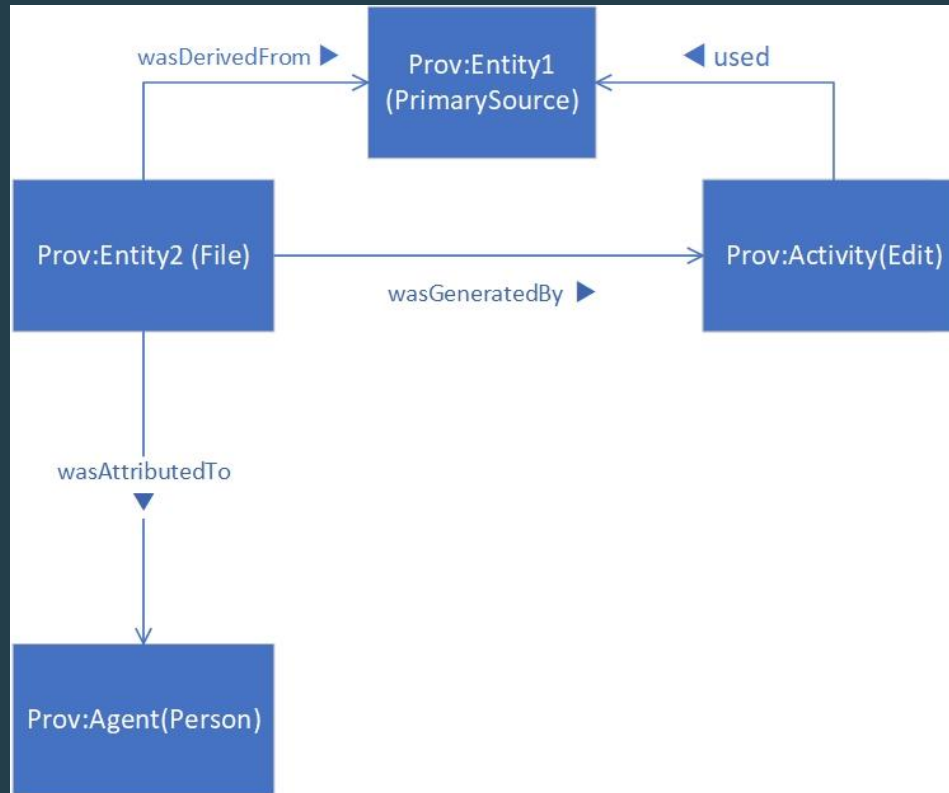**Roles**: Functions entities play in activities. (e.g., qualified technical staff)

Plans: Pre-defined procedures followed in activities. (e.g., measurement method)

Time: Timing of significant events. (e.g. measurement assurance)

PROV-DM (W3C Provenance Data Model)
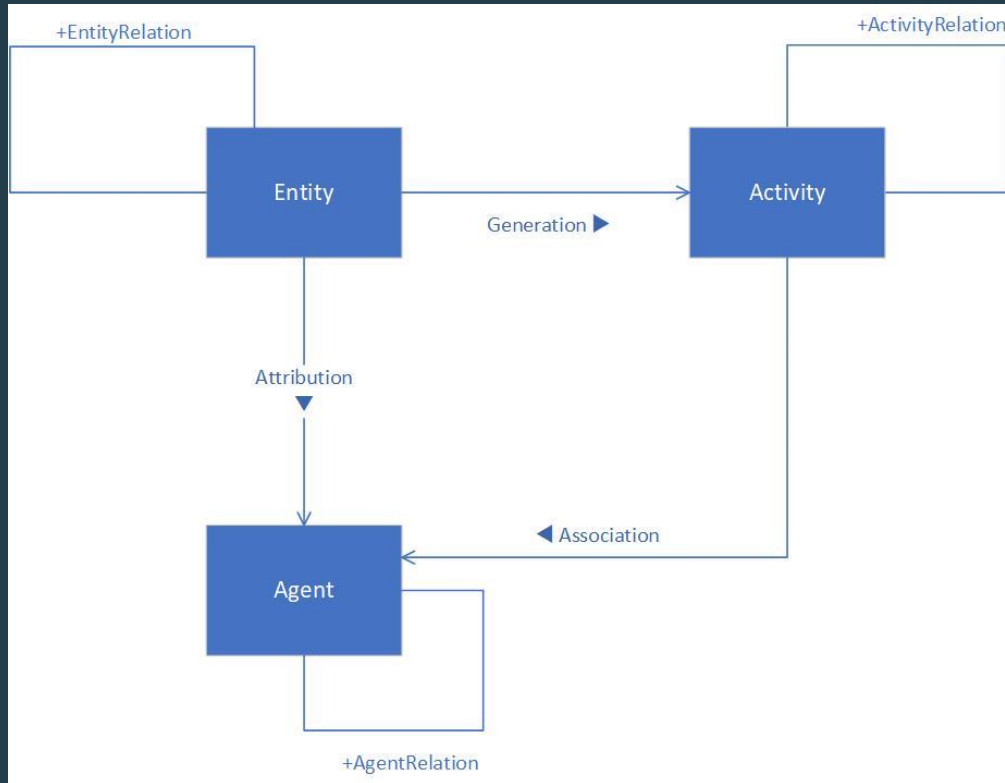
Provenance – Example of a file generated from editing the original source document.

Establish measurement quality from a provenance record?

- Does the organization have the capability to perform the activity?
- Who is the agent qualified to perform the activity?
- Who is the authorizing agent?
- What is the measurement method used?
- What is the measurement system that generated the measurement result?
- **What is the physical model of the measurement result?**
- **What activities are performed to assure measurement accuracy at the time of measurement?**

We can answer these questions with **information** about entities, activities, and people involved in producing a measurement result, and use this information to form assessments about its **quality, reliability or trustworthiness.**

Benefits of adopting existing provenance standards

Allows the metrological community to rethink current modeling approaches.

Clearly defines concepts in a calibration report and a documented chain of calibrations.

Provides a structure with well-defined semantics to express the provenance of metrological traceable measurement results.

Benefits of adopting existing provenance standards

De-risks dependence on internal approaches.

Reuse of existing technology based on a data standard.

Established solutions for provenance, security and confidentiality can mitigate stakeholder concerns.

Develop best practices for implementing FAIR (Findable, Accessible, Interoperable, Reusable) for metrology.

Recommend best practices for implementing metrology for FAIR.

Summary

Clear separation of concepts and metadata in digital formats improves:

- Clarity
- Interoperability
- Quality
- Trustworthiness
- Machine-actionability (of measurement results).

Provenance record incorporates metrological specific details:

- DCC namespaces.
- Standardized taxonomies.
- Other formalized digital document standards.
- **Capture details of measurement assurance – model for metrological timelines.**

Conclusions

Provenance and metrological traceability are distinct yet complementary concepts.

- Both are properties of measurement results.
- Both are essential for the integrity of measurement results.

Model concepts appropriately for machine-actionability.

Provenance metadata supports claims of traceability, quality and trustworthiness of measurement results.

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Thanks

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