

# ***Measurement and Metrology Requirements for Empirical Studies in Software Engineering***

**Alain Abran, ETS, Montreal, Canada**

**Asma Sellami, ETS, Montreal, Canada**

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# Summary

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- ⊙ Motivations and Objectives
- ⊙ Software Metrics and Metrology
- ⊙ Initial Modeling of the ISO Vocabulary on Metrology
- ⊙ Measurement Process Model in Abran and Jacquet
- ⊙ Measurement and Metrology Concepts within SWEBOK
- ⊙ Conclusions and Future Work

# ***Motivations and Objectives***

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- ⊙ **'Software Metrics':** proposed as the measurement tools of choice in empirical studies in SE
- ⊙ **'Metrics':** designed based on the intuitions of researchers and/or an empirical basis characterized by the ease of the counting of some entities of the development process
- ⊙ **The field of 'Software Metrics':** often discussed from the perspective referred to as **'Measurement Theory'**
- ⊙ **Researchers:** investigated the representation conditions, the mathematical properties of the manipulation of numbers...

- ⊙ **'Measurement theory': deals with only a subset of the classical set of measurement concepts**
- ⊙ **Our survey of the literature on software metrics has not come up with references to the classical concepts of metrology**
- ⊙ **Other disciplines: the domain of knowledge of 'Metrology' is the foundation for the development and use of measurement instruments and processes**

## ◎ Objectives

Introduce the full set of **measurement and metrology concepts** as the fundamental tools for empirical studies in software engineering

Investigate and position the measurement concepts within the Guide to the Software Engineering Body of Knowledge – SWEBOK

Strengthen the measurement foundations for empirical studies in software engineering

# *Software Metrics and Metrology*

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- ⊙ In empirical studies (fields of engineering, business administration, social sciences, etc.), measurement is one of a number of analytical tools
- ⊙ Measurement in these sciences is based on a large body of knowledge, metrology
- ⊙ To investigate how software metrics map to the classic domain of metrology, we will use the set of concepts of the ISO vocabulary on Metrology

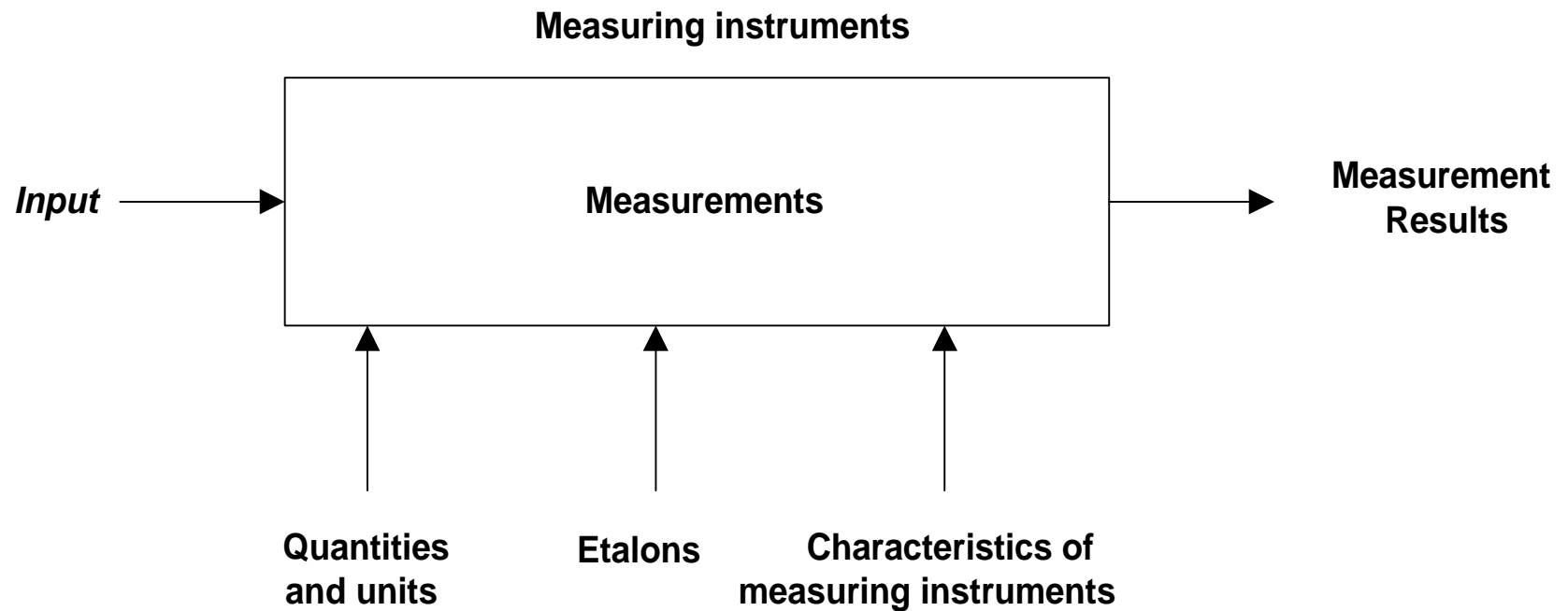
# *Software Metrics and Metrology*

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- ⊙ The mode of representation of ISO vocabulary is challenging in terms of assembling the full set (120) of inter-related terms
- ⊙ To improve the presentation and the understanding of this complex set of inter-related concepts (metrology), we have elected to build models of the relationships across the terms

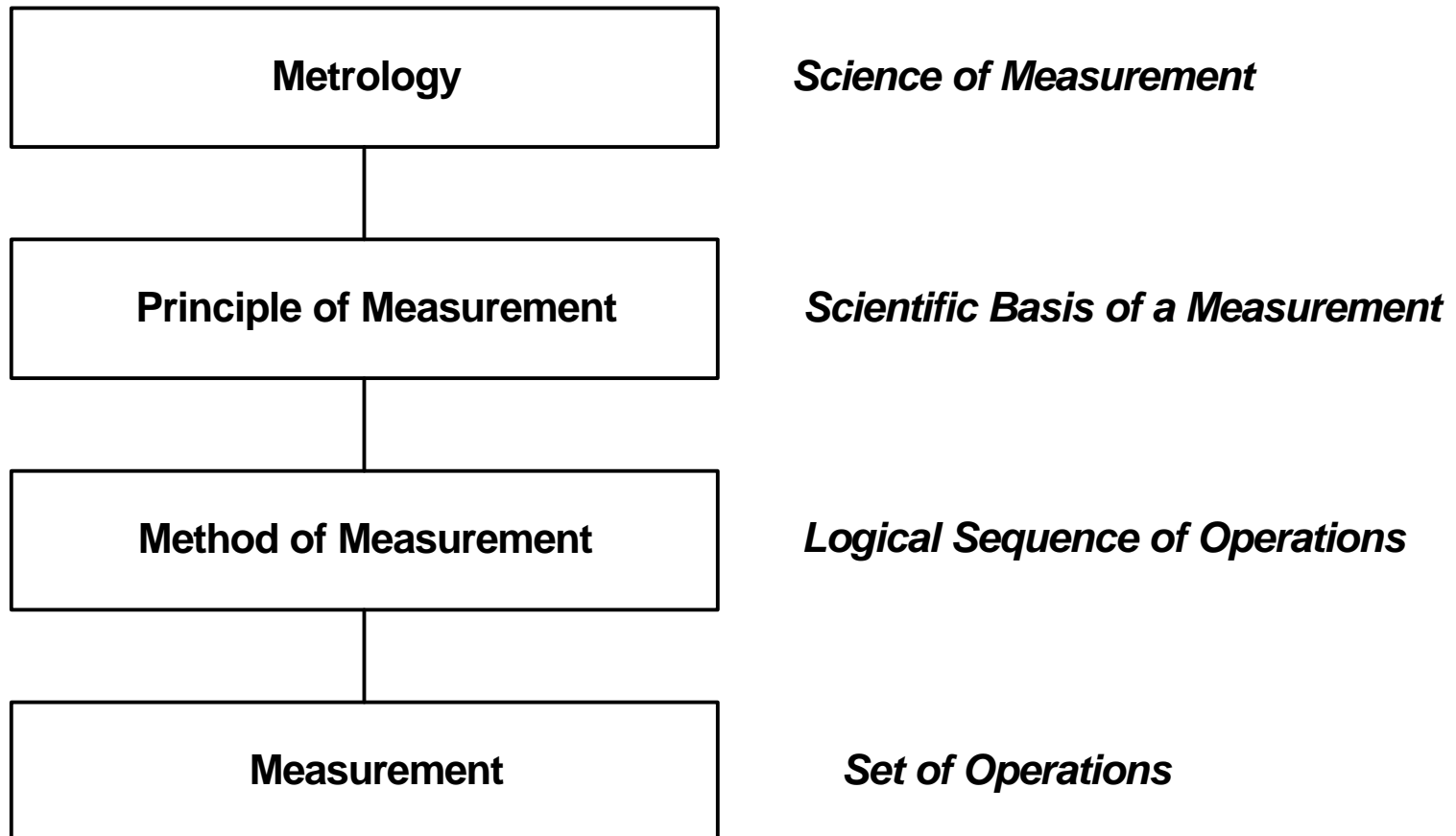
# *Initial Modelling of the ISO Vocabulary on Metrology*

## ⊙ High-level model of the ISO Vocabulary

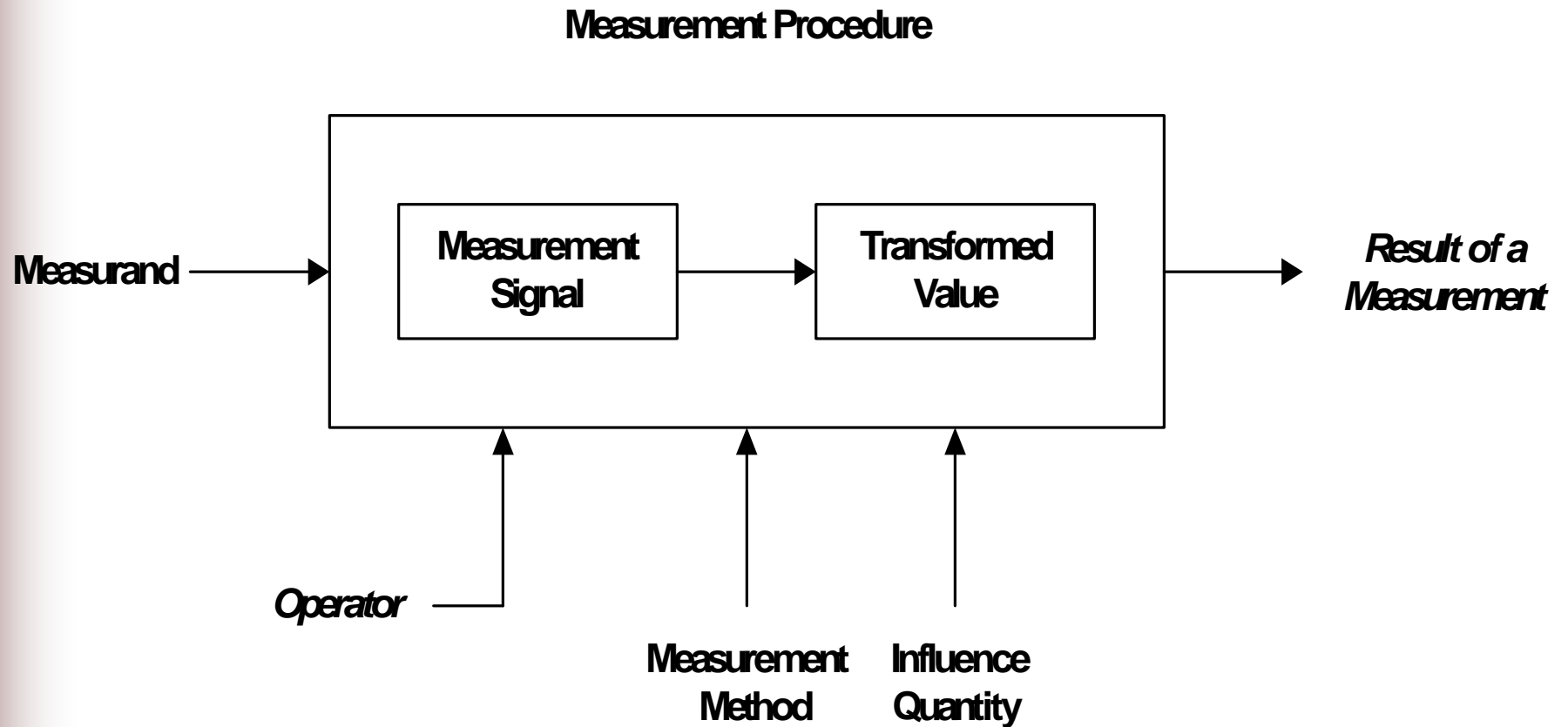




## ⊙ Measurement foundations



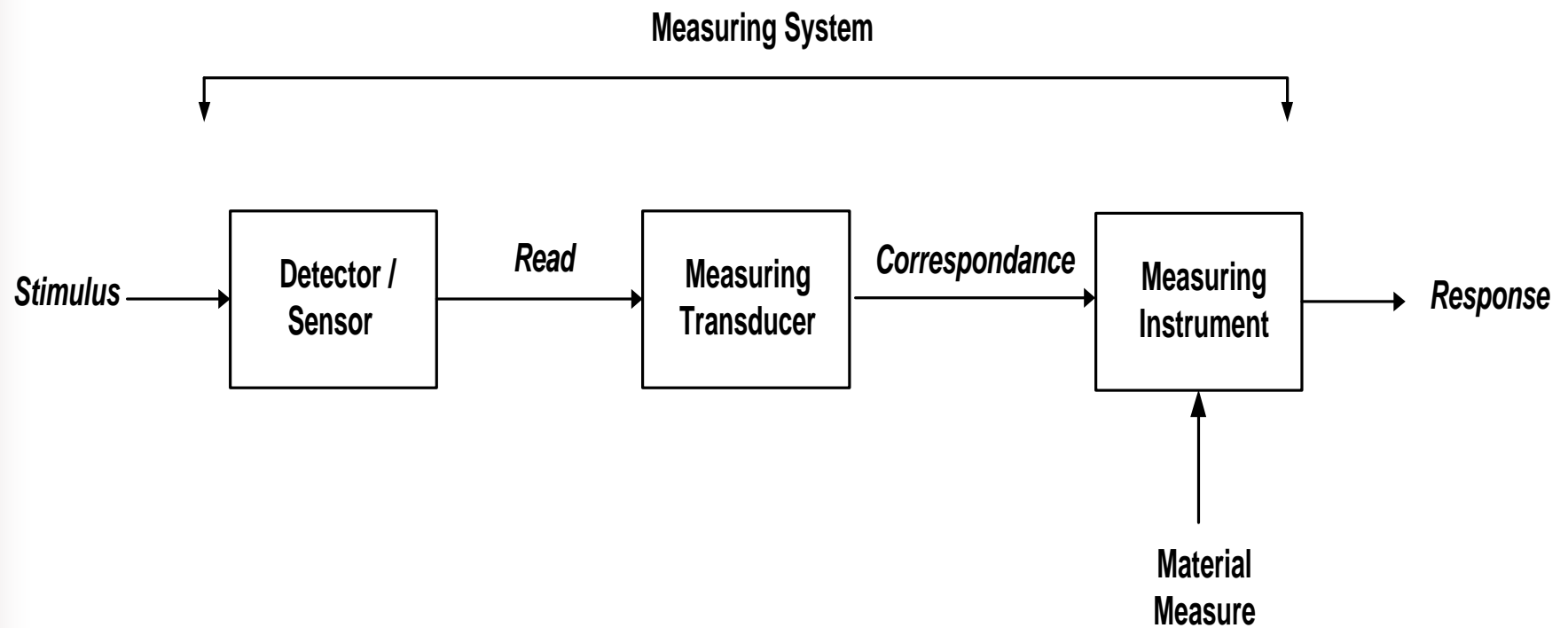
## ⊙ Measurement process



## ⊙ Measurement results

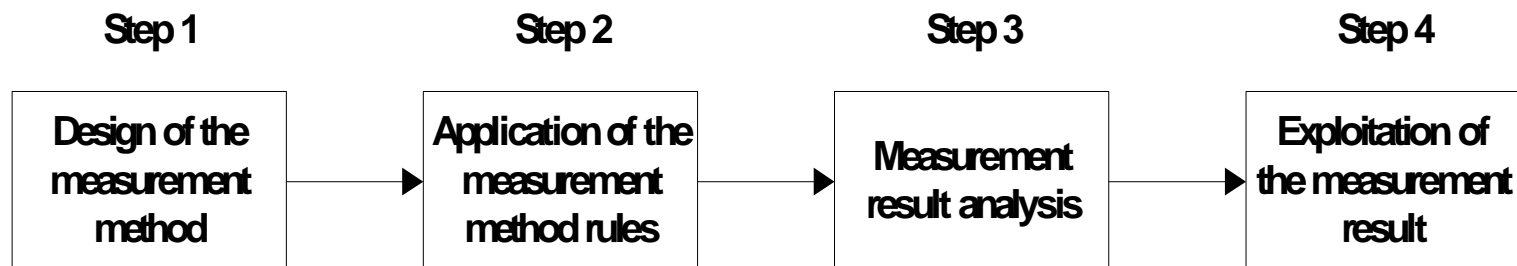
| <i>Types of measurement results</i>   | <i>Modes of verification of measurement results</i>  | <b>Uncertainty of measurement</b>   |
|---|--|---|
| <b>Indication (of a measuring instrument)</b><br><br><b>Uncorrected result</b><br><br><b>Corrected result</b> | <b>Accuracy of measurement</b><br><br><b>Repeatability (of results of measurements)</b><br><br><b>Reproducibility (of results of measurements)</b> | <b>Experimental standard deviation</b><br><br><b>Error (of measurement)</b><br><br><b>Deviation</b><br><br><b>Relative error</b><br><b>Random error</b><br><b>Systematic error</b><br><b>Correction</b><br><b>Correction factor</b> |

## ◉ Measuring instruments



# *Measurement Process Model in Abran & Jacquet*

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# *Measurement and metrology concepts within SWEBOK*

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- ⊙ Using both the ISO set of metrology concepts model and the measurement process model, we can analyze the current status of the field of 'software metrics' as documented in the guide SWEBOK
- ⊙ We analyze the 2001 Trial Version of the IEEE and ISO 19759 Guide to the SWEBOK

| Sections in SWEBOK,<br>Trial Version 1.00              | Measurement-Related Statements   |
|--|--|
| <b>Software Engineering Management</b>                 |  |
| <b>Software Engineering Measurement</b>                |  |
| <b>Goals (p. 8-7)</b>                                  | <b>Determining the goals of a measurement program</b><br><i>Ad hoc</i> approach to software engineering measurement characterised early efforts<br><b>Organizational objectives</b><br><b>Software process improvement goals</b> |
| <b>Measurement Selection (p. 8-8)</b>                  | <b>Goal-driven measurement selection</b><br><b>Measurement validity</b>  |
| <b>Measuring Software and its Development (p. 8-8)</b> | <b>Size measurement</b><br><b>Structure measurement</b><br><b>Resource measurement</b><br><b>Quality measurement</b>   |
| <b>Collection of data (p.8-9)</b>                      | <b>Survey techniques and form design</b><br><b>Automated and manual data collection</b>  |
| <b>Software Measurement Models (p. 8-9)</b>            | <b>Model building, calibration and evaluation</b><br><b>Implementation, interpretation and refinement of models</b>  |

| Sections in SWEBOK, Trial Version 1.00                    | Measurement-Related Statements  |
|---|---|
| <b>Software Quality</b>                                   |   |
| <b>Software Quality Concepts</b>                          |   |
| <b>Measuring the value of quality (p. 11-2)</b>           | <b>Determination of a value of a software project</b>   |
| <b>Measuring Applied to SQA and V&amp;V</b>               |   |
| <b>Fundamentals of Measurement (p. 11-10)</b>             | <b>Theory of measurement</b><br><b>Measurement scales</b><br><b>Measurement programs are useful if they help project stakeholders:</b><br><b>Understand what is happening during their processes</b><br><b>Control what is happening on their projects</b><br><b>Measurement practices: experimentation and data collection</b> |
| <b>Measures (p. 11-11)</b>                                | <b>Measurement models and framework for software quality</b><br><b>Types of measures</b>  |
| <b>Measurement analysis techniques (p.11-11)</b>          | <b>Mathematical and graphical techniques</b><br><b>Statistical based techniques and test</b>  |
| <b>Defect characterization (p.11-11)</b>                  | <b>Defect taxonomies</b><br><b>Analyzing defects</b><br><b>Measurement approaches</b>   |
| <b>Additional Uses of SQA and V&amp;V data (p. 11-12)</b> | <b>Determine how the SQA and V&amp;V processes use measurement directly to support achieving their goals</b><br><b>Reliability models and benchmarks</b>  |



# Measurement and metrology concepts within SWEBOK

| Abran and Jacquet (1997)             | Step 1<br>Design of measurement method | Step 2<br>Application of measurement method              | Step 3<br>Measurement result analysis | Step 4<br>Exploitation of measurement results |
|--------------------------------------|--|--|---------------------------------------|---|
| ISO (1993)                           | Quantities and units                   | Measuring instruments and characteristics of instruments | Measurement results                   |   |
| <b>Software Requirements</b>         |  |  |                                       |   |
| Process quality and improvement      |  |  |                                       | ×   |
| Requirements negotiation             |  |  |                                       | ×   |
| Document quality                     |  |  |                                       | ×   |
| Acceptance tests                     |  |  |                                       | ×   |
| Requirements tracing                 |  |  |                                       | ×   |
| <b>Software Design</b>               |  |  |                                       |   |
| Measures                             |  |  | ×                                     |   |
| <b>Software Testing</b>              |  |  |                                       |   |
| Evaluation of the program under test |  |  |                                       | ×   |
| Evaluation of the tests performed    |  |  |                                       | ×   |

| <b>Abran and Jacquet (1997)</b>                  | <b>Step 1<br/>Design of<br/>measurement<br/>method</b> | <b>Step 2<br/>Application of<br/>measurement<br/>method</b>             | <b>Step 3<br/>Measurement<br/>result analysis</b> | <b>Step 4<br/>Exploitation of<br/>measurement<br/>results</b> |
|--|--|---|---|---|
| <b>ISO (1993)</b>                                | <b>Quantities and<br/>units</b>                        | <b>Measuring instruments<br/>and characteristics of<br/>instruments</b> | <b>Measurement<br/>results</b>                    |   |
| <b>Software Maintenance</b>                      |  |   |   |   |
| <b>Software maintenance<br/>measurement</b>      |  |   |   | ×   |
| <b>Software Configuration Management (SCM)</b>   |  |   |   |   |
| <b>Surveillance of SCM</b>                       |  |   |   | ×   |
| <b>Software Engineering Management</b>           |  |   |   |   |
| <b>Goals</b>                                     |  |   |   | ×   |
| <b>Measurement selection</b>                     |  |   |   | ×   |
| <b>Measuring software<br/>audits development</b> |  |   |   | ×   |
| <b>Collection of data</b>                        |  | ×   |   |   |
| <b>Software measurement<br/>models</b>           |  |   | ×   |   |

| <b>Abran and Jacquet (1997)</b>                   | <b>Step 1<br/>Design of<br/>measurement<br/>method</b> | <b>Step 2<br/>Application of<br/>measurement method</b>                 | <b>Step 3<br/>Measurement<br/>result analysis</b> | <b>Step 4<br/>Exploitation of<br/>measurement<br/>results</b> |
|---|--|---|---|---|
| <b>ISO (1993)</b>                                 | <b>Quantities and<br/>units</b>                        | <b>Measuring instruments<br/>and characteristics of<br/>instruments</b> | <b>Measurement<br/>results</b>                    |   |
| <b>Software Engineering Process</b>               |  |   |   |   |
| <b>Methodology in<br/>process measurement</b>     |  | ×   |   |   |
| <b>Process measurement<br/>paradigms</b>          |  |   |   | ×   |
| <b>Software Quality</b>                           |  |   |   |   |
| <b>Measuring the value of<br/>quality</b>         |  |   |   | ×   |
| <b>Fundamentals of<br/>measurement</b>            | ×  |   |   |   |
| <b>Measures</b>                                   |  |   | ×   |   |
| <b>Measurement analysis<br/>techniques</b>        |  |   |   | ×   |
| <b>Defect characterization</b>                    |  |   |   | ×   |
| <b>Additional use of SQA<br/>and V&amp;V data</b> |  |   |   | ×   |

## ⊙ Mapping of ISO metrology model within measurement process model

| Abran & Jacquet (1997)                   | Step 1<br>Design of measurement methods                                  | Step 2<br>Application of measurement method rules   | Step 3<br>Measurement results analysis                                  | Step 4<br>Exploitation of measurement results |
|--|--|---|---|---|
| ISO Categories of Metrology Terms (1993) | <ul style="list-style-type: none"> <li>• Quantities and units</li> </ul> | <ul style="list-style-type: none"> <li>• Measuring instruments</li> <li>• Characteristics of measuring instruments</li> </ul> | <ul style="list-style-type: none"> <li>• Measurement results</li> </ul> |   |

# ***Conclusions and Future work***

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- ⊙ We have proposed to use our initial modelling of the sets of measurement concepts documented in the ISO vocabulary
- ⊙ We investigated, and position within our model of metrology and the measurement process model, the measurement concepts referred to in SWEBOK
- ⊙ Measurement related-statements in SWEBOK concern the use of measurement results in assessment and predictive models
- ⊙ Very little of the quality of the quantitative inputs to these models, and nothing about the supporting measuring instruments to obtain these inputs

# ***Conclusions and Future work***

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- ⊙ **In the SE literature, there is very little discussion on the topic of measuring instruments which are present in the traditional engineering disciplines**
- ⊙ **Metrology concepts have not yet been extensively discussed or addressed in the 'software metrics' literature**
- ⊙ **In our future, we look at the improvement of our initial modeling of ISO and to analyze the seminal references quoted in each chapter of SWEBOK dealing with measurement-related statements**

# ***Conclusions and Future work***

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- ⊙ **To develop a meta-model that takes into account what figures in our initial modeling of ISO Metrology and what is missing like exploitation of results**
- ⊙ **Much work remains to be done to introduce the full set of measurement and metrology concepts as fundamental tools for empirical studies in software engineering**

***Thank you***