# Traceability for computationally-intensive metrology

## Glossary of terms for computational metrology

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| 10. Supplementary notes This report is an internal project report. | | |
| 11. Abstract This document defines generic basic terms in key areas of computationally-intensive metrology. The definitions of these terms allow the unambiguous and clear formulation of computational aims at each metrology application. | | |
| 12. Key words Traceability, computationally-intensive metrology, metrology software validation. | | |

# Contents

# 1  Introduction

This report is organised as follows. The glossary is presented in the form of a table in section 2. The first column "Term" provides a list of terms relevant to traceability in computationally-intensive metrology. For each term, a definition is provided in the second column "Definition". For some terms, the definition has been obtained from another source and is quoted verbatim. For other terms, the definition is largely based on a definition provided by another source. For all cases where another source is used, the source is indicated in the third column "Reference". The details of all sources of definitions are provided in section 3.

# 2 Glossary

| Term | Definition | Reference |
|---|---|---|
| *Absolute error* | The magnitude of the difference between test and reference results corresponding to a reference problem. | **GPG 16** |
| *Acceptance testing* | Testing of software after delivery and installation in order to verify that it satisfies the customer's needs | **ISTQB Syllabus** |
| *Accuracy testing* | The process of testing to determine the accuracy of a software product | **ISTQB Glossary** |
| *Algorithm effect* | Effect on the correctness of a measurement result arising from limitations of a chosen algorithm to deliver a solution to the problem specified by a computational aim. | **GPG 16** |
| *Algorithm testing* | Investigating the extent to which using a (test) algorithm to solve the problem specified by a test computational aim delivers a solution to the target problem (as specified by the target computational aim). | **GPG 16** |
| *Alpha testing* | Simulated or actual operational testing by potential users/customers or an independent test team at the developers' site, but outside the development organization. | **ISTQB Glossary** |
| *Analytical testing* | Testing based on a systematic analysis of e.g., product risks or requirements. | **ISTQB Glossary** |
| *API (Application Programming Interface) testing* | Testing the code which enables communication between different processes, programs and/or systems. API testing often involves negative testing, e.g., to validate the robustness of error handling (See also interface testing). | **ISTQB Glossary** |
| *Associated feature* | An ideal feature established from a non-ideal surface model or from a real feature through an association operation. | **ISO 17450-1** |
| *Audit* | An independent evaluation of software products or processes to ascertain compliance to standards, guidelines, specifications, and/or procedures based on objective criteria. | **ISTQB Glossary** |
| *Beta testing* | Operational testing by potential and/or existing users/customers at an external site not otherwise involved with the developers, to determine whether or not a component or system satisfies the user/customer needs and fits within the business processes. | **ISTQB Glossary** |

| Term | Definition | Reference |
|---|---|---|
| *Big-bang testing* | An integration testing approach in which software elements, hardware elements, or both are combined all at once into a component or an overall system, rather than in stages (*see also integration testing*). | **ISTQB Glossary** |
| *Black-box testing* | Testing of software using solely the inputs and output of the software – not based on knowledge of the algorithm, or the manner in which that algorithm is implemented. | **GPG 16** |
| *Bottom-up testing* | An incremental approach to integration testing where the lowest level components are tested first, and then used to facilitate the testing of higher level components. This process is repeated until the component at the top of the hierarchy is tested (*see also integration testing*). | **ISTQB Glossary** |
| *Client-server technology* | A model for computer networking that utilizes client and server devices each designed for specific purposes. The client-server technology can be used on the Internet as well as local area networks. | **Bradley** |
| *Combining performance metrics* | Multi-criteria evaluation of the performance of test software in terms of the uncertainty contribution of the test software to the overall measurement result. | |
| *Compliance testing (conformance testing)* | The process of testing to determine the compliance of the component or system. | **ISTQB Glossary** |
| *Computational aim* | An unambiguous specification of the problem solved by software, for example, in the form of the inputs to, and outputs from, the software, and the mathematical model relating the inputs and the outputs. | **GPG 16** |
| *Conversion rule* | A rule by which the numerical values of the parameters in a test parametrization are converted into numerical values of the parameters in the reference parametrization. | **ISO 10360-1** |
| *Converted test parameter values* | Numerical values of the parameters obtained by applying a conversion rule to test parameter values. | **ISO 10360-1** |
| *Customized reference data set* | A reference data set adapted to customer capabilities or requirements. | |

| Term | Definition | Reference |
|------|-----------|-----------|
| *Data effect* | Effect on the correctness of a measurement result arising from the inexactness of data values (including measurement data, reference constants, calibration information, initial and boundary data, etc.). | **GPG 16** |
| *Data format* | A format for encoding data for exchange, that is, the process of taking data structured under a source schema and transforming it into data structured under a target schema, so that the target data is an accurate representation of the source data. | |
| *Defect (Fault, Bug)* | An error in the source code, which occurs during programming. Not all defects will necessarily result in failures. A defect can result in a failure when the environment is changed. | **ISTQB Syllabus** |
| *Development testing* | Formal or informal testing conducted during the implementation of a component or system, usually in the development environment by developers. | **ISTQB Glossary** |
| *Digital certificate* | An electronic encrypted file containing the confirmation that test software has passed performance and quality assurance tests and meets all validation criteria. | |
| *Discretization error* | The error caused by approximating a continuous differential equation with a numerical solution. Usually considered as the difference between an analytic solution and an idealized numerical solution, without considering the effects of finite precision arithmetic. | **GPG 16** |
| *Domain tests* | Tests in which the mathematical formulation of the problem is held fixed, but the domain on which the problem is solved is varied. | **GPG 16** |
| *Dynamic software testing* | Testing by executing the programme code with a given set of test cases. | **Mayers** |
| *Failure* | Deviation of the component or system from its expected delivery, service or result. | **ISTQB Glossary** |

| Term | Definition | Reference |
|------|------------|-----------|
| *Failure mode* | The physical or functional manifestation of a failure. For example, a system in failure mode may be characterized by slow operation, incorrect outputs, or complete termination of execution. | **ISTQB Glossary** |
| *Failure rate* | The ratio of the number of failures of a given category to a given unit of measure, e.g. failures per unit of time, failures per number of transactions, failures per number of computer runs. | **ISTQB Glossary** |
| *Feature* | An element considered to be a subject of test software evaluation, for example, a basic geometric element in Length metrology, such as line, circle, sphere, etc. | **ISO 14660-1** |
| *Fit for purpose software* | Software that satisfies a claim about its numerical performance, for example, expressed in terms of an absolute or relative error, or a performance measure. | **GPG 16** |
| *Functional testing* | Testing based on an analysis of the specification of the functionality of a component or system (*see also black box testing*). | **ISTQB Glossary** |
| *Functionality testing* | The process of testing to determine the functionality of a software product. | **ISTQB Glossary** |
| *Grey-box testing* | Testing of software using the inputs and outputs of the software – but where the testing strategy is based on knowledge of the algorithm and how that algorithm is implemented. | **GPG 16** |
| *Intake test* | A special instance of a smoke test to decide if the component or system is ready for detailed and further testing. An intake test is typically carried out at the start of the test execution phase. See also smoke test. | **ISTQB Glossary** |
| *Integration testing* | Any type of software testing that seeks to verify the interfaces between components against a software design. Software components may be integrated in an iterative way or all together ("big bang"). | **Bezier** |
| *Interface testing* | An integration test type that is concerned with testing the interfaces between components or systems. | **ISTQB Glossary** |

| Term | Definition | Reference |
|---|---|---|
| *Mathematical equivalence (of algorithms)* | Property of algorithms that deliver identical results for given data when implemented correctly using infinite precision arithmetic. | **GPG 16** |
| *Maximum permissible error* | Extreme value of measurement error, with respect to a known reference quantity value, permitted by specifications or regulations for a given measurement, measuring instrument, or measuring system. | **VIM** |
| *Measurement error* | A measured quantity value minus a reference quantity value. | **VIM** |
| *Measurement result* | A set of quantity values being attributed to a measurand together with any other available relevant information. | **VIM** |
| *Measurement uncertainty* | Non-negative parameter characterizing the dispersion of the quantity values being attributed to a measurand, based on the information used. | **VIM** |
| *Metadata* | Structured information associated with the test software containing identification, structuring and administrative data (such as information about sender, recipient, date, serial number identification, etc.). | |
| *Metrology application* | Particular area of applied metrology within a metrology domain, for example, Dimensional metrology, Surface metrology, Coordinate metrology, etc. within the Length metrology domain. | |
| *Metrology domain* | Metrology discipline corresponding to Consultative Committees of CIPM (Comité International des Poids et Mesures): AUV (Acoustics, Ultrasound and Vibration), EM (Electricity and Magnetism), L (Length), M (Mass and Related Quantities), PR (Photometry and Radiometry), QM (Amount of Substance - Metrology in Chemistry), RI (Ionizing Radiation), T (Thermometry), TF (Time and Frequency), U (Units). Moreover, INT (Interdisciplinary) metrology discipline is included. | |
| *Modelling effect* | Effect on the correctness of a measurement result arising from limitations of the chosen mathematical model to represent faithfully the physical problem required to be solved. | **GPG 16** |

| Term | Definition | Reference |
|---|---|---|
| *NMI network* | Well-established network of NMIs (National Metrology Institutes) for worldwide metrology at the highest level. | |
| *Numerical equivalence (of algorithms)* | Property of algorithms that deliver results for given data accurate to within a stated bound (dependent on the problem condition, the input data and the computer arithmetic) when implemented correctly using finite precision arithmetic. | **GPG 16** |
| *Numerical uncertainty* | The numerical uncertainty reflects the fact that in finite precision it is generally not possible for the input and output data to have an exact mathematical relationship. | **TraCIM, p. 22** |
| *Numerical (software) effect* | Effect on the correctness of a measurement result arising from the use of a software implementation of an algorithm to compute a solution to the problem specified by a computational aim. | **GPG 16** |
| *Numerical software testing* | Investigating the extent to which a software implementation delivers a solution to the problem specified by a computational aim. | **GPG 16** |
| *Online software validation* | Process of software validation is accomplished via Internet NMI network. | |
| *Operational acceptance testing* | Operational testing in the acceptance test phase, typically performed in a (simulated) operational environment by operations and/or systems administration staff focusing on operational aspects, e.g. recoverability, resource-behavior, installability and technical compliance. | **ISTQB Glossary** |
| *Operational testing* | Testing conducted to evaluate a component or system in its operational environment. | **ISTQB Glossary** |

| Term | Definition | Reference |
|---|---|---|
| *Parametric data model* | The reference data set is generated with respect to the parametrization of a feature. For any specific type of feature, a choice of parametrization is not unique. For example, a straight line in three dimensions or the axis of a cylinder or a cone can be specified by either a point on the axis and the direction cosines of the axis, or two points on the axis. | (Inspired by) **ISO 10360-1**, 11.1 |
| *Parametrization of a feature* | Choice of algebraic variables to represent a feature. | **ISO 10360-1** |
| *Performance measure* | A quality metric that compares the numerical performance of test software against reference software, accounting for the conditioning of the problem specified by the target computational aim, and the computational precision of the arithmetic used to obtain test and reference results. | **GPG 16** |
| *Performance metric* | Measure of performance of the test software in terms of the uncertainty contribution of the test software to the overall measurement result. | |
| *Performance parameter* | A parameter used to describe a property of a reference problem, and hence to parameterize the space of admissible inputs to the test software. | **GPG 16** |
| *Physical artefact (Physical standard, Material standard)* | Material artefact reproducing a traceable value of a measured quantity of a feature. | **GPG 42** |
| *Problem condition* | A measure that describes the sensitivity of the exact solution of a problem to changes in the problem. | **GPG 16** |
| *Quality metrics* | Quantitative measures of the numerical performance of test software, for example, the absolute and relative errors between test and reference results and a performance measure. | **GPG 16** |
| *Reference algorithm* | An (optimally-stable) algorithm to solve the problem specified by the target computational aim. | **GPG 16** |
| *Reference data set (Numerical artefact, Numerical standard)* | A set of values of the input data designed to simulate a range of measurands as well as typical errors of measurement. A reference data set is generated for the purposes of testing software. | **TraCIM** |
| *Reference data generator* | Software to generate reference data for which the solution to the problem specified by a computational aim is specified a priori. | **GPG 16** |

| Term | Definition | Reference |
|---|---|---|
| *Reference pair* | Reference data set and the corresponding reference parameter values. | **ISO 10360-1** |
| *Reference parameter* | A parameter used to describe a property of a feature. | **ISO 10360-1** |
| *Reference parametrization* | The set of reference parameters of a feature. | **ISO 10360-1** |
| *Reference parameter value* | Numerical value of a reference parameter. | **ISO 10360-1** |
| *Reference problem* | An instance of a problem specified by a computational aim for which the corresponding reference results are known. | **GPG 16** |
| *Reference result* | The solution corresponding to a reference problem. | **GPG 16** |
| *Reference software* | Software (developed to a very high standard) implementing a reference algorithm to solve the problem specified by the target computational aim. | **GPG 16** |
| *Regression testing* | Testing of a previously tested program following modification to ensure that defects have not been introduced or uncovered in unchanged areas of the software, as a result of the changes made. | **ISTQB Glossary** |
| *Relative error* | The magnitude of the difference between test and reference results corresponding to a reference problem expressed as a proportion of the magnitude of the reference results. | **GPG 16** |
| *Safety testing* | Testing to determine the safety of a software product. | **ISTQB Glossary** |
| *Sanity testing* | See smoke testing! | **ISTQB Glossary** |
| *Scalable tests* | A set of reference problems for continuous modelling software, the results of which have a known dependence on some function of the inputs. The tests are generated by fixing the value of the function and varying the input values individually. Such tests aim to explore the accuracy of the algebraic equation solving process and its sensitivity to the input values. | **GPG 16** |

| Term | Definition | Reference |
|---|---|---|
| *Simulated measurement uncertainty* | The simulated measurement uncertainty reflects the fact that the input data will often be generated to simulate data gathered by a measuring system with a specified uncertainty characterization. | |
| *Simulation* | Testing using reference problems defined by reference data sampled from the probability distribution describing the available knowledge about the inexactness of the data. | **GPG 16** |
| *Small-scale tests* | Reference problems for continuous modelling software that are defined using only a small mesh. Such tests aim to test the algebraic equation formulation process. | **GPG 16** |
| *Smoke testing* | A subset of all defined/planned test cases that cover the main functionality of a component or system, to ascertaining that the most crucial functions of a program work, but not bothering with finer details. | **ISTQB Glossary** |
| *Software validation* | Process that aims to provide reasonable confidence that it will meet its operational requirements. | **ISO 90003** |
| *Software verification* | Process that aims to provide assurance that the output of a design and development activity conforms to the input requirements. | **ISO 90003** |
| *Software testing* | An investigation conducted to provide stakeholders with information about the quality of the software. | **Cem Kaner** |
| *Static testing* | Testing of a software development artifact, e.g., requirements, design or code, without execution of these artifacts, e.g., reviews or static analysis. | **ISTQB Glossary** |
| *System testing* | Testing of a completely integrated system to verify that it meets its requirements. | **IEEE** |
| *Target computational aim* | The computational problem that is intended to be solved by test software. | **GPG 16** |
| *Test algorithm* | The algorithm implemented by the test software to solve the problem specified by the test computational aim. | **GPG 16** |
| *Test computational aim* | The computational problem that is actually solved by test software. | **GPG 16** |
| *Test parameter* | A parameter in a test parametrization. | |

| Term | Definition | Reference |
|------|-----------|-----------|
| *Test parametrization* | Parametrization of a feature used by test software. | **ISO 10360-1** |
| *Test parameter value* | Numerical value of a test parameter. | **ISO 10360-1** |
| *Test result* | The result corresponding to a reference problem delivered by test software. | **GPG 16** |
| *Test software* | The software subject to testing. | **GPG 16** |
| *Unit testing (Component testing)* | Testing that verifies the functionality of a specific section of code, usually at the function level. | **Binder** |
| *Visual testing* | Testing that provides developers with the ability to examine what was happening at the point of software failure by presenting the data in such a way that the developer can easily find the information he requires, and the information is expressed clearly. | **Lönnberg** |
| *White-box testing (Clear box testing, Glass box testing)* | Testing based on an analysis of the internal structure of the component or system. | **ISTQB Glossary** |

# 3   References

| | |
|---|---|
| **VIM** | International vocabulary of metrology – Basic and general concepts and associated terms (VIM), 3rd edition, JCGM 2012 |
| **ISO 10360-1** | Geometrical Product Specifications (GPS) – Acceptance and reverification tests for coordinate measuring machines (CMM) – Part 1: Vocabulary |
| **ISO 17450-1** | Geometrical product specifications (GPS) – General concepts – Part 1: Model for geometrical specification and verification |
| **ISO 90003** | Software engineering – Guidelines for the application of ISO 9001:2000 to computer software |
| **ISO 14660-1** | Geometrical Product Specifications (GPS) – Geometrical features – Part 1: General terms and definitions |
| **IEEE** | IEEE Standard Computer Dictionary: A Compilation of IEEE Standard Computer Glossaries. New York: IEEE |
| **GPG 16** | R.M. Barker, P.M. Harris and L. Wright: Software Support for Metrology – Good Practice Guide No. 16: Testing Algorithms and Software. NPL report, December 2005. |
| **GPG 42** | D. Flack: CMM Verification - Measurement Good Practice Guide No. 42, NPL, 2011. |
| **ISTQB Syllabus** | Certified Tester Foundation Level Syllabus, ISTQB http://www.istqb.org/downloads/viewdownload/16/15.html |
| **ISTQB Glossary** | E. van Veenendaal: Standard glossary of terms used in Software Testing, ISTQB http://www.istqb.org/downloads/viewdownload/20/101.html |
| **Bradley** | M. Bradley: Introduction to Client Server Networks, http://compnetworking.about.com/od/basicnetworkingfaqs/a/client-server.htm |
| **Beizer** | B. Bezier: Software Testing Techniques (Second ed.), New York: Van Nostrand Reinhold. pp. 21, 1990 |
| **Binder** | R.V. Binder: Testing Object-Oriented Systems: Objects, Patterns, and Tools. Addison-Wesley Professional. p. 45., 1999 |
| **Cem Kaner** | J.D. Cem Kaner, Exploratory Testing, Keynote at QAI, 2006 |
| **Lönnberg** | J. Lönnberg: Visual testing of software, Helsinki University of Technology, 2003 |
| **Mayers** | G.J. Myers, The Art of Software Testing, John Wiley and Sons, New York, New York, 1979. |
| **TraCIM** | NEW06 TraCIM – Traceability for computationally-intensive metrology, Annex Ia (the JRP protocol), NPL, 2012. |