The impact of the

"Guide to the Expression of Uncertainty in Measurement"

across Metrology

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7th November 2013

"The GUM: Past, Present and Future"

The objectives of metrology

Measurements that are stable

- Long-term trends can be used for decision making

Measurements that are comparable

- Results from different laboratories can be brought together

Measurements that are coherent

- Results form different different methods can be brought together

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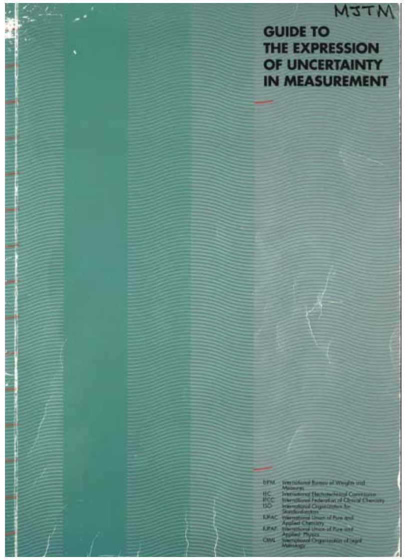
These are achieved through providing the infrastructure to support traceable measurement results (with uncertainties).

The objectives of metrology

Metrological traceability

The SI brochure (8th edition, 2006)

The objectives of metrology



Metrological traceability

The SI brochure (8th edition, 2006)

Measurement uncertainty

The GUM (1st edition, 1993)

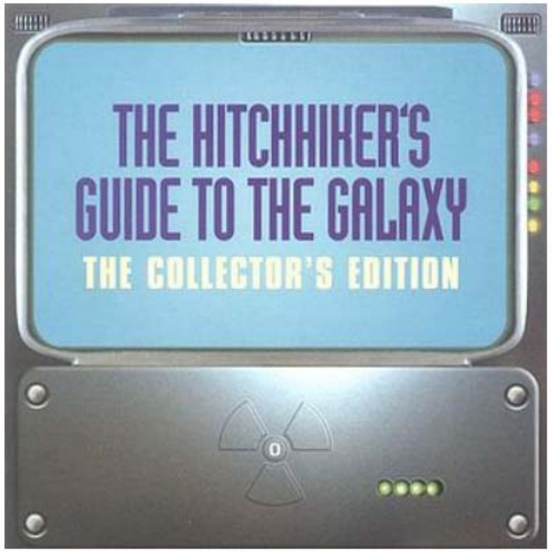
The objectives of metrology

- The SI – agreed by the CIPM and the CGPM
- The GUM – agreed by the JCGM

"to develop and maintain, at the international level, guidance documents addressing the general metrological needs of science and technology, and to consider arrangements for their dissemination"

From the JCGM Charter (December 2009)

The GUM



Note:- Only an artist's impression, no true image of the Hitchhiker's Guide exists.

The GUM

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Summary of the "GUM" procedure

5.1.1 The standard uncertainty of y, where y is the estimate of the measurand Y and thus the result of the measurement, is obtained by appropriately combining the standard uncertainties of the input estimates $x_1, x_2, \ldots, x_N$ (see 4.1).

This *combined standard uncertainty* of the estimate y is denoted by $u_c(y)$.

5.1.2 The combined standard uncertainty $u_c(y)$ is the positive square root of the combined variance $u_c^2(y)$, which is given by

$$u_c(y)^2 = \sum_{i=1}^{n} \left[\frac{\partial f}{\partial x_i}\right]^2 u_c(x_i)^2$$

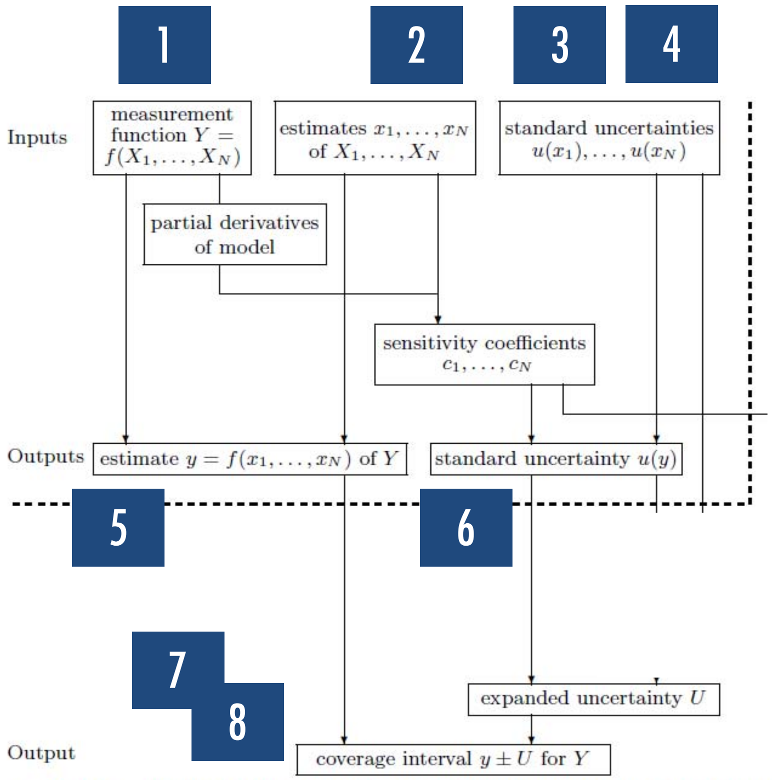
the law of propagation of uncertainty

where f is the function given in Equation (1).

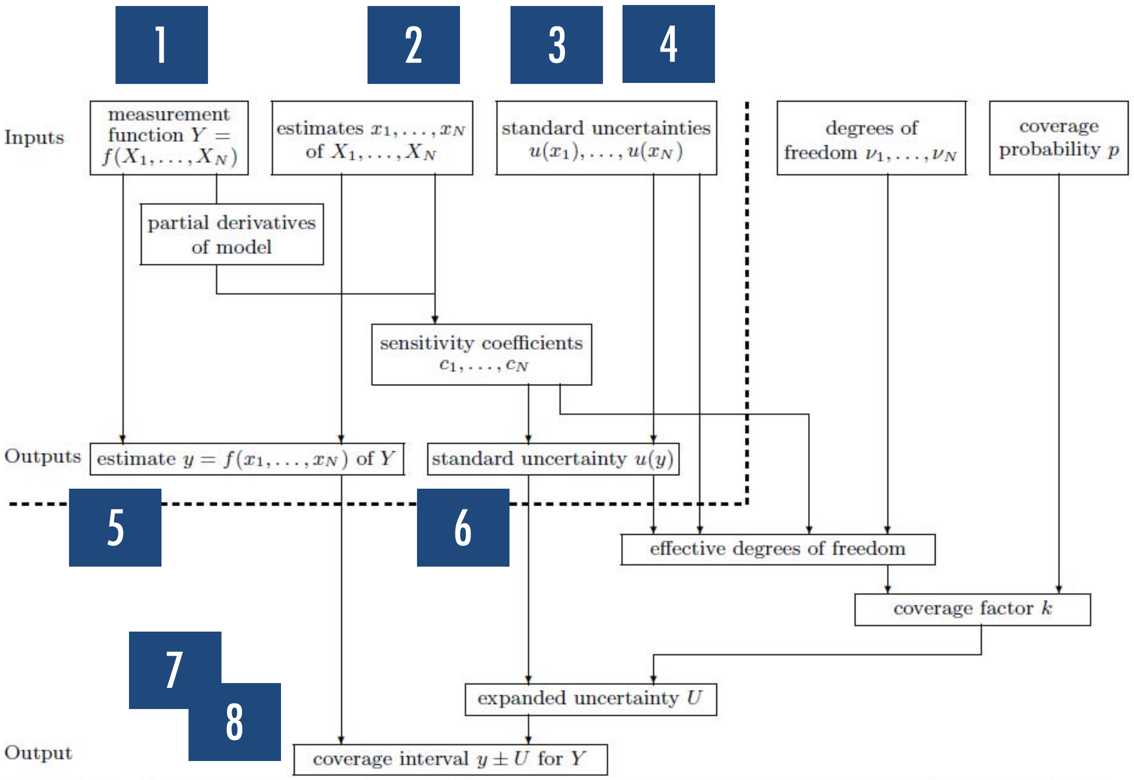
Each $u(x_i)$ is a standard uncertainty evaluated as described in 4.2 (Type A evaluation) or as in 4.3 (Type B evaluation).

The combined standard uncertainty $u_c(y)$ is an estimated standard deviation and characterizes the dispersion of the values that could reasonably be attributed to the measurand Y (see 2.2.3).

Summary of the "GUM" procedure



Summary of the "GUM" procedure



Summary of the “GUM” procedure

B.2.21
random error
result of a measurement minus the mean that would result from an infinite number of measurements of the same measurand carried out under repeatability conditions

NOTE 1 Random error is equal to error minus systematic error.

NOTE 2 Because only a finite number of measurements can be made, it is possible to determine only an estimate of random error.

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[VIM:1993, definition 3.13]

Guide Comment: See the *Guide* Comment to B.2.22.

B.2.22
systematic error
mean that would result from an infinite number of measurements of the same measurand carried out under repeatability conditions minus a true value of the measurand

NOTE 1 Systematic error is equal to error minus random error.

NOTE 2 Like true value, systematic error and its causes cannot be completely known.

NOTE 3 For a measuring instrument, see “bias” (VIM:1993, definition 5.25).

[VIM:1993, definition 3.14]

Guide Comment: The error of the result of a measurement (see B.2.19) may often be considered as arising from a number of random and systematic effects that contribute individual components of error to the error of the result. Also see the *Guide* Comment to B.2.19 and to B.2.3.

Summary of the "GUM" procedure

E.3.6 There are three distinct advantages to adopting an interpretation of probability based on degree of belief, the standard deviation (standard uncertainty), and the law of propagation of uncertainty [Equation (E.3)] as the basis for evaluating and expressing uncertainty in measurement, as has been done in this *Guide*:

a) the law of propagation of uncertainty allows the combined standard uncertainty of one result to be readily incorporated in the evaluation of the combined standard uncertainty of another result in which the first is used;

b) the combined standard uncertainty can serve as the basis for calculating intervals that correspond in a realistic way to their required levels of confidence; and

c) it is unnecessary to classify components as "random" or "systematic" (or in any other manner) when evaluating uncertainty because all components of uncertainty are treated in the same way.

Benefit c) is highly advantageous because such categorization is frequently a source of confusion; an uncertainty component is not either "random" or "systematic". Its nature is conditioned by the use made of the corresponding quantity, or more formally, by the context in which the quantity appears in the mathematical model that describes the measurement. Thus, when its corresponding quantity is used in a different context, a "random" component may become a "systematic" component, and vice versa.

Impact on the CIPM-MRA

Reconnaissance mutuelle
des étalons nationaux de mesure
et des certificats d'étalonnage et de mesurage
émis par les laboratoires nationaux de métrologie

Paris, le 14 octobre 1999

Supplément technique révisé en octobre 2003 (pages 17-20)

Mutual recognition
of national measurement standards
and of calibration and measurement certificates
issued by national metrology institutes

Paris, 14 October 1999

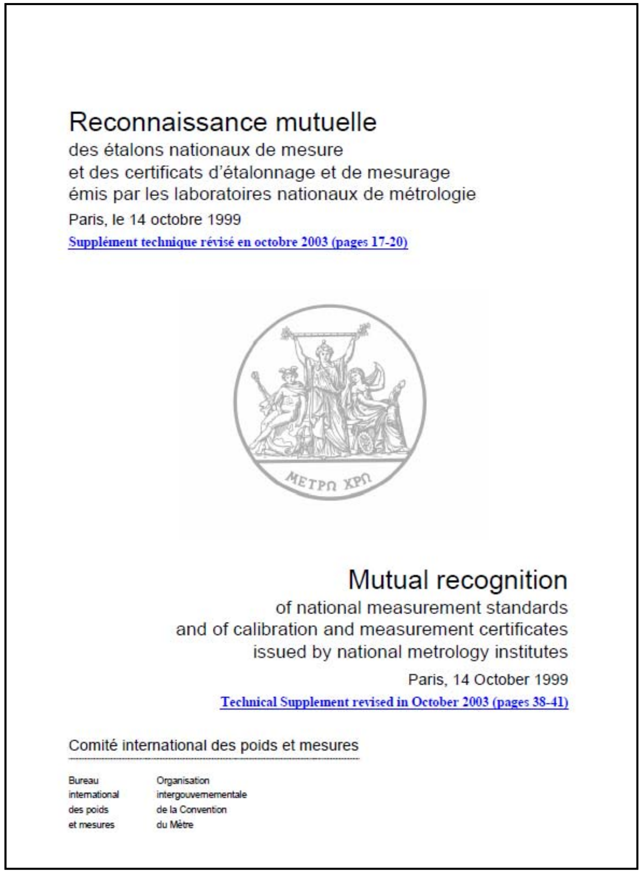
Technical Supplement revised in October 2003 (pages 38-41)

Comité international des poids et mesures

Bureau international des poids et mesures

Organisation intergouvernementale de la Convention du Mètre

Impact on the CIPM-MRA



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"For each key comparison the following are included:

- individual values for each institute together with their declared uncertainties;
- the key comparison reference value with its associated uncertainty;
- for each institute, the deviation from the key comparison reference value and the uncertainty in that deviation (at a 95 % level of confidence), i.e. its degree of equivalence; the degrees of equivalence."

Impact on the CIPM-MRA

- individual values

$$x_i\ , u(x_i)$$

- the KCRV

$$KCRV\ , u(KCRV)$$

- the DoEs

$$d_i\ , u(d_i)$$

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  $$KCRV \, , u(KCRV)$$

- the DoEs

  $$d_i \, , u(d_i)$$

But, why do we need the KCRV and the DoEs (with their uncertainties)?

1. As a way to display the results?
2. As a way to summarize the results?
3. As a way to quantify the level of agreement?
4. As a “best estimate” of the SI value?
5. Or, just because the MRA ask us to?

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The CIPM is initiating a review of the implementation and operation of the MRA.

How does the statistical community want to respond?

The future for the GUM (and the SI)

Significant changes are being planned for the definitions of the base units of the SI, and also for the GUM.

These must be managed very carefully.

- Ensuring that the revised versions are totally correct, validated and represent improvements.
- Providing information (at different levels) to different users.
- Ensuring continuity at the point of change.
- Consulting stakeholders before (and during) the change.

Summary - The objectives of metrology

There will be two new pillars supporting metrology in 2018:

- The "new" SI
- The "new" GUM

They will still be required because they are the basis for:

- Measurements that are stable
- Measurements that are comparable
- Measurements that are coherent

Thank you for your attention