Revision of the GUM: why and how?

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Why a revision?

Merits of the GUM

- Provides widely accepted guidance on measurement uncertainty
- Treats in a common way systematic and random contributions
- Rests on solid principles of probability and statistics
- It is accused of being difficult (by some) or simplistic (by others), which means that it is a good compromise

- First publication in 1993
- Reprint in 1995 with some corrections
- JCGM 100:2008 (free of charge) GUM 1995 with minor modifications
- Until now, a large number of documents based on the GUM has been written. The GUM has been translated into many languages
- In addition, the GUM has been adopted as a standard, in some cases as a law, in many countries

GUM-translations since 2008 10/06/2011

Translation	GUM	GUM-Intro	GUM-S1	GUM-S2	Language	Laboratory/Organism
✔	☐	☐	✔	☐	Russian	VNIIM
✔	✔	☐	✔	☐	Croatian	DZM
✔	✔	☐	☐	☐	Spanish	CEM
✔	✔	☐	☐	☐	Czech	Czech Office for Standards
✔	☐	✔	☐	☐	German	PTB
✔	☐	☐	✔	☐	Spanish	CEM
✔	☐	☐	✔	☐	German	NATG - DIN
✔	☐	☐	☐	✔	Russian	VNIIM
✔	☐	✔	☐	☐	Russian	VNIIM
✔	✔	☐	☐	☐	Serbian	DCDM
✔	☐	✔	☐	☐	Spanish	CEM

Courtesy BIPM

CEN On-line catalogue

ICS: 17.020 - Metrology and measurement in general

Reference number: ENV 13005:1999

Title: Guide to the expression of uncertainty in measurement

Country	National Organization	National Document Reference
Austria	ASI	OENORM ENV 13005
Belgium	NBN	NBN ENV 13005
Bulgaria	BDS	BDS ENV 13005:2008
Croatia	HZN	HRS ENV 13005:2008
Cyprus	CYS	CYS ENV 13005:1999
Czech Republic	UNMZ	CSN P ENV 13005
Denmark	DS	DS/ENV 13005
Former Yugoslav Republic of Macedonia	ISRM	ĐœĐšĐ¢Đ¡ ENV 13005:2012
France	AFNOR	NF ENV 13005
Germany	DIN	DIN V ENV 13005
Greece	ELOT	ELOT ENV 13005
Iceland	IST	FS ENV 13005:1999
Italy	UNI	UNI CEI ENV 13005
Latvia	LVS	LVS ENV 13005:2007 L
Lithuania	LST	LST L ENV 13005:2001
Luxembourg	ILNAS	SEE-ENV 13005:1999
Malta	MCCAA	MSA ENV 13005:2000
Netherlands	NEN	NVN-ENV 13005
Portugal	IPQ	ENV 13005
Romania	ASRO	SR ENV 13005:2003
Slovakia	SUTN	STN P ENV 13005
Slovenia	SIST	SIST ENV 13005:2004
Switzerland	SNV	SN-ENV 13005-1999
Albania	DPS	S H ENV 13005:1999
Bosnia and Herzegovina	BAS	BAS ENV 13005:2010
Tunisia	INNORPI	NT 110.138(2001)

http://www.cen.eu/cen/pages/default.aspx

On these grounds, a revision of the GUM needs careful consideration and strong motivation

Drawbacks of the GUM

It **is** a compromise

It is difficult

It is simplistic

The GUM is difficult

- Its **application** requires notions of
  - Calculus (partial derivatives)
  - Probability (densities and their moments, mean and variance)
  - Statistics (sample statistics, average and standard deviation)

- Its **understanding** requires solid background in
  - Theory of measurement (concepts such as quantity, error, model)
  - Probability and statistics (random variables, differing views of probability, central limit theorem, convolutions, several distributions)

The GUM is simplistic

- No guidance on the (frequent) case of many measurands
- Poor guidance on the construction of a coverage interval (emphasis is on standard uncertainty), limited to a situation optimistically considered as frequently occurring
- Other (comparatively minor) weak sides, such as poor consideration to
  - non-symmetric distributions
  - non-linear measurement models
- The cases above are difficult, probably they had not been considered in the first edition on purpose

Remedies to difficulty

- NONE. *Things should be made as simple as possible, but not simpler*
- The GUM is and will remain a high-level document, some difficulty is unavoidable
- However, the next GUM will be at a level comparable to that of the current GUM – still based on a first-order expansion or, ultimately, Gauss' law of errors

Are the cases not covered in the GUM of practical importance?

- Any calibration of a set of artefacts, be they weights, capacitors, gauge blocks or similar, is a multivariate case

- The CIPM MRA asks for CMCs at the 95 % coverage probability, i.e, CMCs **are** coverage intervals

- Not a few quantities of practical importance are such that the current practice $U = ku$ (with typically $k = 2$) is inappropriate

There was a real need to address the cases not covered in the current GUM

Remedies to simplism

- Difficult problems typically imply difficult solutions
- Coverage interval (and more): see JCGM 101:2008 (Supplement 1)
- Multivariate case: see JCGM 102:2011 (Supplement 2)

Both problems (multivariate case and coverage interval) and solutions were kept out of the GUM, in the attempt to avoid a deep revision

Side effects of remedies

- The GUM and its Supplements are now inconsistent

Why didn't we write Supplements consistent with the GUM?

The GUM is ambiguous

The definition of uncertainty in the GUM is

> parameter, associated with the result of a measurement, that characterizes the dispersion of the values that could reasonably be attributed to the measurand

This is an intrinsically Bayesian view of uncertainty – uncertainty concerns the measurand

The definition contrasts with the way in which uncertainty is obtained, essentially frequentist – uncertainty concerns the measurand estimate, and is itself uncertain

Supplements are unambiguous

- In Supplement 1, PDFs (probability density functions) are used to describe the state of knowledge about each input quantity

- Accordingly, the state of knowledge about the measurand is described by a PDF obtained from those of the input quantities through the measurement model (in a way that is not relevant here)

- This is an intrinsically Bayesian attitude, and is consistently adopted throughout the Supplements

No alternative was possible!

How to revise the GUM?

- Main purpose: to make it consistent with its Supplements

- Secondary purposes:
  - to make it consistent **as much as possible** with VIM3
  - to broaden its applicability to “new” needs
  - to minimize notational and terminological ambiguities

Alignment with Supplements

- Uncertainties (and estimates) are:
  - estimates of moments of frequency distributions, in the current GUM (they have degrees of freedom)
  - exact moments of state-of-knowledge distributions, in the Supplements (no degrees of freedom)
- In the revised GUM, uncertainties (and estimates) will be exact moments of state-of-knowledge distributions, as in the Supplements

Practical impact on standard uncertainty

- With respect to the current GUM, input standard uncertainties obtained from a sample of $n > 3$ repeated indications will be larger by a factor $\sqrt{(n-1)/(n-3)}$

- As a consequence, the output standard uncertainty, *ceteris paribus*, will change, being anyway consistent with the (uncertain) uncertainty provided by the current GUM

- Classification into Type A and Type B evaluations loses its scientific basis – will be kept (de-emphasized) due to non-scientific considerations

- No longer effective degrees of freedom attached to the output uncertainty - Welch-Satterthwaite formula no longer needed

Practical impact on coverage intervals

- In the revised GUM there will be mostly generic guidance on the construction of coverage intervals, this task being given to Supplement 1
- Distribution-free coverage intervals, based on Chebyshev or Gauss inequalities, will be given
- Expanded uncertainty de-emphasized
- Greater consideration to non-symmetric coverage intervals
- Possible impact on KCDB, Appendix C

Cosmetic changes

- Suffix «c» in the combined standard uncertainty u_c dropped (as in JCGM 101, JCGM 102 and JCGM 106)
- New notation u_x allowed as an alternative to $u(x)$
- Introduction of the hatted symbol $\hat{T}$, say, for the estimate of a temperature T (when appropriate)
- Introduction of matrix notation, in parallel with, not in substitution of conventional notation

Further notable features

- Increased guidance on the evaluation of input uncertainties
- Guidance on the evaluation of input covariances
- Clarification of the meaning of loose expressions such as «uncertainty of…» through a dedicated section
- Enhanced examples. Examples concerning the GUM and its Supplements will be collected in a separate document

Thank you for your attention