Tutorial Course on Evaluation of Uncertainty in Measurement, 03-07 December 2007			
Programme by WB + IL + HS + GK 2007-06-26			
Item	**Date/Lecturer**	**Description**	**Notes**
		Introduction to the GUM	
1	03/12 Walter Bich	Guide to the expression of uncertainty in measurement (GUM).	A course on the GUM with heavy tutoring in probability and statistics.
		Concepts of mathematics and statistics	
2	03/12 Walter Bich	Partial derivatives. Integrals. Taylor series expansion. Probability (of an event). Random variable (discrete and continuous). Distributions (univariate and multivariate) and their properties (moments, mixed moments, covariances etc.). Histograms.	
		Derivation of the LPU	
3	03/12 Walter Bich	The indirect measurement. Model of measurement. Measurement outcomes as random variables. Derivation of the law of propagation of uncertainties. Limits of validity.	To demonstrate the classical law of propagation of uncertainties (LPU).
4	03/12 Walter Bich	An historical overview on random and systematic errors. Difficulties involved in that approach. Probability as "degree of belief". Bayesian approach and its advantages. Everything is "random". Pdfs and information. Variance as a measure of uncertainty.	To show the reasons for the adoption of the LPU for systematic as well as for random effects.
		A deeper sight onto LPU. Application of LPU to uncorrelated variables	
5	03/12 Walter Bich	Common models and derivatives. Linear and non-linear models. Sensitivity coefficients. Second-order contributions.	Description of some misunderstandings concerning the present GUM. Fitting a second order polynomial is not a non linear problem.
6	03/12 Walter Bich	Asymmetric distributions. Cosine error, titration etc.	
7	03/12 Walter Bich	Relative uncertainties: advantages and a warning.	
8	03/12 Walter Bich	Evaluation of parameters from a sample (Type A) and subjective description of the degree of belief in a value (Type B). Experimental variance and standard deviation. Biased and unbiased estimates. Pitfalls.	
9	03/12 Walter Bich	Expanded uncertainty, confidence intervals and intervals of confidence. Reliability of input components and degrees of freedom, statistical and subjective. Student's distribution, convolutions and Central Limit Theorem. Effective degrees of freedom and Welch-Satterthwaite formula.	Description of some misunderstandings concerning the present GUM. Difference between 95% and k=2.

		Bayesian inference applied to metrology	
10	04/12 Ignacio Lira	Measurement model relating input quantities –about which information is available- to one or more output quantities -about which information is required.	Presents a common framework for treating available information about input and output quantities.
11	04/12 Ignacio Lira	Modeling of measurement knowledge about a quantity in terms of a probability distribution. The Principle of Maximum (Information) Entropy.	In which cases should several probability distributions be used?
12	04/12 Ignacio Lira	Use of new information to update an input probability density function: Bayes' theorem.	An explanation of this fundamental theorem of Bayesian statistics.
13	05/12 Ignacio Lira	Determination of the distribution for an output quantity (or the joint distribution for more than one output quantity) using the propagation of distributions.	Several applications of Bayes´ theorem are discussed as examples of Bayesian statistics. Among them: evaluation of type A uncertainty, uncertainty due to resolution, interlaboratory comparisons.
		Introduction to Supplement 1	
16	06/12 Walter Bich	Difficulties of the GUM approach to an interval of confidence. Coverage intervals. Frequentist approach vs Bayesian approach. Internal inconsistencies in the GUM. The way out. Supplement 1 (outline). The case of prior knowledge on the measurand. Markov Chain Monte Carlo.	To show the difficulties inherent in the GUM treatment of intervals of confidence and the solution proposed by Supplement 1 (this can largely be taken from the Varenna lecture, or some similar paper – see my presentation at the IMEKO World congress last year).
		GUM Supplement 1; examples with the Monte Carlo Method	
17	06/12 Helio Schechter	Concepts. Assignment of probability density functions to the values of the input quantities. The propagation of distributions.	
18	06-07/12 Helio Schechter	Calculation using Monte Carlo simulation. The number of Monte Carlo trials. Sampling from probability distributions. Evaluation of the model. Distribution function for the output quantity value. Estimate and standard uncertainty. Coverage interval. Reporting results. Computation time. Adaptive Monte Carlo procedure.	
19	07/12 Helio Schechter	Validation of the LPU using Monte Carlo simulation. Examples. Simple additive model. Mass calibration. Comparison loss in microwave power meter calibration.	
		The case of correlated variables (as an introduction to Supplement 2)	
20	07/12 Walter Bich	A reminder of the general LPU. A better sight at covariances appearing in LPU. Correlation coefficient. Matrix notation. LPU in matrix notation. Jacobian matrix. Matrices of variance-covariance and correlation. The uncertainty matrix.	To make the audience aware of hidden correlations and to enable to identify and evaluate them.

21	07/12 Walter Bich	The impact of covariances in uncertainty evaluation: over- and underestimates. Cases of total correlation, positive and negative. Examples.	
22	07/12 Walter Bich	How to evaluate covariances and correlations. Correlation between quantities, which can be modelled analytically. A classical example from calibrations by comparison.	
		Round table on the evolution of the GUM	
23	07/12 Walter Bich Ignacio Lira Hélio Schechter Gregory Kyriazis	Discussions about the present and future of the GUM. The new edition of the VIM. Measurement as inference. The role of information. The increased use of numerical methods.	This time can also be used for answering specific questions of the attendees.