**DIP. DI INGEGNERIA INDUSTRIALE**
DAST (Doctorate in Aerospace Science and Technology)

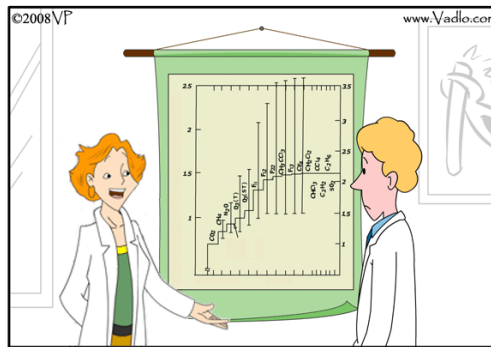# Uncertainty analysis for engineers

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18, 20, 21 November, 2 December

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*Did you really have to show the error bars?*

*(picture from: http://paul-baxter.blogspot.it/2010/06/error-bars-are-necessary-part-of.html)*

Day 1 – November 18th 11 a.m. – 1 p.m. AULA 1.4
**Virtual Room**

*Experimentation, Error and Uncertainty*
- Introduction (degree of goodness, uncertainty analysis)
- The experimental approach (questions and phases)
- Basic concepts and definitions (error and uncertainties, uncertainty intervals)
- Uncertainty of a measured variable: systematic (bias) error, random (precision) error, overall uncertainty
- Brief introduction to Data Reduction Equation (DRE) and sources of uncertainties
- Probability theory and statistics basics
- Definition of mean and variance of a sample population

Day 1 – November 18th 3-5 p.m. AULA 1.5
**Virtual Room**

*Errors and Uncertainties in the Measured Variable*
- Gaussian distribution (measurement normalization, confidence intervals)
- Central limit theorem (statement and implications)
- Sample population confidence intervals
- Criteria for outliers' rejection
- Effect of insufficient sampling time in statistically steady measurements
- Examples
- Taylor Series Method for propagation of uncertainties (including correlation terms, sensitivity coefficients of TSM)
- Expanded uncertainty of a result
- Special functional forms in the TSM


Day 2 – November 20th 2-4 p.m. AULA 1.2
**Virtual Room**

*Uncertainty in a Result Determined from Multiple Variables*
- Example with uncertainty which is a function of a variable
- Experiment planning (examples, comparison of two measurement techniques)
- Practical examples
- Repetition and replication (Moffat's analysis of a timewise experiment)
- Comprehensive example


Day 3 – November 21st 8.30-10.30 a.m. AULA 1.2
**Virtual Room**

*General and Detailed Uncertainty Analysis*
- Random uncertainty (Direct vs TSM estimation)
- Systematic uncertainty (list of error sources, correlated systematic error estimation)
- Exercises on combined uncertainties
- Monte-Carlo methods with examples
- Examples of MCM
- Assignment

Day 4 – December 2nd 10-12 a.m. ON-LINE
**Virtual Room**

*Validation of Simulations*
- Accuracy of derivatives
- Verification (algorithm) & Validation (real world comparison)
- Validation uncertainty (estimation and examples)
- Time-series uncertainty (batch methods, BMBC, maybe ARM, stationarity)


Day 4 – December 2nd 2-4 p.m. ON-LINE
**Virtual Room**

*Data Analysis, Regression and Reporting of Results*
- Regression model uncertainty
- Least square methods
- Uncertainties in the regression model: First model regression (conceptual - equation)
- Calibration errors


*Text book: Hugh W. Coleman and W. Glenn Steele, "Experimentation, Validation, and Uncertainty analysis for engineers", fourth edition, John Wiley & Sons, inc.*