War-Winning Capabilities … On Time, On Cost

Measurement Uncertainty and Why It Is Important to T&E

Sept 2012

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Overview

- Introduction
- Background
- Uncertainty Analysis
- Systematic Error
- Random Error
- Conclusion

Introduction

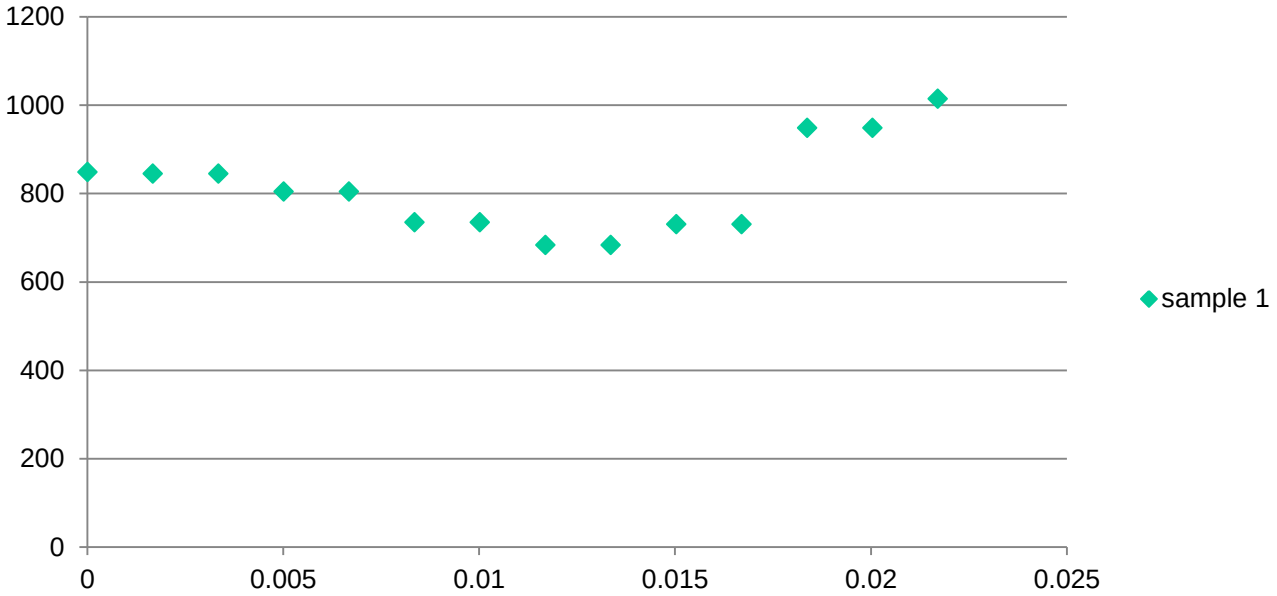
- A measurement result without a statement of uncertainty lacks credibility
  - A measurement is an approximation to the true value
  - Measurement uncertainty identifies variability of the measurement
  - Uncertainty is linked to the reliability of a measurement

Background

- Fundamental instrumentation challenges
- Instrumentation intrusion effects
- Environmental effects
  - Temperature
  - Humidity
  - Shock and vibration
  - Electromagnetic interference

Uncertainty Analysis

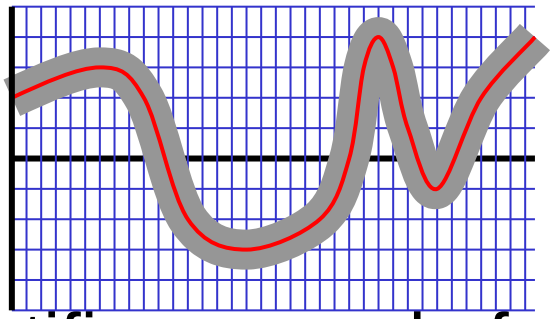
- A measurement is an approximation of the true value
- The true value is never known or knowable



Plot of 14 measurements of the same parameter over a .025 second interval

Uncertainty Analysis

- Every measurement is accompanied by a measurement error
- Types of errors
  - Random
  - Systematic



- Measurement uncertainty quantifies spread of error distribution
- Total measurement uncertainty is the combination of uncertainties due to systematic and random errors

Uncertainty Analysis

- Requirements for measurement uncertainty analysis
  - Objectives identified, test process defined
  - Measurement system and process controlled
  - Calibration corrections applied
  - Data reduction process defined
  - Data acquisition system characterized

Systematic Error

- Systematic error "… is the portion of the total measurement error that remains constant in repeated measurements of the true value." (Reference ASME PTC19.1-1998)
- Total systematic error is the sum of the elemental systematic errors
- Elemental systematic errors can be calibrated out if known, ignored if negligible, or estimated if unknown

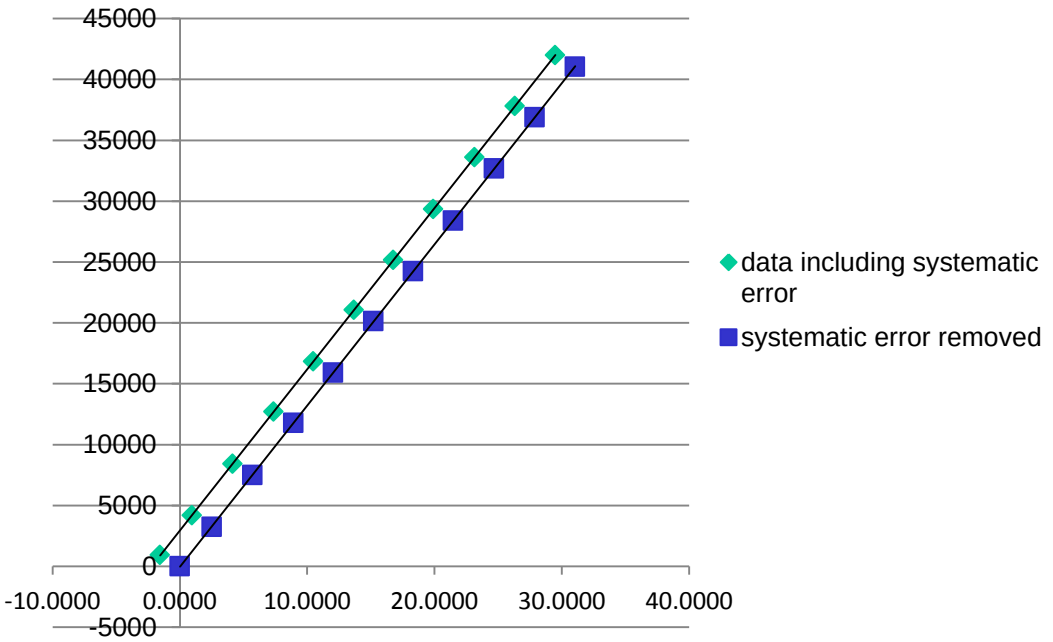
Example Systematic Error

- All data acquisition systems are prone to systematic errors
- Zero load systematic errors detected during calibration of a Data Acquisition System

	System	Load Cell	Strain Gauge
	Load	**Compression Force**	**Brake Torque**
	(Lbs)	**(lbs.)**	**(mV)**
run 1	0	248.1	0.764
run 2	0	248.9	0.782
run 3	0	249.8	0.782

Example Systematic Error

- Systematic error due to affects of instrument zero load offsets
- Approx 2.3K ft-lbs (5.5% FS)
- Plots of uncorrected data and data adjusted to remove systematic error

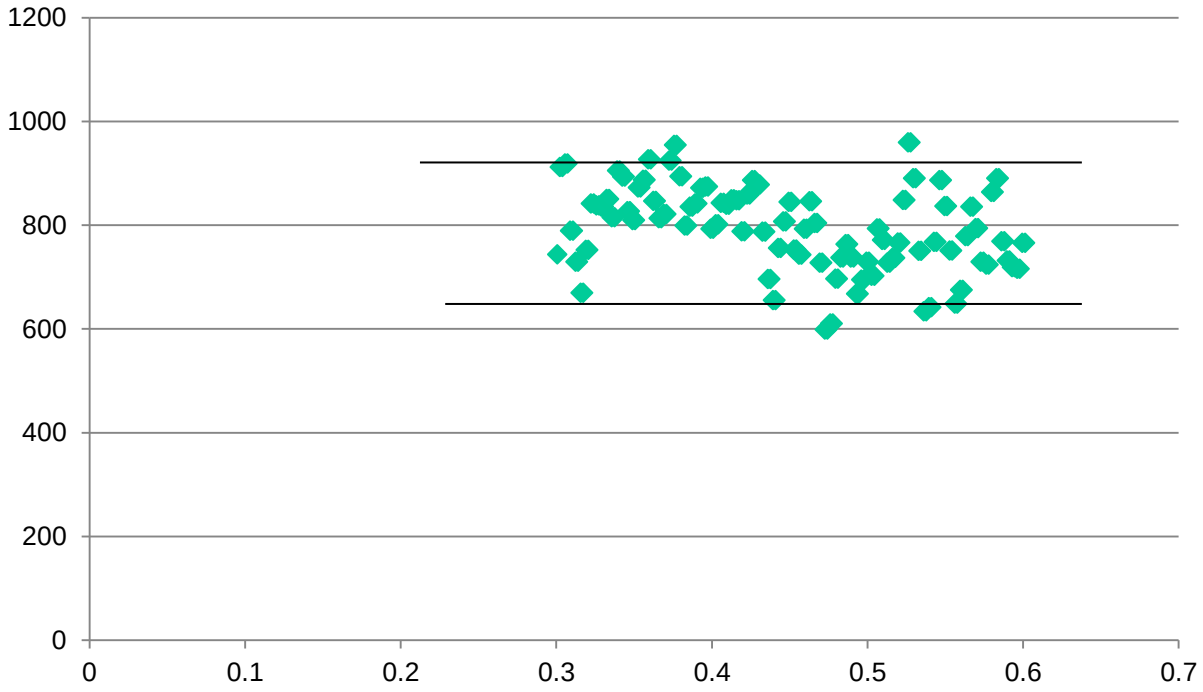


Random Error

- “ Random error,…, is the portion of the total measurement error that varies in repeated measurements of the true value.” (ASME PTC19.1-1998)
- This type of error cannot be corrected
- Uncertainty due to random error is computed from the standard deviation

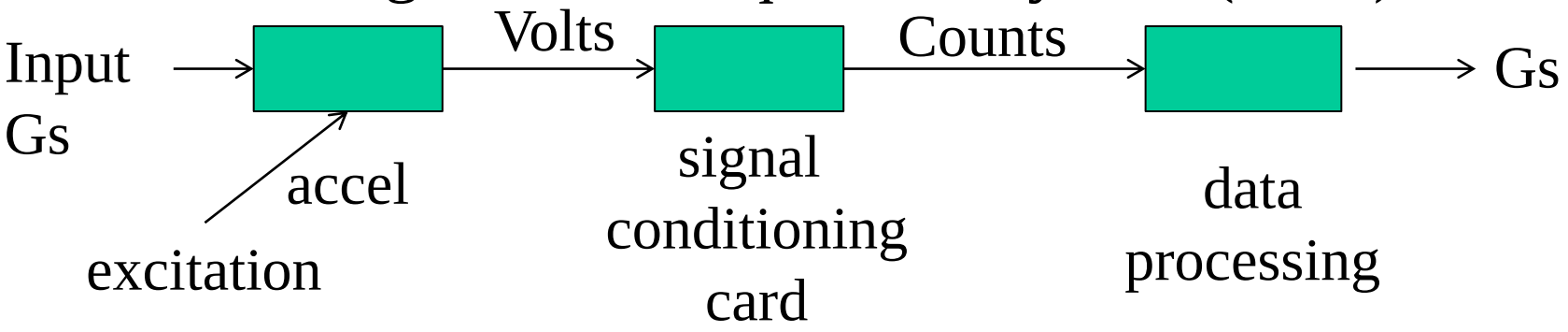
Example Random Error

- **Random error may be estimated by inspection**



Example Sources of Error

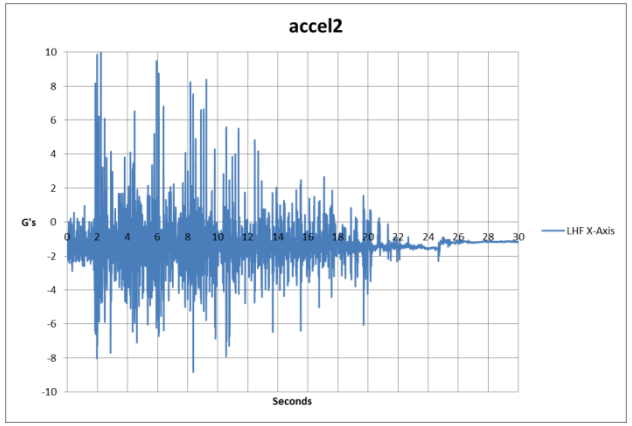
- Block diagram data acquisition system (DAS)

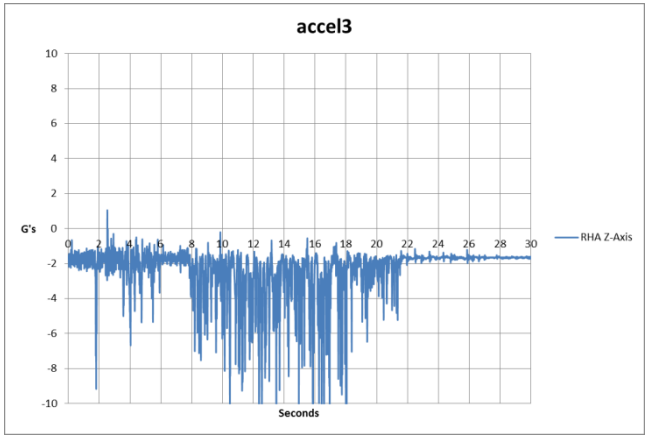


- Accelerometer: excitation voltage, sensitivity, amplitude response, nonlinearity, hysteresis, thermal transient response, zero offset,…
- SCC: accuracy, quantization error, offset error,…
- Data processing: regression error

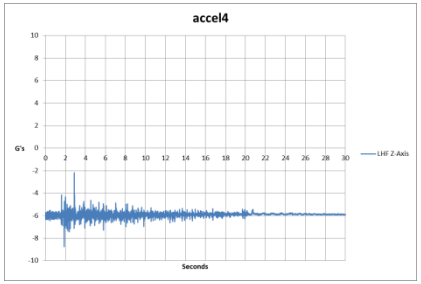
Example Sources of Error

- Data output in engineering units



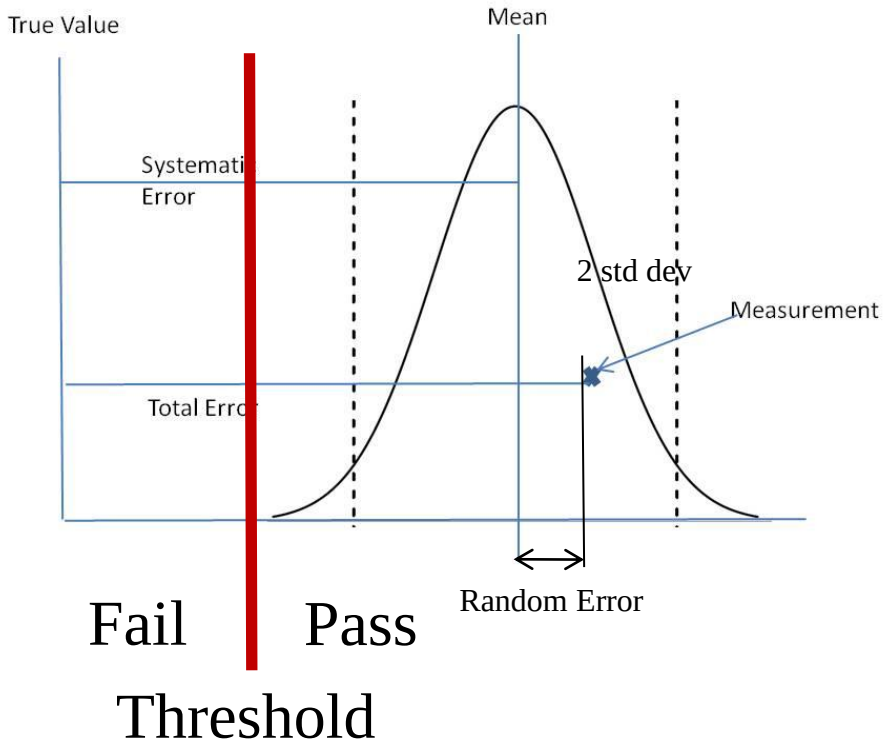


- Sources of error must be considered and added to the error budget from the DAS



Conclusion

- **Impact of combined systematic and random errors can be significant**



Conclusion

- A test result that includes uncertainty information holds more useful information than one without
  - Uncertainty identifies the spread of data from the mean
  - Identifies a confidence level
  - Needed to pass/fail a specification or performance limit
    - Reduce the risk of making a mistake
- References: RCC Document 122-07, ASME PTC 19.1, NIST TN1297 1994 Edition