



Air Force Flight Test Center



AFFTC

War-Winning Capabilities ... On Time, On Cost

Measurement Uncertainty and Why It Is Important to DT&E

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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 of interest**
 - **Uncertainty is linked to the reliability of a measurement**



Background



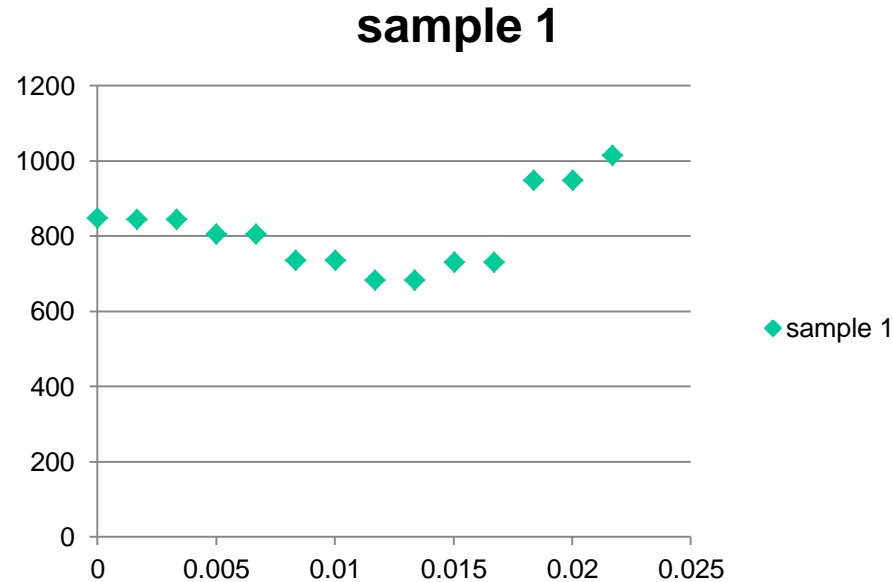
- **Fundamental instrumentation challenges**
- **Instrumentation intrusion effects**
- **Environmental effects**
 - Temperature
 - Humidity
 - Altitude
 - Shock and vibration
 - Electromagnetic interference
 - Data acquisition system maintenance
- **Measurement uncertainty analysis**
 - Does it guarantee data quality and integrity?



Uncertainty Analysis



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



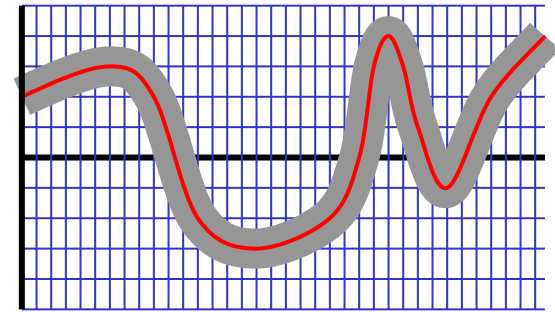
Plot of 14 measurements of the same parameter over a .025 second interval – actual test data



Uncertainty Analysis



- **Every measurement is accompanied by a measurement error**
- **Types of errors**
 - Random
 - Systematic
- **Measurement uncertainty quantifies spread of error distribution**
 - Represents a band about the measurement mean





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)
- **All data acquisition systems are prone to systematic errors**
- **Example systematic error due to affects of instrument zero offsets and installation**

	Load Cell	Strain Gauge
	Torque Force	Brake Torque mV
	(lbs.)	(Primary)
run 1	248.1	0.764
run 2	248.9	0.782
run 3	249.8	0.782

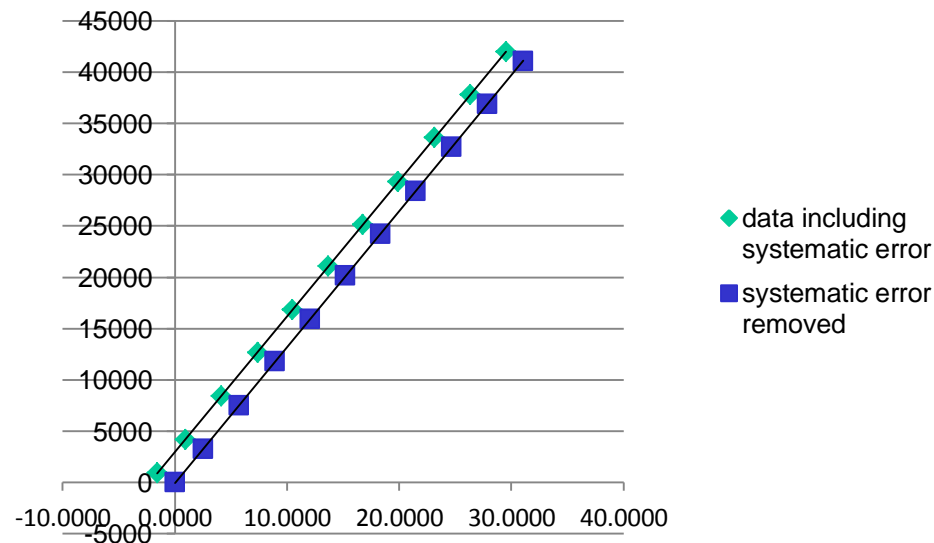
Table 1. Zero load systematic errors detected during calibration of a Data Acquisition System



Systematic Error



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

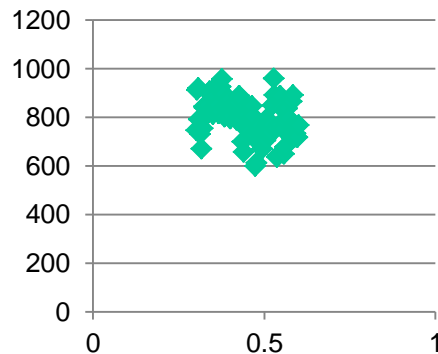




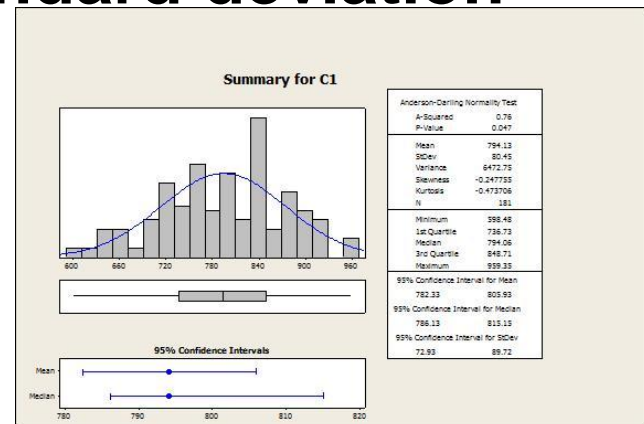
Random Error



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



◆ sample 2

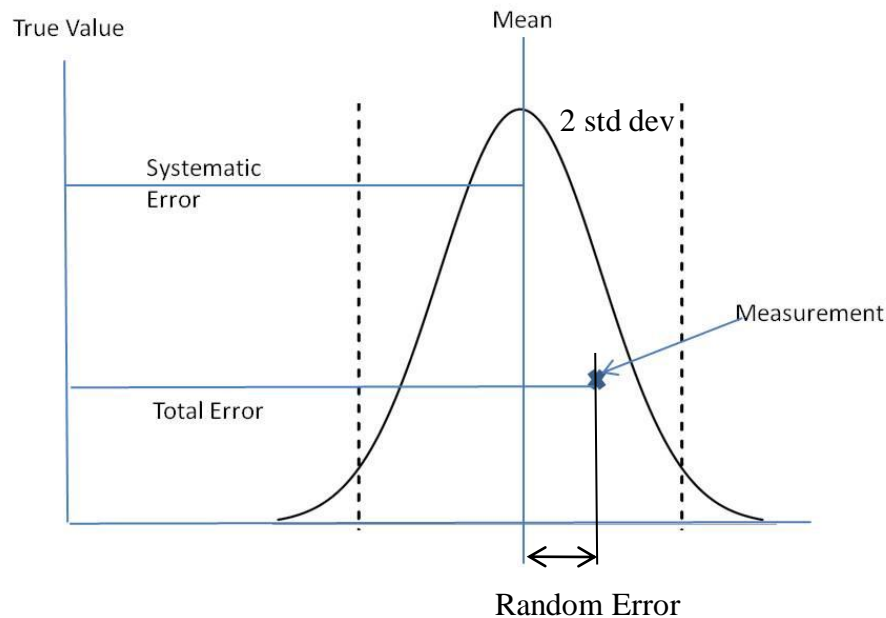




Conclusion



- **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 19.1-1998, NIST TN1297 1994 Edition**