Metrological Traceability and a Game of JeoParody

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California Air Resource Board

Monitoring and Laboratory Division

Standards Laboratory

PQAO Training 2019

Agenda

Definitions

7 Steps of Traceability

Q&A

JeoParody

Metrological Traceability

- Property of a **measurement result** whereby the result can be related to a reference through a **documented** unbroken chain of **calibrations**, each contributing to the **measurement uncertainty** (International Vocabulary of Metrology).

Metrological Traceability Chain

- A metrological traceability chain is defined through a calibration hierarchy (International Vocabulary of Metrology).

Calibration

- Operation that, under specified conditions, in a first step, establishes a relation between the quantity values with measurement uncertainties provided by measurement standards and corresponding indications with associated measurement uncertainties and, in a second step, uses this information to establish a relation for obtaining a measurement result from an indication (International Vocabulary of Metrology).

- Paraphrase:
  - Comparison with measurement standards to produce measurement results ± uncertainty.
  - This is NOT an adjustment!!!

Measurement Uncertainty

- Non-negative parameter characterizing the **dispersion** of the **quantity values** being attributed to a **measurand**, based on the information used (International Vocabulary of Metrology).

- Paraphrase:
  - Value that characterizes measurement variation (dispersion).
  - Linked to the measurement result (quantity value attributed).
  - Refers to quantity being measured (measurand).

Measurand

- Quantity intended to be measured (International Vocabulary of Metrology).

Agenda

Definitions

7 Steps of Traceability
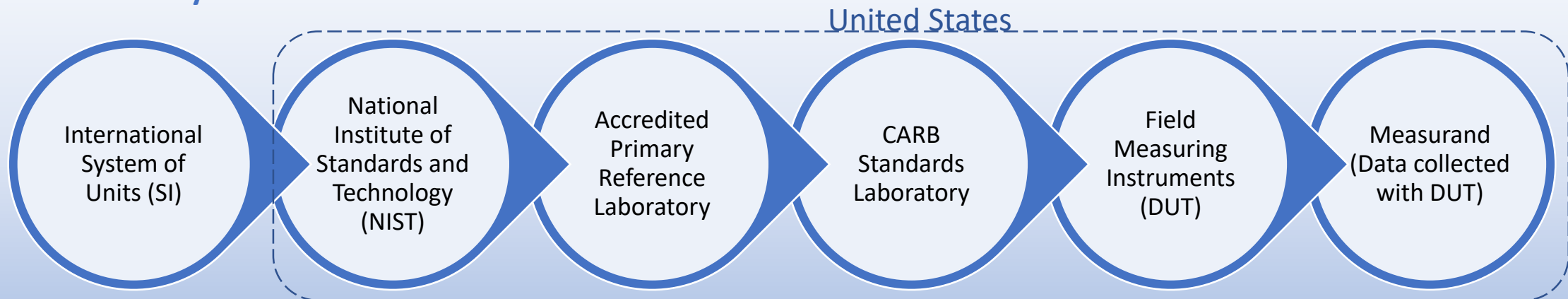
Q&A

JeoParody

Metrological Traceability
Applying the 7 Essential Elements to the Chain of Traceability

CALIFORNIA
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Essential Elements of Traceability

1. SI Units
2. Unbroken Chain of Calibrations
3. Calibration Program
4. Uncertainties
5. Measurement Procedures
6. Technical Competency
7. Measurement Assurance

Traceability Chain

United States

International System of Units (SI) → National Institute of Standards and Technology (NIST) → Accredited Primary Reference Laboratory → CARB Standards Laboratory → Field Measuring Instruments (DUT) → Measurand (Data collected with DUT)

1. SI Units

- SI = International System of Units (from the French *Le Systeme International d'Unites*).

- Modern metric system of measurement used throughout the world.

- Rules and style conventions for printing and using units.

- 7 base units.
  - Kilogram, Meter, Seconds, Ampere, Kelvin, Mole, and Candela

- Standards Laboratory.
  - ppb – nmole/mole; sccm – mL/min; slm – L/min

2. Unbroken Chain of Calibrations

- Hierarchy (Traceability).
- Compare Known vs. Unknown.
- Measurement Process.
  - Measurement Standards.
    - Primary, Secondary, Working
  - Documented Standards.
    - ISO/IEC 17025:2017, NIST Handbook 44

Accredited Primary Reference Laboratory

Measurement Process

CARB Standards Laboratory
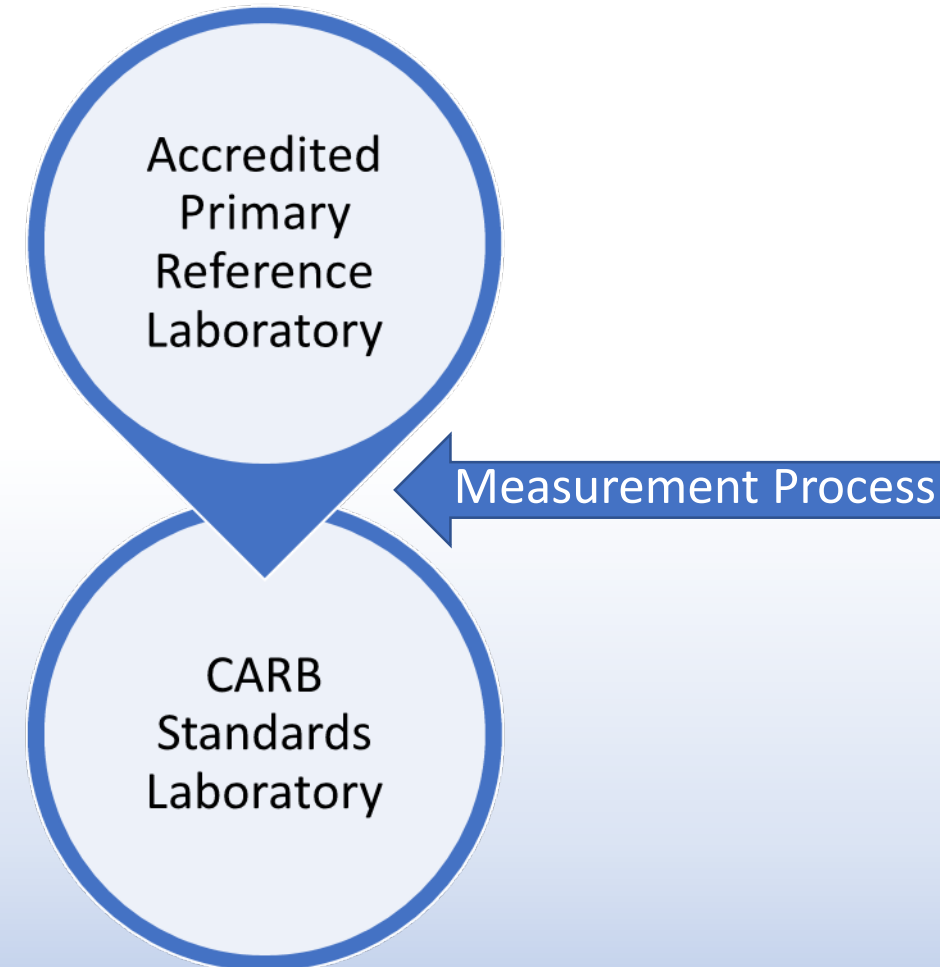
3. Calibration Program

- Supplier Evaluations: Accredited Labs.
  - website: https://ilac.org/signatory-search/
- Calibration and Measurement Capability (CMC).
  - Measurement Parameter (measurand); Range; Uncertainty; Methodology

4. Uncertainty

- Value assigned to "doubt" about the validity of an assigned calibration value.

- Statistics involved in calculating uncertainty.
  - Standard Uncertainty (U_s) expressed as a standard deviation

- 2 methods of uncertainty evaluation.
  - Type A – statistical evaluation and Type B – any other than statistical

- 8 step uncertainty process.
  - 3 types of uncertainty.
    - Standard Uncertainty = U_s
    - Combined Standard Uncertainty = U_c
    - Expanded Uncertainty = U
  - Coverage Factor = *k*.
    - Level of confidence

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5. Measurement Procedures

- Must be Adequate for Intended Use and Followed.

- Verification and Validation.
  - Requirements:
    1. Draft of MP to be evaluated.
    2. Validation procedure and records of results.
    3. Demonstration of competence.
    4. Approval of use.

- Considerations.
  - Accuracy, repeatable, reproducible, proficiency, uncertainties sufficient, traceability of measurement results.

6. Technical Competency

- Proficiency Testing (PT) Plans.

| Participant Performance Statistics		
Normalized Error	**Bias (Difference)**	**Normalized Precision**
$E_n = \left\lvert \dfrac{x_{lab} - \mu_{ref}}{\sqrt{\cup_{lab}^2 - \cup_{ref}^2}} \right\rvert$	$Bias = x_{lab}\text{-}\,x_{ref}$	$P_n = \dfrac{U_{lab}}{\%\ or\ fraction\ of\ tolerance}$

7. Measurement Assurance

- Measurement Assurance is quality control for measurements.
- Ensuring the validity of the results.
- Minimizes the risk of measurement errors.
- Used for the control of measurement performance using check standards in measuring, testing, and calibration processes.

- Measurement Assurance Process:

Control → **Define** → **Measure** → **Analyze** → **Improve** →

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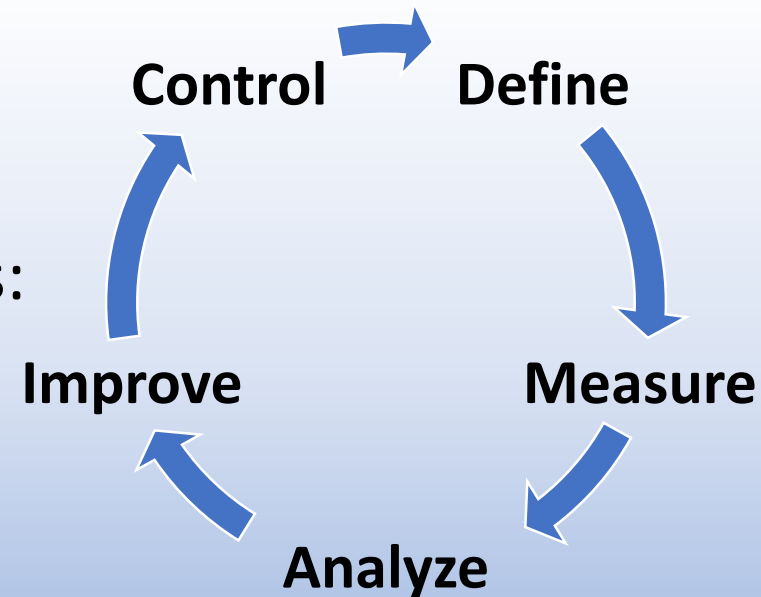
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- Measurement Assurance Process:

Control → **Define**

Improve

Measure

Analyze

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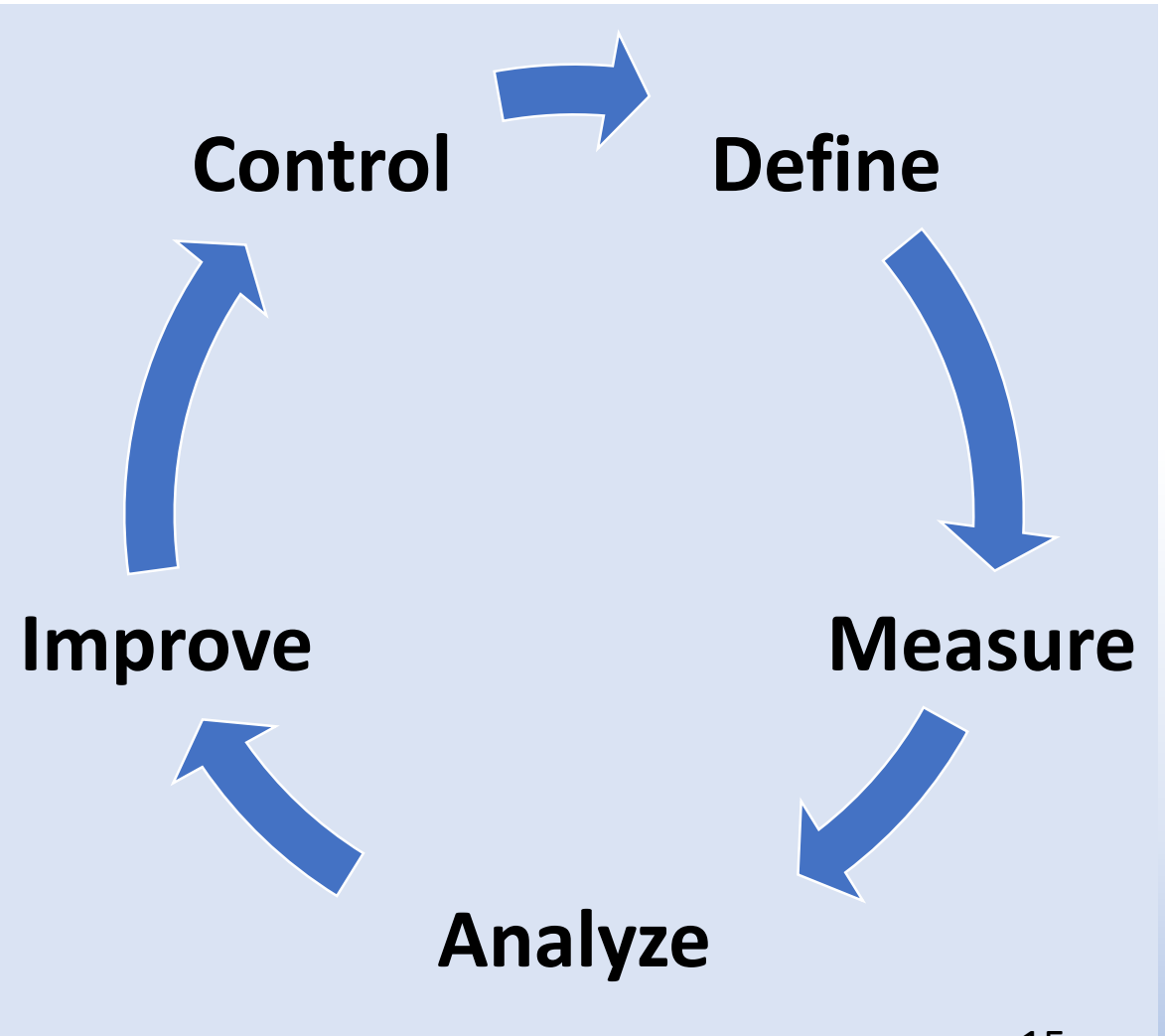
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Questions

Email
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for any follow-up questions.

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The 7 Essential Elements of Traceability: References and Documentation

1. Understanding of the SI **(NIST SP 811)**

2. Unbroken Chain of Calibrations **(NIST GMP 13)**

3. Standard(s) Calibration **(NIST GMP 13 and 11)**

4. Documented Measurement Uncertainties **(NIST SOP 29)**

5. Documented/Validated Procedures **(GMP 12)**

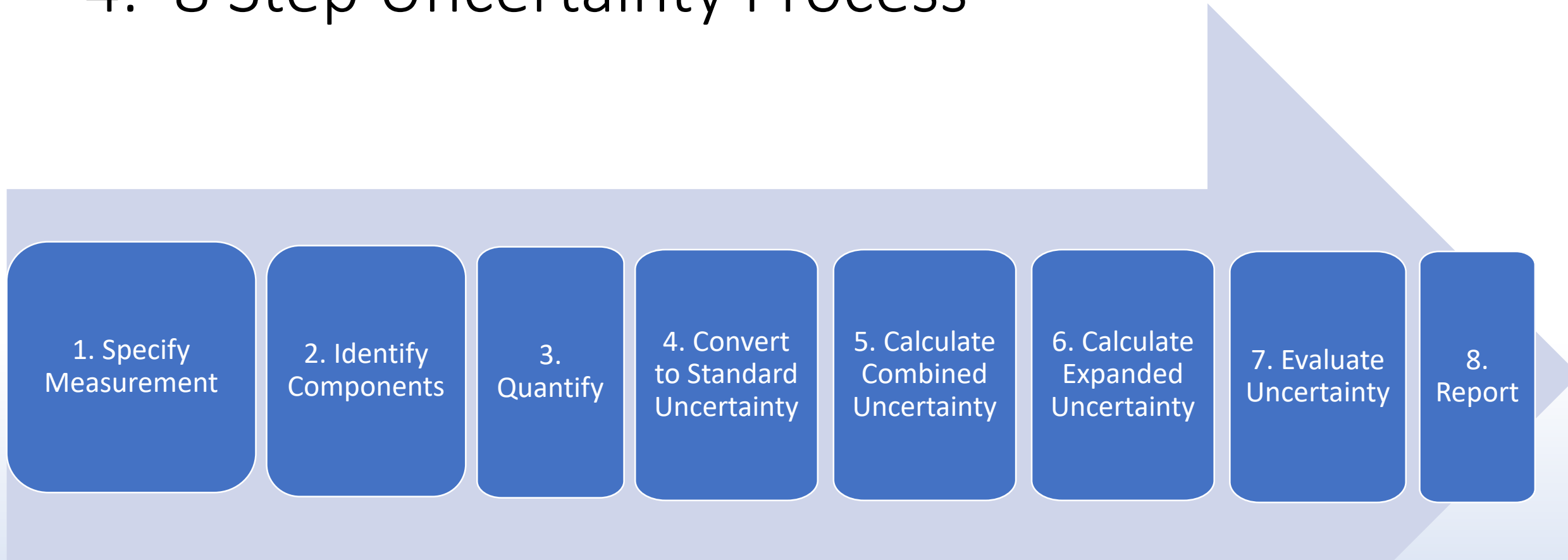6. Technical Competence **(GLP 1)**

7. Measurement Assurance **(GLP 1)**

References

1. International Vocabulary of Metrology – Basic and General Concepts and Associated Terms, VIM, 3rd edition, JCGM 200:2008 (2012 Updates)
   - Available free on BIPM website: www.bipm.org

Side Note

- The ILAC (International Laboratory Accreditation Cooperation) considers the elements for confirming metrological traceability to be an unbroken metrological traceability chain to an international measurement standard or a national measurement standard, a documented measurement uncertainty, a documented measurement procedure, accredited technical competence, metrological traceability to the SI, and calibration intervals.

4. 8 Step Uncertainty Process

| 1. Specify Measurement | 2. Identify Components | 3. Quantify | 4. Convert to Standard Uncertainty | 5. Calculate Combined Uncertainty | 6. Calculate Expanded Uncertainty | 7. Evaluate Uncertainty | 8. Report |

Metrological Traceability
Applying the 7 Essential Elements to the Chain of Traceability

Traceability Chain

International System of Units (SI)

National Institute of Standards and Technology (NIST)

Accredited Primary Reference Laboratory

CARB Standards Laboratory

Measuring Instruments (Candidates/DUT)

Measurand (Data collected with DUT)

Essential Elements of Traceability
1. SI
2. Unbroken Chain
3. Calibration
4. Uncertainties
5. Procedures
6. Competence
7. Measurement Assurance