A. Purpose:

Uncertainty of Measurement is a method of defining and quantifying the magnitude of the parameters associated with a process that may contribute to error, or uncertainty in that process. Since all measurements have a potential for variability; determination of the uncertainty as a process, attempts to allow users of such measurements to understand the reliability and hence suitability of the measured value for the intended use.

The Firearms Unit reports the uncertainty for measurements in cases where there is a “measurement that matters,”~~,~~ specifically for firearm barrel length and overall firearm length.

B. Definitions:

1. <u>Uncertainty of Measurement</u>[4] is a non-negative parameter associated with the result of a measurement that characterizes the dispersion of values that could reasonably be attributed to the measurand.
2. <u>Measurement that Matters</u>: A determined value that is used, or may reasonably be used, by an immediate or extended customer (anyone in the Judicial process) to determine, prosecute, or defend the type or level of criminal charge(s).
3. <u>Type B Evaluation</u> [4]: method of evaluation of uncertainty by means other than the statistical analysis of a series of observations
4. <u>Readability</u>: the smallest increment of the measuring device (i.e. 1/16”)
5. <u>Repeatability</u> : closeness of the agreement between the results of successive measurements of the same item carried out under the same conditions.
6. <u>Linearity</u> : the quality of delivering a significantly identical sensitivity throughout the range of the measuring device.
7. <u>Standard Uncertainty</u> [4] (u_i): a component of uncertainty, represented by an estimated standard deviation equal to the positive square root of the estimated variance.
8. <u>Distribution</u>:
   a. <u>Normal</u> [2]: A pattern of frequency of values arrayed around a central mean value, such that the pattern is consistent with a Gaussian distribution
   b. <u>Rectangular</u> [2]**:** A distribution of values that that there is equal probability that a value lies anywhere within the interval.
9. <u>Combined Standard Uncertainty</u> [2]**:** (u_c**)** square root of the sum of the squares of the uncertainty factors, used to express the uncertainty of many measurement results.
10. <u>Coverage Value</u> **(k):** when applied to the combined uncertainty allows for the definition of the confidence interval; (k = 2 allows for a 95% confidence interval, k = 3 allows for a 99% confidence interval)

11. Expanded Uncertainty **(U):** the interval in which a value (y) can be confidently asserted to lie
12. Index: demonstrates the individual factor's contribution to the event uncertainty
13. Standard Deviation: A value associated with a normal, or Gaussian distribution describing an average departure from the mean value.
14. Measurand[4]: Quantity intended to be measured.

C. Procedure:

The expanded uncertainty of measurement will be reported for all barrel lengths and overall firearm lengths as required. This estimation of uncertainty is determined through the use of a budget approach. The budget approach evaluates the components that contribute to the measurement uncertainty and quantifies their contribution to the whole. The Uncertainty Budget will be maintained in the calibration binder within the Firearms Unit. Historical data from all devices will be used in calculating the uncertainty.

The uncertainty will be determined using the following steps:

1. Define the measurement process.
   a. The Firearms Unit must meet requirements of State Statute 53a-211 in regards to reporting firearm lengths and barrel lengths which is measured in inches. The State Statute that pertains to barrel and overall length is measured in inches, therefore all reporting should continue with this type of measurement standard.
      i. The "measurand" is the barrel length and/or overall firearm length.
   b. The devices used for this process are two 36 inch steel rulers attached to-the PFT Overall/Barrel Measuring Device. The rulers are calibrated and NIST traceable.
      i. The NIST traceable ruler will:
         (a) Be stored and handled within the laboratory in a manner to preserve the integrity of the ruler. When transportation of the device is required the ruler will be packaged to avoid damage.
         (b) Be inspected during the monthly checks as the barrel length data is being acquired. If any visible change such as damage or warpingis noted, the Unit Supervisor/Lead will be notified and the device will be taken out of service. No periodic checks of the devices are required due to the robustness of the device.
         (c) Will be calibrated every 5 years by an external calibration service that is accredited to ISO/IEC 17025:2005; the accreditation must be through IACC, or ILAC and the scope of accreditation must include the service needed.

(i) Calibration of the ruler is considered a critical service and as such the Quality Section or Unit Supervisor/lead will evaluate the vendor prior to assure they meet the above requirements prior to sending the device for calibration.

(ii) The service provider will be required to provide a traceability certificate (however named). This certificate will be reviewed by the Quality Section or the Unit

(iii)Supervisor/lead to assure that the device continues to meet the needs of the Firearms section prior to use.

(iv) In the event that no companies are available that are accredited and perform the needed service the Quality Section will work with the Unit Supervisor /Lead to approve a non-accredited vendor based on ASCLD/LAB International criteria.

2. Identify the components that contribute to the uncertainty.
   a. Components related to the measuring device.
      i. Scale readability
      ii. Scale resolution
      iii. Calibration uncertainty (of ruler)
      iv. Calibrated ruler error
      v. Proper use, storage and handling of ruler
   b. Components related to the analysts.
      i. Multiple analysts
      ii. Training
      iii. Experience
      iv. Visual acuity
      v. Time of day, day of week, interruptions, workload
   c. Components related to the test method.
      i. Using same method to perform test
      ii. Differences between analysts in establishing parallel position to measuring device
      iii. Differences between analysts in establishing the zero point on the measuring device
      iv. Differences in measuring barrel length in revolvers versus other handguns
   d. Components related to the laboratory facility.
      i. Temperature variation impacting the coefficient of expansion of the measuring device
      ii. Lighting

iii. Space

3. Determine how much each component contributes to the whole (i.e. quantify).
4. Convert quantities to standard uncertainties.
5. Calculate combined standard uncertainty.
6. Expand the combined standard uncertainty by the coverage factor (k).
   a. (k) is 2 allowing a 95.45% probability that the reported value falls within the reported uncertainty range.
7. Evaluate the expanded uncertainty; review the obtained value to determine if it makes sense.
   a. Is the obtained expanded uncertainty so large that it is of no value (example a U that is +/- 15 inches would not be useable)
   b. Does the obtained expanded uncertainty meet the needs of the customer (the user of the report)?

      Example: too large of an uncertainty may not allow the user of the report to make determinations related to State regulations on firearm possession.

   c. Review to possibly identify calculation errors. In calculating the uncertainty the fractions will be converted to decimals (1/16th being 0.0625 and 1/8th being 0.125). Evaluation of the historical data will use all the decimals so no more than 4 for the device with a 1/16th resolution. The resulting SD from this step will be rounded to 2 decimal places. Other factors used in the uncertainty budget will be as listed from the manufacturer or the calibration company (readability, resolution, tolerance and device uncertainty). At the combined uncertainty step the calculated value will be rounded up to no more than 4 decimal places. At the Expanded Combined Uncertainty step the decimal will be converted to a fraction. Rounding up will provide a greater uncertainty therefore being more conservative.

      Example:

      1) Subtotal of standard uncertainty = 0.05424846
      2) Combined uncertainty = 0.0313
      3) Expanded Uncertainty = 0.0625 = 1/16

   d. When taking the measurements of the barrel or length, if the measurement should fall between two fractions of an inch, the analyst will round up to the next closest fraction.
8. Report the uncertainty.
   a. Uncertainty will be reported in inches (or fraction of an inch).
   b. The coverage factor will be included on the report.

9. The uncertainty budget will be prepared by the Deputy Director or their designee. This budget will be reviewed by the Assistant Director or their designee. The Quality Manager be provided the results after review if no changes are necessary. The review will determine if there has been any substantial changes to the individual components of the uncertainty budget.
    a. If there is no substantial changes the Quality Manager or designee will note on the Quality Event tracking worksheet and a copy of the signed uncertainty budget will be stored in the laboratory notebook containing the uncertainty budget within the Firearms Unit.
    b. If the uncertainty needs to be recalculated and results in a new uncertainty value, the evaluation will be reviewed by the Quality Manager. Additionally the Unit Supervisor/lead will inform the section members of the change. The report template, forms QR FA-2 and QR FA-17 will need to be updated with the new uncertainty.
10. The uncertainty budget will reevaluated/reviewed every five years or sooner when any of the following occur:
    a. New employees are authorized by the laboratory to conduct casework in which uncertainty is reported. As part of the training program, the employees that will be conducting casework that will use the uncertainty budget will participate in the monthly QC checks acquiring the data used in the uncertainly budget.
    b. A new measuring device is placed into service.
    c. The measuring device is recertified.
11. Example of budget chart:

Measurand: Barrel Length and Overall Firearm Length				
Factor	Value (x), g	Uncertainty of the individual factors (u_i), inches	Distribution	Index (Relative contribution to u_i in %)
Readability	From manufacturer	x/distribution value	**Rectangular** (use the square root of 3 as the distribution value)	The uncertainty for the factor divided by the subtotal of the standard uncertainties **$(u_i)^2 /(\sum(u_i)^2)$**
Repeatability #	Determined in house this is the SD determined as listed above	Since this is a normal distribution the value is the SD obtained from the calculations	**Normal –** (normal distributions needs no estimation of the value since it has been calculated)	The standard uncertainty for the factor divided by the subtotal of the standard uncertainties **$(u_i)^2 /(\sum(u_i)^2$**
Resolution	From manufacture	x/distribution value	**Rectangular** (use the square root of 3 as the distribution value)	The standard uncertainty for the factor divided by the subtotal of the standard uncertainties **$(u_i)^2 /(\sum(u_i)^2$**
Device Uncertainty	From Calibration Certificate (if reported as expanded uncertainty divide number by 2	x/distribution value	**Rectangular** (use the square root of 3 as the distribution value)	The standard uncertainty for the factor divided by the subtotal of the standard uncertainties **$(u_i)^2 /(\sum(u_i)^2$**
Error of measuring device	From Manufacturer	x/distribution value	**Rectangular** (use the square root of	The standard uncertainty for the factor divided by the subtotal of

			3 as the distribution value)	the standard uncertainties **$(u_i)^2/(\sum(u_i)^2$**
Subtotal of the uncertainty $(\sum(u_i)^2)$		Sum of the square of each of the uncertainty factors		
Uc = square root of $(\sum(u_i)^2)$	Square root of the sum of the squared uncertainty components	inches		
Expanded Uncertainty (U); where (k) = 2	Uc*the coverage factor U =(u_cx2)	**inches**		
*Thermal Expansion of measuring tool ±5°C (coefficient of 0.0016%/°C)	Possible error is ± (0.0016)(%/°C)x(5°C)x(36 inch ruler) = ± 0.00288 inch.			

This component will capture multiple uncertainty components related to analysts, the facility and the test method itself.

*Thermal may be considered in the calculation of uncertainty for the device.

D. Sources of Error:

1. Not considering all components of uncertainty for the measuring process.
2. Applying the wrong type of distribution based on the data.

E. Reference:

1. Expert Trigger Pull Uncertainty article, Forensic Magazine, authors Dana Sevigny, Jeff Salyards
2. A Beginner's Guide to Uncertainty of Measurement, National Physical Laboratory United Kingdom, 2001, Author Stephanie Bell
3. [2]"NIST Reference on Constants, Units and Uncertainty" http://physics.gov/cuc/uncertainty
4. [4]International Vocabulary of Metrology – Basic and general concepts and associated terms **(VIM)** 3rd edition
5. Guidelines for Barrel and Overall Length Measurements of Firearms, ANSI/ASB Best Practice Recommendation 060, First Edition