UCBudget Editor Users Guide

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Introduction

The *UCBudget Editor* is a utility for creating or editing uncertainty budget data and is intended to be used as the basis of an uncertainty budget for one or more measurements. The utility was written around the idea of a coordinate measuring machine but can be applied to other equipment. The uncertainty budget data file can be used by other software for automatic calculation of uncertainty values.

The *UCBudget Editor* can be used to create a *Calibration and Measurement Capability* report by simulating conditions that approximate the best case scenario of a particular measurement. Selection of specific equipment can be done so that direct modification of the uncertainty budget data to accommodate different measurement conditions is not required.

The output format of the report data is PDF or CSV. The PDF output is created as a presentable report whereas the CSV output is intended to be used for additional evaluation or testing using any spreadsheet software.

Program Concept

The concept of the *UCBudget Editor* utility is to separate the different areas of measurement uncertainty contributors into components. A single component would represent one or more uncertainty sources such as a laser, step gauge, gauge block, or thermometer. Each component contains a set of associated uncertainty items and each item can be common or unique to a specific piece of hardware through an identifier such as a serial number.

The traditional method for an uncertainty budget is to have all the uncertainty data in a spreadsheet. Spreadsheets works well when the uncertainty does not change but, as is often the case, many of the conditions that affect uncertainty change from machine to machine particularly when dealing with CMM's.

To solve the problems of a fixed budget the following ideas are adhered to:

- Expressions use variables as much as possible instead of constants. This allows for maximum flexibility when conditions influencing uncertainty change.
- Components are customized for specific equipment. This includes different kinds of step gauges or gauge blocks where each has the potential for unique uncertainty items.
- Functions dealing with the uncertainty data are isolated and portable so they can be used by other software.
- Budget data contains multiple configuration options. A calibration of a CMM consists of several tests all of which can be described within a single budget data file.

Illustration 1 shows a concept block diagram of the *UCBudget Editor* utility. The block diagram contains uncertainty components representing different abstract error sources with two components combined in a single reporting group. The two uncertainty components that are not part of the uncertainty group are identified as variables and used in expressions for the two primary uncertainty components.

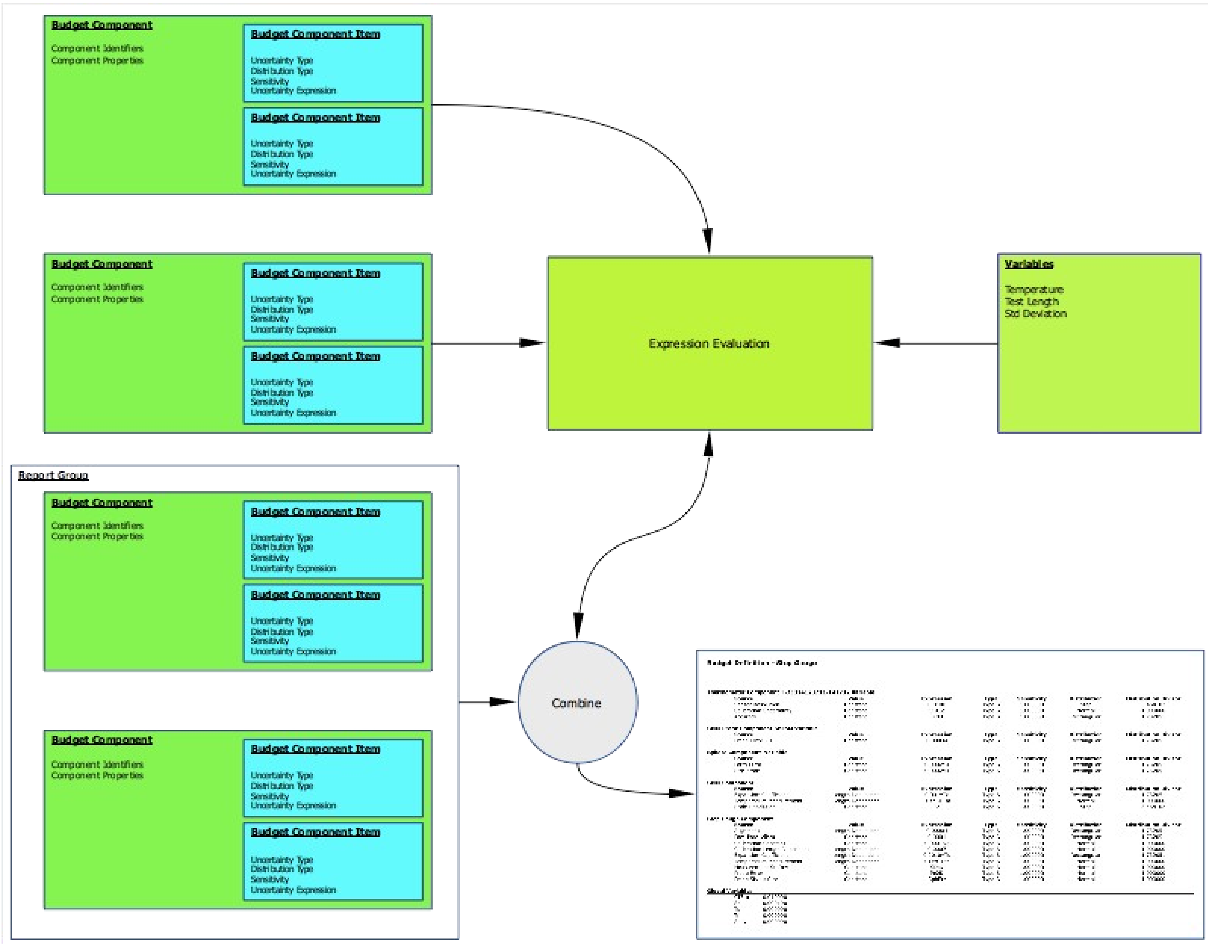


Illustration 1: Concept layout of the UCBudget Editor program.

Uncertainty Component

An uncertainty component is a grouping of related uncertainty items applied to a specific type of equipment or equipment abstraction such as a step gauge, CMM, thermometer, or laser. An example of an uncertainty component is shown in illustration 2.

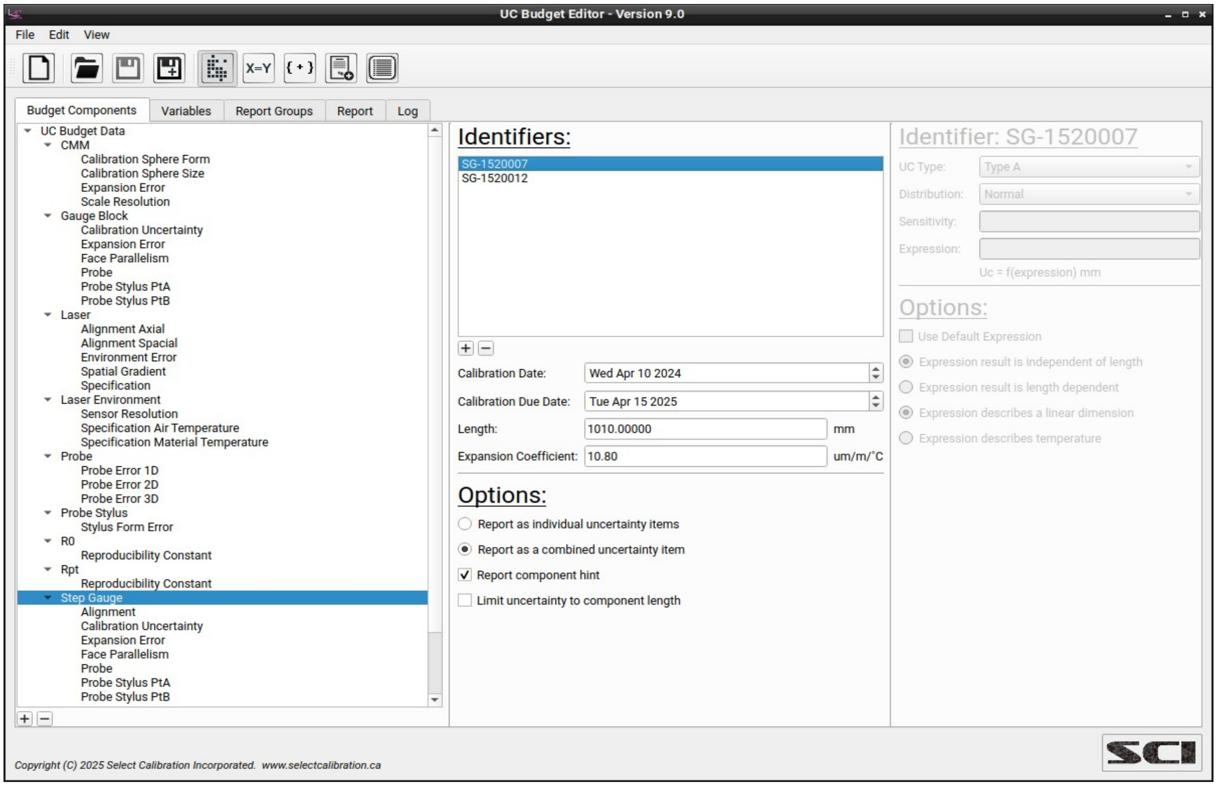


Illustration 2: Uncertainty budget components and component options.

The *Budget Components* view has three sections where the left side shows the budget data in a tree, the right side shows options specific to the active budget component item, and the central view shows options specific to the active budget component. Illustration 2 shows an example of how a budget component will appear when selected.

Table 1: Budget Component Entries and Options

Option	*Description*
Identifiers	List of all unique equipment assigned to a specific budget component.
Calibration Date	Date of calibration for the selected equipment identifier.
Calibration Due Date	Date the identified equipment is due for calibration
Length	Nominal length of the identified equipment if applicable.
Expansion Coefficient	Nominal expansion coefficient of the identified equipment.
Report as individual uncertainty items	Make the individual uncertainty items directly accessible but not the component. See description below for details.
Report as a combined uncertainty item	Make the combined uncertainty directly accessible but not the individual component items. See description below for details.
Report component hint	Visibility hint that can be used by other software. This setting is not used by the *UCBudget Editor* but can be

Option	*Description*
	used by other software to decide if this is component should be hidden to the end user. See description below for details.
Limit uncertainty to component length	Only calculate uncertainty to the length of the component. See description below for details.

Identifiers

Each uncertainty component can have a list of uniquely identified equipment. Each equipment identifier can have unique attributes such as the calibration date, length, expansion coefficient, and the uncertainty expression.

The identifiers allow customization of the uncertainty expressions specific to equipment. An example of this would be a group of gauge blocks that have different lengths, calibration dates, and possibly different uncertainty expressions. The specific identified item can be chosen when generating the report.

Report as Individual or Combined Uncertainty

The uncertainty component items can be treated as a group or accessed directly. When set to *Report as a combined uncertainty item* the result is a single value for the report or for use in variables. When set to *Report as individual uncertainty items* each component sub item will be directly accessible.

The option for individual uncertainty items can be useful in some cases. An example of this would be for probes where different uncertainties exist depending on the probe characteristics and the number of probing directions used for specific measurement. Instead of having multiple budget components to handle all probes and configurations only one probe component item is needed containing all the probe configurations that could be used.

Report Component Hint

This option is not used directly by the *UCBudget Editor* utility but is intended for external utilities that generate calibration reports using the budget data. Selecting this option is a hint that the selected component should be visible to the user from the software using this budget data.

Limit Uncertainty to Equipment Length

When calculating length dependent uncertainties this option will limit the calculated uncertainty to the length of the equipment. An example where this option is suitable is when there is a combination of different length items such as a gauge block and a laser. The length of the laser measurement will likely be greater than that of the gauge block so any length dependent uncertainty items specific to the gauge block should be limited to the length of the gauge block and not extend to the full length of the measurement.

The uncertainty calculated from expressions that use the length variable directly (variable L) are not limited to the equipment length.

Uncertainty Component Item

An uncertainty component item is an individual uncertainty entry for the uncertainty component.

Each component item will produce an uncertainty value that will be combined with other component items to produce a final uncertainty value for the uncertainty component.

The editor for the uncertainty component item is active when any budget component item is selected from the budget data. An example of an active budget component item is shown in illustration 3.

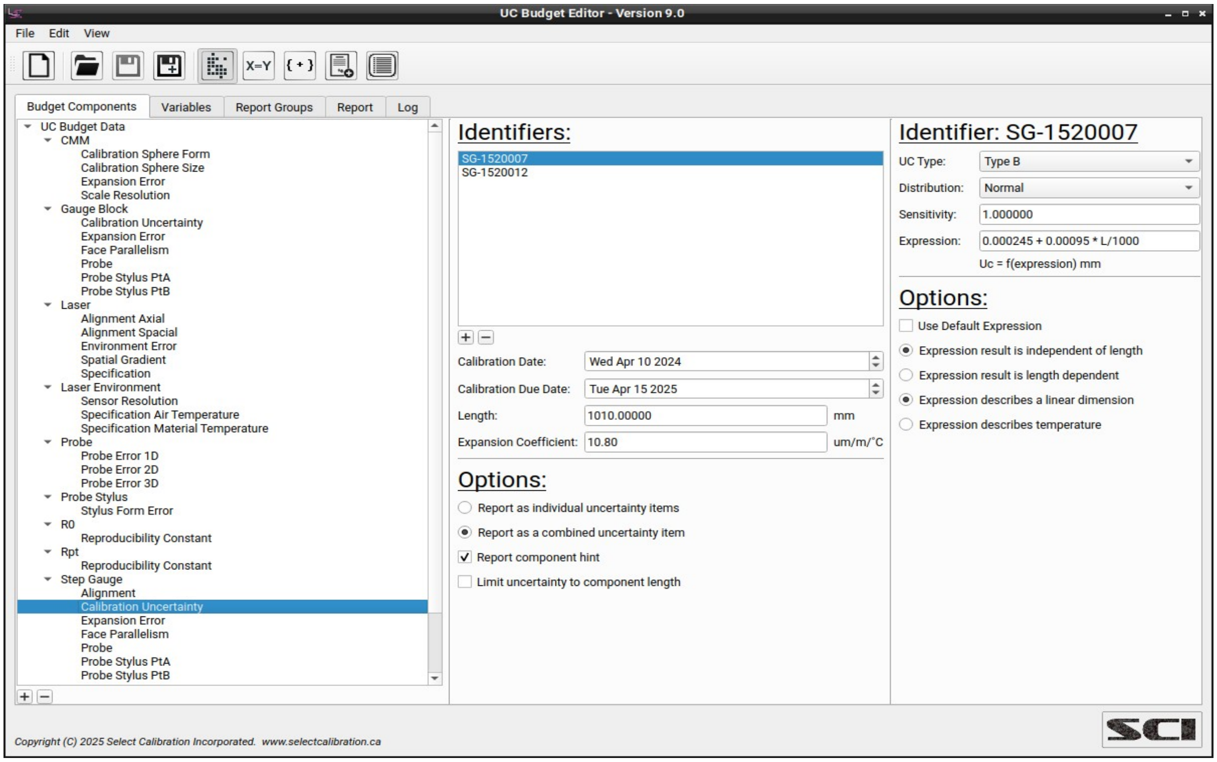


Illustration 3: Editor for a specific component item.

Table 2: Budget Component Item Entries and Options

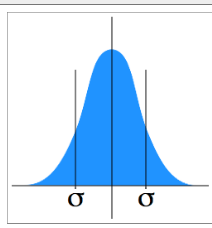
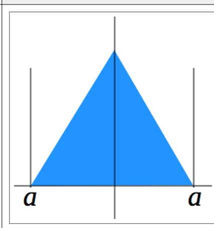
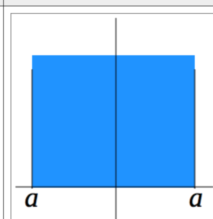
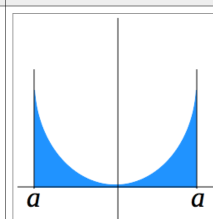
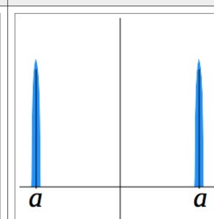
Option	*Description*
UC Type	Describes how the uncertainty value was determined. Entry can be either *Type A* or *Type B*. This selection does not influence the final reported value but does provide information about the uncertainty source.
Distribution	Description of the distribution type of the entry expression. All uncertainty values are converted to a normal distribution and this setting defines how the conversion is performed.
Sensitivity	The influence from this particular item on the results of the uncertainty expression.
Expression	Value or formula used to calculate the uncertainty result from this specific component item.
Use Default Expression	When checked, the selected equipment uses the default expression and not a unique, equipment specific, expression.

Option	*Description*
Expression result is independent of length	Expression result is constant and not based on length. *Constant expressions that include the length variable 'L' may be the equivalent of a length dependent expression depending on how the variable is used.*
Expression result is length dependent	The expression is assumed to be length dependent. The result of the expression is combined with the current length as compared to 1 meter.
Expression describes a linear dimension	The expression is treated as a linear dimension in mm or mm/m.
Expression describes temperature	The expression is treated as a temperature in °C or °C/m.

Linear and temperature units cannot be mixed in the same uncertainty component or even in the same reporting group. Combining linear and temperature expressions can only be done through the use of variables.

Distribution Types

Each expression entered is converted into a standard unit of uncertainty based on the selected distribution type. The different types of distribution are described in the following table:

	Normal	Triangular	Rectangular	U	Step
Graphical					
Equivalent Standard Uncertainty	$S=\sigma$	$s=\frac{a}{(\sqrt{6})}\simeq 0.41\,a$	$s=\frac{a}{(\sqrt{3})}\simeq 0.58\,a$	$s=\frac{a}{(\sqrt{2})}\simeq 0.71\,a$	$s=\frac{a}{(2\sqrt{3})}\simeq 0.29\,a$
Examples	Type A evaluations that follow a normal distribution.	Noise, vibration	Calibration certificates, manufacturer's specifications	Temperature variation	Digital readout verniers, operator read scales

Component Item Expressions

The expressions used for the component items can be a constant value or a formula with variables. A number of variables for use in expressions are automatically provided by the *UCBudget Editor.* Additional expression variables based on uncertainty components can be added if required.

The expression interpreter used in the *UCBudget Editor* can support a few mathematical operators and functions that were deemed useful. The expressions are processed using normal rules for operator precedence.

Table 3: Expression operators

Operator	*Description*
+	Addition. The sum of the two operands.
-	Subtraction. The second operand subtracted from the first.
*	Multiplication. The product of the two operands.
/	Division. The first operand divided by the second.
^	Power. The first operand is raised by the power of the second.
()	Parenthesis. Used to override default precedence rules. i.e. 2+3*5 will be interpreted differently then (2+3)*5.
SIN()	Trigonometric sine function of an angle. The angle is in radians.
COS()	Trigonometric cosine function of an angle. The angle is in radians.
TAN()	Ratio between the sine and cosine.
ASIN()	Trigonometric inverse sine function to produce the angle in radians.
ACOS()	Trigonometric inverse cosine function to produce the angle in radians.
ATAN()	Inverse tangent function. The returned angle is in radians.
SQRT()	Square Root. Returns the square root of the value. Example: 'Sqrt(3^2 + 4^2)' will return a value of 5.
SUMSQ()	Sum Square. Returns the squared sum of the comma separated input values. Example: 'Sumsq(1,2,3,4,5)' will return a value of 55.

Expression operators and functions listed above are the only ones supported.

Variables

Variables are names that represent a value that can be used when writing component item expressions. A list of static variables is created automatically based on the input conditions as shown in illustration 4. Additional variables can be added from uncertainty components or individual component items.

The *UCBudget Editor* allows the user to enter values representing the conditions for the evaluation of the budget data. This is shown on the left side of the Variables section as shown in illustration 4 and is described in the following table.

Table 4: Variable Inputs:

Variable	*Description*
Machine Expansion Coefficient	Expansion coefficient of the machine axis. This value becomes variable CTEm
Machine Scale Resolution	Scale resolution of the machine axis. This value becomes variable Sr
Minimum Temperature	Minimum temperature. Impacts variables Td and Tr.

Variable	*Description*
Maximum Temperature	Maximum temperature. Impacts variables Td and Tr.
Temperature Gradient	Temperature gradient. This value becomes variable Tg.
Mean Standard Deviation	Standard deviation used for each test length.
Start Position	Measurement starting position. Value is always zero.
End Position	Measurement end position. This value affects Lmax.
Increment	Increment value between start and end for multiple evaluations.
Spacial Measurement	Indicates measurement is 3D and not parallel to a machine axis.

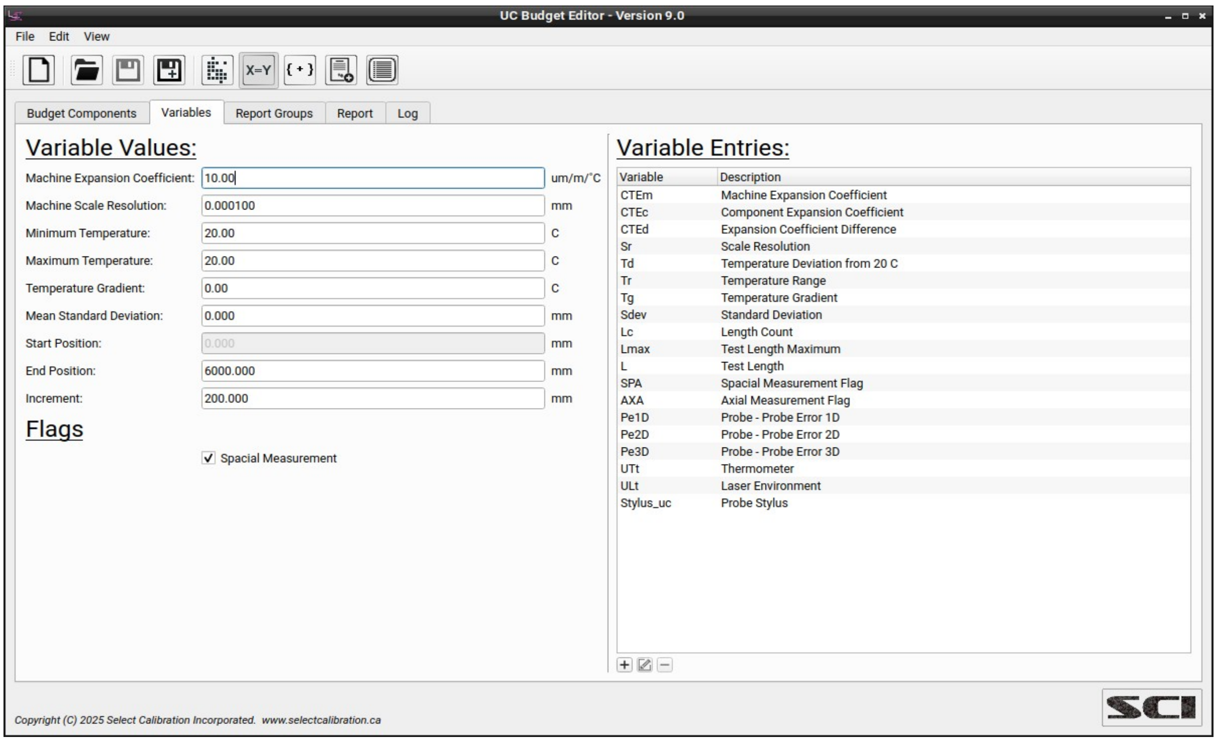


Illustration 4: Variable section of the UCBudget Editor program

Table 5: Variable Entries

Variable	*Description*
CTEm	Value representing the expansion coefficient of the machine.
CTEc	Value representing the expansion coefficient of the equipment.
CTEd	Absolute difference between CTEm and CTEc.
Sr	Scale Resolution.
Td	Temperature deviation from the reference temperature of 20°C.
Tr	Temperature range.
Tg	Temperature gradient.
Sdev	Value representing the average measurement standard deviation.
Lc	Value representing the number of over length measurements.

Variable	*Description*
Lmax	Value representing the maximum length of the specific measurement line in mm.
L	Value representing the length of the measurement in mm.
SPA	Value of 1 or 0. Set to 1 if the measurement is 3D.
AXA	Value of 1 or 0. Set to 1 if the measurement is parallel to the X, Y, or Z axis.

Variable CTEx

The variables CTEm and CTEc represent the expansion coefficient of the machine and measurement artifact respectively. The variable CTEd is the absolute difference between the two. When used in an expression the value is converted to mm/m/°C from the input value of um/m/°C. For example: An input expansion coefficient value of 11.5 um/m/°C for the machine's coefficient of thermal expansion results in the corresponding CTEm variable set to a value of 0.0115 mm/m/°C.

Variable Sr

This variable is the scale resolution of the machine's axis. This value is in mm.

Variable Td

This variable represents the average temperature deviation relative to the reference temperature of 20°C. The variable Td is an absolute value and based on the average input temperatures.

Variable Tr

This variable represents the difference between the maximum and minimum temperatures from all measurements. The variable Tr is an absolute value.

Variable Tg

This variable represents the range of temperature that exists during a single measurement. This variable is similar to *Tr* except it applies to only a single measurement. If the machine is inside an environment with a thermal gradient then the three scale axis will each have a different temperature depending on their relative position.

Variable Sdev

This variable is the standard deviation from multiple measurements at a specific length. Measurements that report the average of multiple samples will likely need to consider the standard deviation from the samples as part of the uncertainty.

Variable Lc

This variable represents the number of over length measurements. This is typically used when measurements are staged and the uncertainty from moving the gauge needs to be considered. An example where this kind of variable is useful is when measuring an axis with a length of 1800 mm but using a step gauge with a length of only 600 mm requiring three positions of the gauge to cover the entire axis length. The value of variable *Lc* will be 0 (zero) for the initial position, 1 (one) for the second, 2 (two) for the third, and so on.

The calculation length used to determine the value of variable Lc is 100.1% of the nominal equipment length. The additional 0.1% ensures the variable is not inadvertently set to the wrong position value when measurements are done at the equipment length.

Variable Lmax

This variable contains the maximum length of the measurement line. This variable can be used to dynamically calculate the impact of misalignment errors. When dealing with fixed length equipment such as a step gauge or gauge block it is possible to estimate the maximum alignment error in advance and treat this as a simpler expression. When dealing with a measurement that does not have a fixed length such as a laser the alignment error must be calculated dynamically and would be based on the maximum measured length.

Variable L

This variable contains the length of the evaluated measurement. Normally this is not needed in length dependent expressions as length dependent expressions automatically calculate against the evaluated measurement length but there are some cases where the measurement length is needed directly in the expression.

The following expression produces a length dependent result with an offset at length zero:

```
0.003+0.004*L/1000
```

Expressions with length dependent components should always be defined as constant in the UCBudget Editor otherwise a secondary scaling to the actual length is performed. Expressions defined as length dependent will always be zero at length zero where the above example will have a minimum value of 0.003 at length zero.

Variable SPA

Variable SPA will have a value of 1 (one) if the measurement axis is in 3D space otherwise it will be 0 (zero). Measurements axis must be greater than 10 degrees from the X, Y, and Z axis to be considered 3D. The use of SPA and AXA variables allows uncertainty expressions to be switched on or off for different types of measurement scenarios. An example where the use of this makes sense is when using a laser where one measurement is parallel to an axis and the second measurement is from corner to corner and the range in temperatures between the three axis is greater than zero. The temperature gradient between the three axis creates an uncertainty value that doesn't exist when measuring parallel to one axis as the laser only knows one, combined, temperature.

The following expression is related to temperature gradient between the three machine axis:

```
SPA * Tg * [some_value]
```

This uncertainty expression is based on the temperature gradient (Tg) between the three machine axis and will always be zero unless the measurement is in 3D. When measuring parallel to an axis this specific uncertainty is effectively disabled.

Lasers can have up to three material temperature sensors and this gives a better overall average but the laser only calculates corrections from the average of the three sensors and has no way to deal with the temperature gradient.

Variable AXA

Variable AXA will have a value of 1 (one) if the measurement axis is within 10 degrees of the X, Y, or Z axis otherwise it will be 0 (zero). The use of SPA and AXA variables allows uncertainty expressions to be switched on or off for different types of measurement scenarios.

The following expression is for the laser alignment uncertainty parallel to the X, Y, or Z axis:

```
AXA * ( L - L * COS( ATAN( [max_position_error] / Lmax )))
```

This uncertainty expression will return a non-zero result only if parallel to an axis.

Parallel is currently defined as anything within 10 degrees of one of the machine axis and may change in the future if needed.

User Defined Variables

User defined variables allow the use of a budget component in one or more expressions. The variables could represent an abstraction of a component such as a specific type of probe or it can allow combining incompatible budget components. One example of combining incompatible budget components is a thermometer and gauge block which might result in this kind of expression:

```
UTt * CTEd
```

Where *UTt* represents the uncertainty of the thermometer and *CTEd* is the difference in CTE between the machine and measured artifact.

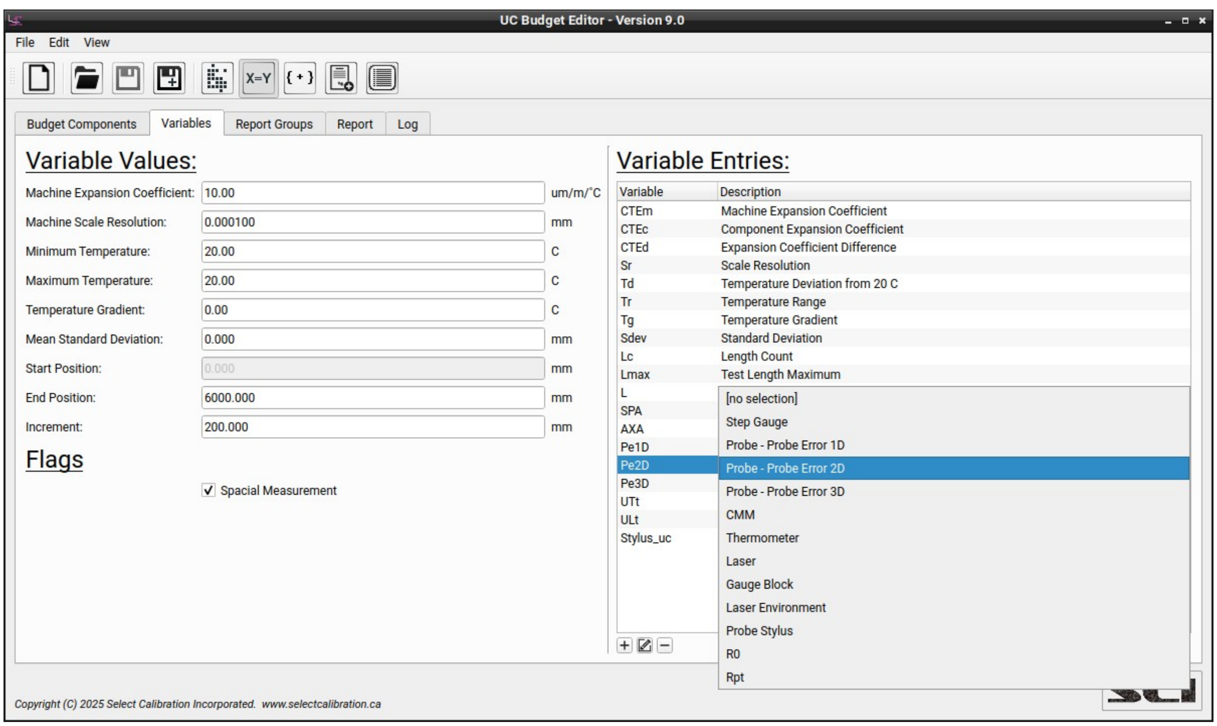


Illustration 5: Variables view of the UCBudget Editor utility. The right side shows how the value of custom variable Pe2D is assigned.

The options for the variable source depends on the number of uncertainty components and if the uncertainty component is set to report as individual or combined uncertainty. For individual items the list will show the name of the component followed by the name of the component item. Illustration 5 shows an example of the Pe2D variable and how the value of this is assigned.

User defined variables are not evaluated recursively. A user defined variable based on a component using another user defined variable will not work properly as it will not be evaluated past the first level. There are no scenarios where this kind of recursion makes sense but it may be changed in the future if the need arises.

User Defined Variable Example

In this example a 500 mm gauge block is used with an expansion coefficient of 10 um/m/°C. The length of the gauge block is corrected by using temperature compensation. The uncertainty of length is calculated from the uncertainty of the temperature measurement and the uncertainty of the expansion coefficient.

Example:

Thermometer_Component (assigned to variable Ut): 0.13 °C

Gauge_Block_Component_Item_1 expression (length dependent): CTEc * Ut
Gauge_Block_Component_Item_2 expression (length dependent): CTEc * 0.1

Where:

The item *Thermometer_Component* is the result of everything related to the uncertainty of temperature measurement using the thermometer (calibration uncertainty, display resolution, sensor type, …). This value is assigned to a variable called *Ut*.

The *Gauge_Block_Component_Item_1* expression represents the uncertainty of length based on the expansion coefficient of the gauge and the measurement uncertainty of the thermometer used to sample the temperature.

The *Gauge_Block_Component_Item_2* expression represents the uncertainty of the expansion coefficient of the gauge block. This assumes the expansion coefficient uncertainty is 10%.

When *Gauge_Block_Component_Item_1* and *Gauge_Block_Component_Item_2* are combined (along with other contributing uncertainty sources) the result describes the measurement uncertainty when using the gauge block. This can be further combined with other uncertainty components that makes sense.

The uncertainty value of variable Ut would be a normal uncertainty therefore the distribution of *Gauge_Block_Component_Item_1* would also be a normal distribution for this aspect of uncertainty contribution. *Gauge_Block_Component_Item_2 should have a rectangular distribution as 10% of CTEc could be anywhere within the 10% range.*

The expansion coefficient variable CTEc is 10 um/m/°C and automatically converted to 0.010 mm/m/°C when used inside an expression.

Report Groups

Report groups describe one or more uncertainty components that are used to create a report. A report group is required in order to create an uncertainty report.

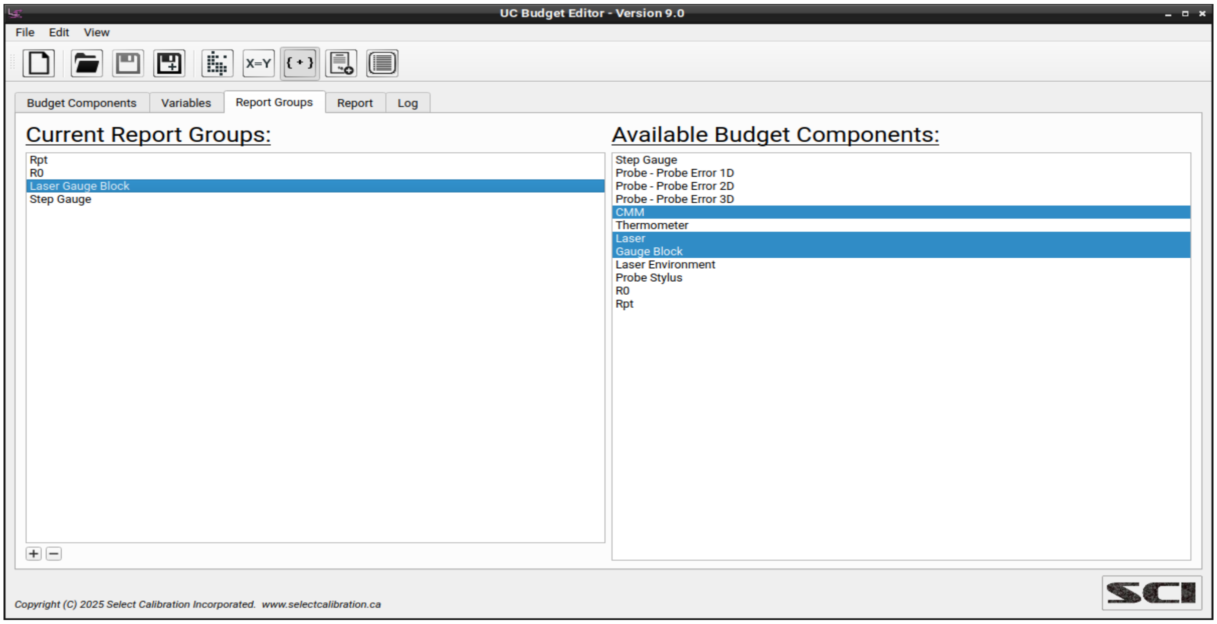


Illustration 6: View of the reports group. The report group named Laser Gauge Block is the result of combining the uncertainty components CMM, Laser and Gauge Block.

The report group budget components are set by selecting one or more entries from the budget data. Selecting an existing report group will highlight the uncertainty components that has been associated with it.

In the example shown in illustration 6 a report group was created called *Laser Gauge Block* and the budget components that make up this group are *CMM*, *Laser*, and *Gauge Block*. When the report group is selected for reporting purposes any additional budget components referenced by the variables will be included in the reported data. Illustration 7 shows an example of the data referenced for the report from the selection of the *Laser Gauge Block* report group.

Budget components used as variables should not be included as part of the report group. They will be reported automatically if used by any selected component expressions.

Report View

The report page shows all of the uncertainty components that are used to calculate the report based on a selected report group. An example of the data used for the report is shown in illustration 7.

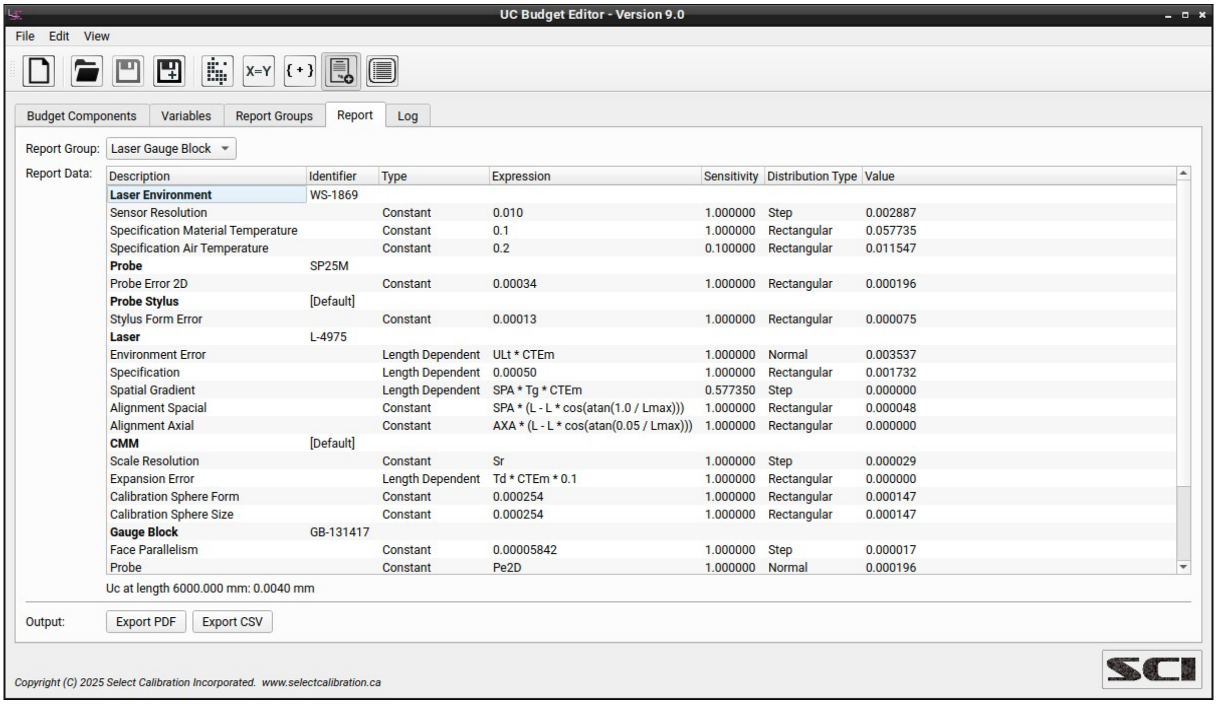


Illustration 7: View of the report tab. When a report group is selected the information is presented allowing selection of equipment identifiers prior to generating a report.

The PDF and CSV outputs are nearly identical in content and layout with the report precision of the CSV data set higher than that of the PDF. The format of the two report types are identical otherwise.

Uncertainty groups that are used as variables will be identified with the word *Variable* in the component title. This information is reported to show how the variable value was derived.

Log Data

The Log Data view provides additional information about the report data as to what is shown from the report window. Any error messages are automatically sent to the log window.

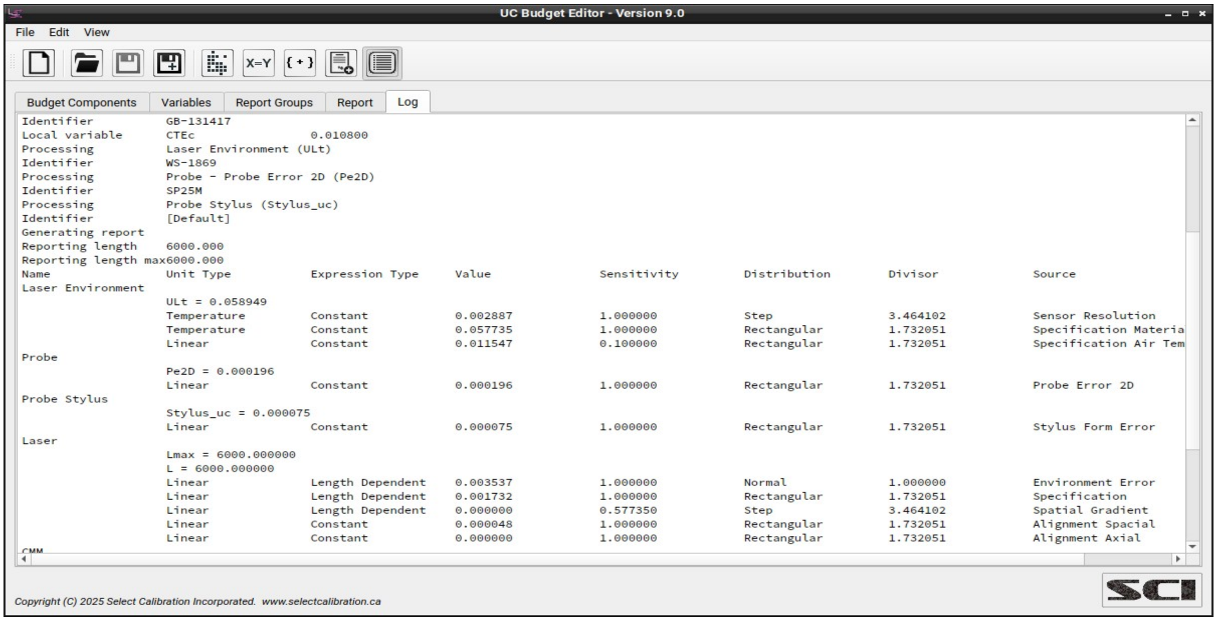


Illustration 8: Log data showing calculation details.

Report Data Format

The report created by the *UCBudget Editor* program consists of three sections. The first section is a detailed listing of all budget components used directly or indirectly. The second section is a list of global variables based on the input data. The third section shows the individual values and calculation results.

The uncertainty expression calculated at the bottom of the report is derived from the individual calculated uncertainty items at the specified report increment. The uncertainty expression is in the form of the polynomial (i.e. $y = ax^2 + bx + c$) which can describe both a linear and curved uncertainty data shape. The format of the expression on the report is $uc = a + bL + cL^2$ where *L* is the length in meters and *uc* is the uncertainty in millimeters at length *L*.

The expanded uncertainty assumes that *k=2* represents a 95% coverage and does not take into account the degrees of freedom or the *t-distribution*. Future versions of this utility may include the option to find the best coverage value based on the effective degrees of freedom (see ISO Guide 98-3:2008).

Report Example

The following is a sample report from the *UCBudget Editor* program for an ISO 10360-2 step gauge measurement on a coordinate measuring machine.

The report group used in this example contain only the *CMM* and *Step Gauge* components with other items added automatically if referenced by variables. The created report created starts with a definition of the data.

Budget Definition - Step Gauge

Thermometer Component T-75014120711-141732 Variable

Source	Value	Expression	Type	Sensitivity	Distribution	Divisor
Sensor Resolution	Constant	0.01	Type B	1.000000	Step	3.464102
Calibration Uc	Constant	0.00435	Type B	1.000000	Normal	1.000000
Specification	Constant	0.05	Type B	1.000000	Rectangular	1.732051

Probe Component SP25M Variable

Source	Value	Expression	Type	Sensitivity	Distribution	Divisor
Probe Error 2D	Constant	0.00034	Type B	1.000000	Rectangular	1.732051

Probe Stylus Component Variable

Source	Value	Expression	Type	Sensitivity	Distribution	Divisor
Stylus Form Error	Constant	0.00013	Type B	1.000000	Rectangular	1.732051

CMM Component

Source	Value	Expression	Type	Sensitivity	Distribution	Divisor
Scale Resolution	Constant	Sr	Type B	1.000000	Step	3.464102
Expansion Error	Length Dependent	Td * CTEm * 0.1	Type B	1.000000	Rectangular	1.732051
Calibration Sphere Form	Constant	0.000254	Type B	1.000000	Rectangular	1.732051
Calibration Sphere Size	Constant	0.000254	Type B	1.000000	Rectangular	1.732051

Step Gauge Component SG-1520007

Source	Value	Expression	Type	Sensitivity	Distribution	Divisor
Alignment	Length Dependent	0.00004	Type B	1.000000	Rectangular	1.732051
Face Parallelism	Constant	0.00163465	Type B	0.666667	Step	3.464102
Calibration Uncertainty	Constant	0.000245 + 0.00095 * L/1000	Type B	1.000000	Normal	1.000000
Expansion Error	Length Dependent	Td * CTEc * 0.1	Type B	1.000000	Rectangular	1.732051
Temperature Deviation	Length Dependent	UTt * CTEd	Type B	1.000000	Normal	1.000000
Probe	Constant	Pe2D	Type B	1.000000	Normal	1.000000
Probe Stylus PtA	Constant	Stylus_uc	Type B	1.000000	Normal	1.000000
Probe Stylus PtB	Constant	Stylus_uc	Type B	1.000000	Normal	1.000000

Global Variables

CTEm	0.010000
Sr	0.000100
Td	0.000000
Tr	0.000000
Tg	0.000000
Sdev	0.000000
SPA	1.000000
AXA	0.000000

Select Calibration Incorporated. www.selectcalibration.ca Page 1

Illustration 9: ISO 10360.2 step gauge uncertainty budget example, initial page.

Budget components that are identified with the name *Variable* are automatically added if an expression in the selected budget components contain a variable referencing these items. In this example variables *UTt*, *Pe2D*, and *SphErr* are used and defined from the *Thermometer Component*, *CMM Probe Component*, and *Sphere Component*.

The section marked *Global Variables* are input values such as temperature and measurement standard deviation. These values are input manually and are not tied to any other uncertainty item and therefore listed separately.

Following the definition of the budget data on the initial page the subsequent pages show the measurement uncertainty calculated at each of the lengths defined by the range and increment in the variable section of the *UCBudget Editor* utility.

Budget Data - Step Gauge

	Position (mm)	0.0	101.0	202.0	303.0	404.0	505.0	606.0	707.0	808.0	909.0	1010.0
Thermometer Component T-75014120711-141732 Variable												
Export Variables	UTt	0.02934	0.02934	0.02934	0.02934	0.02934	0.02934	0.02934	0.02934	0.02934	0.02934	0.02934
Source	Sensor Resolution	0.00289	0.00289	0.00289	0.00289	0.00289	0.00289	0.00289	0.00289	0.00289	0.00289	0.00289
	Calibration Uc	0.00435	0.00435	0.00435	0.00435	0.00435	0.00435	0.00435	0.00435	0.00435	0.00435	0.00435
	Specification	0.02887	0.02887	0.02887	0.02887	0.02887	0.02887	0.02887	0.02887	0.02887	0.02887	0.02887
Probe Component SP25M Variable												
Export Variables	Pe2D	0.00020	0.00020	0.00020	0.00020	0.00020	0.00020	0.00020	0.00020	0.00020	0.00020	0.00020
Source	Probe Error 2D	0.00020	0.00020	0.00020	0.00020	0.00020	0.00020	0.00020	0.00020	0.00020	0.00020	0.00020
Probe Stylus Component Variable												
Export Variables	Stylus_uc	0.00008	0.00008	0.00008	0.00008	0.00008	0.00008	0.00008	0.00008	0.00008	0.00008	0.00008
Source	Stylus Form Error	0.00008	0.00008	0.00008	0.00008	0.00008	0.00008	0.00008	0.00008	0.00008	0.00008	0.00008
CMM Component												
Source	Scale Resolution	0.00003	0.00003	0.00003	0.00003	0.00003	0.00003	0.00003	0.00003	0.00003	0.00003	0.00003
	Expansion Error	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
	Calibration Sphere Form	0.00015	0.00015	0.00015	0.00015	0.00015	0.00015	0.00015	0.00015	0.00015	0.00015	0.00015
	Calibration Sphere Size	0.00015	0.00015	0.00015	0.00015	0.00015	0.00015	0.00015	0.00015	0.00015	0.00015	0.00015
Step Gauge Component SG-1520007												
Local Variables	CTEd	0.00080	0.00080	0.00080	0.00080	0.00080	0.00080	0.00080	0.00080	0.00080	0.00080	0.00080
	CTEc	0.01080	0.01080	0.01080	0.01080	0.01080	0.01080	0.01080	0.01080	0.01080	0.01080	0.01080
	L	0.00000	101.000	202.000	303.000	404.000	505.000	606.000	707.000	808.000	909.000	1010.00
Source	Alignment	0.00000	0.00000	0.00000	0.00001	0.00001	0.00001	0.00001	0.00002	0.00002	0.00002	0.00002
	Face Parallelism	0.00031	0.00031	0.00031	0.00031	0.00031	0.00031	0.00031	0.00031	0.00031	0.00031	0.00031
	Calibration Uncertainty	0.00024	0.00034	0.00044	0.00053	0.00063	0.00072	0.00082	0.00092	0.00101	0.00111	0.00120
	Expansion Error	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
	Temperature Deviation	0.00000	0.00000	0.00000	0.00001	0.00001	0.00001	0.00001	0.00002	0.00002	0.00002	0.00002
	Probe	0.00020	0.00020	0.00020	0.00020	0.00020	0.00020	0.00020	0.00020	0.00020	0.00020	0.00020
	Probe Stylus PtA	0.00008	0.00008	0.00008	0.00008	0.00008	0.00008	0.00008	0.00008	0.00008	0.00008	0.00008
	Probe Stylus PtB	0.00008	0.00008	0.00008	0.00008	0.00008	0.00008	0.00008	0.00008	0.00008	0.00008	0.00008
Uncertainty												
	Combined	0.00050	0.00056	0.00062	0.00069	0.00077	0.00085	0.00093	0.00102	0.00110	0.00119	0.00128

Uncertainty Expression

Uc(K=1): 0.00050+0.00061L+0.00018L^2 mm (L is length in meters)
Uc(K=2): 0.00099+0.00121L+0.00035L^2 mm (L is length in meters)

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Illustration 10: ISO 10360.2 step gauge uncertainty budget example, subsequent page(s).

The sample position is displayed on the first line of the report for each page. The number of pages created is defined by the range and increment requested and how many samples will fit on an individual page.

The *Uncertainty* value at the bottom of the data is the sum of the constant and length dependent uncertainty items. The budget components that are marked as *Variable* are not directly added to the combined uncertainty but indirectly through the expressions that reference them.

The last line in the report contains the uncertainty expression and the expanded uncertainty expression. The expanded expression assumes a coverage of 2 (k=2) for 95% confidence level.

A future version of the UCBudget Editor will include the calculations and input necessary to evaluate the effective degrees of freedom for a coverage of 95% using a modified distribution (t-distribution).

Report Validation

Validation of the data is necessary to prove that the output is correct. To facilitate the validation of the uncertainty budget the export option can create CSV files with higher resolution than the PDF version. When loaded in a spreadsheet program all of the calculations and combining the budget item components can be performed manually. If the final value of the independent calculation agrees with the data reported by the *UCBudget Editor* utilities then this demonstrates the software is producing the proper output.

Revision History

Date	*Version*	*Changes*
Jan 11, 2015	4.0	- Rewrite of program from previous *UCBudget Editor* utility.
Apr 19, 2017	4.1	- Update to Qt 5.6. - Changed report group section to be clearer. - Add buttons to suitable sections for adding and removing items. - Removed information tab.
Nov 27, 2017	5.0	- Update of program and cleanup of documentation. - Added ability to directly access measurement length for uncertainty expressions.
Feb 18, 2018	5.1	- Changed format of uncertainty expressions.
Mar 10, 2018	6.0	- Added temperature gradient variable 'Tg'. - Added option to drag+drop budget files. - Changed default path on GNU/Linux to home folder. - Fixed problem where modification of variables not treated as a change in the data. - Fixed reported uncertainty value in status display at max length. - Change of default path for GNU/Linux. - Added options to rename identifiers, variables, and reporting groups. - Added separate export buttons for PDF and CSV files. - Button for manual updating of the report tab was added. - Automatic updating of the report tab added.
Dec 25, 2023	7.0	- Numerous changes to GUI and layout of windows. - Formatting changes of PDF reports. - Unblock report view when errors are reported.
Jan 16, 2024	-	Documentation update.
Apr 20, 2024	7.1	[bug fix] Switching between identically named uncertainty items does not update the identifier list. [bug fix] Switching between uncertainty items with a selected identifier shows the default expression. [bug fix] Modification of uncertainty expression does not enable save option.
Jun 4, 2024	8.0	Moved budget data handling routines into an external library.
Jan 9, 2025	9.0	[bug fix] Report group update after component name changes - Added standard trig functions. - Added SPA, AXA variables to identify spacial or axial data. - Added variable Lmax.