

MetroVal

**Advanced Calibration Software
With Real Time
Uncertainty and Prediction analysis**

Newton Metrology Ltd.

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Outline

- ✚ MetroVal overview
- ✚ Procedure
- ✚ Uncertainty
- ✚ Prediction
- ✚ Math capabilities
- ✚ Operating
- ✚ Reporting
- ✚ Providing Services by COM interface
- ✚ Running as command line by another program

MetroVal

is a general purpose flexible
calibration and **analysis** program
that can fit many situations and requirements
and is utilized in many fields of calibration.

It complies with international metrology standards and
recommendations such as

ISO GUM (& supplement 1) = for uncertainty

ISO 17025 = for accreditation

ILAC G8 = for compliance with specification

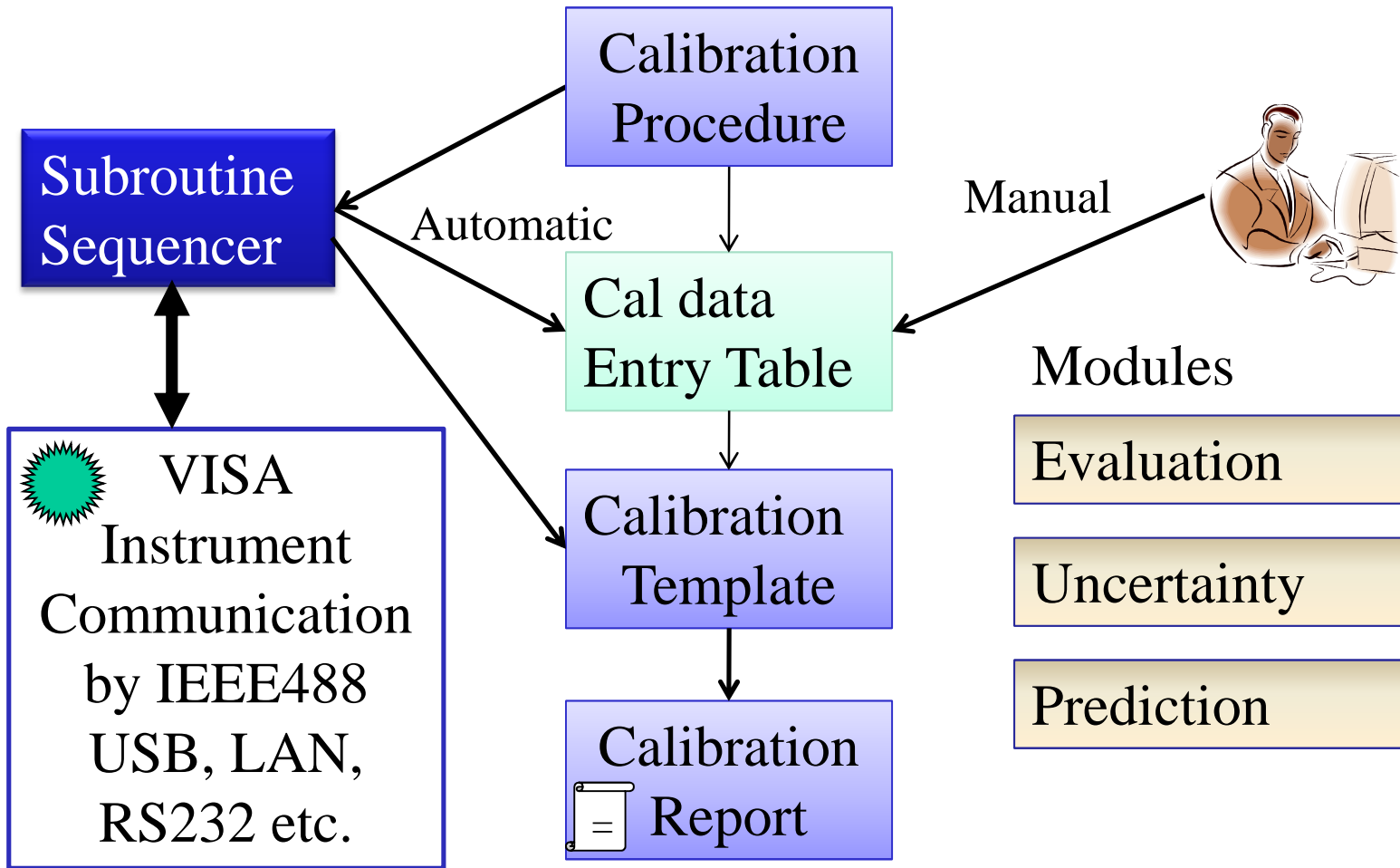
ILAC G24 / OIML D 10 = for recalibration intervals

and has many capabilities beyond these standards.

MetroVal's features were fine tuned and continue to be, based
on users feedback.



MetroVal Block Diagram



The calibration procedure is a table written by non-programmers. Each cell contains a parameter, an instruction or a link. The table is executed line by line.

Sequencer

Data for prediction

Available uncertainty methods

Accredited capability

Unc. Page & components

Subroutine

Row	Cal Point	Unc. file	Page	Symbol(s)	Instruction/Ima	Repea	Histor	Param	ID string	Filter	Unc Meth	Toler	BM	Unit
1	DC Voltag													
2		C:\Docu												
3	100 mV		1	Predict570(&DC01set			F:\FLUtest	DC VOL						
4				&DCV		10								
5				UUTres		0								
6											ISO			mV
7	1 V		2	Predict570(&DC1set			F:\FLUtest	DC VO						
8				&DCV		10								
9				UUTres		0								
10											ISO			1e-6V
11	10 V		3	Predict570(&DC10set			F:\FLUtest	DC VOL						

Unc Method

Sequencer: C:\MetroVal Files\DMM calibration using 5700.prc

File Edit Update-Sequencer Cal-Procedure Data-Table Graph Help

Enable Edit/Save Simulate

visa32.dll found in C:\WINDOWS\system32

Configuration Sequencer Variables

Test From row 1 to bottom Now on row 3 Step Variables: 0 Stop

Row	&Symbol/F	Instrument	Command	Parameter	Value	Additional param	User
1	DC Volta						
2	100 mV						
3	&DC01set	1061A	Prompt	Short the input wit			
4			Send	F3;C1;R0			F3:DC
5			Wait	1000			
			Send	Z			zero,
			Wait	10000			
			Send	R2			R2: 1
9		5700	Send	OUT 100 MV			
10			Prompt	Connect the UUT			
11			Send	OPER			
12			Wait	3000			
13	&DCV	1061A	Receive		13041.9:		
14			Wait	3000			
15	1 V						

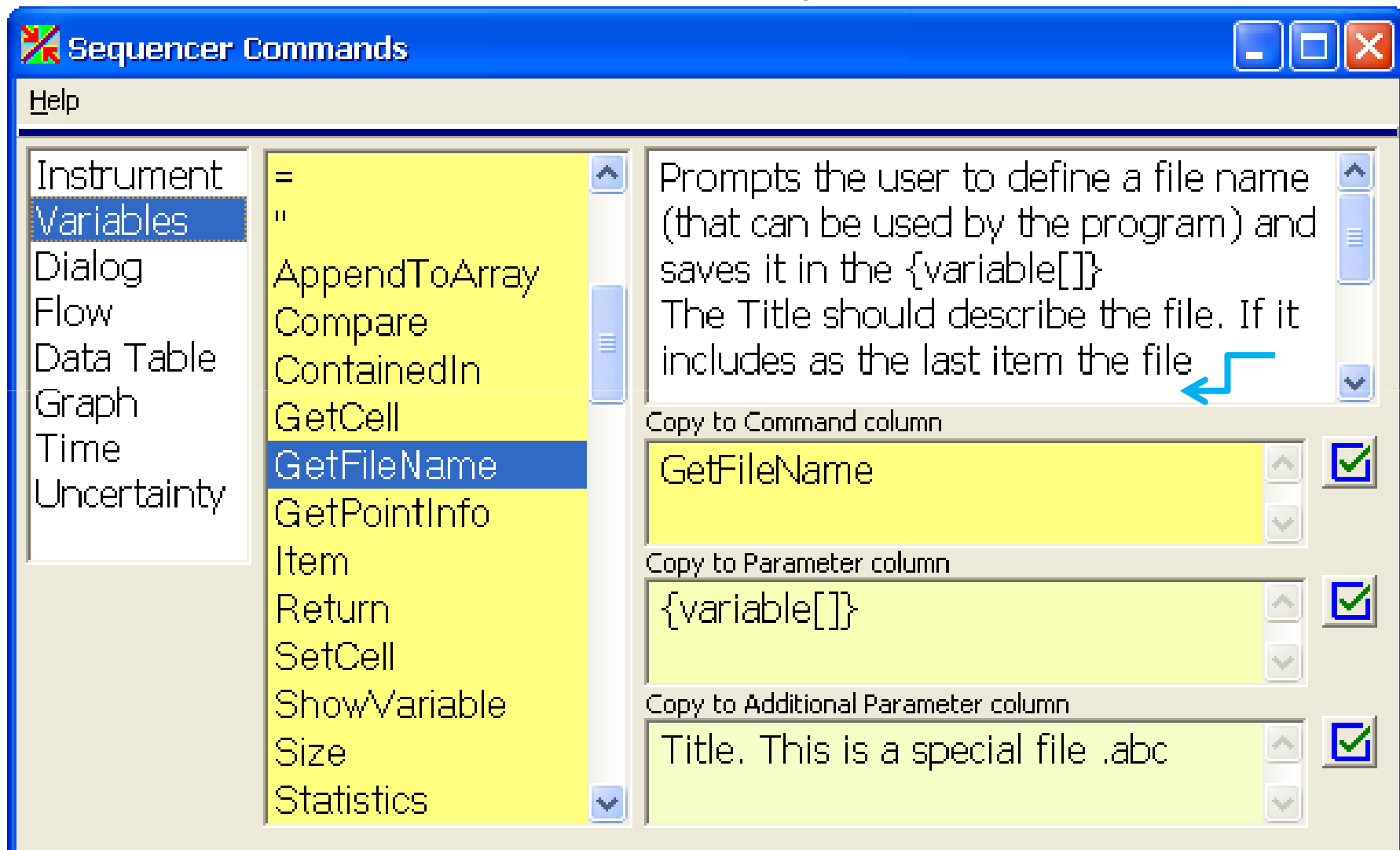
The Sequencer

Subroutine starts here

VISA sends an instrument command

... and the instrument responds

Right clicking on a Command field in the Sequencer opens a command editor which allows editing commands and variables.



Available Uncertainty Methods



- # **GUM** (first order Taylor expansion). Expanded uncertainty computation is extended to include correlations. C-sensitivities and result uncertainties may be complex numbers.
- # **Simplified Monte Carlo** (assuming Root-Sum-Squares equation). May use complex numbers as with the GUM method.
- # **Monte-Carlo simulation directly from the measurement equation.** The equation may include complex numbers. Distributions and reference values are given in the budget table. It can compute c-sensitivities. Produces the **most correct results.**

Uncertainty Budget (1)

The screenshot displays the MetroVal software interface. The main window shows a 'Components Table' with the following data:

Symbol	Description of the component	Value of	Unit of u	Distribution	Confid	Divisor	c Sensit	Unit of c	u - Stan	c*u contr	d.f.	Mean (or me	Deviation - t	Referenc
U1	Predicted value for today	0.003	V	Normal	2	1	1		0.0015	0.0015	999	0.11	0.01	0.1
U2	UUT resolution	0.001	V	Rectangle			$=1/\sqrt{1+2j}$		0.003464	0.003464	999			
U3	Repeatability	4.787135	V	Normal	1	1	1		4.787135	4.787135	3	0.001075	-0.098925	0.1
U4	Voltage Controller	0.0005	V	Triangle			$=1/\sqrt{6}$		0.001224	0.001224	999			0

Below the components table is a 'Results Table' showing the overall uncertainty budget:

Uncertainty	Value	Unit	confid	k factor	d.f.
uc Combined	0.004	V			
U Expanded (ISO)	0.0078	V	0.95	1.96	1.64E
MC Expanded (MC)	0.0073	V	0.95	1.8	
Val Deviation	-0.0889	V			

Callouts in the image:

- A green box at the top right says "c-sensitivity can be complex" with an arrow pointing to the 'c Sensit' column in the components table.
- A green box at the bottom left says "Methods: GUM and Monte-Carlo can be complex and correlated" with arrows pointing to the 'UUT resolution' and 'Repeatability' rows.
- A green box at the bottom right says "Each budget page contains one cal point" with an arrow pointing to the 'Results Table'.
- A green box on the right side says "Deviation" with an arrow pointing to the 'Val Deviation' row in the results table.

Methods: GUM and Monte-Carlo can be complex and correlated

Each budget page contains one cal point

Uncertainty Budget (2)

Links to Procedure

Graphic analysis

The screenshot shows a software window with a menu bar (File, Page, Edit, Window, Calc(ISO), Histogram, Monte-Carlo, Estimator, Help, Stop) and a toolbar. The main area contains several tables and controls:

- Components Table:** A table with columns: Symbol, Description of the component, Value of, Unit of u, Distribution, Confid, Divisor, c, Sensit, Unit of c, u - Stan, c*u contr, d.f., Mean or me, Deviation - t, Refer. It lists components U1 (Rb Prd), U2 (&Repeel), U3 (UUTRe), and U4 (Temperature influence).
- Correlations Table:** A table with columns: Ui, Uj, r(i,j), correlation, x. It shows a correlation of 1 for r1.
- Results Table:** A table with columns: Uncertainty, Value, Unit, confid, k factor, d.f. It shows results for 'Combined' (0.54 Hz), 'Expanded (ISO)' (1.2 Hz), 'Expanded (MC)' (1.5 Hz), and 'Deviation' (511.00 Hz).
- Measured Data Table (repeatability):** A table with columns: Line U2, Ui->, RefData, =col(RefData). It lists data for lines 1 through 5.

Callouts in the image:

- A red arrow points from the 'Links to Procedure' box to the 'Description' field in the Components Table.
- A red arrow points from the 'Graphic analysis' box to the 'Distribution' column in the Components Table.
- A red arrow points from the 'Computed field' box to the '=col(RefData)' formula in the Measured Data Table.
- A red arrow points from the 'Measured, imported and computed columns' box to the 'RefData' and '=col(RefData)' columns in the Measured Data Table.

Uncertainty Budget (3)

Uncertainty Spreadsheet

File Page Edit Window Histogram ▶ Calc(GUM) ▶ Simple-Monte-Carlo ▶

Stop

Page 1 Description Equation: $u(1)^2$ EQ

Components Table Target page number Last Suggested Components

	Value of	Unit of u	Distribution	Confid	Divisor	c	Sensit	Unit of c	u - Stan	c*u contr	d.f.	Mean
U1	1		Rectangle	1	1.73205	0.6			0.577350	3.4641	999	3
U2												

Correlation table:

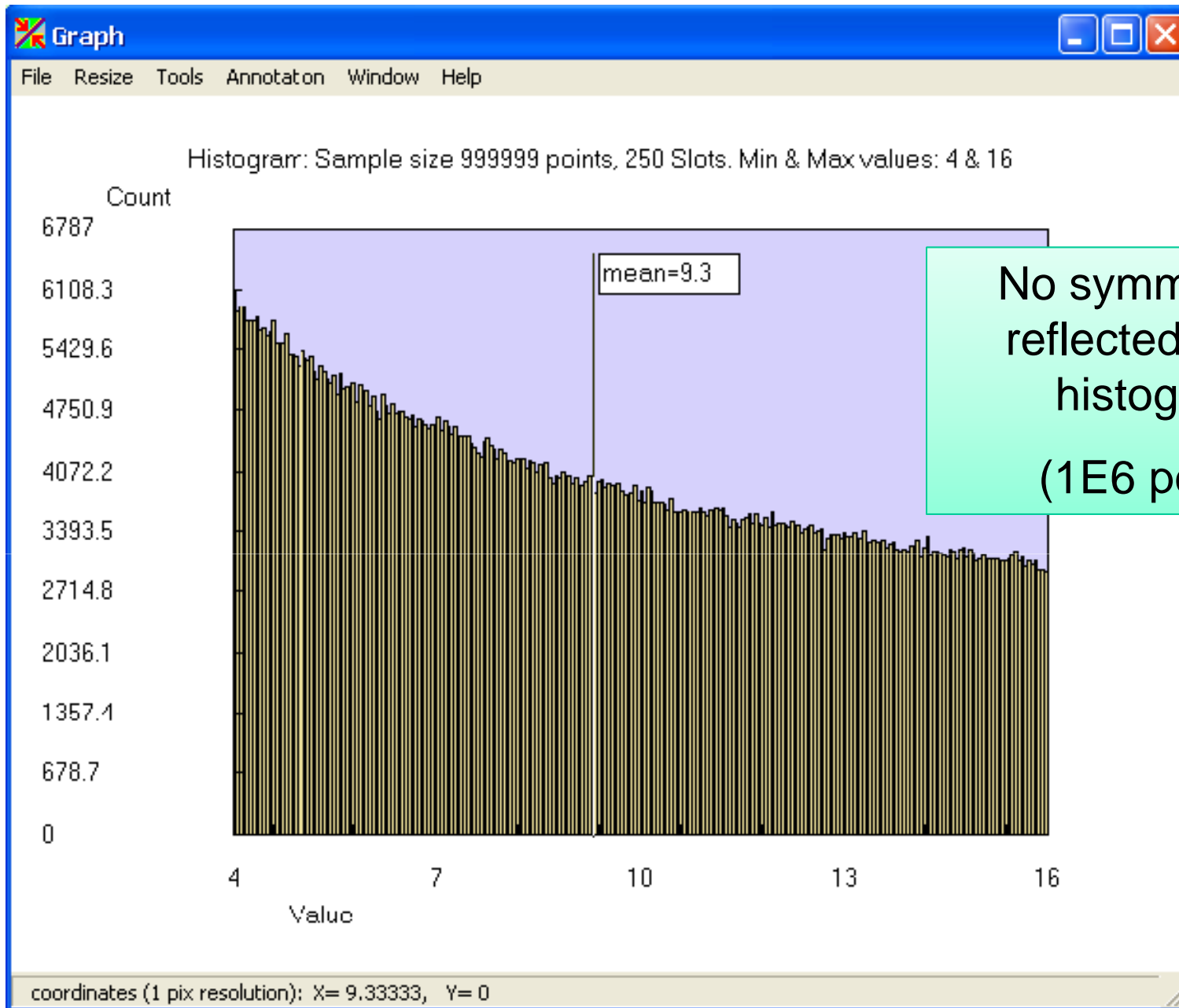
	U1	U2
U1	1	
U2		1

Results Table Unit Confidence 0.95

	Uncertainty	Value	Unit	confid	k factor	d.f.	Low	High
uc	Sigma (MC)	3.48						
U	Expanded (GUM)	6.8		0.95	1.96	999		
MC	Expanded (MC)	5.7		0.95	1.6		5.1	6.3
Val	Mean (MC)	9.3					4.2	15.6

Callout Boxes:

- Unsymmetrical measurement equation (points to Equation: $u(1)^2$ EQ)
- GUM fails (points to the GUM Expanded uncertainty of 6.8)
- Difference with GUM [4.1.4] = 9 (points to the difference between MC and GUM expanded uncertainties)
- With M-C from equation, high and low endpoints are computed (points to the Low and High values in the Results Table)



Uncertainty from Measurement Equation by Monte-Carlo simulation

Measurand Description Editor

Measurand (tested) id

Ref. Value (Applied, Input) REAL Ref. Value IMAGINARY Unit

Parameter id String Function Status

Comment /

Procedure for calibration or test / Reference system

Paste to 'Description' Undo paste Copy Today > Year Month Day

Measurement Equation Editor
Use U(i) for the component in line i show equation Use 10000 points Calculate

$$\left(\frac{((u(1)+u(2)j) - (u(3)+u(4)j)) / (u(5)+u(6)j)}{1 + ((u(7)+u(8)j) - (u(9)+u(10)j)) / (u(13)+u(14)j)} \right) / \left(\frac{(u(11)+u(12)j) - (u(15)+u(16)j)}{((u(17)+u(18)j) - (u(19)+u(20)j)) / (u(21)+u(22)j)} \right) / \left(\frac{(u(23)+u(24)j) - (u(25)+u(26)j)}{(u(27)+u(28)j)} \right) / \left(\frac{(u(3)+u(4)j) (U(29)+u(30)j) / (u(5)+u(6)j)}{1 + ((u(7)+u(8)j) - (u(9)+u(10)j)) / (u(13)+u(14)j)} \right) - \left(\frac{(u(11)+u(12)j) - (u(15)+u(16)j)}{((u(17)+u(18)j) - (u(19)+u(20)j)) / (u(21)+u(22)j)} \right) \left(\frac{(u(23)+u(24)j) - (u(25)+u(26)j)}{(u(27)+u(28)j)} \right)$$

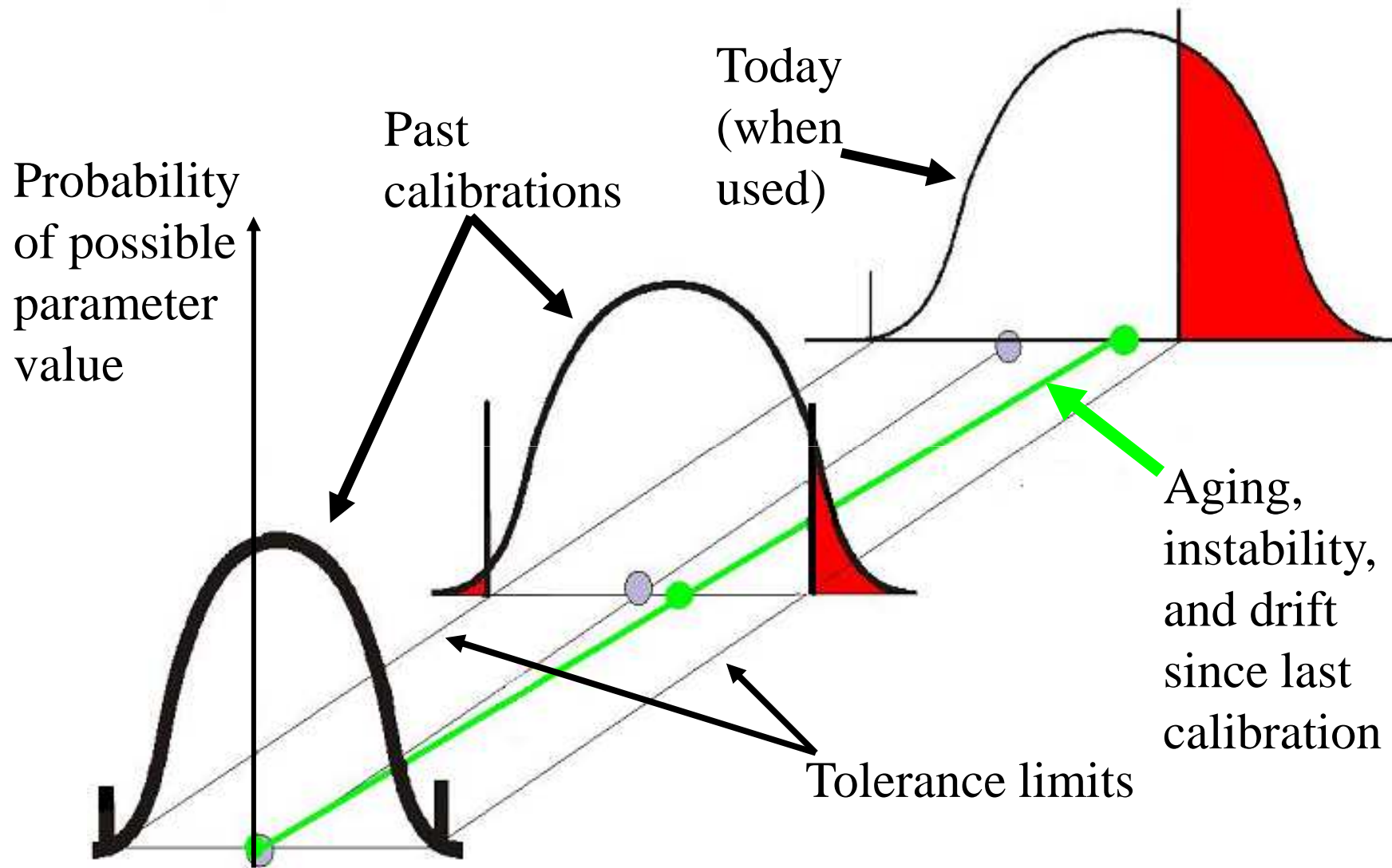
Results Table

	Uncertainty	Value
uc	Sigma (MC)	0.0801
U	Expanded (ISO)	0.0801
MC	Expanded (MC)	0.0801
Val	Mean (MC)	0.0801

Compute derivatives

j is Imaginary unit

Why use prediction as an uncertainty component?



The contribution of reference instrument's aging, drift and instability to the total measurement uncertainty is important. It is especially significant when

- ✚ Doing proficiency testing
- ✚ Calibrating or comparing reference instruments of similar quality
- ✚ Comparing instruments over a long period of time
- ✚ Monitoring the quality of reference instruments
- ✚ Verifying aging and other instability specifications
- ✚ Estimating recalibration intervals

Past Calibrations used for Prediction and Interval Analysis

Predictor - History File: C:\Documents and Settings\... MetroVal files\4808hisa.his

File Edit Search Characters Schedule Predict Graph Report Help

Reload this file
C:\Documents and Settings\MetroVal files\4808hisa.his

An Example History (4808)

Line	Day	Month	Year	Unit1	Input Value	Output Value	Unit2	Deviation	Uncertainty	Parameter	Status	id String	k	df	Con
17	6	5	2000	V	-1	-0.9999999	ppm	0	2.6	DCV	OK	008, Gain -ve, 1V,	2		
18	6	5	2000	V	0	0	Same	0	1E-06	DCV	OK	009, Offset +ve, 10V,	2		
19	6	5	2000	V	10	10.000002	ppm	0.2	2.1	DCV	OK	010, Gain +ve, 10V,	2		
20	6	5	2000	V	19	18.999998	ppm	-0.1	2.3	DCV	OK	011, 19V Gain, 10V,	2		
21	6	5	2000	V	0	1E-06	Same	1E-06	1E-06	DCV	OK	012, Offset -ve, 10V,	2		
22	6	5	2000	V	-10	-10.000001	ppm	-0.1	2.1	DCV	OK	013, Gain -ve, 10V,	2		
23	6	5	2000	V	-19	-18.999999	ppm	0	2.3	DCV	OK	014, -19V Gain, 10V,	2		
24	6	5	2000	V	0	0	Same	0	1E-05	DCV	OK	015, Offset +ve, 100V,	2		

Year: 2000, Month: 5, Day: 6

Unit 1: V, Unit 2: ppm

Parameter: DCV, Status: OK, id String: 011, 19V Gain, 10V,

Comment: k: 2, df: 999, Confidence: 95.45

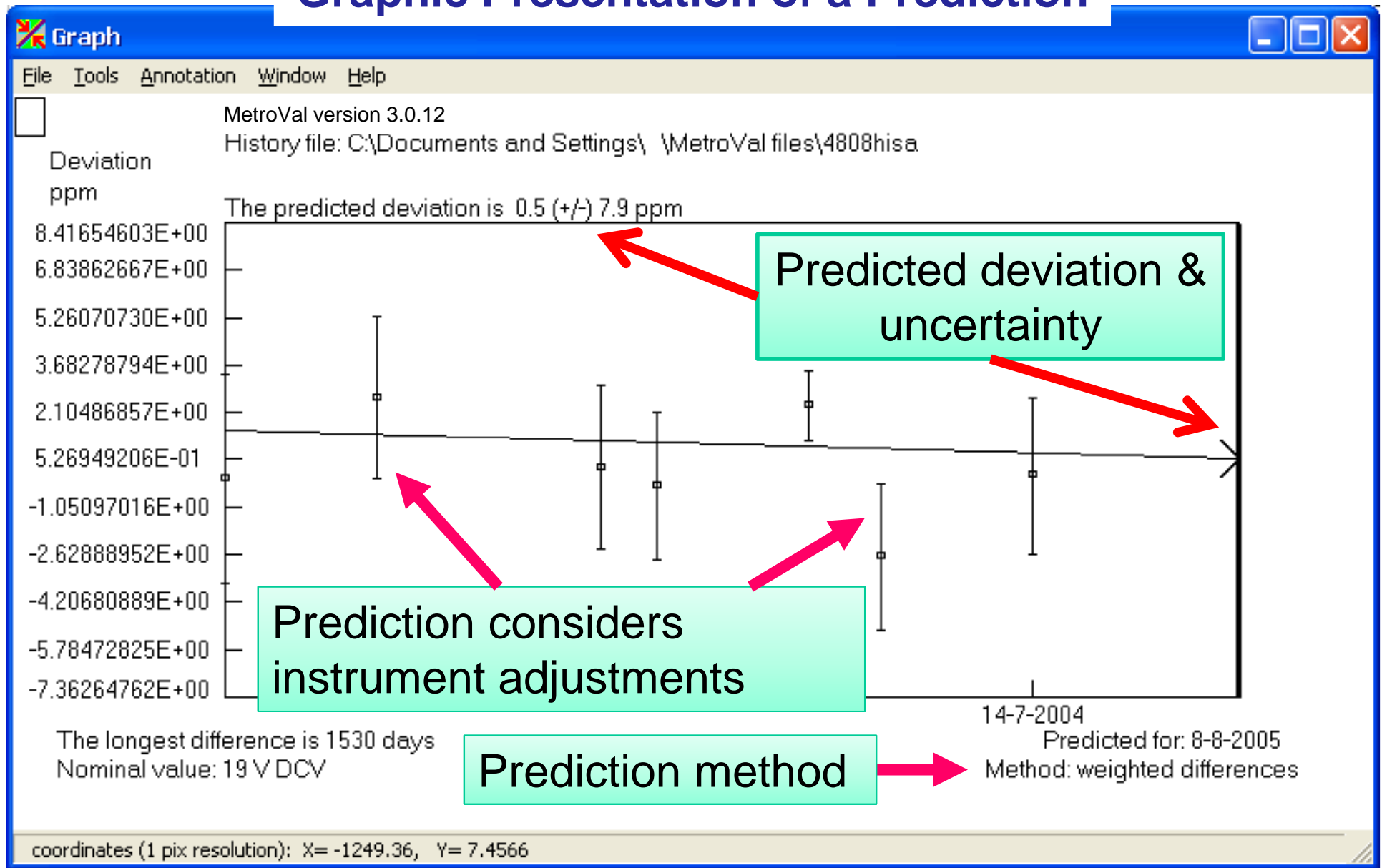
Adjustment info, spec etc.

Run predictions and graphics

k, df, confidence

Each row is one calibration point

Graphic Presentation of a Prediction



Available Prediction Methods



- ✚ **Weighted Linear Regression.** Takes into consideration both **regression statistics** and **measurement uncertainties**. Best for white noise instabilities.
- ✚ **Weighted Linear Regression of Differences.** Advantage when instrument passes occasional **adjustments** (“as received” and “as left”). Best for random walk instabilities.
- ✚ MetroVal program can chose the best method and use it when in automatic mode.

Uncertainty & Procedure Linker (in function view)

Linker - Function View (Beta)

Procedure Description: Calibration of
 Tolerance Version: Automatic
 Procedure version

Function: 1, DC Voltage
 Function Comment:

1. Procedure | 2. Functions | 3. Points | 4. Uncertainty Components | 5. Points for a Component

Component U2 Accept

#	U1	U2	U3	U4
Description	certificate	non-linearity 90 day Sp	drift taken as specificat	UU
Symbol (Link)				
Rpt'd Meas. Header	ktubloyino			
Unc Distribution	Normal	Rectangle	Rectangl	
Divisor (k)	2	=sqrt(3)	=sqrt(3)	
Sensitivity: value unit	1	1	1	
Repetitions	1	0	0	
Prediction File				
Prediction Filter				

U2 Data Source

- Repeated measurements
- Unc & Mean
- Unc only (ignore mean)
- Mean only
- Reference (true) value
- Unc mean Ref predefined

U2 Input Method

- By Sequencer
- Manual at run-time
- From this table
- From Prediction

non-linearity 90 day Spec

The Linker is used to make the Procedure, Uncertainty & Prediction in one step

What is Visible to the Operator?



The procedure tree with calibration points to choose for the present job.

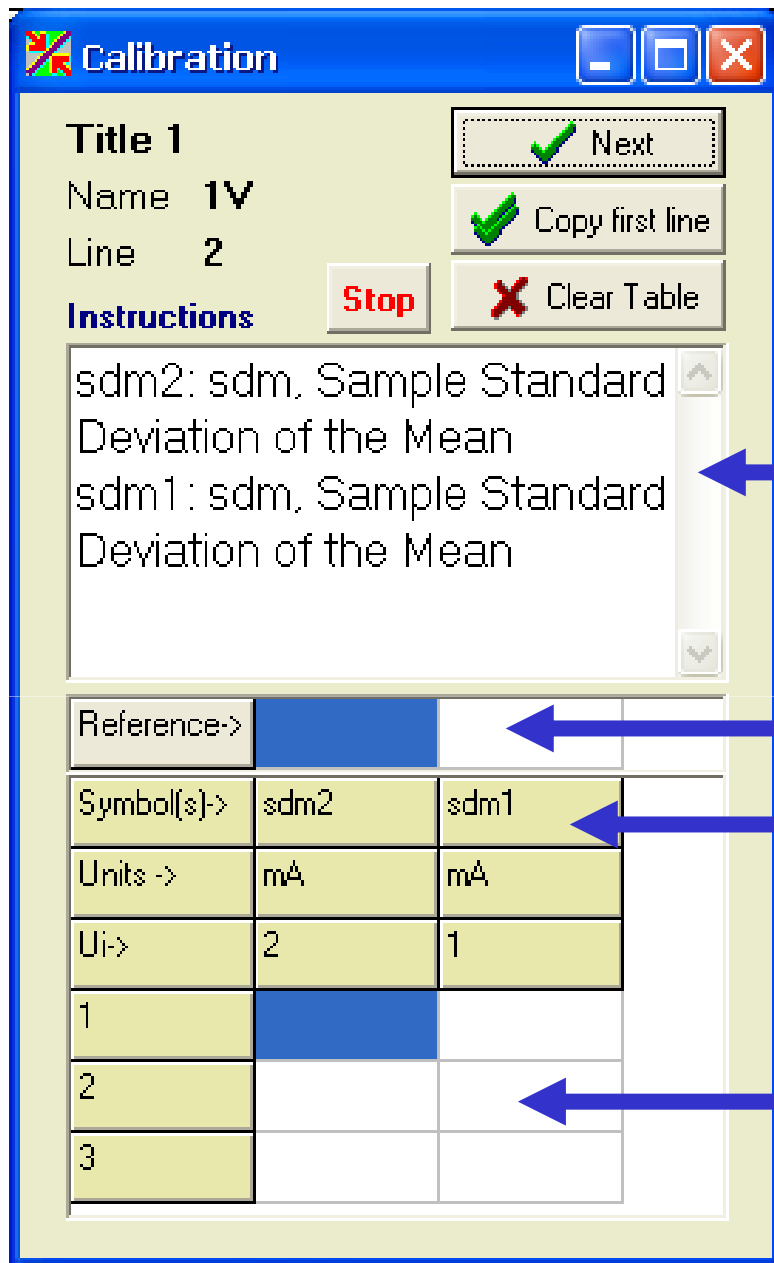
The screenshot shows the 'Cal Procedure Filter' application window. The title bar includes the application name and standard window controls. The menu bar contains: File, Select-all, Skip-all, Instr., Exapand-all, Hide-all, Help, OK, Stop. The main area displays a 'Procedure Tree' with the following items:

- 1 Title: DC Voltage (checked)
- 23 Title: AC Voltage (checked)
- 116 Title: DC Current (checked)
 - 117 Point: 100 μ A (checked)
 - 121 Point: 1 mA (unchecked)
 - 125 Point: 10 mA (checked)
 - 129 Point: 100 mA (checked)
 - 133 Point: 1 A (unchecked, highlighted)
- 137 Title: AC Current (checked)
- 154 Title: DC Resistance (unchecked)

At the bottom of the window is a table with the following data:

Row	Address	Serial	Name	Used as	Message
1		!	1061A	Under Calibrati	
2	GPIB0::4::INS	FLUKE,5700A	5700	Reference	

Instruments used by VISA for the selected cal points



Calibration

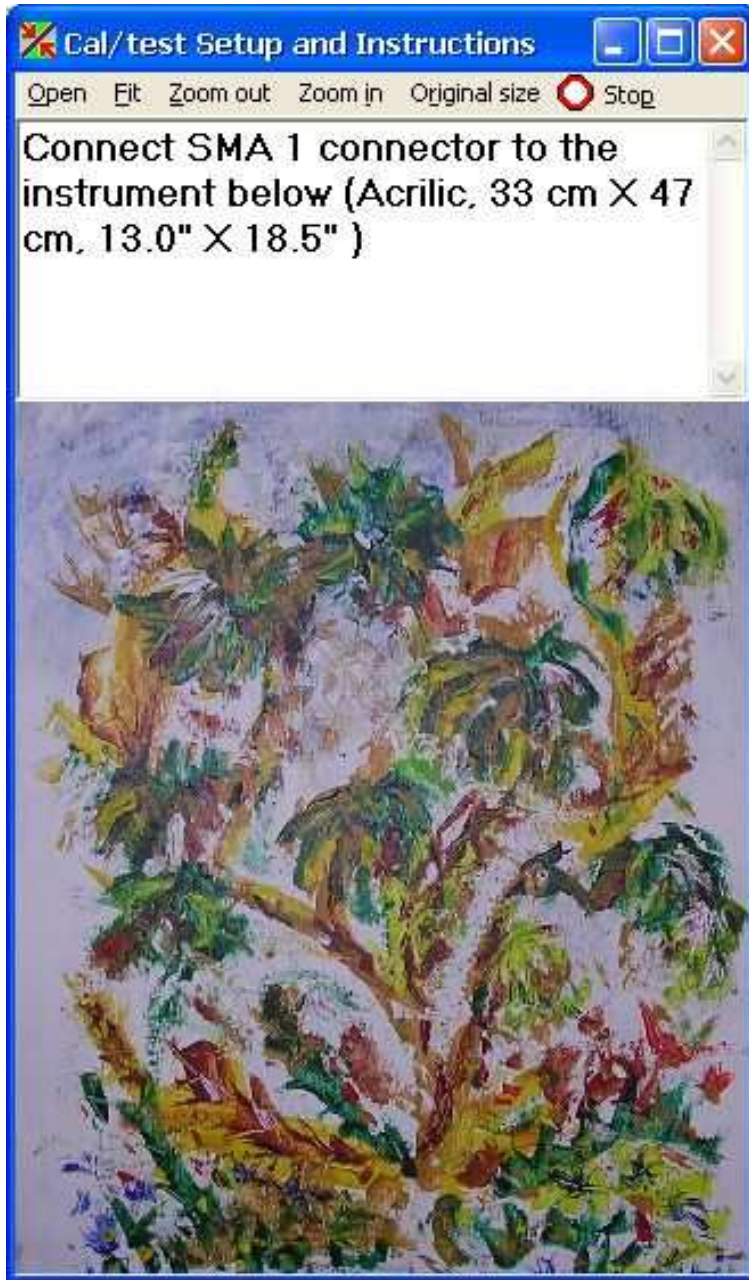
When running calibration manually...

Component description from uncertainty budget

Components reference values

Correlated components measured simultaneously and processed together (e.g. sigma of difference).

Measurements' entry fields. In automatic calibration MetroVal uses VISA for automatic reading & data entry.



Instructions to Operator

← Text

and

← Graphics

Step by step instructions to operator with optional graphic aids, prompts and inputs.

Graphical presentation of uncertainty, result and spec

The screenshot shows a software window titled "Cal Procedure: C:\Users\Alex\Desktop\pars\Balance up to 11 points from INI v1.prc". The interface includes a menu bar (File, Edit, Window, Preview-Instruction, Filter, Control, New-Template, Calibrate, Stop, Help) and a toolbar with icons for Filter, Control, New-Template, Calibrate, Stop, and Help. A progress bar at the top displays "Accuracy, up 11.018" with a green bar and a red arrow pointing to it. Below the progress bar is a table with columns: Row, Function, Point, Unit, Ref., Read, Meas., Dev., Unc., k, L Limit, H Limit, L Tol, H Tol, Tol., and Pass?. The table contains 15 rows of data, with the last row (row 58) highlighted in blue. An "Input" dialog box is open in the foreground, displaying the instruction "Enter the resolution (last count) in units kg for this reading of 10 kg" and the value "0.0001".

Row	Function	Point	Unit	Ref.	Read	Meas.	Dev.	Unc.	k	L Limit	H Limit	L Tol	H Tol	Tol.	Pass?
7	Standard Dev	2.018	g		5	0								0.02	Pass
8	Standard Dev	10	kg		5	0								0.02	Pass
12	Eccentricity	Back Left	kg	9		9	0							0.02	Pass
13	Eccentricity	Back Right	kg	9		9	0							0.02	Pass
14	Eccentricity	Front Left	kg	9		9	0							0.02	Pass
15	Eccentricity	Front Right	kg	9		9	0							0.02	Pass
30	Accuracy	up 2.018	g	2.018000		0	-2.01800	0.00011	1.96					0.02	Fail
37	Accuracy	up 3.018	g	3.018000		3.00000	-0.01800	0.00011	1.96					0.02	Pass
44	Accuracy	up 1.018	kg	1.018000		1.0000	-0.01800	0.00011	1.96					0.02	Pass
51	Accuracy	up 10	kg	10.000000		9.99998	-2E-05	0.00011	1.96					0.02	Pass
58	Accuracy	up 11.018	kg											0.02	Pass

Progress of calibration

Instruction and input

Report Designer and Viewer


File Front-Pages Data-pages Edit Windows Help

Page_1 Layout / 3 Only front pages

Placeholder for a 1:3 layout of the page.

The Famous Calibration Company

km 34 kvish 6
make a left turn next to Moshe's budke
email: FCL@etc.cal



Calibration Certificate

Certificate Number 0

Customer:
Most Important company Ltd.
10 Main street, Yehupitz

Instrument
Mizin Model:qwe
1234F 12345678A

A layout (1:3) of the page

A report designer allows you to design your certificate (1:1). It accepts parameters in real time.

Calibration Results Report

Results Report for Certificate 0

Done for fun only during holidays.

Frequency accuracy at 3 dBm input power

Fitted number of significant digits

Point/ Param.	Unit	Ref.	Measured	Dev.	Unc.	k
1 MHz	Hz	1000000.000	1000500.00	500.00	0.58	1.65
10 MHz	Hz	10000000.000	10000499.93	499.93	0.51	1.66
100 MHz	Hz	100000000	1.0000045E+08	4.5E+02	1.7E+02	3.10
200 MHz	Hz	200000000.000	200000499.45	499.45	0.67	1.77

k factor computed for every point

Power step attenuator at 50 MHz

Point/ Param.	Unit	Ref.	Measured	Dev.	Unc.	k	Tolerance	Pass/NC Fail	Not Accredited
60 dB	%	0	14.3	14.3	3.8	2.81	15	NC	*
50 dB	%	0	4.2	4.2	1.3	2.80	10	Pass	*
40 dB	%	0	3.1	3.1	1.7	2.88	10	Pass	*
30 dB	%	0	1.91	1.91	0.42	2.60	1	Fail	*

*** End Of Report ***

Possible inclusion of graphs and Data Tables

Pass/Fail per ILAC G8

Automatic indication of not accredited items

If not otherwise stated, the expanded uncertainties are for the confidence probability of about 95% and k=2. Pass/NC/Fail based on deviation from nominal plus uncertainty

The Famous Metrology Conference

Results Report for Certificate 0 , Cal Date: 19-11-2008

All-in-one-universal-instrument, s/n 0987654321

that never needs calibration or adjustment

Pass/NC/Fail depends on asymmetric uncertainties. Extension of ILAC G8

Calibration of artifact 1234, function z

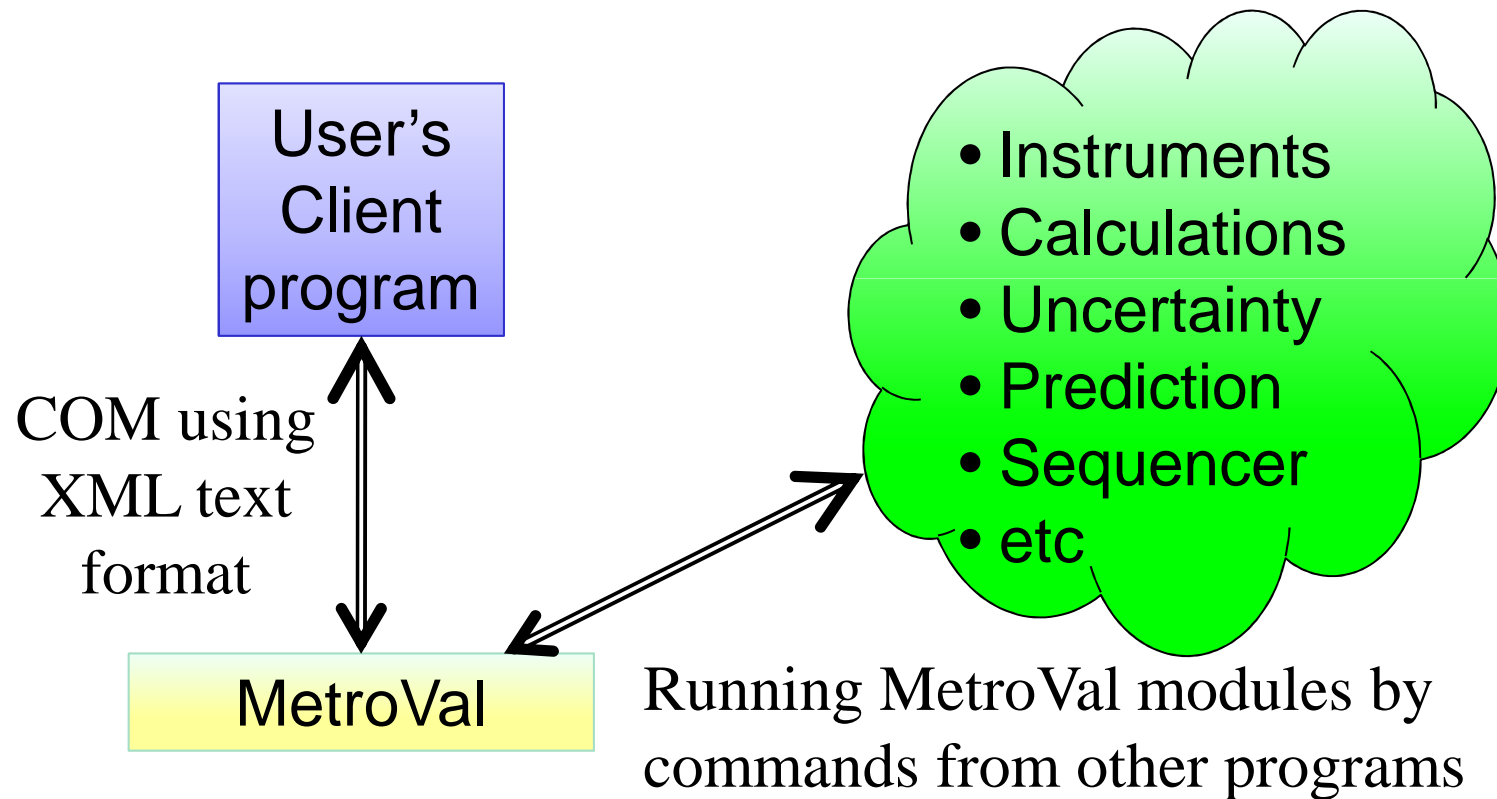
Point Name	Unit	Ref.	Measured	Dev.	Unc.	k	Low Tol.	High Tol.	Pass /Fail	Not Acc
20	mm	20.00052	19.9994	-0.0011	-0.0017 +0.0027	2	-0.01	0.01	Pass	*
100	mm	100.00153	100.0017	0.0002	-0.0023 +0.0016	2	-0.01	0.01	Pass	*

*** End Of Report Data ***

Accreditation should allow for asymmetric BMC

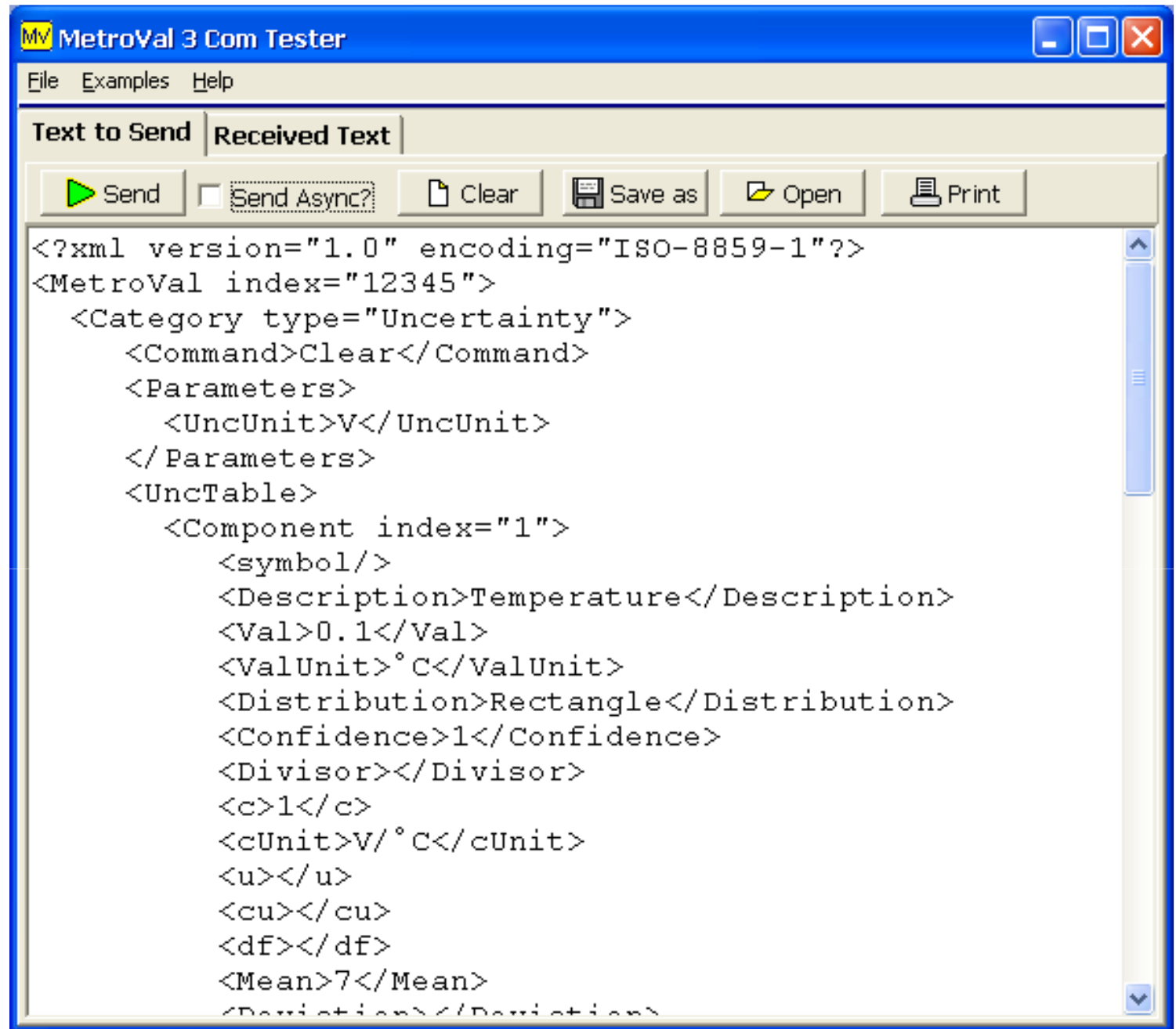
Reporting asymmetric uncertainties

MetroVal can function as a COM server to provide services requested by other programs

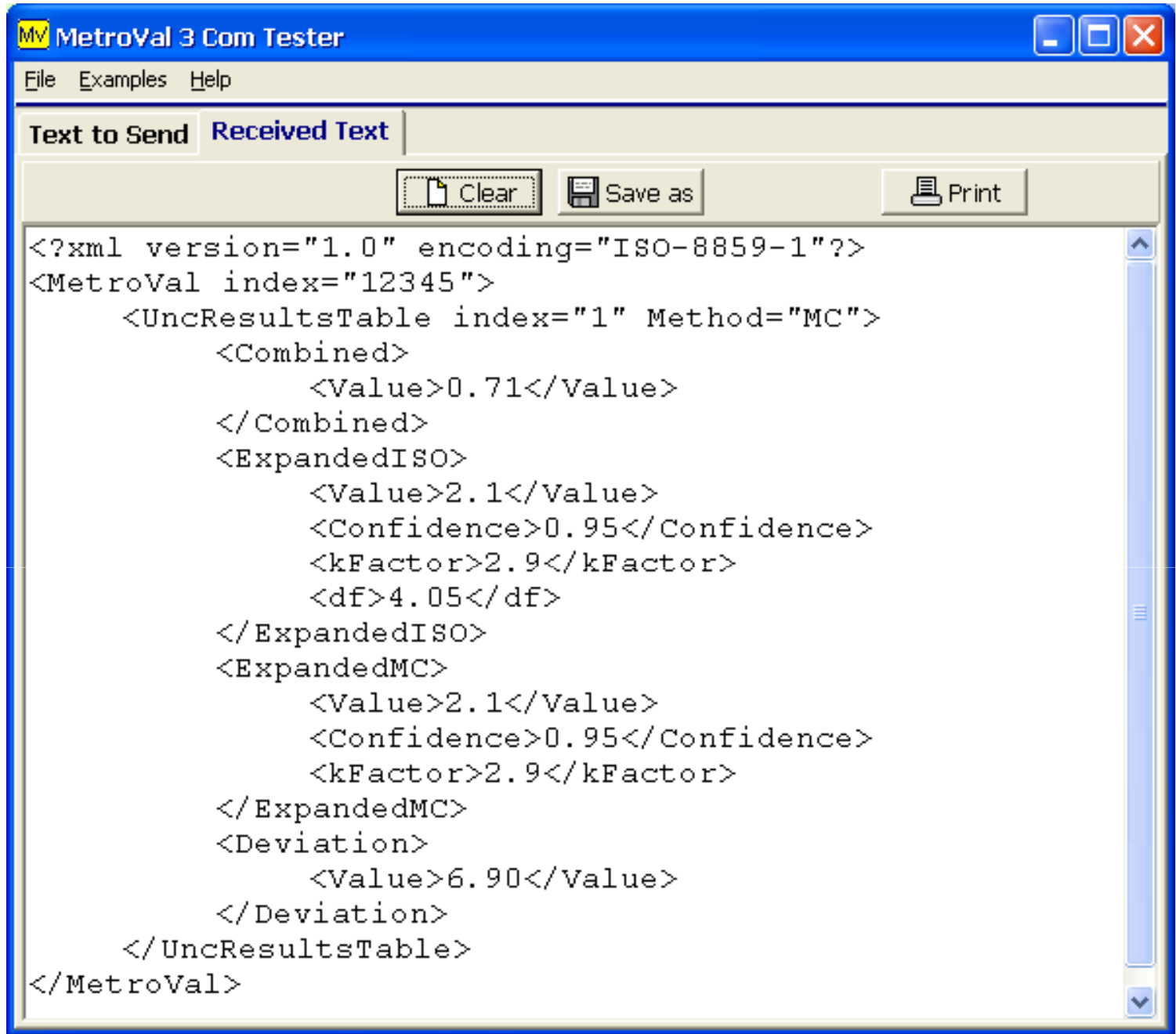


A COM Tester program is provided for free download.

In this example an uncertainty budget is sent to MetroVal using XML format.



And here is the calculated uncertainty sent back by MetroVal also using XML text.



The screenshot shows the MetroVal 3 Com Tester application window. The title bar reads "MetroVal 3 Com Tester". The menu bar includes "File", "Examples", and "Help". The interface has two tabs: "Text to Send" and "Received Text", with "Received Text" being the active tab. Below the tabs are three buttons: "Clear", "Save as", and "Print". The main text area displays the following XML output:

```
<?xml version="1.0" encoding="ISO-8859-1"?>
<MetroVal index="12345">
  <UncResultsTable index="1" Method="MC">
    <Combined>
      <Value>0.71</Value>
    </Combined>
    <ExpandedISO>
      <Value>2.1</Value>
      <Confidence>0.95</Confidence>
      <kFactor>2.9</kFactor>
      <df>4.05</df>
    </ExpandedISO>
    <ExpandedMC>
      <Value>2.1</Value>
      <Confidence>0.95</Confidence>
      <kFactor>2.9</kFactor>
    </ExpandedMC>
    <Deviation>
      <Value>6.90</Value>
    </Deviation>
  </UncResultsTable>
</MetroVal>
```

MetroVal can be started by another program
(for example MS Access).

The program transfers to MetroVal the name of
an INI file as a command line parameter.

MetroVal loads the parameters (eg. cal points)
from the INI and executes the calibration.

When calibration is ended, MetroVal closes and
the focus is transferred to the calling program.