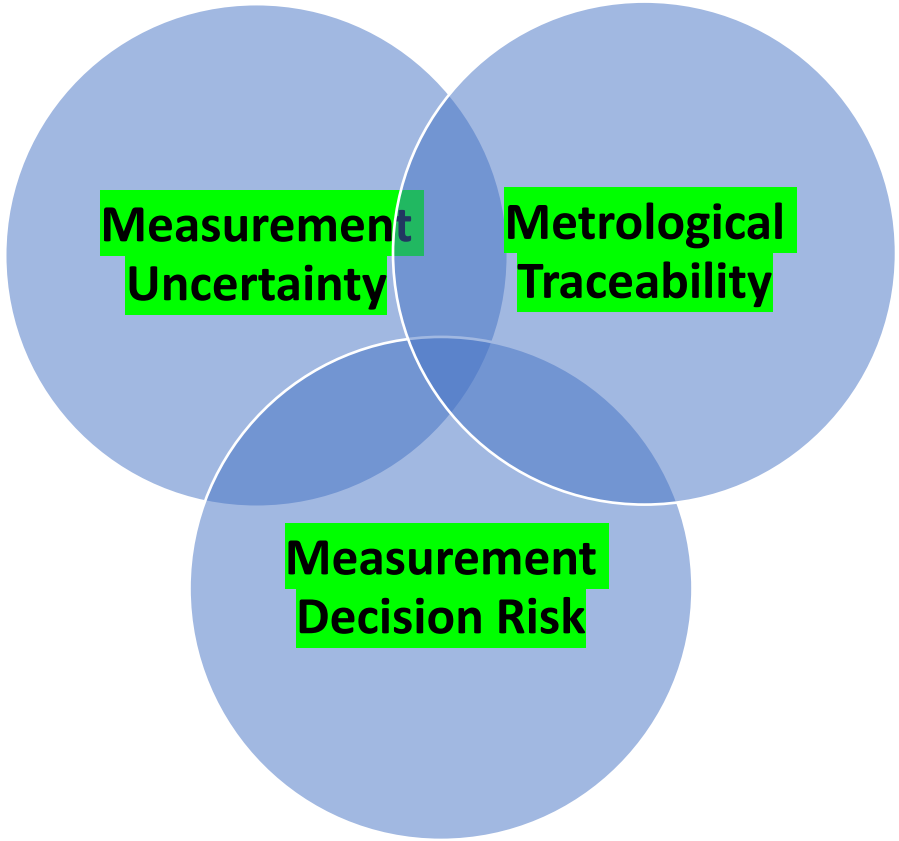
CPR for Confidence in Your Measurements



SCAN ME

Proper Evaluation of Uncertainty (DS) *(Source A2LA June 2009 Newsletter)*

"Type A"

Item #	Name	Requirement	Comment
1	Repeatability	Must have	Try getting 10 or more measurements so you have at least 9 DoF.
2	Reproducibility	If possible	i.e long term data.
3	Stability / Drift	If possible	See item 6 in Type B Table
4	Others	If possible	

"Type B"

Item #	Name	Requirement	Comment
5	Reference value from the Accredited, Traceable Certificate	Must have	With this value listed you have proof of traceability
6	Absolute Specification for calibration interval	Must have to check if item 5 is less than item 6	Also, if you have long term stability for this parameter for this range, you can set the multiplier/divisor to 0.
7	Resolutions of standards used	Always list	This is usually small to the rest, but there are exceptions.
8	Resolution of UUT	Always list	This is usually small to the rest, but there are exceptions.
9	Environmental effects	Must have There can be multiple lines for it	This is usually small to the rest, but there are exceptions.
10	Any other entries that might be helpful for others		

Calculating Repeatability and Reproducibility

- Take Repeatability data, compile R&R. Sounds simple right?

	Tech 1	Tech 2	Tech 3
Nom. Value ->	100	100	100
1	100.000 309	99.999 849	99.999 929
2	100.000 328	100.000 095	100.000 026
3	100.000 058	99.999 821	100.000 192
4	100.000 149	100.000 102	100.000 001
5	100.000 304	100.000 022	100.000 081
6	99.999 830	100.000 136	99.999 833
7	100.000 139	100.000 506	99.999 744
8	100.000 213	99.999 669	100.000 025
9	100.000 353	99.999 681	100.000 072
10	100.000 271	99.999 820	100.000 227

Group Mean	**100.000 060**		
Mean	100.000 196	99.999 970	100.000 013
StdDev	0.000 160 30	0.000 254 91	0.000 148 48
DOF	9	9	9
Sum of Squares (SS)	2.31273E-07	5.84805E-07	1.98413E-07
	Group (Tech) 1	Group (Tech) 2	Group (Tech) 3

Error of SS	1.01449E-06	
Total DOF	27	(in UOM)
Repeatability	0.000 193 84	1.94
Reproducibility	0.000 119 70	1.20

Calculating Repeatability and Reproducibility

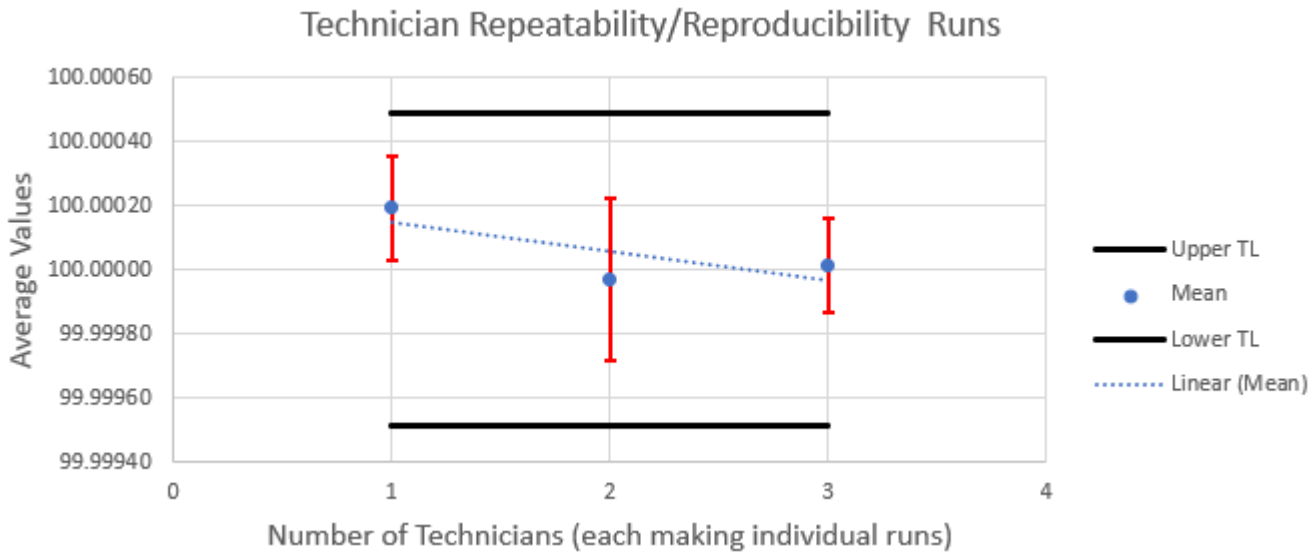
- Anything look out of place?

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*	*% of Total Variance*
Tech 1	10	1000.001 955	100.000 196	25.697E-09	22.8%
Tech 2	10	999.999 701	99.999 970	64.978E-09	57.6%
Tech 3	10	1000.000 130	100.000 013	22.046E-09	19.6%

ANOVA - Single Factor

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	2.86563E-07	2	1.43282E-07	3.813351641	3.478%	3.354130829
Within Groups	1.01449E-06	27	3.75737E-08			
Total	1.30105E-06	29				



The Correct Definition and Calculation of TUR (HZ)

$$\text{T.U.R.} = \frac{\text{U.U.T. Tolerance}}{\text{Calibratio n Process Uncertain ty}}$$

- **The ratio of the span of the tolerance of a measurement quantity subject to calibration to twice the 95% expanded uncertainty of the measurement process used for calibration.** ANSI/NCSLI Z540.3-2006

- **The ratio of the tolerance, TL, of a measurement quantity, divided by the 95% expanded measurement uncertainty of the measurement process where TUR = TL/U.** ILAC G8:2019

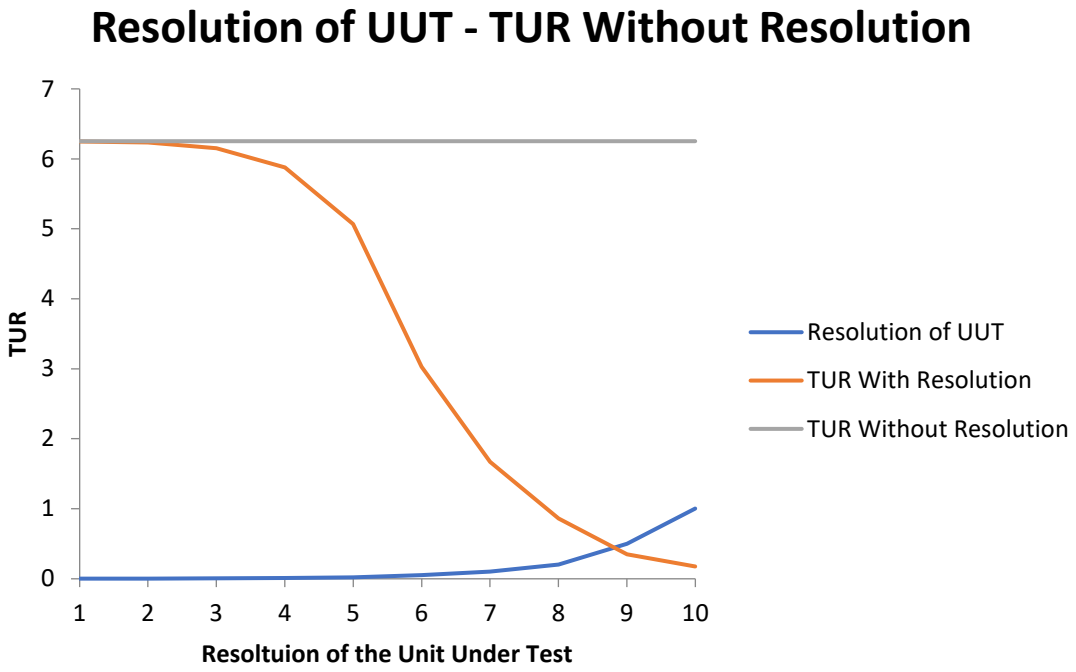
The Correct Definition and Calculation of TUR (HZ)

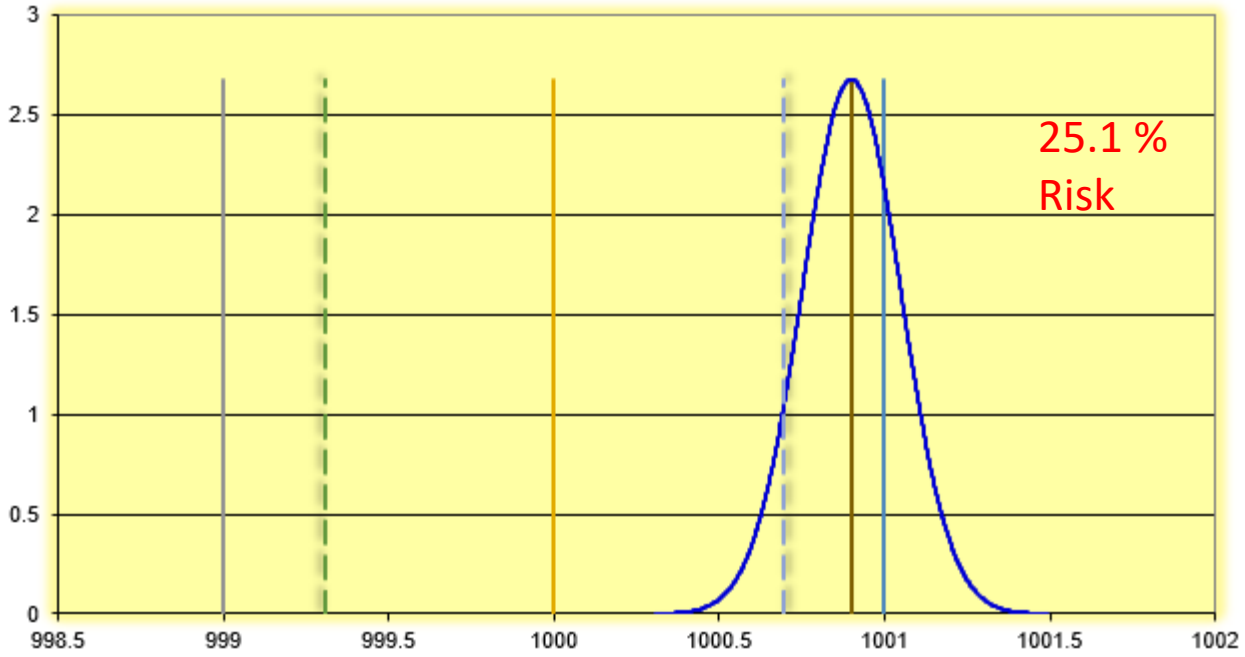
$$\mathbf{TUR} = \frac{\mathbf{Span\ of\ the\ \pm Tolerance}}{\mathbf{2\ x\ k_{95\%}}\left(\sqrt[2]{\left(\frac{\mathbf{CMC}}{\mathbf{k_{CMC}}}\right)^2 + \left(\frac{\mathbf{Resolution_{UUT}}}{\sqrt[2]{12}}\right)^2 + \left(\frac{\mathbf{Repeatability_{UUT}}}{1}\right)^2 + \cdots (u_{Other})^2}\right)}$$

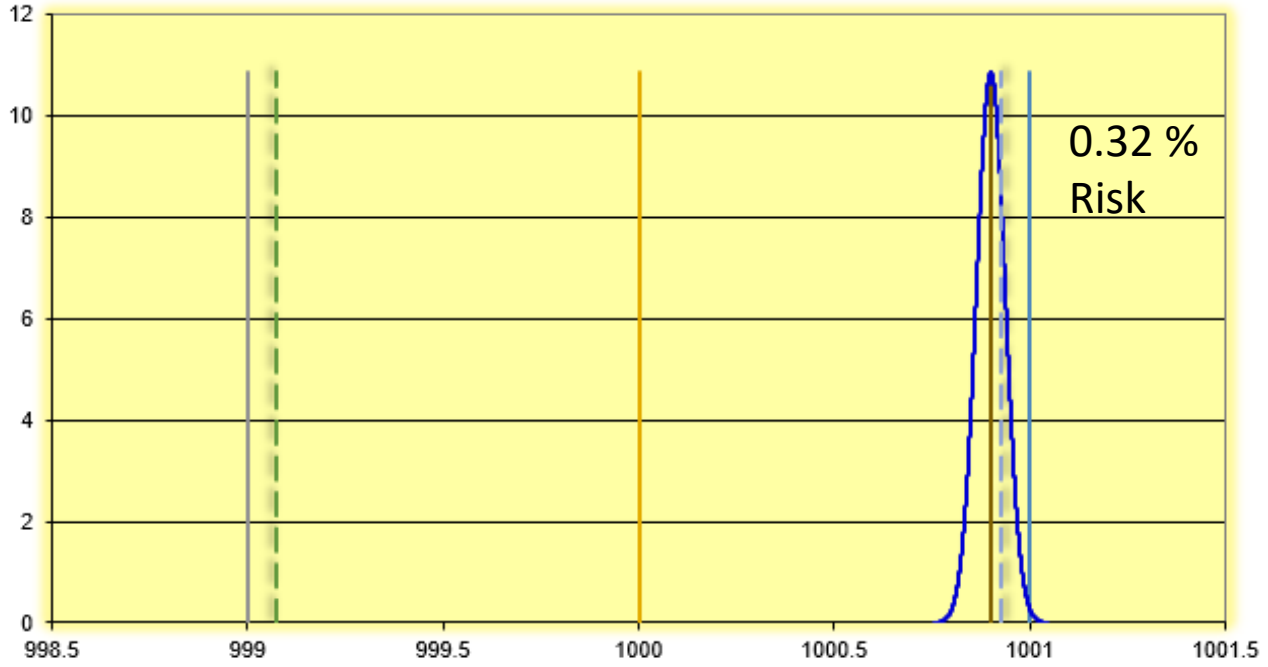
Example of a TUR Formula (Adapted from the ANSI/NCSL Z540.3 Handbook)

- This definition of the TUR from ANSI/NCSL Z540.3 Handbook aligns very closely with ILAC P14:09/2020, which states, "Contributions to the uncertainty stated on the calibration certificate shall include relevant short-term contributions during calibration and contributions that can reasonably be attributed to the customer's device. Where applicable, the uncertainty shall cover the same contributions to uncertainty that were included in evaluation of the CMC uncertainty component, except that uncertainty components evaluated for the best existing device shall be replaced with those of the customer's device. Therefore, reported uncertainties tend to be larger than the uncertainty covered by the CMC."

Resolution

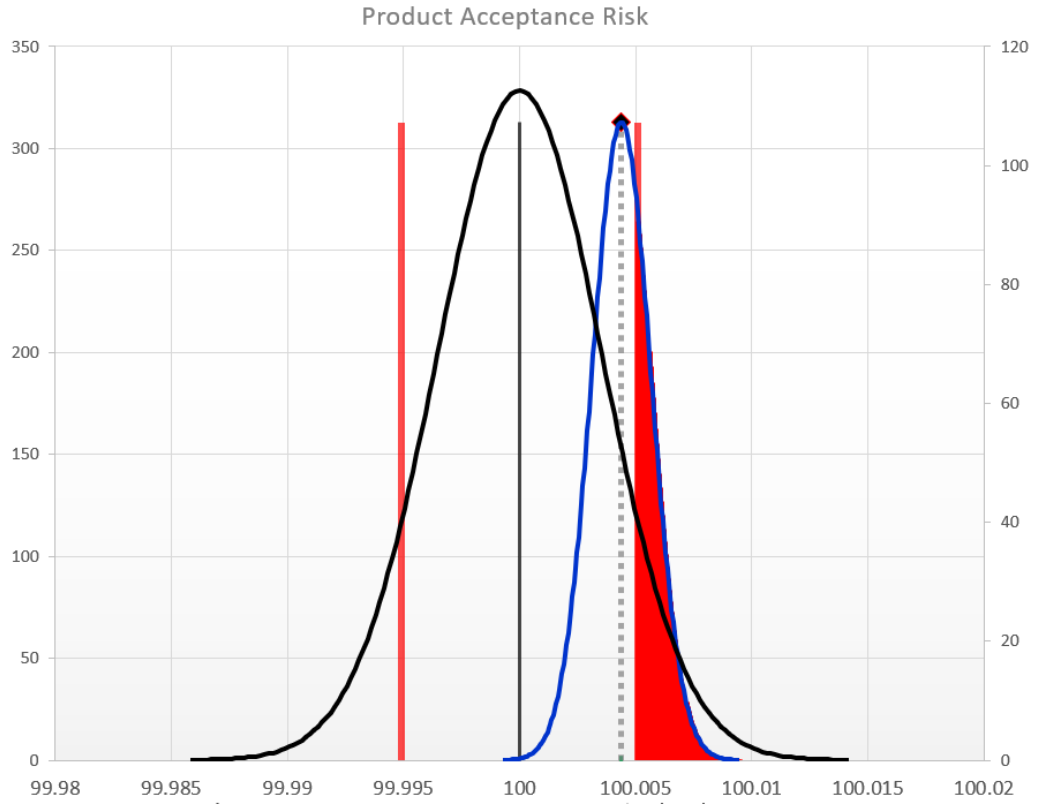

Resolution of UUT - TUR Without Resolution
TUR
Resoltuion of the Unit Under Test
Resolution of UUT
TUR With Resolution
TUR Without Resolution


25.1 %
Risk

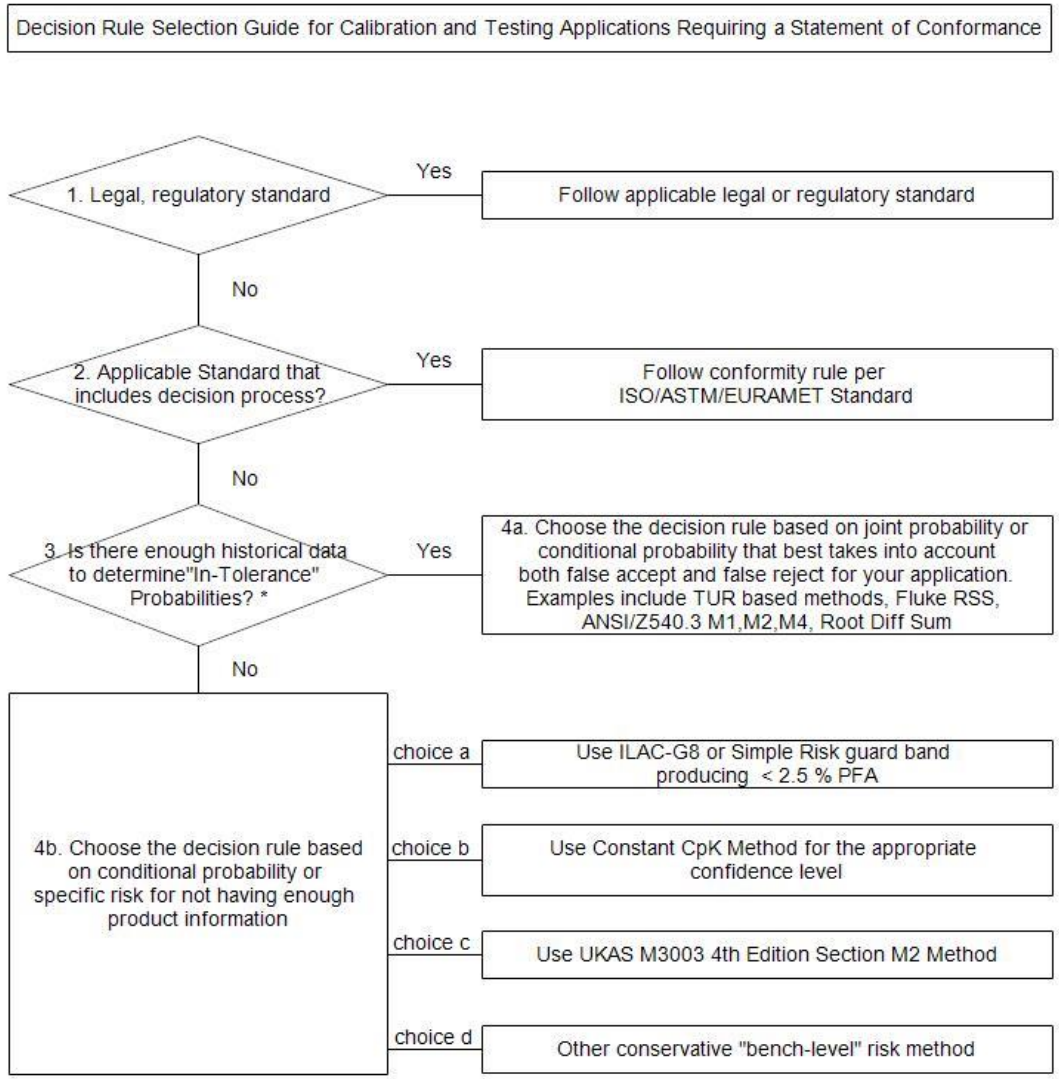

0.32 %
Risk

Global Consumers' Risk in Evaluation of Decision Rules

Data Input	Direct Measurements Reported Result
Nominal Value (Engineering Units)	100
Lower Specification Limit(±0.0045 %)	99.9949
Upper Specification Limit(±0.0045 %)	100.0051
Measured Value =	100.004 382
Combined Std. Uncty (k=1)	0.001275
In-Tolerance Probability =	71.338%
Total Risk =	**28.662%**
Upper Limit Risk =	28.661 850%
Lower Limit Risk =	0.000 000%
Test Uncertainty Ratio (TUR) =	2.00
Process Capability (C_{pk}) =	0.188
Customer (Consumer) Risk =	1.8513%
Lab (Producer) Risk =	1.3986%
Test Point PFR =	10.8513%
Beginning of Period Reliability =	98.1487%

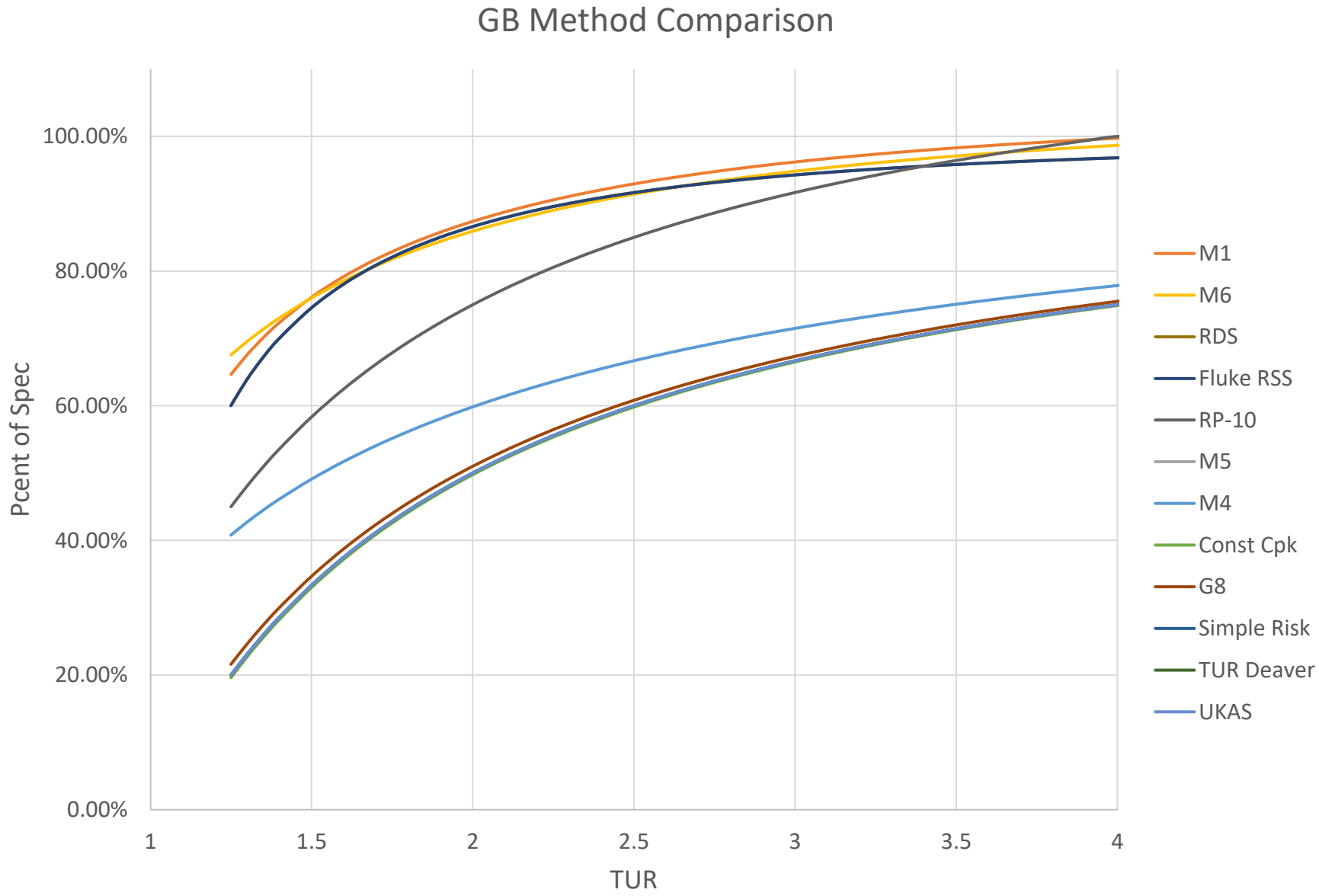


Selecting the Appropriate Decision Rules (HZ)



*3. *Note: The formula to determine "In-Tolerance" Probability from historical data is*
SampleSize = ln(1-Confidence)/ln(Target $_{\text{Reliability}}$)

Selecting the Appropriate Decision Rules (GC)



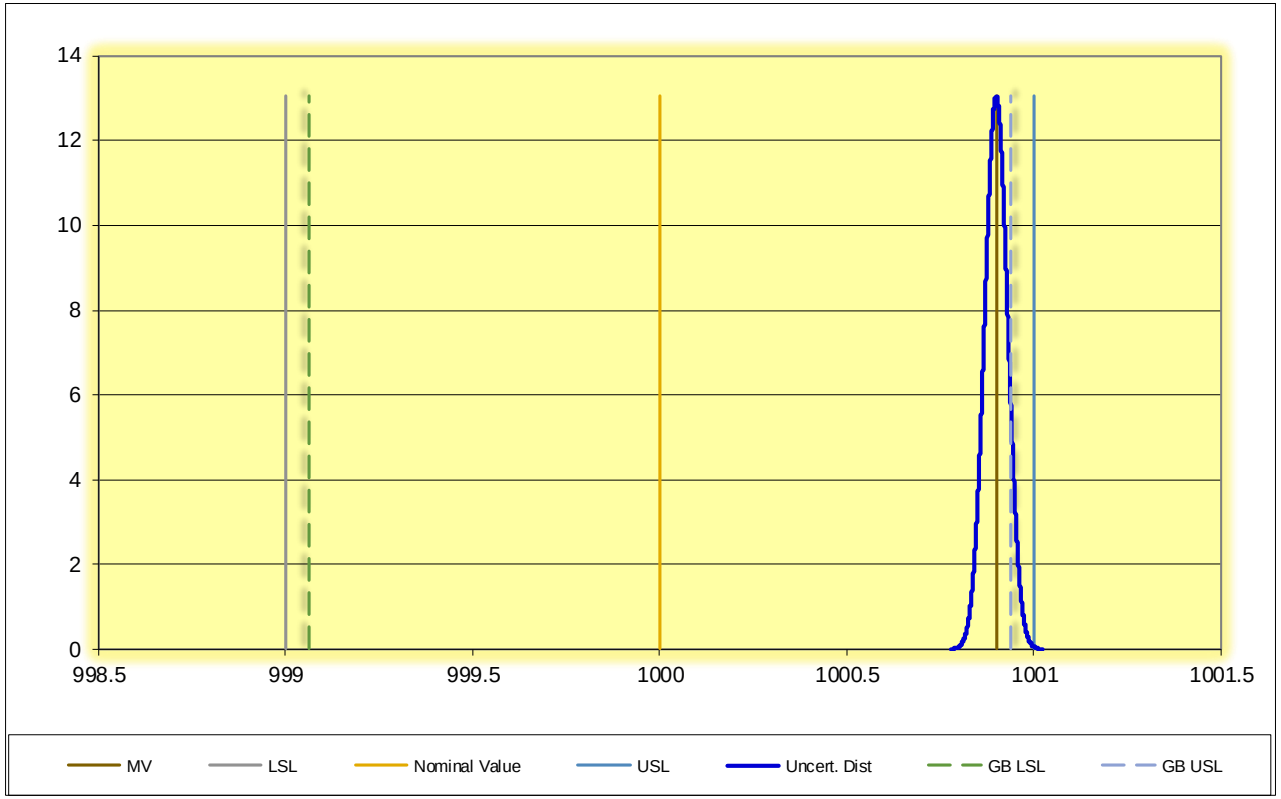
Global Consumers' Risk in Evaluation of Decision Rules (DS)

Global consumer's risk is defined in JCGM 106:2012. The role of CPU in conformity assessment is defined as "the probability that a non-conforming item will be accepted based on a future measurement result."

If only one tier of the calibration chain cares about the measurement decision risk, then the whole process is at risk. When this risk is propagated throughout succeeding tiers, can we expect the process to work properly?

Why Cpk Might be the Most Useful Tool in Making Conformity Decisions (HZ)

Nominal Value	**1000.0**
Lower specification Limit	999.0
Upper Specification Limit	1001.0
Measured Value	**1000.9**
Measurement Error	0.9
Std. Uncert. (k=1)	**0.031**
Total Risk	**0.05%**
Upper Limit Risk	0.05%
Lower Limit Risk	0.000%
TAR=	50
TUR =	**16.36591312**
Cpk=	**1.669991134**
Simple Guard Band with Subtraction Uncertainty Only	
Guard Band LSL	**999.061**
Guard Band USL	**1000.9389**
Guard Band Limits for Risk of	2.00%
Guard Band LSL	**999.063**
Guard Band USL	**1000.937**



CpK = min(((USL-Measured Value)/ 3 x Std. Uncertainty)),((Measured Value – LSL)/3 x Std. Uncertainty)))

Why Cpk Might be the Most Useful Tool in Making Conformity Decisions (GC)

Std Unc

k =1	TUR	Pcent	Lower Limit	Upper Limit	Measured Value	P(In-Tol)	P(OOT)	LL Risk	UL Risk	Total Risk	Cpk
0.004 808	1.04	3.85%	100.000	100.000	100.000	96.19%	3.81%	1.54%	2.27%	3.81%	0.6667
0.004 386	1.14	12.28%	99.999	100.001	100.001	97.20%	2.80%	0.52%	2.27%	2.80%	0.6667
0.003 906	1.28	21.87%	99.998	100.002	100.002	97.63%	2.37%	0.09%	2.28%	2.37%	0.6667
0.003 676	1.36	26.47%	99.997	100.003	100.003	97.70%	2.30%	0.03%	2.28%	2.30%	0.6667
0.003 333	1.5	33.33%	99.997	100.003	100.003	97.72%	2.28%	0.00%	2.27%	2.28%	0.6667
0.003 125	1.6	37.50%	99.996	100.004	100.004	97.72%	2.28%	0.00%	2.27%	2.28%	0.6667
0.002 941	1.7	41.18%	99.996	100.004	100.004	97.72%	2.28%	0.00%	2.27%	2.28%	0.6667
0.002 778	1.8	44.44%	99.996	100.004	100.004	97.72%	2.28%	0.00%	2.27%	2.28%	0.6667
0.002 632	1.9	47.37%	99.995	100.005	100.005	97.72%	2.28%	0.00%	2.27%	2.28%	0.6667
0.002 500	2	50.00%	99.995	100.005	100.005	97.72%	2.28%	0.00%	2.27%	2.28%	0.6667
0.002 381	2.1	52.38%	99.995	100.005	100.005	97.72%	2.28%	0.00%	2.28%	2.28%	0.6667
0.002 273	2.2	54.55%	99.995	100.005	100.005	97.72%	2.28%	0.00%	2.27%	2.28%	0.6667
0.002 174	2.3	56.52%	99.994	100.006	100.006	97.72%	2.28%	0.00%	2.27%	2.28%	0.6667
0.002 083	2.4	58.33%	99.994	100.006	100.006	97.73%	2.27%	0.00%	2.27%	2.27%	0.6667
0.002 000	2.5	60.00%	99.994	100.006	100.006	97.73%	2.27%	0.00%	2.27%	2.27%	0.6667
0.001 923	2.6	61.54%	99.994	100.006	100.006	97.72%	2.28%	0.00%	2.28%	2.28%	0.6667
0.001 852	2.7	62.96%	99.994	100.006	100.006	97.72%	2.28%	0.00%	2.28%	2.28%	0.6667
0.001 786	2.8	64.29%	99.994	100.006	100.006	97.72%	2.28%	0.00%	2.28%	2.28%	0.6667
0.001 724	2.9	65.52%	99.993	100.007	100.007	97.72%	2.28%	0.00%	2.28%	2.28%	0.6667
0.001 667	3	66.67%	99.993	100.007	100.007	97.73%	2.27%	0.00%	2.27%	2.27%	0.6667
0.001 613	3.1	67.74%	99.993	100.007	100.007	97.73%	2.27%	0.00%	2.27%	2.27%	0.6667
0.001 563	3.2	68.75%	99.993	100.007	100.007	97.73%	2.27%	0.00%	2.27%	2.27%	0.6667
0.001 515	3.3	69.70%	99.993	100.007	100.007	97.72%	2.28%	0.00%	2.28%	2.28%	0.6667
0.001 471	3.4	70.59%	99.993	100.007	100.007	97.72%	2.28%	0.00%	2.28%	2.28%	0.6667
0.001 429	3.5	71.43%	99.993	100.007	100.007	97.73%	2.27%	0.00%	2.27%	2.27%	0.6667
0.001 389	3.6	72.22%	99.993	100.007	100.007	97.73%	2.27%	0.00%	2.27%	2.27%	0.6667
0.001 351	3.7	72.97%	99.993	100.007	100.007	97.72%	2.28%	0.00%	2.28%	2.28%	0.6667
0.001 316	3.8	73.68%	99.993	100.007	100.007	97.72%	2.28%	0.00%	2.28%	2.28%	0.6667
0.001 282	3.9	74.36%	99.993	100.007	100.007	97.72%	2.28%	0.00%	2.28%	2.28%	0.6667
0.001 250	4	75.00%	99.993	100.007	100.007	97.73%	2.27%	0.00%	2.27%	2.27%	0.6667
0.001 217	4.11	75.67%	99.992	100.008	100.008	97.73%	2.27%	0.00%	2.27%	2.27%	0.6667
0.001 190	4.2	76.19%	99.992	100.008	100.008	97.73%	2.27%	0.00%	2.27%	2.27%	0.6667
0.001 163	4.3	76.74%	99.992	100.008	100.008	97.73%	2.27%	0.00%	2.27%	2.27%	0.6667
0.001 136	4.4	77.27%	99.992	100.008	100.008	97.72%	2.28%	0.00%	2.28%	2.28%	0.6667
0.001 111	4.5	77.78%	99.992	100.008	100.008	97.73%	2.27%	0.00%	2.27%	2.27%	0.6667
0.001 087	4.6	78.26%	99.992	100.008	100.008	97.72%	2.28%	0.00%	2.28%	2.28%	0.6667
0.001 064	4.7	78.72%	99.992	100.008	100.008	97.72%	2.28%	0.00%	2.28%	2.28%	0.6667
0.001 042	4.8	79.17%	99.992	100.008	100.008	97.73%	2.27%	0.00%	2.27%	2.27%	0.6667
0.001 020	4.9	79.59%	99.992	100.008	100.008	97.72%	2.28%	0.00%	2.28%	2.28%	0.6667
0.001 000	5	80.00%	99.992	100.008	100.008	97.72%	2.28%	0.00%	2.28%	2.28%	0.6667
0.000 746	6.7	85.07%	99.991	100.009	100.009	97.72%	2.28%	0.00%	2.28%	2.28%	0.6667
0.000 500	10	90.00%	99.991	100.009	100.009	97.73%	2.27%	0.00%	2.27%	2.27%	0.6667

Why Cpk Might be the Most Useful Tool in Making Conformity Decisions

$$Cpk = \text{Minimum}\left(\frac{UpperSpec - MeasuredValue}{3 \times uCal}\right), \left(\frac{MeasuredValue - LowerSpec}{3 \times uCal}\right)$$