Who Needs Another Tutorial on Risk or Decision Rules?

ASQ Measurement Quality Division
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Who Needs Another Session on Risk or Decision Rules?

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Who Needs Another Session on Risk or Decision Rules?

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IndySoft

Abstract

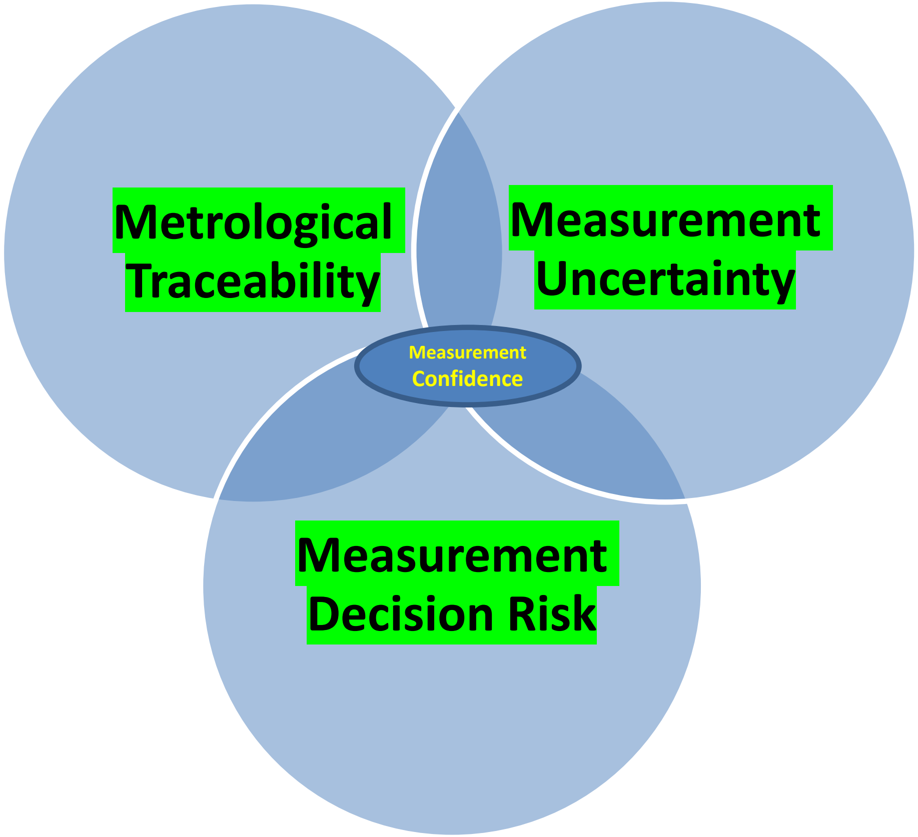
This 1-hour session will help the participant eliminate much of the noise on decision rules. It will provide guidance anyone can take away and implement in their laboratory. This session aims to give guidance beyond simply requesting a 4:1 TUR (antediluvian) or accepting a shared-risk scenario as with simple acceptance.

When a calibration report is provided, a typical concern for the customer is to know if the item calibrated is within the tolerance specified so they can continue using the device (i.e., many want a new sticker ☺).

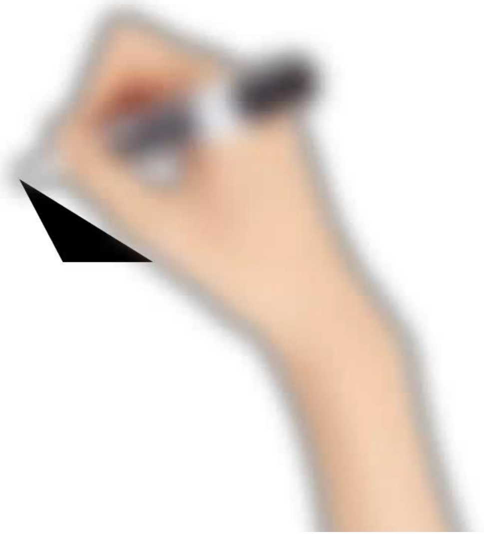
Learning Objectives

1. Understanding What Measurement Traceability is.
2. Know the role Measurement Uncertainty plays in Decision Rules.
3. Understanding the Basics of Decision Rules.
4. Be able to define Specific and Global Risk.

Measurement Confidence

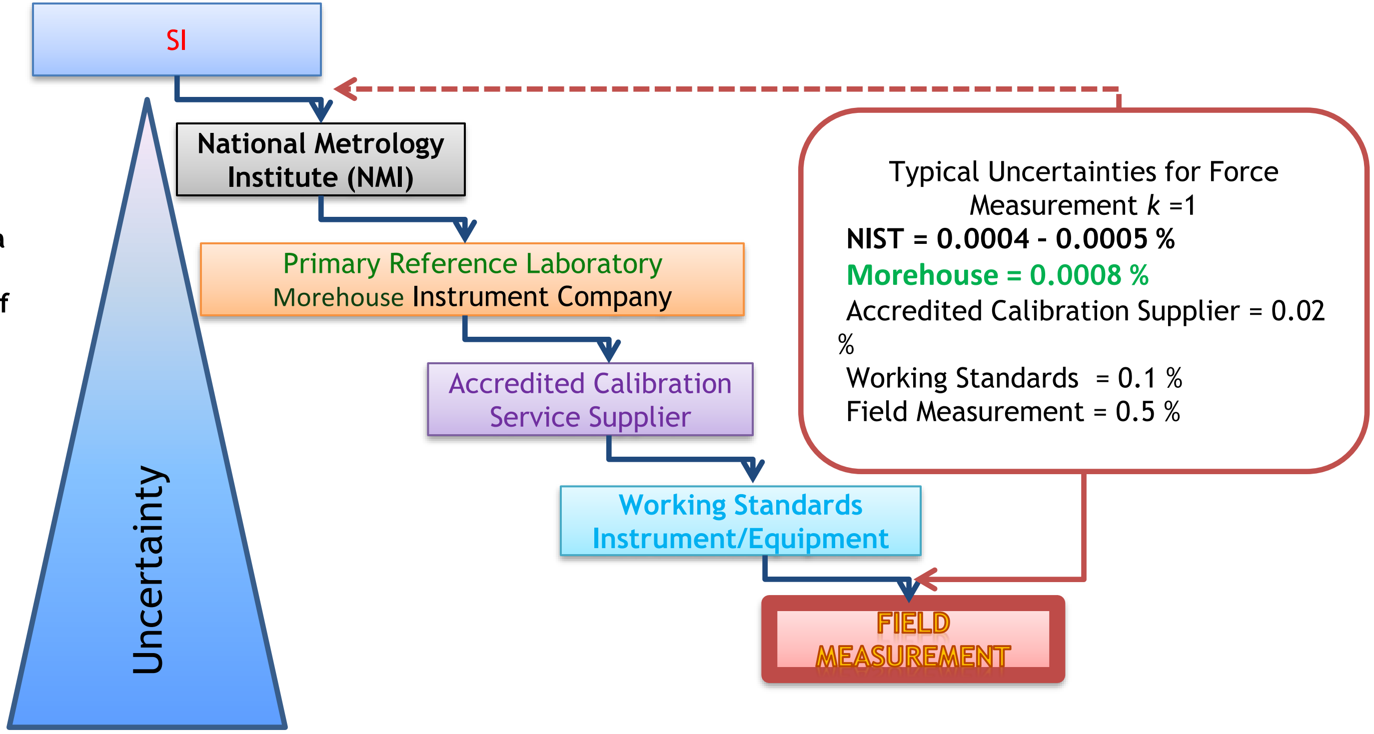


Measurement Risk Overview



Measurement Uncertainty's Relation to Measurement Hierarchy

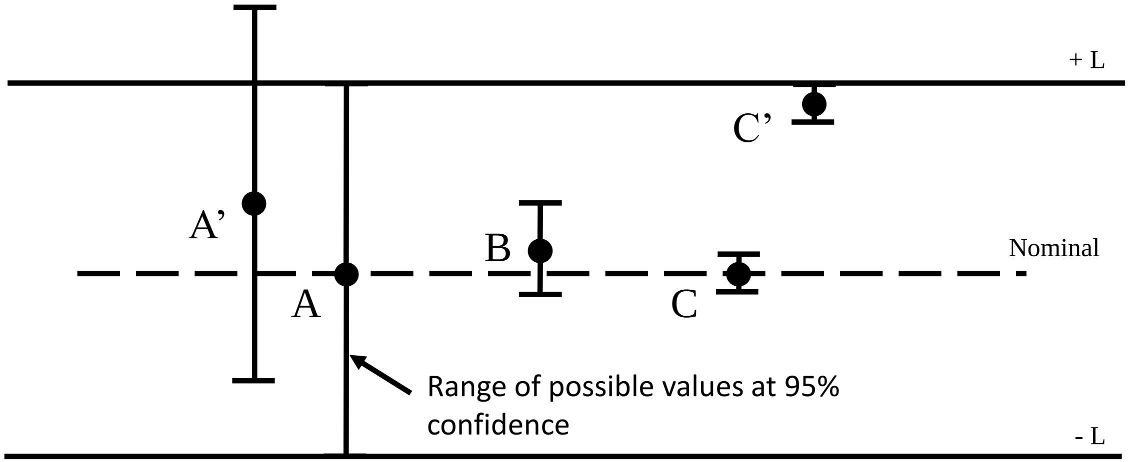
Measurement Uncertainty Data is cumulative from one level of hierarchy to another!



Introduction - Measurements, Uncertainty, and Specifications

Measurement Uncertainty: The doubt that exists about a measurement's result

- Every measurement—even the most careful—always has a margin of doubt
- Uncertainty is the inherent limitation of a measurement process, due to instrumentation and process variation
- Measurement uncertainty does not include mistakes



Measurement Uncertainty

CMC is defined as Calibration and Measurement Capability. It often includes the following standard uncertainty contributors:

- Repeatability
- Resolution
- Reproducibility
- Reference Standard Uncertainty
- Reference Standard Stability
- Environmental Factors

7.6.1 Laboratories shall identify the contributions to measurement uncertainty. When evaluating measurement uncertainty, all contributions that are of significance, including those arising from sampling shall be taken into account using appropriate methods of analysis.

Measurement Uncertainty

Let us examine CMC (Calibration Measurement Capability) using a primary standard as the reference and how it affects the Expanded Uncertainty. A **Primary Standard as the Reference (CMC 0.0016 % for *k* = 2 or 0.16 lbf @ 10K)**

Measurement Uncertainty Budget Worksheet									
Laboratory	Morehouse Primary Standards								
Parameter	FORCE	Range	10K	Sub-Range					
Technician	HZ	Standards Used							
Date									
Uncertainty Contributor	**Magnitude**	**Type**	**Distribution**	**Divisor**	**df**	**Std. Uncert**	**Variance (Std. Uncert^2)**	**% Contribution**	**u^4/df**
Reproducibiliy	000.0000E+0	A	Normal	1.000	10	000.00E+0	000.00E+0	0.00%	000.0E+0
Repeatability	57.7350E-3	A	Normal	1.000	5	57.74E-3	3.33E-3	7.51%	2.2E-6
U-7643 LLF	65.0000E-3	A	Normal	1.000	200	65.00E-3	4.23E-3	9.52%	89.3E-9
Resolution of UUT	100.0000E-3	B	Resolution	3.464	200	28.87E-3	833.33E-6		
Environmental Conditions	75.0000E-3	B	Rectangular	1.732	200	43.30E-3	1.88E-3		
Stability of Ref Standard	288.0000E-3	B	Rectangular	1.732	200	166.28E-3	27.65E-3		
Ref Standard Resolution	24.0000E-3	B	Resolution	3.464	200	6.93E-3	48.00E-6		
			None	0.000					
Morehouse CMC	160.0000E-3	B	Expanded (95.45% k=2)	2.000	200	80.00E-3	6.40E-3	14.43%	204.8E-9
			Combined Uncertainty (u_c)=			**210.62E-3**	**44.36E-3**	**100.00%**	**6.4E-6**
			Effective Degrees of Freedom			**309**			
			Coverage Factor (k) =			**1.97**			
			Expanded Uncertainty (U) K =			**0.41**	**0.00414%**		

14.43 % Contribution

Measurement Uncertainty

Let’s examine CMC (Calibration Measurement Capability) using a secondary standard as the reference and how it affects the Expanded Uncertainty.

Accredited Calibration Supplier with Secondary Standards as the Reference (CMC 0.04 % for *k* = 2 or 4 lbf)

Measurement Uncertainty Budget Worksheet									
Laboratory	Morehouse Primary Standards								
Parameter	FORCE	**Range**	10K	**Sub-Range**					
Technician	HZ	**Standards Used**							
Date									
Uncertainty Contributor	**Magnitude**	**Type**	**Distribution**	**Divisor**	**df**	**Std. Uncert**	**Variance (Std. Uncert^2)**	**% Contribution**	**u^4/df**
Reproducibiliy	000.0000E+0	A	Normal	1.000	10	000.00E+0	000.00E+0	0.00%	000.0E+0
Repeatability	378.5939E-3	A	Normal	1.000	5	378.59E-3	143.33E-3	3.43%	4.1E-3
U-7643 LLF	65.0000E-3	A	Normal	1.000	200	65.00E-3	4.23E-3	0.10%	89.3E-9
Resolution of UUT	100.0000E-3	B	Resolution	3.464	200	28.87E-3	833.33E-6		
Environmental Conditions	75.0000E-3	B	Rectangular	1.732	200	43.30E-3	1.88E-3		
Stability of Ref Standard	288.0000E-3	B	Rectangular	1.732	200	166.28E-3	27.65E-3		
Ref Standard Resolution	24.0000E-3	B	Resolution	3.464	200	6.93E-3	48.00E-6		
			None	0.000					
Accredited Cal Supplier CMC	4.0000E+0	B	Expanded (95.45% k=2)	2.000	200	2.00E+0	4.00E+0	95.74%	80.0E-3
			Combined Uncertainty (u_c)=			**2.04E+0**	**4.18E+0**	**100.00%**	**84.1E-3**
			Effective Degrees of Freedom			**207**			
			Coverage Factor (k) =			**1.97**			
			Expanded Uncertainty (U) K =			**4.03**	**0.04030%**		

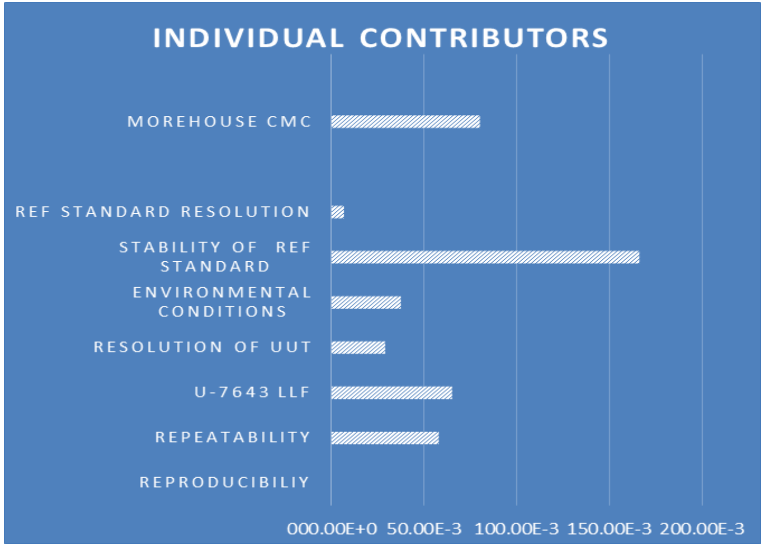
95.74 %
Contribution

Measurement Uncertainty

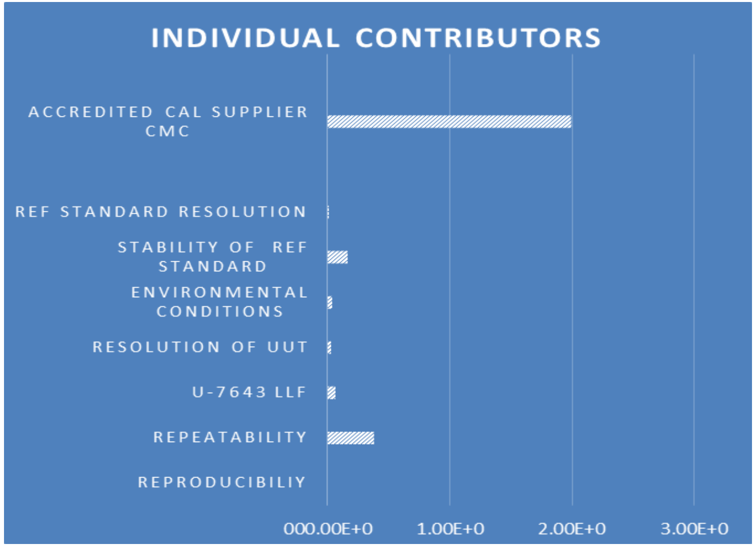
Let's examine CMC (Calibration Measurement Capability) and what the Reference CMC does to the calibration results. Deadweight Primary Standard Versus Secondary Standards

Expanded Uncertainty when calibrated with Primary Standards is approximately 10 times lower than using secondary standards

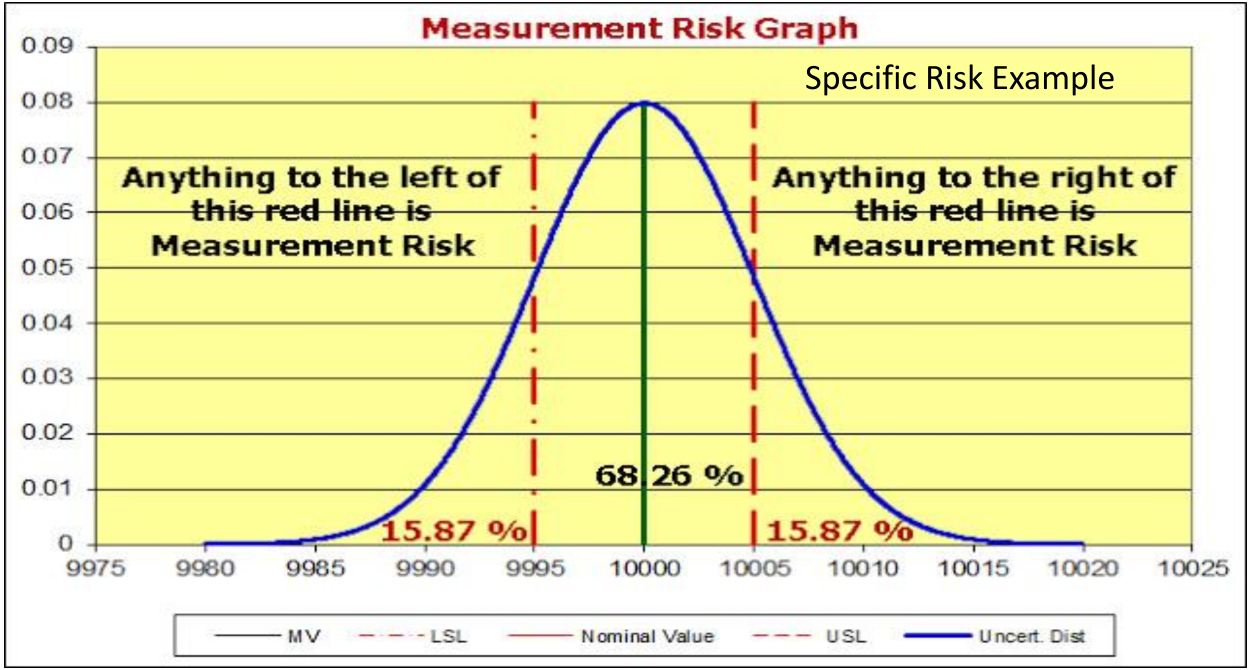
Expanded Uncertainty @ 10K = 0.41 lbf
Morehouse CMC = 0.16 lbf
Repeatability = 0.057 lbf



Expanded Uncertainty @ 10K = 4.03 lbf
Accredited Cal Supplier CMC = 4.00 lbf
Repeatability = 0.379 lbf



Measurement Decision Risk Uncertainty



ISO/IEC 17025: 2017 Section 3.7 defines a decision rule as a rule that describes how measurement uncertainty is accounted for when stating conformity with a specified requirement.

A calibration laboratory cannot make a statement of conformity or "Pass" an instrument without violating ISO/IEC 17025:2017, as section 3.7 defines a Decision Rule as a rule that describes how measurement uncertainty is accounted for when stating conformity with a specified requirement. Some may argue that you can take it into account by ignoring it.

To that end, can we all decide to take all red stoplights into account and start ignoring them?

- UKAS LAB 48 Decision Rules and Statements of Conformity

Types of Risk (Errors)

Type I - Type II Error			
		Calibration	
		In Tolerance (GOOD)	**Out Of Tolerance (BAD)**
Decision Made	**Called In Tolerance - ACCEPT**	**(1-α)** ***Calibration Lab's Confidence (Probability of Correct Accept - PCA)***	**β** ***Type II Error (Probability of False Accept - PFA)***
	Called Out of Tolerance - REJECT	**α** ***Type I Error (Probability of False Reject - PFR)***	**(1- β)** ***End User's Confidence (Probability of Correct Reject - PCR)***

Types of Risk (Errors)

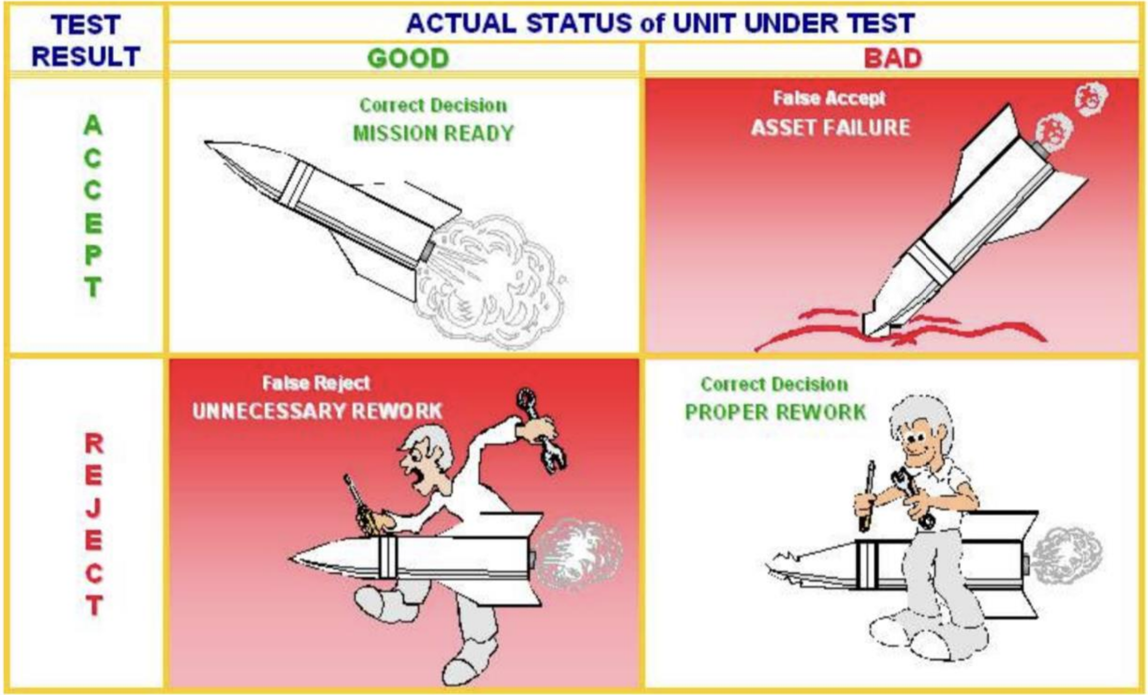


Image from NAVSEA (asq711.org)

Consumer and Producer Risk

There are two general types of risks associated with conformity decisions.

Consumer Risk:

The probability that a non-conforming item is accepted. Also known as Type II error, pass error, false accept risk (FAR), and probability of false acceptance (PFA).

Producer Risk:

The probability that a conforming item is rejected. Also known as Type I error, fail error, false reject risk (FRR), and probability of false reject (PFR).

Consumer risk can have potential negative impacts to product/system performance.

Producer risk has a direct impact on the cost of manufacturing, testing and/or calibration.

Consumer and Producer Risk

Consumer Risk, depending on the criticality of the measurement, can lead to:

- Loss of life or mission
- Reduced end-item function, capacity, or utility
- Warranty expenses
- Damage to corporate reputation
- Loss of future sales
- Punitive damages
- Legal fees, etc

Producer Risk can result in additional costs because of:

- Unnecessary rework, adjustments, repairs, and retests
- Increased scrap of good product
- Increased frequency of inspections or calibrations
- Decreased availability of the hardware
- Out-of-tolerance reports or administrative reaction (reverse traceability reports)

Consumer and Producer Risk

Specific Risk (also called bench-level risk) is based on a specific measurement result.

It triggers a response based on measurement data gathered at time of test.

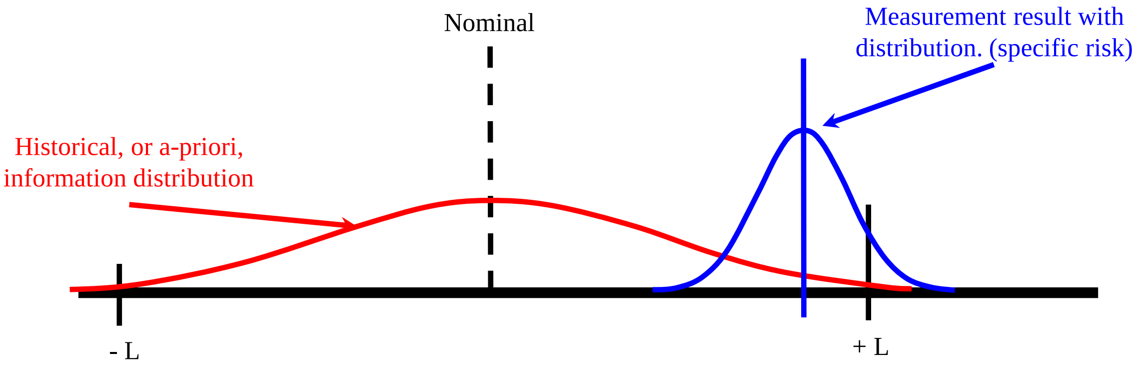
It may be characterized by one or two probability distributions, depending on the method.

Any representation with only one probability distribution is always a specific risk method.

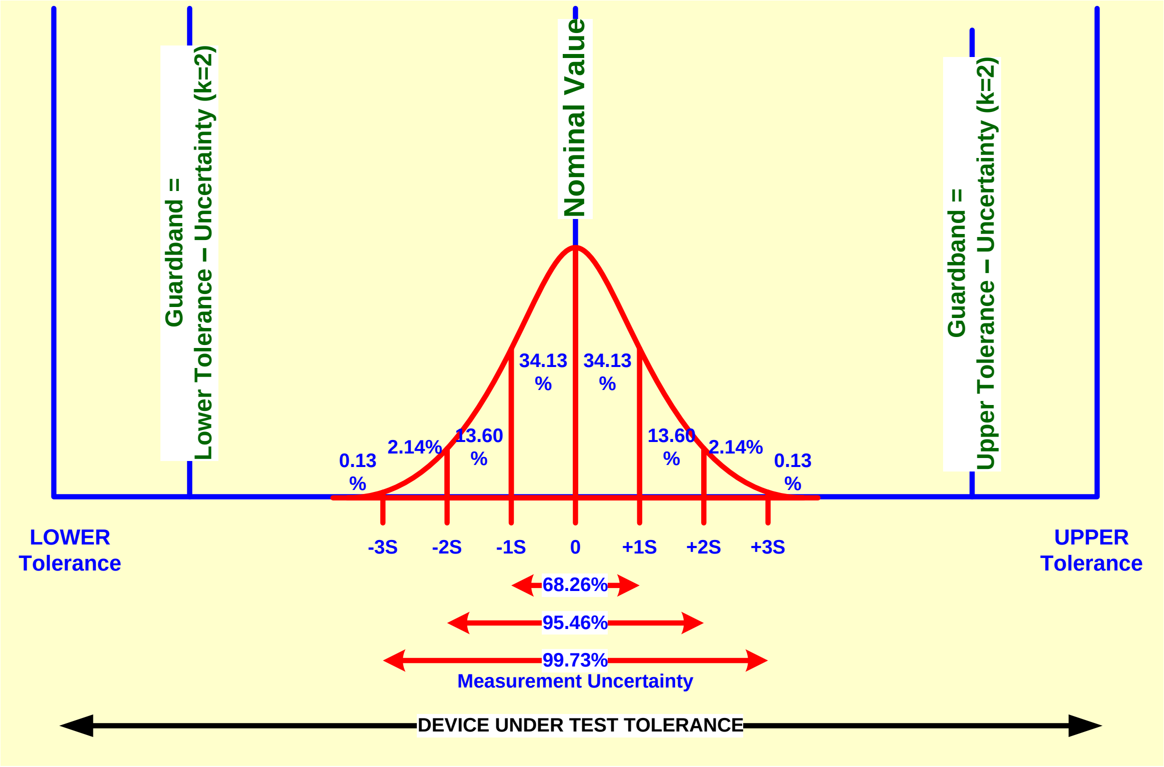
Global Risk (also called process-level risk) is based on a future measurement result.

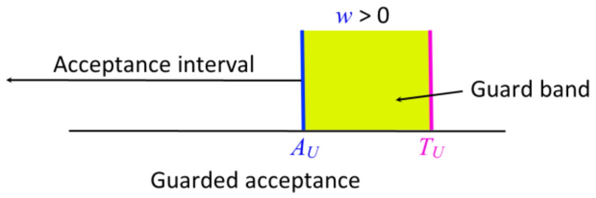
It is used to ensure the acceptability of a documented measurement process.

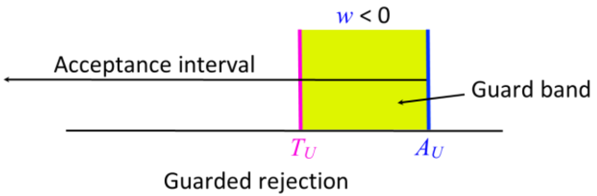
It is based on expected or historical information and is usually characterized by two probability distributions.



Instrument Measurement Uncertainty Guard Banding







Statement of Conformity

When performing a measurement and subsequently making a statement of conformity, for example, in or out-of-tolerance to the manufacturer's specifications or Pass/Fail to a particular requirement, there are two possible outcomes:

a. The result is reported as conforming with the specification

b. The result is reported as not conforming with the specification

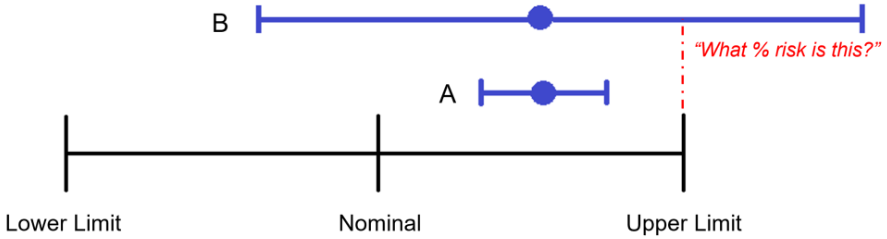
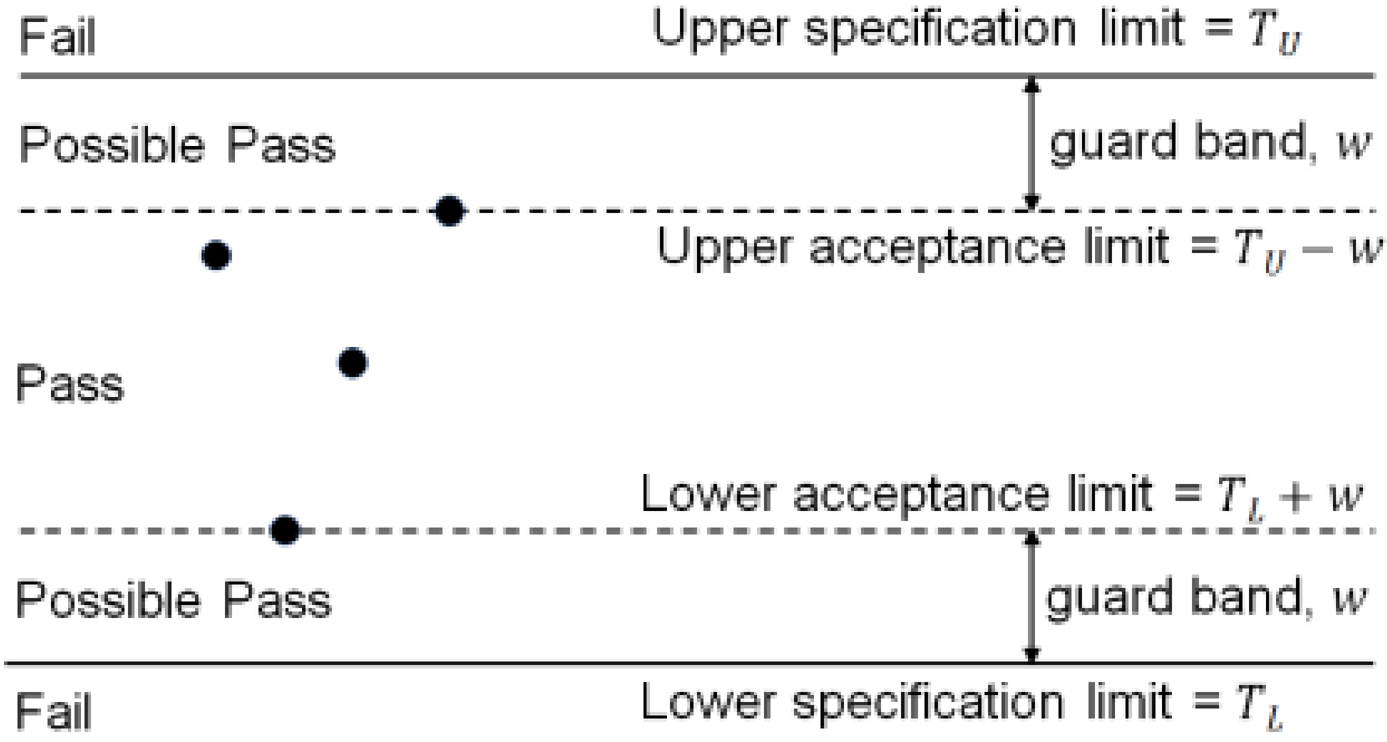


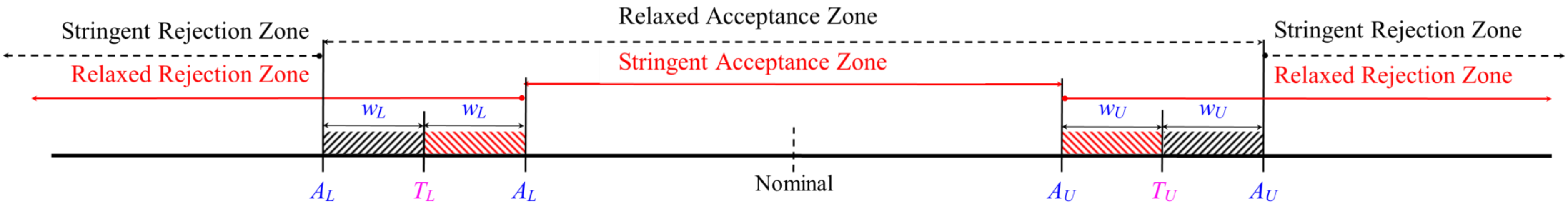
Illustration of Measurement Decision Risk

Non-Binary Statement with Guard Band

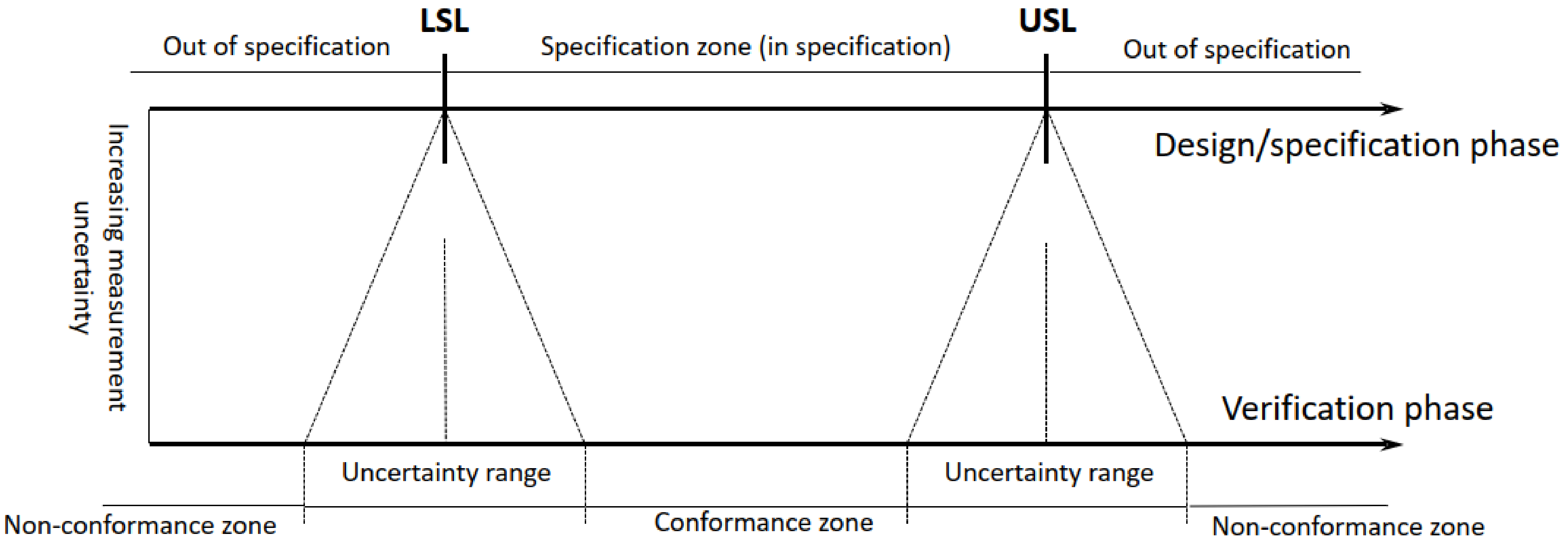


Example from UKAS LAB 48

ASME B89.7.3.1-2001 – Specific Risk



The Size of Acceptance limits is Determined by the Measurement Uncertainty and Desired Risk Level.



ISO 14253-1:2017

Classic 50 % risk scenario with “Simple Acceptance” at the bench level (w = 0), No Guard Band.

Risk Calculator	
Upper Tolerance T_U	1500.2000
Lower Tolerance T_L	1499.8000
Nominal Value	1500.0000
Measurement Unc um	0.0400
Measured Value xm	1500.2000
Tolerance T	0.40

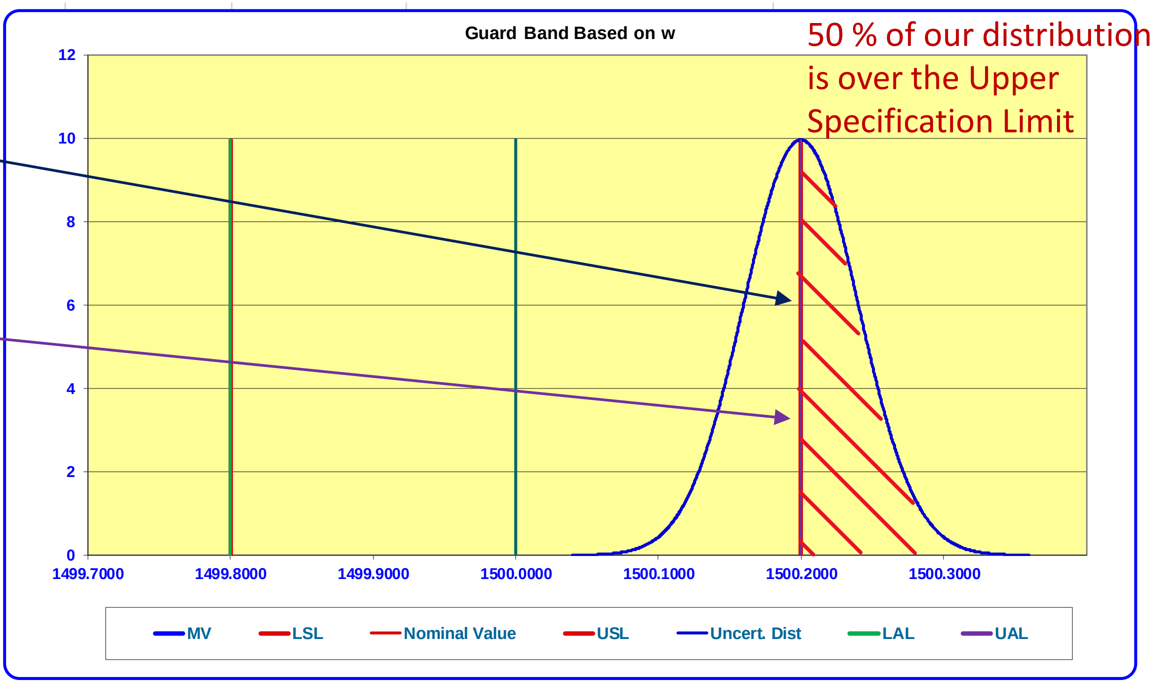
Probability of Conformance (p_c)	50.000%
Probability of NonConformance ($1 - p_c$)	50.000%

Setting the Guard Band Upper and Lower AL	
Guard Band Upper G_u (AL= TL - w)	1500.2000
Guard Band Lower G_L (AL = TL + w)	1499.8000

Setting AL based on Guard Band	
r	0.0000
$w = U_{95} * r$	0.00000
C_m	2.50000

Setting AL based on Guard Band w	
Upper Acceptance Limit	PASS
Lower Acceptance Limit	PASS

Area of Curve Outside of the AL	50.000%



Star Wars Example

With a 2-meter hole and a 0.5-meter Photon Torpedo.

What would be the acceptance limits using a specific risk example?

Star Wars Example – AL for 2.5 % Maximum risk

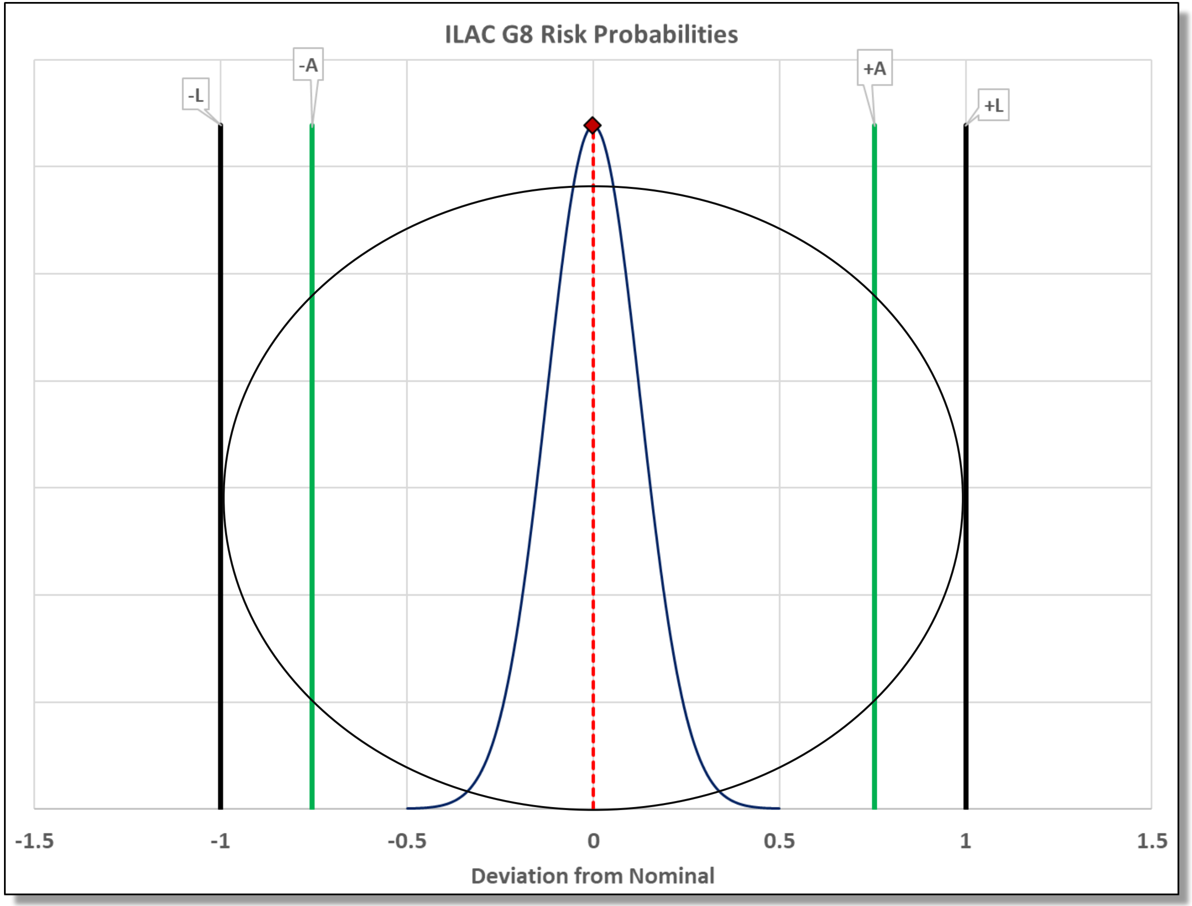
Risk Calculator	
Upper Tolerance T_U	1
Lower Tolerance T_L	-1
Nominal Value (default = blank, otherwise 0)	
Measured Value xm	0.0000
Measurement Unc um	0.1250
Maximum Allowable Risk	2.50%
Tolerance T	2.00

Probability of Conformance (p_c)	100.000%
Probability of NonConformance (1 - p_c)	0.000%

Setting the Guard Band Upper and Lower AL	
Guard Band Upper G_u (AL= TL - w)	0.7550
Guard Band Lower G_L (AL = TL + w)	-0.7550

Setting AL based on Probability of Conformance	
Probability of Conformance (pc)	97.50%
r	0.9800
$w = U_{95} * r$	0.24500
C_m (TUR)	4.00000

Setting AL based on Guard Band w	
Upper Acceptance Limit	PASS
Lower Acceptance Limit	PASS



Star Wars Example – Measured Value not Centered

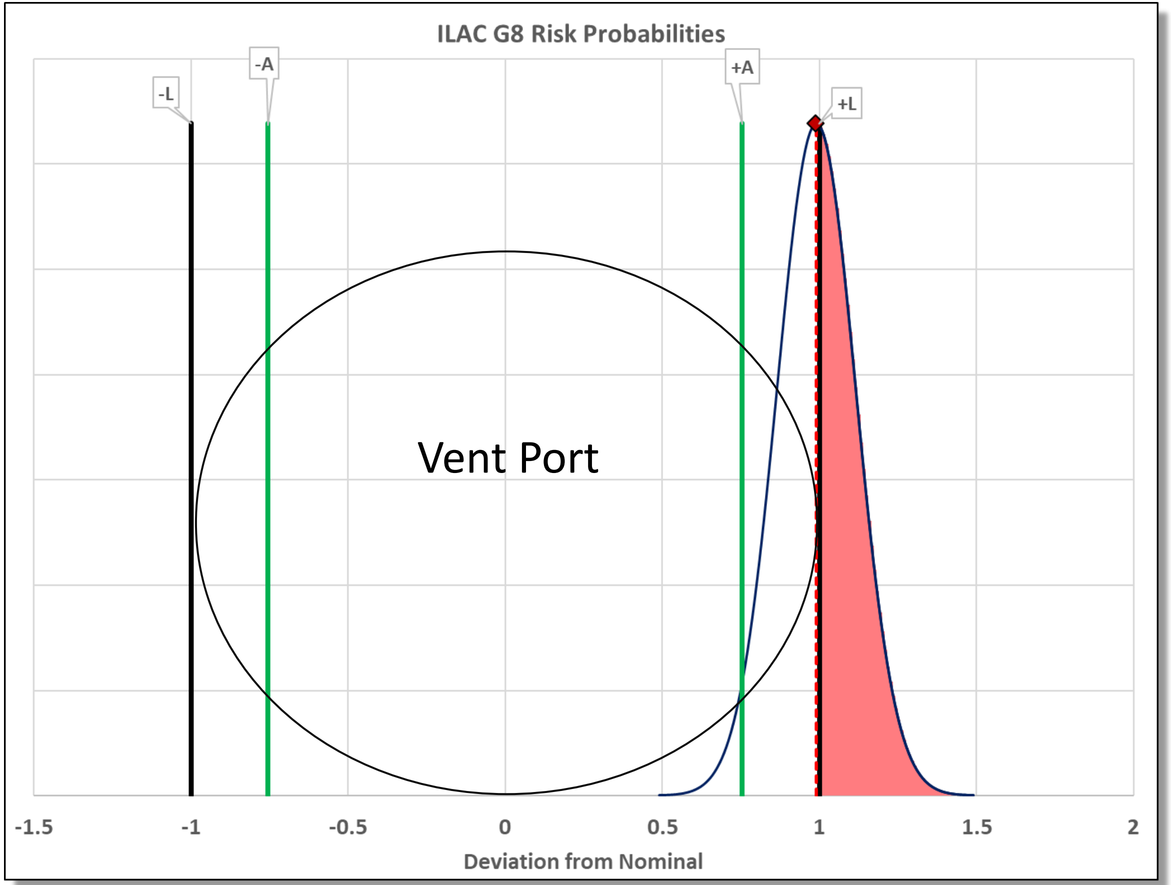
Risk Calculator	
Upper Tolerance T_U	1
Lower Tolerance T_L	-1
Nominal Value (default = blank, otherwise 0)	
Measured Value xm	0.9900
Measurement Unc um	0.1250
Maximum Allowable Risk	2.50%
Tolerance T	2.00

Probability of Conformance (p_c)	53.188%
Probability of NonConformance (1 - p_c)	46.812%

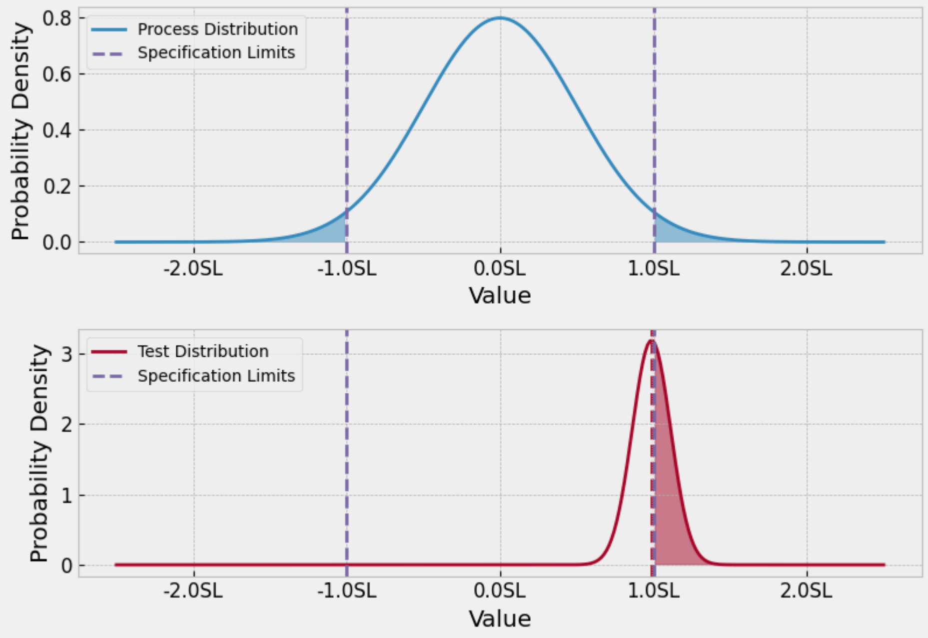
Setting the Guard Band Upper and Lower AL	
Guard Band Upper G_u (AL= TL - w)	0.7550
Guard Band Lower G_L (AL = TL + w)	-0.7550

Setting AL based on Probability of Conformance	
Probability of Conformance (pc)	97.50%
r	0.9800
w = U_{95} * *r*	0.24500
C_m (TUR)	4.00000

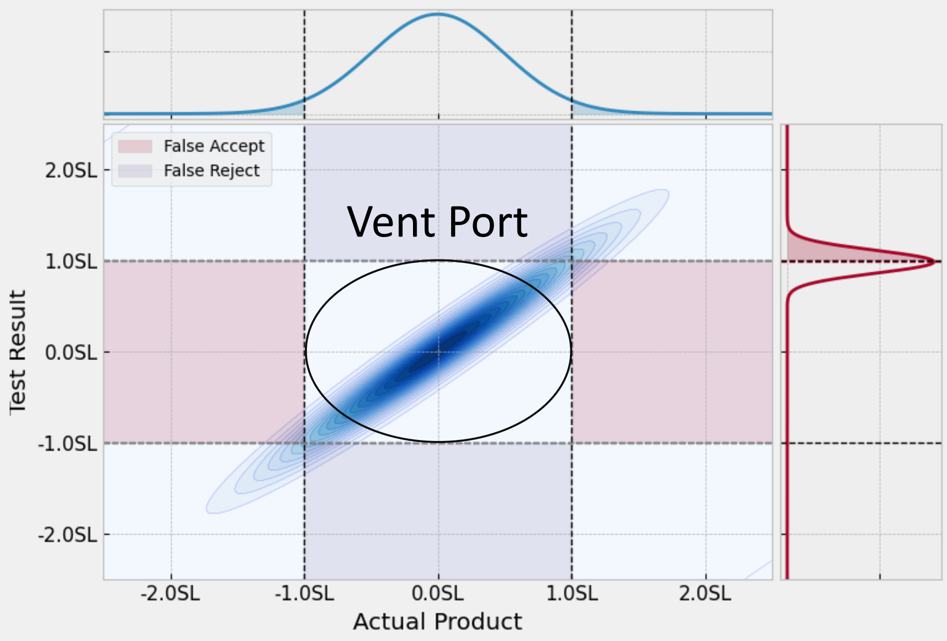
Setting AL based on Guard Band w	
Upper Acceptance Limit	FAIL
Lower Acceptance Limit	PASS



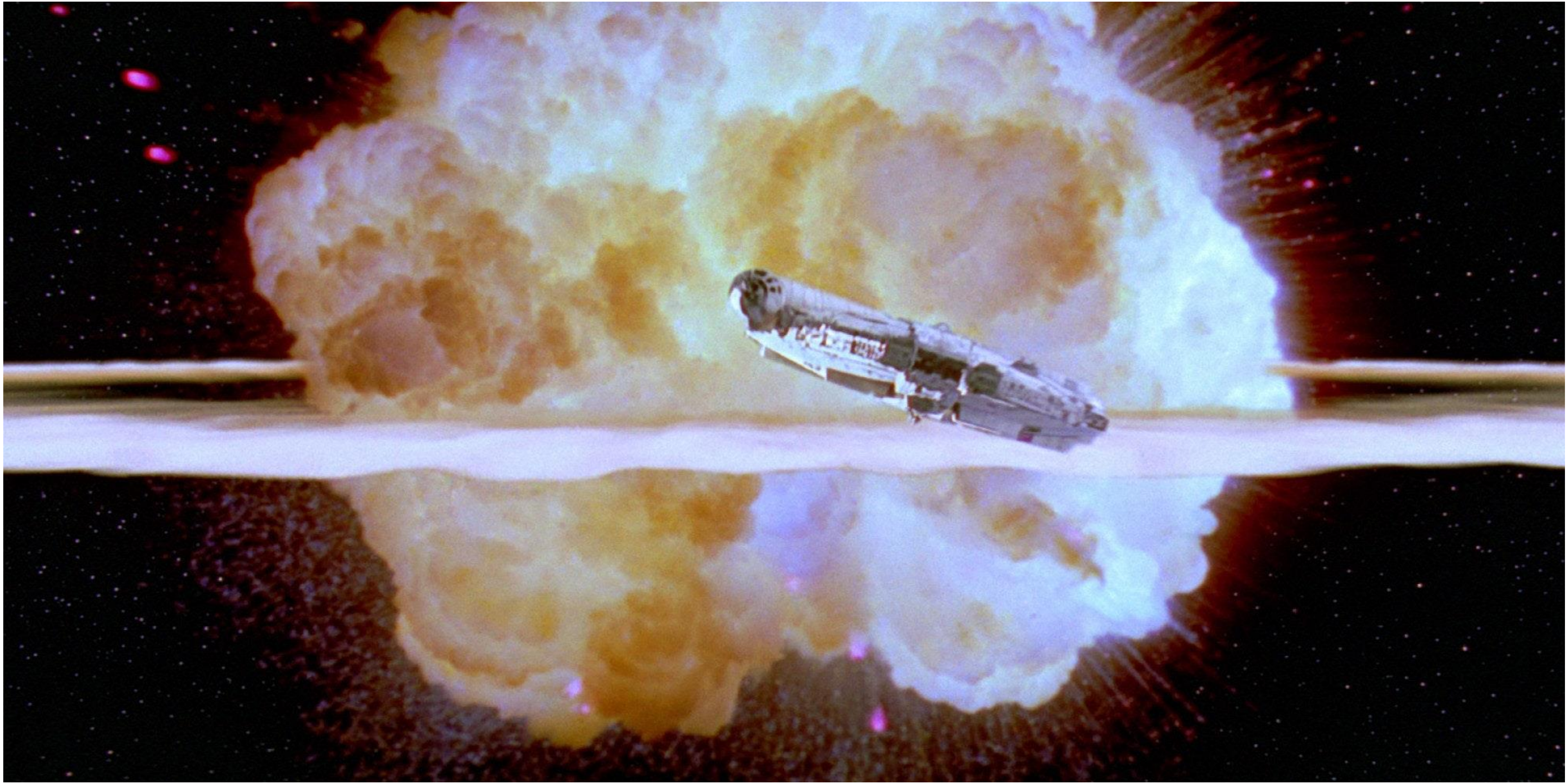
Star Wars Example



Process Risk	Specific Measurement Risk	Global Risk
Process Risk: 4.6%	TUR: 4.0	Total PFA: 0.79%
Upper limit risk: 2.3%	Measured value: 0.99	Total PFR: 1.5%
Lower limit risk: 2.3%	Result: ACCEPT	-
Process capability index (Cpk): 0.67	Specific FA Risk: 46%	-



Process Risk	Specific Measurement Risk	Global Risk
Process Risk: 4.6%	TUR: 4.0	Total PFA: 0.79%
Upper limit risk: 2.3%	Measured value: 0.99	Total PFR: 1.5%
Lower limit risk: 2.3%	Result: ACCEPT	-
Process capability index (Cpk): 0.67	Specific FA Risk: 46%	-



Global Risk

Global Risk (also called process-level risk) is based on a future measurement result.

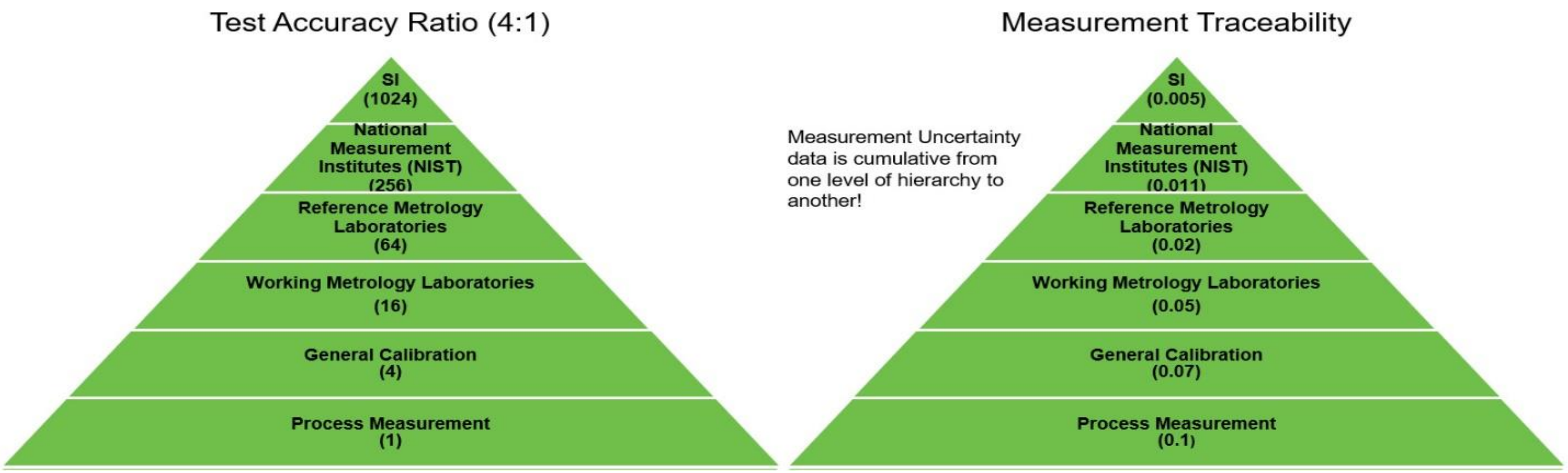
It is used to ensure the acceptability of a documented measurement process.

It is based on expected or historical information and is usually characterized by two probability distributions.

The term TUR (Test Uncertainty Ratio) is commonly used as a simplified approach to evaluating global risk. When we know the tolerance, we are working to, we have a high enough sample size to know the shape and the distribution of the calibration results.

We can then use TUR with End of Period reliability, or even by itself, to calculate the appropriate uncertainty that corresponds to the maximum amount of false accept risk we are okay with.

Outdated Practices Can Lead to Higher Risk



In *Measurement Decision Risk – The Importance of Definitions*, Scott M. Mimbs provides an example of a digital micrometer using a TAR 25:1 ratio. Comparing this example with the definition of TUR found in the ANSI/NCSL Z540.3 Handbook produces a 1.5:1 ratio for the same measurement.

Test Uncertainty Ratio (TUR)

Test Uncertainty Ratio: 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.

NOTE: This applies to two-sided tolerances.

ANSI/NCSL Z540.3 – 2006 Definition

UUT – Unit Under Test

TUR (Test Uncertainty Ratio)

$$\mathbf{TUR} = \frac{\textbf{Span of the } \pm \textbf{ Tolerance}}{2 \text{ x } \mathbf{k}_{95\%} \left(\sqrt[2]{\left(\frac{\mathbf{CMC}}{\mathbf{k}_{\mathbf{CMC}}}\right)^2 + \left(\frac{\mathbf{Resolution}_{\mathbf{UUT}}}{\sqrt[2]{12}}\right)^2 + \left(\frac{\mathbf{Repeatability}_{\mathbf{UUT}}}{1}\right)^2 + \cdots (\mathbf{u}_{Other})^2} \right)}$$

UUT Tolerance = (USL-LSL)/2

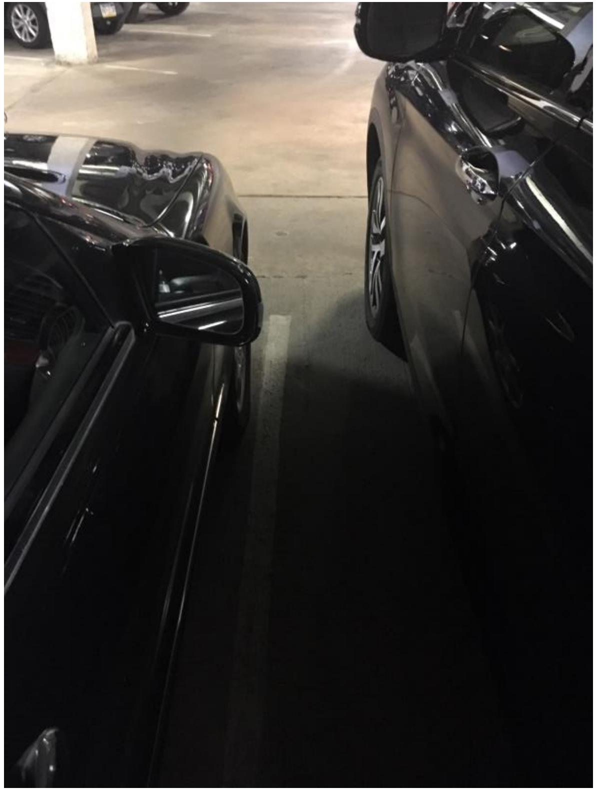
CMC = Reference labs Calibration and Measurement Capability

k = coverage factor

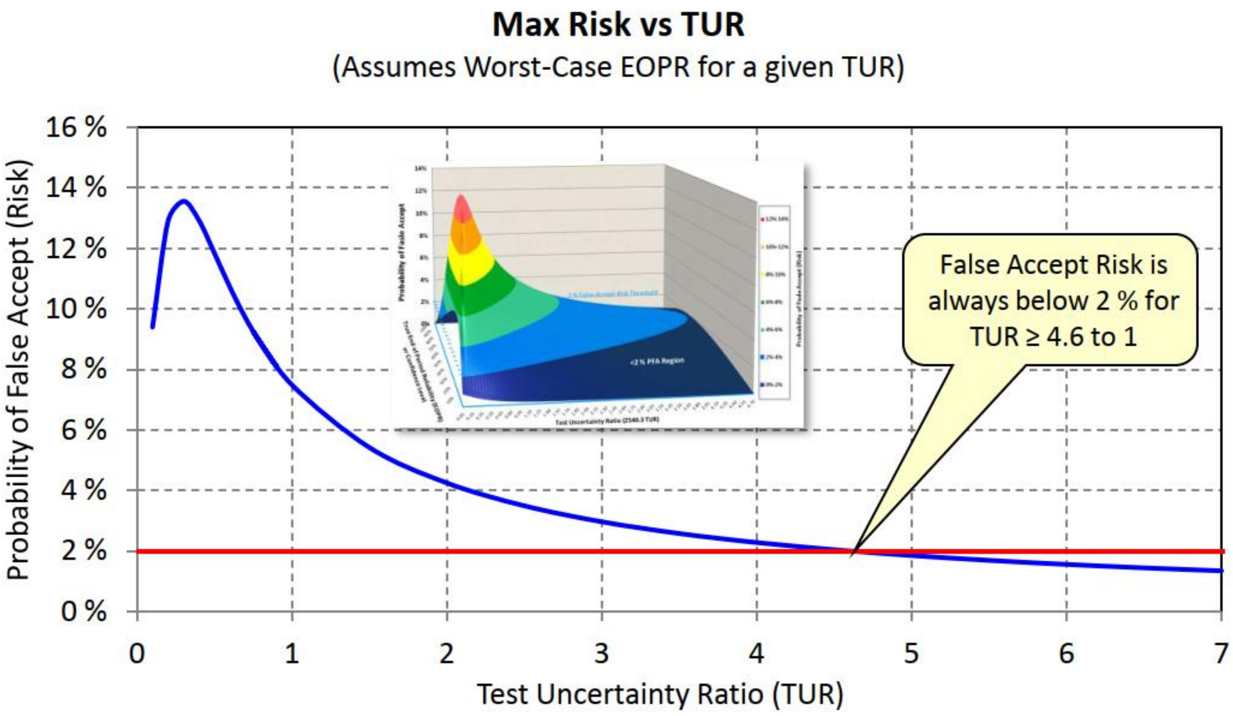
ANSI/NCSL Z540.3 Handbook Definition

The lab with the smaller uncertainties will typically produce larger TURs, giving you more space to be in tolerance!

The lab with the larger uncertainties will typically produce smaller TURs, giving you less space to be in tolerance!



Global Risk



The image is taken from Implementing Strategies for Risk Mitigation In the Modern Calibration Laboratory

Global vs Specific Risk Example

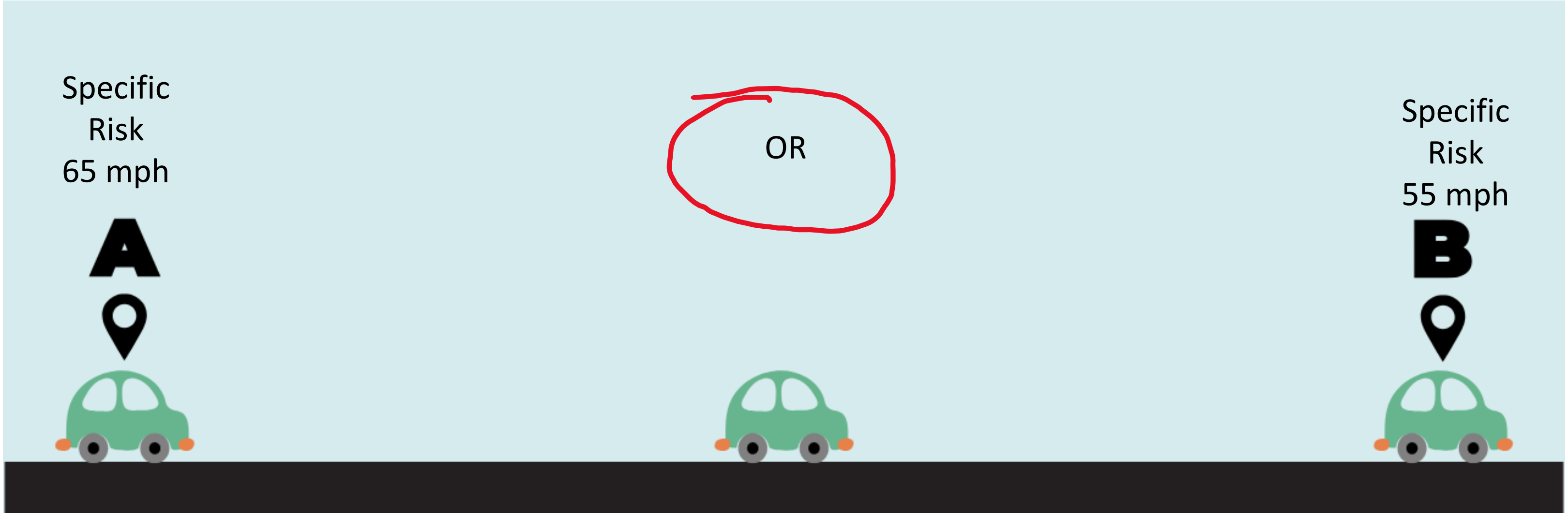
A company has hired us to measure the speed of cars on a stretch of a single-lane road.

The customer has indicated they are okay with 57 -63 miles per hour (MPH) speeds.

Thus, our specification limit is based on 60 MPH ± 3 MPH. The posted speed limit is 60 MPH.

After much discussion, we decided to set up two radar guns at points A and B for the first day and report the results. (Example of Specific Risk is based on measuring individual speeds at point A or point B)

Specific Risk



If we wanted to look at the car's speed using Specific Risk, we might have a radar gun at either points A or B. In this example, the car is clocked at 65 mph at point A and 55 MPH at point B. Each point is 5 MPH below or above the speed limit.
Note: Using the average of these two would be considered a global risk while taking just one is a specific risk.

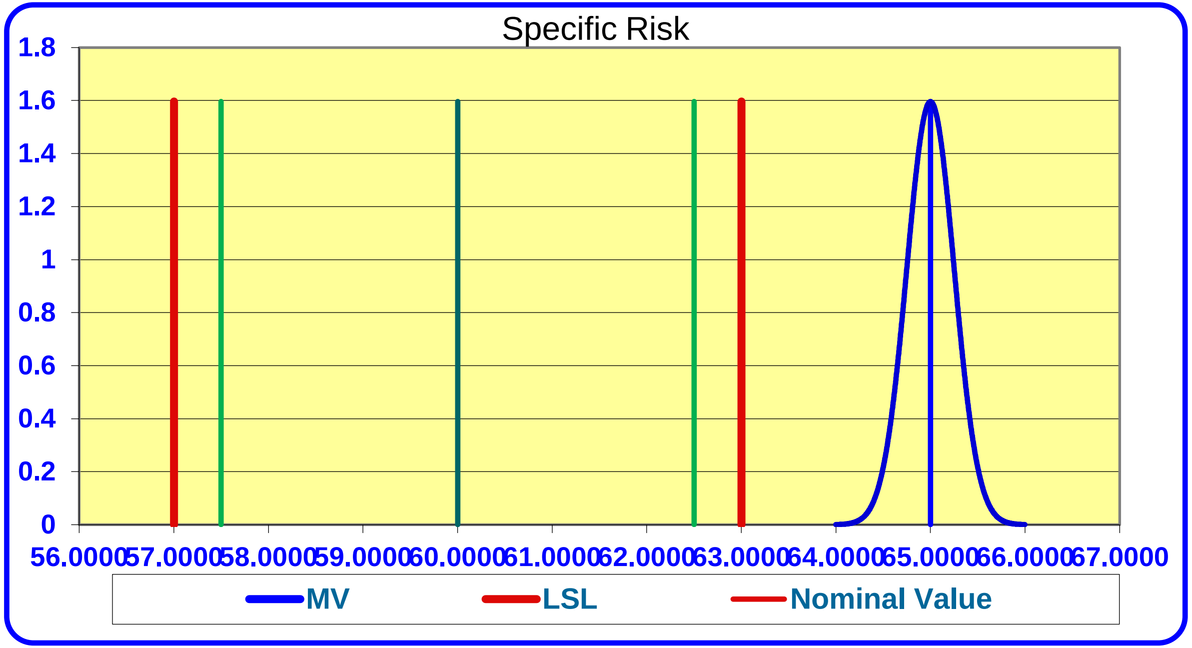
Specific Risk (Radar Gun at Point A)

Risk Calculator	
Upper Tolerance T_U	63.0000
Lower Tolerance T_L	57.0000
Nominal Value	60.0000
Measurement Unc um	0.2500
Measured Value xm	65.0000
Tolerance T	6.00

Probability of Conformance (p_c)	0.000%
Probability of NonConformance (1 - p_c)	100.000%

Setting the Guard Band Upper and Lower p_c	
Select Desired Conformance Probability	0.977
Guard Band Upper G_u	62.5000
Guard Band Lower G_L	57.5000

Specific Risk (Bench-Level)	
Conditional Probability False Accept	100.000%
Conditional Probability False Reject	0.000%



5 MPH Above (TUR 6:1)

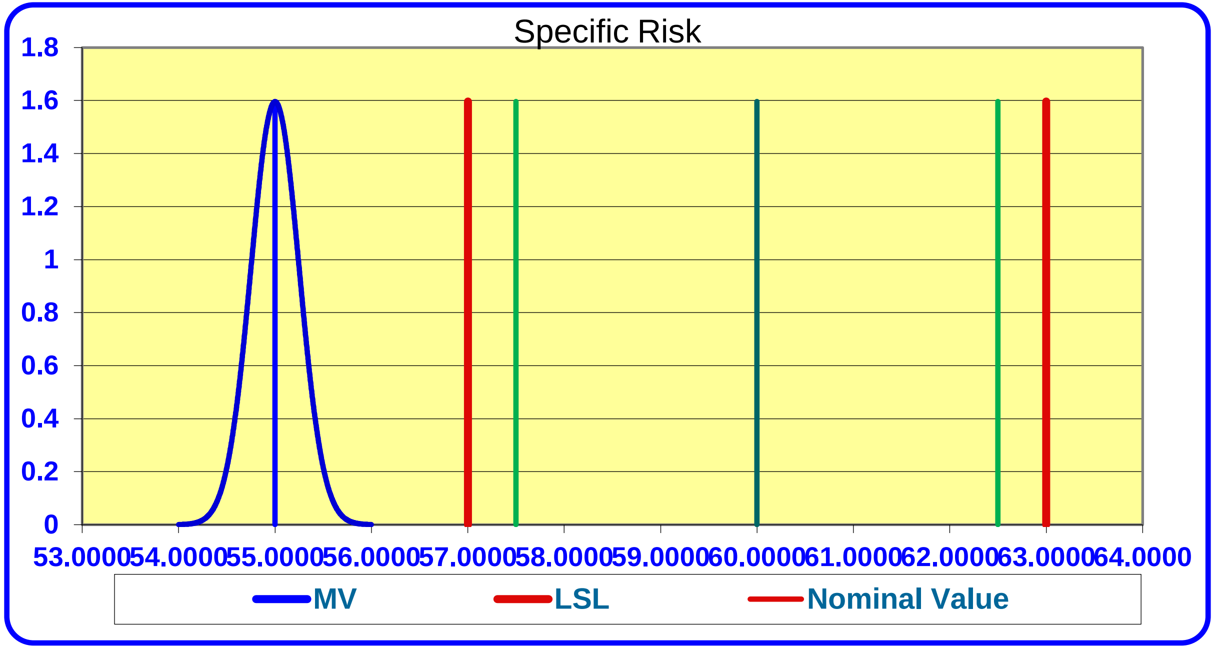
Specific Risk (Radar Gun at Point B)

Risk Calculator	
Upper Tolerance T_U	63.0000
Lower Tolerance T_L	57.0000
Nominal Value	60.0000
Measurement Unc um	0.2500
Measured Value xm	55.0000
Tolerance T	6.00

Probability of Conformance (p_c)	0.000%
Probability of NonConformance ($1 - p_c$)	100.000%

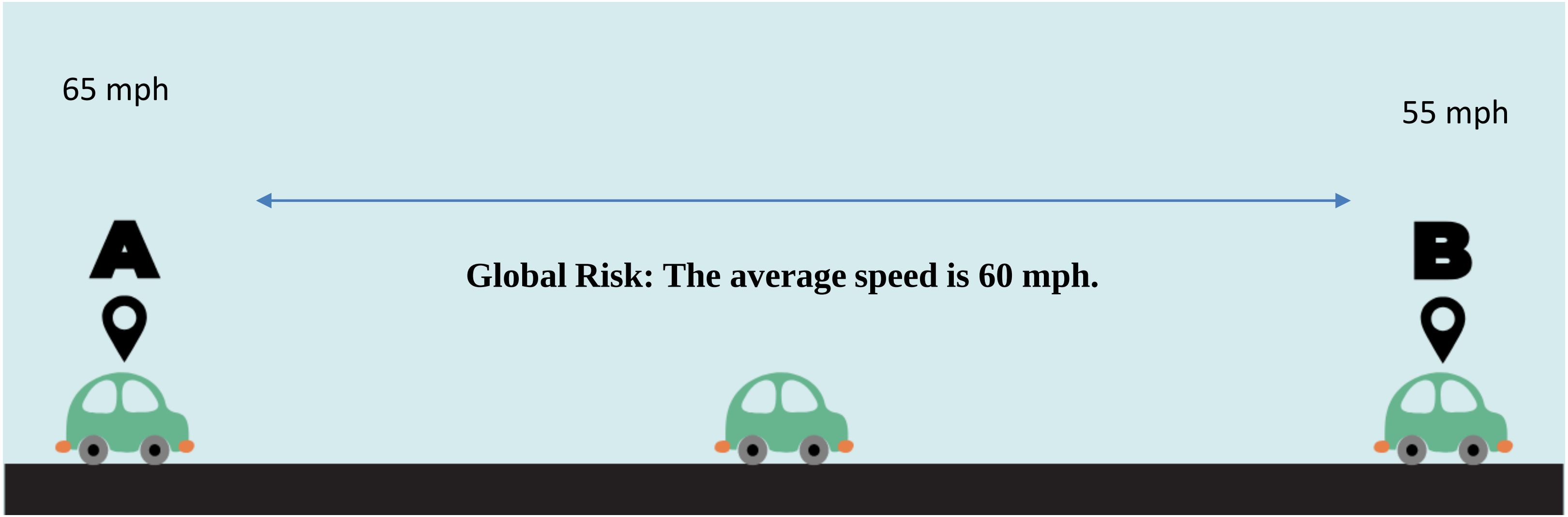
Setting the Guard Band Upper and Lower p_c	
Select Desired Conformance Probability	0.977
Guard Band Upper G_u	62.5000
Guard Band Lower G_L	57.5000

Specific Risk (Bench-Level)	
Conditional Probability False Accept	100.000%
Conditional Probability False Reject	0.000%



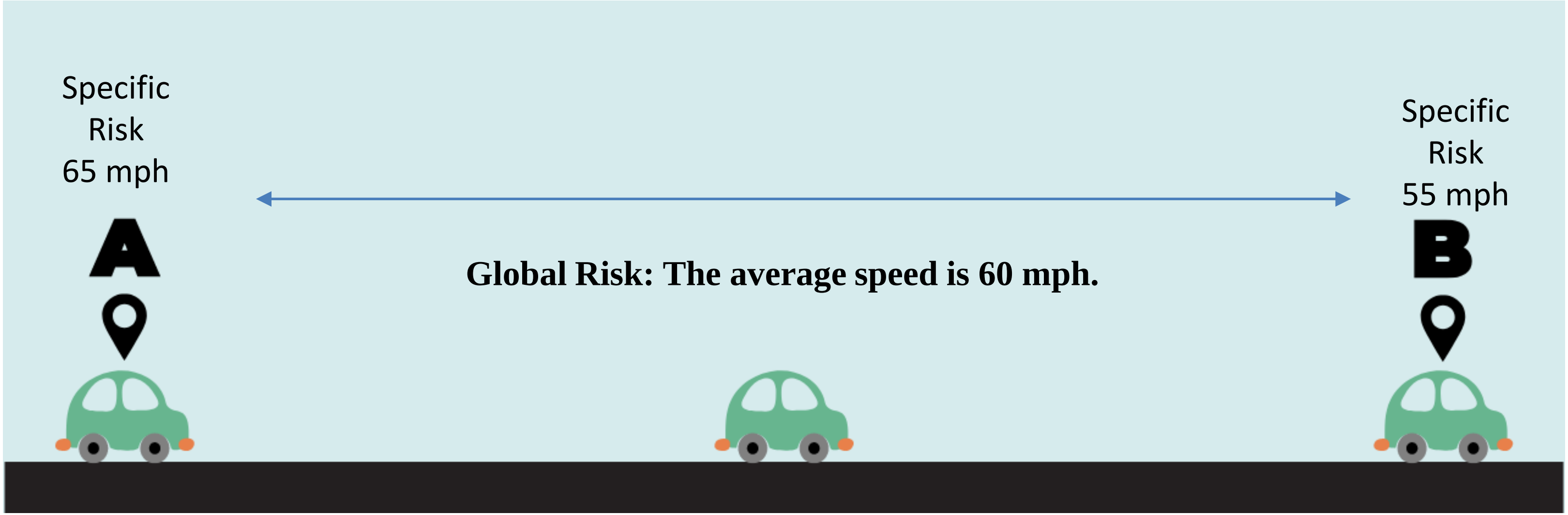
5 MPH Above (TUR 6:1)

Global Risk



The car enters point A, traveling at 65 MPH, and then 0.5 miles into the drive, travels at 55 MPH.
Global risk is based on measuring the average speed once a reliability target has been met (we took 10,000 data points and found 98 % to be good).

Global Risk and Specific

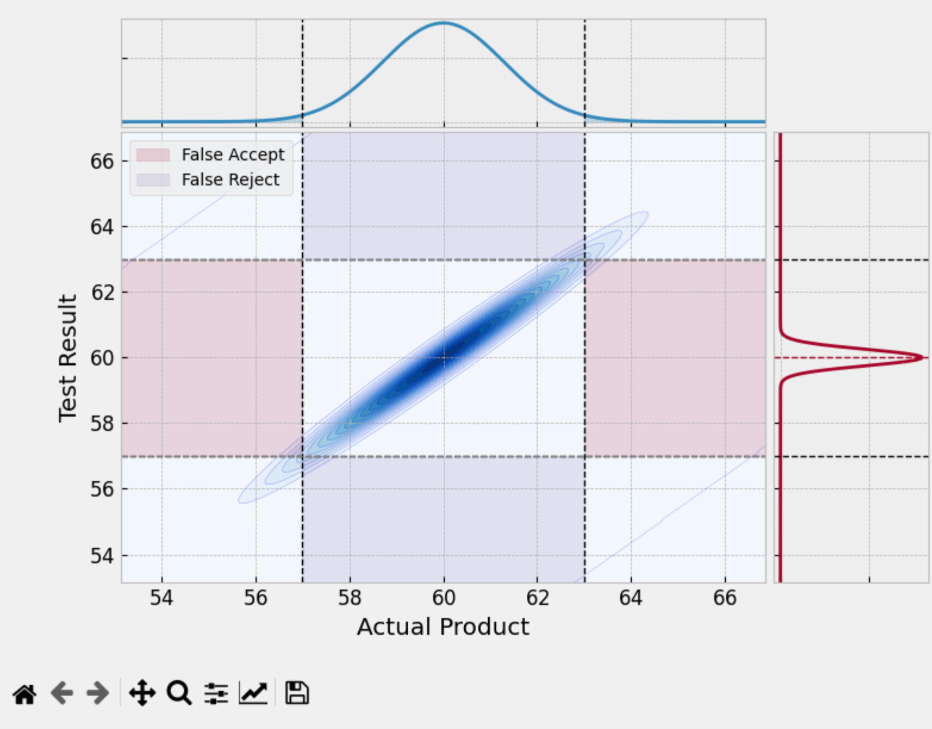


Global Risk - According to our data, about 1 % of drivers will drive over 63 MPH and 1 % below 57 MPH. We may not know the specific speeds at points A and B, though we will know the average speed on the mile stretch of road. – This might be good enough for what we want to measure.

Global Risk Results

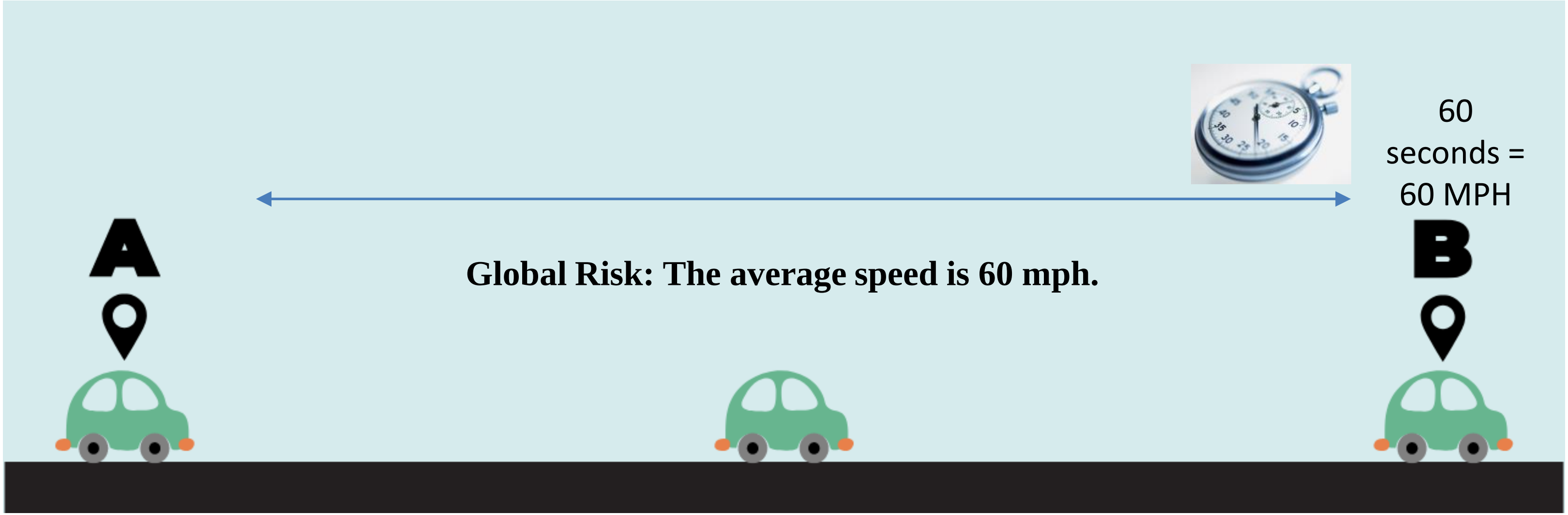
On Day 1, we recorded about 10,000 vehicles. Out of the 10,000 vehicles, 9,800, or 98 %, are observed to be driving between 57 – 63 MPH.

In our example, Global Risk is found by using 2 Radar Guns and taking the average



Process Risk	Specific Measurement Risk	Global Risk
Process Risk: 2.0%	TUR: 6.0	Total PFA: 0.32%
Upper limit risk: 1.0%	Measured value: 60	Total PFR: 0.54%
Lower limit risk: 1.0%	Result: ACCEPT	-
Process capability index (Cpk): 0.78	Specific FA Risk: 1.8e-31%	-

Global Risk

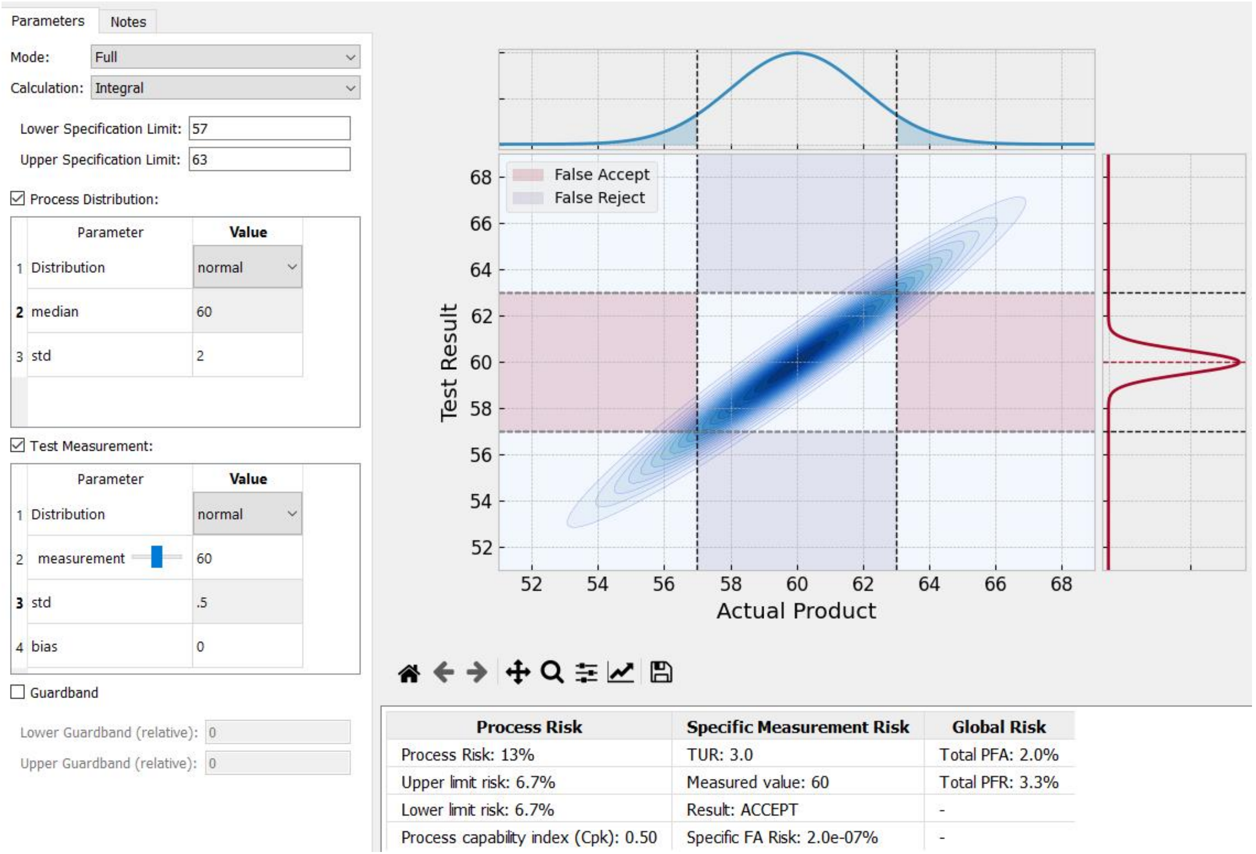


Since two radar guns are very good (high TUR), though expensive, maybe we consider a method that is less expensive, maybe an automated time-based method.

With a less accurate method our TUR might be 3:1 or half as good. What would this look like?

Global

Global Risk – Using a less accurate means of measuring (A process with a higher measurement uncertainty)



Global Versus Specific Risk Summary

Specific Risk is dependent on a single probability function and can be referred to as Probability of Conformance from the customer's point of view.

Global Risk is dependent on two probabilities, the second being the *a priori* knowledge, which could be taken as the process or instrument reliability.

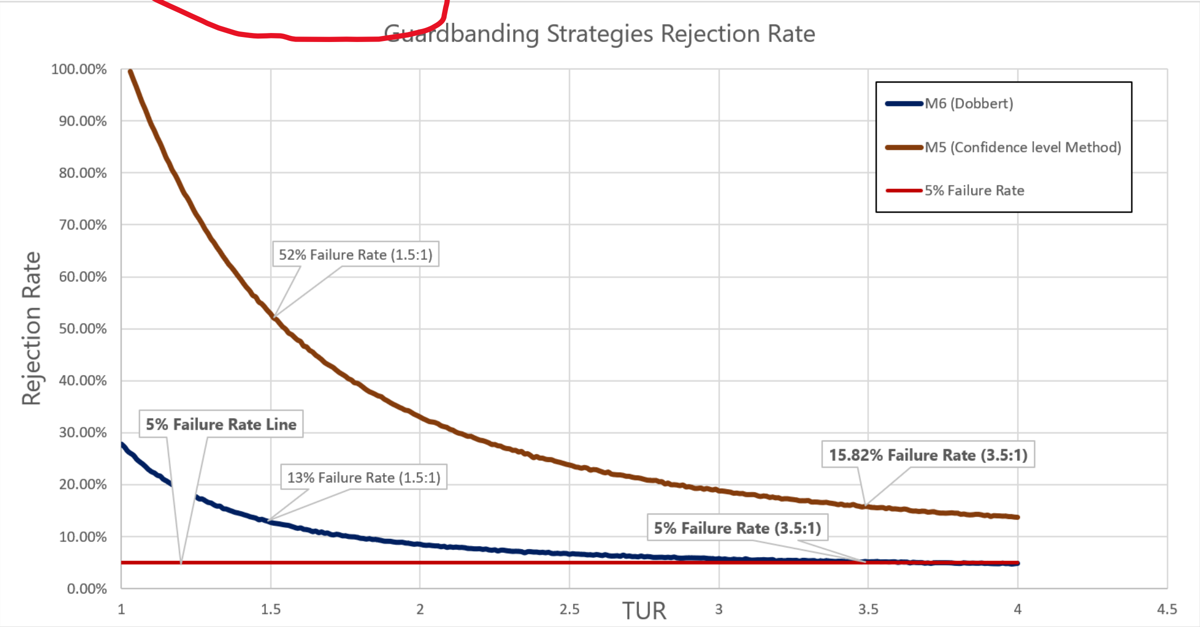
Typically, when we talk about TUR, we are talking about Global Risk.

Though TUR is also a ratio that can be useful at the Specific Risk level as higher TURs increase our acceptance zone.

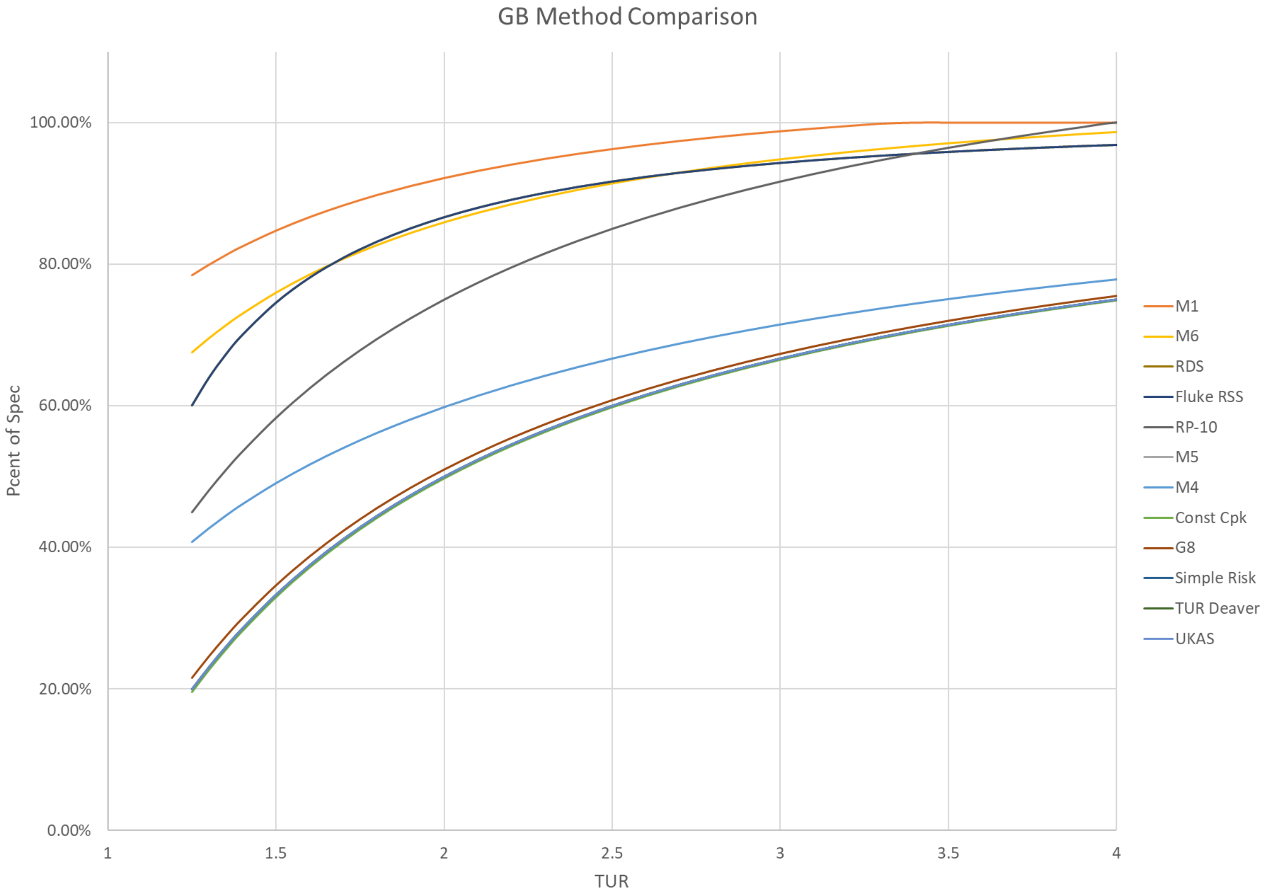
TUR's vs Total Cost due to false rejection & retest

DMM Price	DMM	UUT Spec	1 sigma	TUR	PFA	PFR	Total Rejections	False Rejects	Cost Due to FR	Cost to Retest	Likely Yield	Specific Risk Rejections x
$875	Fluke 289A	±0.2	0.59390	0.168	-	-	-	-	-	-	-	
$1,225	Fluke 8808A	±0.2	0.21038	0.475	-	-	-	-	-	-	-	
$1,650	Tek DMM6500	±0.2	0.11740	0.852	-	-	-	-	-	-	-	
$4,405	Keysight 34470A	±0.2	0.06939	1.441	0.542%	27.962%	36,798	27,962	$499,201	$1,294,224	63.02%	4
$13,481	Fluke 8558A	±0.2	0.01038	9.630	0.970%	1.035%	65	1	$879	$2,280	99.94%	
$14,315	Keysight 3458A	±0.2	0.00711	14.064	0.671%	0.702%	30	0	$0	$0	99.97%	
$19,429	Fluke 8588A	±0.2	0.00677	14.779	0.639%	0.667%	27	0	$0	$0	99.97%	

Widets Produced =	100,000
Cost per Widget =	$13.50
Cost to Retest Individual Pieces =	$35.00



Selecting the proper Guard Banding method



Case Study– "Deflate Gate"

- Deflate gate suggested that the New England Patriots used an illegal process for lowering the inflation of game footballs at the behest of quarterback Tom Brady

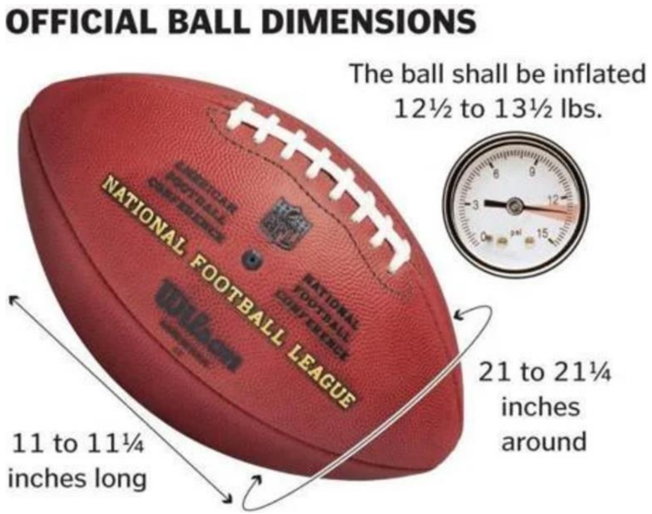
NFL Rulebook (Goodell 2014) states "The ball *shall* be made up of an inflated (12.5 to 13.5 pounds) urethane bladder enclosed in a pebble grained, leather case (natural tan color) without corrugations of any kind. It *shall* have the form of a prolate spheroid, and the size and weight *shall* be:

Long axis = 11 to 11.25"

Long circumference = 28 to 28.5"

Short circumference = 21 to 21.25"

Weight = 14 to 15 oz.



Case Study– "Deflate Gate"

- The NFL Chose to use the following gauges - One "no name" the other model CJ-01 manufactured for Wilson by Jiao Hsiung Industry Corp. (Exponent findings 2015)
- The process: two measurements were taken on each game ball (11 balls in total) at halftime, with a different gauge and operator used for each. Degrees of freedom = 1
- Although both gauges likely produced by Jiao Hsiung Industry Corp (JHIC), Wilson has no stated accuracy. The display reads ±0.05 PSIG (the last digit is either 0 or 5)

- Similar gauges have a stated accuracy of ±1% of Full Scale (FS) which equates to ±0.2 PSIG where FS = 20 PSIG – <u>we will assume this is the accuracy of the game gauges</u>

- Neither gauge used in the game had a traceable calibration, which makes the specification difficult to prove and therefore the true accuracy is likely worse

Case Study– "Deflate Gate"

- At best, that gauge can provide ±3.3 PSIG (~0.817 x 4) uncertainty (assuming a 4:1 TUR desired) – it's 6.6x less accurate than the NFL requirement of ±0.5 PSIG

		u(Accuracy)	u(StDev)	u(Resolution)		
		0.11547	0.15000	0.01443		
	df	100000.00	1.00	100000.00		
Measurement Equation Inputs	**Value**					
Accuracy	0.20000	0.31547	0.20000	0.20000		
StDev	0.15000	0.15000	0.30000	0.15000		
Resolution	0.05000	0.05000	0.05000	0.06443		
Result	0.40000	0.51547	0.55000	0.41443		
		0.11547	0.15000	0.01443	$c_i u_i$	
u_c =	0.18985	0.01333	0.02250	0.00021	$(c_i u_i)^2$	
df =	2.57	37.0%	62.4%	0.6%	<–rel $(c_i u_i)^2$	100.0%
k =	4.303	1.00000	1.00000	1.00000	c_i	Σrel $(c_i u_i)^2$
U =	0.81684		204.21%	$U_{relative}$, %		

Risk Calculator	
Upper Tolerance T_U	13.5
Lower Tolerance T_L	12.5
Nominal Value (NV)	13
Measured Value xm	13.0000
Measurement Unc um	0.4084
Maximum Allowable Risk (PFA)	2.5000%
Tolerance T	1.00

In-Tol Probability with given U_{c95} (as is)	77.91%
Probability of non-conformance	22.09%

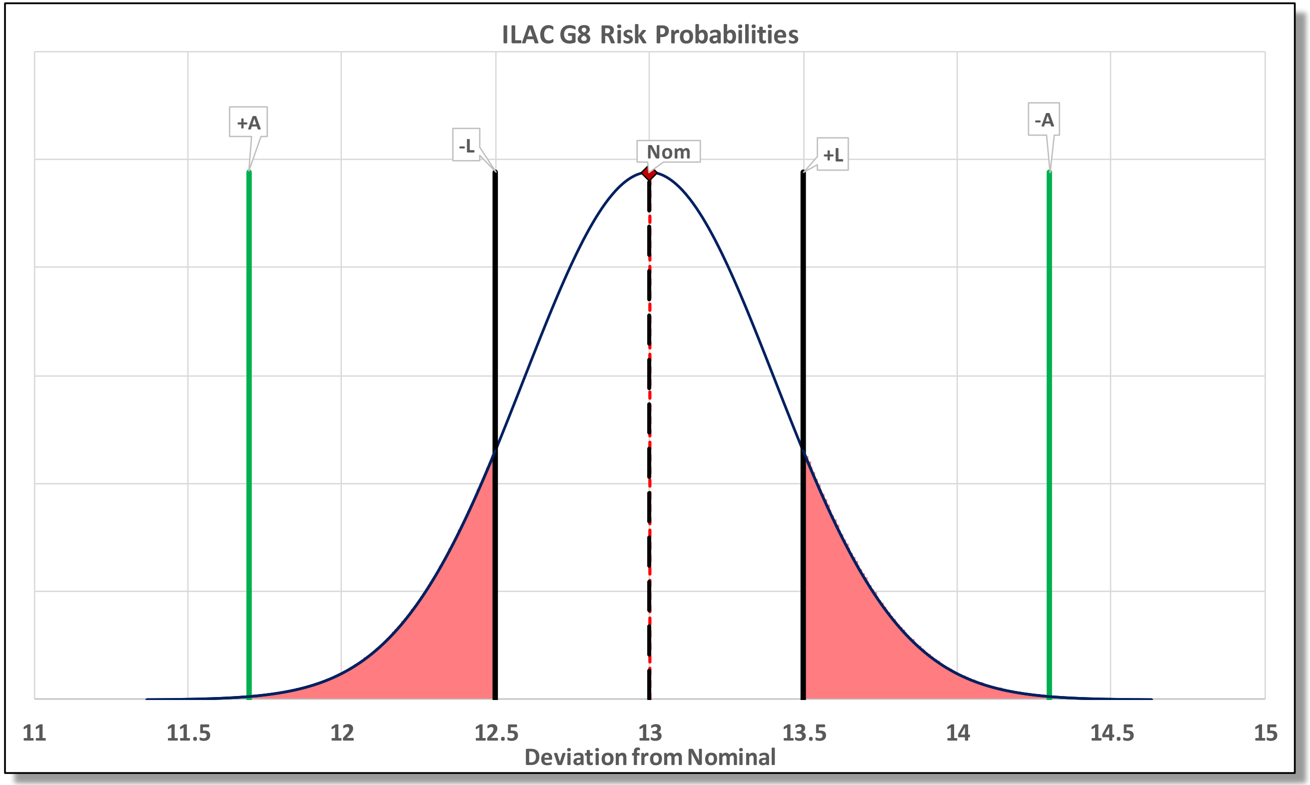
Probability of Conformance (p_c)	77.913%
Probability of NonConformance (1 - p_c)	22.087%

Setting the Guard Band Upper and Lower AL	
Guard Band Upper G_u (AL= TL - w)	13.5000
Guard Band Lower G_L (AL = TL + w)	12.5000
Relaxed Upper Acceptance Limit	14.3005
Relaxed Lower Acceptance Limit	11.6995

Setting AL based on Probability of Conformance	
Probability of Conformance (pc)	97.50%
r	0.9800
w = U_{95} * *r*	0.80049
C_m (TUR)	0.61211

Setting AL based on Guard Band w	
Upper Acceptance Limit	PASS
Lower Acceptance Limit	PASS

Data Inputs



Case Study– "Deflate Gate" Conclusion

- The NFL used an inappropriate instrument to verify the pressure integrity of the game ball

- "Deflate gate" totaled more than $22.5M by end of investigation

- The Additel GP30, at ±0.05% FS (±0.015 psig) costs ~$714 (including an accredited calibration)

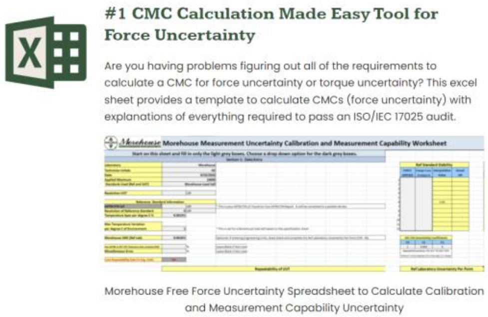
- The NFL used a $30 gauge which, at best, is good for measurements ±3.5 psig

Decision Rules Conclusion

- Calculating Measurement Uncertainty correctly is essential to everything that comes after it including decision rules.
- Metrological Traceability relies on a documented unbroken chain of contributions, each contributing to the measurement uncertainty, linking them to an appropriate reference.
- A decision rule should take into account the measurement uncertainty.

Want More Information?

Action Item: Connect with us on LinkedIn



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