Welcome to the Webinar!

Measurement Risk (Measurements gone wrong)

Presented by:
Henry Zumbrun, Morehouse Instrument Company

Hosted by PJLA- Tracy Szerszen, President

September 28, 2023
1:00-2:00 PM EST

PJLA

Webinar Overview

Discuss the importance of:

Understanding the tasks requested of your customer—17025 Section 7.1

The importance of appropriate equipment and personnel -*17025 6.2 and 6.4*

Making accurate decisions on results and the risks associated with this process -*17025 7.8*

Webinar Housekeeping

- This webinar will be recorded
- All PJLA webinars are made available on our website & YouTube channel

  https://www.pjlabs.com/training/pjla-webinars/past-webinars
- All attendees are muted
- Please utilize the question tool bar to submit questions to be answered at the end of presentation

Measurements Gone Wrong

Our Purpose

We create a safer world by helping companies improve their force and torque measurements.

Presenter

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- www.mhforce.com

Measurements gone f$&@ing wrong!)

What **happens if we do not perform force measurements properly?**

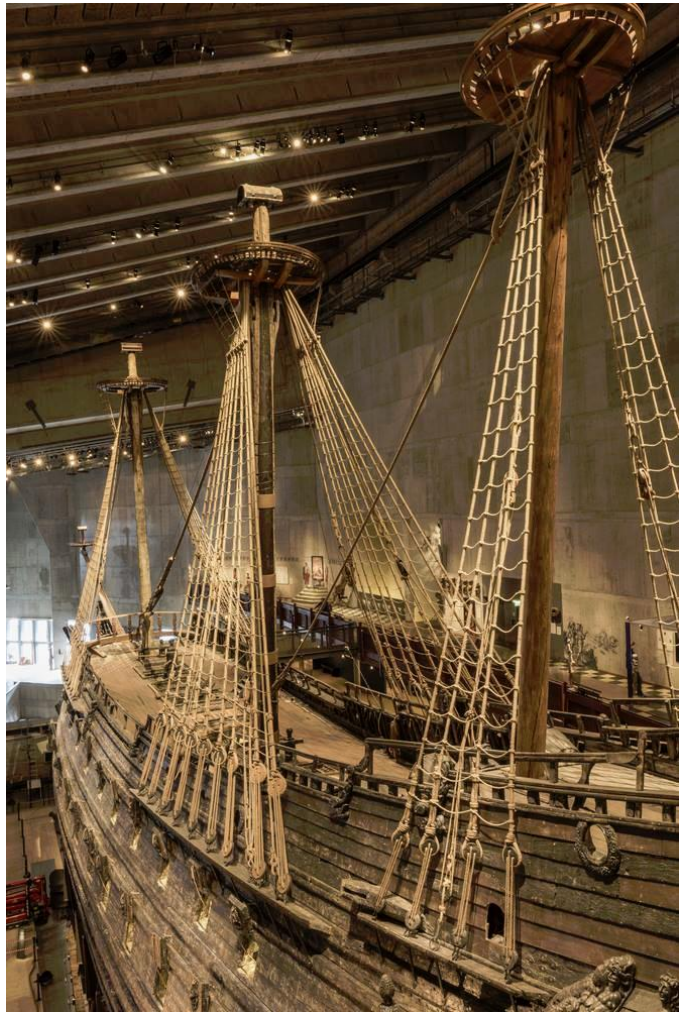
This session is to help you make the world a bit safer by understanding the consequences of bad decisions.

Why Measurements Matter

Why Calibration Matters

Why Measurements Matter – Same Units

- The Swedish warship Vasa, which famously sank in 1628 less than a mile into its maiden voyage, was built asymmetrically.
- Archaeologists have found four rulers used by the workers, two turned out to be based on Swedish feet with 12 inches (30.48cm). The other two used Amsterdam feet, with 11 inches (27.94cm).



The Importance of Torque Control

- If the tension is too high, the tightening process may cause bolt failure.

Pictured Above: Metal snap from Jeff Nihel's dragster, apparently the bolts on the left exhaust manifold were over-torqued… bolts then failed, manifold popped off and 4000bhp of exhaust gas launches the car in the air at over 200mph!

Measurement Risk

Measurement Risk

- You can see the crash for yourself but let us tell you about the findings of the subsequent investigation.
- There were **two intertwined causes of the crash.** Heavy rains before takeoff caused fuel to get into data sensors which were responsible for calculating speed and altitude among other things.

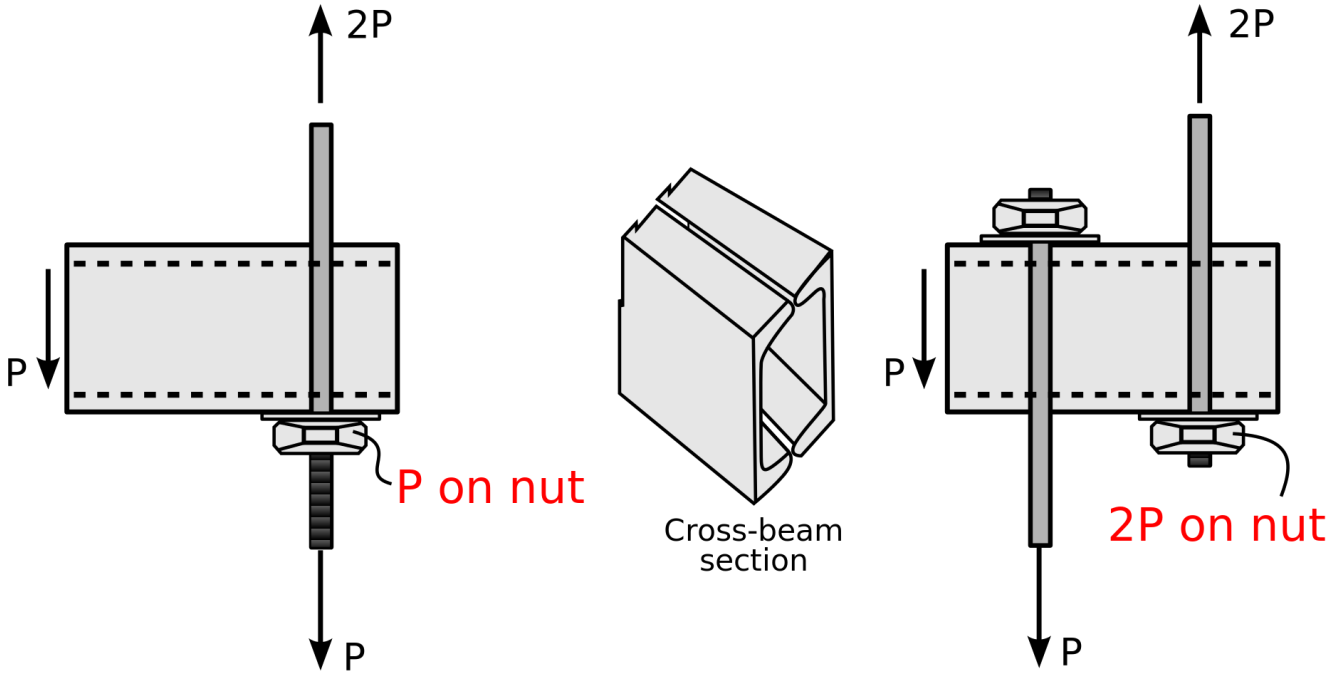
Measurement Risk

- This mixture of water and fuel caused condensation to build up on the sensors which were near the planes surface. When maintenance crew were calibrating them before the flight, they were unaware of this build up **causing them to calibrate them wrong.**
- **It's only a 2 billion dollar mistake**

Measurements gone f@&4ing wrong!

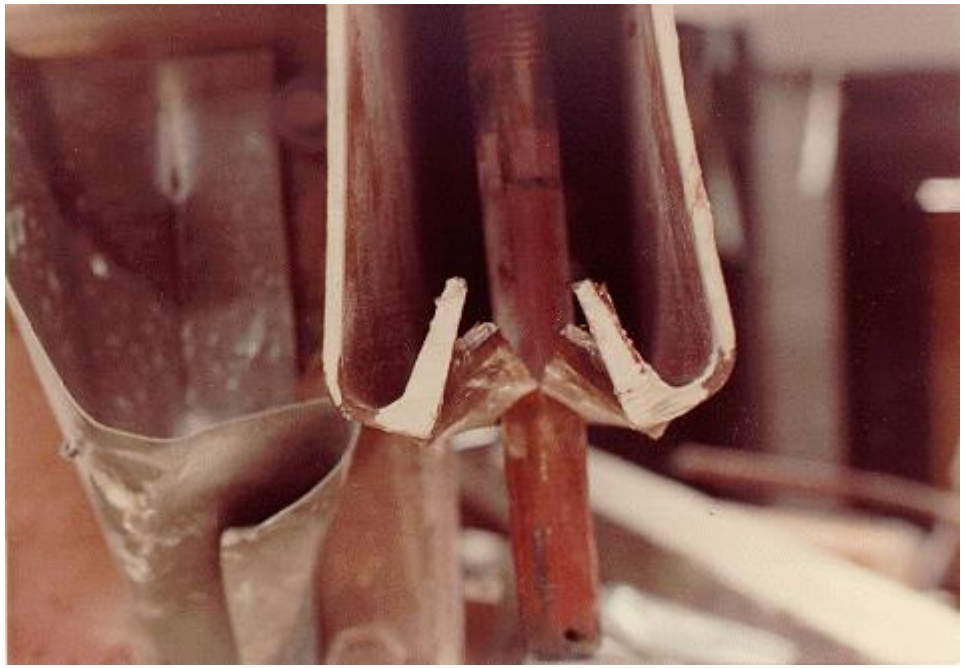
On July 17, 1981, the Hyatt Regency Hotel in Kansas City, Missouri, suffered the structural collapse of two overhead walkways. Loaded with partygoers, the concrete and glass platforms cascaded down, crashing onto a tea dance in the lobby, killing 114 and injuring 216. Kansas City society was affected for years, with the collapse resulting in billions of dollars of insurance claims, legal investigations and city government reforms.

Measurements gone f@&4ing wrong!



(a) Original design

(b) Actual construction



The design vis-à-vis the final construction of the walkway support system. The construction doubled the force on the nut, which is located on a welded joint

Even this original design supported only 60% of the minimum load required by Kansas City building codes

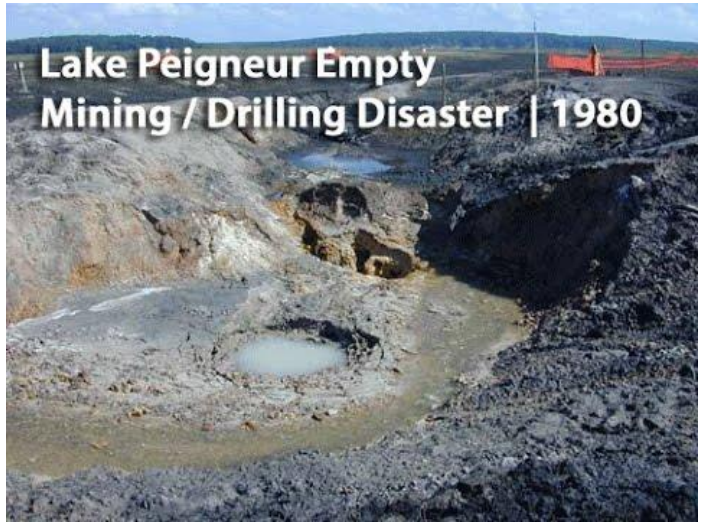
Measurements gone f@&4ing wrong!

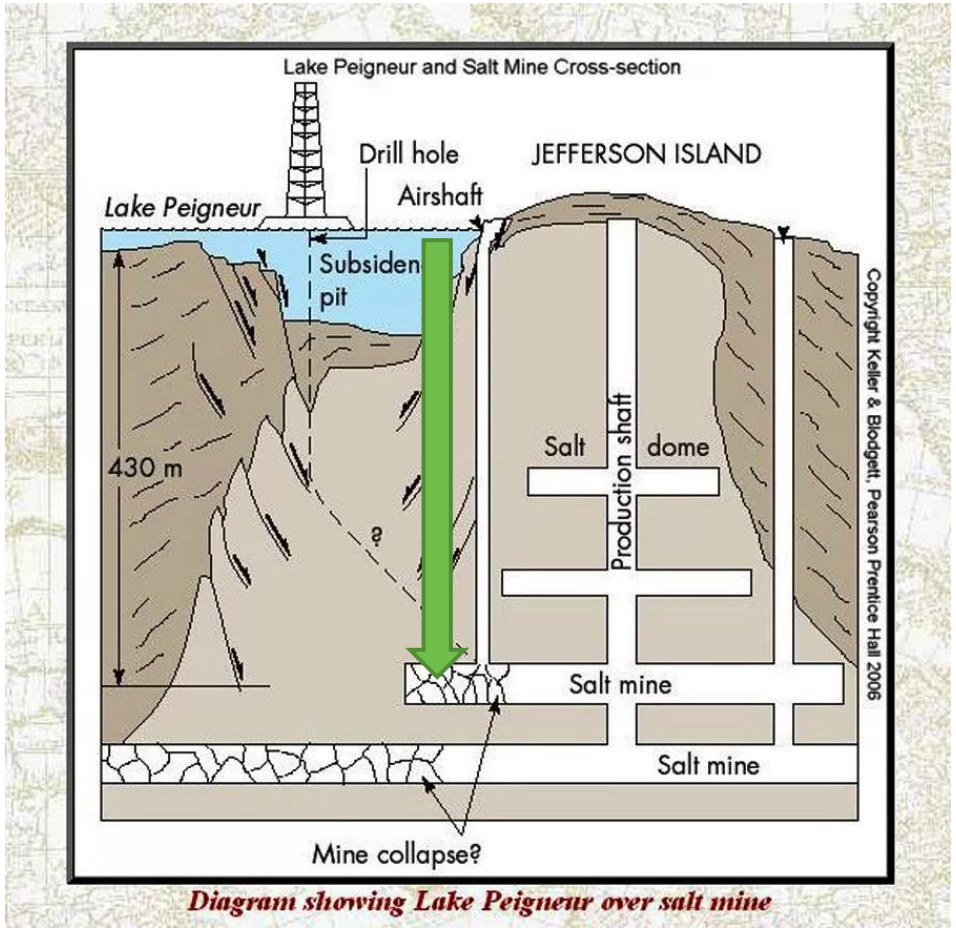
An investigation concluded that it would have failed even under one-third of the weight it held that night. Convicted of gross negligence, misconduct, and unprofessional conduct, the engineering company lost its national affiliation and all engineering licenses in four states, but was acquitted of criminal charges

In the months following the disaster, more than 300 lawsuits sought a cumulative total of $3 billion

Measurements gone f@&4ing wrong!

On November 20, 1980, an oil rig contracted by Texaco accidentally drilled into the Diamond Crystal Salt Company salt mine under the lake. Because of an incorrect or misinterpreted coordinate reference system (the rig with the coordinate system set up backwards) and the 14-inch (36 cm) drill bit entered the mine, starting a chain of events that turned the lake from freshwater to salt-water, with a deep hole. [Video on youtube.]





Measurement Risk

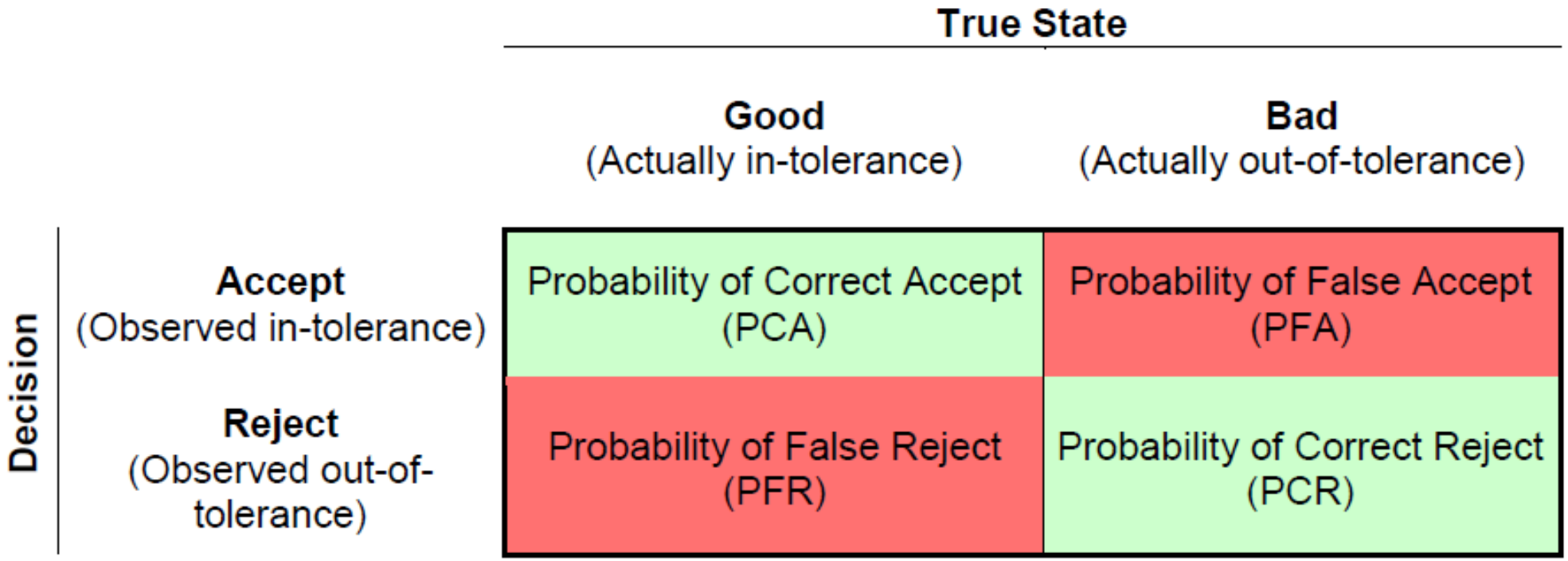
What does this really mean?

All measurements have a percentage of likelihood of calling something good when it is bad, and something bad when it is good. You might be familiar with the terms consumer's risk and producer's risk. **Consumer's risk refers to the possibility of a problem occurring in a consumer-oriented product; occasionally, a product not meeting quality standards passes undetected through a manufacturer's quality control system and enters the consumer market.**

An example of this would be the batteries in the Samsung Note 7 phone. The batteries can potentially overheat, causing the phone to catch on fire. In this case, the faulty battery/charging system of the phone device was approved through the quality control process of the manufacturer, which was basically a 'false acceptance.' If you owned one of these phones, there was a risk of injury to you.

In metrology, this is called the probability of false acceptance (PFA). If the Uncertainty of the Measurement is not less than the tolerance required, there will be a significant risk of false acceptance.

Measurement Risk



Measurement Risk

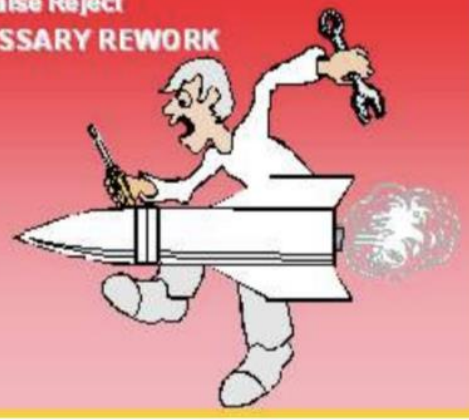
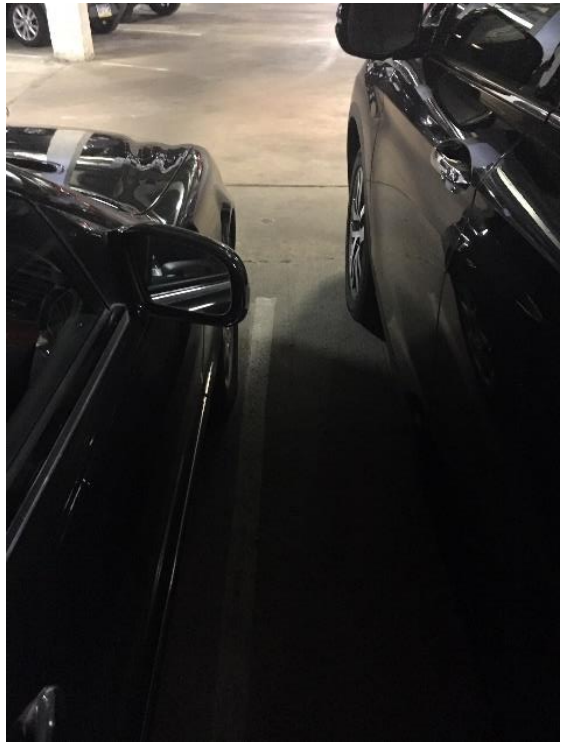
TEST RESULT	ACTUAL STATUS of UNIT UNDER TEST	
	GOOD	BAD
ACCEPT	Correct Decision MISSION READY 	False Accept ASSET FAILURE 
REJECT	False Reject UNNECESSARY REWORK 	Correct Decision PROPER REWORK 

Image from NAVSEA (asq711.org)

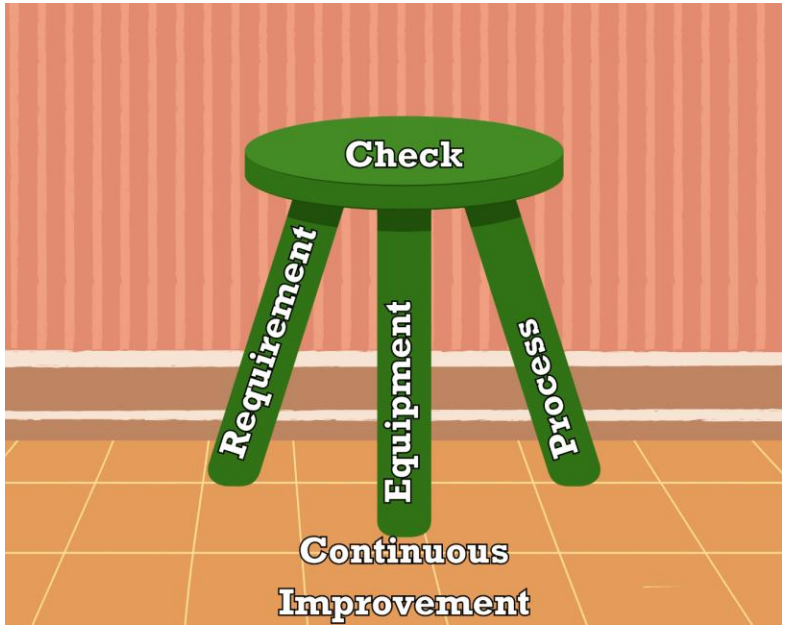
The larger the TUR(Smaller MU), the more room you have!

The lab with the larger uncertainties will produce smaller TUR's, giving you less space to be in tolerance!



3 Rules to Lessen Your Measurement Risk

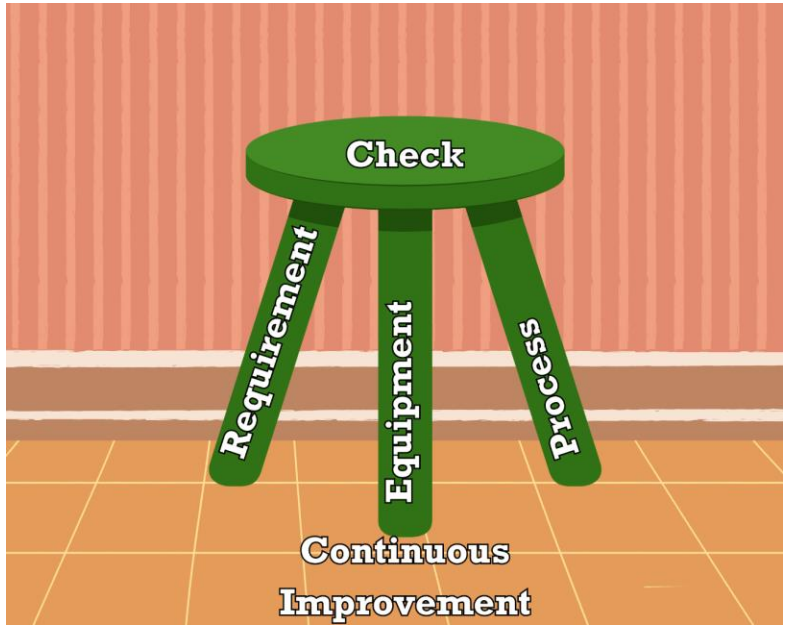
- **Rule #1. Know the Right Requirements** – This first rule involves knowing what is needed to accomplish the task at hand.
- **Rule # 2. Choose the Right Equipment** – Always choose Measuring and Test Equipment that is capable of achieving the measurement tolerance required.
- **Rule # 3. Have the Right Processes** – This last rule requires having a training program and proof of training (records) to validate the individuals performing the calibration or using the equipment.



3 Rules to Lessen Your Measurement Risk

Rule #1. Know the Right Requirements -This first rule involves knowing what is needed to accomplish the task at hand.

- The more accurate the system, the higher the costs will be to procure the equipment and have it calibrated.
- For most tests, a TUR of 4:1 will meet the guidelines set fourth in ANSI Z540.1 of ensuring that the total risk is less than 4 %.
- If the requirement is 0.1 % of applied, and the stability of the device is 0.2 % over a one-year period, the device would need to have the calibration interval shortened.



What happens when Rule #1 is not followed

BP Texas Refinery Moments before and immediately after the explosion

Knowing The Right Requirements

The Accident

- Distillation tower and attached blow down drum overfilled
- ~7600 gallons flammable liquid released
- Liquid ignited by an idling diesel truck

Proximate cause

- High-level alarm malfunctioned
- Level transmitter miscalibrated
  - Outdated 1975 data sheet
  - Level transmitter indicated liquid level falling
  - Level actually rising rapidly

Knowing The Right Requirements

Root causes

- Cost-cutting, production pressures, and failure to invest
- Lack of preventative maintenance and safety training
- Procedural workarounds to compensate for the deteriorating equipment

The Cost

- 15 deaths,
- 180 injured
- Over $2 billion, including lawsuits

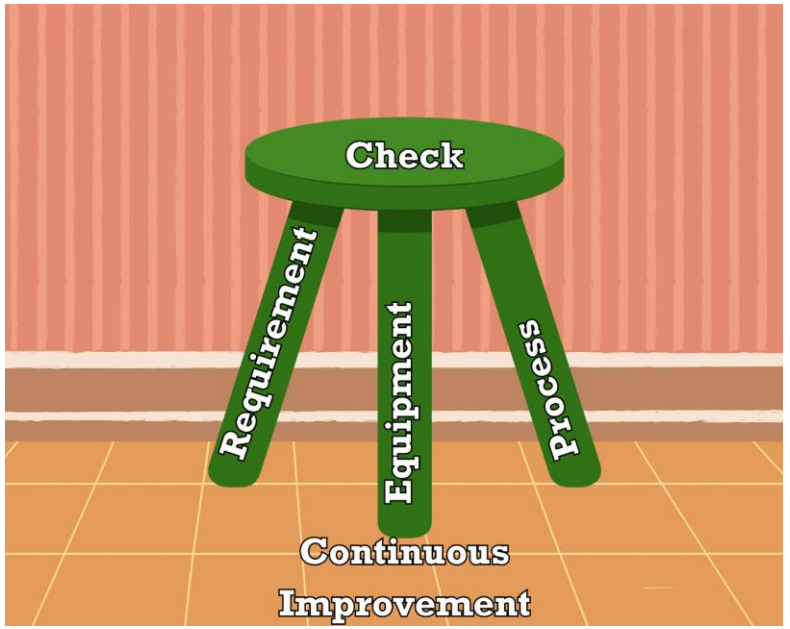
The Aftermath

Special Thank You to Scott Mimbs for providing this example

3 Rules to Lessen Your Measurement Risk

Rule # 2. Choose the Right Equipment – Always choose Measuring and Test Equipment that can achieve the measurement tolerance required.

- If you need to certify that an instrument is within a tolerance of 1 %, you cannot use a standard with a 1 % tolerance to perform the calibration.
- Several manufacturers do not understand TUR and do not include the instrument's resolution or repeatability, or the reference standard used to perform the calibration, in their accuracy claims.
- On most of these instruments, no reference standard in the world may lower the risk if the instrument shows any bias.



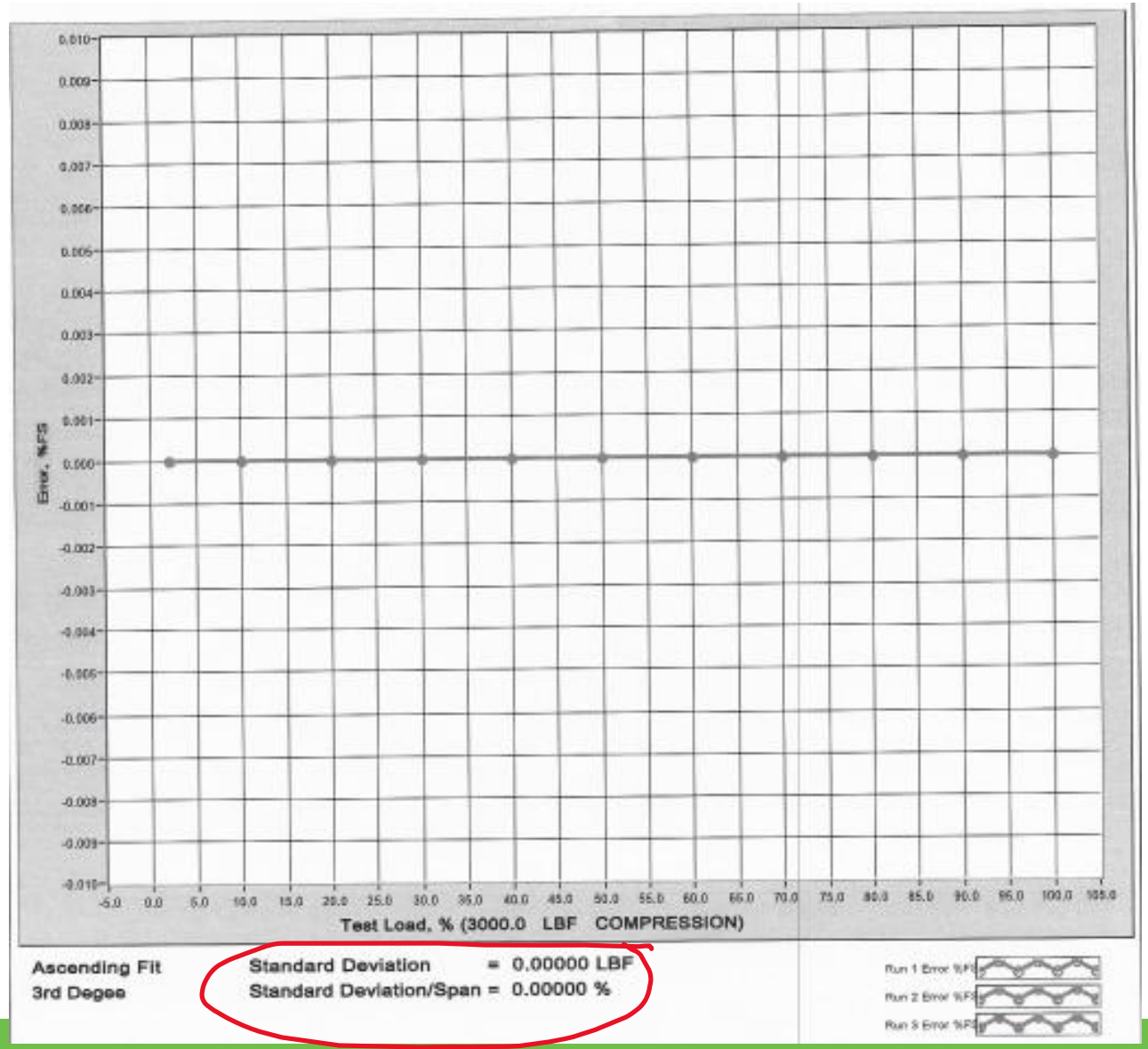
Rule # 2. Choose the Right Equipment

Pin B (2.0030 to 2.0060)	Pin A (2.0005 to 2.0045)
50,070	50,010
50,050	50,020
50,040	50,010
50,070	50,020
50,090	50,020
50,060	50,030
50,080	50,010
50,070	50,030
50,090	50,020
50,090	50,070
50,080	50,060
50,100	50,070
17.81640375	22.74696117
Out of 24 tests 13 did not meet spec ± 50	

The Effect of UUT Resolution on Bias, Risk & Uncertainty

Here we set the resolution to 0.01. What might happen if the resolution were set to 1?

The Effect of UUT Resolution on Bias, Risk & Uncertainty



FORCE LBF	Output 1 07/30/2021 7:45 LBF	Output 2 07/30/2021 8:18 LBF	Output 3 07/30/2021 8:27 LBF
60.0	60	60	60
300.0	300	300	300
600.0	600	600	600
900.0	900	900	900
1200.0	1200	1200	1200
1500.0	1500	1500	1500
1800.0	1800	1800	1800
2100.0	2100	2100	2100
2400.0	2400	2400	2400
2700.0	2700	2700	2700
3000.0	3000	3000	3000

FORCE LBF	Error 1 LBF	Error 2 LBF	Error 3 LBF
60.0	0	0	0
300.0	0	0	0
600.0	0	0	0
900.0	0	0	0
1200.0	0	0	0
1500.0	0	0	0
1800.0	0	0	0
2100.0	0	0	0
2400.0	0	0	0
2700.0	0	0	0
3000.0	0	0	0

FORCE LBF	Fitted LBF	Ascending Coefficients
60.0	60	A0=-0.0000[illegible]E+0
300.0	300	A1=1.0000[illegible]E+0
600.0	600	A2=4.41508E-[illegible]
900.0	900	A3=-9.91541E-23
1200.0	1200	
1500.0	1500	
1800.0	1800	
2100.0	2100	
2400.0	2400	
2700.0	2700	
3000.0	3000	

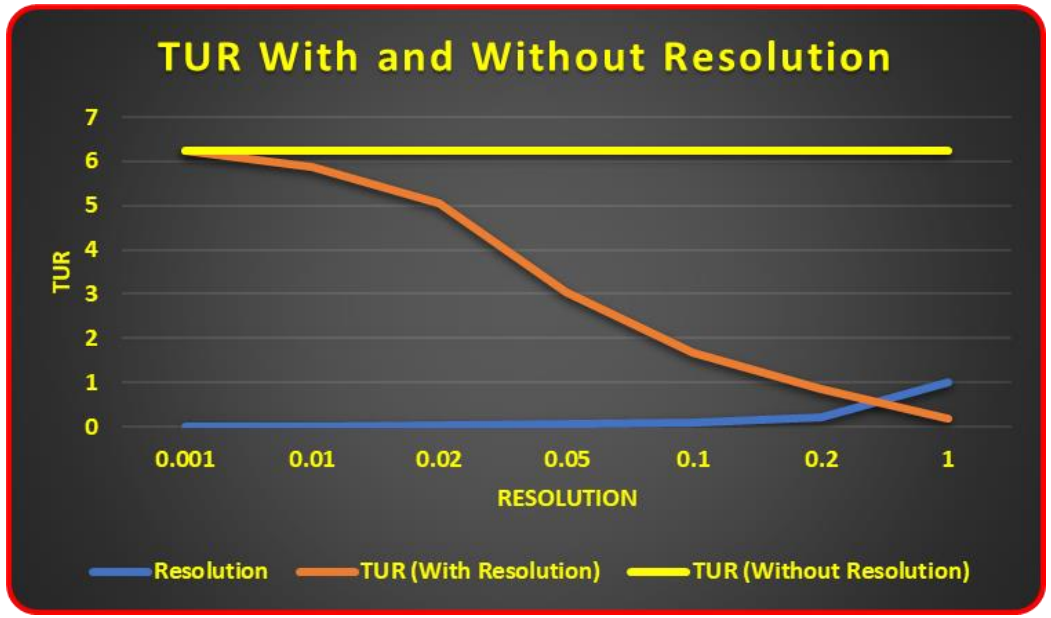
Standard Deviation = 0 LBF
Standard Deviation/Span = 0.00000 %

Lower Limit Factor = 0.0 LBF
Class A Lower Force Limit = 60.0 LBF

We create a safer world by helping companies improve the

The Effect of UUT Resolution on Risk & Uncertainty

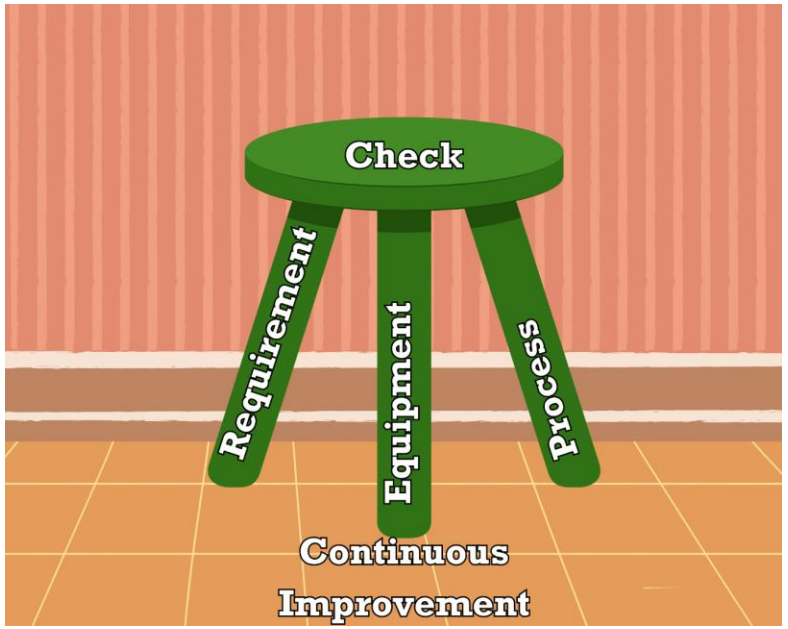
TUR cannot be the ratio of the Manufacturer's accuracy tolerance to the reference standard uncertainty, per ANSI/NCSL Z540.3 and ILAC-G8:09/2019



When the resolution is considered, the TUR starts at 6.25:1 with a UUT resolution of 0.001 kgf and then declines to 0.17:1 with a UUT resolution of 1.0 kgf. When the resolution is not accounted for, the TUR ratio stays at 6.25:1 regardless of the resolution. If a calibration laboratory uses the Test Value Uncertainty, then the UUT's resolution could be ignored in the conformity assessment.

3 Rules to Lessen Your Measurement Risk

Rule # 3. Have the Right Processes – This last rule requires having a training program and proof of training (records) to validate the individuals performing the calibration or using the equipment.



- It is important to maintain and follow procedures that adequately support the end-product performance
- There should be a process in place that ensures all aspects of the standards are being carefully satisfied in the calibration process
- Use of Proper Adapters and making sure the instrument's calibration matches how it is being used in the field or lab.

The Right Processes?

Torque Measurement

[redacted]™ Tension Link Dynamometers are used by Texas oil field companies to measure the torquing force being applied to equipment. As this equipment is being serviced and assembled, these precision measurement devices play a vital role in ensuring proper specifications are being achieved while also improving operational efficiency and safety.

"Our customers love the precision they get from th[redacted] Tension Links," [redacted] Director for Industrial Scale Company, Inc. "Before, there wasn't any way to know how much torque was being applied, but now they can ensure they are meeting the required specifications."

The TL8500™ Tension Links have also yielded increased operational efficiency by reducing the staff and equipment required to perform these types of jobs.

"One of the main reasons [redacted]™'s are being used is due to the optional audible alarm available," continued Marquis, "Combined with their large, easy-to-read display, knowing when the optimal force reading has been reached is now be a one man job."

A large display and an audible alarm let workers know when the optimal torque has been reached.

A large, backlit, LCD display and long battery life make the TL8500™ Tension Link a top choice for many different applications and industries.

Torque= lift force x Sin(t) x wrench length
t = angle and assuming 45 degrees based on visual from picture, sine would be square root of 2 divided by 2 or about 0.71 (This equate to about 29 % error in the torque measurement). If the angle where 90 degrees the sine error goes away.

Is this a good way to accurately measure torque?

The Right Processes

What's Wrong Here?

PERFORMANCE

TEST LOAD APPLIED (lbf)	Recorded Readings (Lb) Run 1	Run 2	Run 3	Fitted	Error 1	Error 2	Error 3
0	0.0	0.0	0.0	0.05	0.05	0.05	0.05
500	499.9	499.8	500.3	500.06	0.16	0.26	-0.24
1000	1000.1	1000.1	1000.3	999.94	-0.16	-0.16	-0.36
2000	1999.4	1999.3	1999.5	1999.52	0.12	0.22	0.02
3000	2999.1	2999.0	2999.2	2999.08	-0.02	0.08	-0.12
4000	3998.7	3998.6	3999.0	3998.84	0.14	0.24	-0.16
5000	4998.8	4998.8	4999.0	4998.89	0.09	0.09	-0.11
6000	5999.2	5999.3	5999.5	5999.26	0.06	-0.04	-0.24
7000	6999.7	6999.9	7000.2	6999.86	0.16	-0.04	-0.34
8000	8000.4	8000.4	8000.7	8000.51	0.11	0.11	-0.19
9000	9000.7	9000.8	9001.0	9000.95	0.25	0.15	-0.05
10000	10000.5	10000.8	10001.3	10000.81	0.31	0.01	-0.49
4000	4001.5	4001.4	4001.4				
0	-0.2	0.0	0.0				

POLYNOMIAL COEFFICIENTS FOR A

Coefficients*	
Coefficient A0=	5.072350e-002
Coefficient A1=	1.000166e+000
Coefficient A2=	-3.470746e-007
Coefficient A3=	7.319854e-011
Coefficient A4=	-3.939503e-015

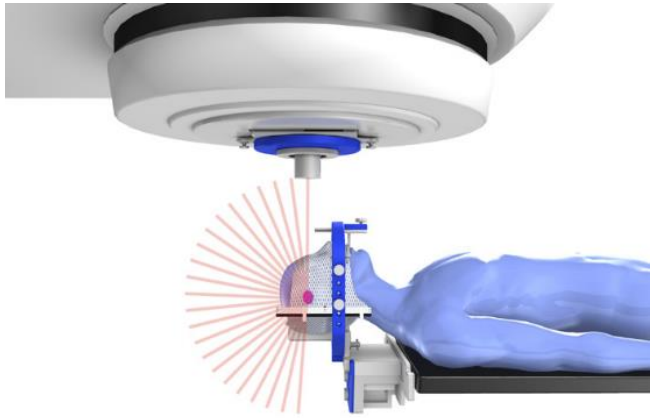
Standard Deviation	=	0.20026	lbf
Standard Deviation / Span	=	0.00200	%
Lower Limit Factor	=	0.48	lbf
Class A Lower Limit	=	192.3	lbf

*Reading = A0 + A1*Load + A2*Load^2 + A3*Load^3 + A4*Load^4
**Load = IA0 + IA1*Reading + IA2*Reading^2 + IA3*Reading^3 + IA4*Reading^4

Per Section 8.6 of ASTM E74-18, *"The verified range of forces shall not include forces outside the range of forces applied during the calibration."*

The Right Processes?

Incorrectly calibrated radiation treatment system overdosed 152 cancer patients



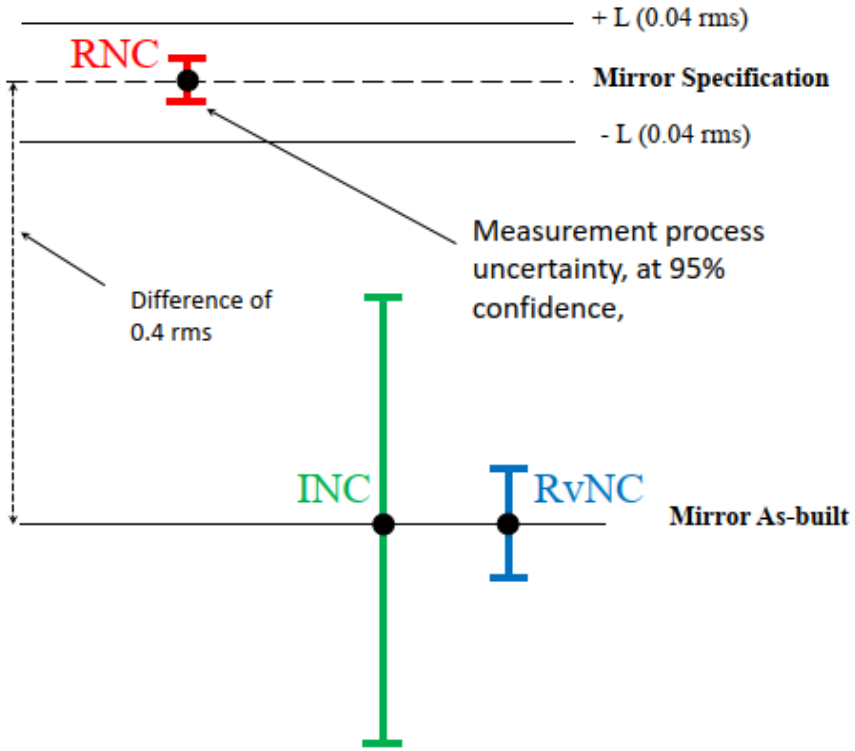
- CoxHealth of Springfield, MO inadvertently overdosed 152 cancer patients, 76 of which received up to 70% higher than prescribed dosages
- The device, a BrainLAB stereotactic radiation system used to treat areas 1.1 centimeters or smaller, was initially incorrectly calibrated by the CoxHealth chief physicist in 2004
- The error went undetected for five years, until September 2009 when another CoxHealth physicist received training on the BrainLAB system
- Although the calibration error was corrected, as of February 2012, the CoxHealth BrainLAB program remains suspended while lawsuits are settled

The Right Processes?

The Right Processes?

- Hubble Space Telescope (HST) launched April 24, 1990
- On-orbit checkout revealed HST could not be properly focused
- Ensuing investigation indicated the primary mirror was not built to specifications
- A servicing mission to correct the error was flown in December 1993 at a cost of over $1 billion USD

The Right Processes?



RNC: Reflective Null Corrector. Designed and built by Perkin-Elmer, the manufacturer of the primary mirror.

RvNC: Refractive Null Corrector. Standard for producing primary telescopes.

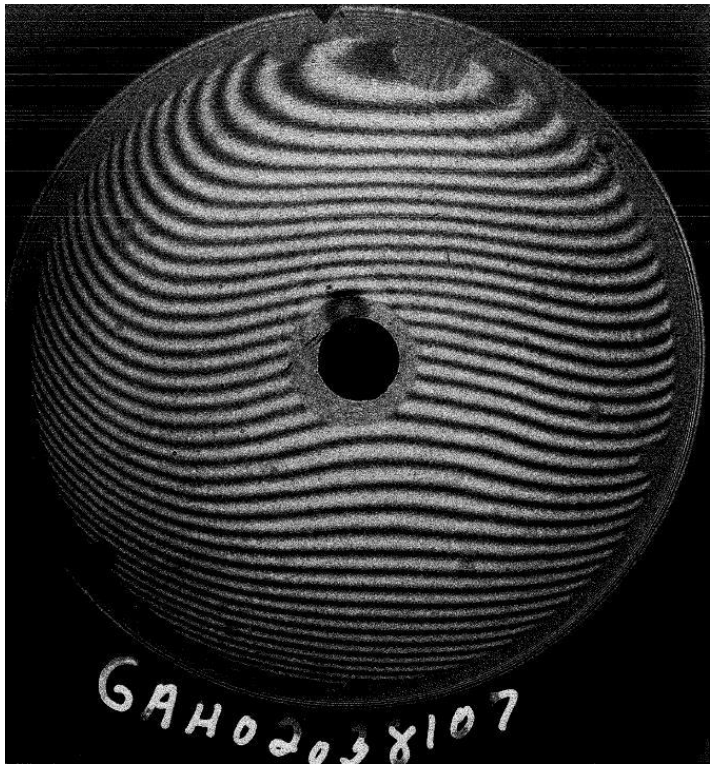
INC: Inverse Null Corrector. Designed to simulate a perfect mirror as a check for the RNC.

- Error was ten times specification
- The optical test used to manufacture mirror was set-up incorrectly
- The RvNC and INC clearly showed the error, yet both were discounted
- There was a mindset to discount any independent measurements less accurate than the RNC
- Discounting the INC and RvNC data was, in essence, "shopping for the answer they wanted"

"The project manager must understand the accuracy of critical measurements."

HST Failure report

The Right Processes?



Interferogram showing spherical aberrations (0.4 wave error)

Inverse Null Corrector (INC)

- Inserted under RNC, in place of mirror
- Used to check components of the RNC by simulating a “perfect” primary mirror
- INC accurate to ±0.14 wave rms
- Showed RNC error of 0.4 wave rms

Although the INC only had an accuracy of ±0.14 wave, this was easily good enough to reveal the 0.4 wave error, far outside the ±0.04 wave spec. Finding was dismissed.

The Right Processes?

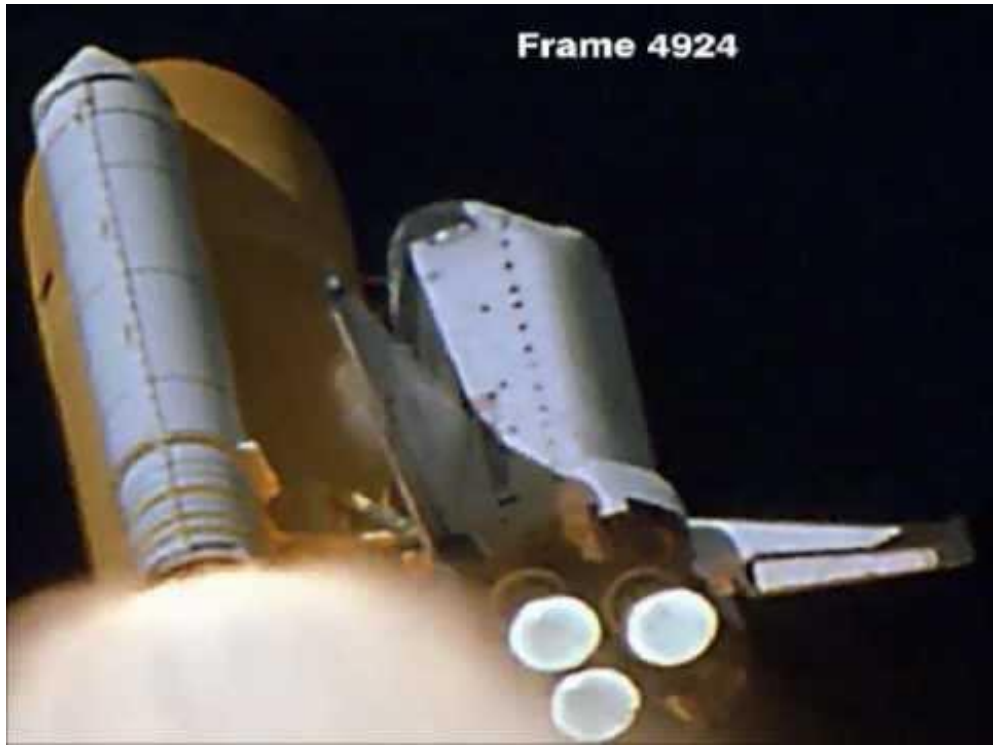
The internet theory is that a speck of paint on a device used to test the mirror resulted in distorted measurements. Luckily, scientists managed to fix the problem in 1993, using an instrument called the Corrective Optics Space Telescope Axial Replacement (Costar).

Can we believe the internet?

The Right Calibration Provider

- Has a measurement process uncertainty capable of meeting your needs and follows published standards
- Replicates how the instrument is being used
- Uses the right adapters to ensure results are repeatable
- Has competent technicians with training records
- Follows published standards
- Reports measurement uncertainty correctly
- Is rated highly and is reliable for on-time delivery

Communication – Death by Powerpoint



Communication – Death by Powerpoint

- Research showed that despite the years of engineering and planning, the downfall could be attributed to a technical communication failure following the debris damage and prior to reentry. In simple terms, years of engineering work from the smartest minds the world has to offer were undone by a few PowerPoint slides

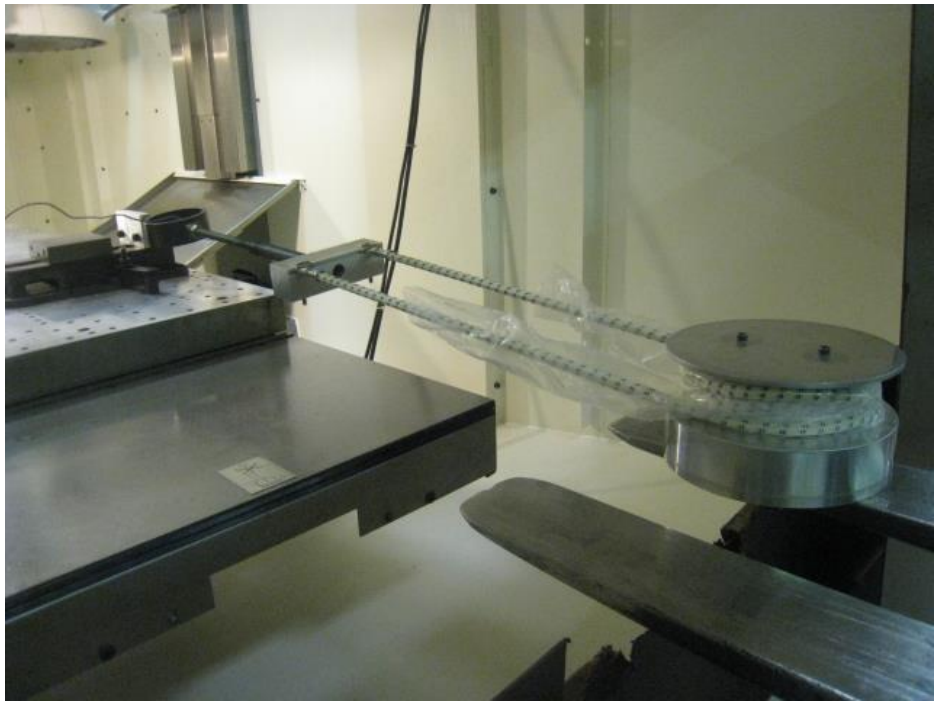
Review of Test Data Indicates Conservatism for Tile Penetration

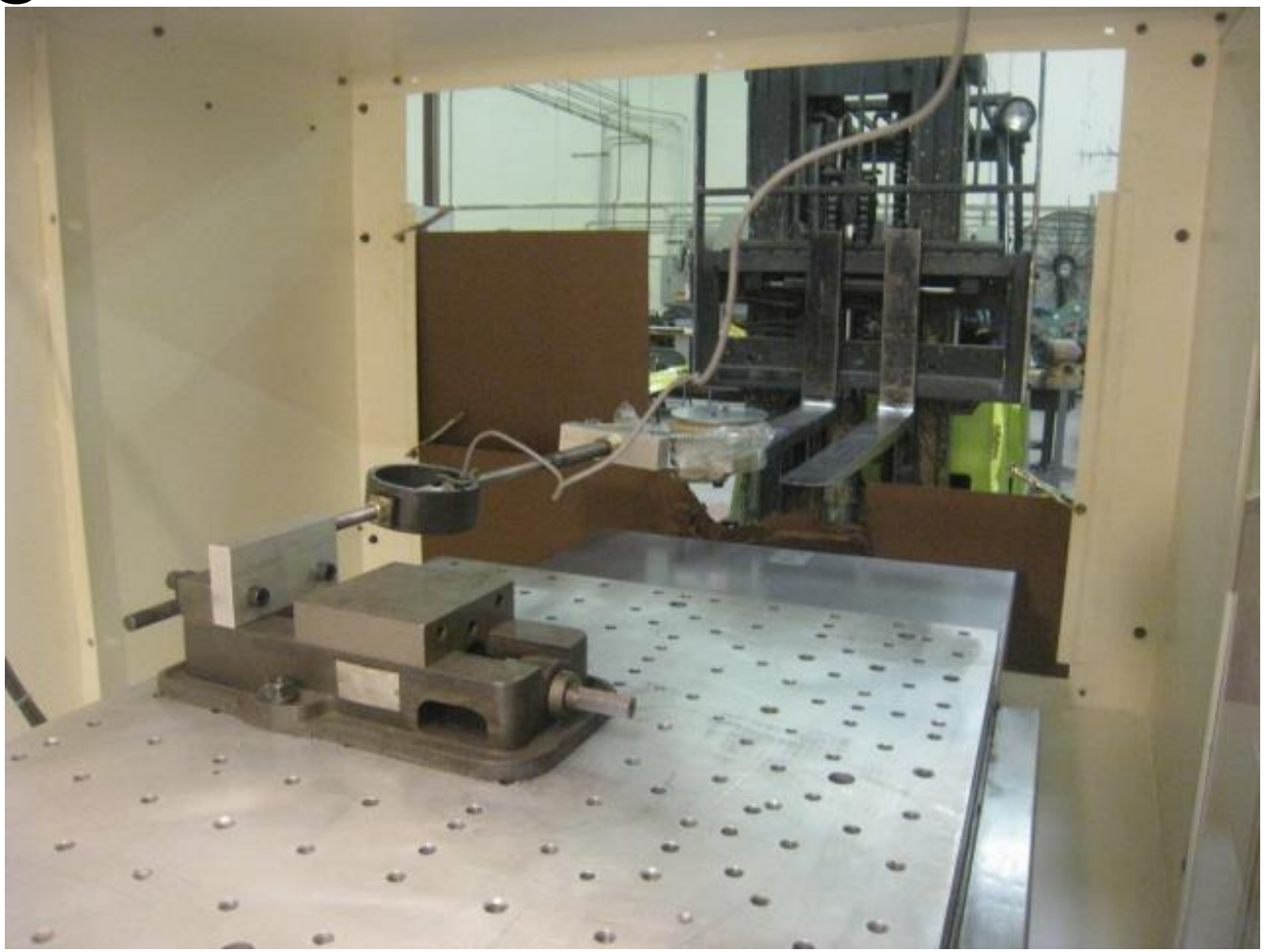
- The existing SOFI on tile test data used to create Crater was reviewed along with STS-87 Southwest Research data
  - Crater overpredicted penetration of tile coating significantly
    - Initial penetration to be described by normal velocity
      - Vaires with volume/mass of projectile (e.?g. 200ft/sec for 3cu. Ln)
    - Significant energy is required for the softer SOFI particle to penetrate the relatively hanrd tile coating
      - Test results do show that it is possible at sufficient mass and velocity
    - Conversely, once tile is penetrated SOFI can cause significant damage
      - Minor variations in total energy (above penetration level) can cause significant tile damage
  - Flight condition is significantly outside of test database
    - Volume of ramp is 1920cu in vs 3 cu in for test

Too Close to Home

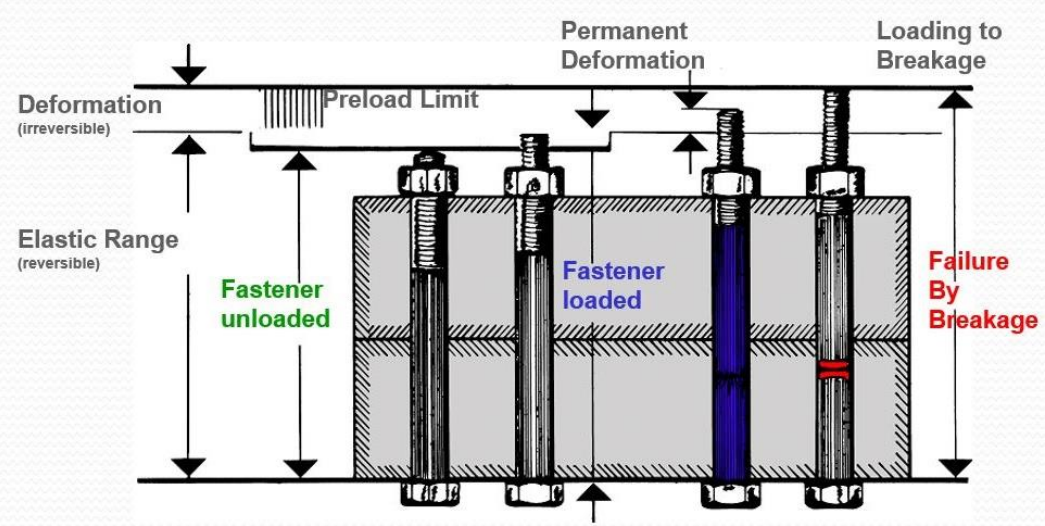
This is what happens when a smaller pin is used for a tension link or crane scale calibration and a driving force behind our Clevis adapters (Patent No. 11,078,052)

Too Close to Home





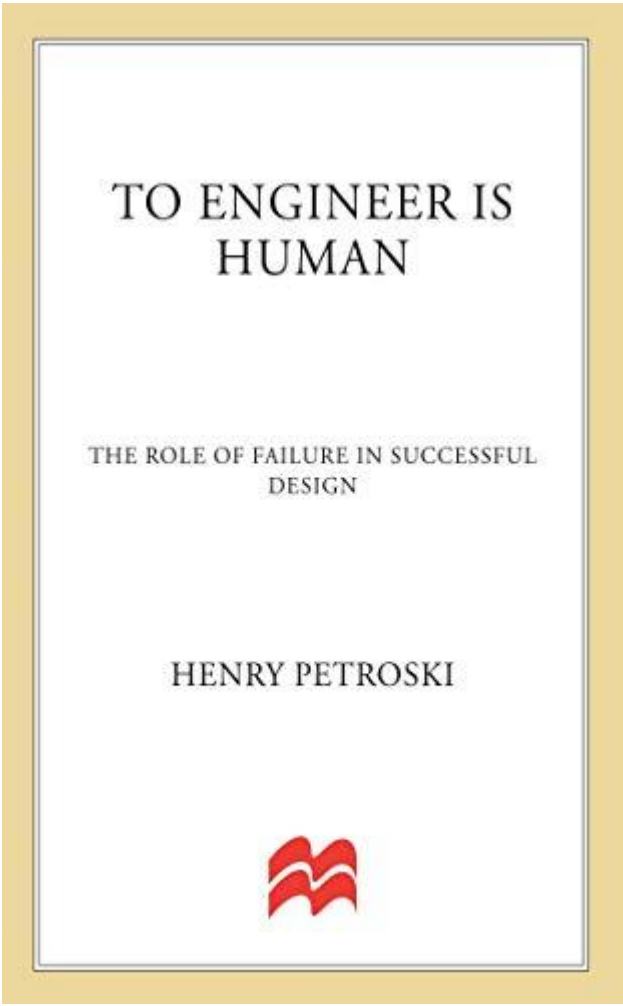
Too Close to Home



Conclusion

- Engineering failure is measured in two ways: human death toll and materials lost.

- "Failures appear to be inevitable in the wake of prolonged success, which encourages lower margins of safety. Engineers and the companies who employ them tend to get complacent when things are good; they worry less and may not take the right preventative actions."



Conclusion

Please join us in educating the people who underestimate the importance of following the standards, asking the right questions, using the proper machines, and adapters.

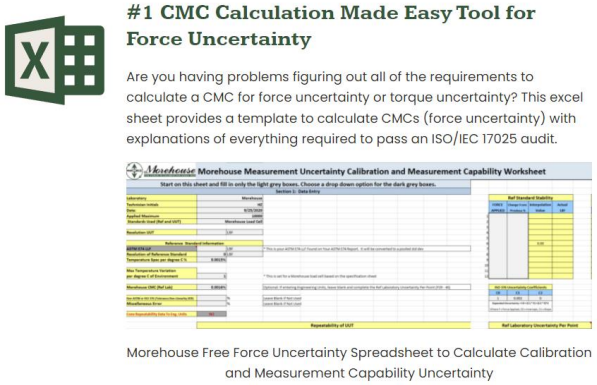
Using what was presented today, you can help us create a safer world by helping companies improve their force measurements.

Morehouse

We create a better safer world by helping companies improve their force and torque measurements

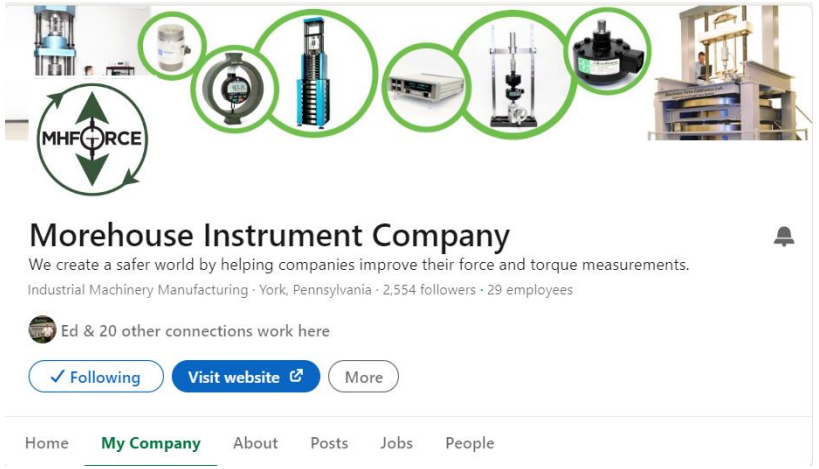
Want More Information?

[Morehouse YouTube Videos]



Morehouse Free Force Uncertainty Spreadsheet to Calculate Calibration and Measurement Capability Uncertainty

[Morehouse Free Downloads]



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Contact us at info@mhforce.com

Time for Questions and Answers

Join us for Future Webinars!

PJLA

Thursday, October 26, 2023 – 1:00pm ET
A Look at ISO/IEC 17025:2017 – Overview of the Requirements Specified for Equipment in Section 6.4

Wednesday-November 8th- 10am EST Ideagen –Virtual Summit
Matthew Sica Leveraging Technology to Improve Quality
Register through Ideagen- https://www.ideagen.com/

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Thank You!