

Integrated Development

Impact of Measurement Uncertainty on
the Development Cycle

Agenda

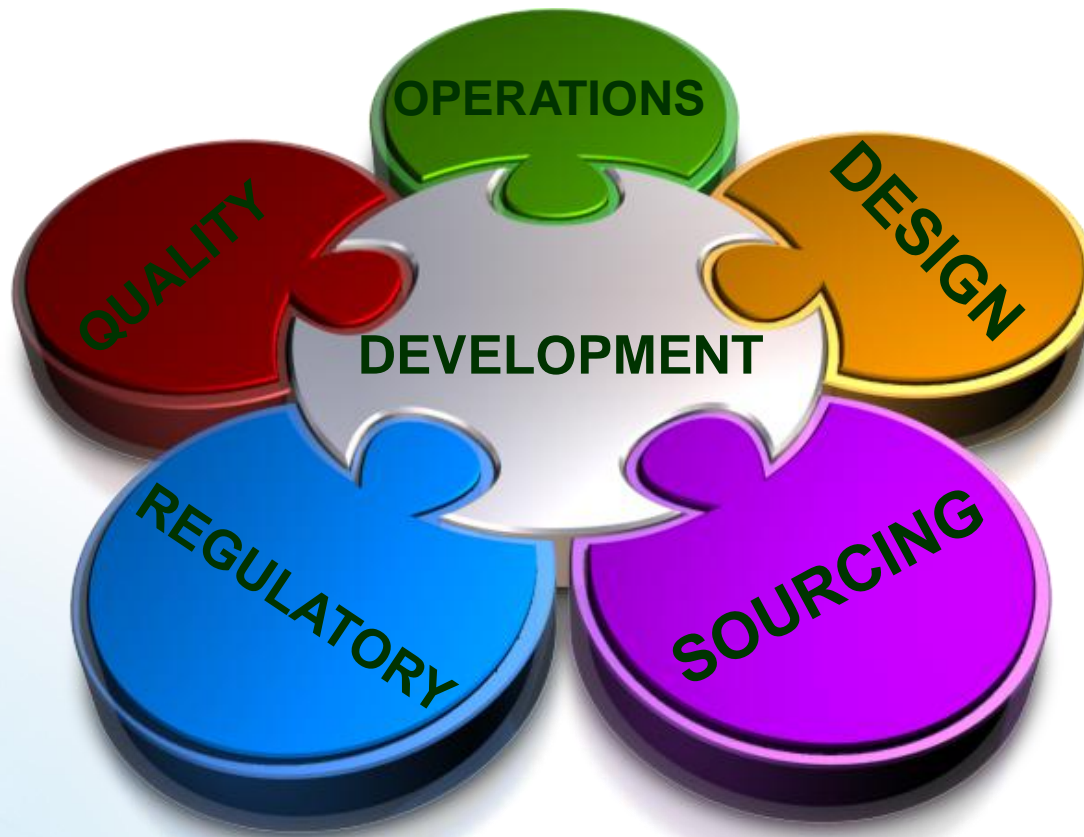
- Concept Overview
 - Quality as an accumulation of error
 - Sources of Error
 - Flow of Error in System
 - Impact of MU on development cycle outputs
 - Quality
 - Cost
 - Time to Market
- Example
- Conclusions
- Questions

Integrated Development

Concept Overview

The background is a solid blue color with a gradient. There are several white, semi-transparent lines and shapes that create a sense of depth and movement. A prominent feature is a glowing, metallic-looking object in the lower center, which appears to be a stylized representation of a computer chip or a similar electronic component. The overall aesthetic is clean, modern, and technical.

Integrated Development Environment - Background



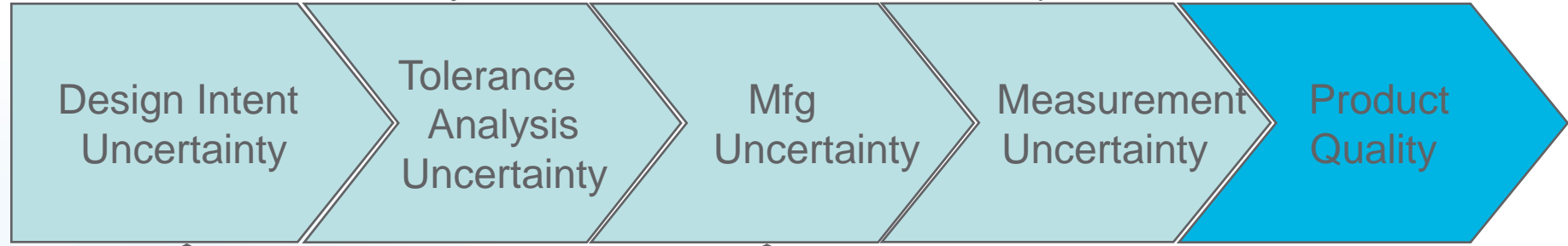
Integrated Development Environment

- Quality
- Time to Market
- Cost

Quality: A Function of Uncertainties

Difference between actual assembly behavior and simulated behavior

Difference between what is measured and the actual measurement

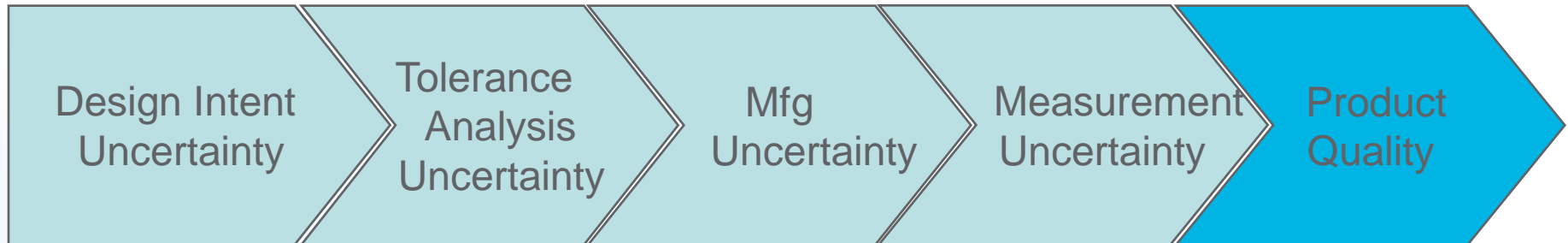


Difference between design intent and what is allowed by documentation

Difference between documented requirements and actual component

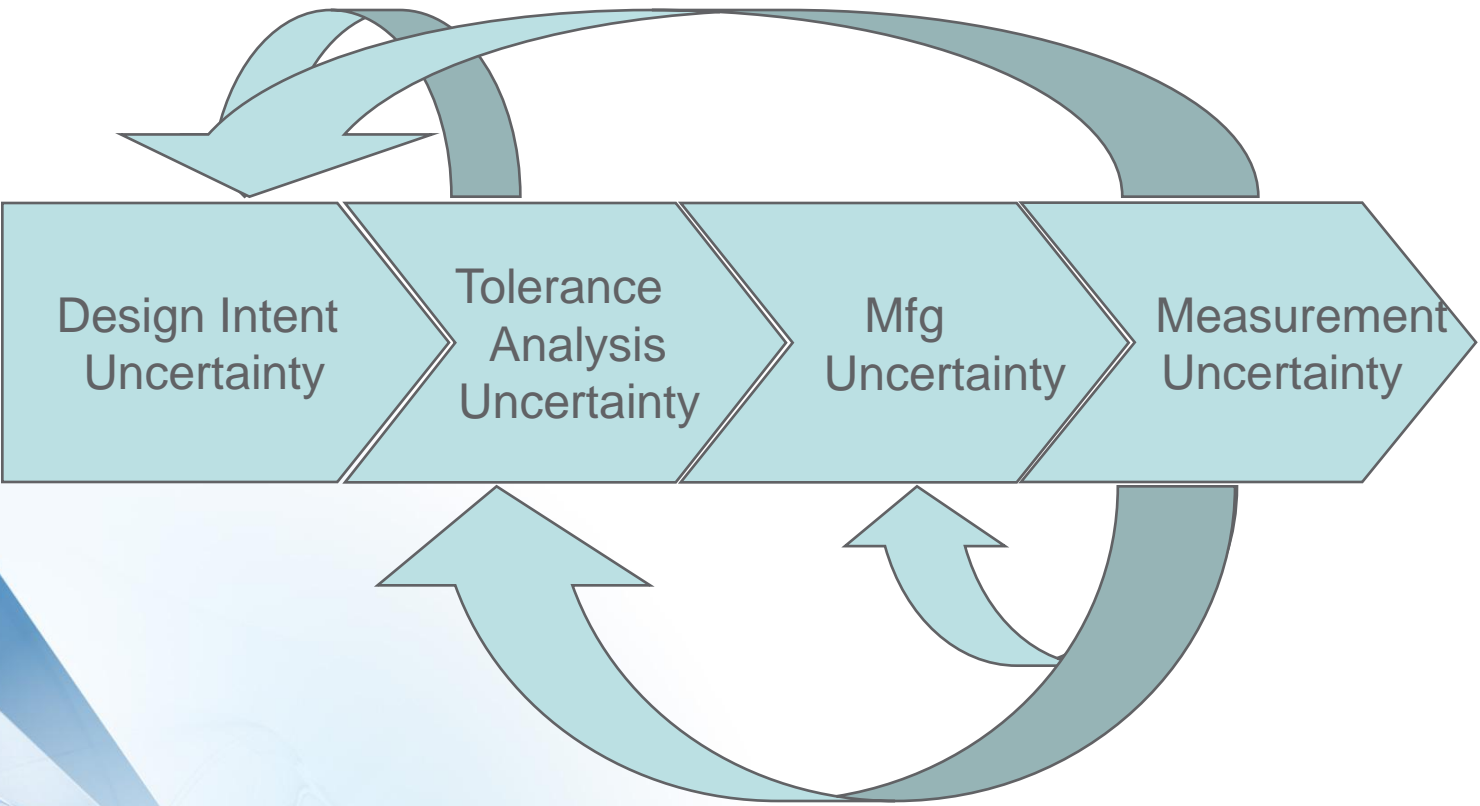


Quality: A Function of Uncertainties

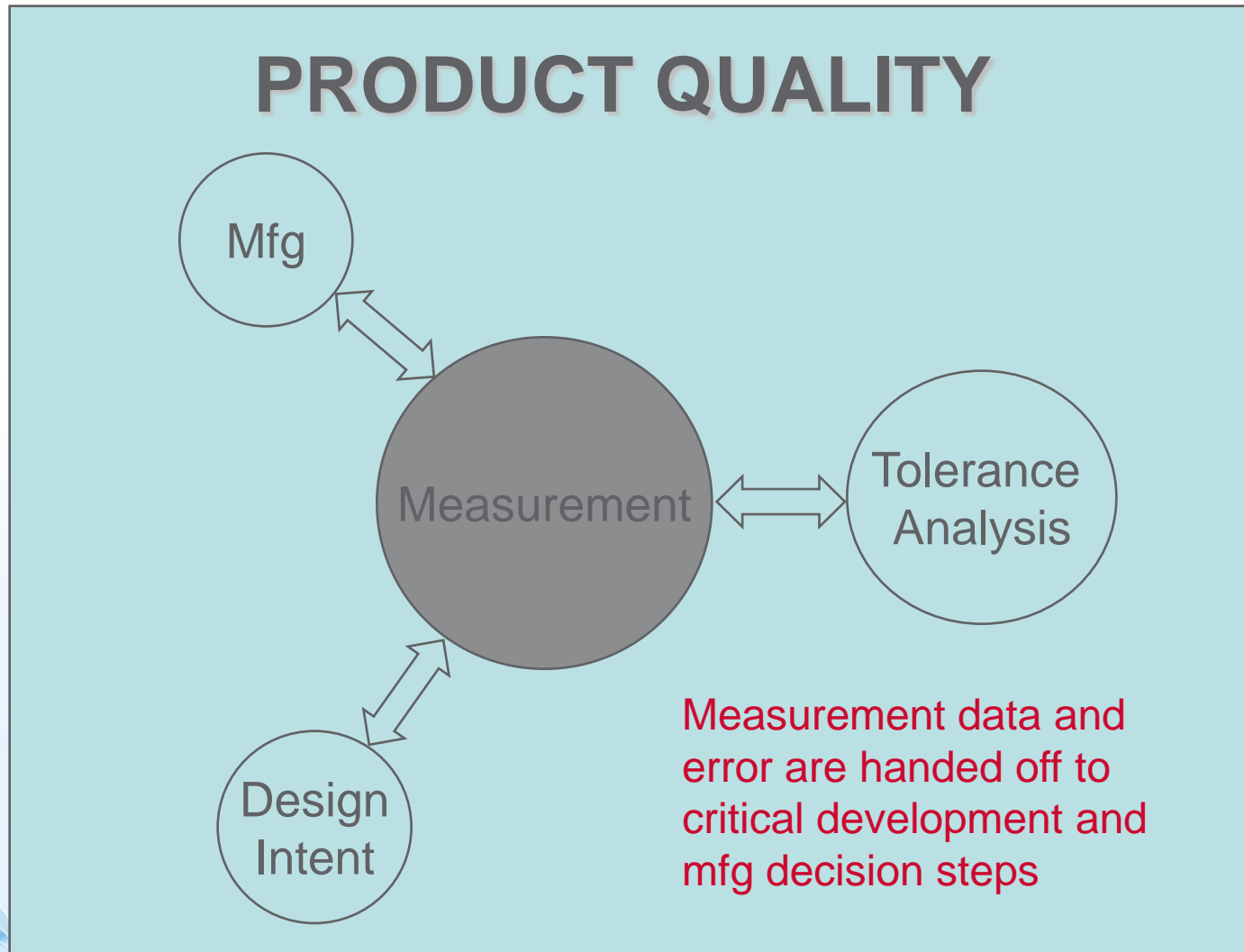


- **Determines Design Predictability**
- **Crosses Organizational Boundaries**

The Flow of Uncertainty



Quality: A Function of Uncertainties



Driving Down Uncertainty

DESIGN
Advanced Tolerance
Analysis Techniques

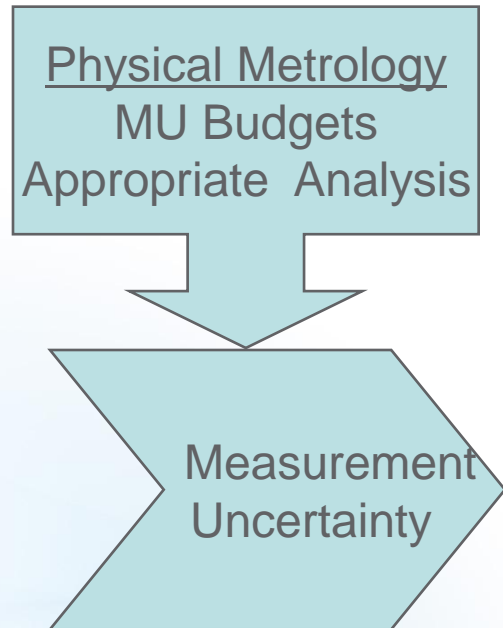
Physical Metrology
MU Budgets
Appropriate Analysis



DESIGN
Dimensioning &
Tolerancing Strategy

Mfg
More precise design
intent,
Process improvements

Impact of Measurement Uncertainty On Development



Misclassification

- Single value vs. capability

Measurement Uncertainty : Scenario 1

Classify unacceptable capability as acceptable

- Move ahead with Development
 - Component Qualifications
 - Development Builds and Testing
 - IQ/OQ/PQ
 - Design Verification Builds and Testing
- Fail at some point in these processes

Scenario 1: Impact

- Delay Product Launch (Lost Revenue)
- Tool Changes (Cost)
- Repeat Development work (Delays resources and impact to other developments)

Measurement Uncertainty: Scenario 2

Classify **acceptable** capability as **unacceptable**

- Do one of the following
 - Change Tool
 - Change design and perform tolerance analysis
- Act of changing tool or design likely created MU scenario-1

Integrated Development

Metrology Impact on Development

The background is a deep blue gradient. In the lower-left quadrant, there is a 3D wireframe cube rendered in a lighter blue, semi-transparent style. Several thin, white, curved lines sweep across the scene, creating a sense of motion and depth. The overall aesthetic is clean, modern, and technical.

Pin and Hole Simulation - Design

- Hole DIA : $.252 \pm .001$: Min Cpk 1.2
- Pin DIA : $.250 \pm .001$: Min Cpk 1.2 (Strength and fit into assembly)
- Clearance Requirement: $.000 - .004$: Min Cpk 1.33 (Fit and Wobble)

- Method – Monte Carlo

- Tools – Crystal Ball and Minitab

- Assumptions

- Measurement Error is the same for each component

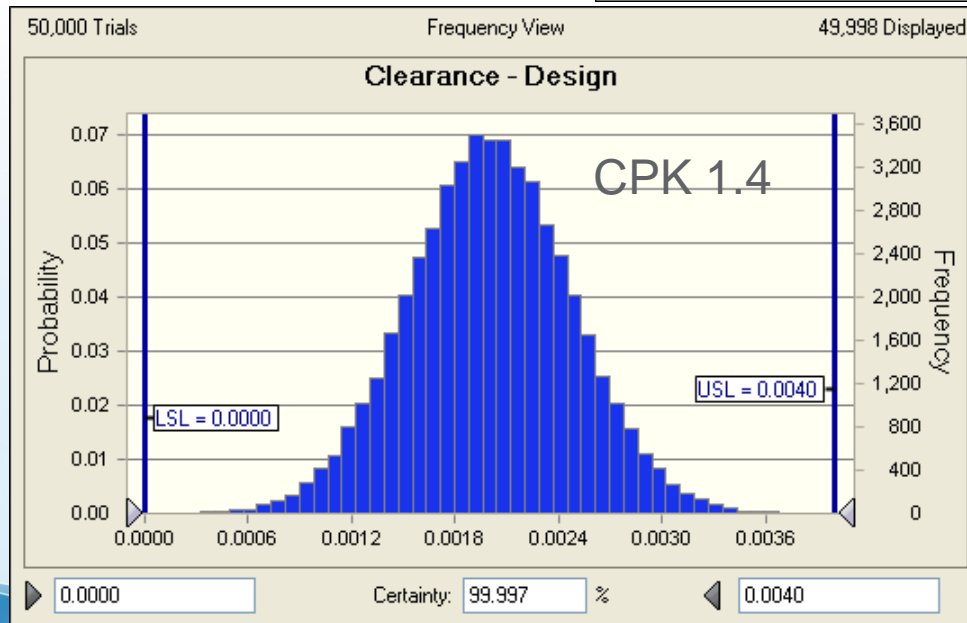
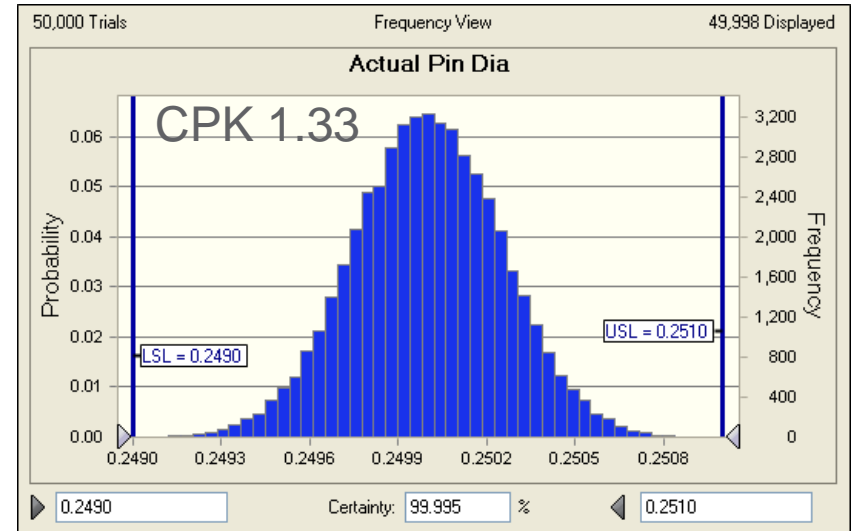
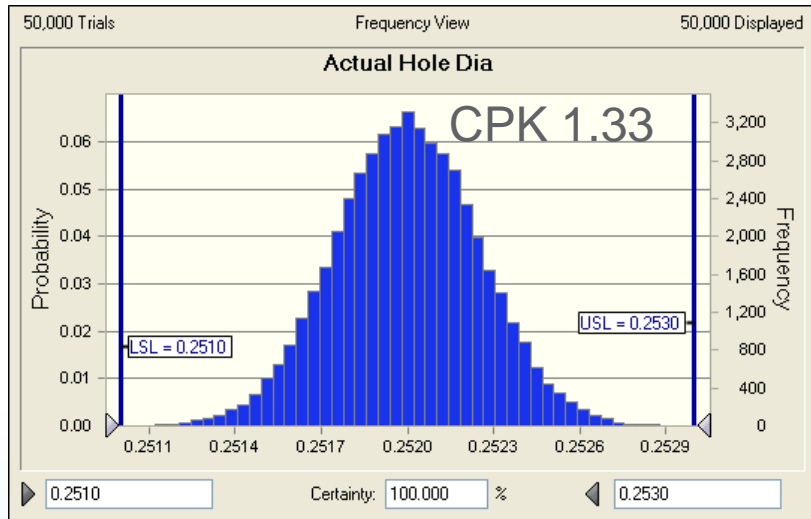
- Measurement Uncertainty is Composed of Bias and GR&R

- GR&R is normally distributed: 25% of Tolerance Zone

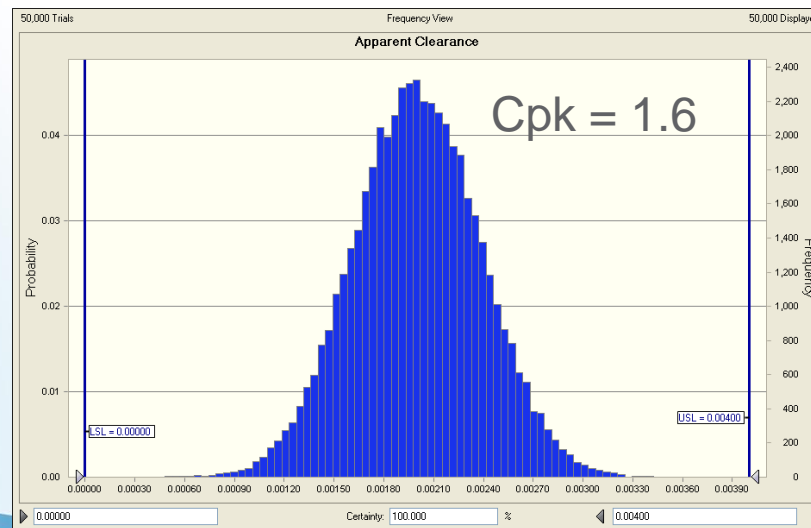
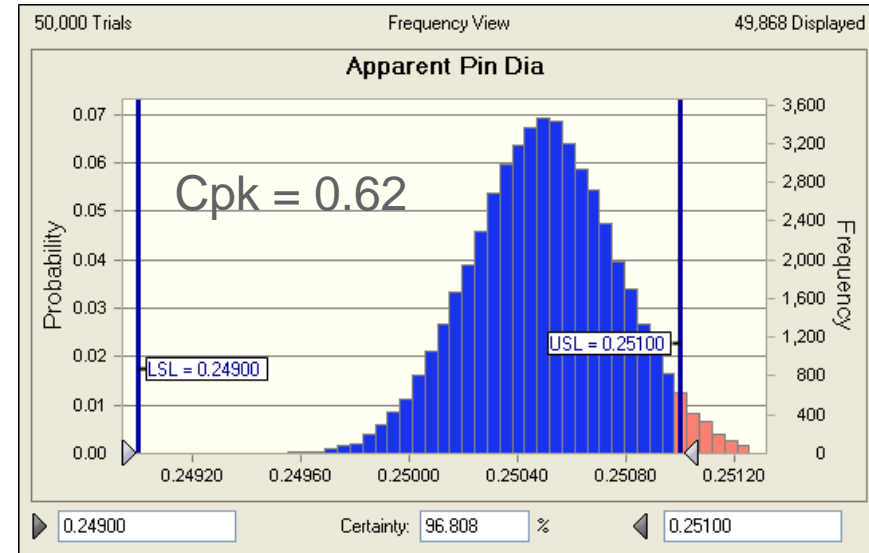
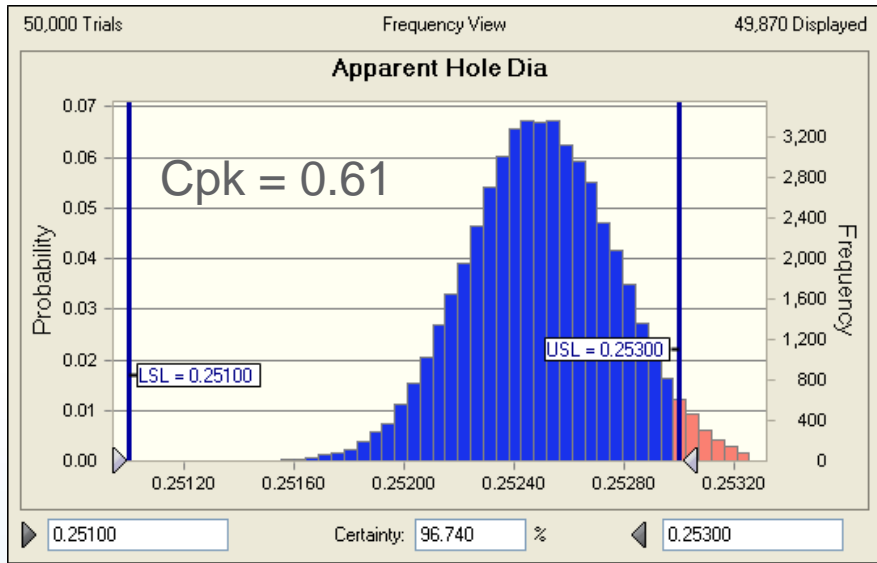
- Bias = $.0005$ "

- Actual parts are perfect (Normally distributed, Centered on Nominal with Cpk = 1.33)

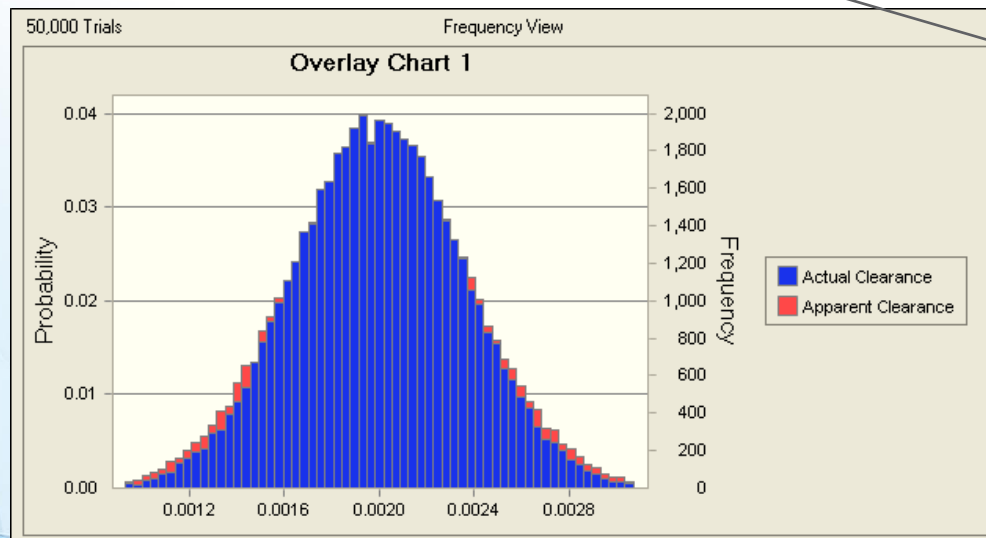
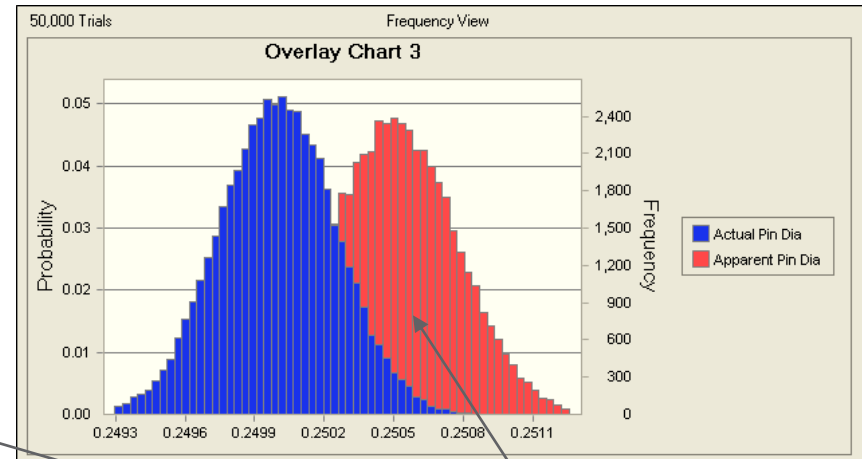
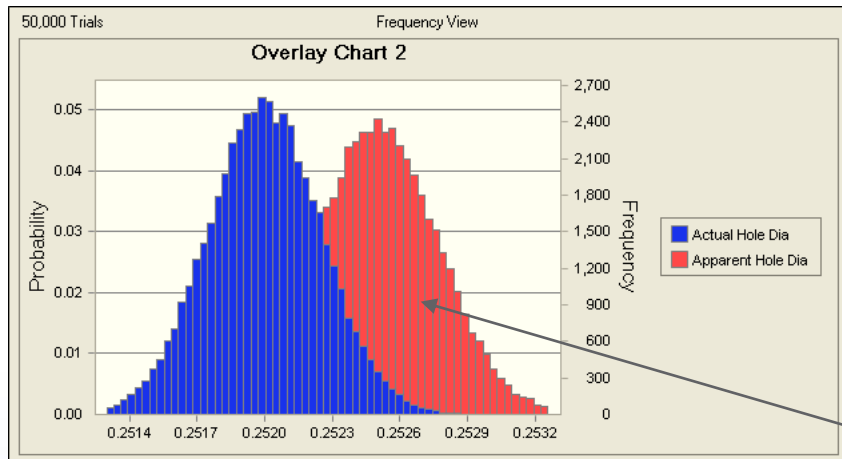
Pin and Hole - Simulation



Pin and Hole - Simulation



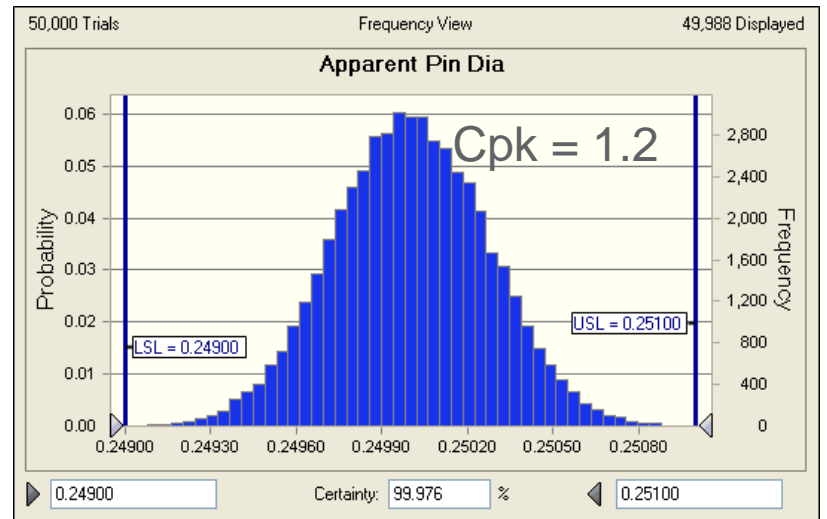
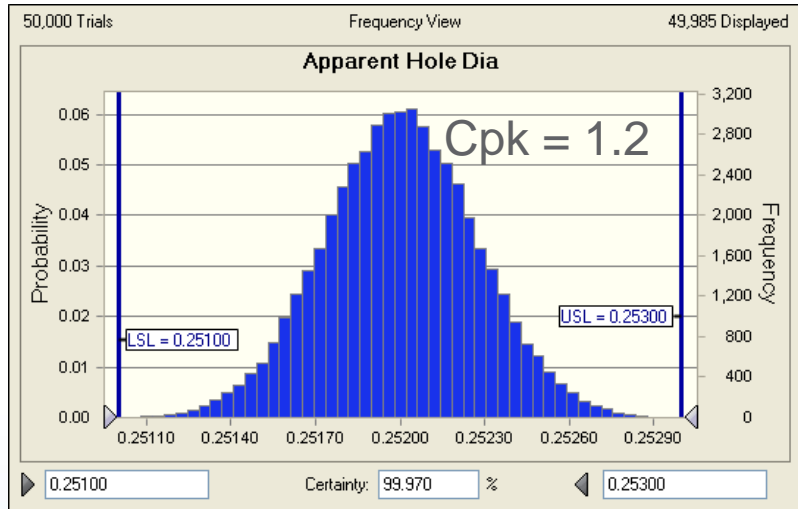
Pin and Hole - Simulation



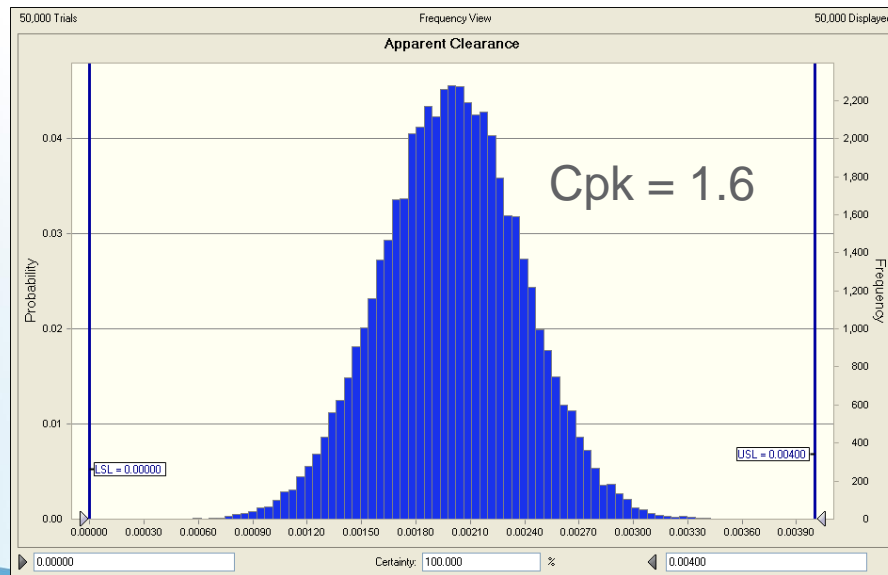
Scenario 1 – Led to believe good parts are bad

Instruct Mfg to move process mean $-.0005$ ”

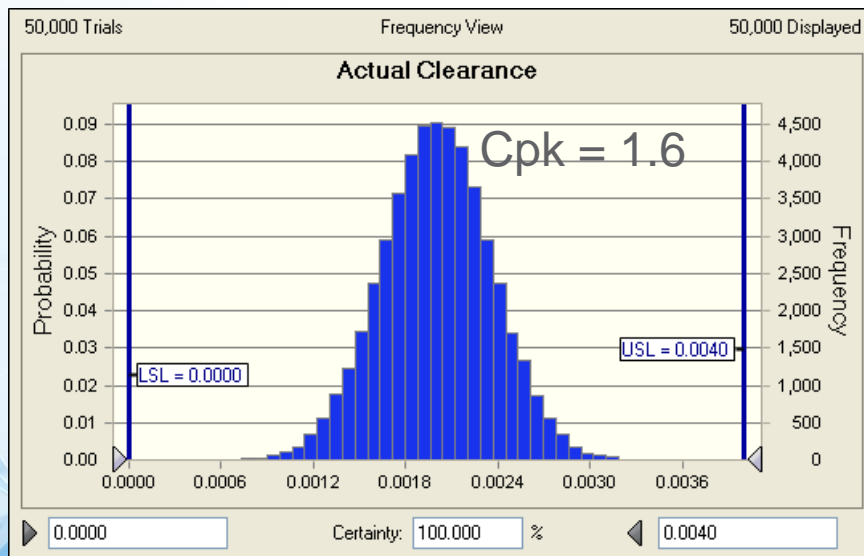
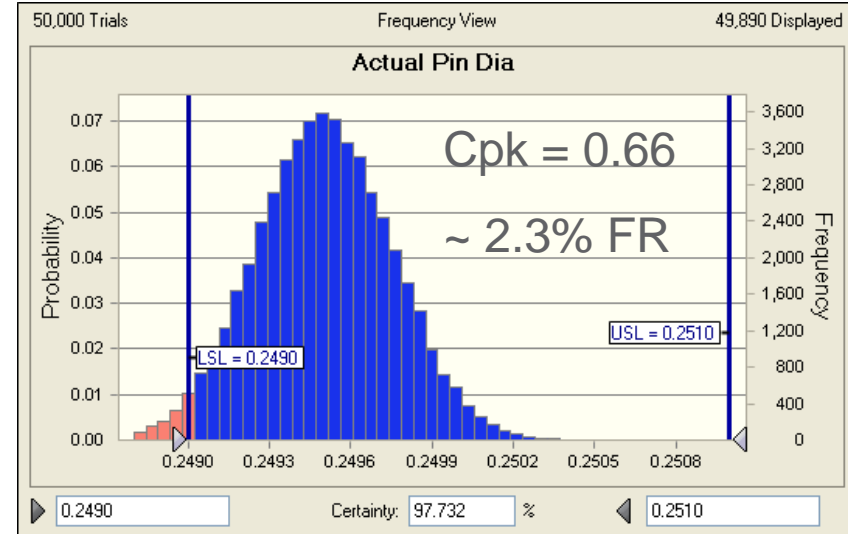
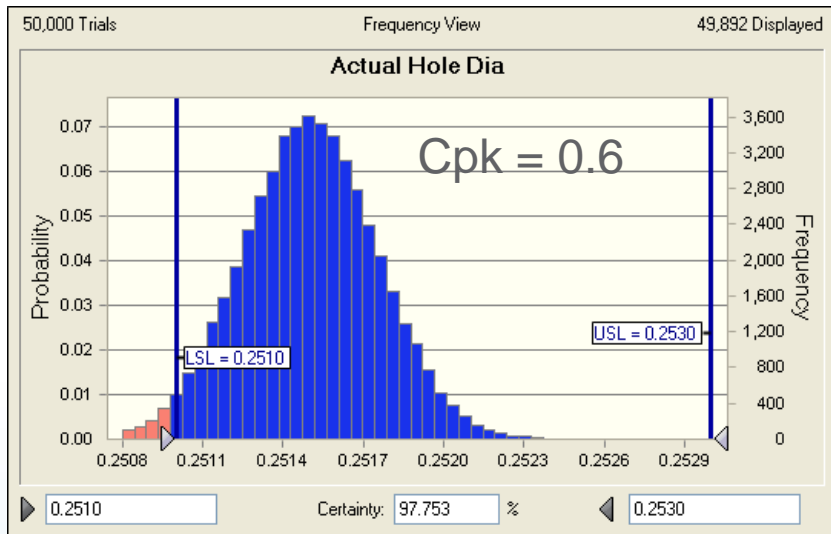
Pin and Hole – Simulation



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Pin and Hole - Simulation



2.3% Failure rate
may not be caught
Testing; Likely show
up in the field

Pin and Hole - Summary

- Good parts were made to look bad by way of Measurement Uncertainty
- Process mean was changed to move the distribution “into spec”
- Now bad parts were made to look good
- Bad parts were used in Development
- Two Possible Outcomes:
 - Get lucky and see a 2% failure rate in development testing
 - Go to production and field issues once sufficient volumes are reached
- Responding mostly to Bias Error

Key Take-Aways

- Capability of component distributions are more important than ever because of the *predictive design* goals
- Error sources in distribution estimates cut across all disciplines and must be quantified
- All sources must be controlled if predictive goal is to be reached
- Bias (as a percentage of tolerance) has the larger impact on misclassification than %GR&R and should be quantified

Thank You

The background is a deep blue gradient. In the lower-left quadrant, there is a complex, glowing, crystalline or molecular-like structure. It consists of several interconnected, semi-transparent blue surfaces that reflect light, creating bright highlights and soft shadows. The structure appears to be composed of thin, intersecting planes and curves, giving it a three-dimensional, ethereal quality. The overall aesthetic is clean, modern, and professional.

Continuing Work

