

# Integrated Development

Impact of Measurement Uncertainty on  
the Development Cycle

# Agenda

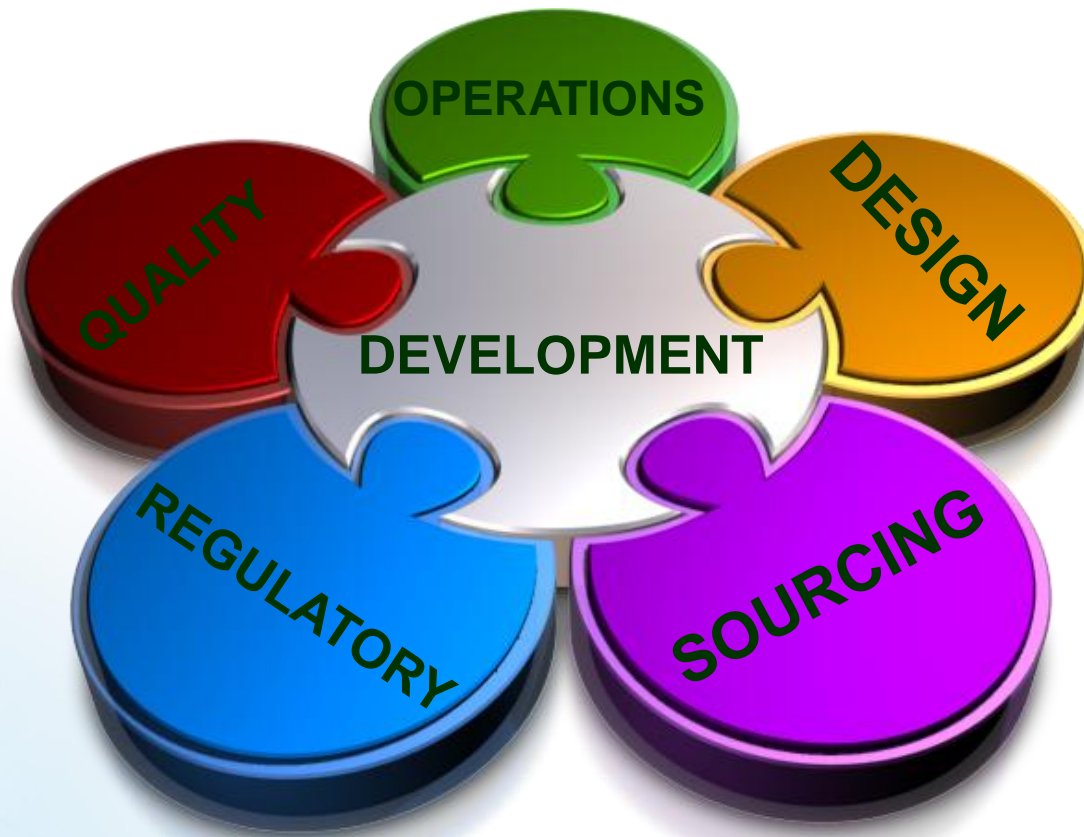
- Concept Overview
  - Quality as an accumulation of error
  - Sources of Error
  - Flow of Error in System
  - Impact of MU on development cycle outputs
    - Quality
    - Cost
    - Time to Market
- Example
- Conclusions
- Questions

# Integrated Development

## Concept Overview

The background is a solid blue gradient. In the lower-left quadrant, there is a complex, abstract white and light blue structure that resembles a stylized, glowing object or a network of interconnected nodes. Several thin, white lines radiate from this central area towards the top-left and bottom-right corners of the slide.

# 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

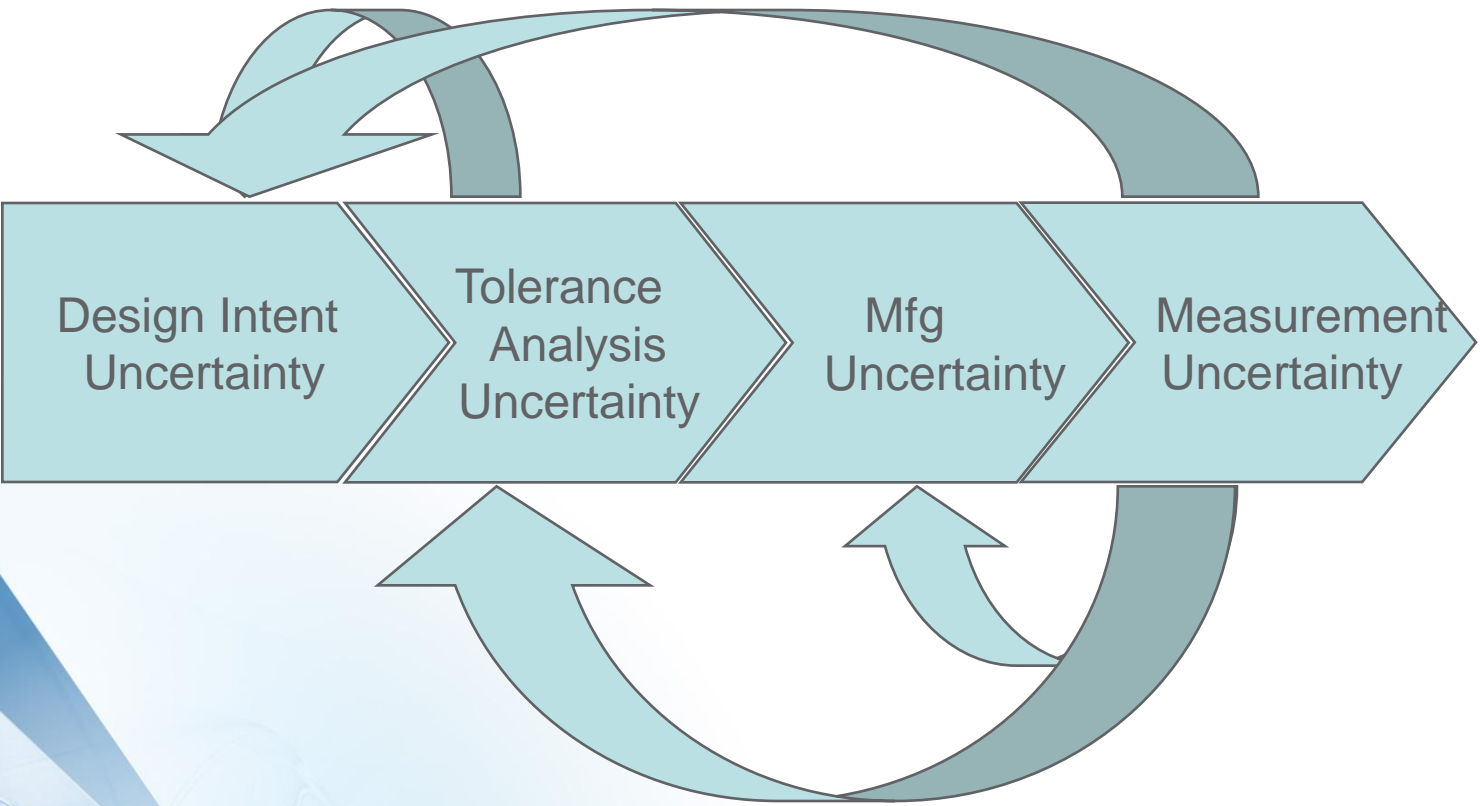


# Quality: A Function of Uncertainties



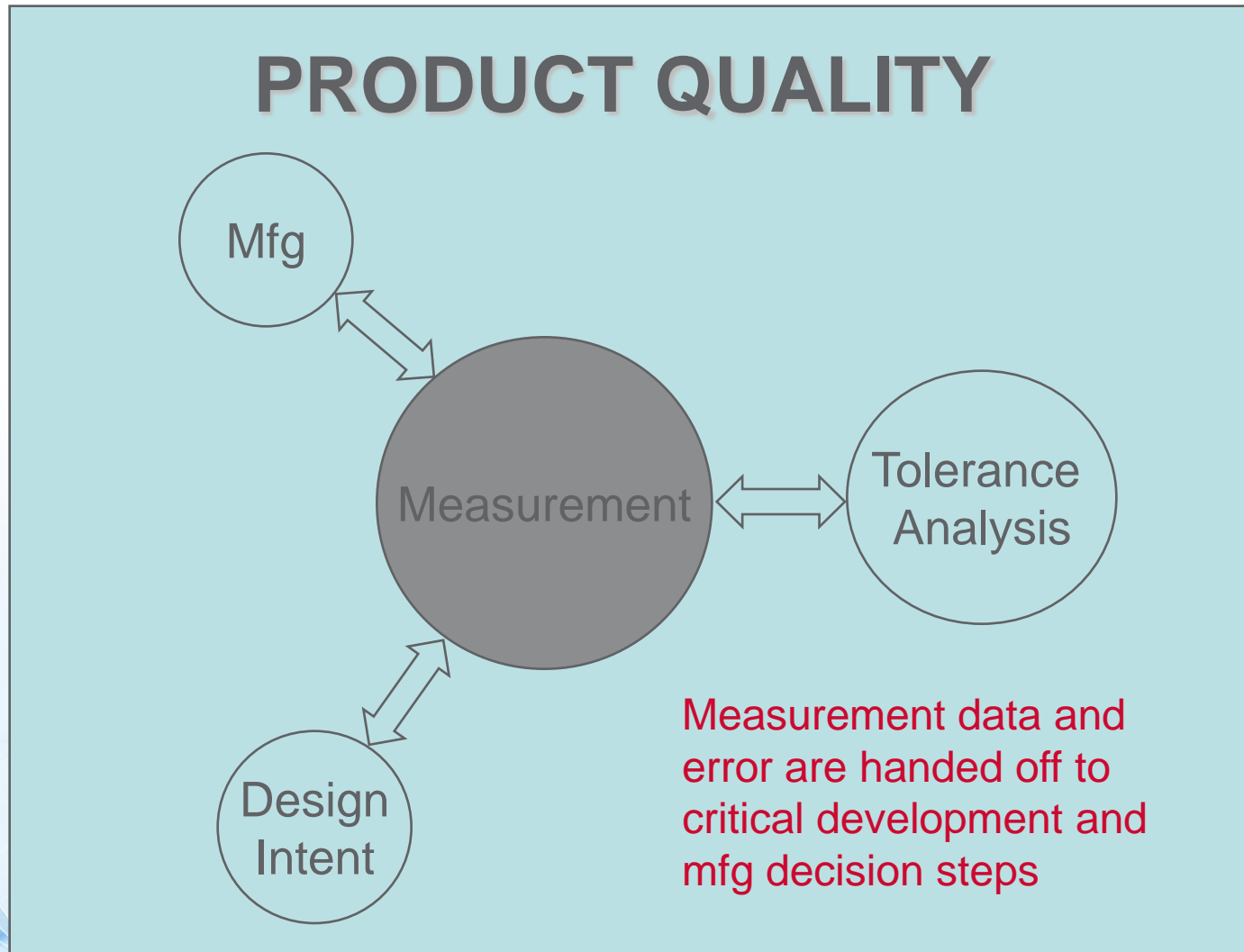
- **Determines Design Predictability**
- **Crosses Organizational Boundaries**

# The Flow of Uncertainty





# Quality: A Function of Uncertainties



# Driving Down Uncertainty

DESIGN  
Advanced Tolerance  
Analysis Techniques

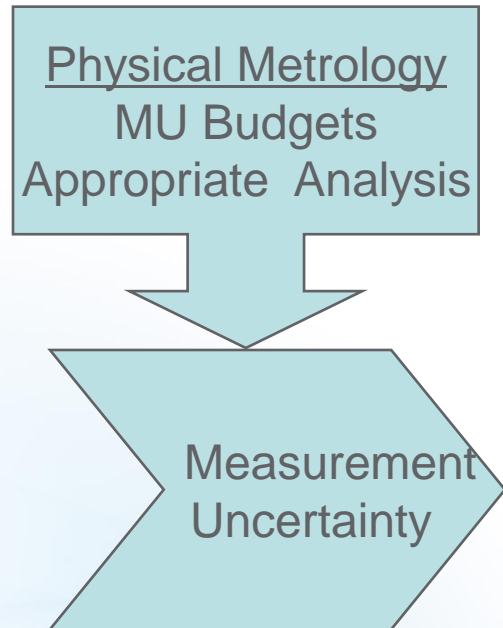
Physical Metrology  
MU Budgets  
Appropriate Analysis



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 complex, glowing, crystalline or molecular-like structure composed of many thin, intersecting lines and surfaces, some of which are highlighted with a bright white glow. Several broad, semi-transparent white bands or light rays sweep across the scene from the left and bottom, creating a sense of dynamic movement and depth.

# 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

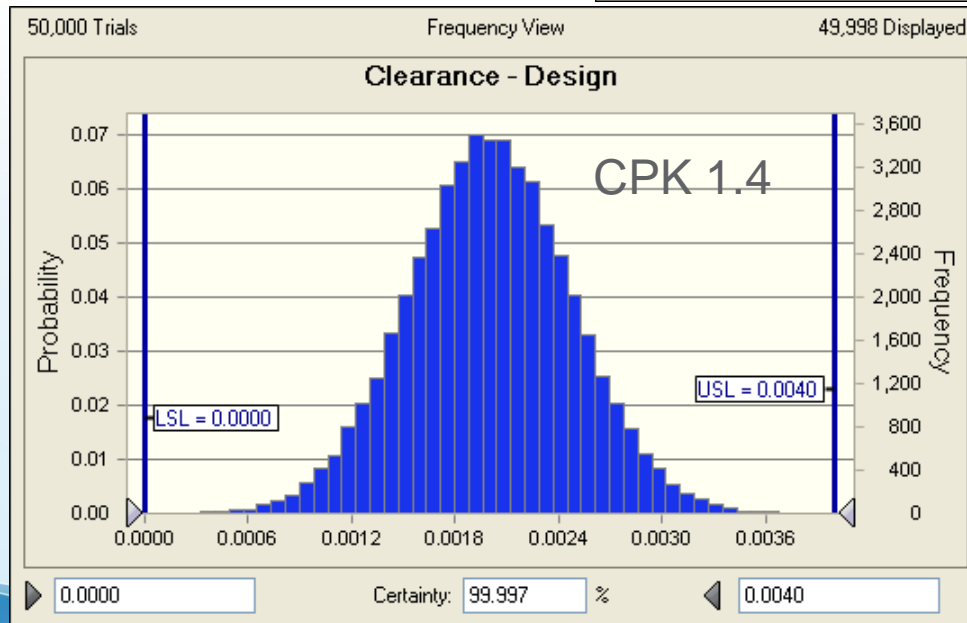
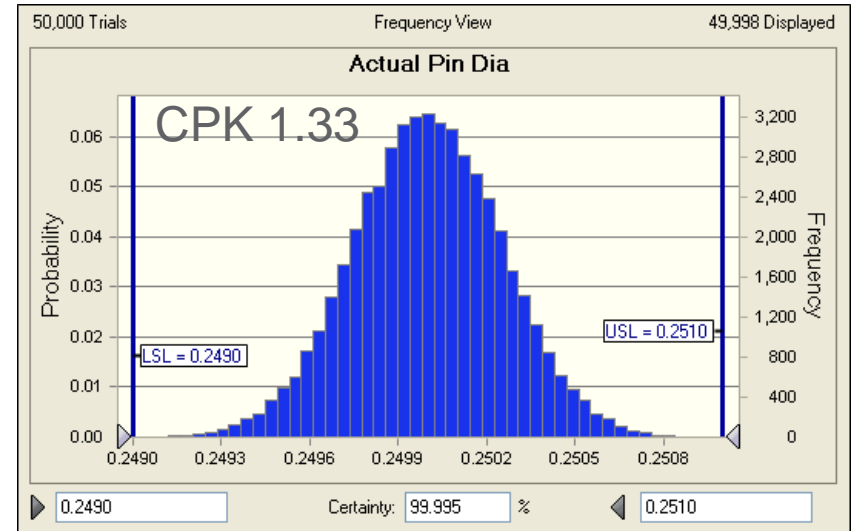
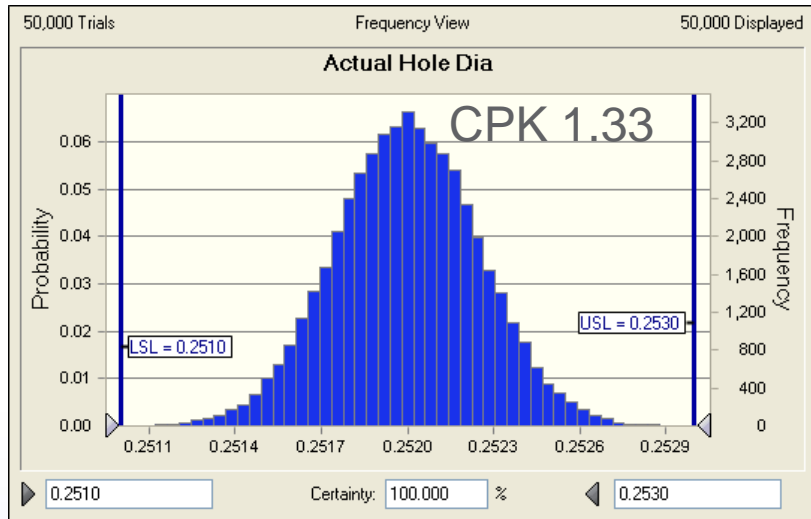
- GR&R is normally distributed: 25% of Tolerance Zone

- Bias =  $.0005$ "

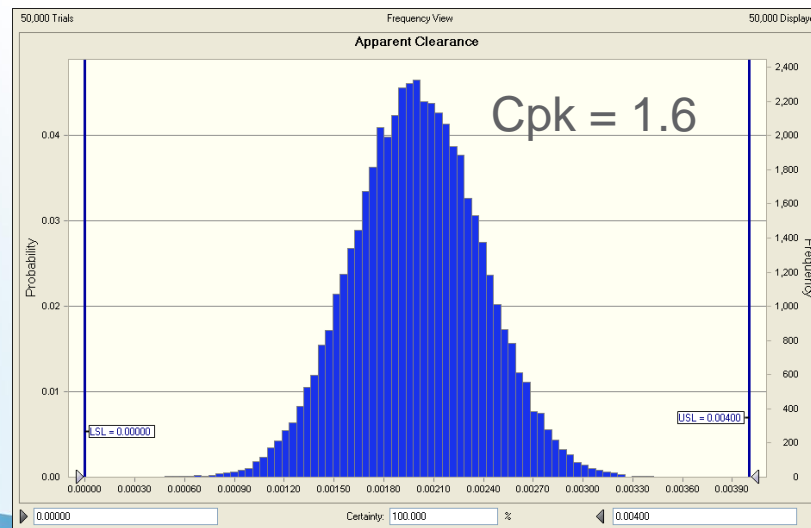
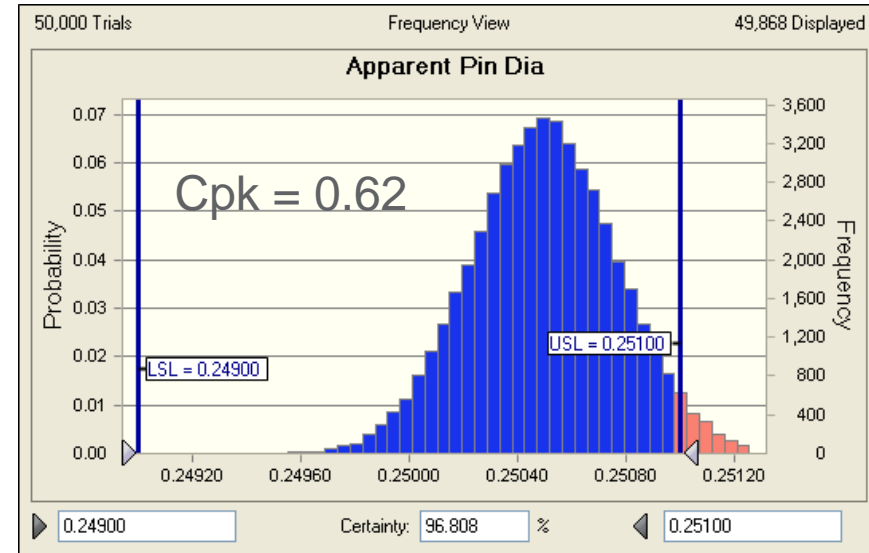
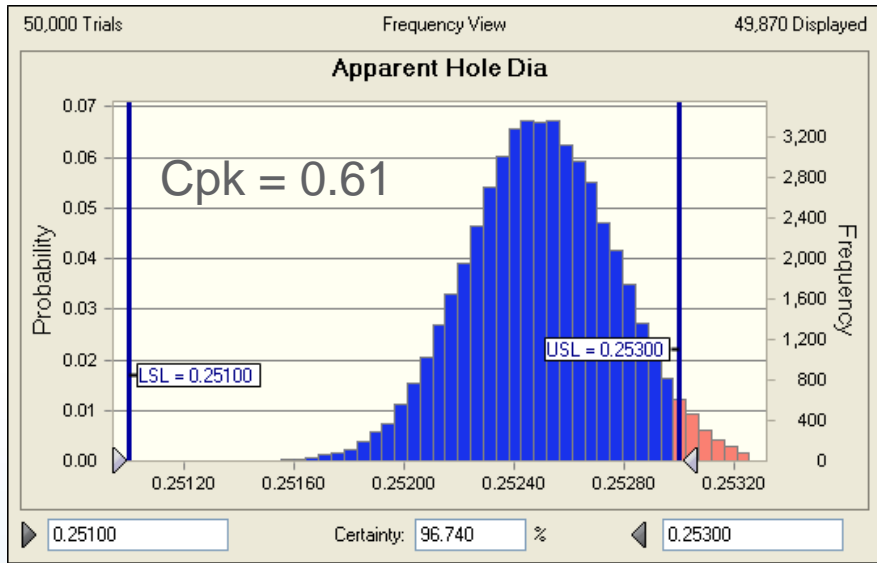
- Actual parts are perfect (Normally distributed, Centered on Nominal with Cpk = 1.33 )



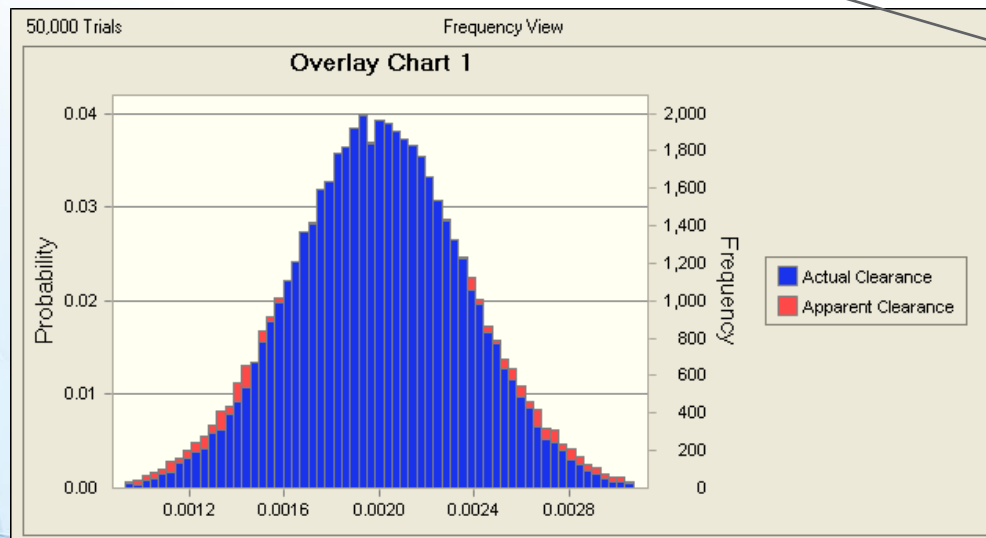
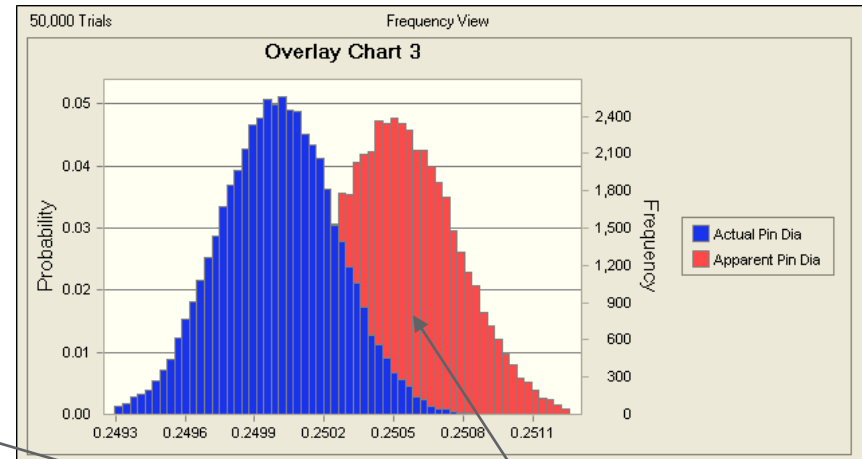
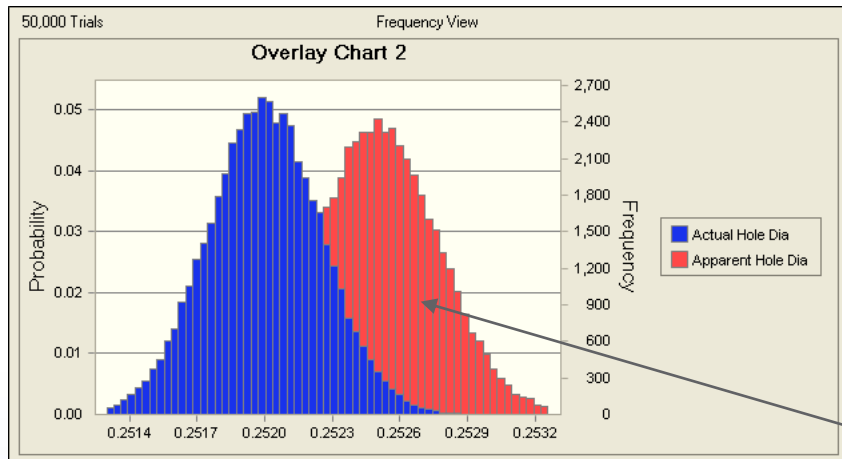
# Pin and Hole - Simulation



# Pin and Hole - Simulation



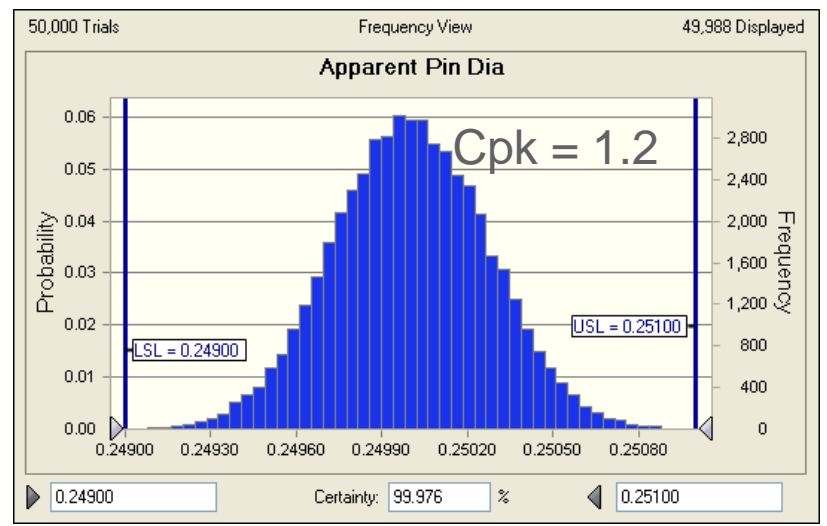
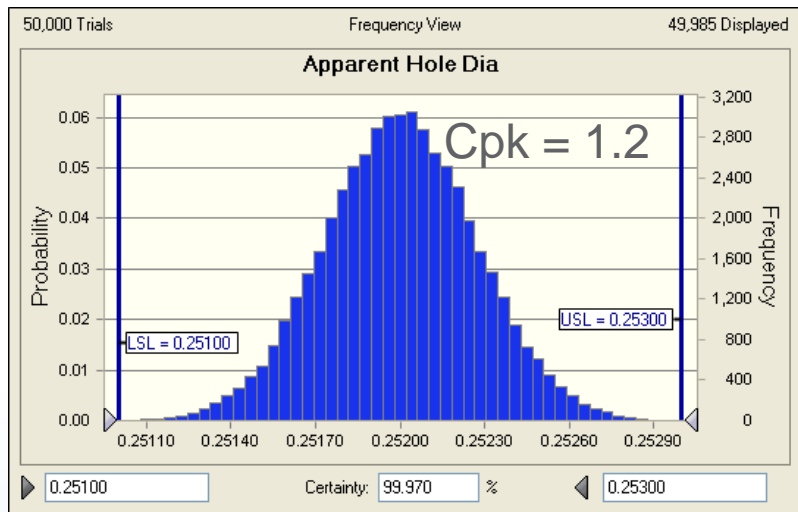
# Pin and Hole - Simulation



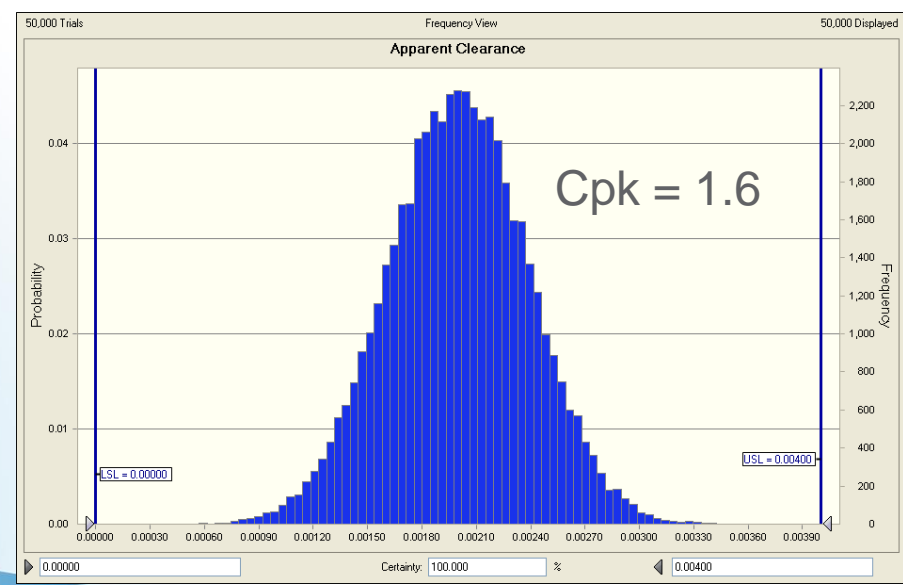
Scenario 1 – Led to believe good parts are bad

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

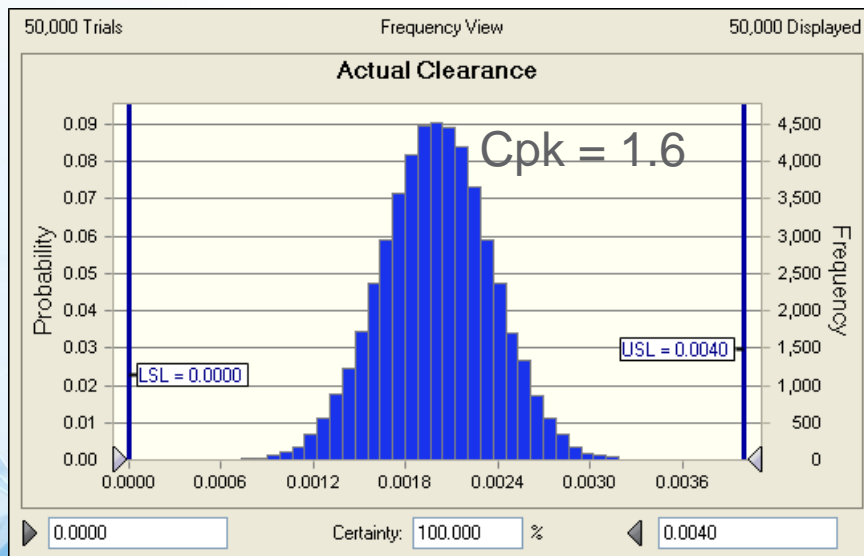
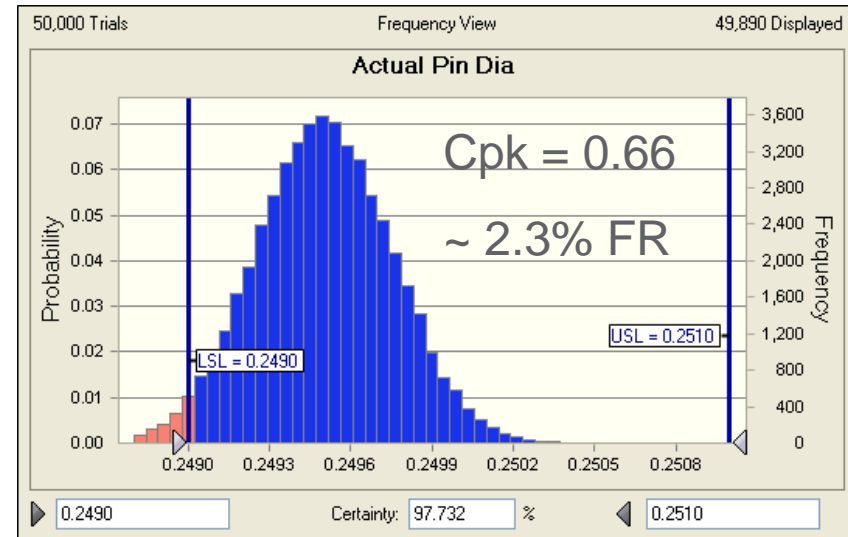
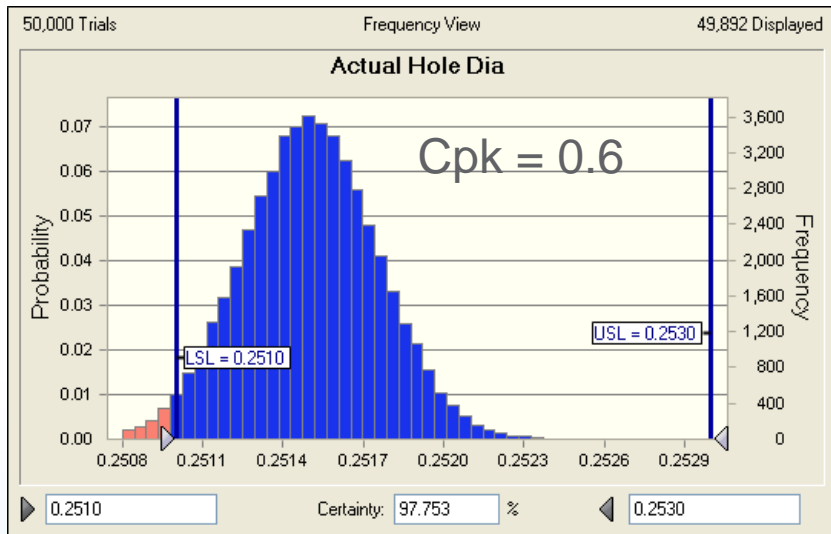
# Pin and Hole – Simulation



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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 a bright, multi-faceted appearance. Thin, white, curved lines sweep across the scene, intersecting the glowing structure and adding a sense of motion and depth. The overall aesthetic is clean, modern, and high-tech.



# Continuing Work

