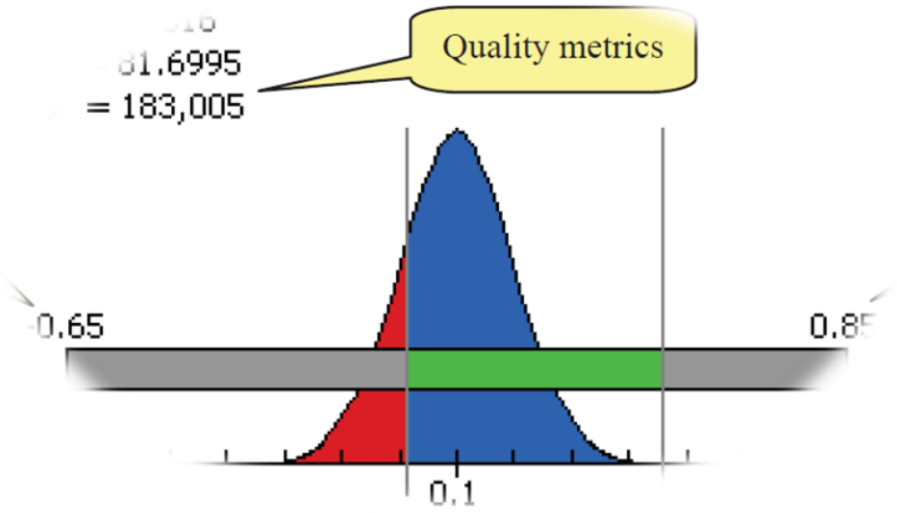
Computer Aided Tolerancing

PTC® Live Global

JUNE 7-10 – NASHVILLE, TN



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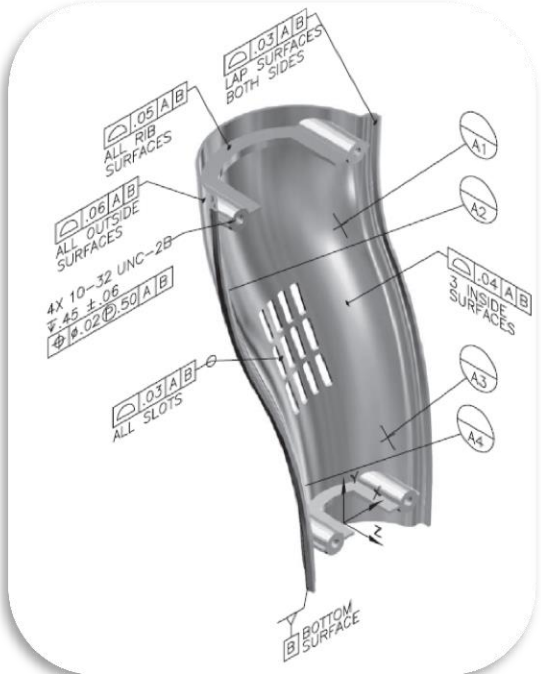
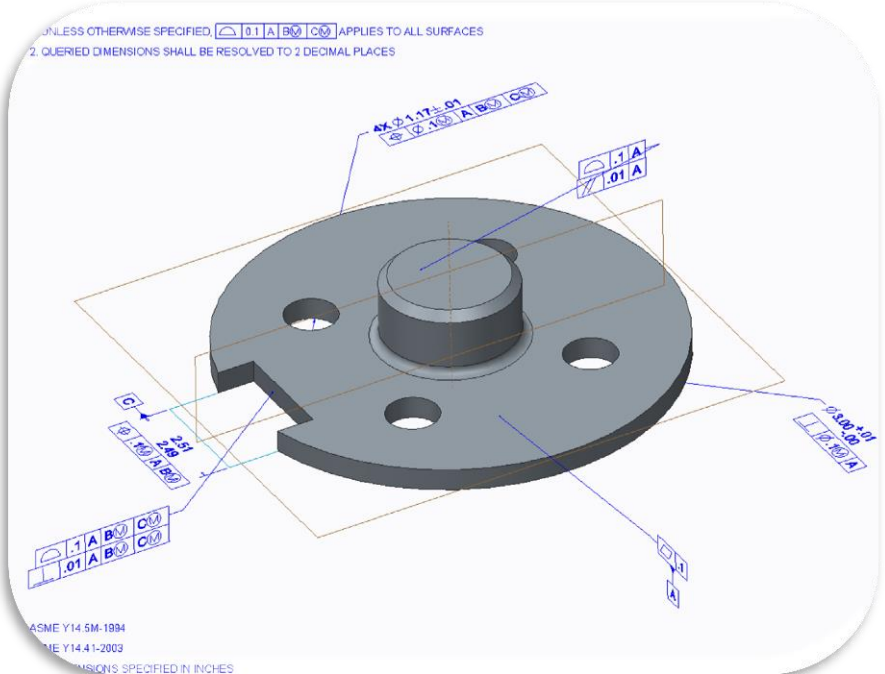
www.aes.nu

Geometric Dimensioning and Tolerancing (GD&T)

- *GD&T* is a language for communicating engineering design specifications
- GD&T includes all the symbols, definitions, mathematical formulae, and application rules necessary to embody a viable engineering language

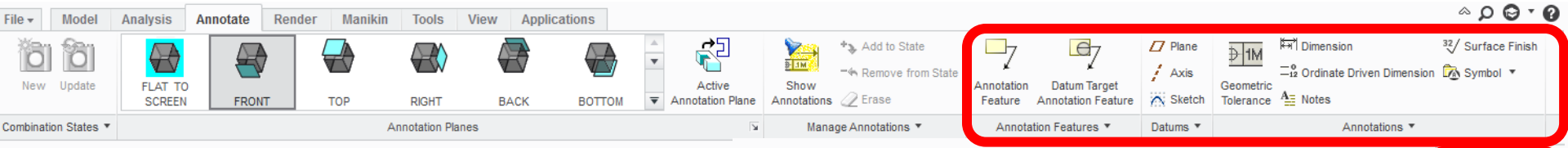
Statistics gathered by one of the top 3 CAD providers have found that 80% of manufacturing errors were down to incorrect use of GD&T



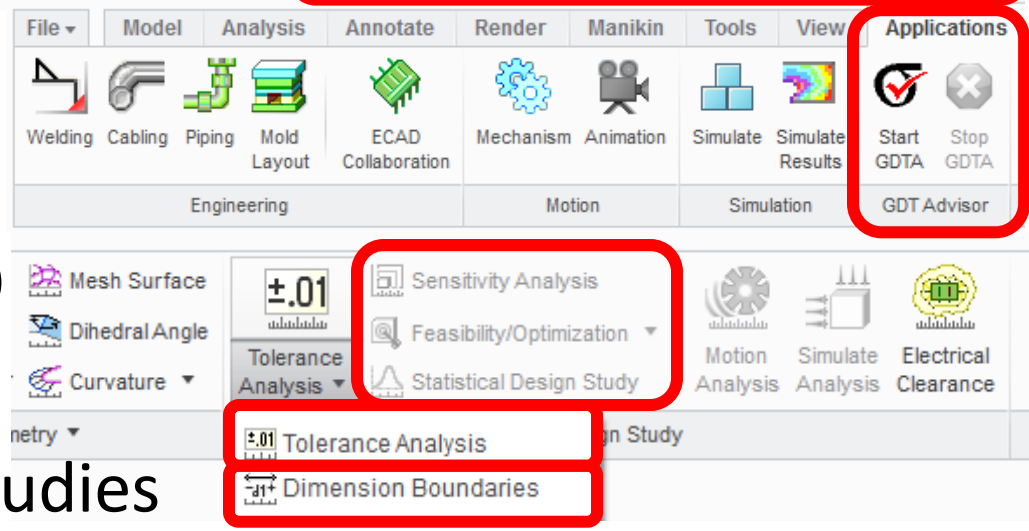


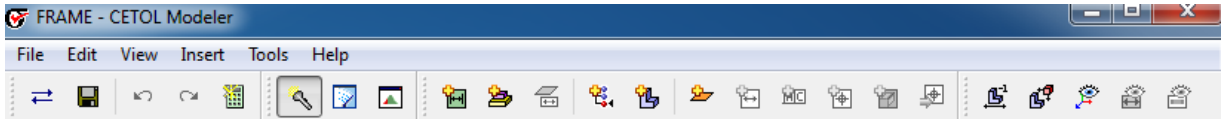
Tolerance Processes within CREO

1. Annotate Features GD&T Features



2. GDT Advisor
3. Dimension Boundaries
4. Tolerance Analysis (1D TAE)
5. BMX Sensitivity
6. BMX Statistical Design Studies
7. CETOL 6σ

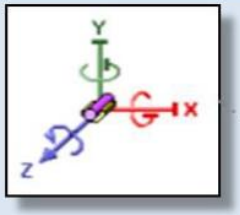




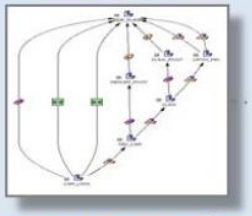
   a. 3D Tolerance Analysis
   b. Generates Geometric Dimensioning and Tolerancing Features
   c. Tolerance Optimization for Assembly Quality

CETOL 6σ Components

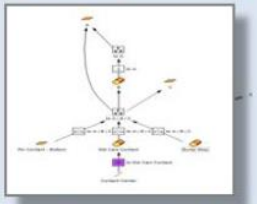
Modeling



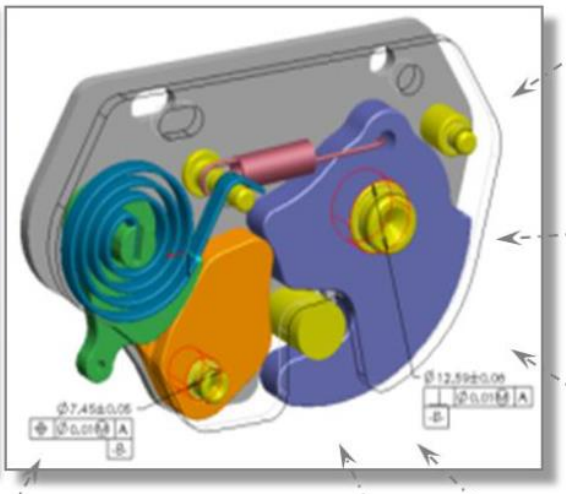
Feature to Feature Constraints



System Constraints

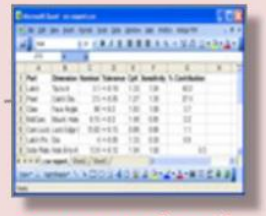


Dimension Constraints



Reporting

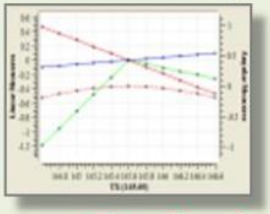
Report Wizard



Export Wizard

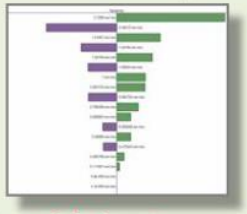
Design Analyzer

Analysis & Verification

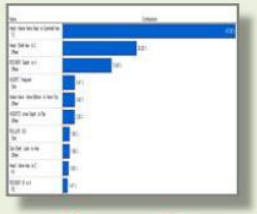


System Visualization

Measure Results



Sensitivity Pareto



Contributor Pareto

MBE requires 3D Model Base Definition

File | Model | Analysis | Annotate | Render | Tools | View | Applications

Welding | Mold/ Cast | Simulate | Simulate Results | Start GDTA | Stop GDTA

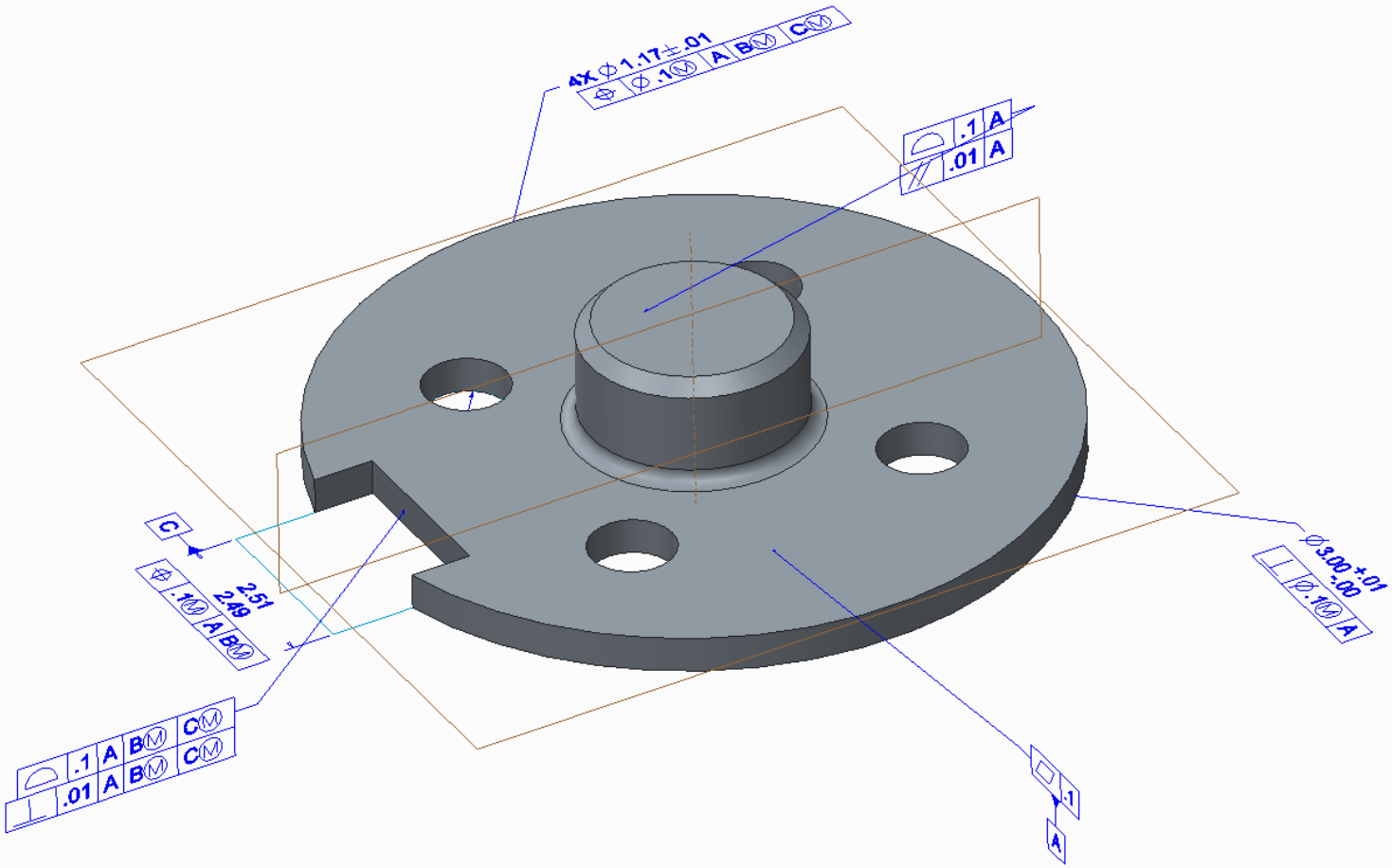
Engineering | Simulation | GDT Advisor

Model Tree

- GDTA1.PRT
  - RIGHT
  - TOP
  - FRONT
  - PRT_CSYS_DEF
  - Sketch 1
  - Extrude 1
  - Sketch 2
  - Extrude 2
  - Sketch 3
  - Extrude 3
  - Round 1
  - Chamfer 1
  - Sketch 4
  - Pattern 1 of Extrude 4
    - Extrude 4 [1]
    - Extrude 4 [2]
    - Extrude 4 [3]
    - Extrude 4 [4]
  - Group GDT_ADVISOR
    - GDT_DEF_CSYS
    - Group FEAT_PLANAR_SURFACE_1
    - Group DRF_DRF_A
    - Group FEAT_SHAFT_1
    - Group DRF_DRF_AIB_M
    - Group FEAT_SLOT_1
    - Group DRF_DRF_AIB_MIC_M
    - Group FEAT_PLANAR_SURFACE_4
    - Group FEAT_PLANAR_SURFACE_5
    - Group FEAT_PATTERN_1
  - Insert Here

NOTES:

1. UNLESS OTHERWISE SPECIFIED, ⌓ | 0.1 | A | B Ⓜ | C Ⓜ APPLIES TO ALL SURFACES
2. QUERIED DIMENSIONS SHALL BE RESOLVED TO 2 DECIMAL PLACES



ASME Y14.5M-1994

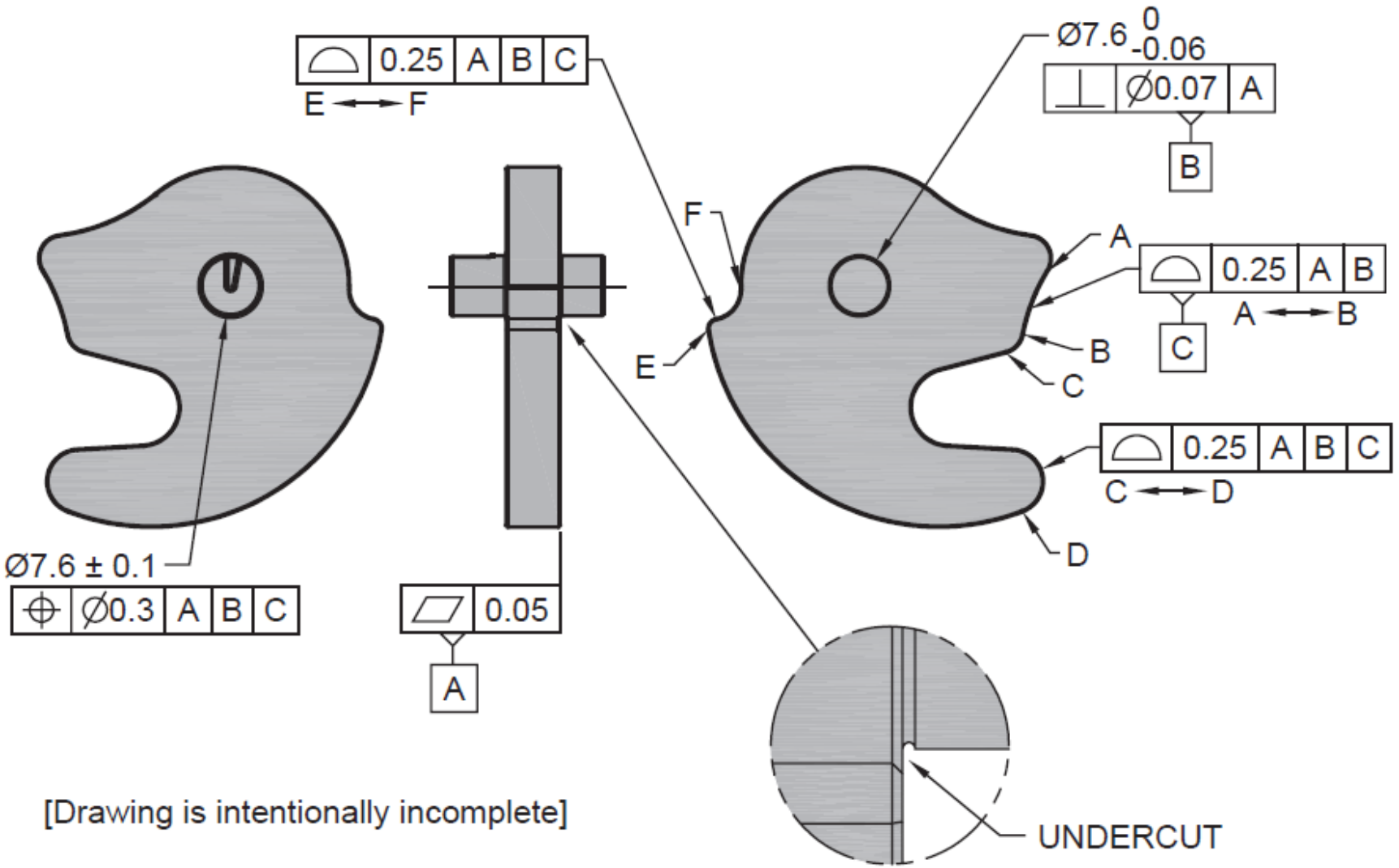
ASME Y14.41-2003

ALL DIMENSIONS SPECIFIED IN INCHES

Drawing Associativity

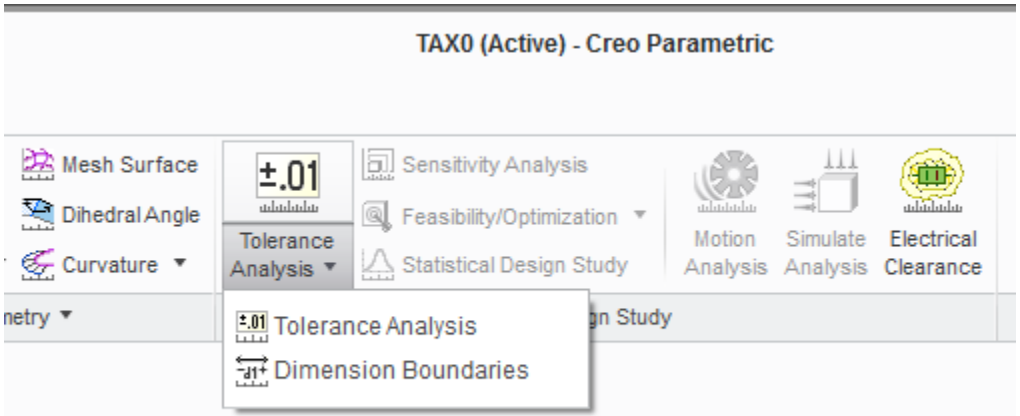
NOTES (UNLESS SPECIFIED OTHERWISE):

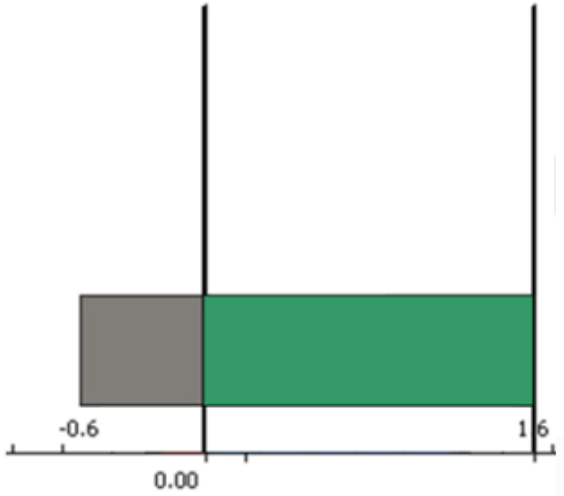
1. DIMENSIONING AND TOLERANCING PER ASME Y14.5-2009.

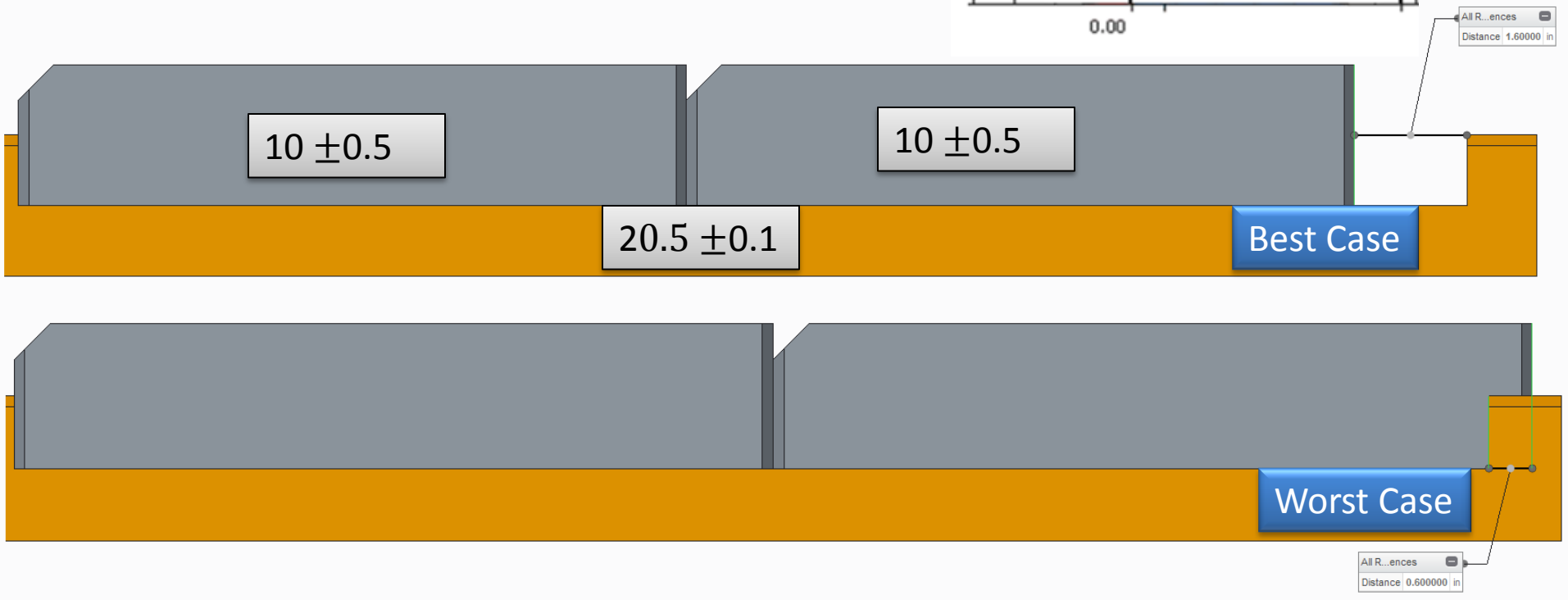


[Drawing is intentionally incomplete]

Tolerance Analysis with Dimension Boundaries

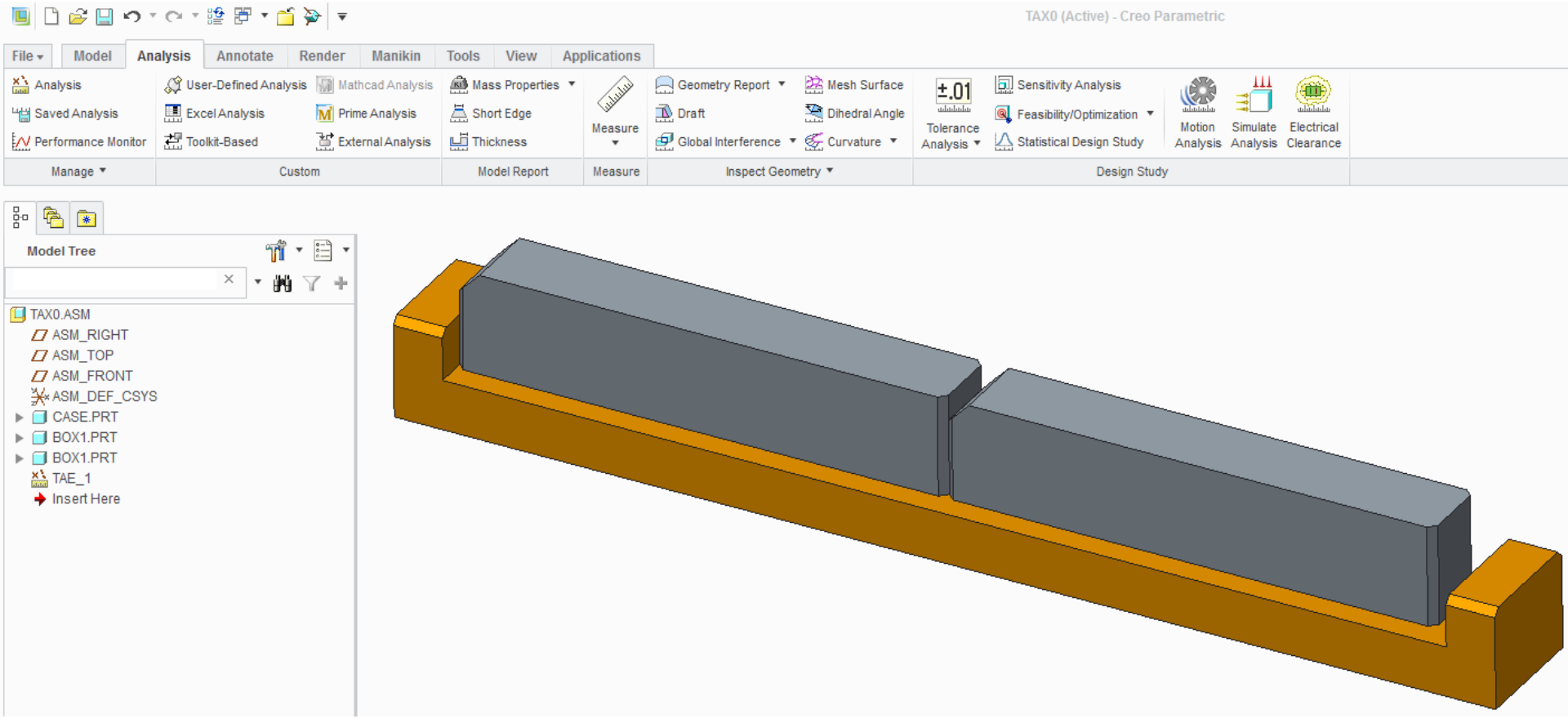






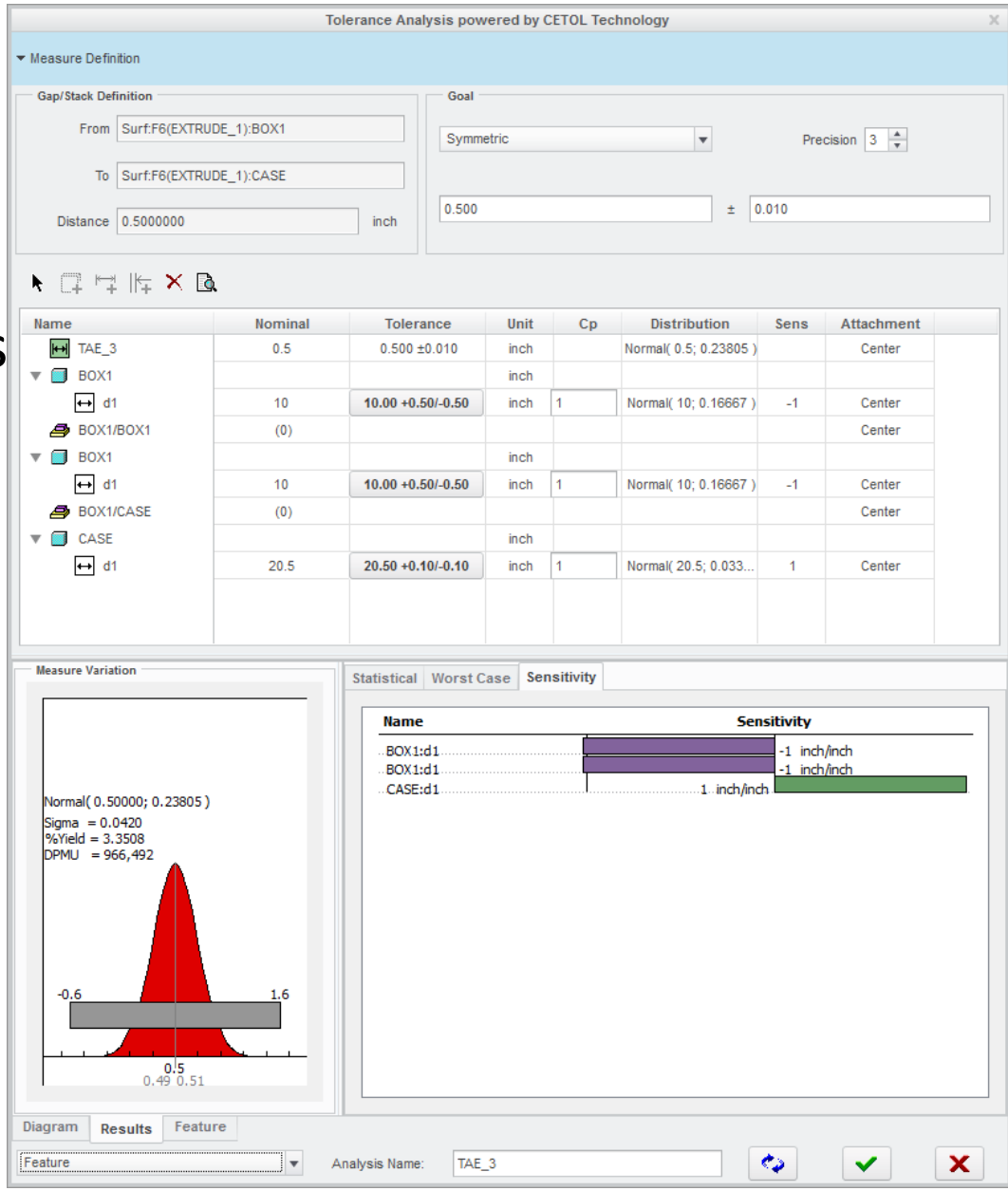
Tolerance Analysis with TAE Feature

- PTC CREO® Tolerance Analysis Extension (TAE) solves one-dimensional problems with a Dimension Loop Diagram, generates sensitivities and statistical tolerance analyses

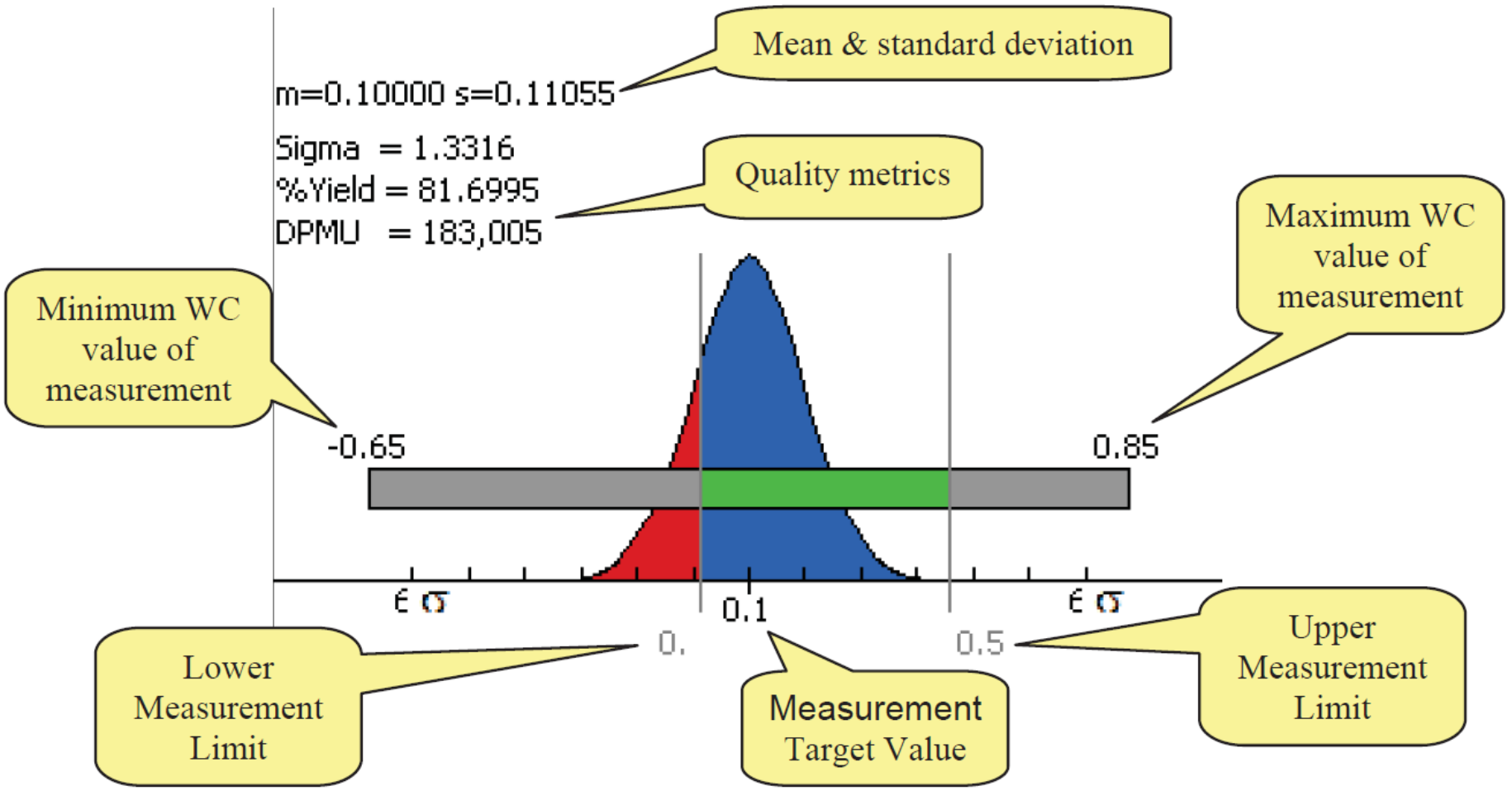


Statistical Analysis and Sensitivity

- 1D Tolerance Stack-up
- For Gap > zero:
  - Sigma Quality Level
  - Defects Per Million Units
  - Percent Yield
  - M & σ of Gap
- Best-Worst Case
- Sensitivity
- Nominal & Tolerances can be adjusted live
- Report Generation

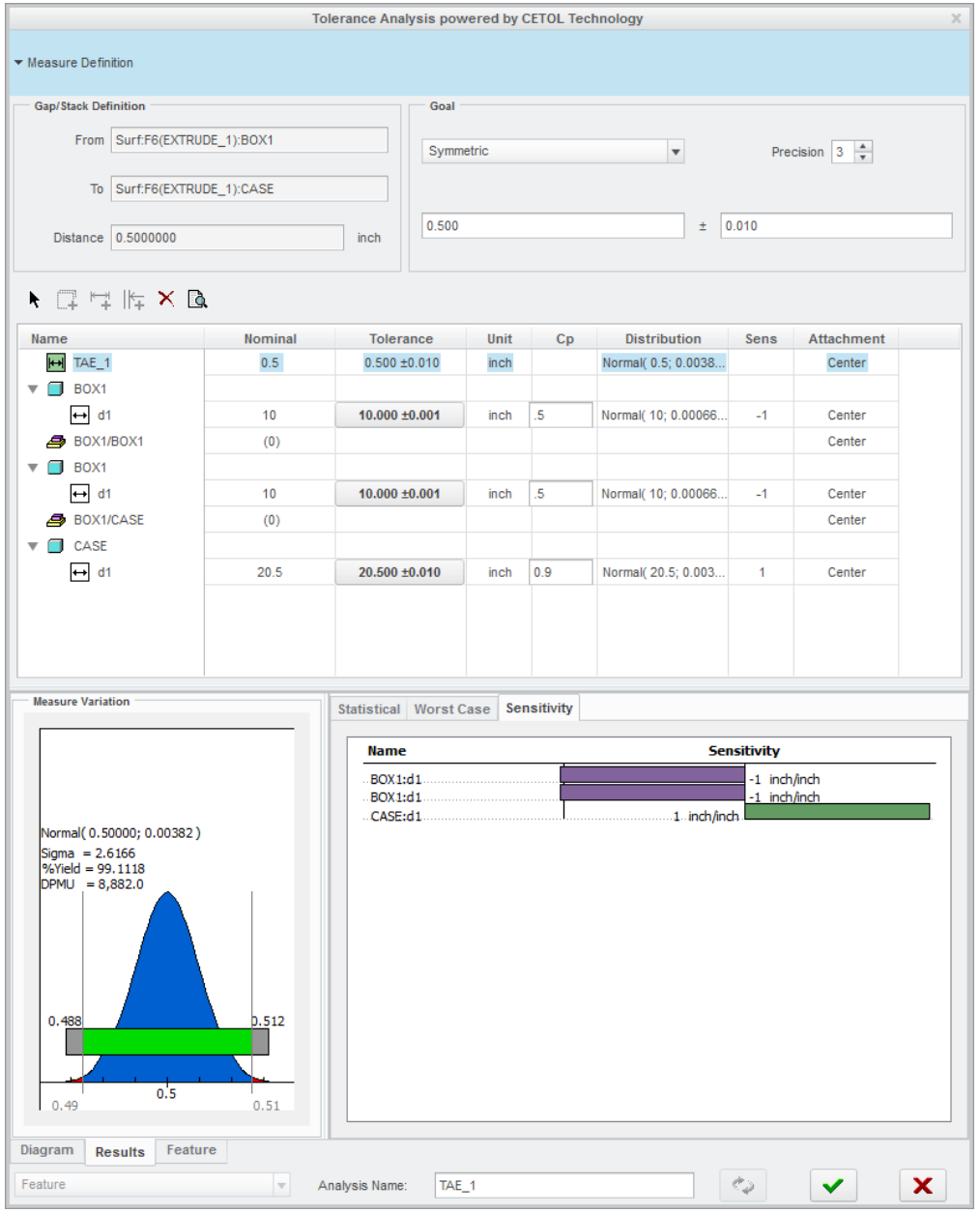


Results summary plot - Sigma Quality metrics



Design Modifications

- Interactive / real time Modification of Tolerance Bounds
- Modifications are associative to the model
- Tolerance Analysis Feature can be used with Behavioral Modeling



Tolerance Analysis powered by CETOL Technology

Measure Definition

Gap/Stack Definition

From: Surf:F6(EXTRUDE_1):CASE

To: Surf:F6(EXTRUDE_1):BOX1

Distance: 0.5000000 inch

Goal

Limits

Precision: 3

1.500

0.000

Name	Nominal	Tolerance	Unit	Cp	Distribution	Sens	Attachment
TAE_2	0.5	1.500/0.000	inch		Normal(0.5; 0.23805)		Center
CASE			inch				
d1	20.5	20.50 +0.10/-0.10	inch	1	Normal(20.5; 0.033...	1	Center
CASE/BOX1	(0)						Center
BOX1			inch				
d1	10	10.00 +0.50/-0.50	inch	1	Normal(10; 0.16667)	-1	Center
BOX1/BOX1	(0)						Center
BOX1			inch				
d1	10	10.00 +0.50/-0.50	inch	1	Normal(10; 0.16667)	-1	Center

Dimension Loop Diagram

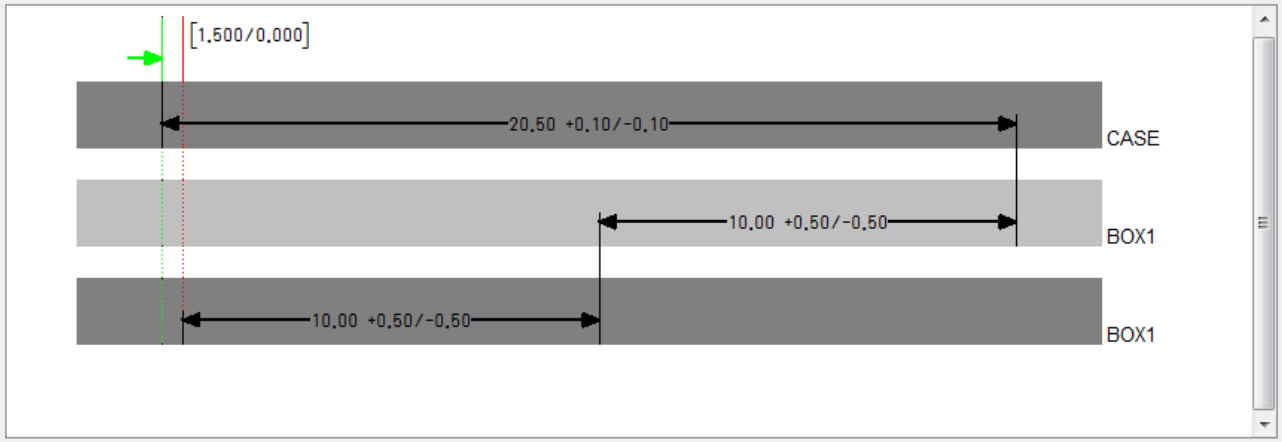
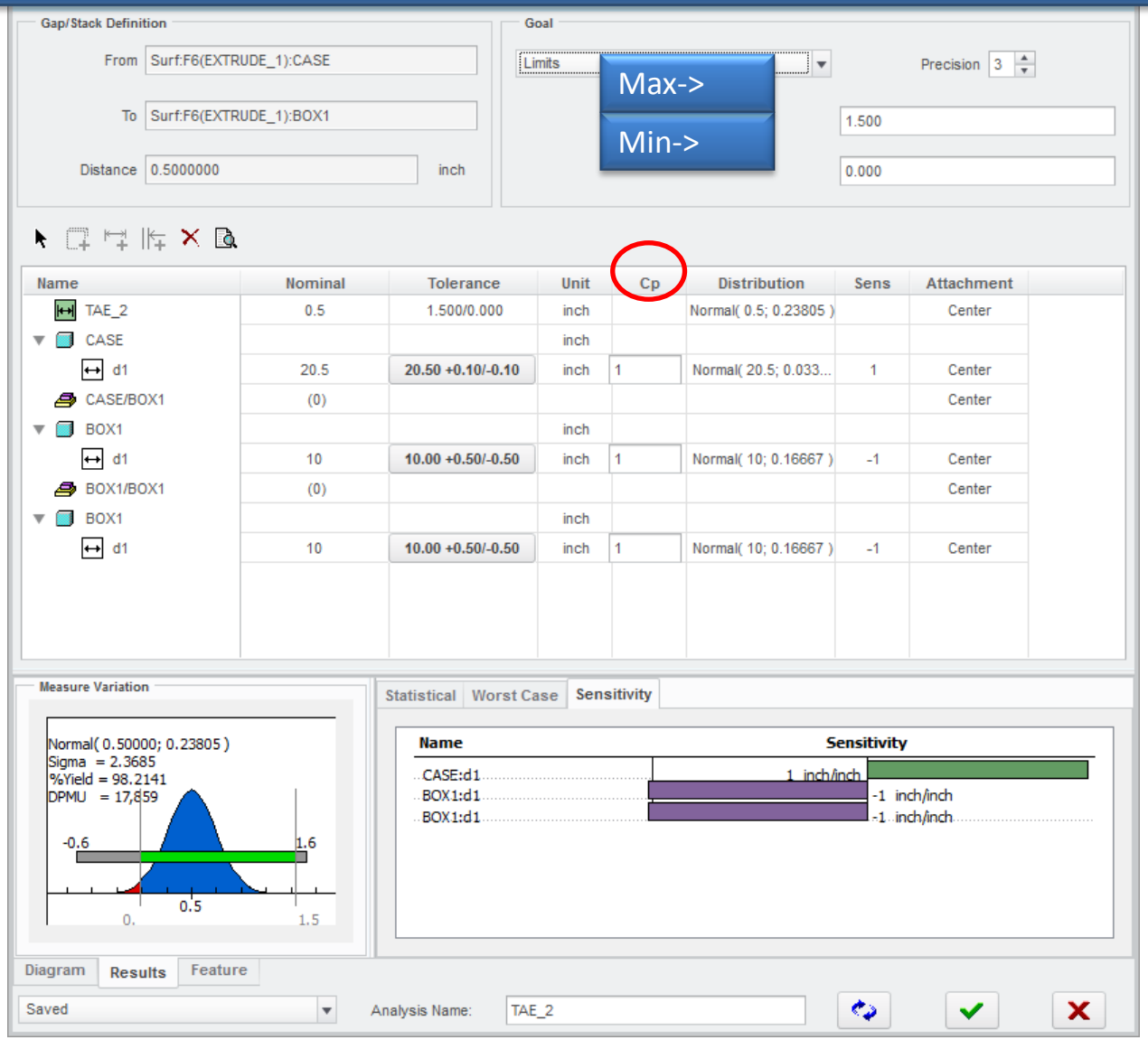


Diagram | Results | Feature

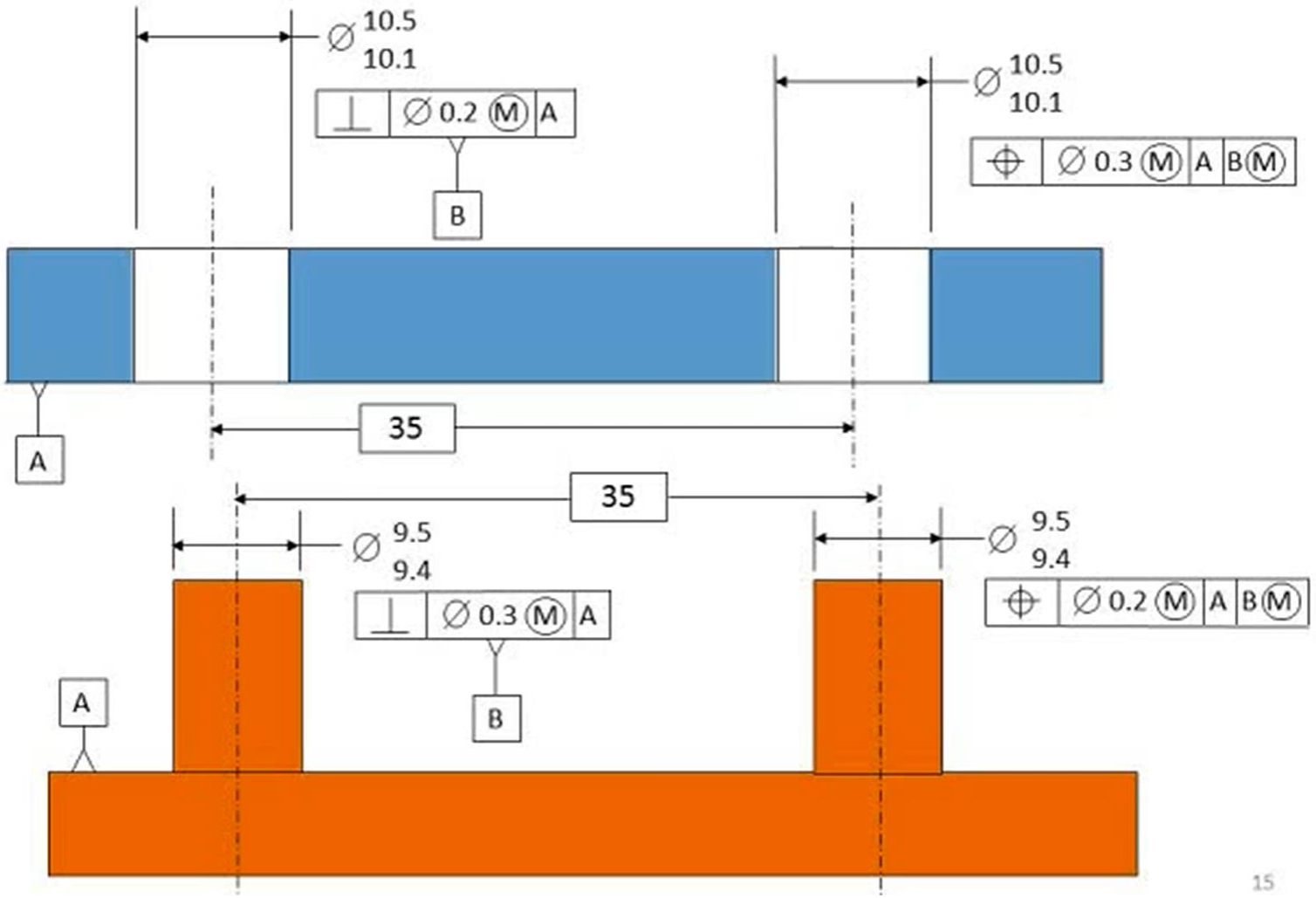
Saved

Analysis Name: TAE_2

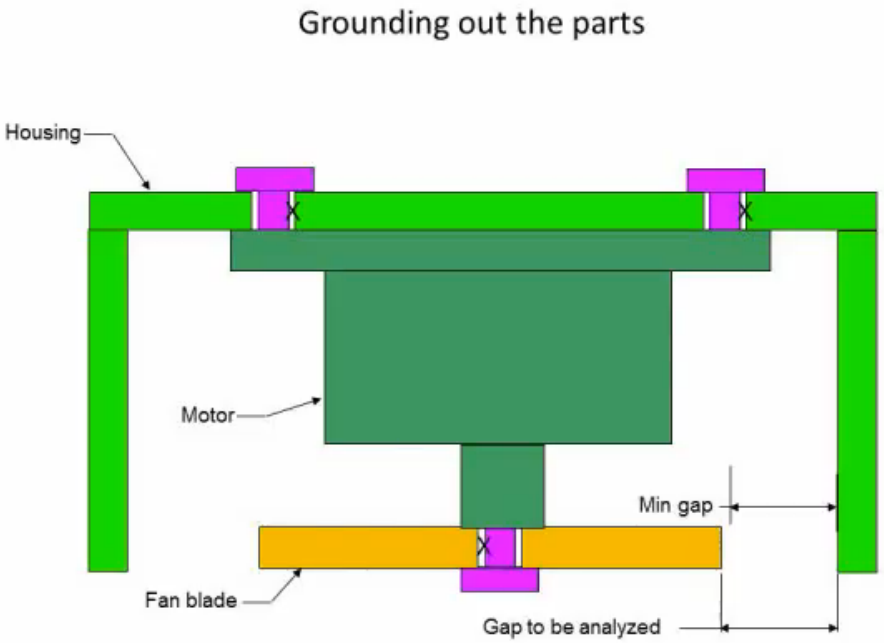
Cp relates the mean and variability of the process or machine to the permissible range of dimensions allowed by the specification or tolerance

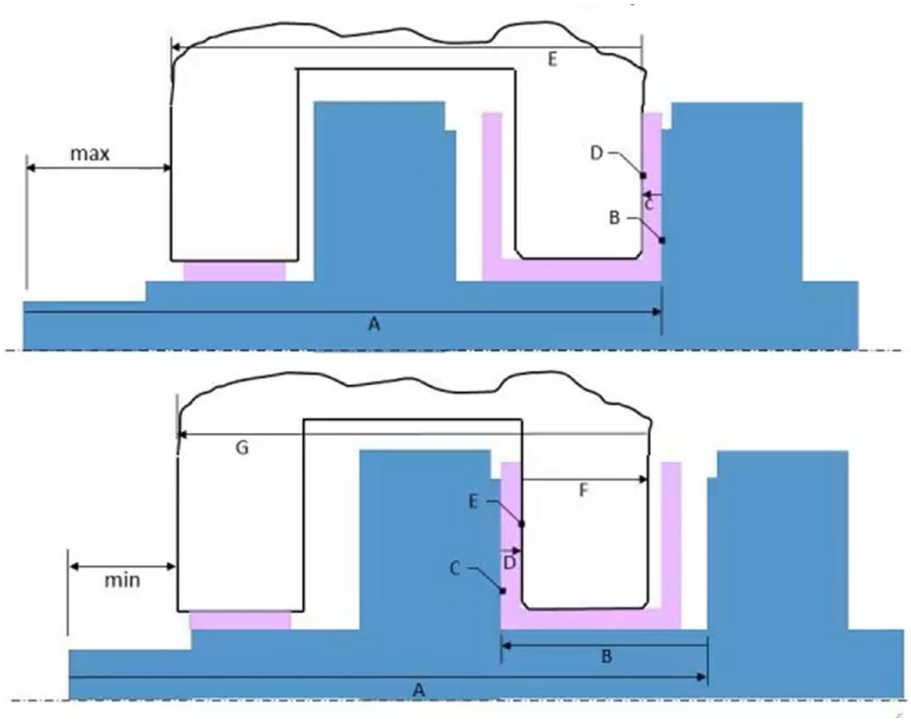


Do the two components assemble?

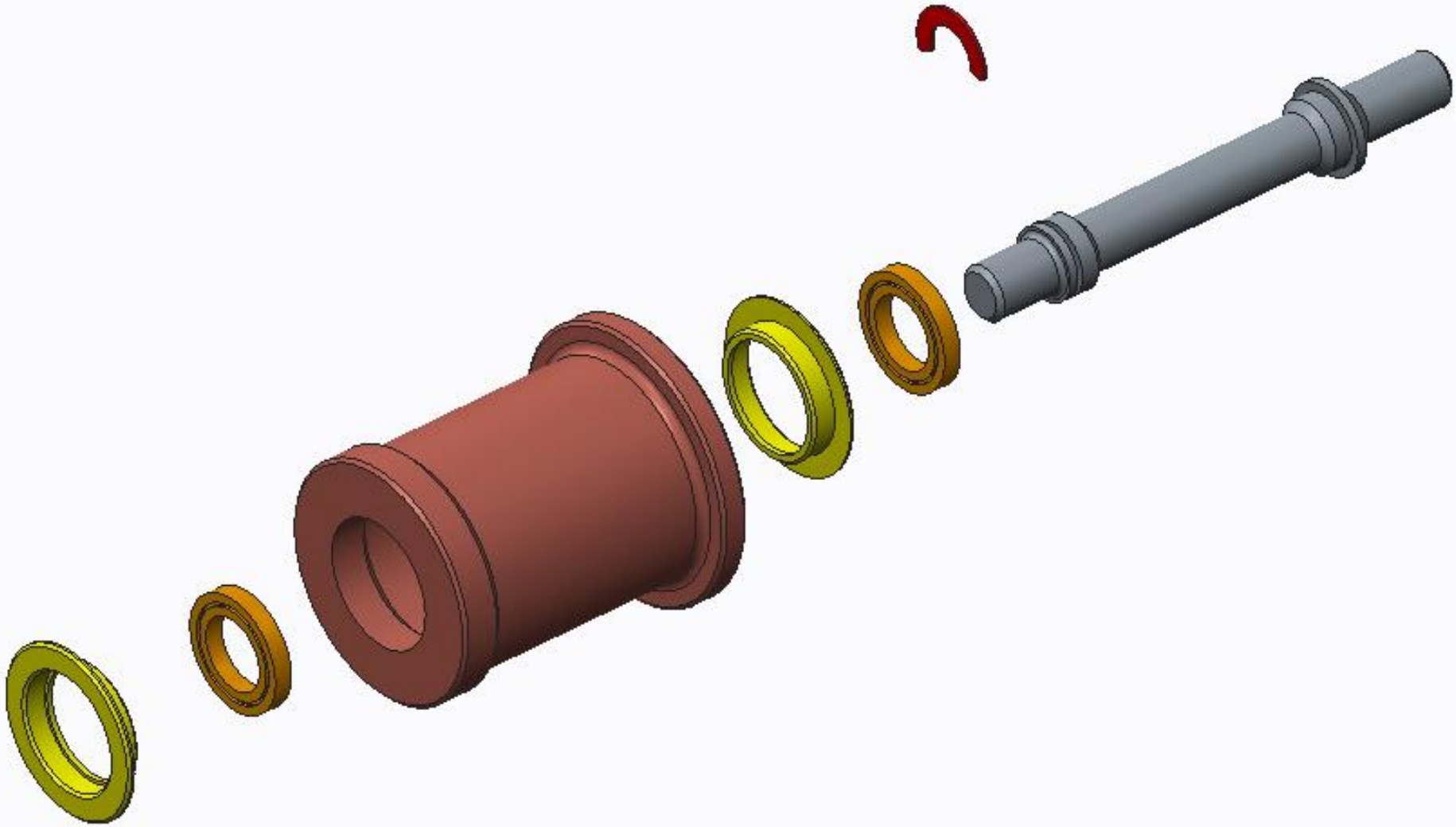


Configurations for Gap Analysis

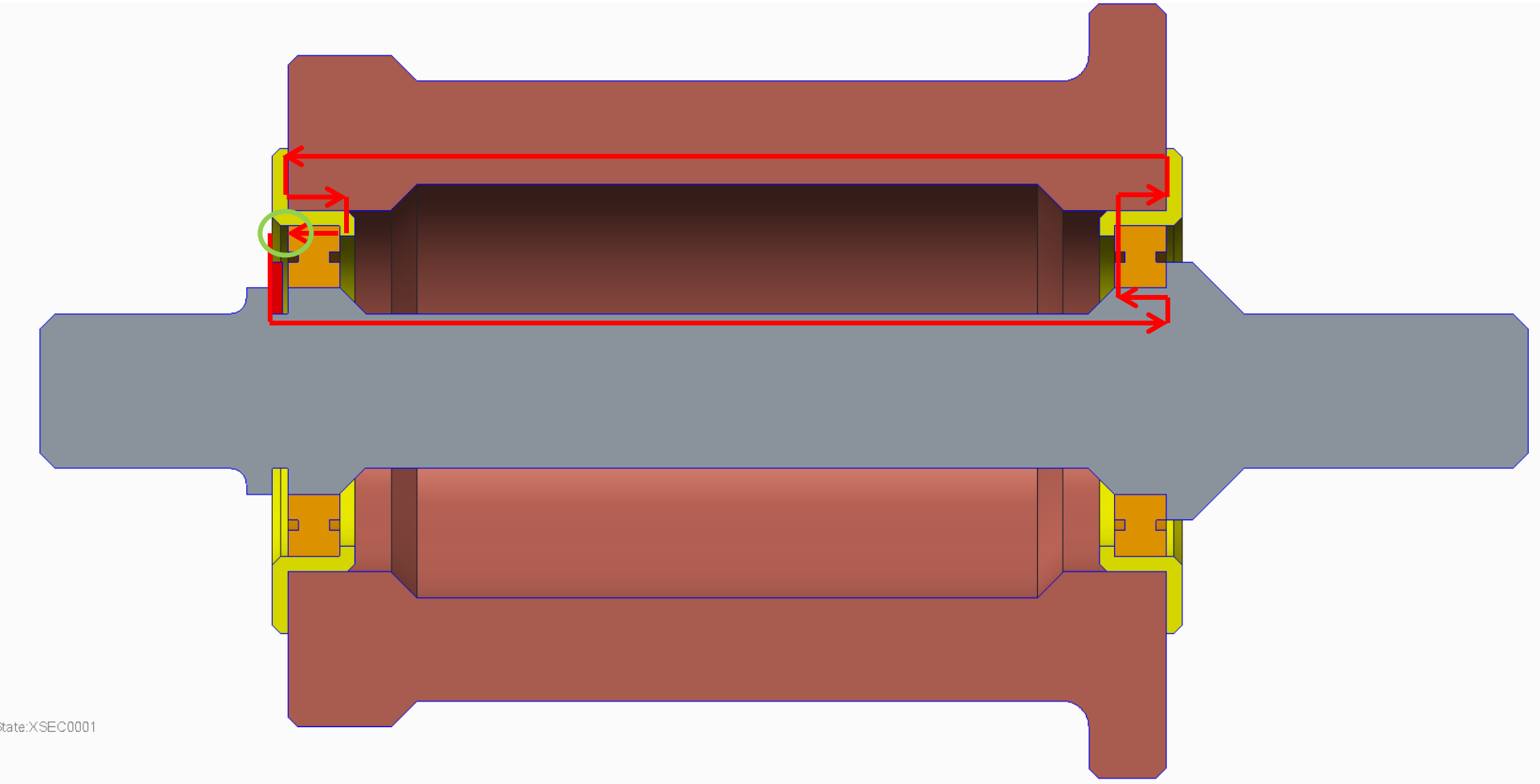




Motor TAE Example Exploded View

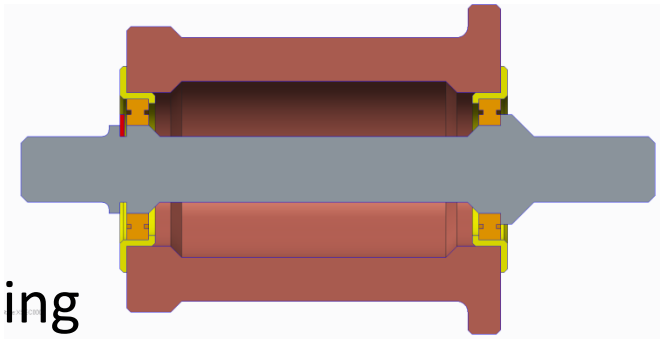


Mechanical Tolerance Stacks –Loop Diagram



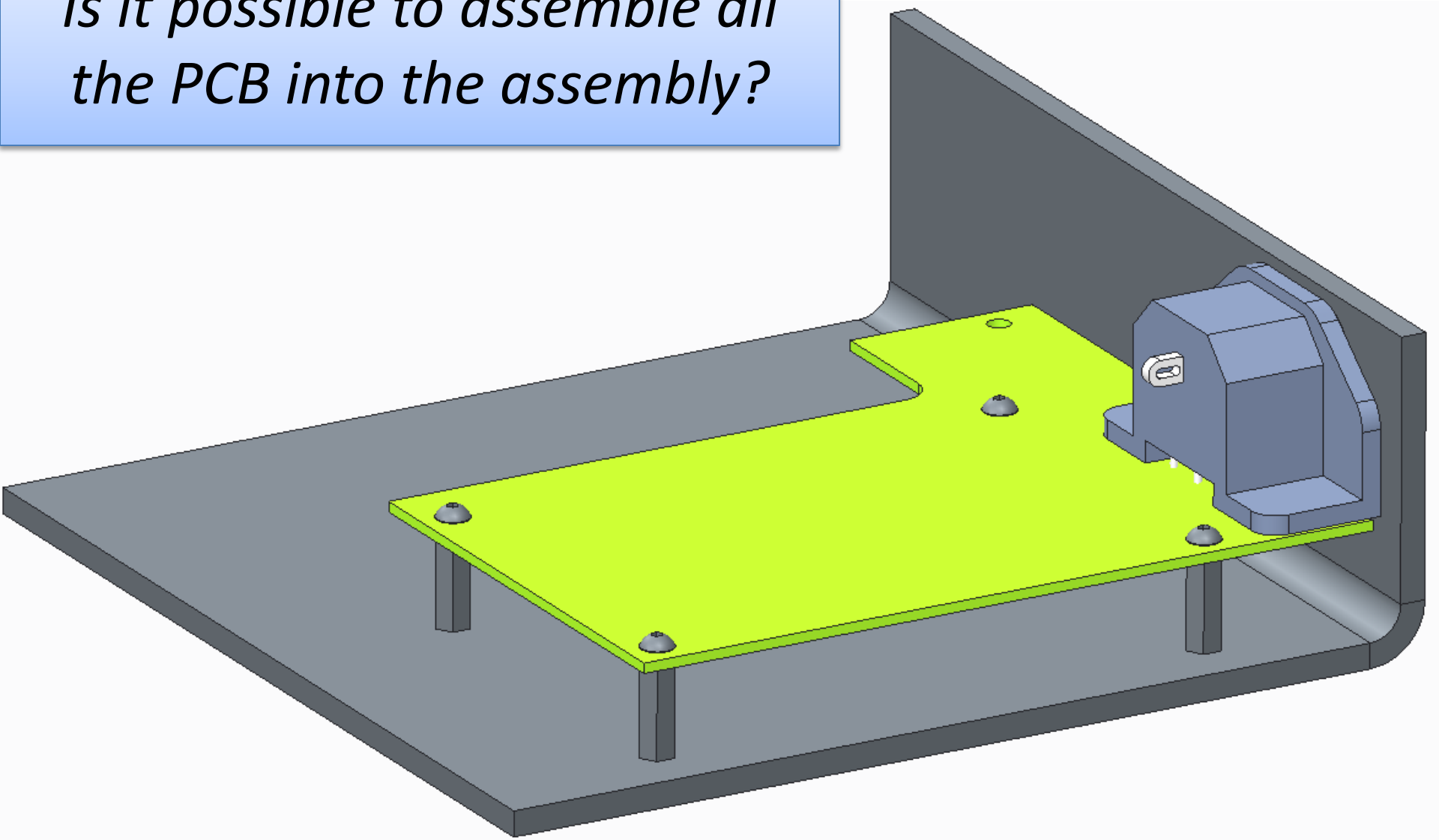
Typical Requirements

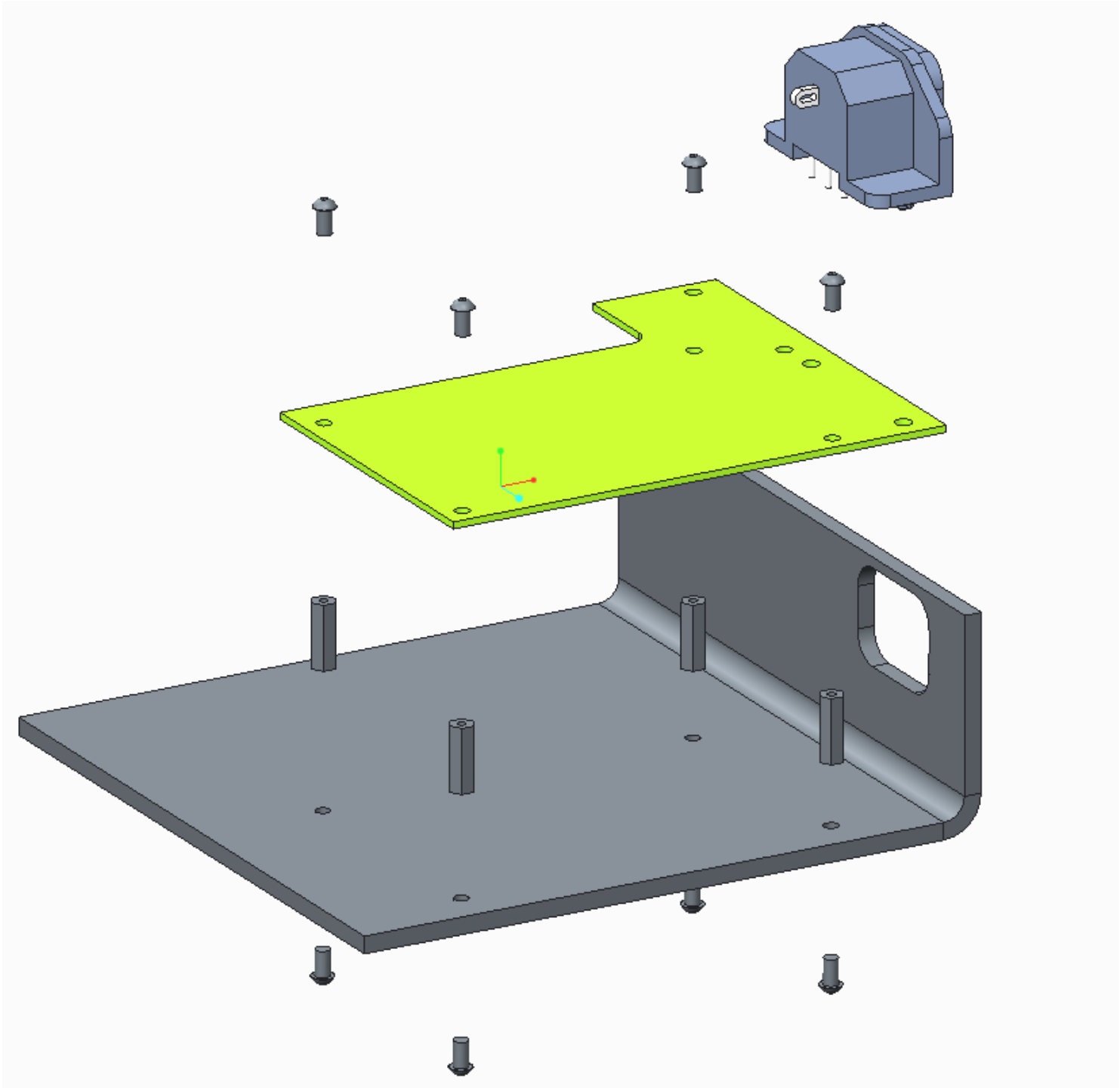
- The gap between the shaft and the inner bearing cap must always be greater than zero (to ensure that the rotor is clamped and the bearings are preloaded)
- The gap between the housing cap and the housing must always be greater than zero (to ensure that the stator is clamped)
- Amount of “squeeze” on an o-ring
- Amount of “preload” on bearings
- Sufficient “material” for subsequent machining processes
- Interference requirements, such as when pressing pins into holes
- Optical requirements, such as alignment of optical elements



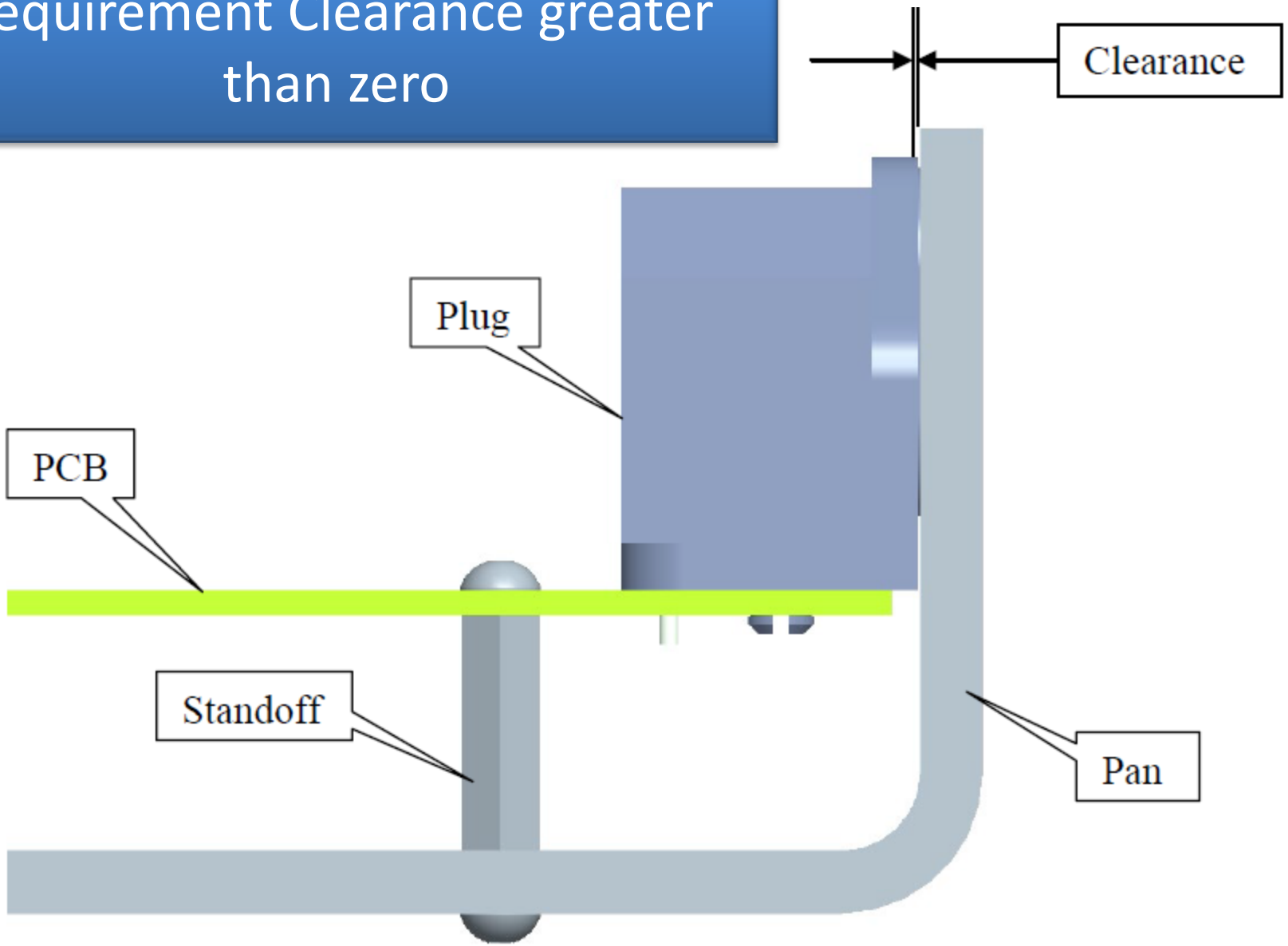
Circuit Board TAE Example

Is it possible to assemble all the PCB into the assembly?

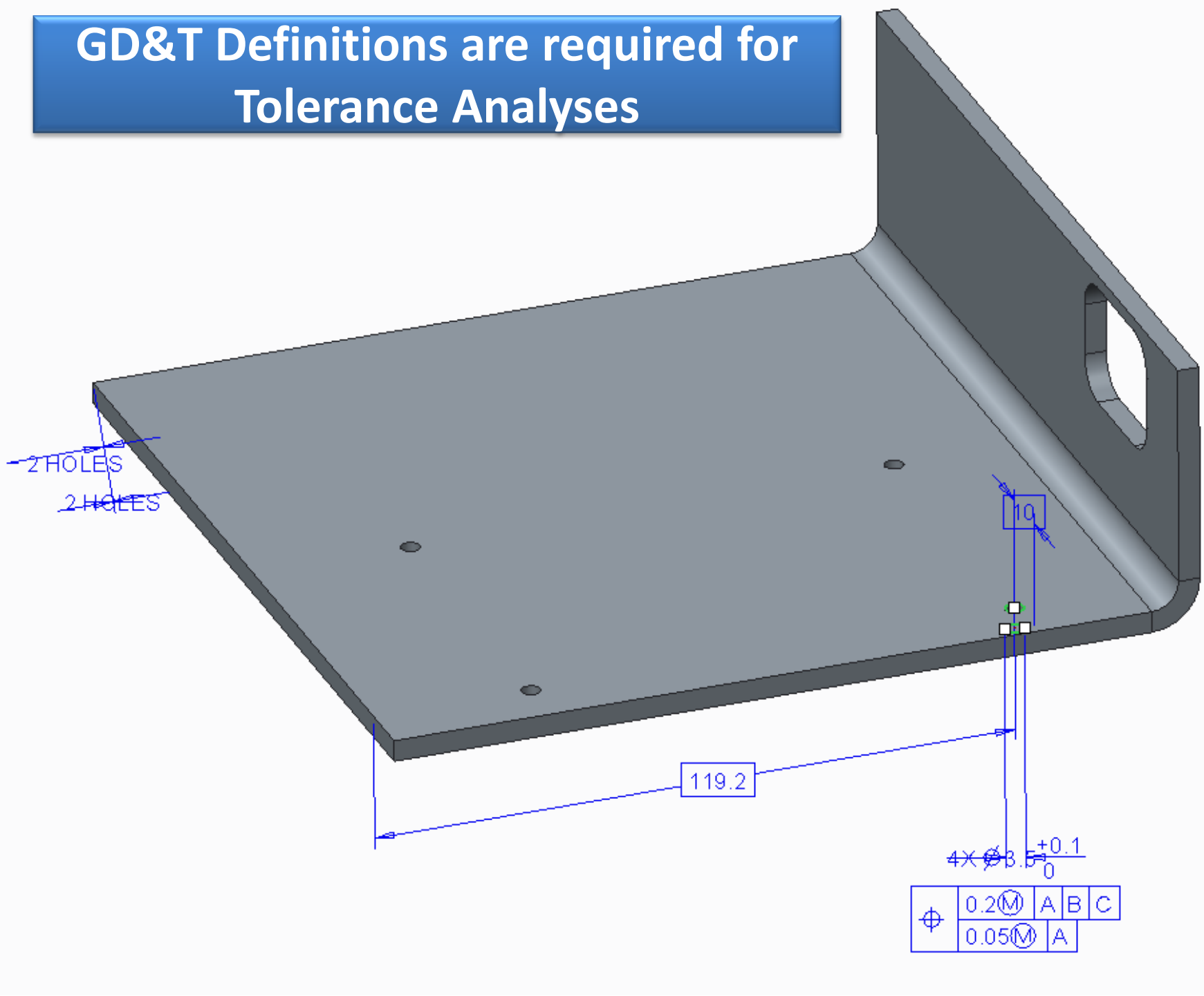




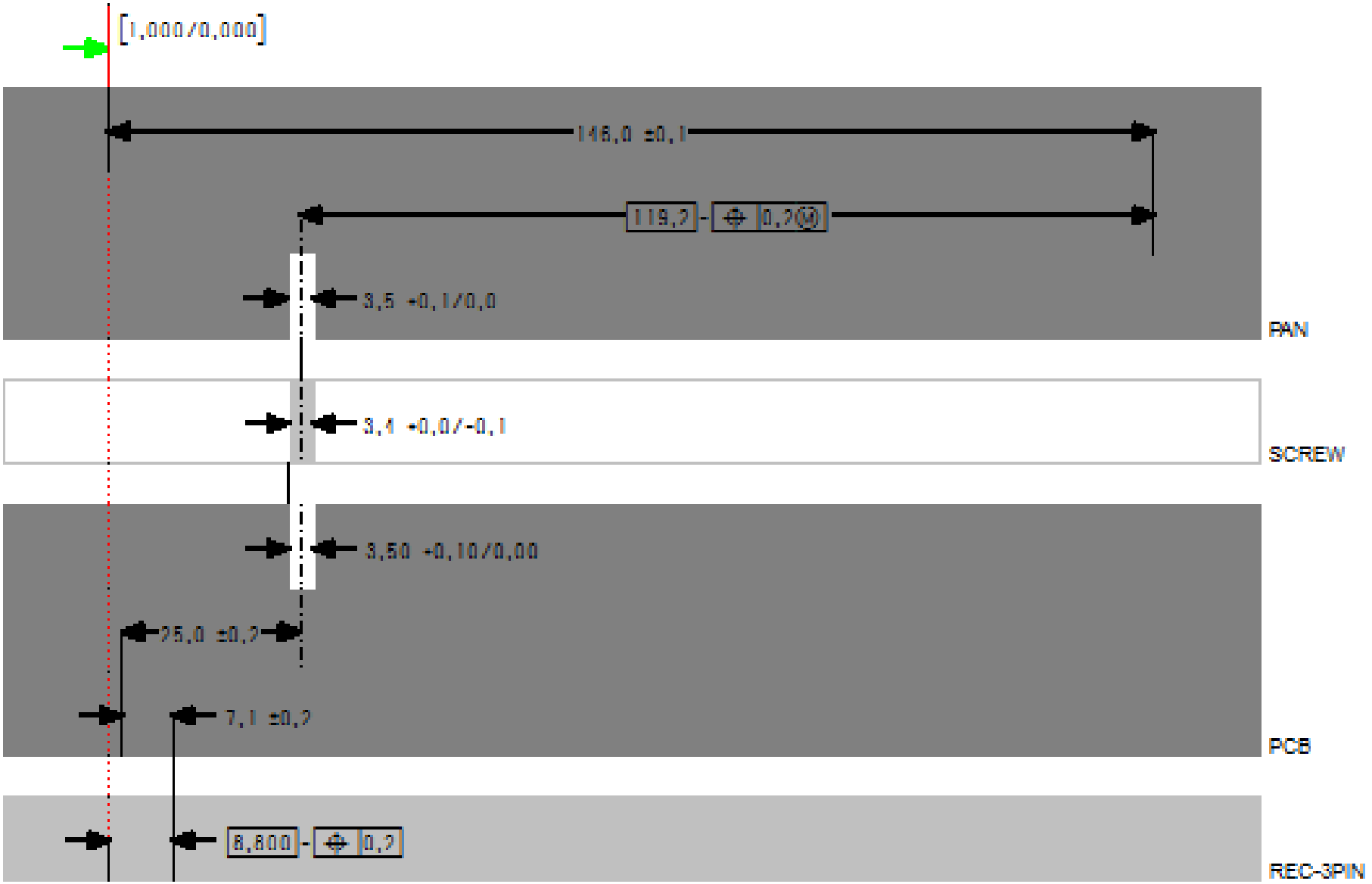
Requirement Clearance greater than zero



GD&T Definitions are required for Tolerance Analyses

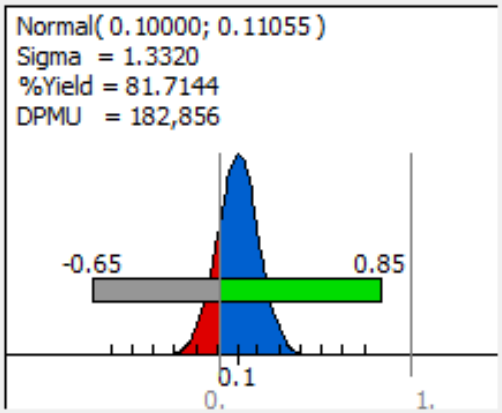


Mechanical Tolerance Stacks –Loop Diagram

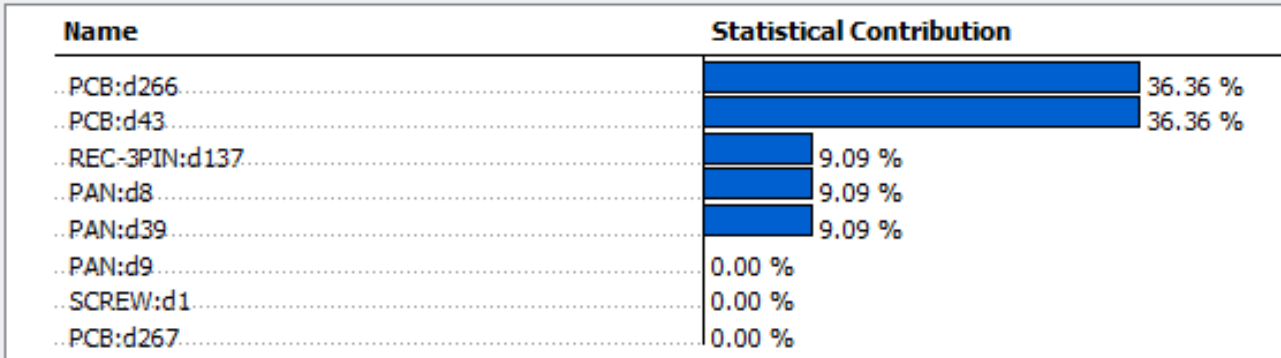


Name	Nominal	Tolerance	Unit	Cp	Distribution	Sens	Attachment
TAE_1	0.1	1.000/0.000	mm		Normal(0.1; 0.11055)		Center
PAN			mm				
d39	146	146.0 ±0.1	mm	1	Normal(146; 0.0333...	1	Center
d8	119.2	|POS|0.2(M)|	mm	1	Normal(119.2; 0.033...	-1	
d9	3.5	3.5 +0.1/0.0	mm	1	Normal(3.55; 0.016...	0	Center
PAN/SCREW	(0)						Center
SCREW			mm				
d1	3.4	3.4 +0.0/-0.1	mm	1	Normal(3.35; 0.016...	0	Center
SCREW/PCB	(0)						Center
PCB			mm				
d267	3.5	3.50 +0.10/0.00	mm	1	Normal(3.55; 0.016...	0	Center
d266	25	25.0 ±0.2	mm	1	Normal(25; 0.06666...	-1	Center
d43	7.1	7.1 ±0.2	mm	1	Normal(7.1; 0.0666...	1	Center
PCB/REC-3PIN	(0)						Center
REC-3PIN			mm				
d137	8.8	|POS|0.2|	mm	1	Normal(8.8; 0.0333...	-1	

Measure Variation

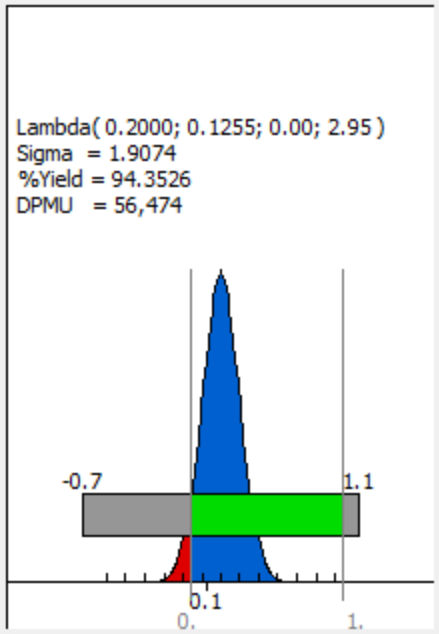


Statistical | Worst Case | Sensitivity

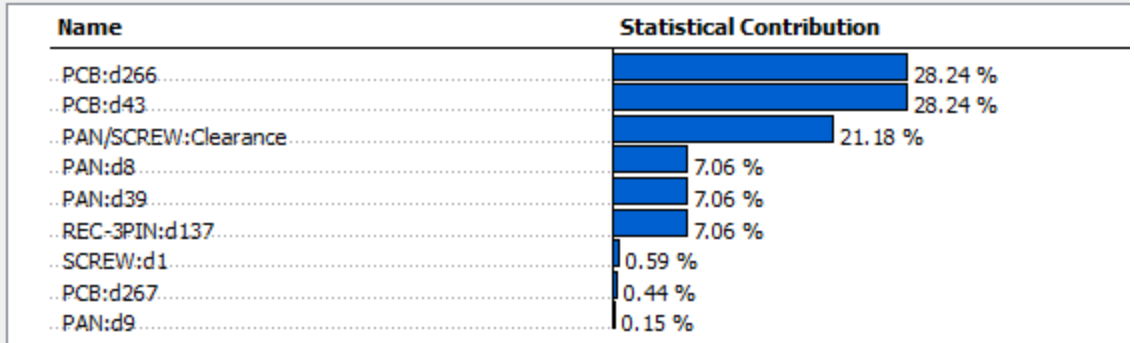


Name	Nominal	Tolerance	Unit	Cp	Distribution	Sens	Attachment
TAE_1	0.15	1.000/0.000	mm		Lambda(0.2; 0.12546; 0...		Center
PAN			mm				
d39	146	146.0 ±0.1	mm	1	Normal(146; 0.033333)	1	Center
d8	119.2	|POS|0.2(M)|	mm	1	Normal(119.2; 0.033333)	-1	
d9	3.5	3.5 +0.1/0.0	mm	1	Normal(3.55; 0.016667)	0	Center
PAN/SCREW	(0)	0.150/-0.150	mm		Lambda(0; 0.058135; 0;...		Float
SCREW			mm				
d1	3.4	3.4 +0.0/-0.1	mm	1	Normal(3.35; 0.016667)	-0.5	Center
SCREW/PCB	(0.05000000000000...						Left
PCB			mm				
d267	3.5	3.50 +0.10/0.00	mm	1	Normal(3.55; 0.016667)	0.5	Center
d266	25	25.0 ±0.2	mm	1	Normal(25; 0.066667)	-1	Center
d43	7.1	7.1 ±0.2	mm	1	Normal(7.1; 0.066667)	1	Center
PCB/REC-3PIN	(0)						Center
REC-3PIN			mm				

Measure Variation



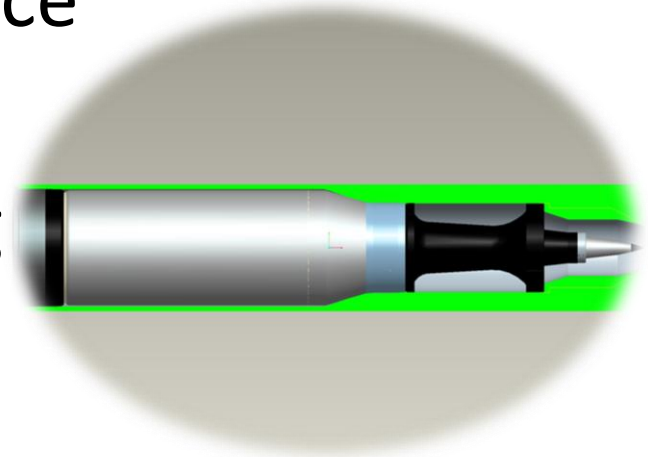
Statistical | Worst Case | Sensitivity



Typical TAE Application

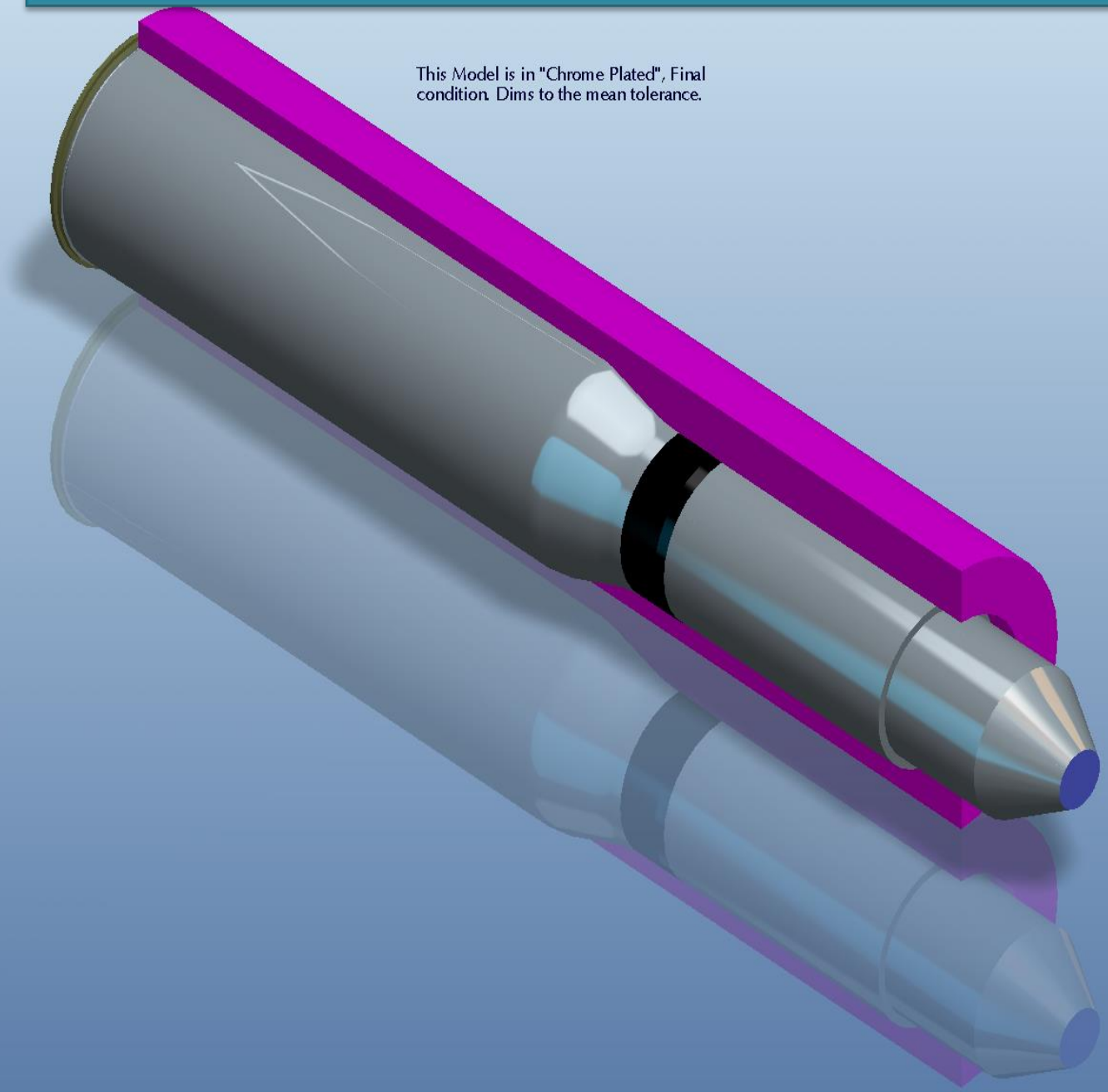
- DOD Quality performance requirements
- Reliability and Materiel availability metrics as KPP

- Demonstration of compliance with virtual prototypes
- Immediate feedback during development process

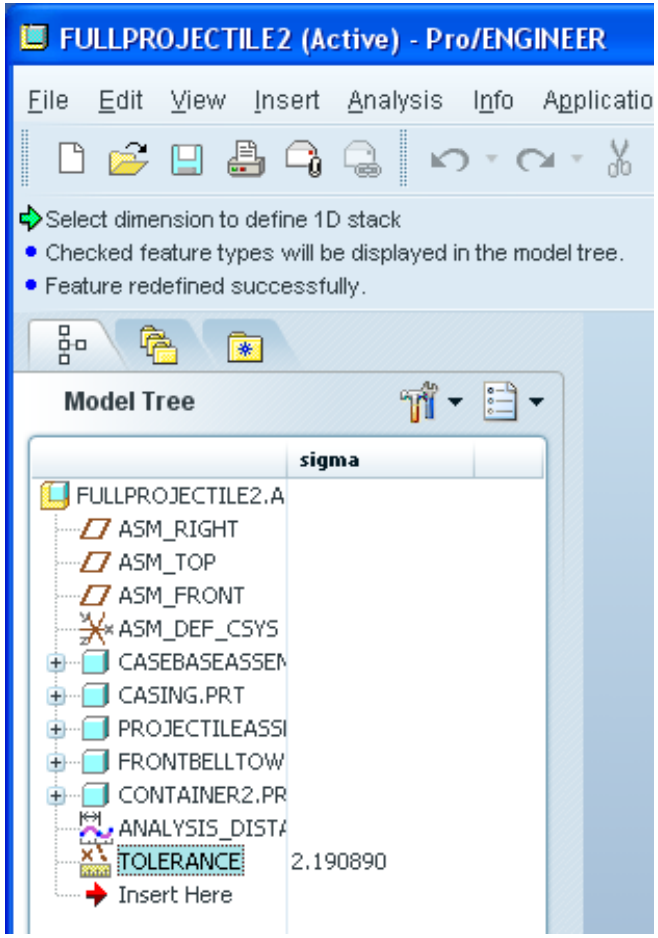


- Experimental Validation is required

ICD Solid Model



CAD Integration



Tolerance Analysis Report

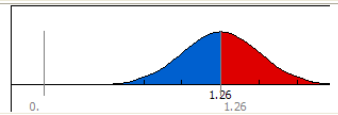
Report Generated On Fri July 16 2010 @ 08:20:35 pm
Analysis Report By: Maiki Vlahinos
Company : GD OTS

Measurement Details

Pro/E Model	**FULLPROJECTILE2.asm**
Tolerance Analysis Measurement	**CETOL_2**
Design Specification	**1.26/0.00**
Solved Nominal	**1.26**

Measurement Results

Derivative-Based Statistical Analysis

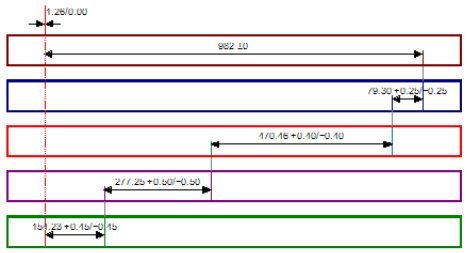


Sigma = 0.6745
% Yield = 49.9998
DPMU = 500,002

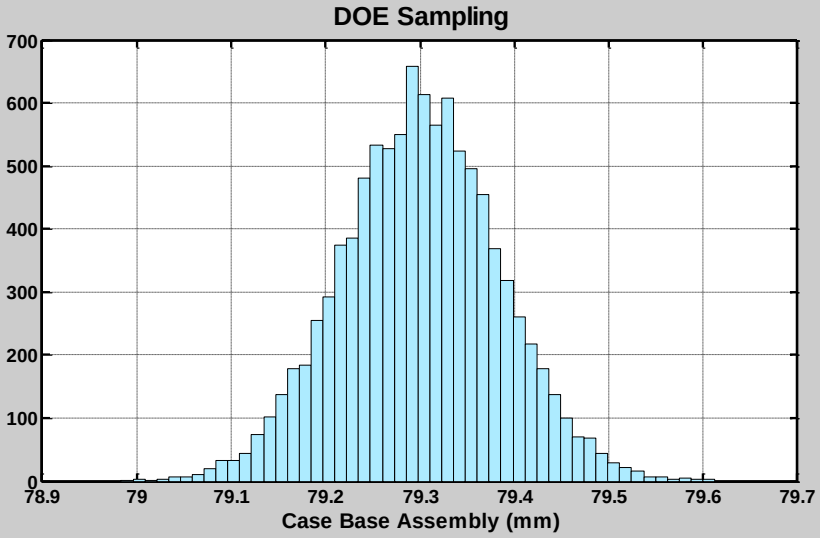
Dimension Details

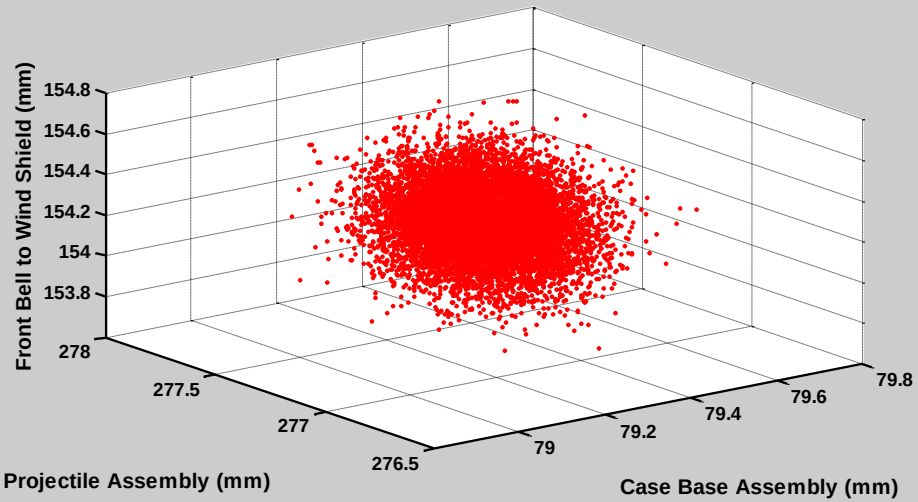
Name:	Dim./Tolerance:	Cp	Sensitivity	Variance/Contribution Statistical
PROJECTILEASSEMBLY:d1	277.25 +0.50/-0.50	1.00	-1	37.04%
FRONTBELLTOWINDSHIELD:d1	154.23 +0.45/-0.45	1.00	-1	30.00%
CASING:d1	470.46 +0.40/-0.40	1.00	-1	23.70%
CASEBASEASSEMBLY:d1	79.30 +0.25/-0.25	1.00	-1	9.26%
CONTAINER2:d6	982 ±0	1.00	1	0.00%

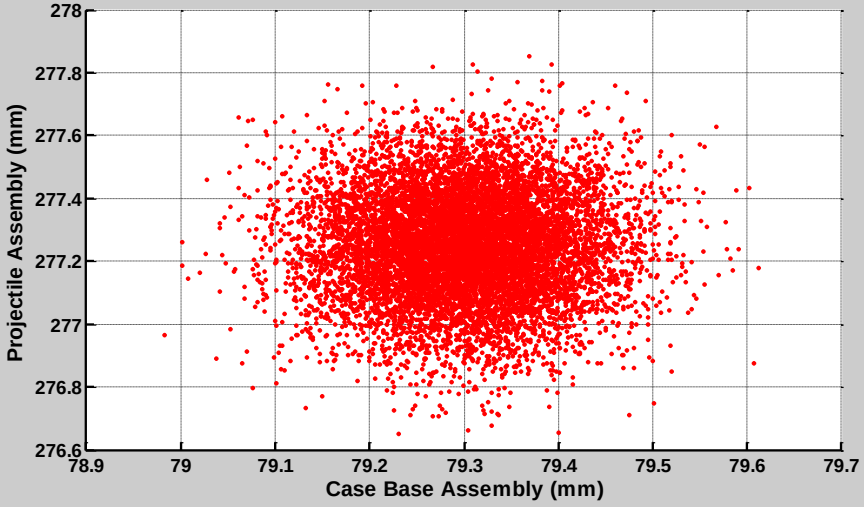
Dimension Loop Diagram

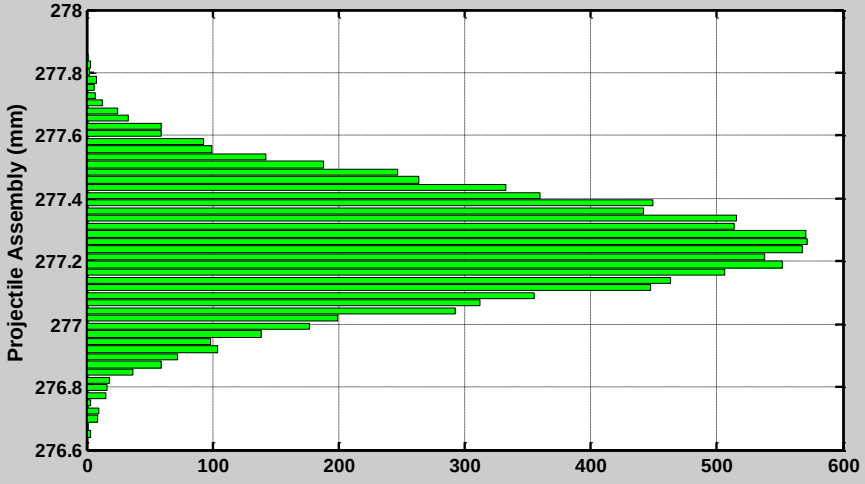


Sampling in Stack-up Tolerance Example

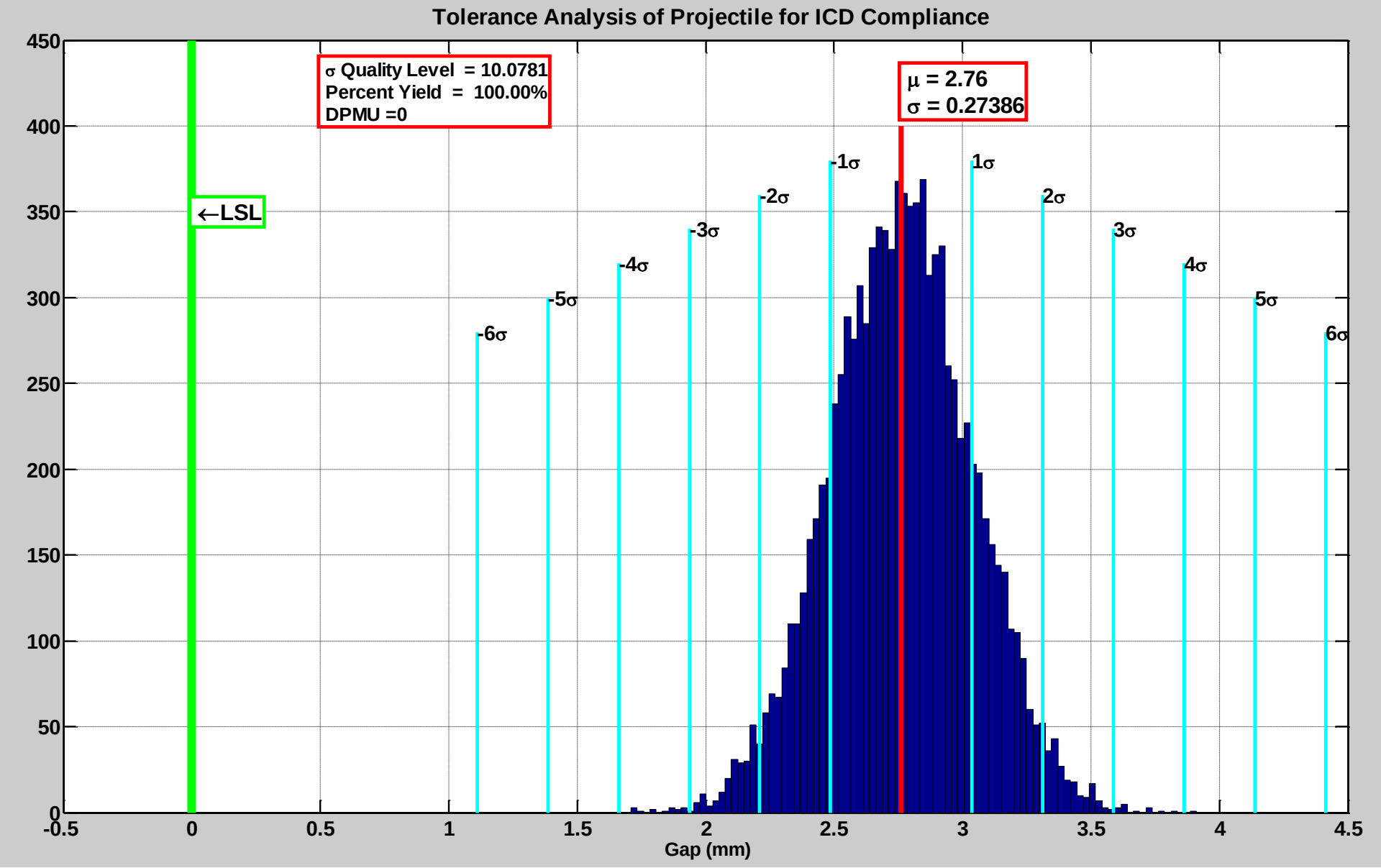




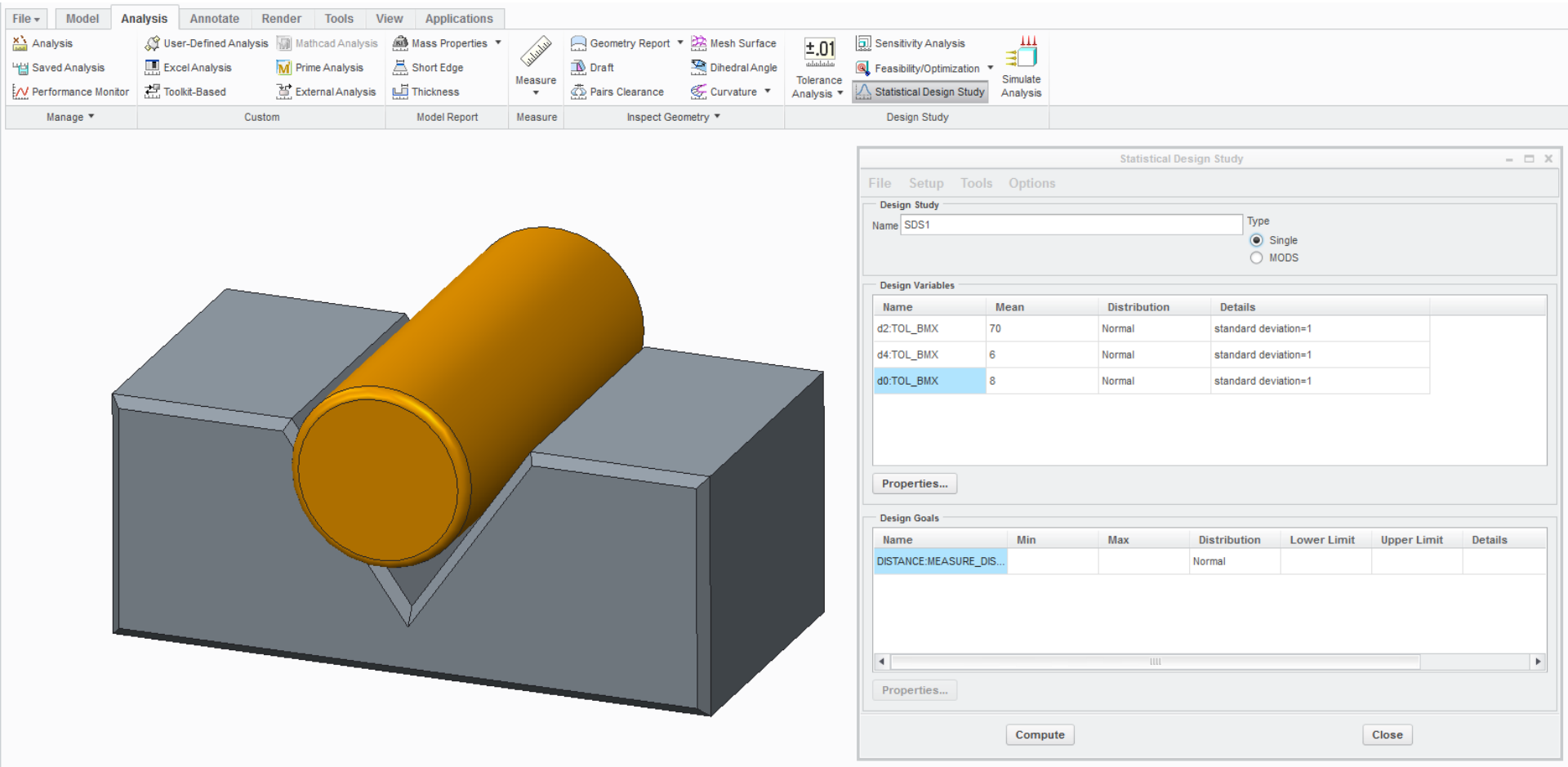




Typical Results of Tolerance Analyses



Using BMX's Statistical Design Studies for Sigma quality evaluation



Design Goal Statistical Properties

Name
ASURE_DISTANCE_1

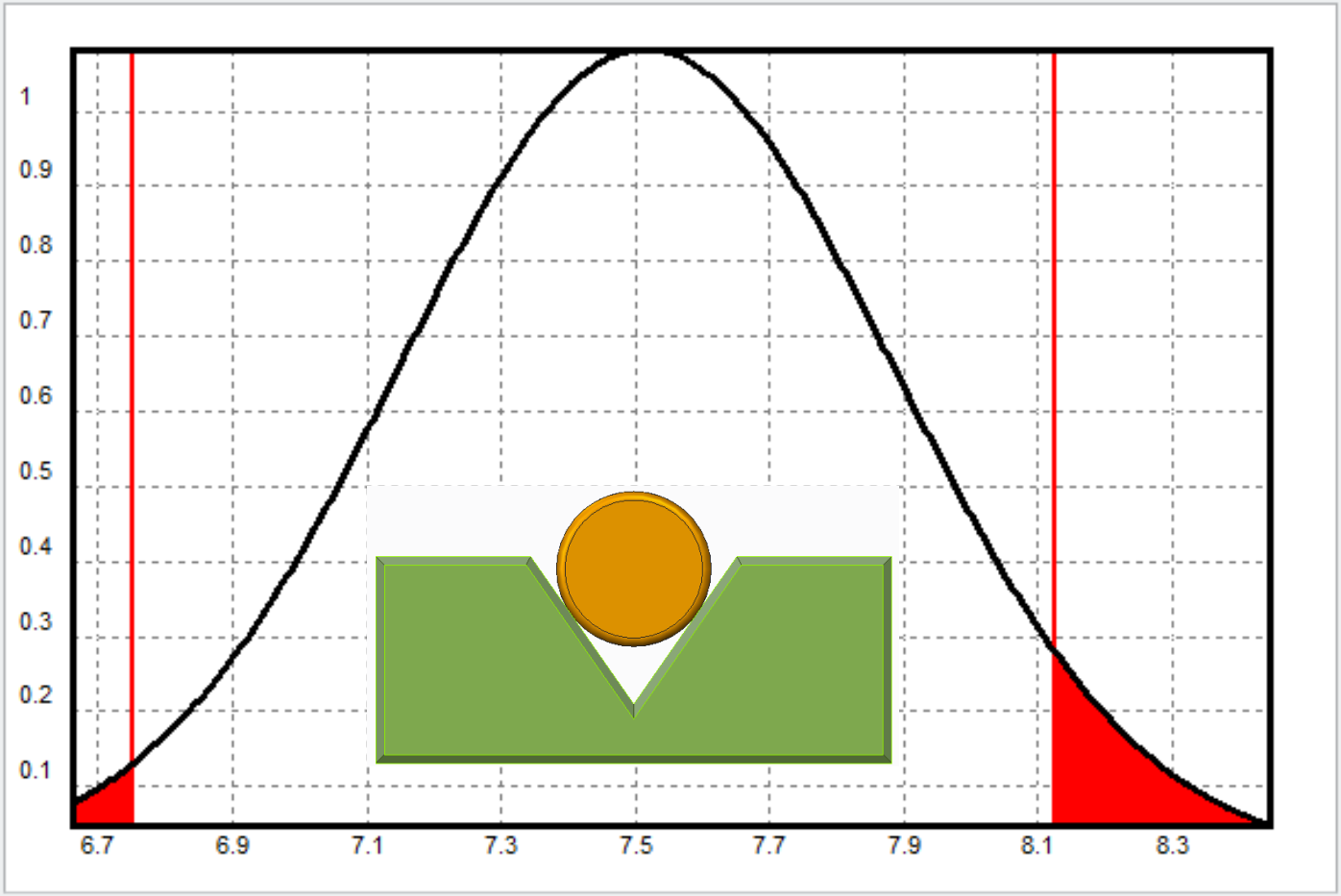
Min
6.66040794452

Max
8.44451825842

Distribution
Normal

Mean
7.516559226

Standard deviation
0.3693968907



Show samples

Lower limit
6.75

DPMU
68752.41295

Upper limit
8.125

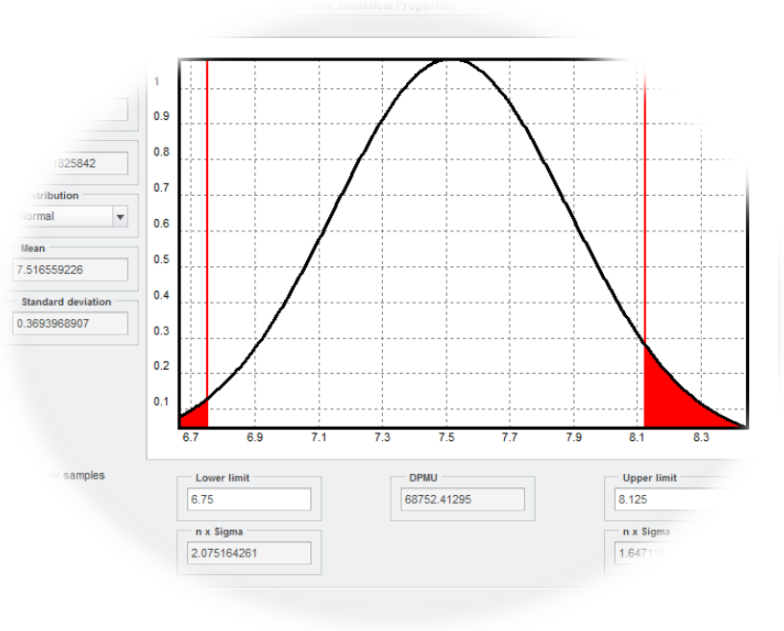
n x Sigma
2.075164261

n x Sigma
1.647119371

Ok

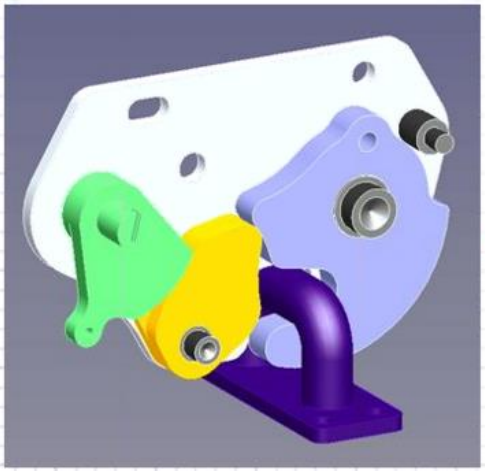
Cancel

Live Demonstration of BMX Statistical Design Studies

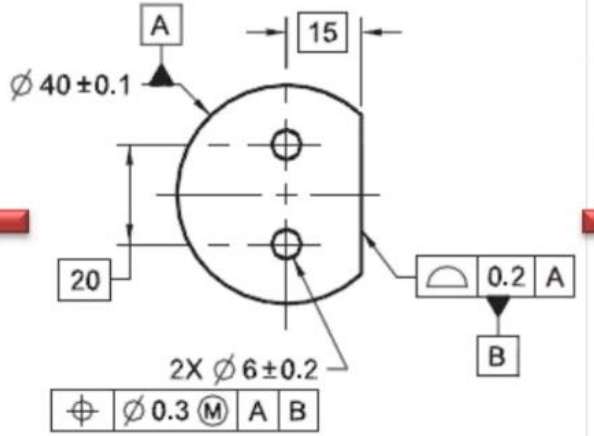


What is CETOL 6σ?

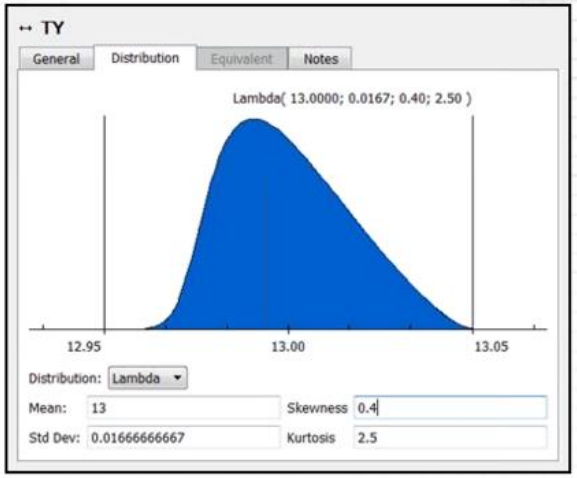
Functional Assembly Interfaces



Part Feature Controls



Expected Variation



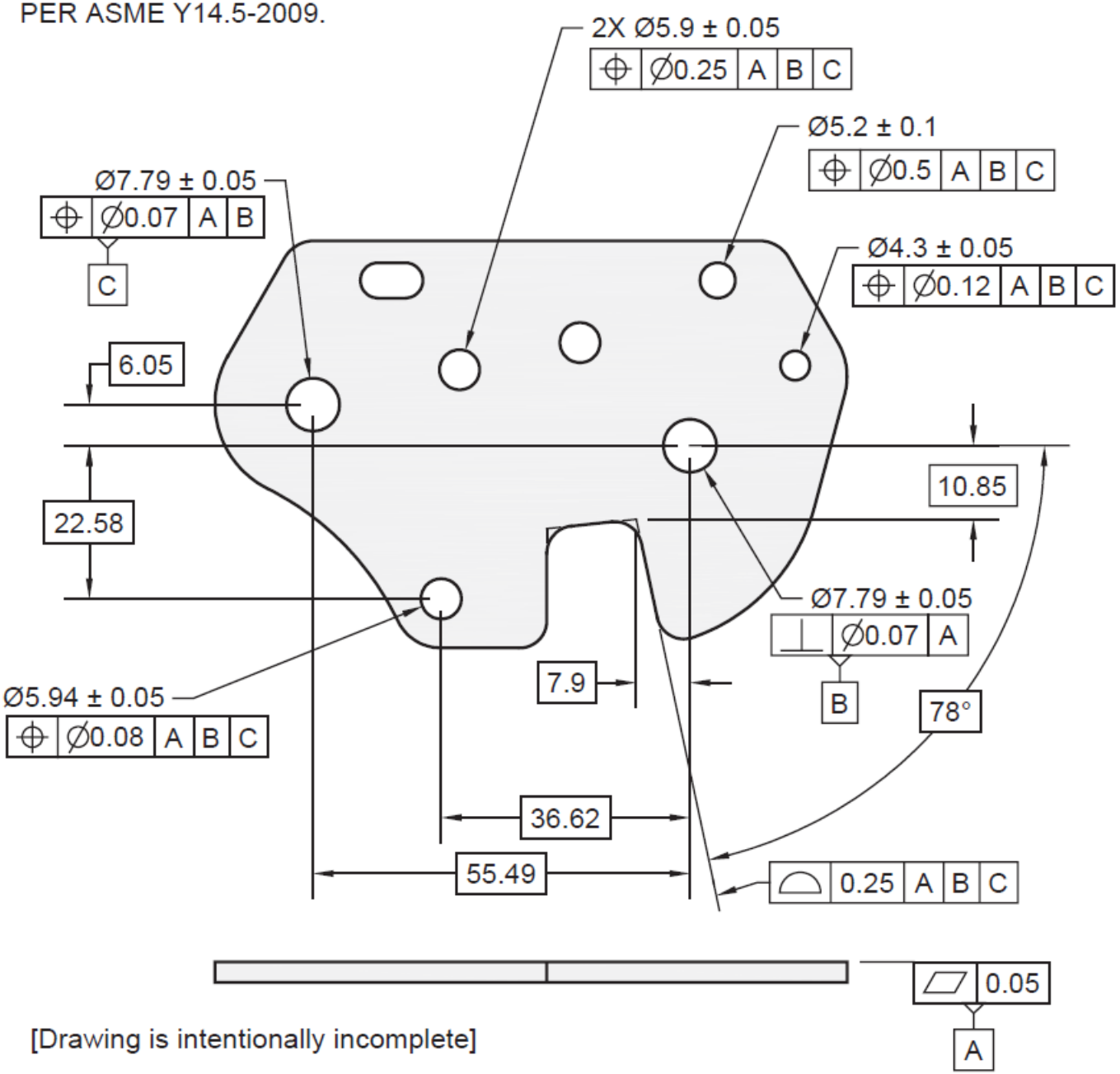
Tolerance analysis software that answers:

- ✓ Does is assemble?
- ✓ Does it work?
- ✓ Is it repeatable?
- ✓ Is it understood?
- ✓ **Is it profitable?**

And where to make improvements if not.

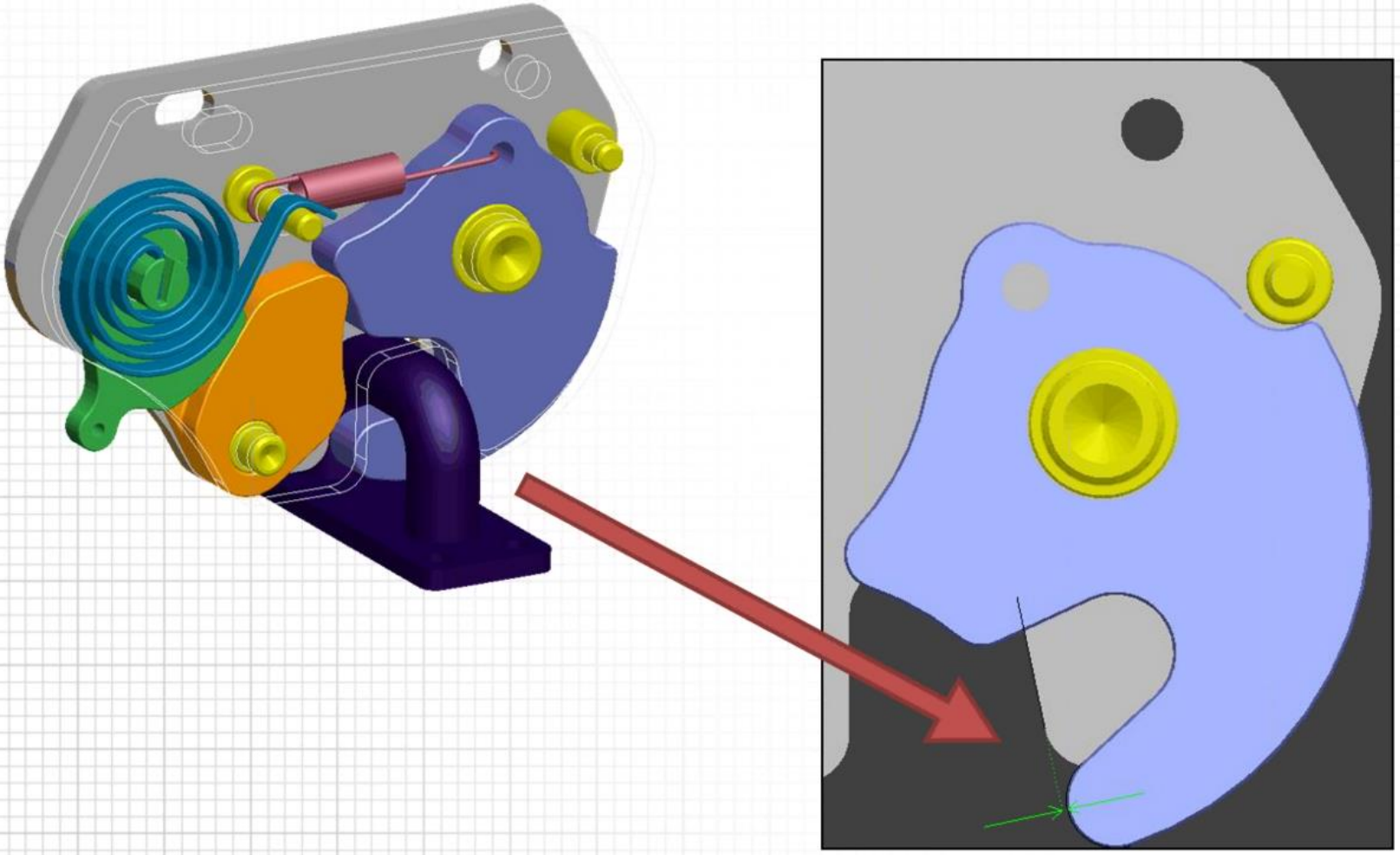
NOTES (UNLESS SPECIFIED OTHERWISE):

1. DIMENSIONING AND TOLERANCING PER ASME Y14.5-2009.



[Drawing is intentionally incomplete]

CETOL Demo – Model Intro



Requirement: Tip of blue part (Claw) always behind the plane of notch in grey side plate

Steps for 3D Tolerance Analysis

- Define appropriate GD&T of all relevant components
- Define as measurements the functional performance requirements
- Define the joints and constraints between parts
- Examine the part dimensioning details
- Validate model / configurations
- Calculate sensitivities
- Evaluate results
- Select critical impactful mean values
- Select critical impactful tolerance values