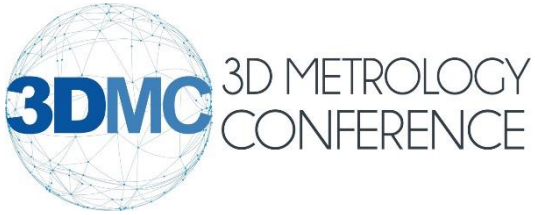
Incorporating Metrology Data Into 3D Tolerance Analysis for Design Refinement and Verification

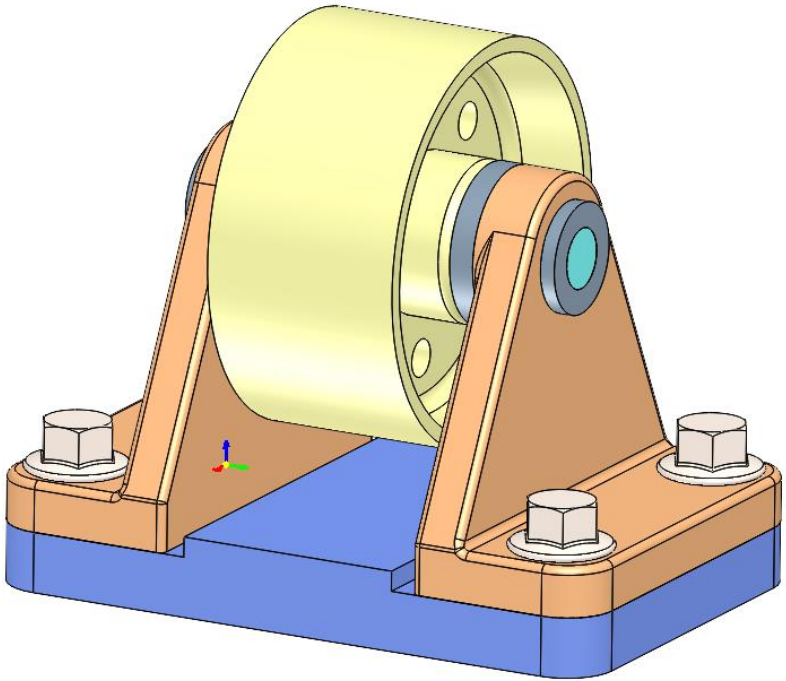


26th September 2024
University of Loughborough

Matt Savage, EnginSoft UK

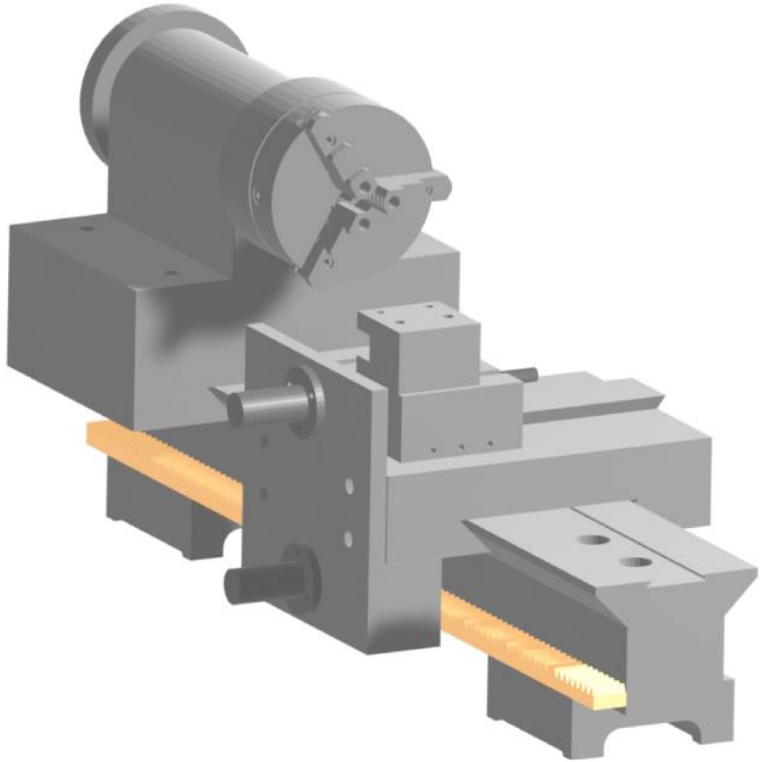
Aims

- Understand challenges with 1D tolerance analysis
- Gain an appreciation of 3D tolerance analysis for design refinement and verification
- Learn how to incorporate metrology data to ensure design quality



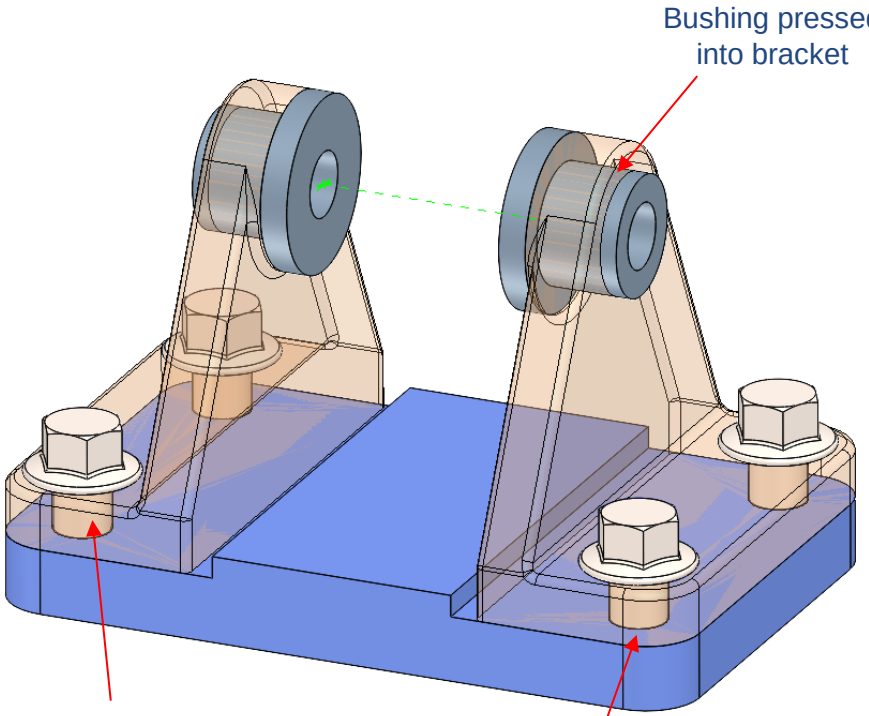
Background

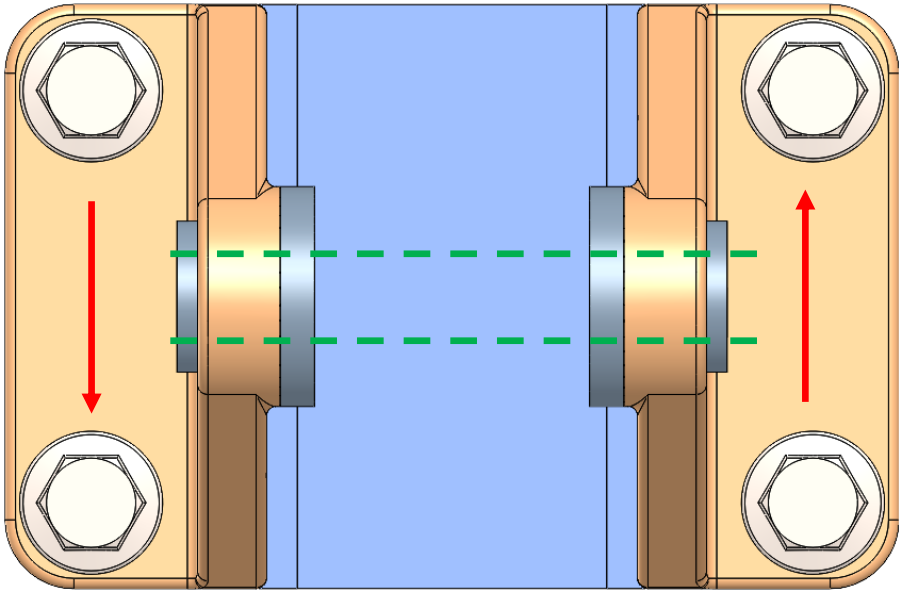
- High accuracy measuring devices require **high precision components**
- **Controlling tolerances** is vital to control **quality**
- **Tight tolerances** will increase manufacturing **cost**
- Manufactured parts might not meet the **intended design specification**



ENGINSOFT

Caster Wheel Assembly

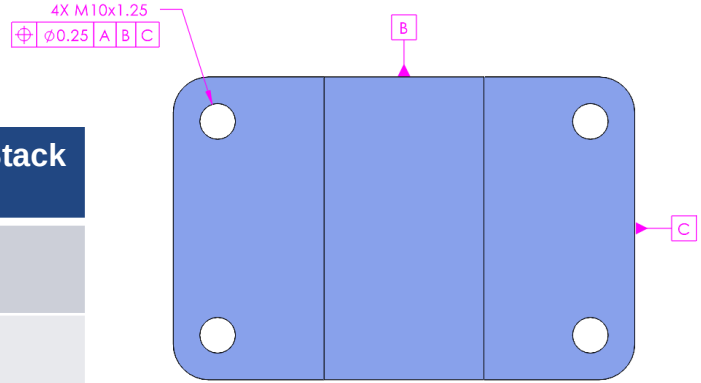


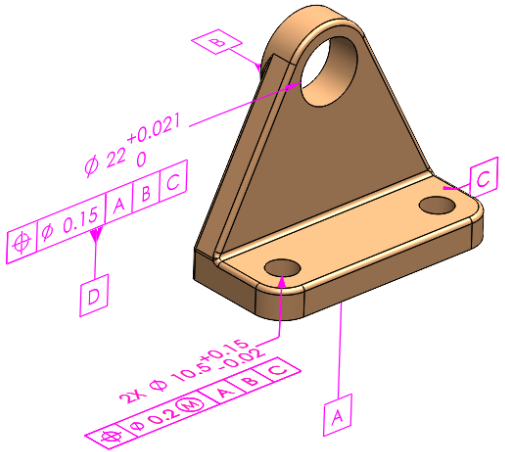


ENGINSOFT

1D Tolerance Stack Up

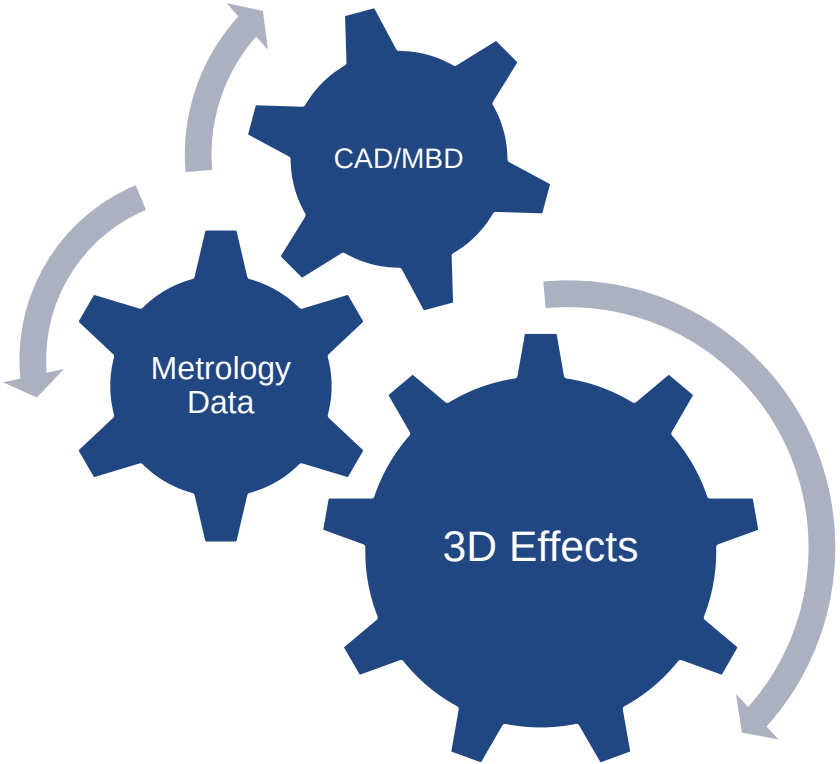
Step	Tolerance (mm)	Added Variation (mm)	Cumulative Stack (mm)
1 – RHS Bushing Position	Pos 0.15	+0.075	0.075
2 – RHS Bracket Hole Position	Pos 0.2	+0.1	0.175
3 – RHS Bracket Hole Size	+0.15 (diameter) -0.02 (+0.25 float)	+0.375	0.55
4 – RHS Plate Hole Position	Pos 0.25	±0.125	0.675
5 – LHS Plate Hole Position	Pos 0.25	±0.125	0.8
6 – LHS Bracket Hole Size	+0.15 (diameter) -0.02 (+ 0.25 float)	+0.375	1.175
7 – LHS Bracket Hole Position	Pos 0.2	+0.1	1.275
8 – LHS Bushing Position	Pos 0.15	+0.075	**1.35**





ENGINSOFT

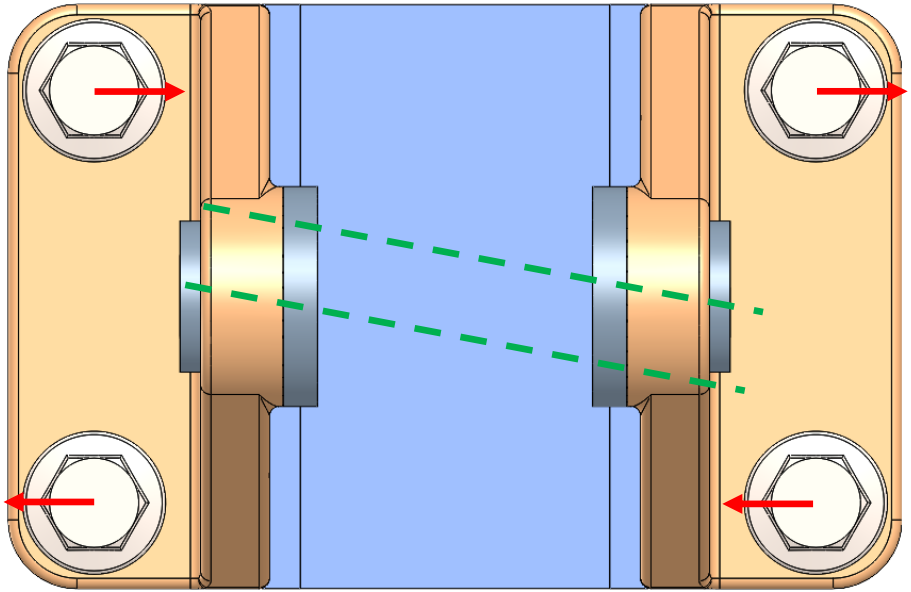
1D Challenges



ENGINSOFT

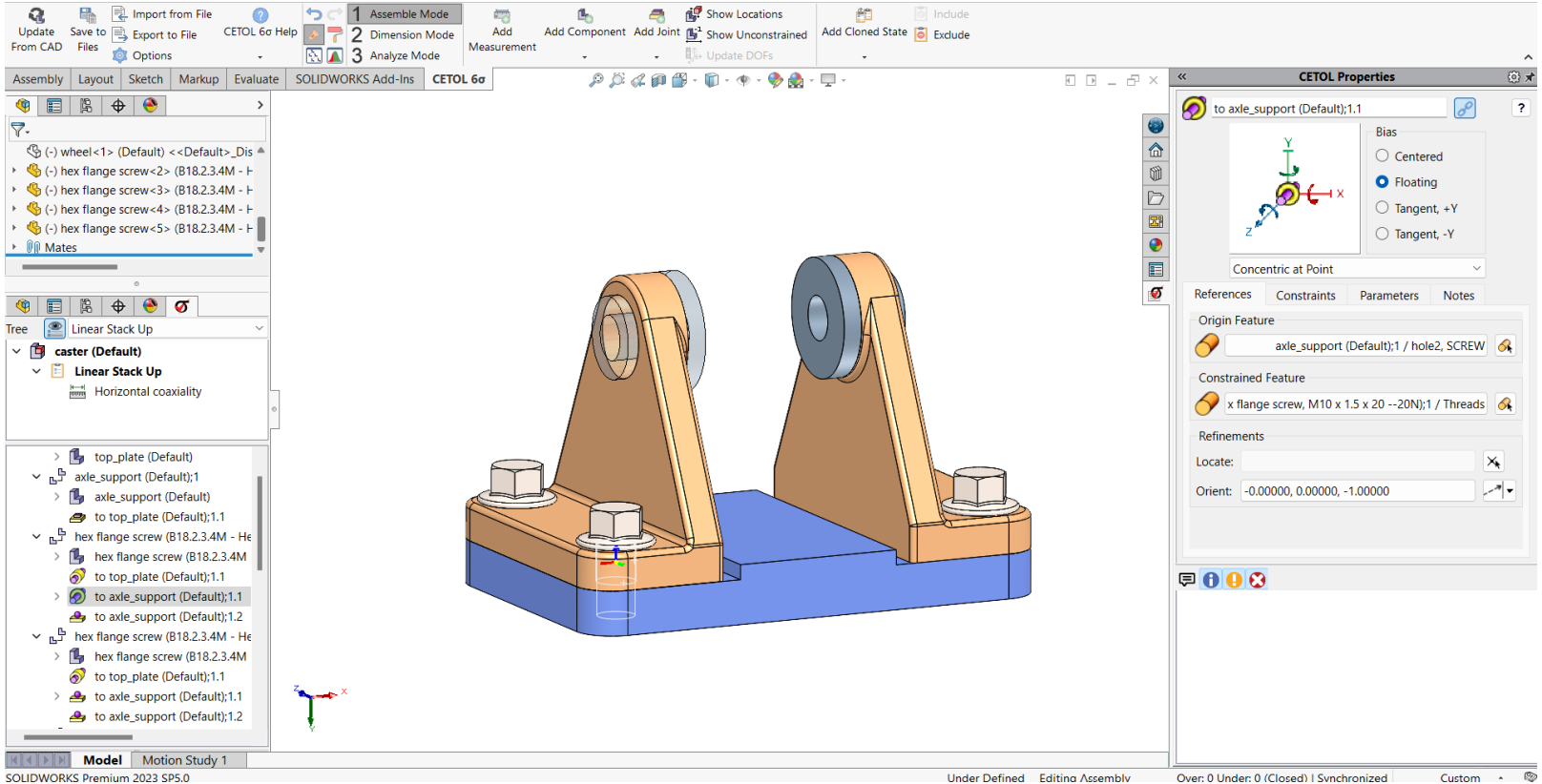
3D Effects in Tolerance Analysis

- Lets looks again at the previous stack up…



- a) how difficult is an angular stack up?
- b) which combination of linear and angular variation provides the largest misalignment?
- c) how do we determine this with a spreadsheet?

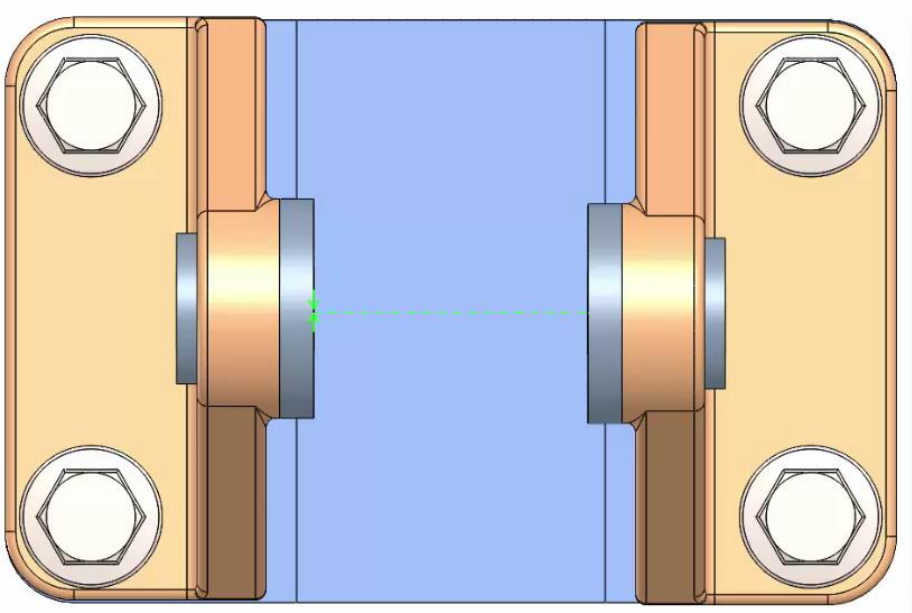
CETOL 6σ



ENGINSOFT

3D Tolerance Analysis

- Dedicated software packages (e.g. CETOL 6σ) allow you to:
  - Model assembly conditions
  - Add in GD&T definitions
- Worst case using this method is 2.6mm (compared to 1.35mm)

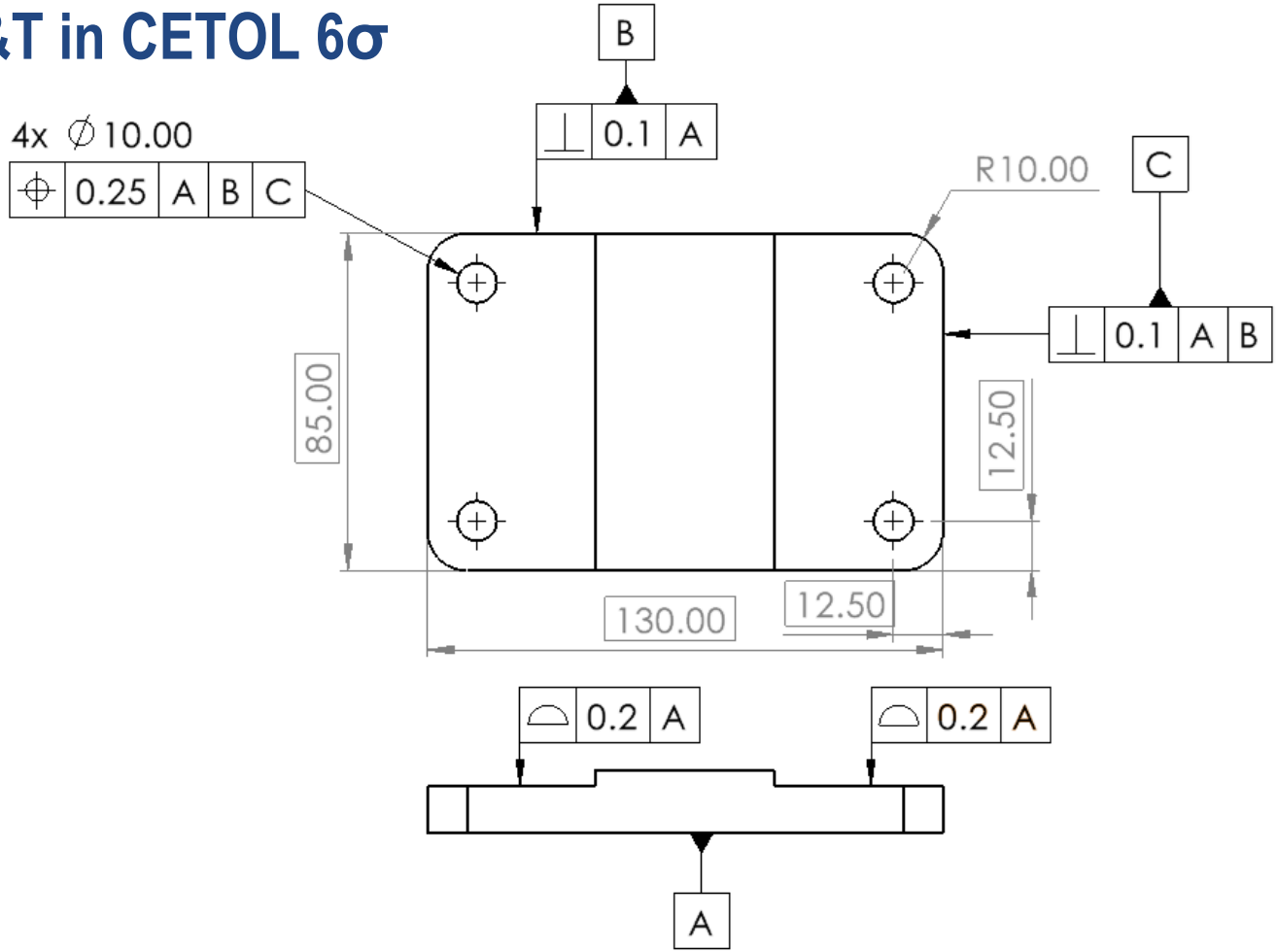


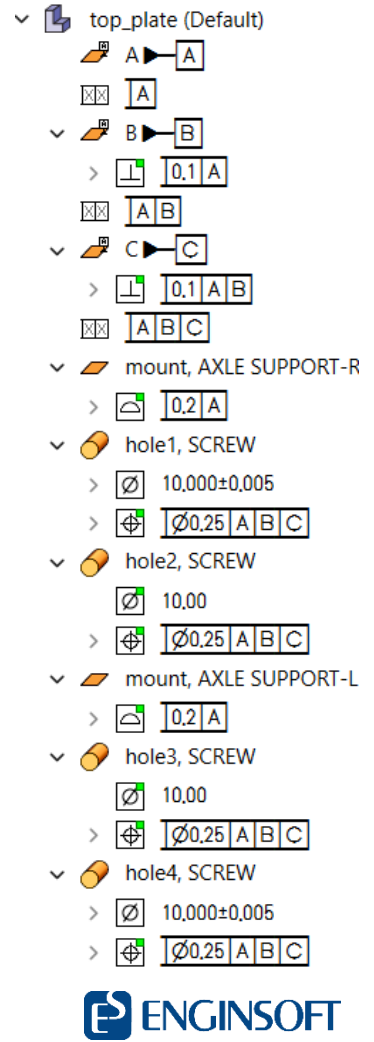
3D GD&T Definitions

- How do we account for these kinds of variation?
  - What does a position tolerance mean?
  - Does it control angular variation as well as position?
  - Which datums is it referencing?
  - Does the pin that fits inside it always go in straight?

ENGINSOFT

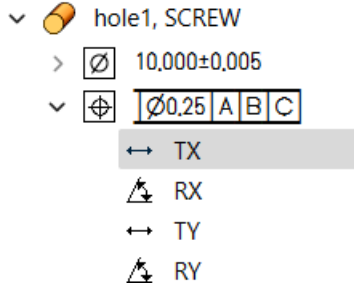
GD&T in CETOL 6σ

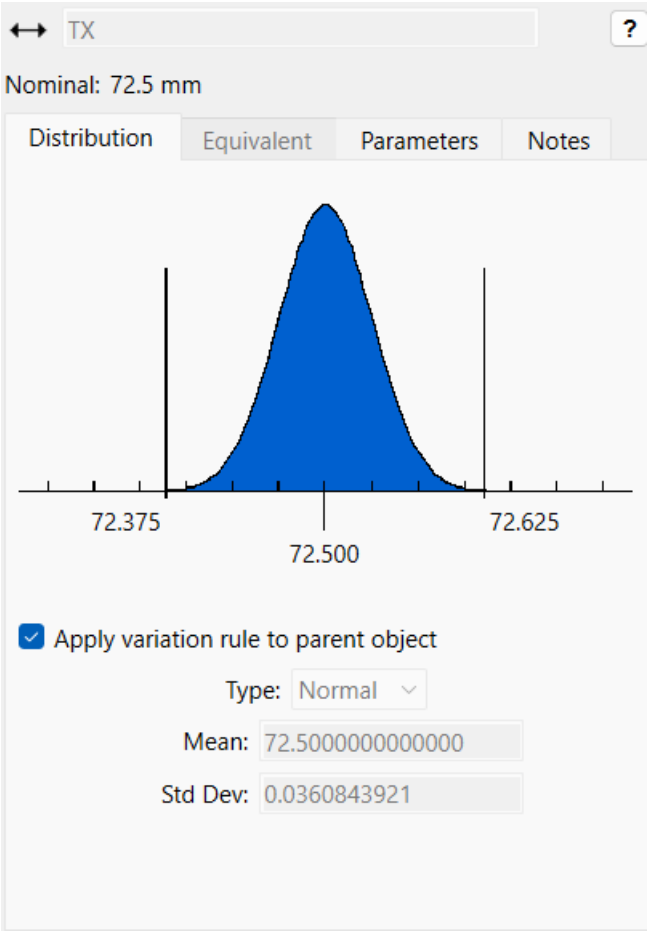




ENGINSOFT

GD&T Distributions





Metrology in 1D Stack Ups

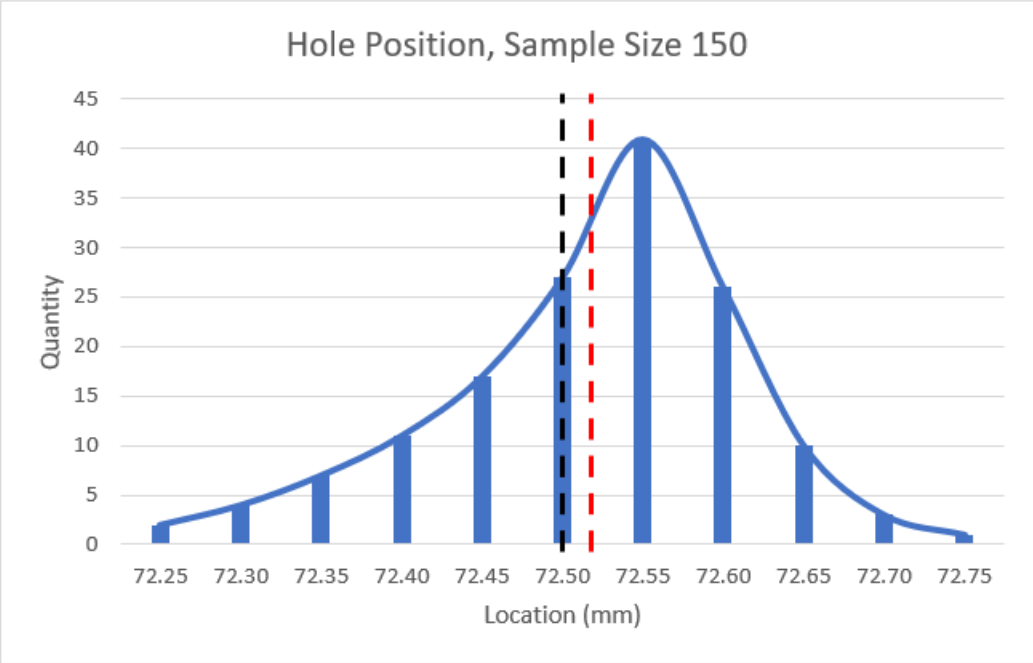
- Statistical analysis requires Standard Deviation (σ)

$$\sigma_{ASM} = \sum_{i=1}^{n} \sigma_i^2 \,^{\frac{1}{2}}$$

- Metrology data provides four moments of distribution
  - Mean
  - Standard Deviation
  - Skewness ← These two make 1D
  - Kurtosis ← stack ups challenging

Adding Metrology Data

Location (mm)	Quantity
72.25	2
72.30	4
72.35	7
72.40	11
72.45	17
72.50	27
72.55	41
72.60	26
72.65	10
72.70	3
72.75	1



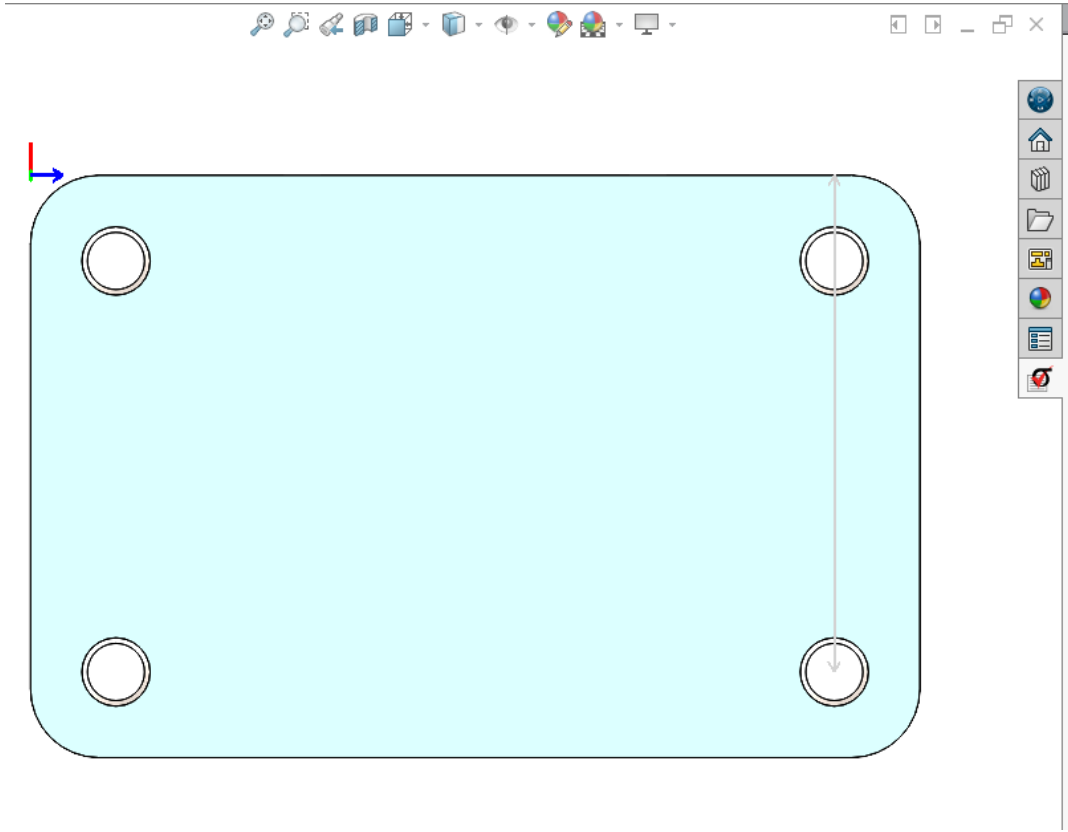
Statistical Moment	Value
Mean	72.52
Standard Deviation	0.09
Skewness	-0.55
Kurtosis	0.31

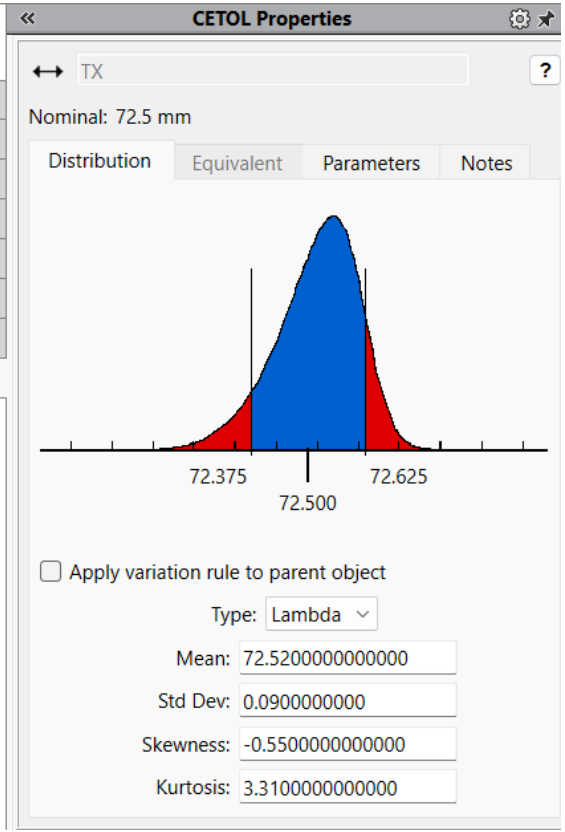
Design Target

Mean

ENGINSOFT

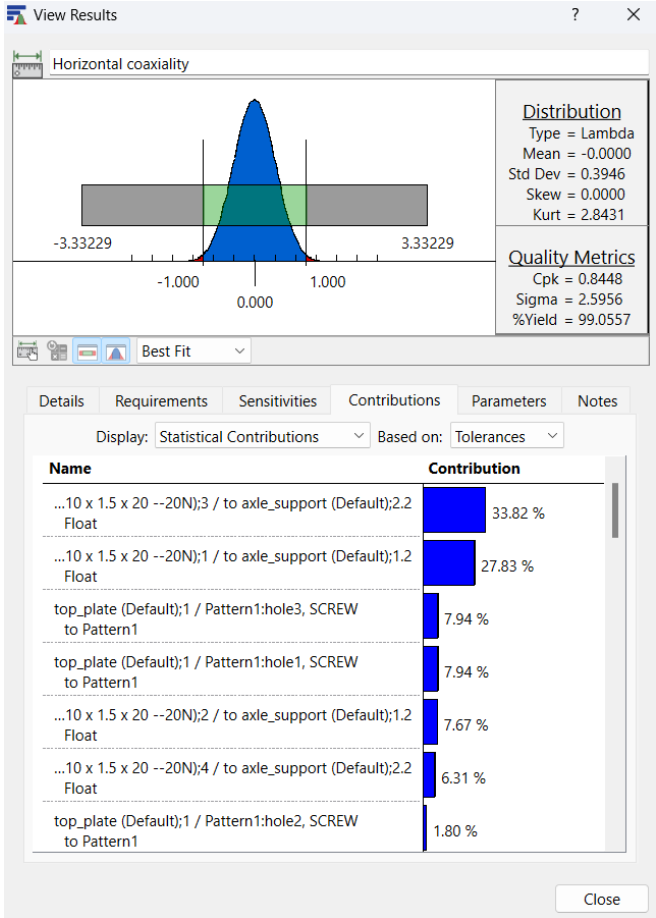
Metrology Results in CETOL 6σ





Results and Contributors

- True worst case is 3.3mm misalignment
  - Production sees a 1% scrap rate
- CETOL 6σ highlights key contributors
  - Float between screw and bracket hole has largest effect on variation
- What If Analysis
  - Alter tolerances to visualise change in results



Conclusions

- 3D tolerance analysis using **CETOL 6σ** provides further insight not available using 1D stack ups
- **Metrology data** can be included for every variable from any sample size
- Design iteration and **model rework limited** once the model is built

Matt Savage
m.savage@enginsoftuk.com

www.tolerance-analysis.co.uk

Thank you!

ENGINSOFT

www.enginsoft.com