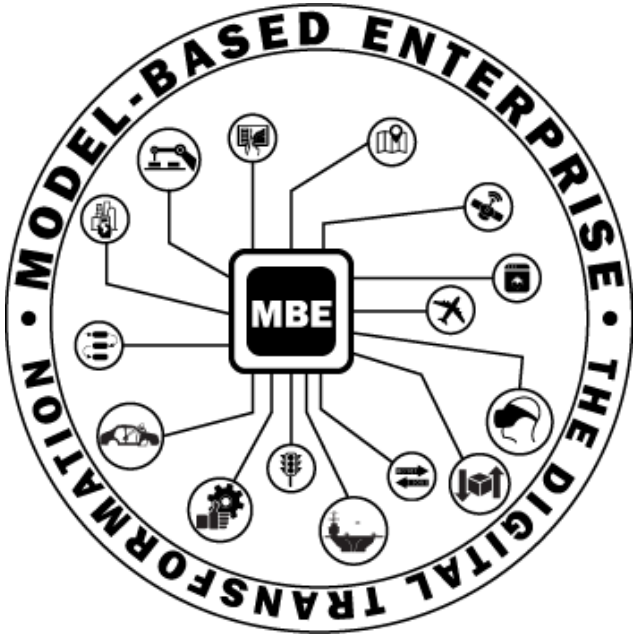
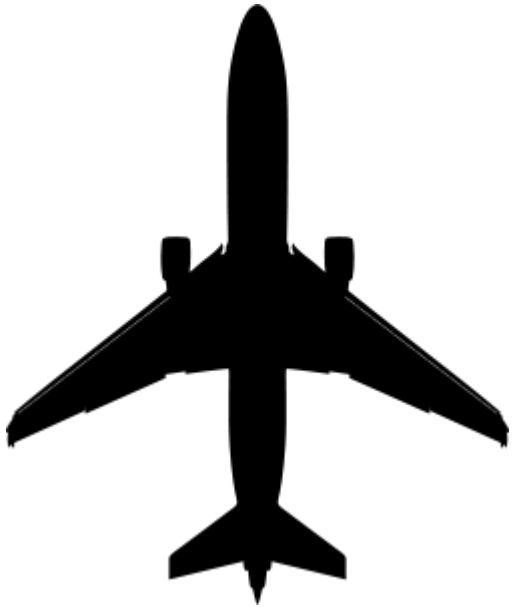


A consortium for software testing in coordinate metrology

Dr. Craig Shakarji, NIST

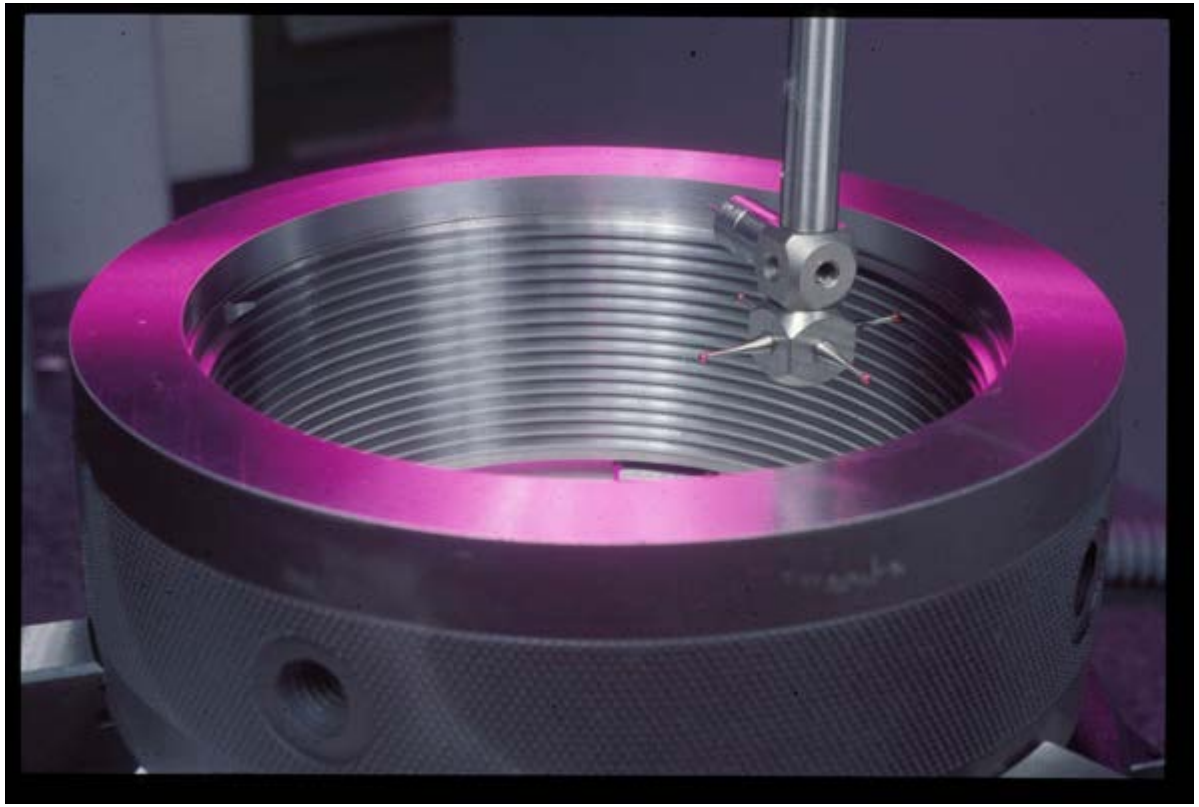
April 3, 2019

Difficulty of comprehensive software testing



While physical testing can reveal software issues, the cost of physical testing compared with the exponential number of if-then cases in software make physical testing alone incomplete

Software transforms a CMM from an accurate, primitive point collector to an immensely flexible measuring instrument

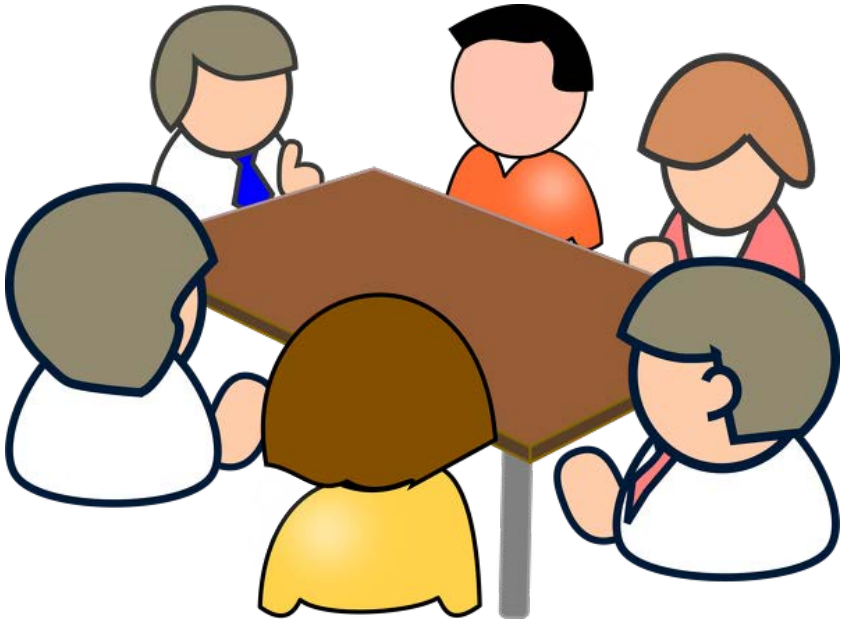


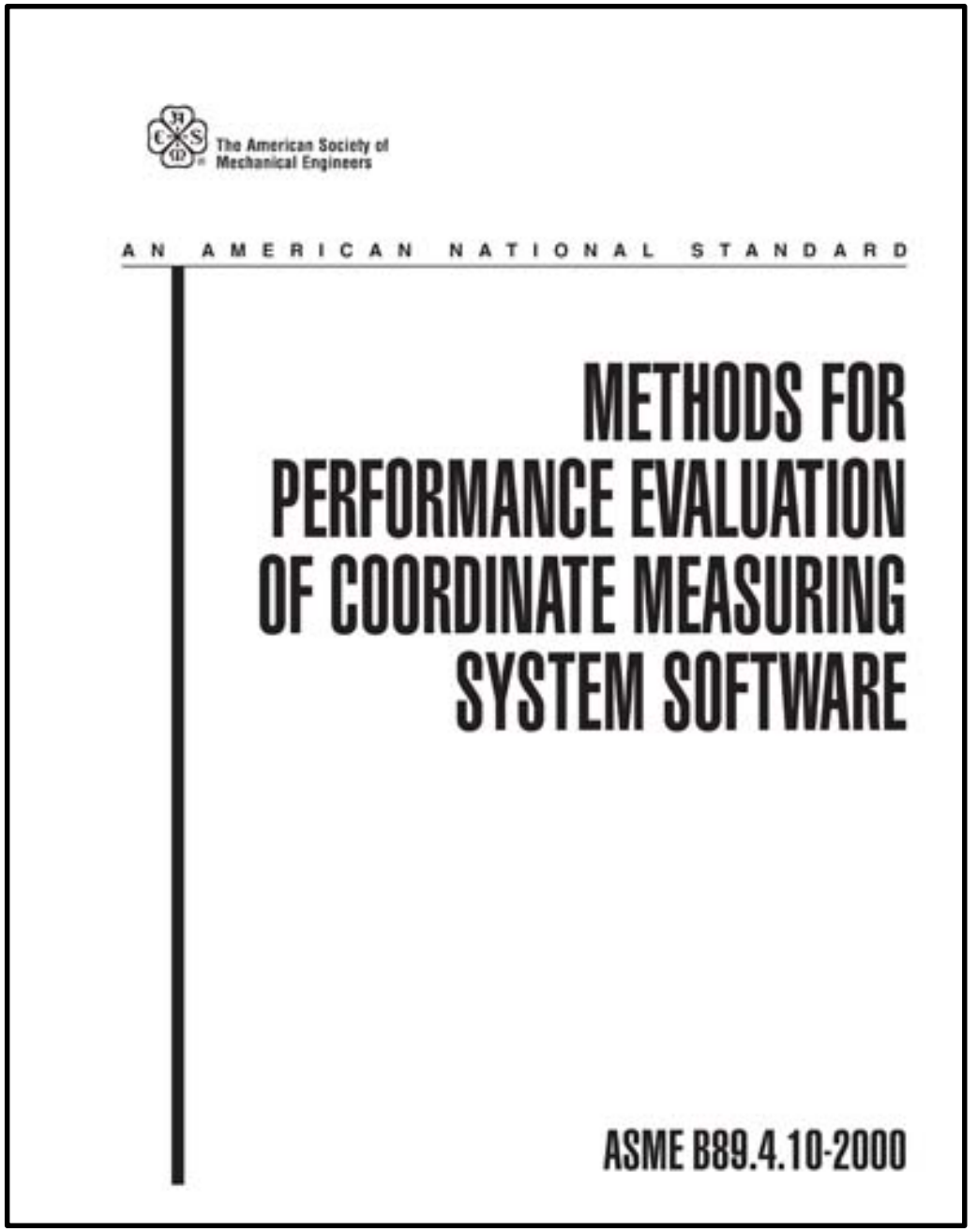
1988 GIDEP alert on software for Coordinate Measuring Machines

Popular least-squares does not give “right” answer for several GD&T problems

Even though alert was for “methods divergence,” verification of software came to the forefront of discussions

This led to a national standard effort on software testing





ATEP-CMS software testing at NIST

ASME B89.4.10-2000 Standard Default Test

Geometry Type	Mean (RMS) Deviation			
	Separation (μm)	Tilt (arc seconds)	Radius/dist (μm)	Apex (arc seconds)
Lines	$< 10^{-5}$	$< 10^{-7}$	—	—
Lines 2D	$< 10^{-5}$	$< 10^{-7}$	—	—
Planes	$< 10^{-5}$	2.6×10^{-5}	—	—
Circles	7×10^{-5}	1.3×10^{-6}	8×10^{-5}	—
Circles 2D	4×10^{-5}	6×10^{-6}	6×10^{-5}	—
Spheres	3×10^{-4}	—	2.7×10^{-4}	—
Cylinders	$< 10^{-5}$	3.6×10^{-4}	$< 10^{-5}$	—
Cones	3×10^{-2}	1.9×10^{-2}	1×10^{-3}	3.1×10^{-2}

What is and is not tested?

TESTED	NOT TESTED
Unconstrained least squares fitting of basic geometric shapes 	Fits for min-zone, max-inscribed, min-circumscribed, minimum-total-distance, constrained least-squares, etc. Constrained fits Weighted fits Datum reference frame establishment GD&T size verification GD&T tolerance verification Complex surface fitting Very large numbers of points

But even the limited scope of testing has had a tremendous impact

The egregious errors are usually not so dangerous. They are easily seen.

The smaller errors are the bigger problem.

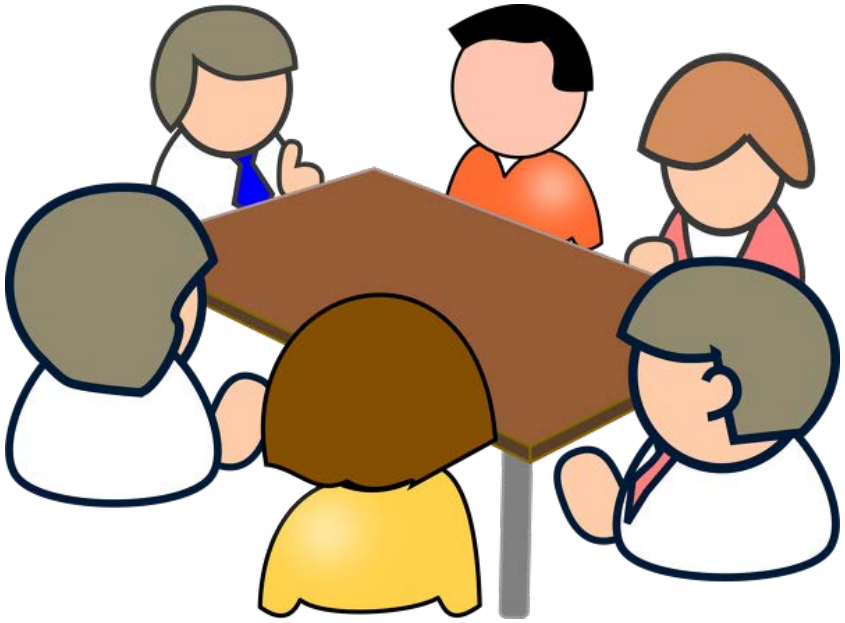
Least-squares algorithms have improved! Have other fitting algorithms?

Tests done with eight software vendors on non-least-squares algorithms

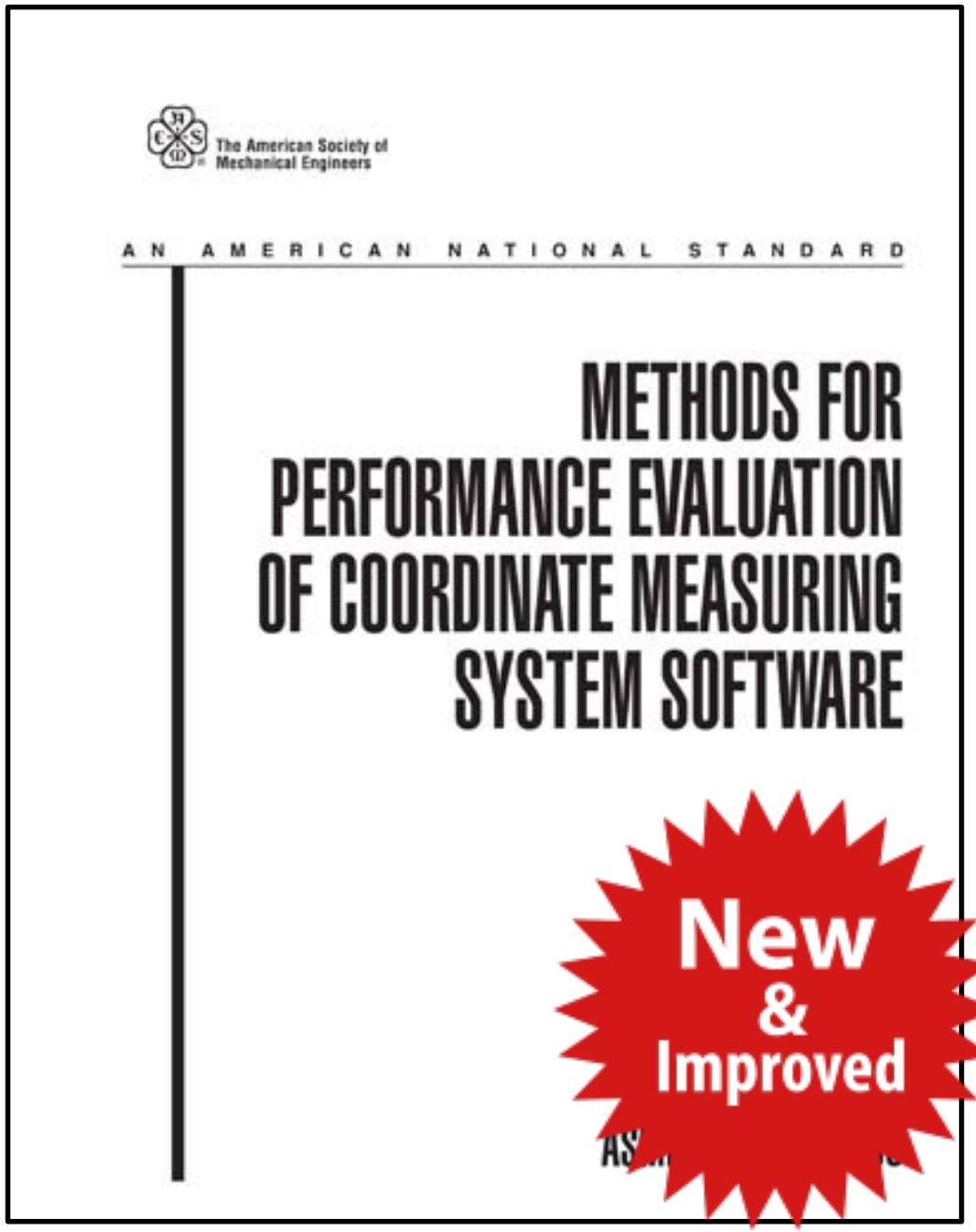
	A	B	C	D	E	F	G	H
MZ line								
MZ Plane								
MZ Circle								
MZ Sphere								
MZ Cylinder								
MZ Cone								
MI Circle							NR	NR
MI Sphere							NR	NR
MI Cylinder							NR	NR
MC Circle							NR	NR
MC Sphere							NR	NR
MC Cylinder							NR	NR

Even though company names are not listed, some cells were changed color to ensure nobody can walk away saying anything for certain! But the general outcome is faithfully represented above, meaning the results were troublesome.

This is leading to a new ASME standard for testing. Set for ballot this year



But even this expansion is limited in extent



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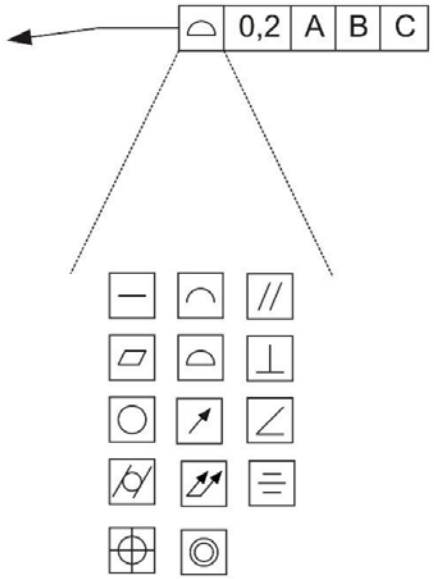
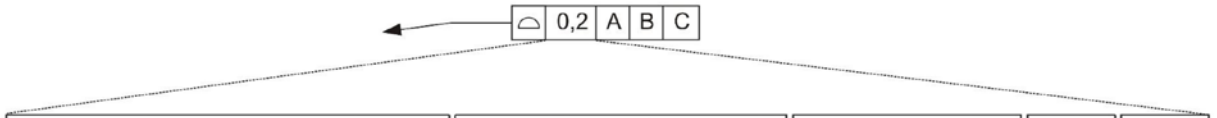
15th CIRP Conference on Computer Aided Tolerancing – CIRP CAT 2018

A Brief Analysis of Recent ISO Tolerancing Standards and Their Potential Impact on Digitization of Manufacturing

Edward P. Morse[a], Craig M. Shakarji[b], Vijay Srinivasan[b]*





Tolerance zone					Toleranced feature				Characteristic		Material condition	State
Shape	Width and extent	Comb.	Unequal	Con-straint	Filter[a] Type	Filter[a] Indices	Ass. tol. feature	Derived feature	Association[b]	Parameter[c]		
Φ SΦ	0,02 0,02-0,01 0,1/75 0,1/75×75 0,2/Φ4 0,2/75×30° 0,3/10°×30°	CZ SZ	UZ+0,2 UZ-0,3 UZ+0,1:+0,2 UZ+0,2:-0,3 UZ-0,2:-0,3	OZ VA ><	G S etc.	0,8 -250 0,8-250 500 -15 500-15 etc.	Ⓒ Ⓖ Ⓝ Ⓣ Ⓧ	Ⓐ Ⓟ Ⓟ25 Ⓟ32-7	C CE CI G GE GI X N	P V T Q	Ⓜ Ⓛ Ⓡ	Ⓕ
1a	1b	2[d]	3	4[d]	5a	5b	6	7[d]	8	9	10[d]	11
8.2.2.1					8.2.2.2				8.2.2.3		8.2.2.4	8.2.2.5

1.5 X 10^{20} combinations

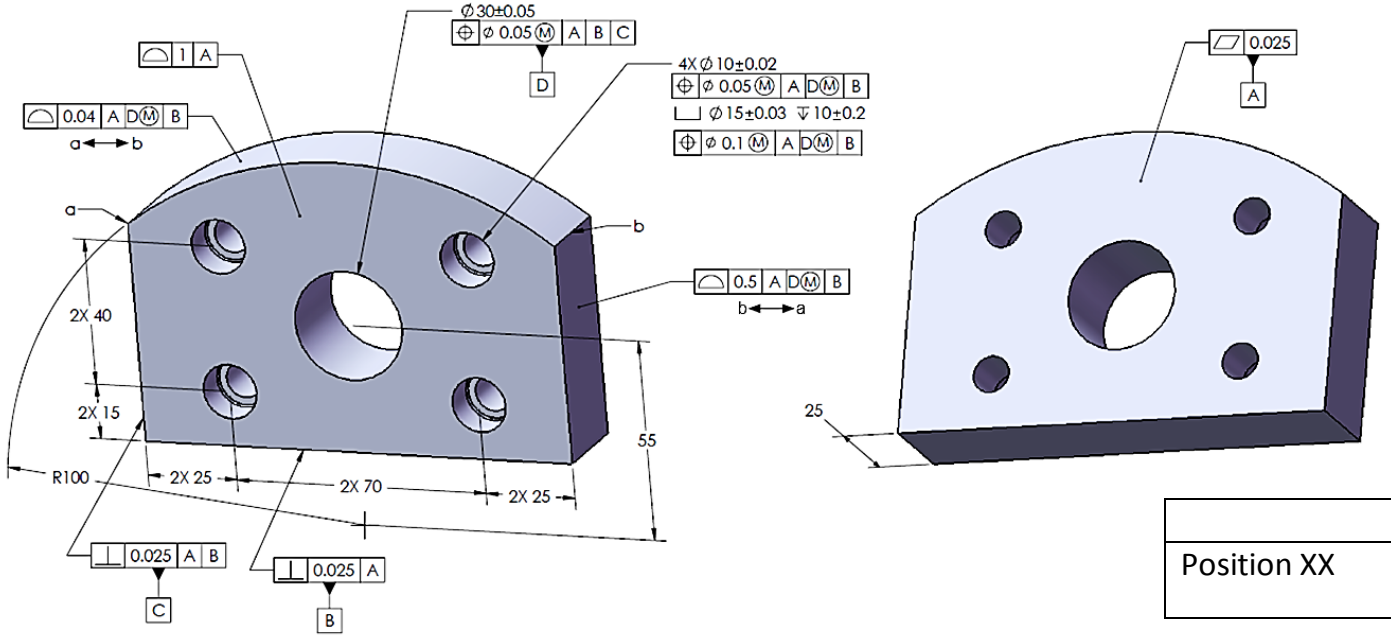
150 Quintillion

Etc.

Which brings us to today

A consortium can be helpful on three fronts:

1. Input on continued expansion of Standard
2. Input on continued expansion of NIST Test service
3. The building of a compilation of test data sets with reference results



	A	B	C	D	E
Position XX	✓	✓		✓	✗

Needs for an industrial consortium

Confidentiality 

Benefit 

We have industrial interest already
Seeking additional interested parties

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