SAND2007-4800C

Initial Evaluation of a Micro-CMM

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Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company,
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A new class of CMMs is available.

- Small work volumes
  - typically 100mm x 100mm x 100mm
- Fine positional accuracy
  - <300nm
- Low contact force
  - <1mN

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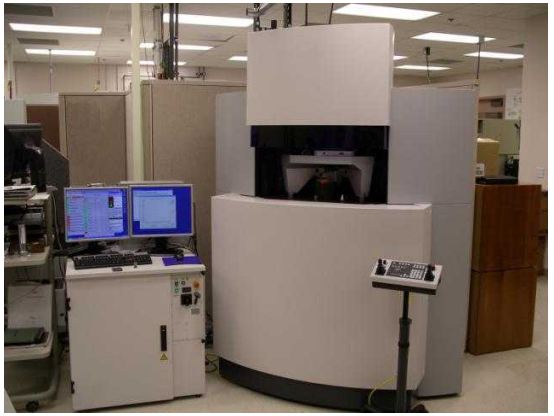
SNL has acquired a micro-CMM.

- Meso-scale manufacturing and system development department
  - 10^{1}mm in size
  - 10^{-1}mm features
  - 10^{-3}mm tolerances
- MPE_E of (0.250+L/666)μm
- 0.5mN probing force
- 100mm x 100mm x 100mm work volume
- Tactile and vision probes
- Surveillance camera for operation



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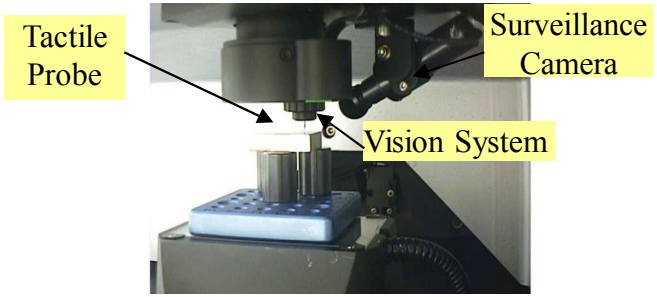
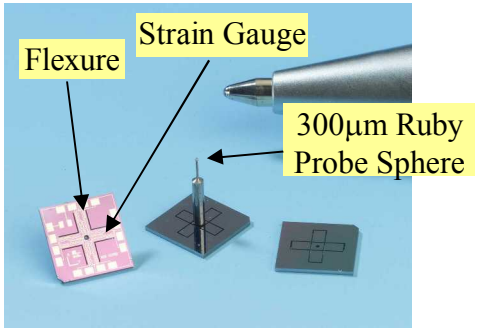
Precision design principles support accuracy claims by vendor

- Dual bridge design minimizes Abbe offsets
- Air bearing design modifications increases stiffness
  - >40 air bearings
- Active vibration isolation
- Thermal shielding
- Glass scales
- Linear motors
  - Heat generation proportional to load

Silicon flexure tactile probe applies low contact force, ~0.5mN

- 120μm and 300μm diameter probes readily available
- Flexure + strain gauge sensing technology
  - Analog nature enables scanning
- Force-deflection response linearized during special calibration
- Max deflection is ~100μm





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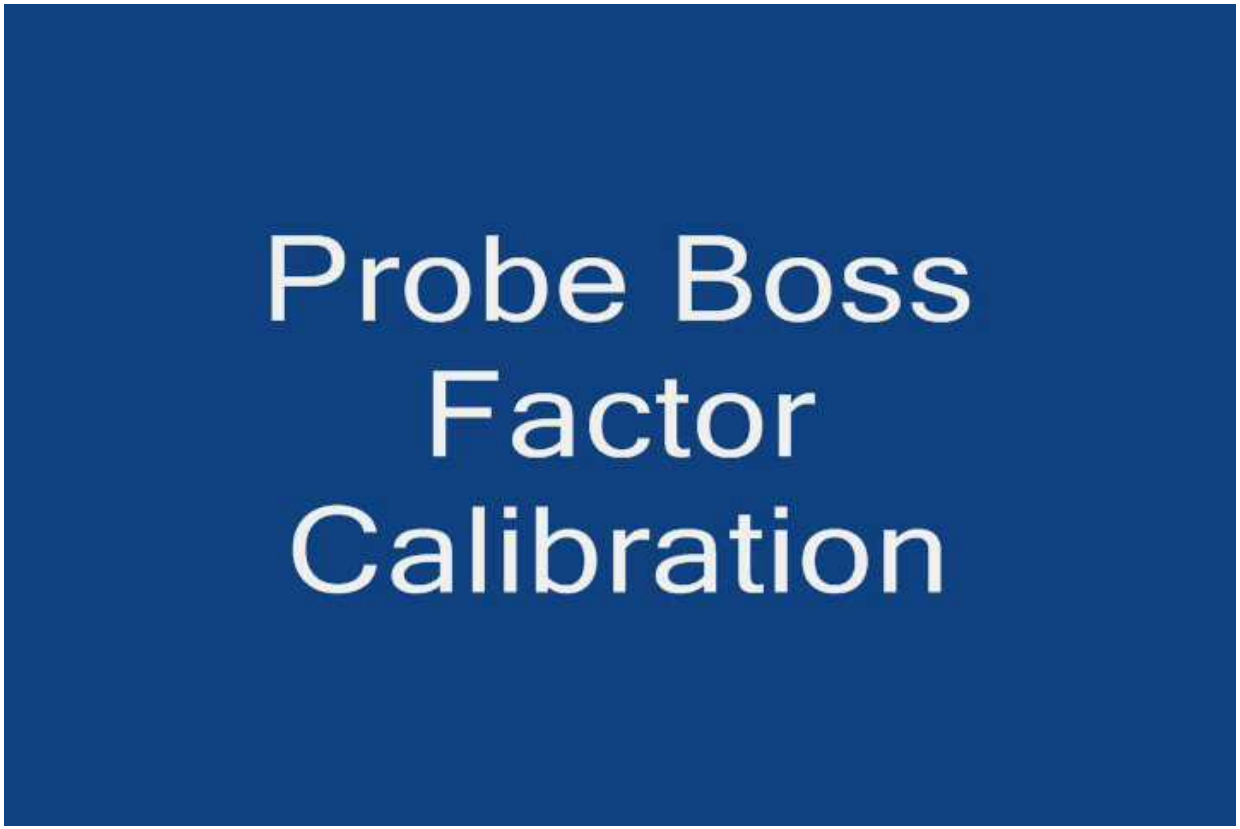
Force-Deflection Linearization Video



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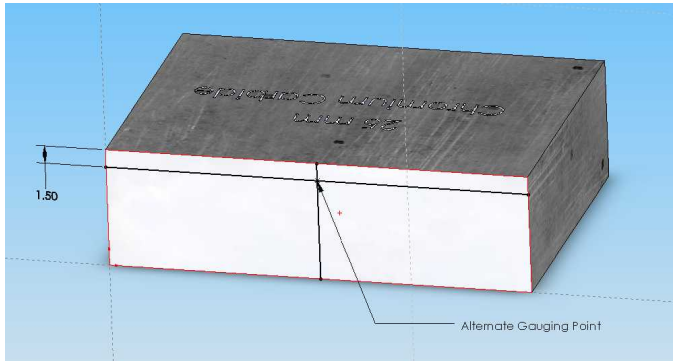
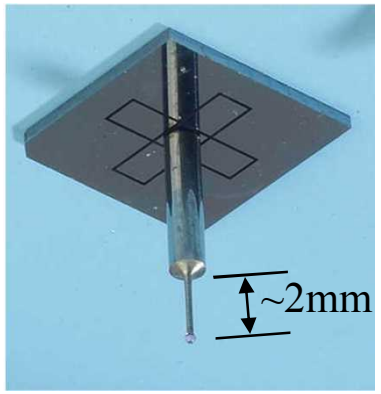
Evaluation requires special calibration of gauge blocks

- Shank length is approximately 2mm
- Unable to reach standard gauging point
- Alternate gauging point as shown
- Certification by SNL primary standards laboratory on gauge block interferometer





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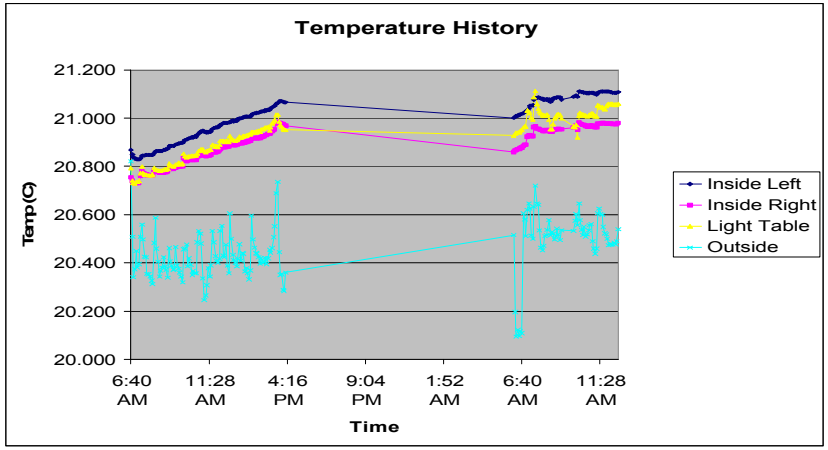
Temperature and cleanliness are important at these levels

- Temperature
  - Absolute and gradient restrictions
  - Manual thermal compensation for this study
  - Minimize handling
- Cleaning
  - Spectroscopic grade IPA and acetone
  - Probe is delicate



Probe Cleaning

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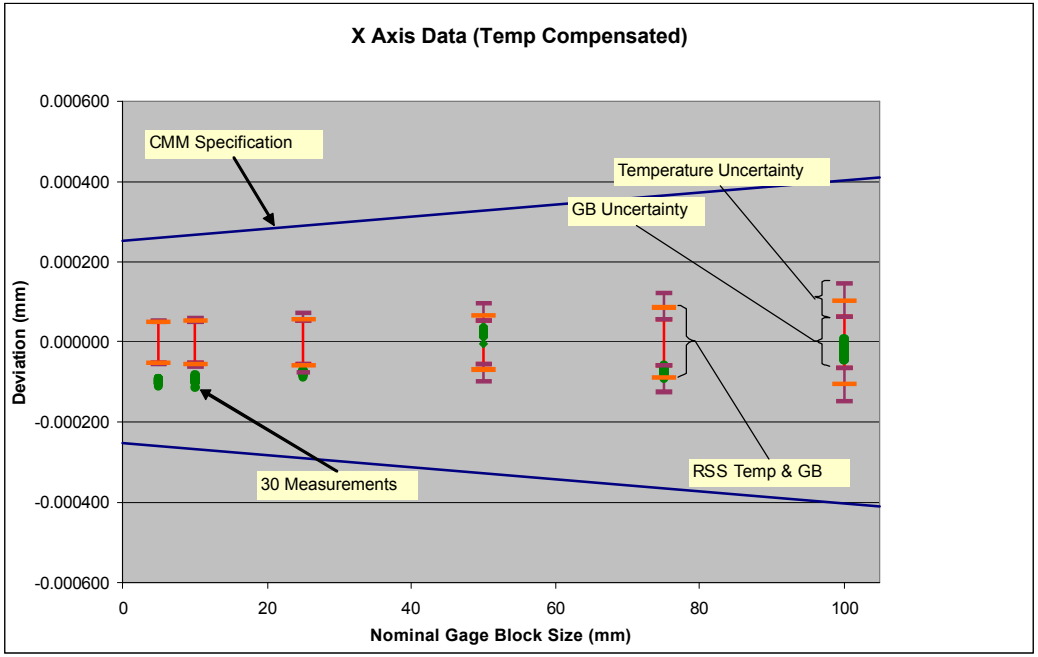
X-Axis Results

- **Excellent repeatability**
- **Well within specification**



Temperature compensated x-axis results.

	5mm	10mm	25mm	50mm	75mm	100mm
Range	21 nm	32	16	45	32	54
Average	-98 nm	-93	-77	25	-74	-17
Std. Dev.	5 nm	6	4	10	7	16
F25 Spec +/-	258 nm	265	288	325	363	400

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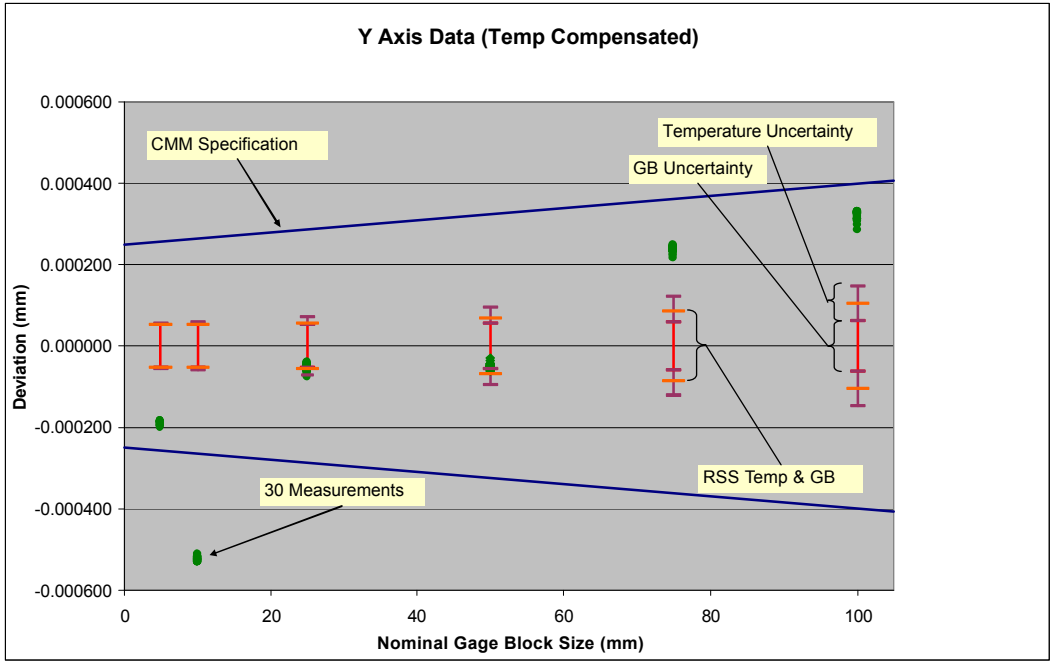
Y-Axis Results

- Excellent repeatability
- One set of outliers
  - Dust?
  - Not supported by other measurements
- Balance within specification



Temperature Compensated Y-Axis Results.

	5mm	10mm	25mm	50mm	75mm	100mm
Range	17 nm	22	37	33	35	49
Average	191 nm	*-524*	-54	-49	237	320
Std. Dev.	5 nm	5	8	7	7	11
F25 Spec +/-	258 nm	265	288	325	363	400

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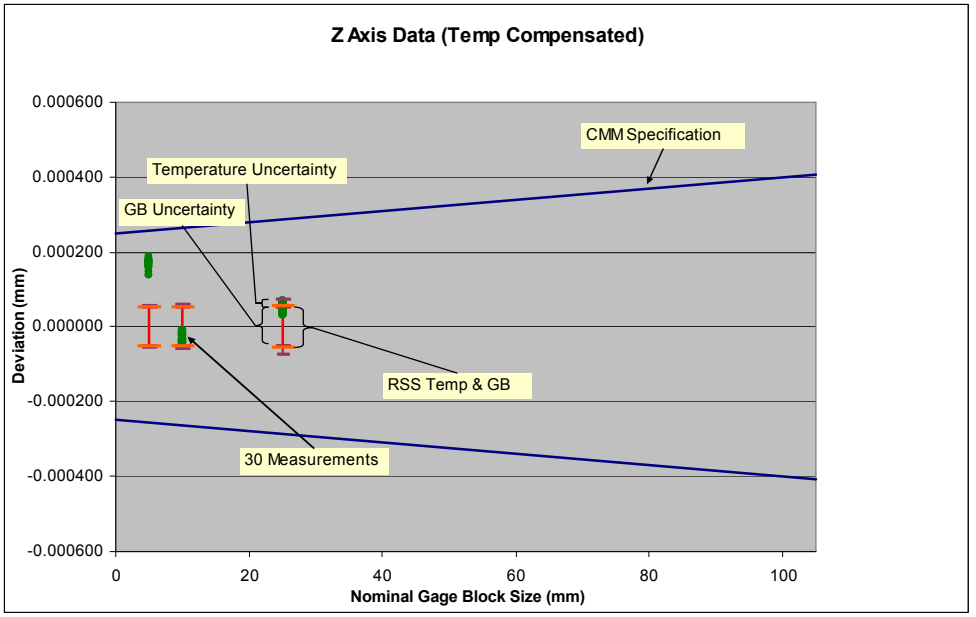
Z-Axis Results

- Mechanical constraints reduce gauge block set
- Sample repeatability as x- and y-axes
- Within specification



Temperature compensated z-axis data.

	5mm	10mm	25mm	50mm	75mm	100mm
Range	50 nm	45	41	NA	NA	NA
Average	168 nm	-31	49	NA	NA	NA
Std. Dev.	11 nm	12	12	NA	NA	NA
F25 Spec +/-	258 nm	265	288	325	363	400

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Squareness Results

- 75mm gauge block in x-y plane
- 0.675 arcsec out-of square

Squareness data.

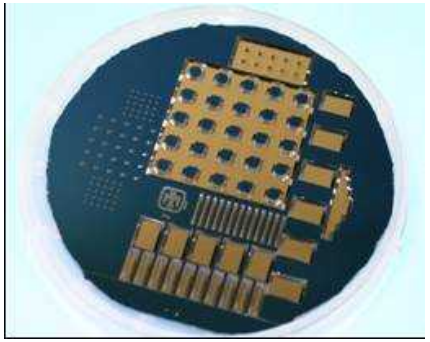
	75mm (+X,+Y)	75mm (-X,+Y)
Range	21 nm	63
Average	-205 nm	286
Std. Dev.	5 nm	14

Important considerations for micro-CMMs

- High purity cleaners
- No canned/compressed air
  - High force
  - Cools parts
- Mechanical cleaning of probes may be done with extreme care
- Linearization and offset for force-deflection curve
  - Slope: Once per installation
  - Intercept: Daily

Conclusions and future work

- Initial results are encouraging
- 4:1 measurements at the 1μm level are certainly achievable
- Current machine is not error mapped
- Upgrade machine installation in progress
- Calibration artifact for hybrid tactile-vision system under development



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