Laser Trackers: Testing and Standards

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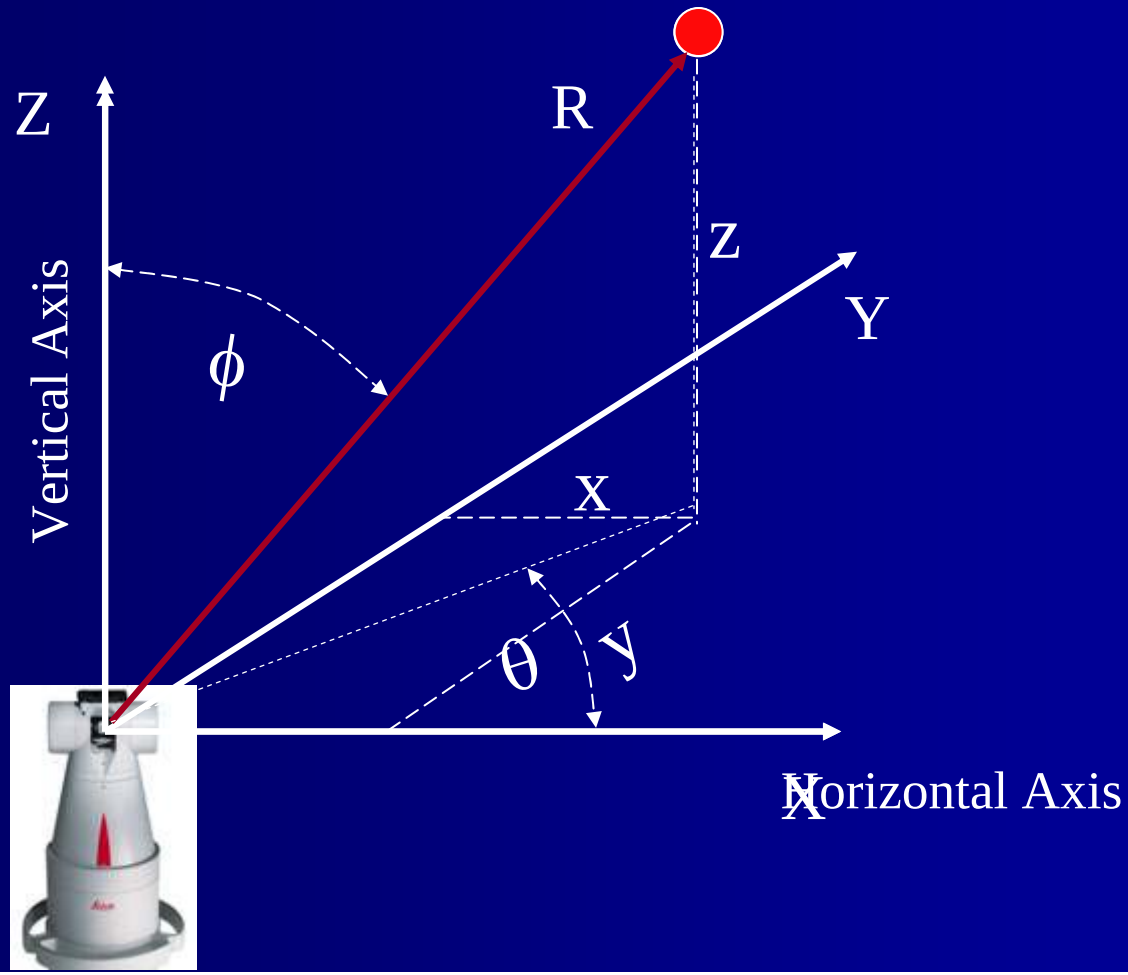
Overview

- Briefly about Laser Trackers
- B89.4.19 Standard & Tests Results
- VDI/VDE 2617 Draft Standard
- Final Remarks

Laser Trackers: Coordinate Measuring Machines Using Spherical Coordinates



Laser Trackers: Optics Link the Workpiece & CMM

- Allows large measurement volumes
- Bring the tracker to the workpiece
- Lower capital costs than large conventional CMMs
- Factory can be reconfigured

Laser Trackers:
Type of Ranging Systems

HeNe Interferometer

- Very High Accuracy
- Do NOT break beam during measurement
- Requires cooperative target, e.g. retroreflector

Absolute Distance Measuring System

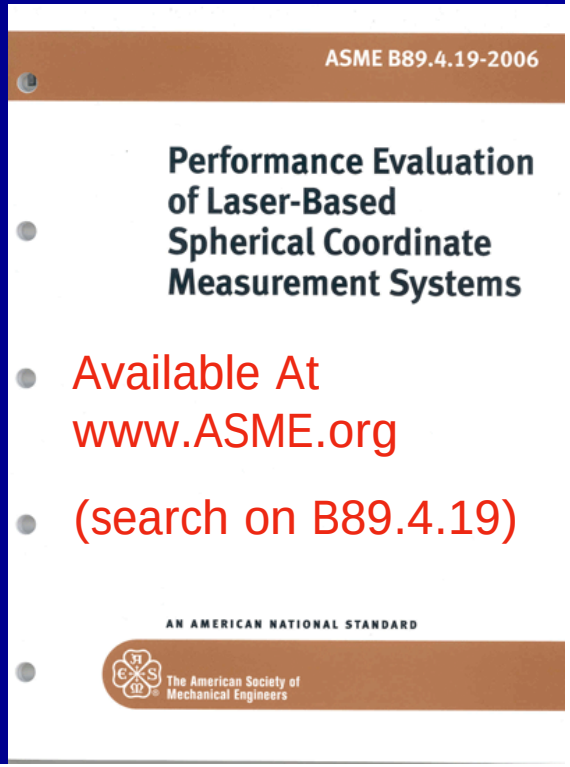
- Good Accuracy
- Can break beam & measure directly to targets
- Requires cooperative target, e.g. retroreflector

Laser Radar

- Non cooperative target OK
- Moderate accuracy
- More expensive

ASME B89.4.19 Laser Tracker Standard

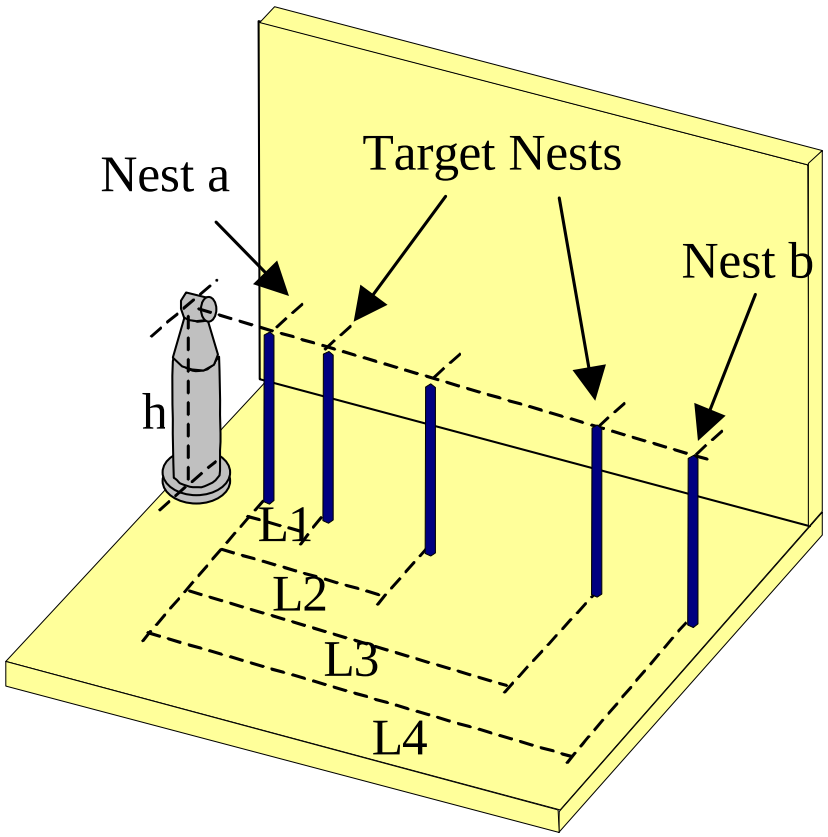
- Designed to Test Cooperative Target Systems
- Focused on Manufacturing (Indoor) Environment
- Tests Ranging and Volumetric Performance
- Does not address:
  - Outdoor Environments
    - Rain; Fog
  - NonCooperative Targets:
    - Concrete; Wood; Dirt
  - Dynamic effects
    - Motion in the field of view



Available At www.ASME.org

(search on B89.4.19)

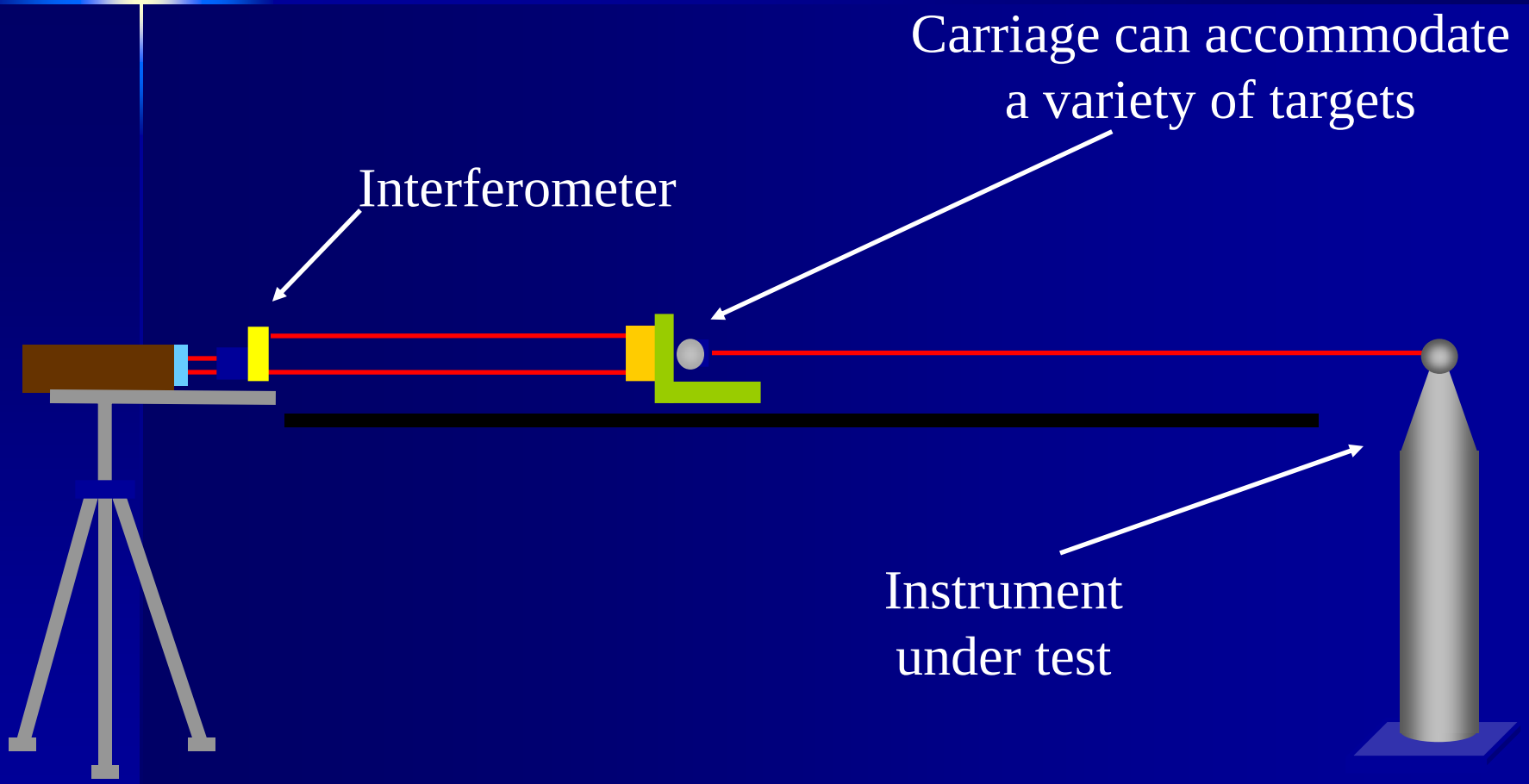
Ranging Test using 6 Calibrated Lengths



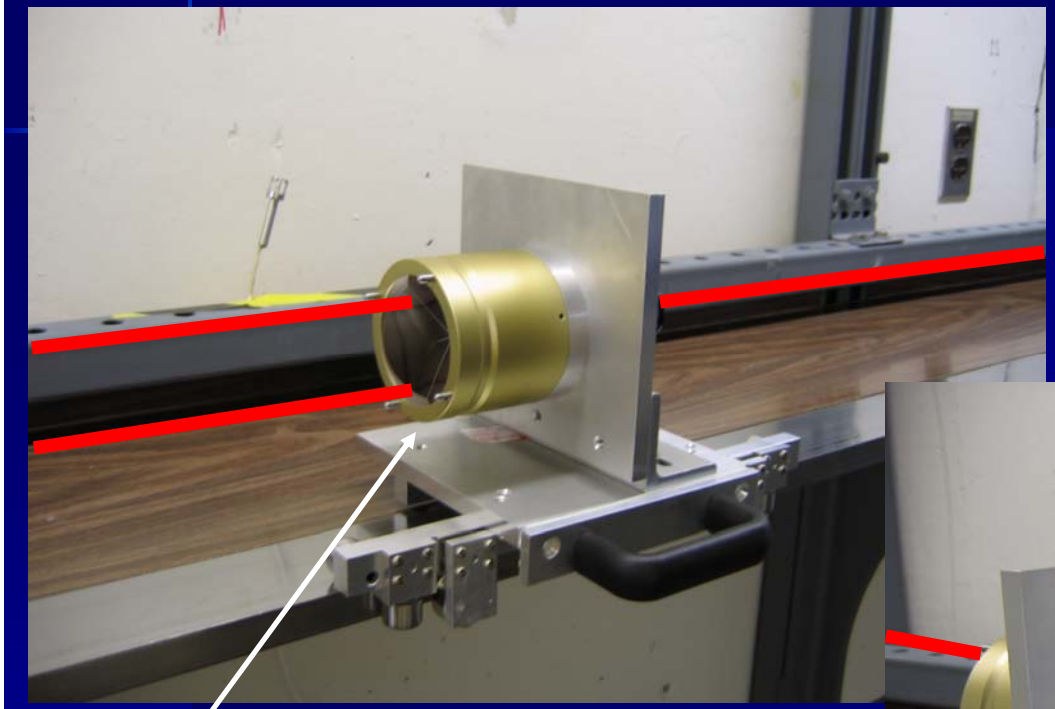
Position number.	*Reference Lengths (**R**=Maximum Ranging Distance)*
1	$L_1 \approx 18\%R$
2	$L_2 \approx 36\%R$
3	$L_3 \approx 54\%R$
4	$L_4 \approx 72\%R$
5	*User selected*
6	*User selected*

1D Cooperative Target Range Facility

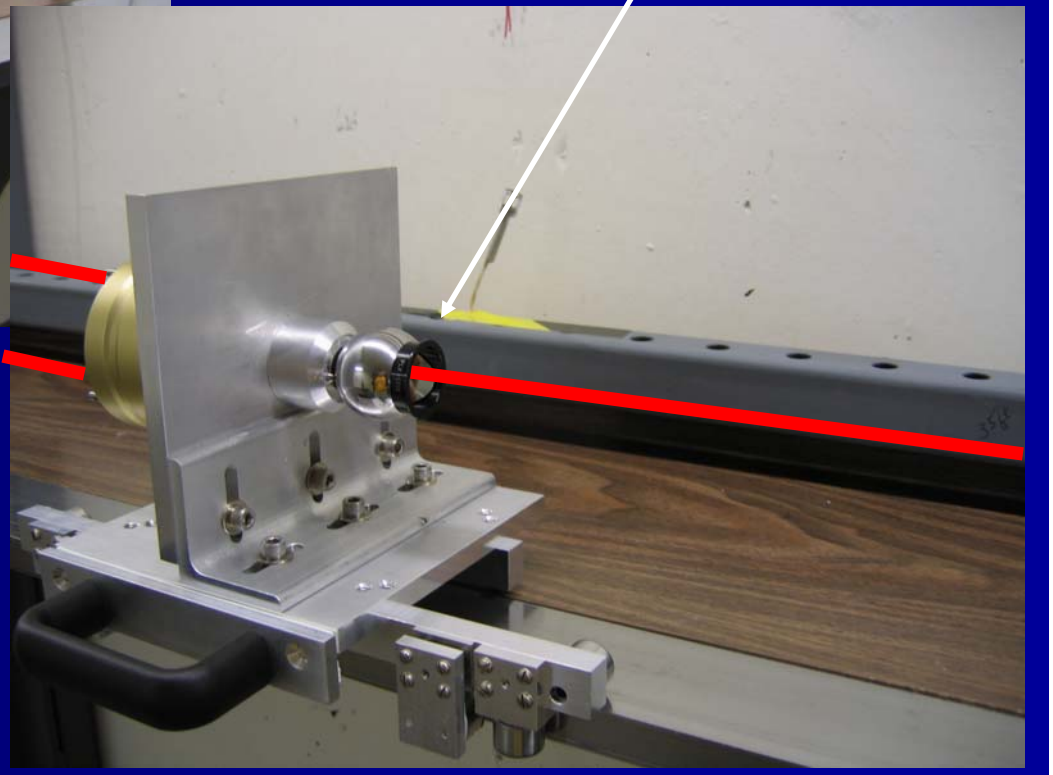
NIST System Configuration



1-D Cooperative Target Range Facility



Target retroreflector



Reference retroreflector

1-D Cooperative Target Range Facility

Range: 60 m (200 feet)

Temperature: 20 ± 0.2 ° C

Sensors:

U(T) = 0.01 °C, spaced @ 10 m

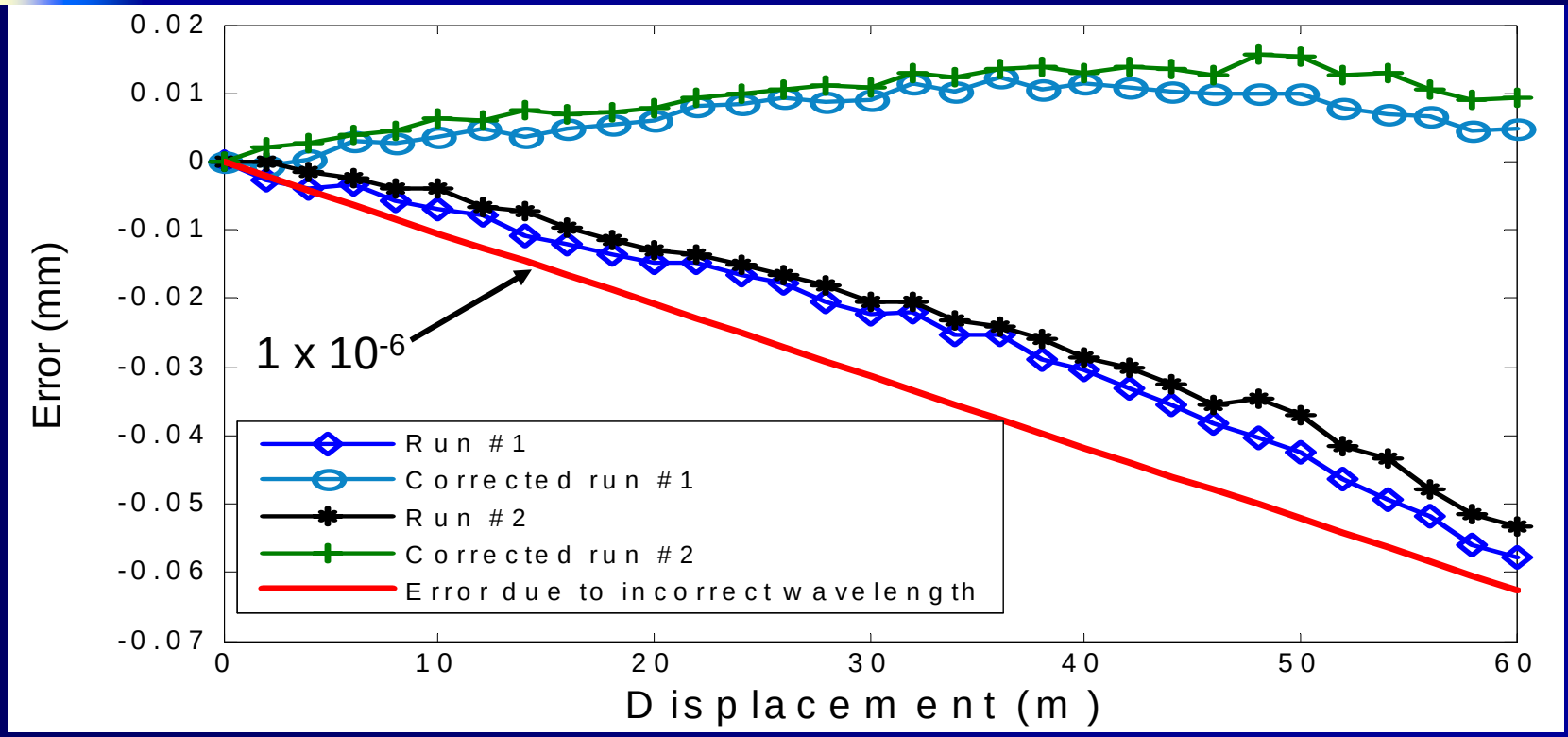
U(P) = 20 Pa

U(RH) = 1 % RH

U(L) = 5 μm + 3 × 10^{-7}

1-D Cooperative Target Range Facility

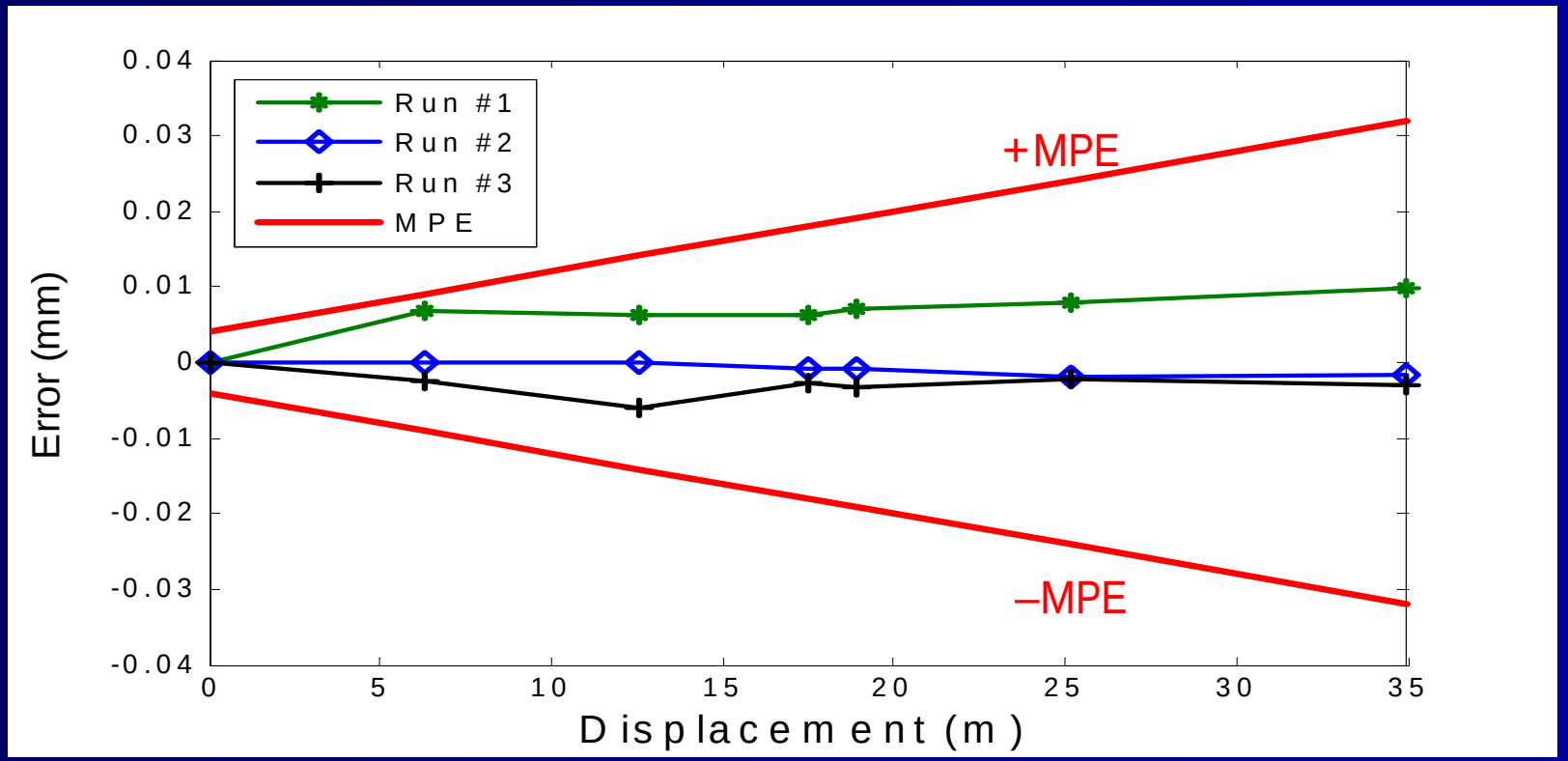
Ranging test of an IFM tracker showing vacuum wavelength error



Wavelength in instrument = 632.990400 nm
Calibrated wavelength (NIST) = 632.991061 nm
Difference = 0.6×10^{-3} nm
Relative length error = 0.6×10^{-3} nm / 633 nm = 1×10^{-6}

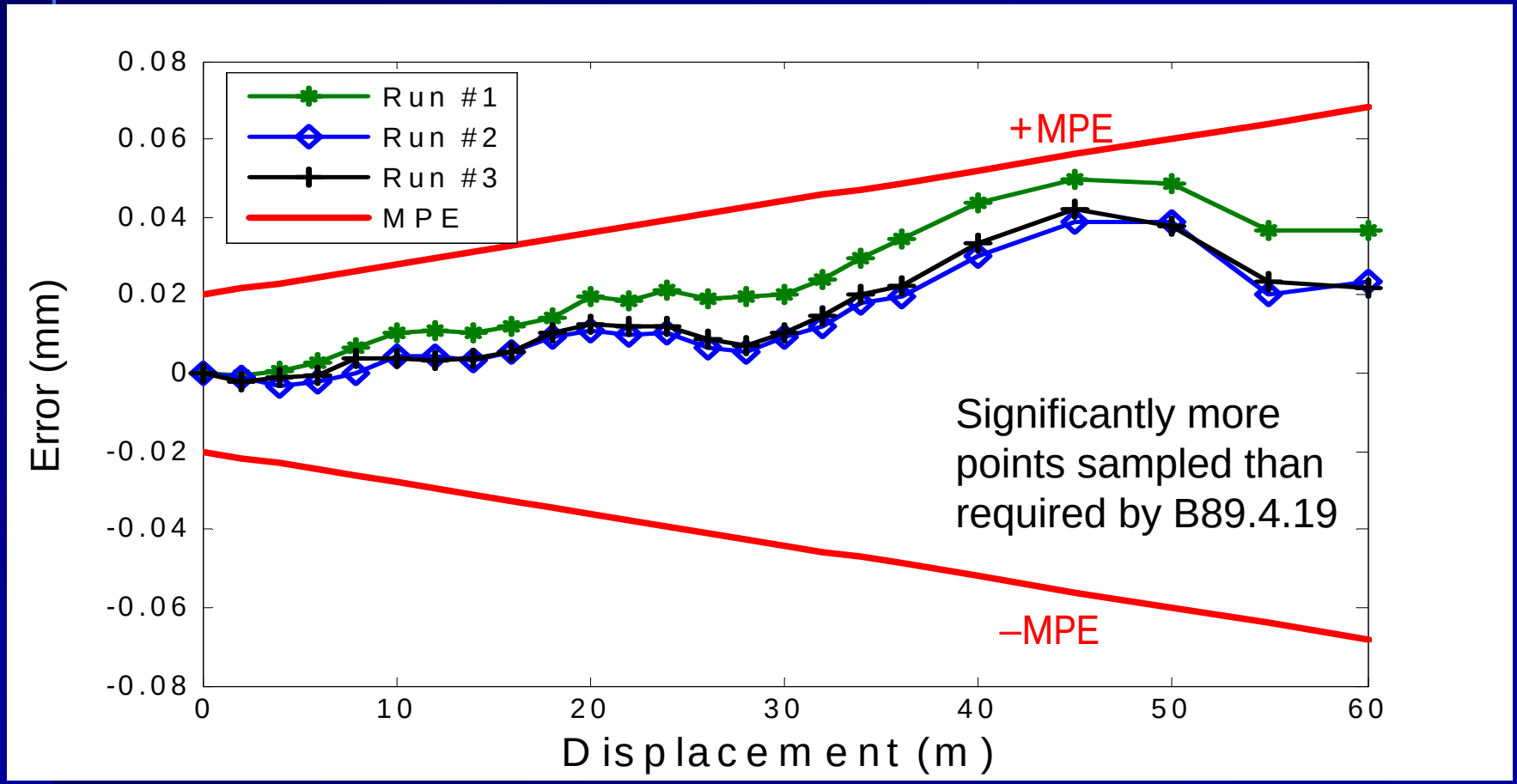
1-D Cooperative Target Range Facility

Ranging test of an IFM tracker; passing specifications



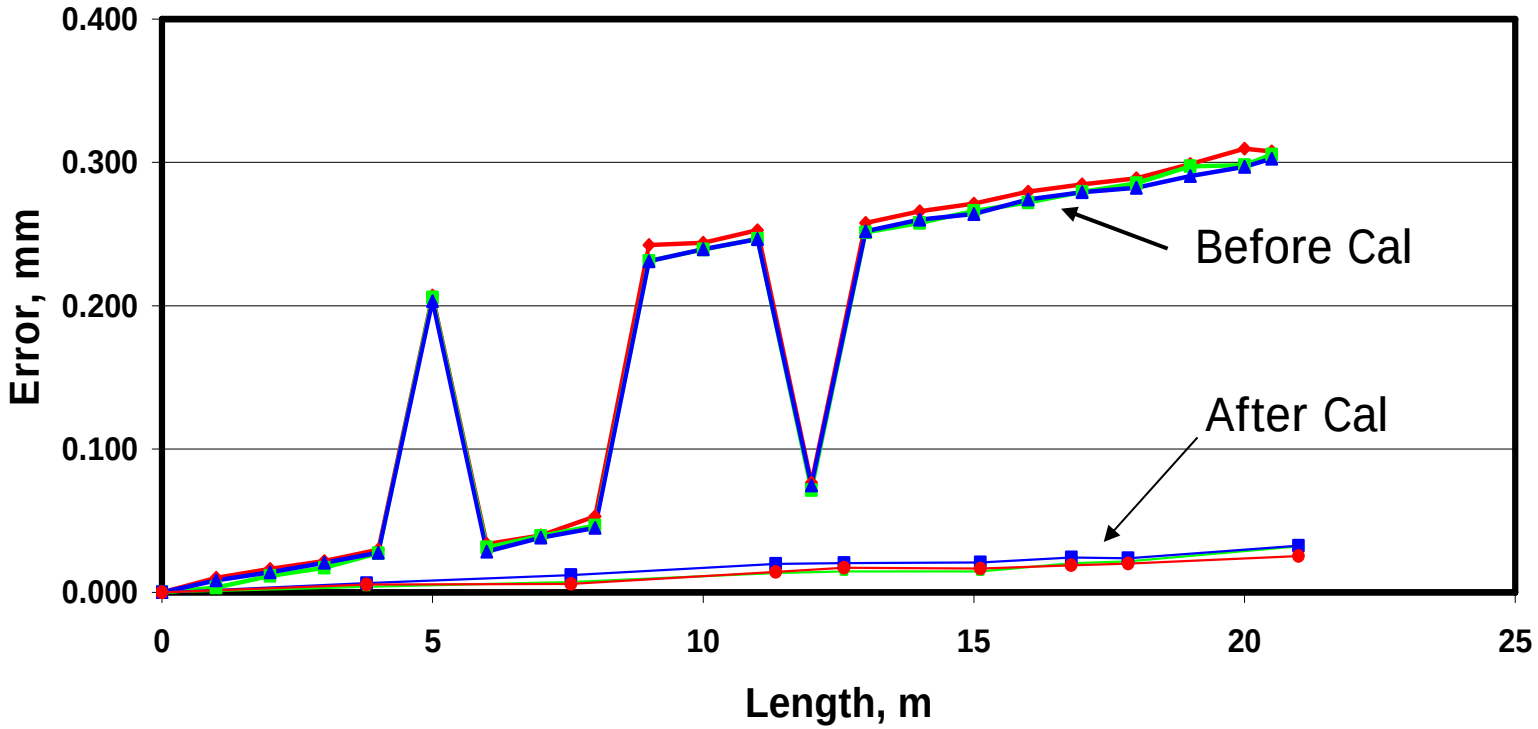
1-D Cooperative Target Range Facility

Ranging test of an ADM tracker passing specifications

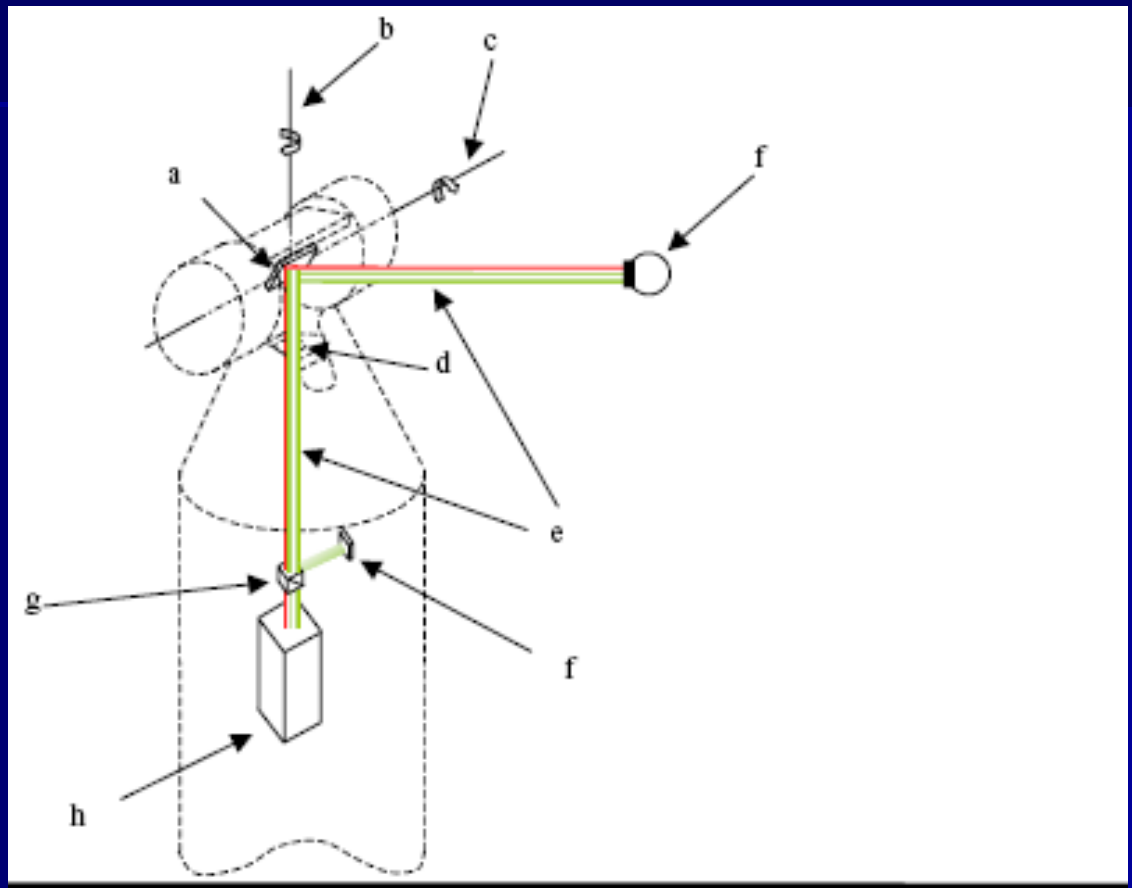


1-D Cooperative Target Range Facility

Ranging test of an ADM tracker showing complex range errors before compensation & small errors after compensation



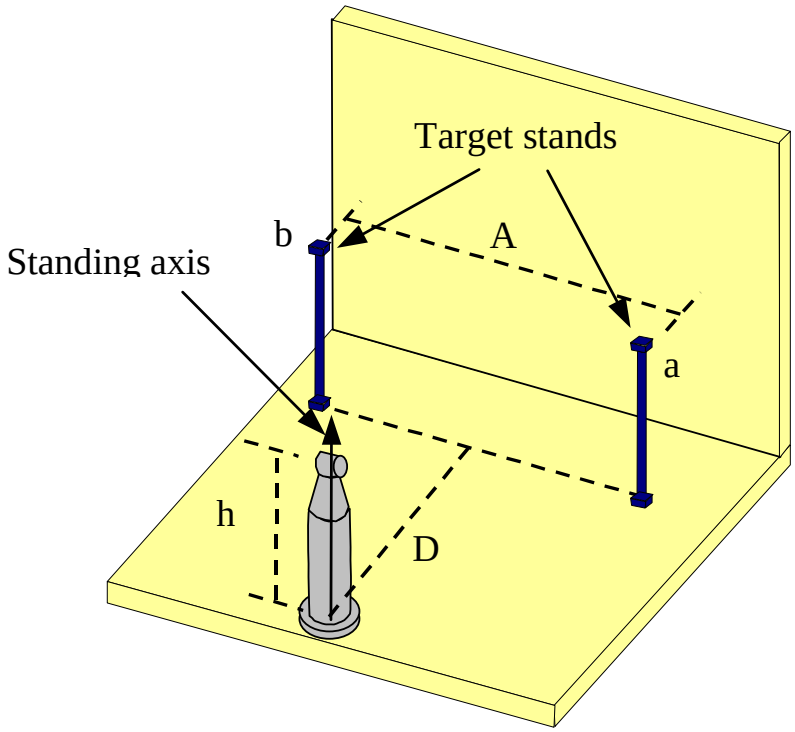
Volumetric System Tests: Check Optical-Mechanical Alignments



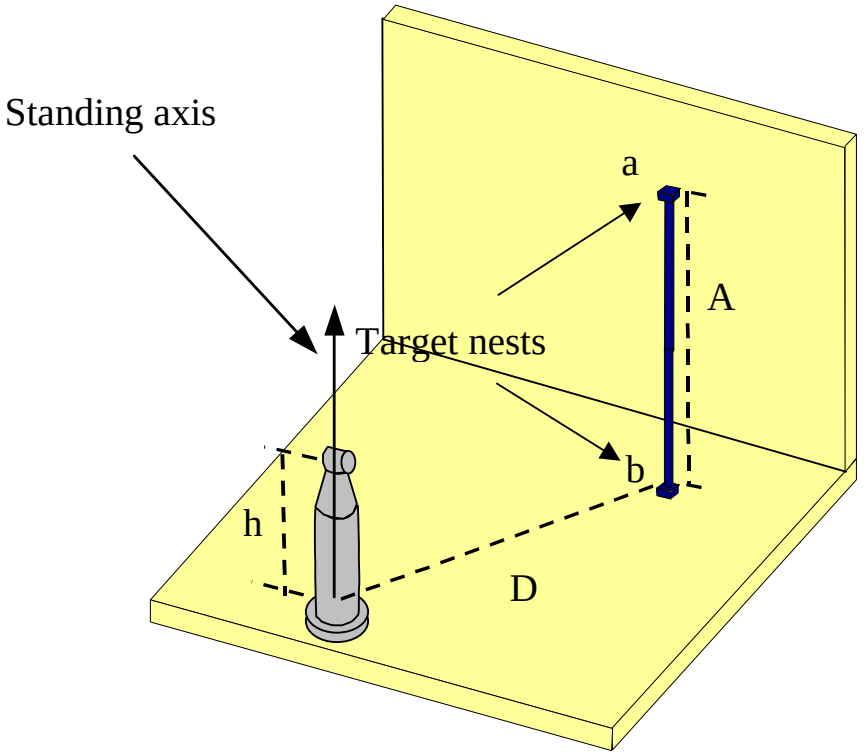
a. Beam steering turning mirror
b. Standing or vertical axis
c. Horizontal or transit axis
d. Cover plate
e. Laser beam
f. Position Sensing Device (PSD)
g. Beam splitting interferometer
h. Laser head
i. Spherically Mounted Retroreflector (SMR)

Volumetric System Tests

Horizontal Positions

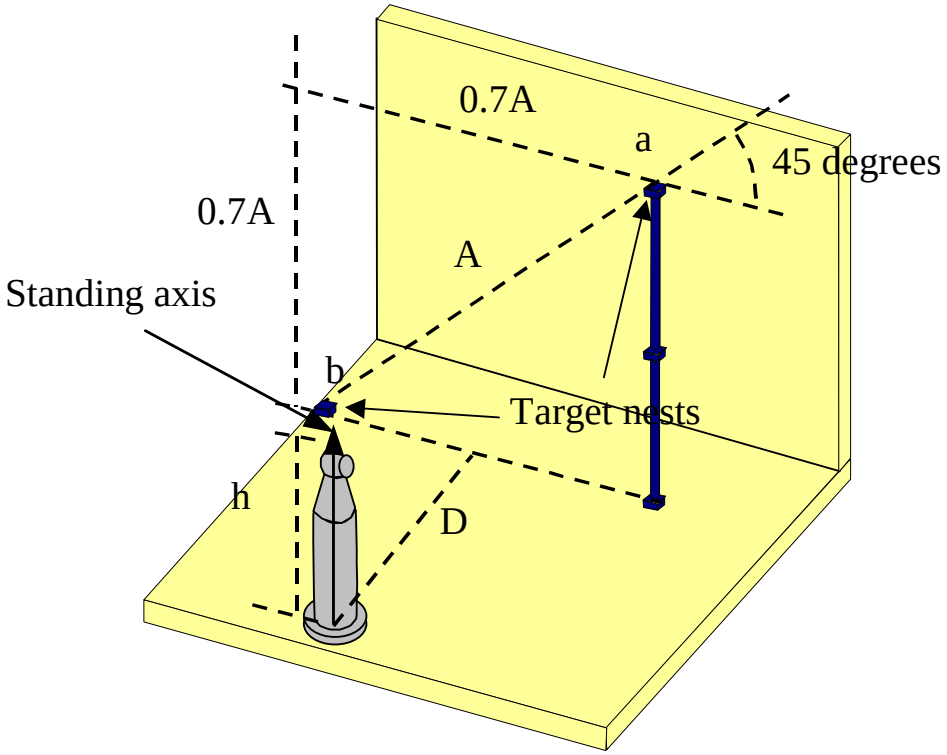


Vertical Positions

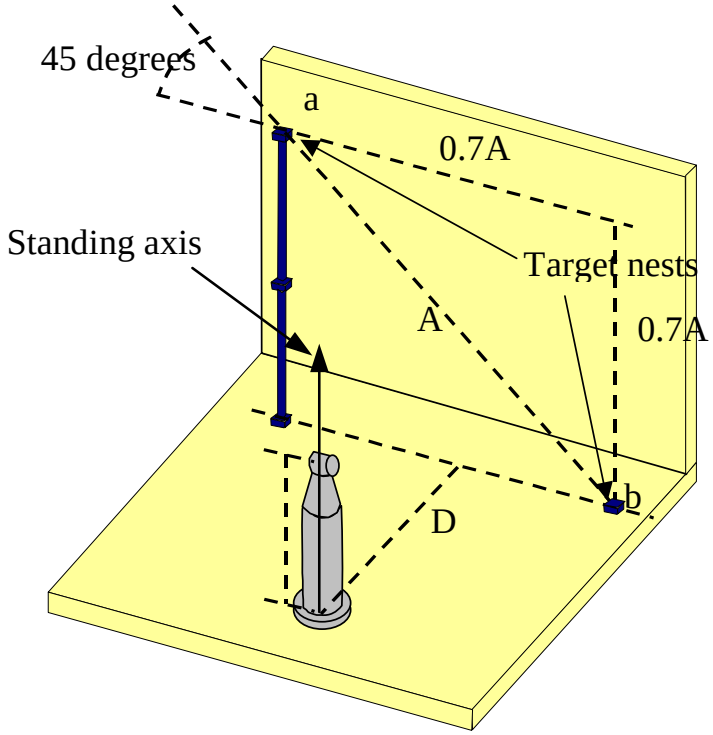


Volumetric System Tests

Right Diagonal Position

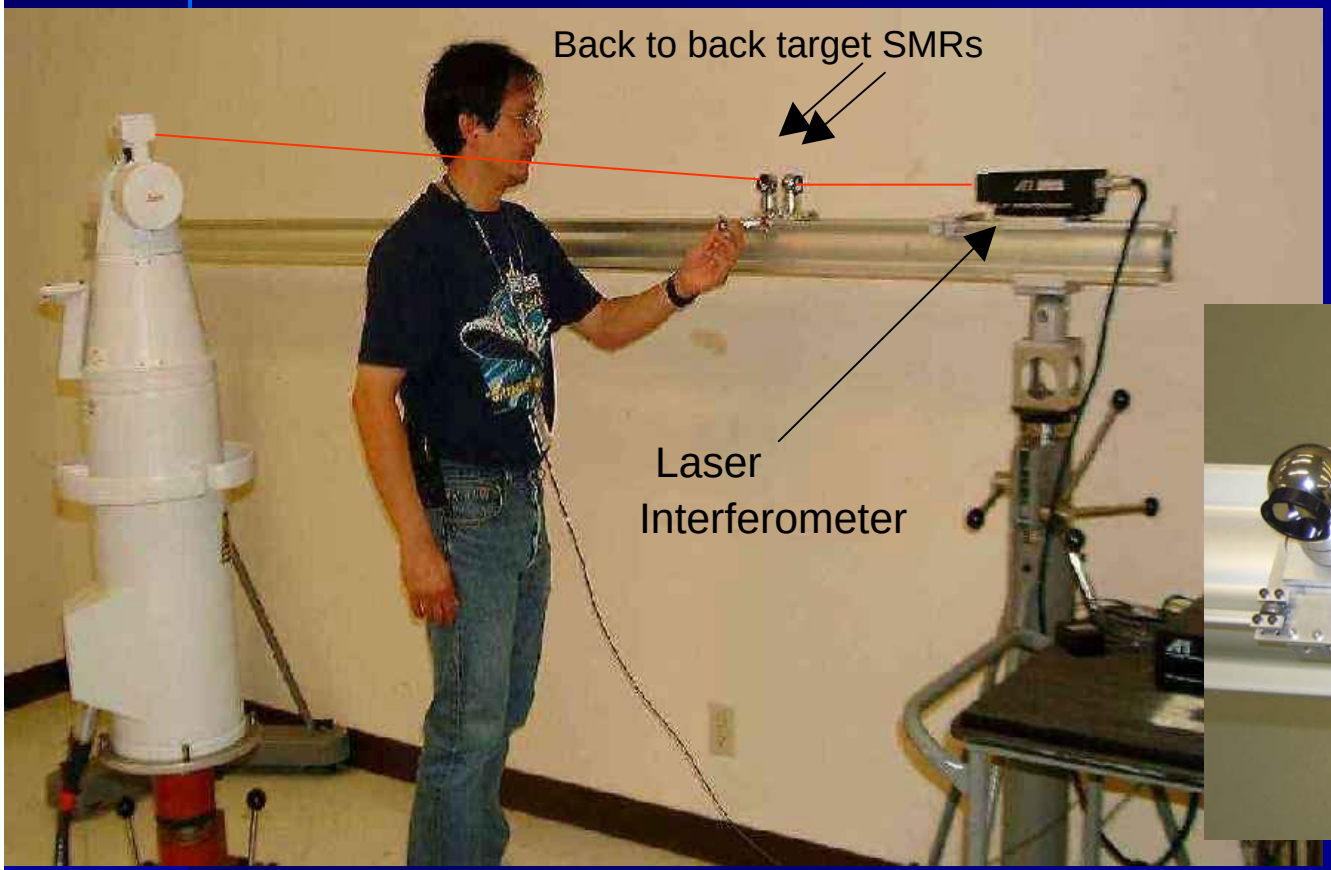


Left Diagonal Position



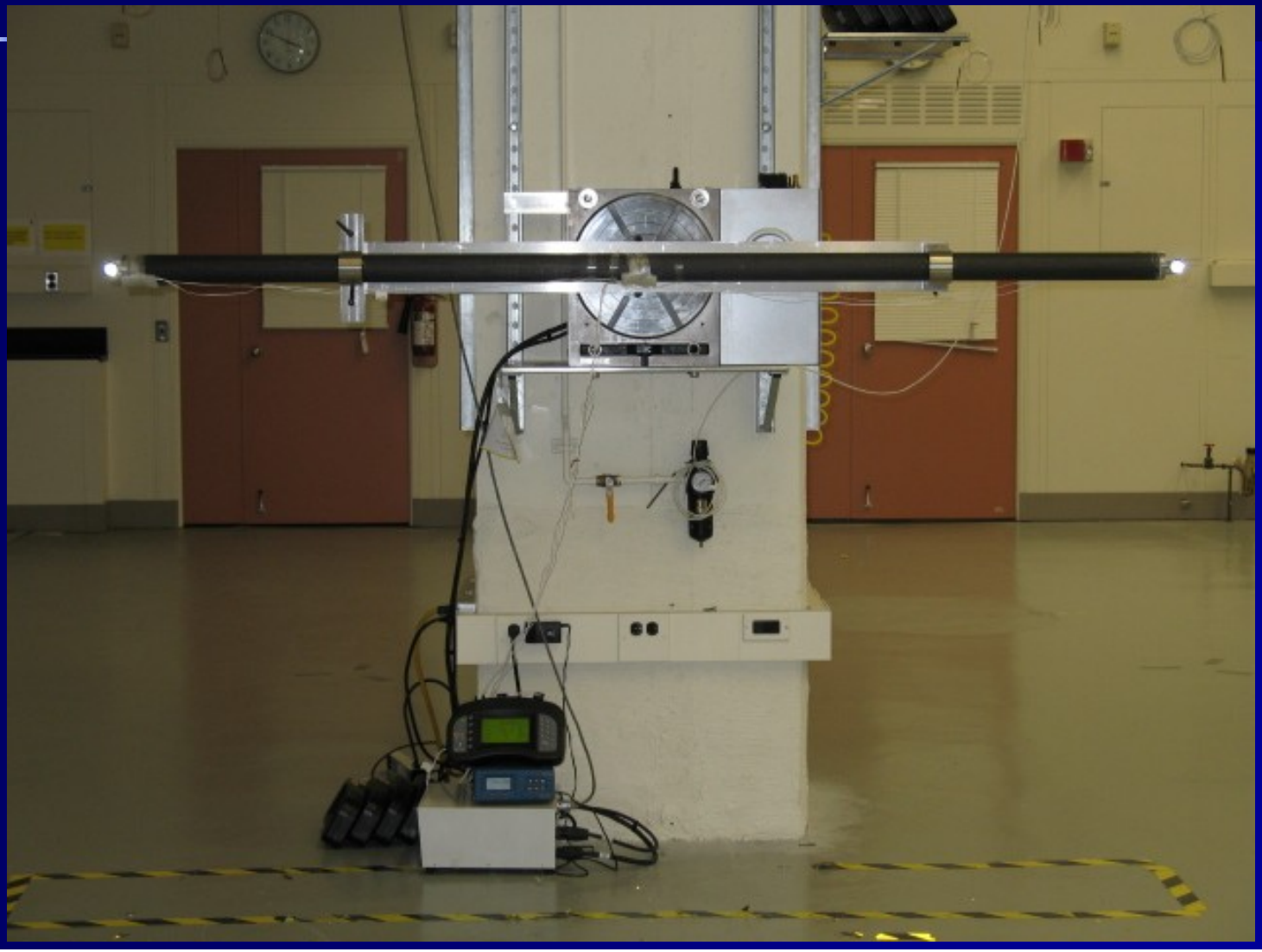
Large Scale Volumetric Test Facility

B89.4.19 Volumetric System Tests
(Horizontal Tests)



B89.4.19 Volumetric System Tests

(Horizontal Tests – Physical Artifact)

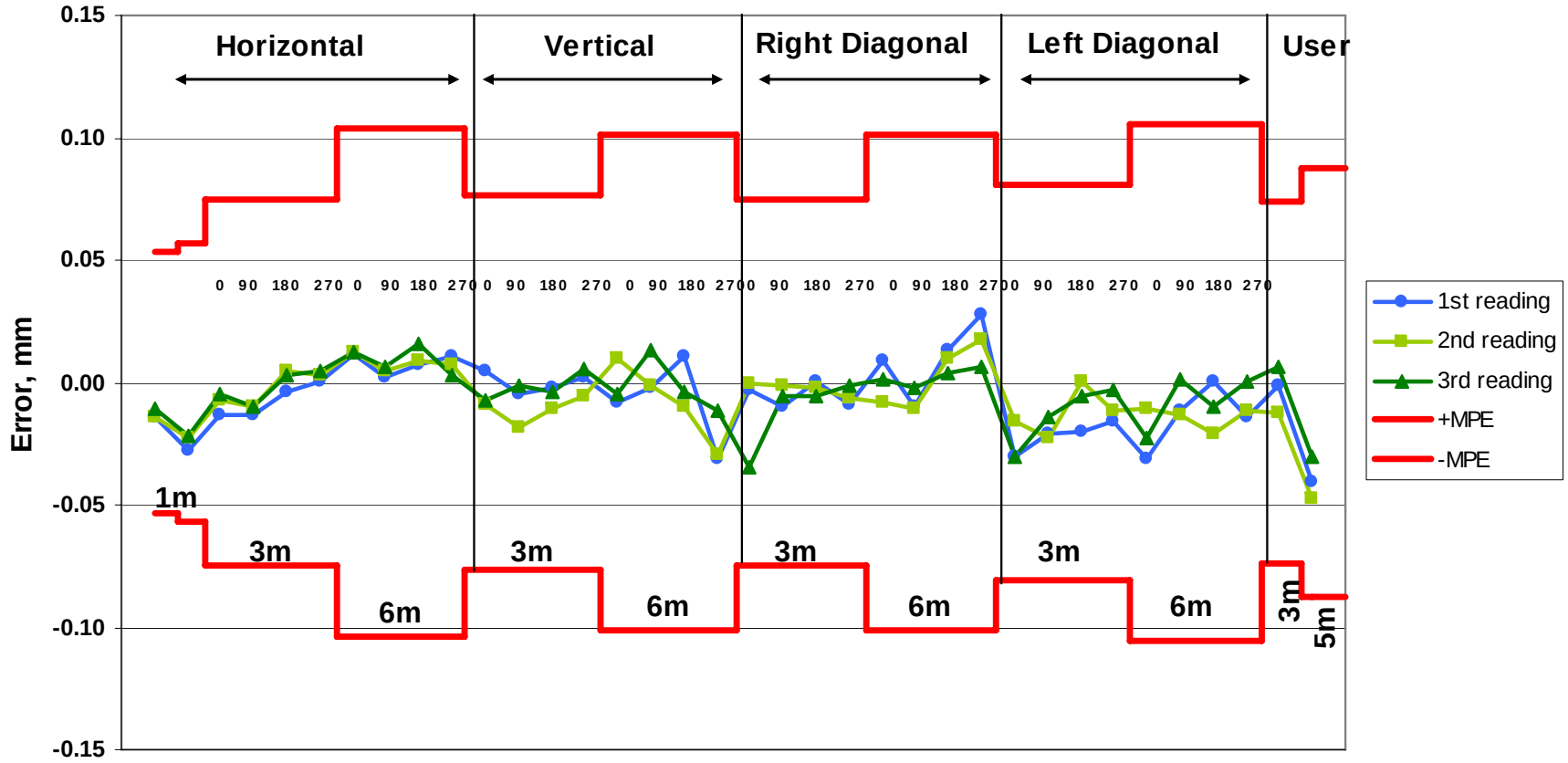


B89.4.19 Volumetric System Tests

(Diagonal Tests)

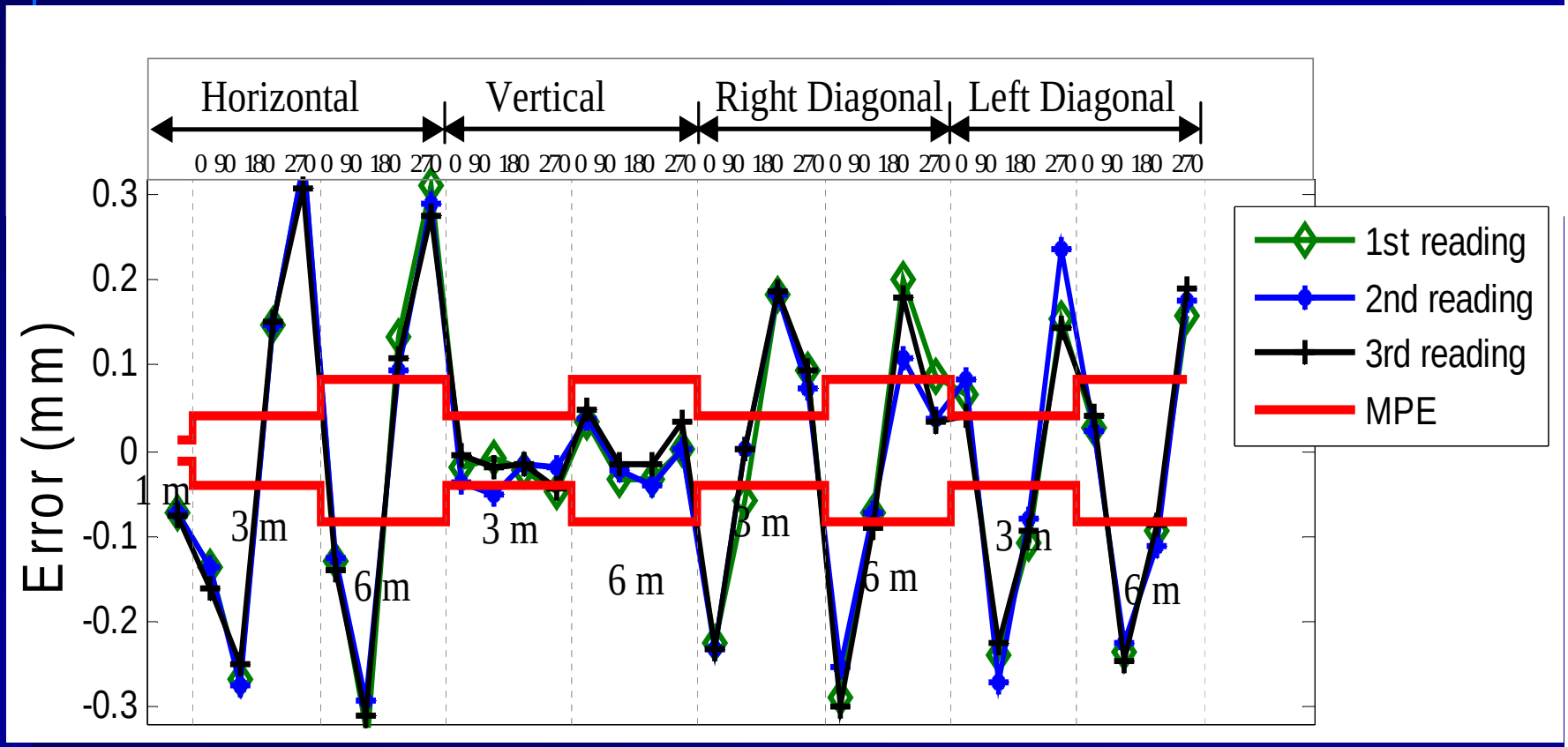
B89.4.19 Volumetric System Tests

Volumetric test of an ADM, passing MPE specifications



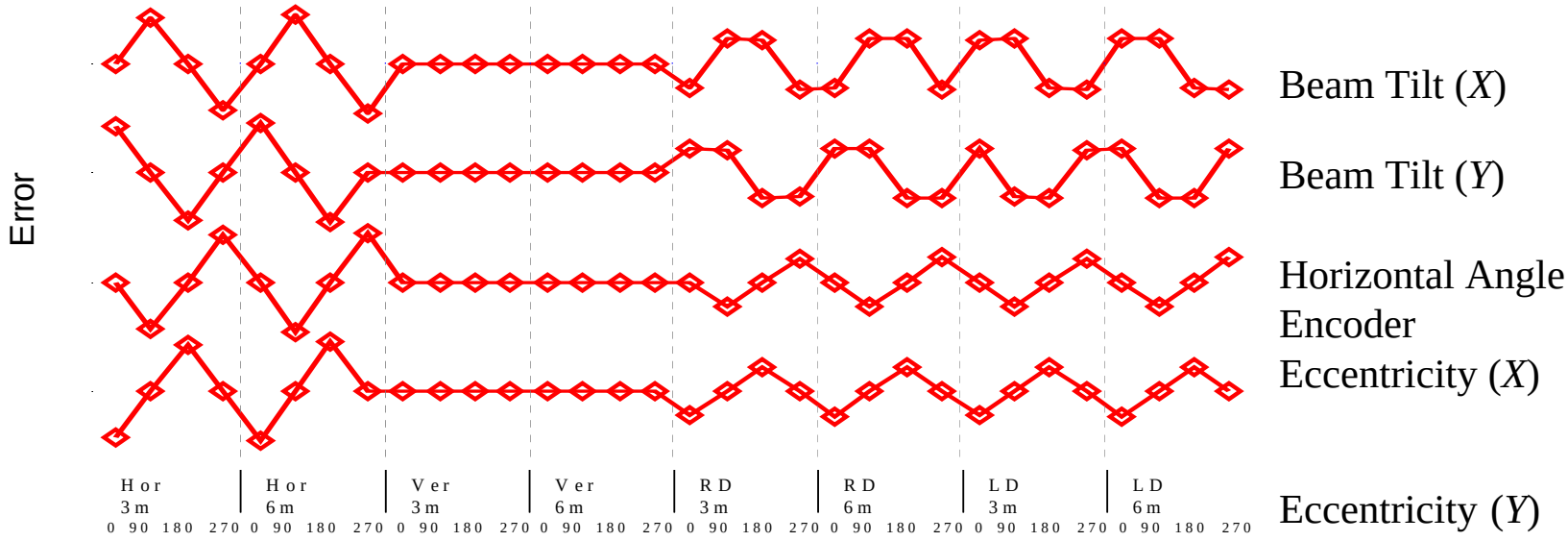
B89.4.19 Volumetric System Tests

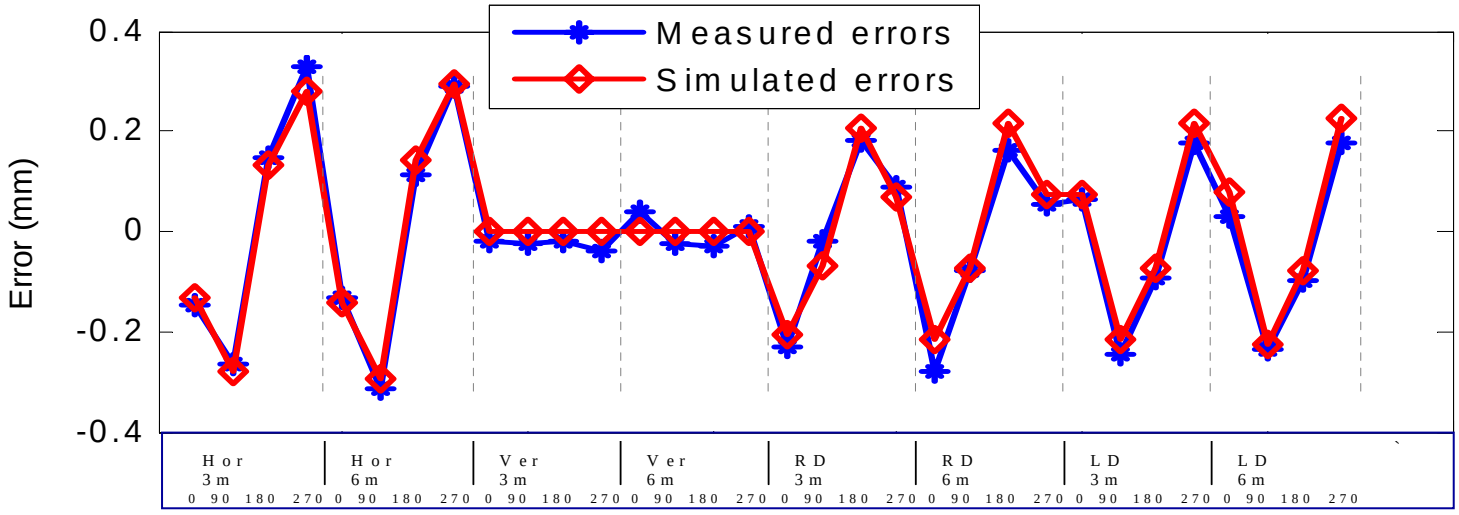
Volumetric test of an IFM tracker, failing MPE specifications



B89.4.19 Volumetric System Tests

Simulated and actual errors for the volumetric test

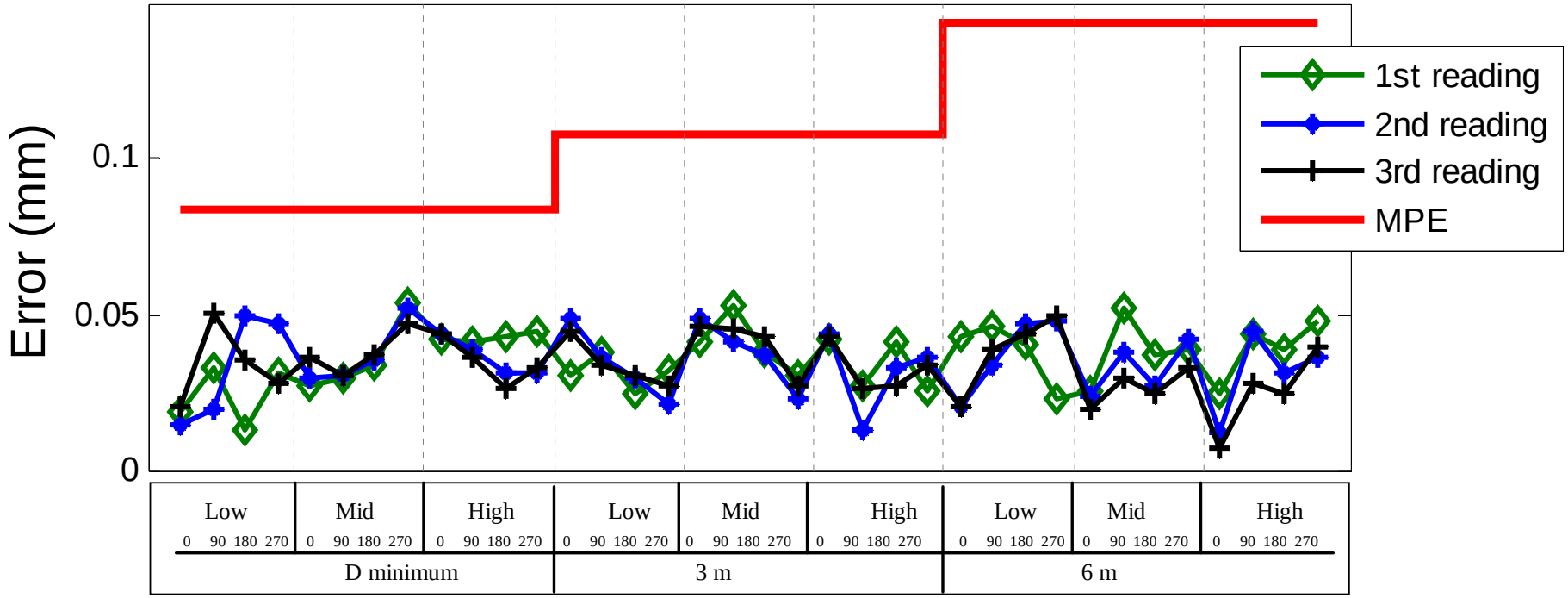




B89.4.19 Two Face Test

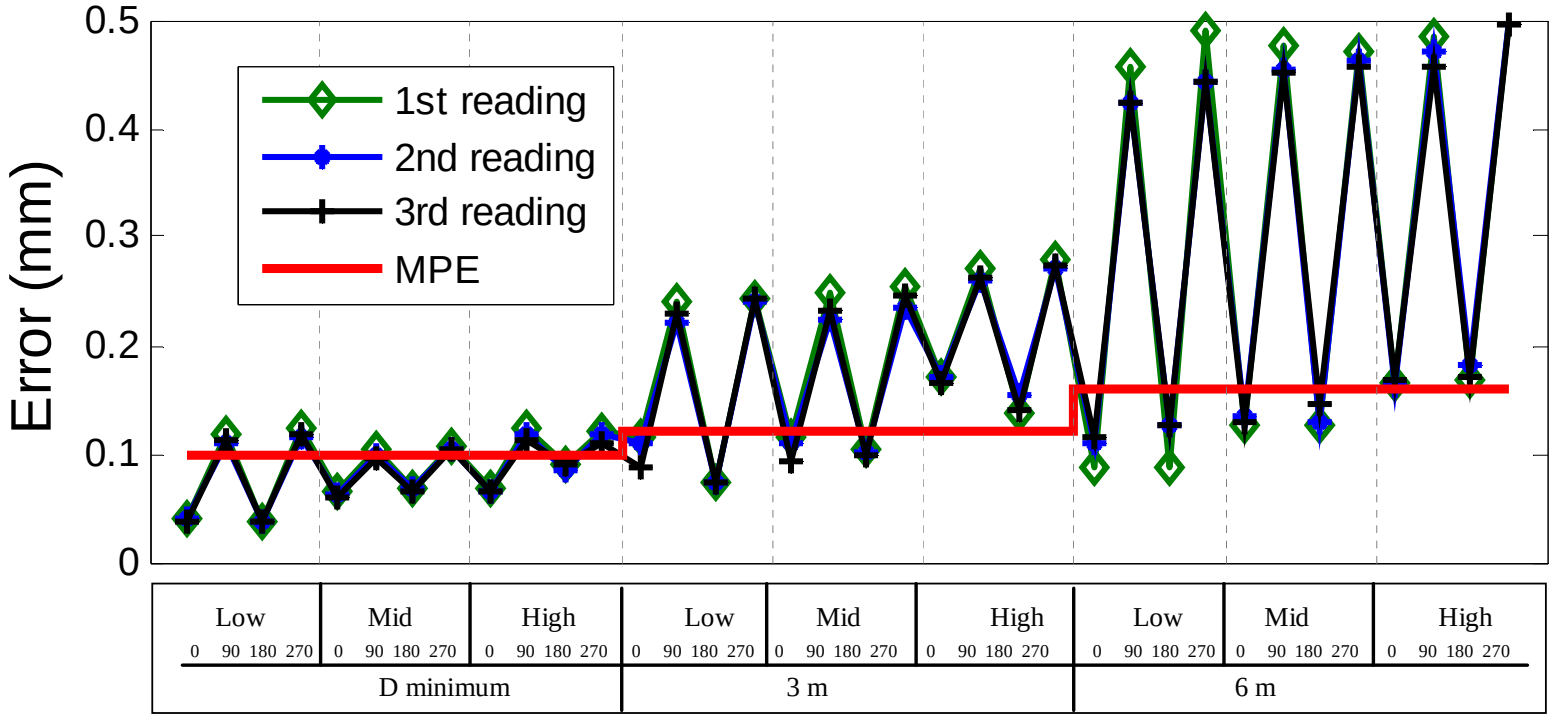
B89.4.19 Two Face Tests

Two face test of an ADM tracker, passing MPE specifications



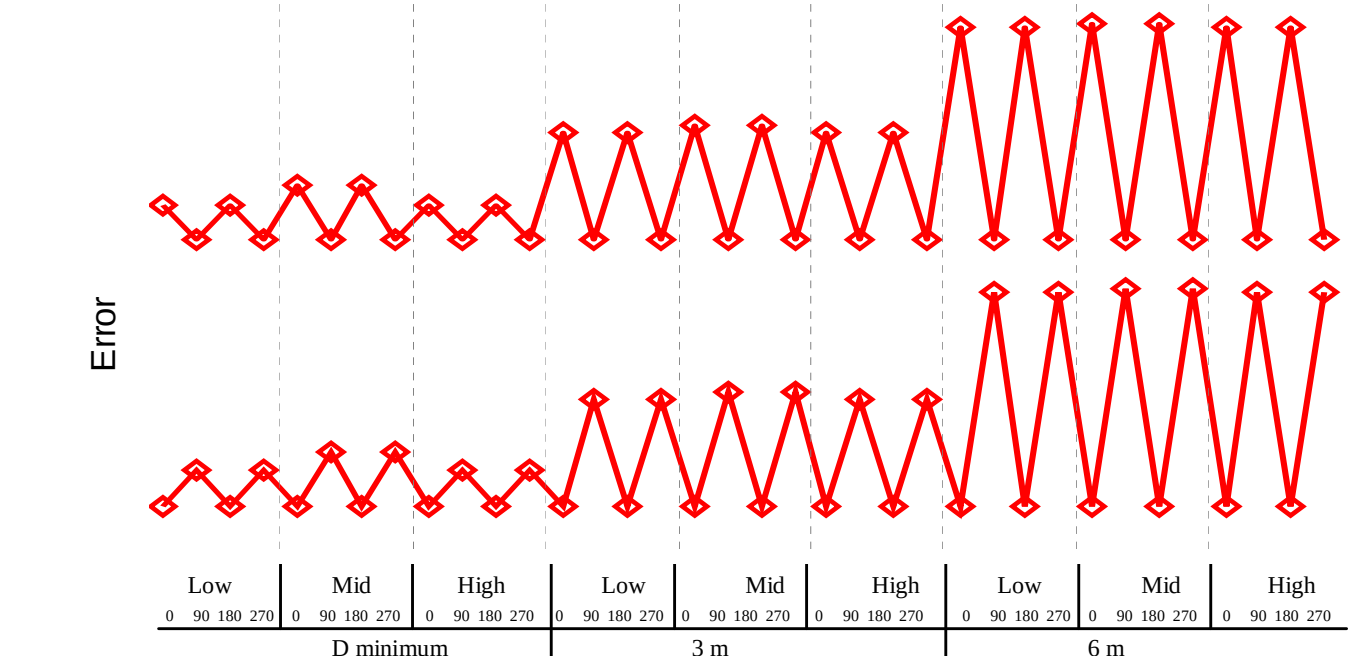
B89.4.19 Two Face Tests

Two face test of an ADM tracker, failing MPE specifications



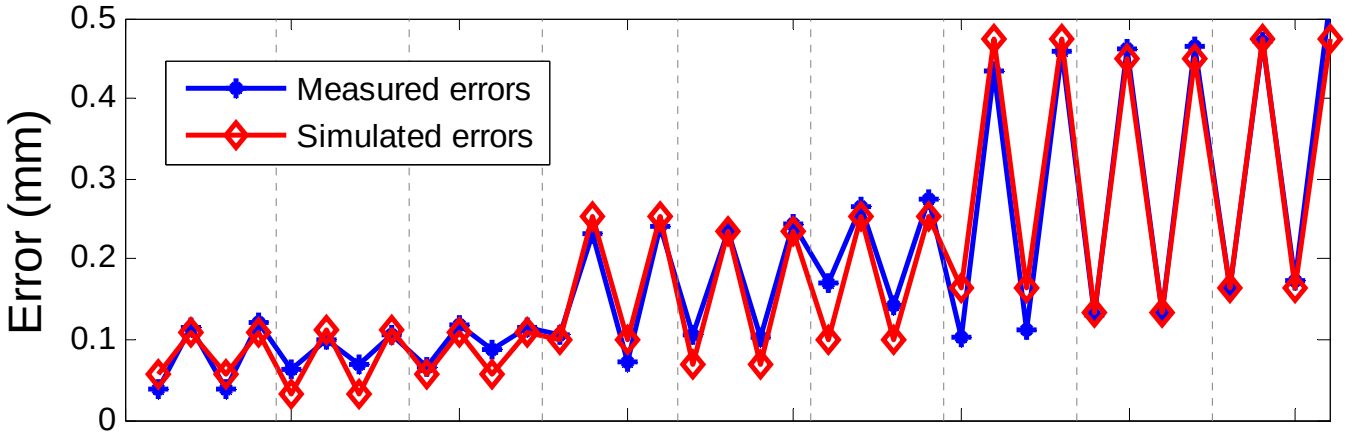
B89.4.19 Two Face Tests

Simulated and actual errors for the two face test



Horizontal angle encoder eccentricity (X)

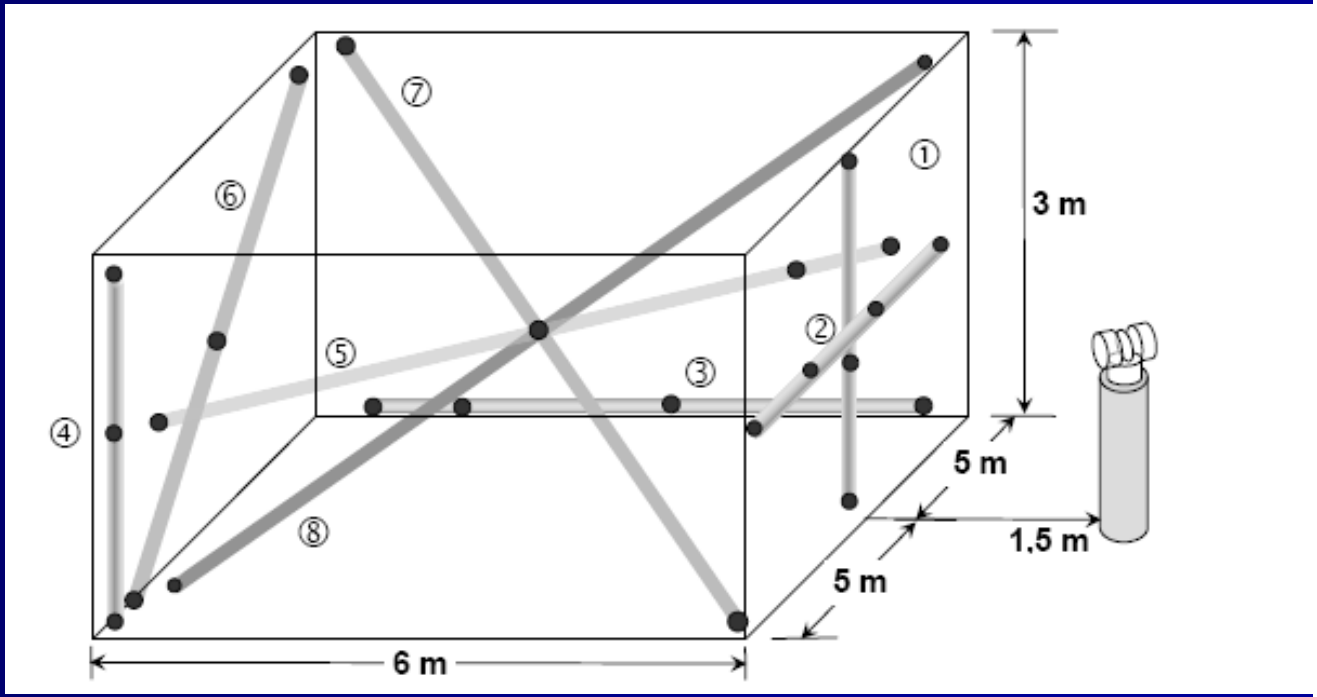
Horizontal angle encoder eccentricity (Y)



VDI / VDE Tracker Draft

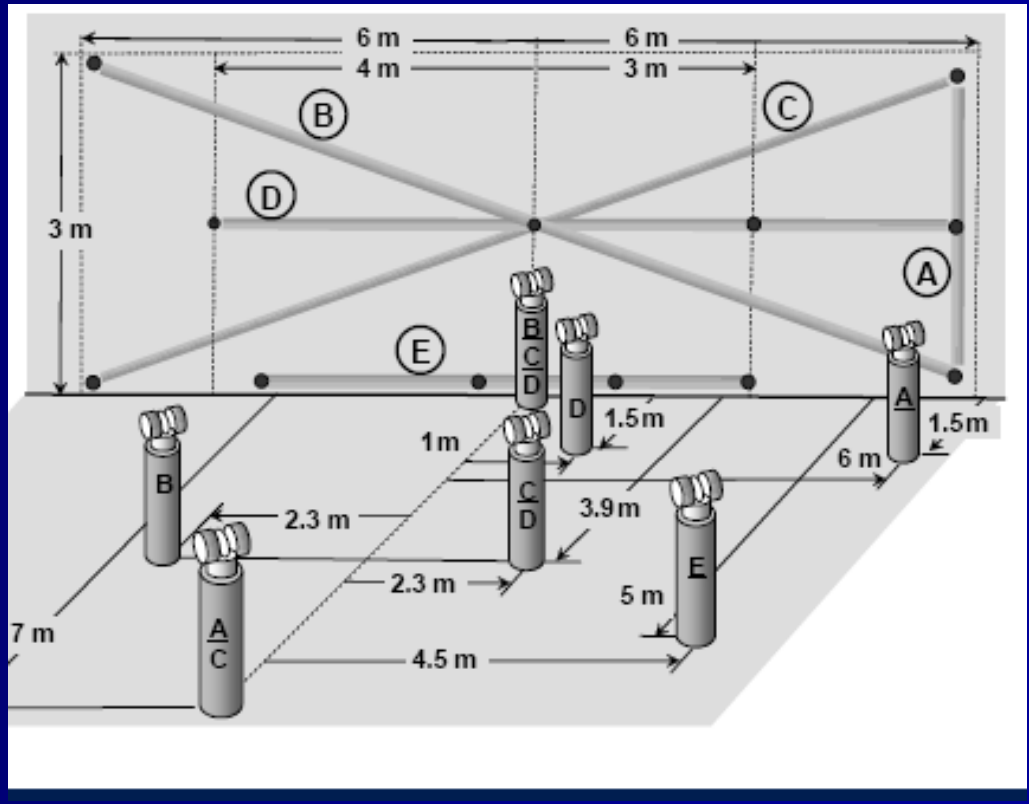
Use a measurement volume ≈ 3 x 6 x 10 m with multiple calibrated lengths created via distances between fixed mounts

Evaluate the observed errors against the manufacture's MPE specification



VDI / VDE Tracker Draft

Projecting the lengths onto a wall and moving the tracker makes the set up easier



VDI / VDE Tracker Draft

“Probe Test” to check the SMR size and form

Similar to the ISO CMM probe test

25 measurement points on a calibrated test sphere:

Report: Size and Form error

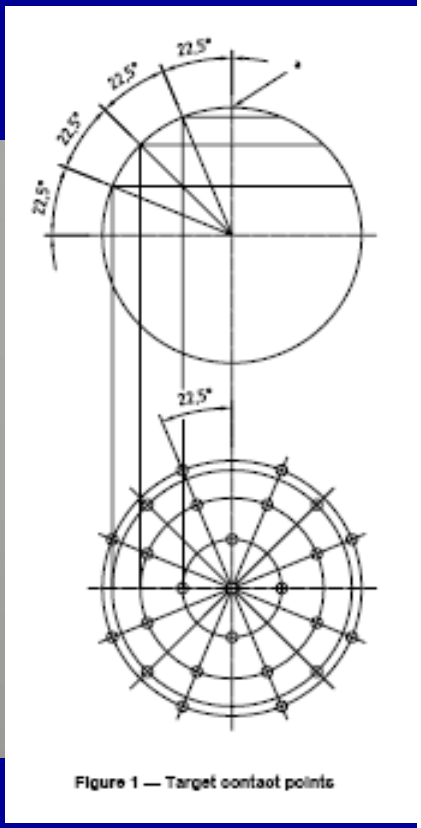


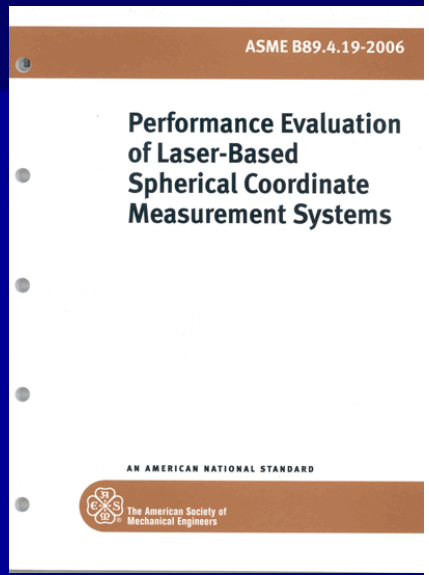
Figure 1 — Target contact points

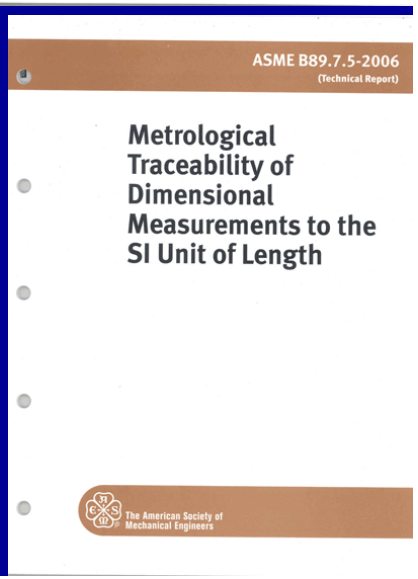
Final Thoughts On Laser Trackers

- Large Measurement Volumes; range > 30 m
  - Very Low Cost Compared to Large CMMs
- Portable, Bring the Tracker to the Workpiece
  - Allows Factory Floor to be Easily Reconfigured
- ADM Systems Yield Direct Measurements
  - No Issue with Beam Breakage or “Walkout”

Final Thoughts On Laser Trackers

- Standardized Tracker Tests Allow
  - For manufacturers to specify performance
  - For users to test performance
  - Detection of most tracker errors
  - Test results that are metrologically traceable
    - (e.g., per ASME B89.7.5)
- ISO Working Draft for Trackers
  - Combines B89 & VDI work
  - Improves sensitivity to errors
  - Includes SMR probe test
  - Includes workpiece CTE compensation test





Laser Trackers: Testing and Standards

Q & A

Disclaimer:

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