Automating Laser Tracker Calibration and Technique Comparison

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Introduction

- Laser Tracker Calibration Goals
- Standard Tests → Traceable Length Comparison
- Automating Standard Tests → Laser Rail
- Technique Comparisons
  - Length Based v. Redundant Multi-Station Measurement Network Analysis (RMSMN) i.e., USMN
  - Sampling Strategy
  - Time Study
- Summary

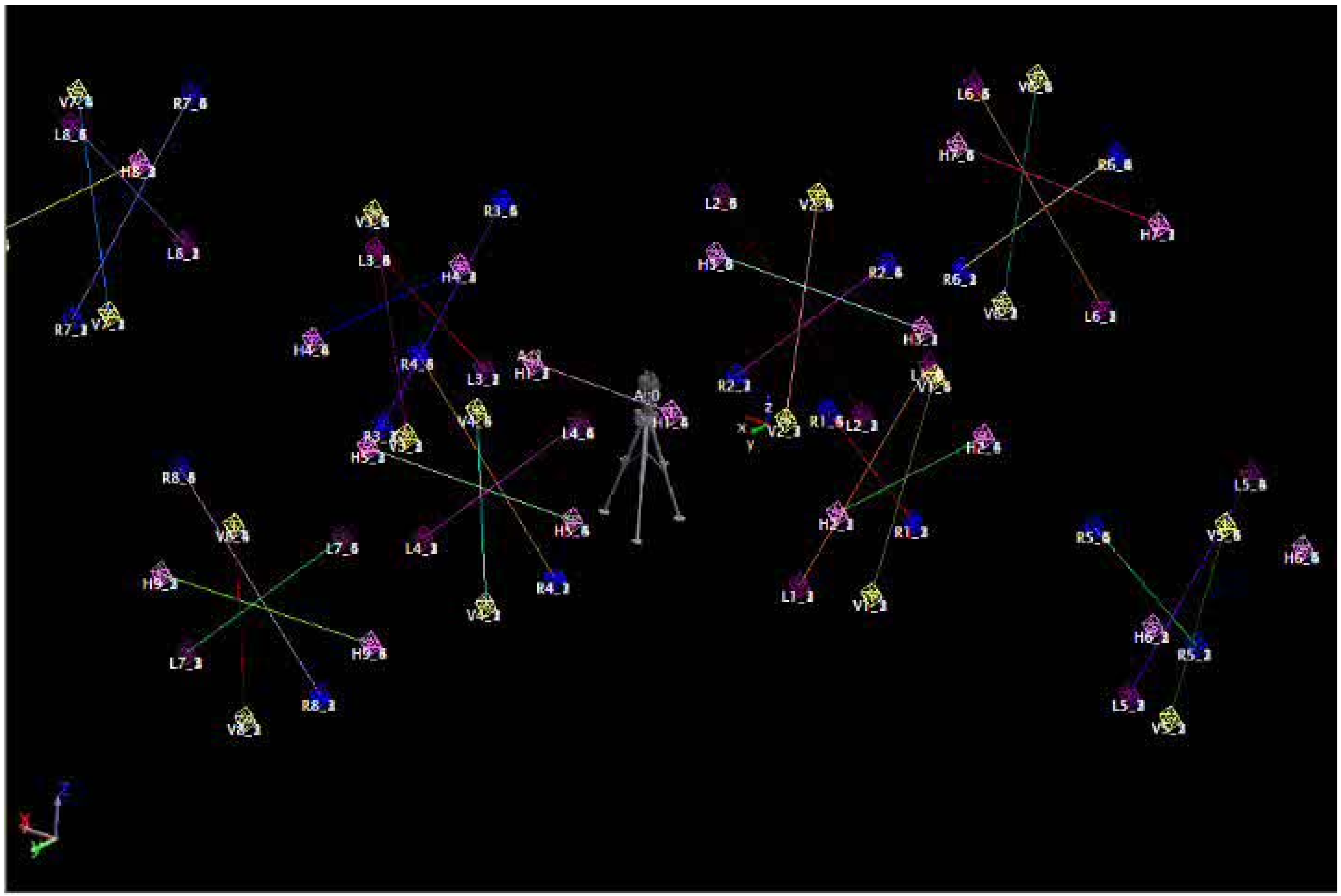
Laser Tracker Calibration Goals

- Evaluate laser tracker instrument's performance against specification
- Communicate to system users and manufacturers
- Test two methods
  - Use network of traceable length standards
  - Distributed 3D network of points with traceable length standards
- Configuration setup and environment affect instruments performance

Ex: Standard Traceable Length Based Test

- Inputs include instruments and their measurements
  - Calibration of the scale length
  - Measurement of scale length in 53 positions
  - Two optional bar measurement positions
- Compares all measured lengths to calibrated length(s)
- Tests against manufacturer's specification (MPE)
  - Specifications tend to vary with respect to range
- Primary outputs
  - Pass / Fail results

Ex: Standard Traceable Length Based Test



Ex: Standard Test Results

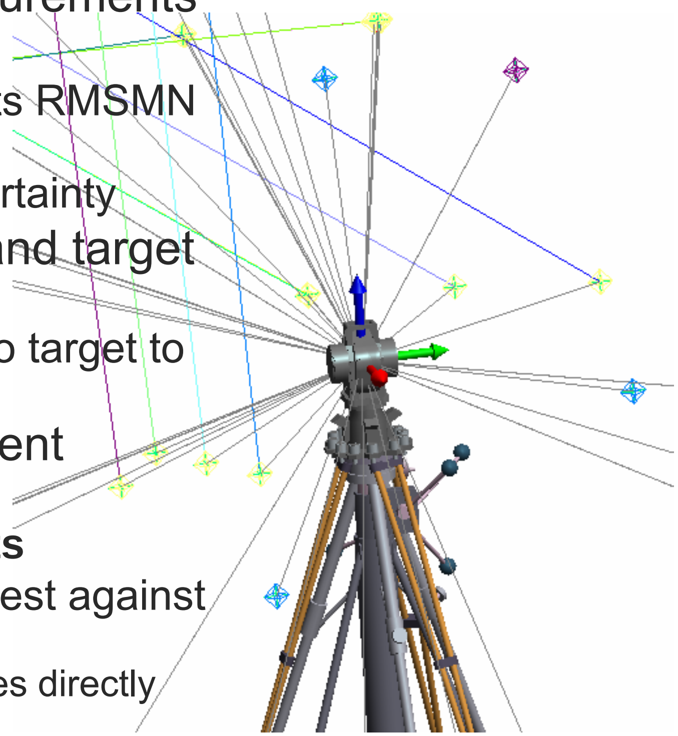
Manufacturer's Performance Specification and Test Results

Test (Position)	IFM Specification and Test Results		
	MPE	**δ**	**Pass**
Horizontal (1)	30	42.5	No
Horizontal @ 2 m (2,3,4,5)	40	19.1	Yes
Horizontal @ 6 m (6,7,8,9)	90	24.0	Yes
Vertical @ 2 m (1,2,3,4)	40	12.6	Yes
Vertical @ 6 m (5,6,7,8)	90	29.9	Yes
Right Diagonal @ 2 m (1,2,3,4)	40	62.4	No
Right Diagonal @ 6 m (5,6,7,8)	90	66.0	Yes
Left Diagonal @ 2 m (1,2,3,4)	40	29.8	Yes
Left Diagonal @ 6 m (5,6,7,8)	90	56.8	Yes

(All units μm)

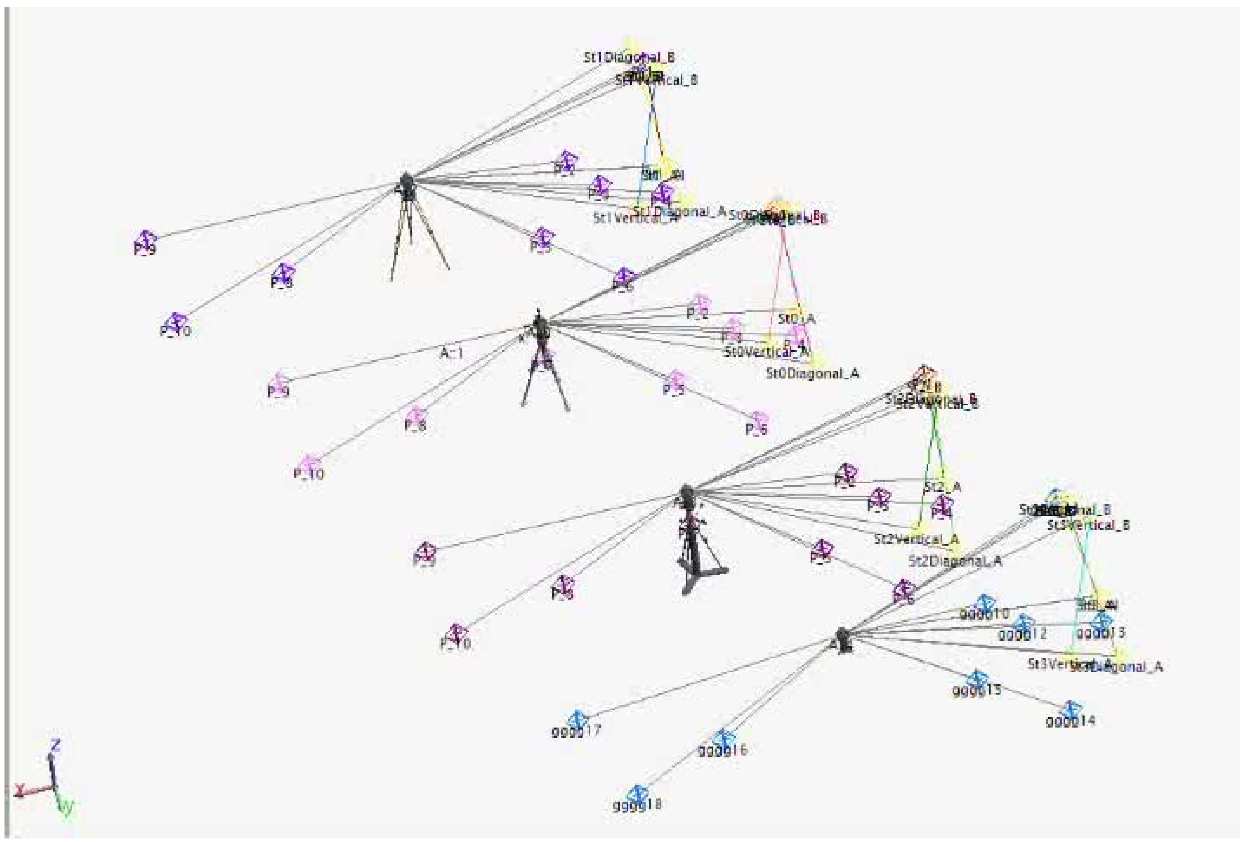
Unified Spatial Metrology Network

- Inputs include instruments and their measurements
  - Multiple stations to common targets
  - Actual geometric network of measurements RMSMN computes estimated target field
  - Inputs for instrument's measurement uncertainty
- Computes optimum instrument positions and target locations
  - Uses instrument uncertainties and range to target to weight optimization solution
- Primary outputs … from actual measurement network
  - **Optimized Network of Stations + Targets**
  - **Analyzes Instrument Performance** … (Test against Manufacturer's Specifications)
    - Results test instrument uncertainty estimates directly (H,V and R)
  - Estimate target uncertainty (Monte-Carlo Analysis)



Ex: RMSMN Performance Test

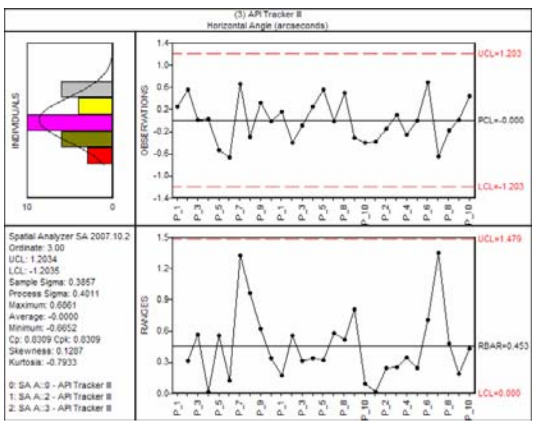
- 4 Station network with traceable lengths



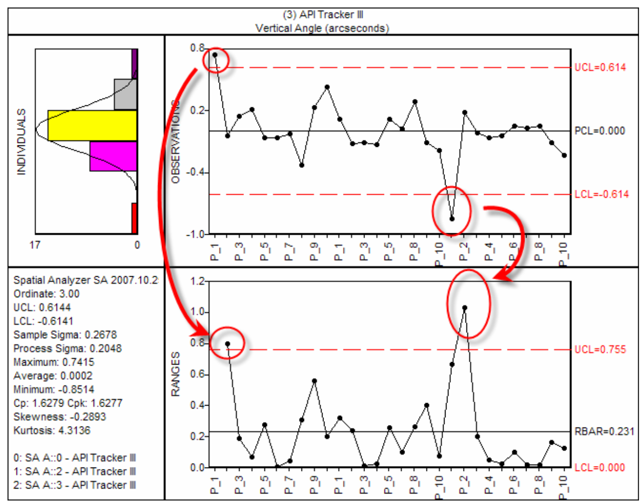
RMSMN Results

- Hz, V and Range Instrument Performance Results

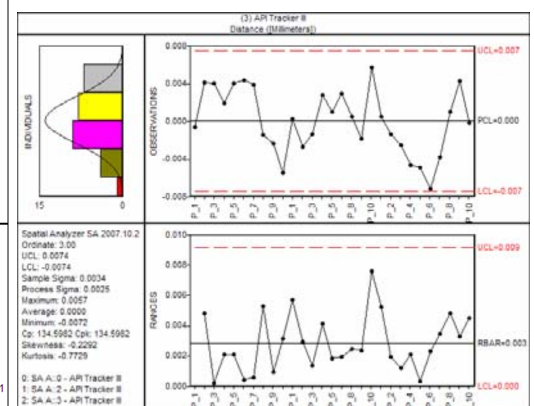
Horizontal Angle



Vertical Angle

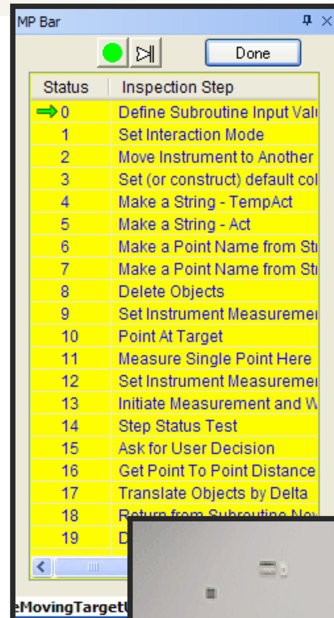


Range Job Units



Automating Standard Tests

- Scripting Calibration Measurement Process
  - Minimize operator variation, prompts
  - Target naming convention
  - Automated analysis
  - In-Process feedback
  - Consistent Reporting
- Laser Rail → Traceable Length Standard
  - Integrated interferometer → minimize uncertainty
  - Interface … correlates target naming and uncertainty



Technique Comparisons

Length Standard Test (e.g., B89)

- Traceable process
- Produced with Uncertainty Statements
- Extensive measurements → when successful ensures confidence
- Low risk of False Positive
- Repeatable by customer and manufacturer
- Result not always directly applicable to instrument properties
- Not always applicable to geodesy or surveying applications

RMSMN Test (e.g., USMN)

- Include traceable length standard(s) in network
- Applicable to/used on real jobs/surveys → Industrial, Surveying and Geodesy applications
- Results match instrument properties with Uncertainty Statements
- Short measurement process + analysis ≈ 1 hr
- Produces target uncertainty estimates
- Test metrology networks with different instrument types

Technique Comparisons

Length Standard Test

- Measurement process Approximately 2 operators → 5 hrs
  - 438 measurements on ≈ 53 bar positions
  - Naming Blunders
- Environmental variation on Length Standard
  - Shop temperature delta ±2°C on 2m Alum → 95 μm bar
  - Bar holding fixture variation (small but significant errors)
- Typical reflector errors ≈ 5 μm
- Risk of False Negative

RMSMN Test

- Measurement process
  - Setup dependent on environment
  - Challenge → adequate vertical variation
- Non-standard setup difficult to repeat by users and manufacturers
- Does not require traceable length standard(s) in network
- Risk of False Positive

Summary

- Goal → Test measurement performance of Laser Trackers, angles, interferometers and Absolute Distance Measuring
- Automating standard tests is important for robustness
  - Individual trackers taken through process repeatedly
  - Reduces measurement time
  - Enables operator to collect a broader range of length observations
  - Laser Rail improves sampling strategy and confidence in test results
- Standard Length v. RMSMN Techniques
  - Both successfully evaluate performance with Uncertainty
  - RMSMN for actual Industrial and Geodesy applications/surveys
    - Shorter measurement time… savings
    - Communicate instrument performance graphically

References & Questions

- References
  - B89.4.19 - 2006 Performance Evaluation of Laser-Based Spherical Coordinate Measurement Systems
  - Dan Sawyer, LVMC 05 presentation
  - Steve Phillips, Laser Tracker Standard Update and the NIST 60 m Ranging Facility
  - Joe Calkins, USMN, 03 Dissertation
  - John Palmateer, Boeing Technical Fellow
- Questions … Thank you…