## Automating Laser Tracker Calibration and Technique Comparison

**Scott Sandwith**  
New River Kinematics

**Rainer Lott**  
Automated Precision Inc.

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Introduction

- Laser Tracker Calibration Goals
- Standard Tests $\rightarrow$ Traceable Length Comparison
- Automating Standard Tests $\rightarrow$ 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
### Manufacturer's Performance Specification and Test Results

<table>
<thead>
<tr>
<th>Test (Position)</th>
<th>IFM Specification and Test Results</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>MPE</td>
</tr>
<tr>
<td>Horizontal (1)</td>
<td>30</td>
</tr>
<tr>
<td>Horizontal @ 2 m (2,3,4,5)</td>
<td>40</td>
</tr>
<tr>
<td>Horizontal @ 6 m (6,7,8,9)</td>
<td>90</td>
</tr>
<tr>
<td>Vertical @ 2 m (1,2,3,4)</td>
<td>40</td>
</tr>
<tr>
<td>Vertical @ 6 m (5,6,7,8)</td>
<td>90</td>
</tr>
<tr>
<td>Right Diagonal @ 2 m (1,2,3,4)</td>
<td>40</td>
</tr>
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</tr>
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</tbody>
</table>

*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…