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ENGINEERS . SURVEYORS . PLANNERS

River of Knowledge

How Good is Laser Scanning?

Delivering Inspired Infrastructure for 100+ Years

William Paul, PLS

Background

- California Licensed Land Surveyor since 2010 (PLS 8744)
- 19+ years of survey experience
- Expertise in construction Staking, laser scanning and all things 3D
- Laser scanning since 2010
- ACI 117 Tolerance Committee
- CLSA Central Valley President-Elect

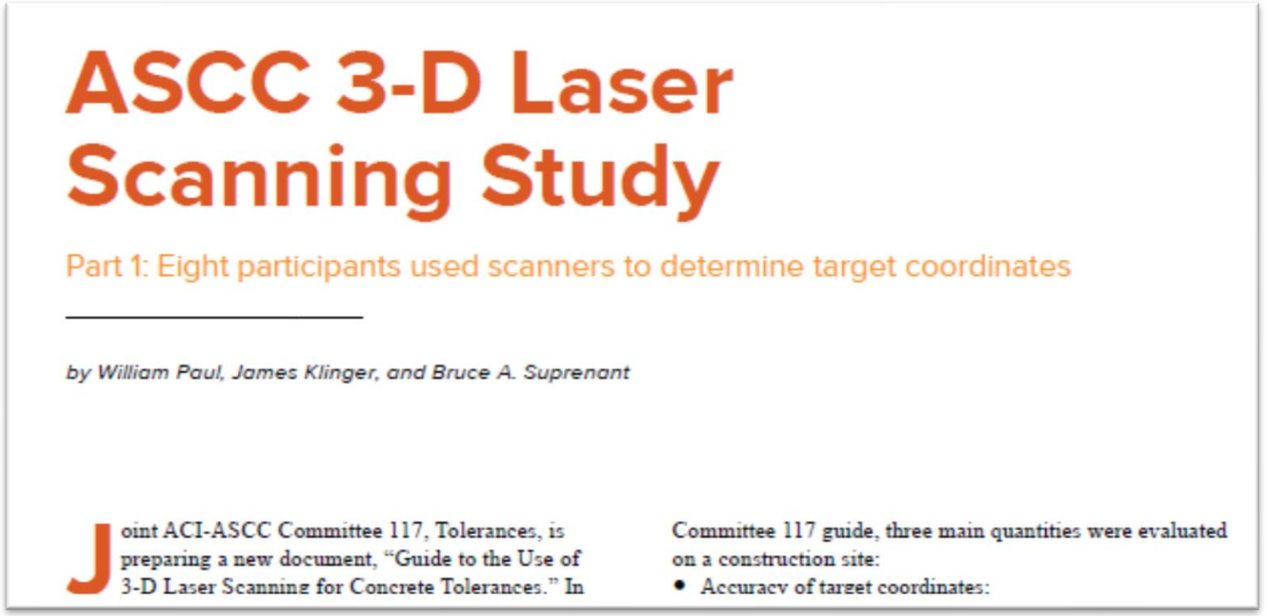
BKF

- California engineering & surveying firm
- 14 offices, 500+ employees
- 101 years in business
- ENR California Design Firm of the Year

Overview

Topics we will cover:

- Is laser scanning accurate?
- What does accuracy actually mean?
- Results from 2018 ASCC laser scanning study
- The future of laser scanning and concrete tolerances
- Questions



ASCC 3-D Laser Scanning Study

Part 1: Eight participants used scanners to determine target coordinates

by William Paul, James Klinger, and Bruce A. Suprenant

Joint ACI-ASCC Committee 117, Tolerances, is preparing a new document, "Guide to the Use of 3-D Laser Scanning for Concrete Tolerances." In

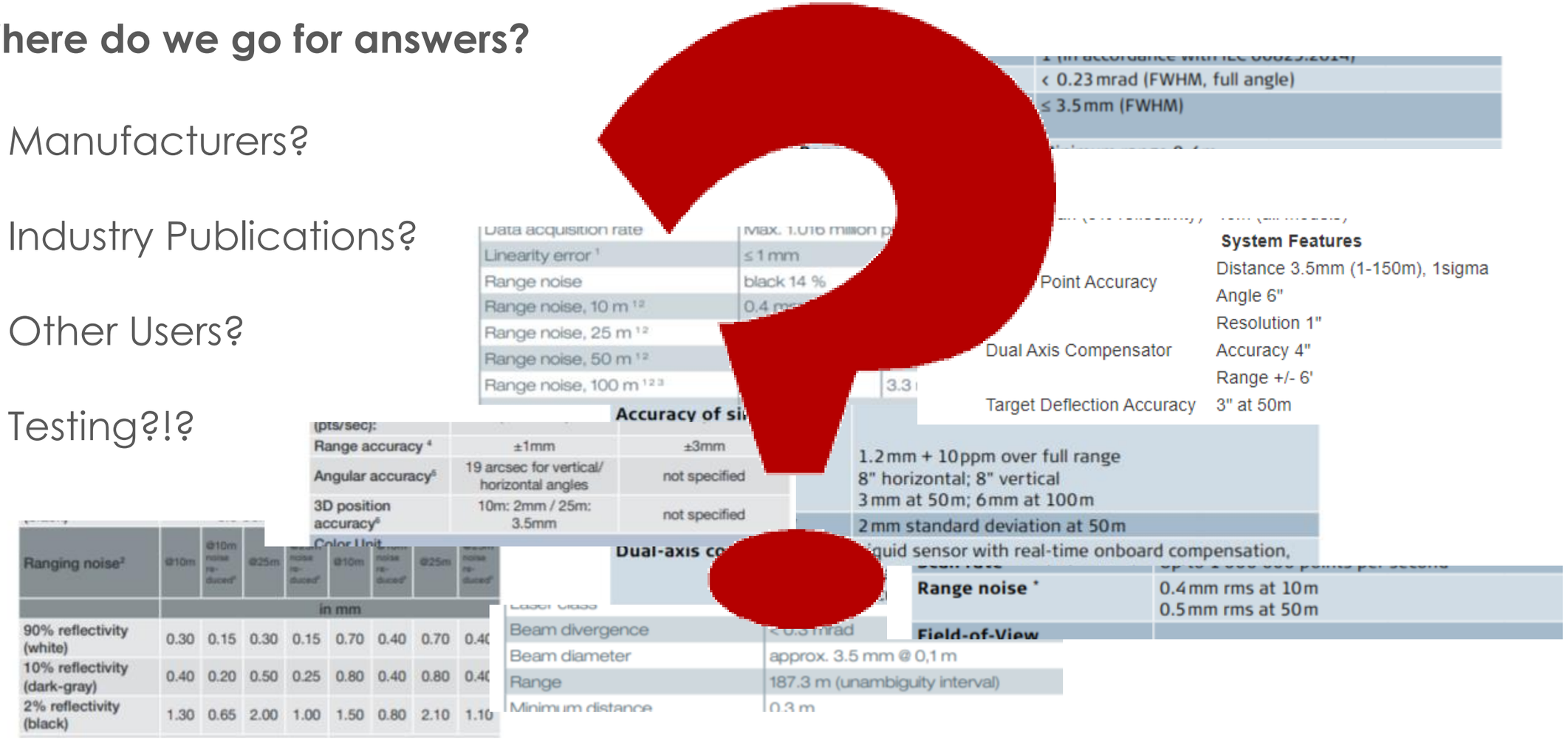
Committee 117 guide, three main quantities were evaluated on a construction site:

- Accuracy of target coordinates:

Is Laser Scanning Accurate?

Where do we go for answers?

- Manufacturers?
- Industry Publications?
- Other Users?
- Testing?!?

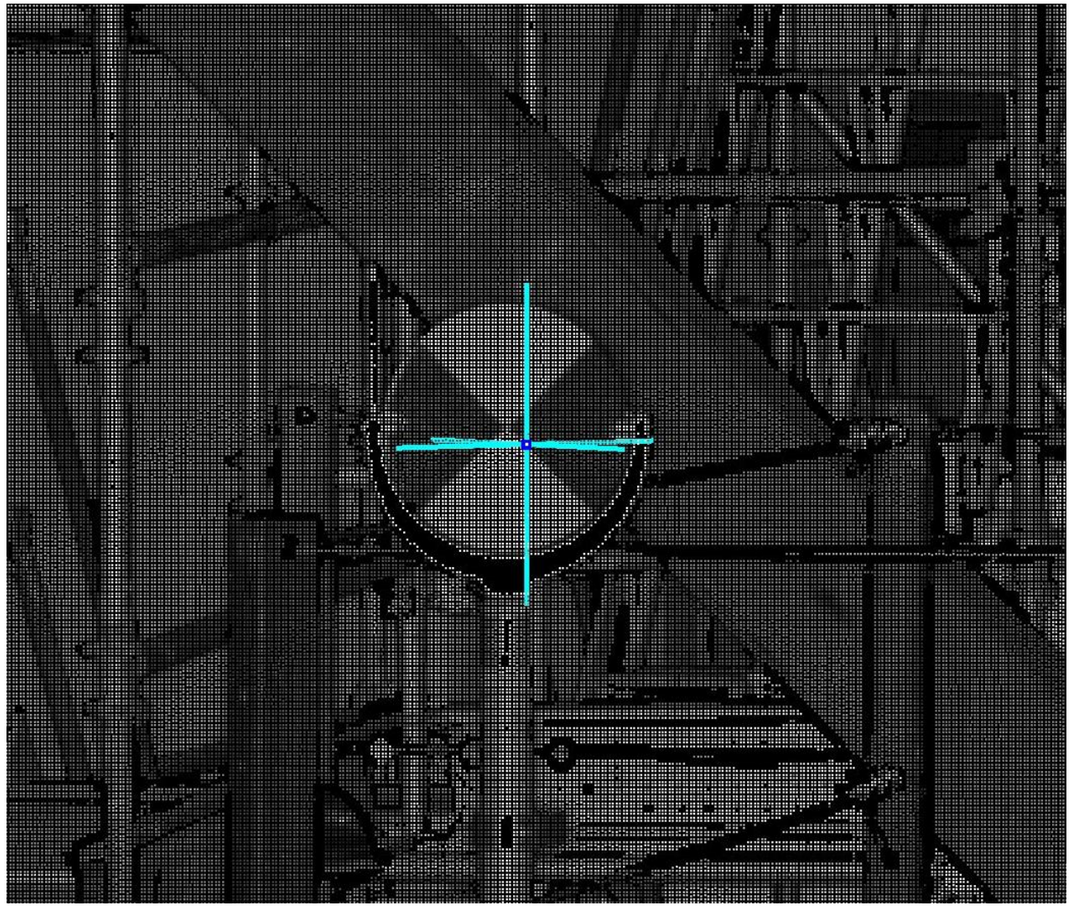


What Does Accuracy Really Mean?

Definition

- Dictionary:
  - The degree to which the result of a measurement, calculation, or specification conforms to the correct value or a standard

- Real World:
  - Accurate means correct and reliable



What Does Accuracy Really Mean?

Accuracy vs. Precision

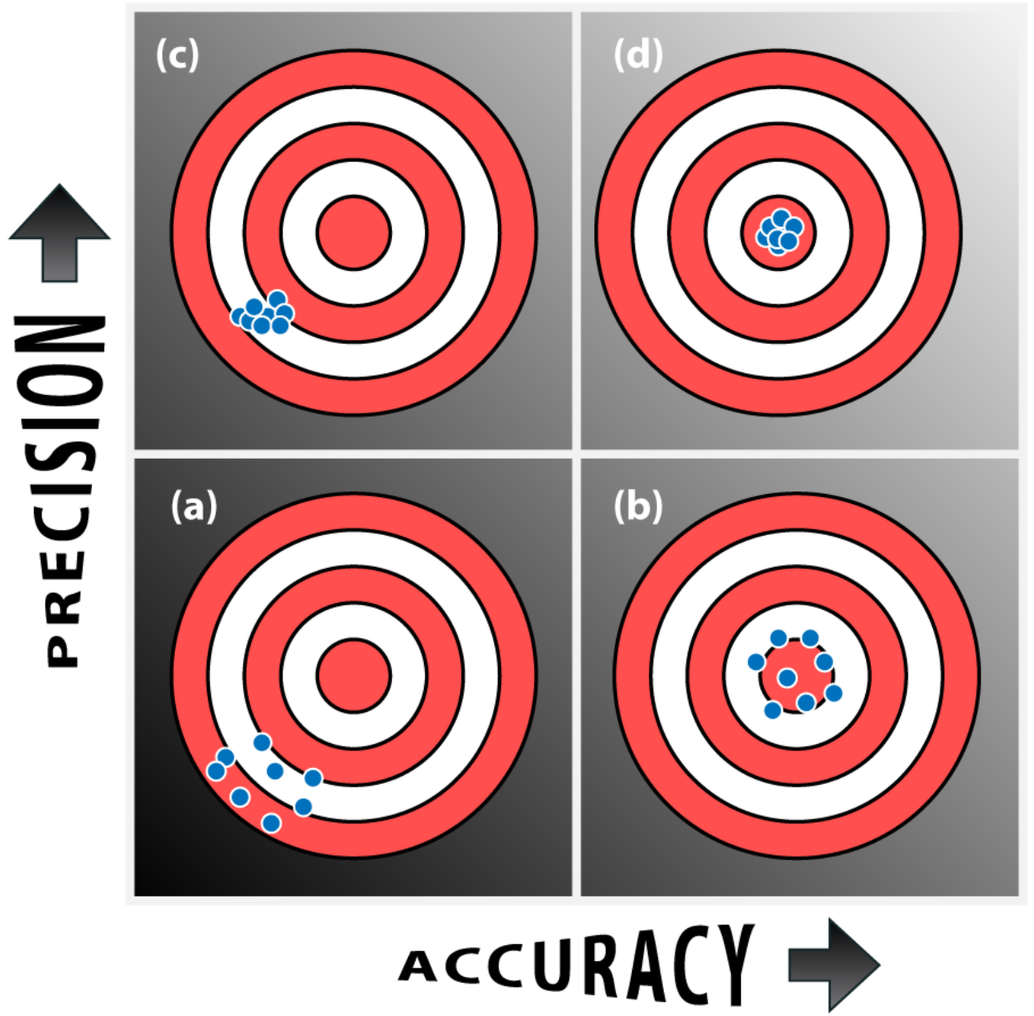
a) Neither precise nor accurate

b) Accurate but not precise

c) Precise but not accurate

d) Precise and accurate!

- 95% Confidence Interval?



Repeatability vs. Reproducibility

Are they the same thing?

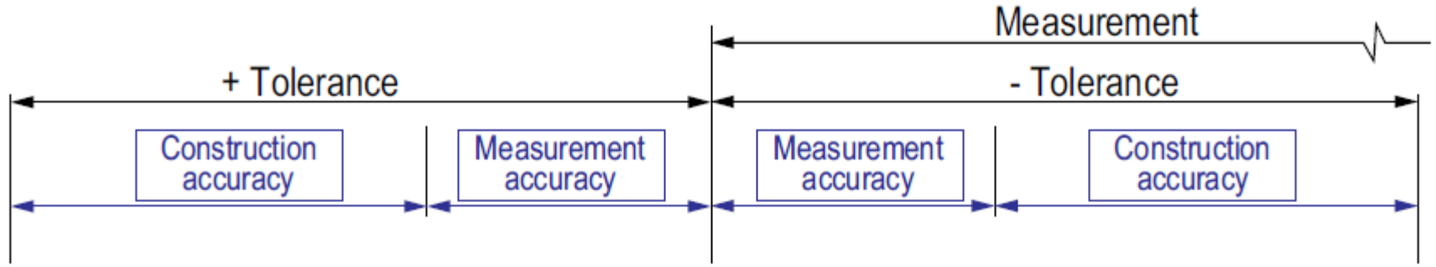
- Repeatability:
  - Can the same operator use the same hardware and processing to re-create similar results.

- Reproducibility
  - Can a different operator using different hardware and processing recreate similar results?

How Accurate is Accurate Enough?

How much error is acceptable to measure for ACI 117 tolerance compliance?

- Test Uncertainty Ratio (TUR)?



A specified tolerance includes a measurement accuracy and a construction accuracy

- ANSI/NCSL Z540.3-2006 requires TUR to be 4:1, i.e. 1/8" accuracy is ok for 1/2" tolerance

ASCC Laser Scanning Study

What did we do?

- 2 Different Slabs
- 8 Participants
- Each participant scanned each slab twice
- Target coordinates were provided
- Participants reported measured coordinates on 10 targets and FF/FL numbers

ASCC Laser Scanning Study Results

Table 2:
Ground-level error analysis for target coordinates

Participant	Day	Error in x and y (SRSS of [reference – measured] for x and y), in.				Error in z (reference – measured), in.			
		Minimum	Average	Maximum	Standard deviation	Minimum	Average	Maximum	Standard deviation
A	1	0.147	0.200	0.270	0.051	−0.091	0.004	0.080	0.064
	2	0.147	0.194	0.270	0.045	−0.091	0.004	0.080	0.064
B	1	0.020	0.056	0.137	0.037	0.020	0.056	0.137	0.037
	2	0.050	0.122	0.218	0.054	−0.051	0.044	0.163	0.066
C	1	0.036	0.192	0.323	0.092	−0.095	−0.001	0.138	0.079
	2	0.028	0.163	0.242	0.069	−0.094	0.002	0.126	0.069
D	1	0.010	0.231	1.097	0.348	−0.084	0.063	0.340	0.112
	2	0.076	0.145	0.240	0.063	−0.052	0.042	0.187	0.078
E	1	0.040	0.084	0.149	0.036	−0.087	0.012	0.203	0.085
	2	0.037	0.083	0.168	0.042	−0.097	−0.010	0.131	0.077
F	1	0.020	0.052	0.078	0.020	−0.097	0.021	0.164	0.087
	2	0.028	0.063	0.115	0.030	−0.025	0.025	0.110	0.051
G	1	0.027	0.095	0.223	0.055	−0.450	−0.062	0.218	0.199
	2	0.035	0.111	0.172	0.043	−0.330	−0.062	0.278	0.180
H	1	0.007	0.084	0.233	0.069	−0.090	0.010	0.107	0.067
	2	0.020	0.063	0.121	0.031	−0.090	−0.015	0.089	0.059

Note: All targets on vertical surfaces (concrete columns and walls); 1 in. = 25 mm

ASCC Laser Scanning Study Results

Table 7:
Comparison of errors for eight participants versus three participants with the lowest errors

	Eight participants			Three participants with lowest errors		
	X	Y	Z	X	Y	Z
Count	310	310	310	114	114	114
Minimum	−0.673	−0.516	−0.450	−0.157	−0.232	−0.097
Maximum	1.083	0.360	0.340	0.121	0.212	0.164
Average	0.009	−0.005	0.013	−0.004	−0.011	0.013
SD	0.125	0.106	0.082	0.056	0.074	0.057
8 × U	1.002	0.852	0.653	0.445	0.590	0.456

Based on the data in this study, our analyses indicate that it would be appropriate to use a laser scanner for specification compliance when measuring a vertical tolerance of 5/8 in. (15.9 mm) or more and a horizontal tolerance of 1 in. or more.

Where Do We Go From Here?

Laser Scanners are <u>NOT</u> going away!

- ACI/ASCC Laser Scanning Best Practice Guide under development
- Specification compliance and quality control are not the same thing!
- How accurate is accurate enough?
- If they can't effectively be measured, are the tolerances to blame?
- Results of F number testing in follow-up article to be published soon