RC22281: Laser Scanning Basics and Application in Concrete Construction

Josh DeStefano
DPR Construction

Philip Lorenzo
Rithm

Class summary

This class will explain the fundamentals of laser scanning, explore its value in building construction, and reveal how reality-capture tools are shaping the future of the industry. Attendees will gain a basic understanding data collection, processing workflows in ReCap, and analysis for ASTM E1155 Concrete Floor Flatness & Levelness (FF/FL) reporting.

Key learning objectives

At the end of this class, you will be able to:

- Understand and explain the basics of reality capture
- Learn about applications of laser scanning in building construction
- Discover the process of analyzing laser-scan data to achieve FF/FL report
- Learn how to use ReCap to process laser-scan data

Agenda

new ways to measure floor flatness

- Introductions
- Laser Scanning Basics
- Laser Technology Implementation
- Enabling the Future

Introductions

Get to know your presenters

PRODUCT MANAGER

Philip Lorenzo

- Rithm founder
- USIBD Technology Co-Chair
- ASTM 1155 Committee
- UC Berkeley Guest Lecturer
- Reality Capture Advisor, Brick & Mortar VC

Introductions

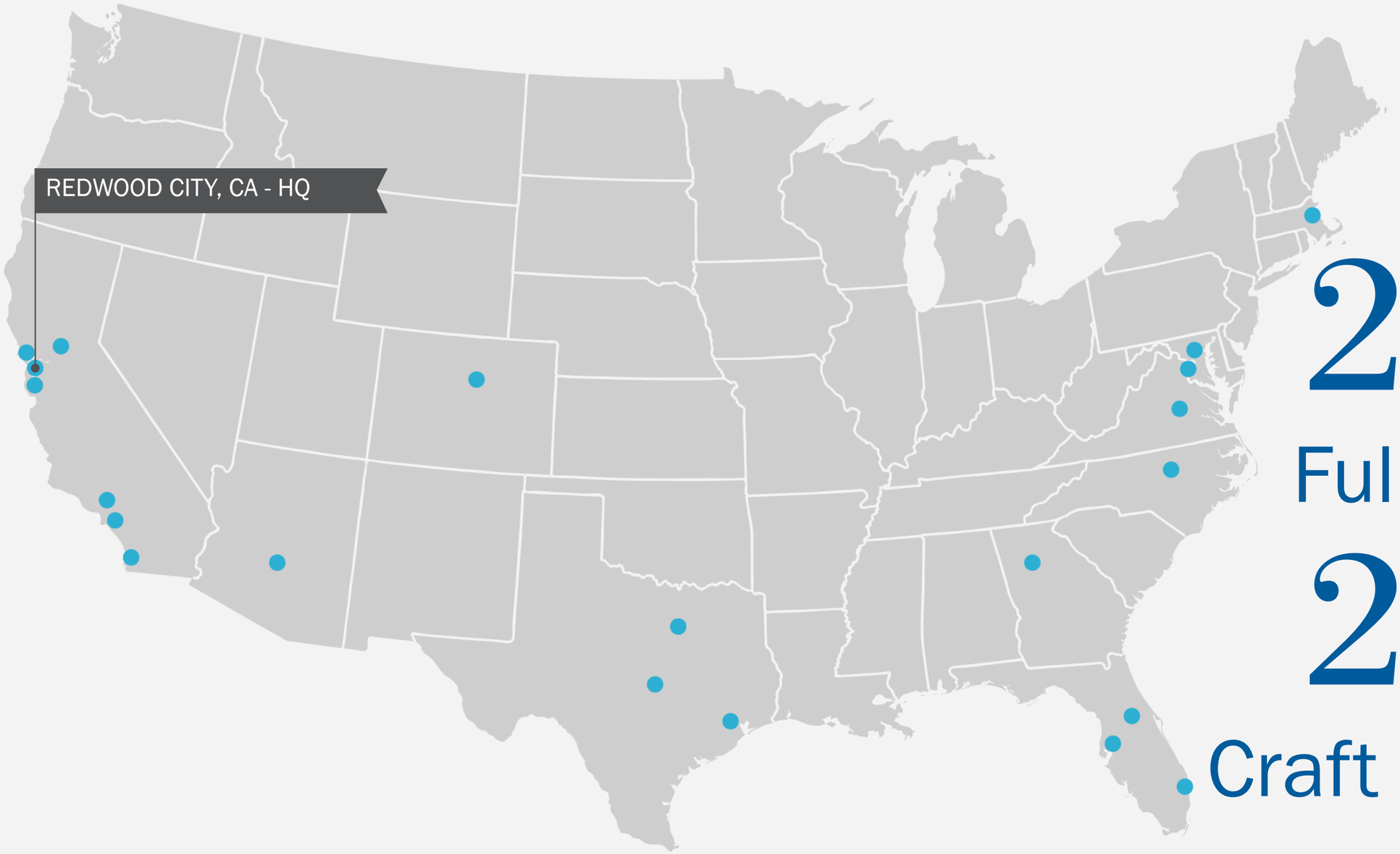
Get to know your presenters

CONSTRUCTION TECHNOLOGY LEADER

Josh DeStefano

- Construction technology at DPR SoCal
- 15 years in AEC
- AGC CM-BIM
- Guest Lecturer at Cal Poly, CSULB, USC, AECX
- USIBD Technology Co-Chair

DPR Offices



2,000
Full-time staff

2,000
Craft employees


20
Largest contractor in the
U.S. (ENR 2016)

Core Markets

Advanced Technology

Healthcare

Higher Education

Life Sciences

Commercial

2015 National Rankings

Engineering News Record (ENR)

ENR

THE TOP 400

NUMBER 365

BRIDGING THE GAP

Firms Sticking With Tactics That Worked in Lean Times

Throughout 30 years of firm rankings on ENR's Top 400 Contractors list, one fact remains constant: the cyclical nature of the industry. Some recessions were deep and prolonged, such as the downturns following the Arab-oil boycott in the 1970s, the savings-and-loan debacle in the late 1980s and the market crash following the burst of the dot-com bubble and the 9/11 terror attacks in 2001. The industry is only now emerging from the housing and banking crises of the late 2000s.

Each recession took its toll on the industry. But for those contractors that survived these downturns, the lessons learned were invaluable. Even as the industry slowly climbs out of this latest trough, contractors continue to embrace the processes that helped them make it through the past six years.

Evidence of the market's recovery can be seen in this year's ENR Top 400 Contractors list. As a group, the Top 400 garnered $324.16 billion in contracting revenue in 2013, an increase of 4.8% from 2012's $309.43 billion. The figure is still below the record $338.38 billion in 2008 revenue, reported in our 2009 Top 400.

Domestic contracting revenue accounted for the Top 400's overall increase this year, rising 6.6% in 2013, to $249.34 billion, while international contracting revenue fell 0.8%, to $74.83 billion.

While the domestic market clearly is beginning to make progress toward prosperity, it still has a way to go to match the Top 400's record $281.36 billion in domestic contracting revenue, reported at the end of the building boom in 2008.

The biggest gainer among markets was petroleum, up 21.1%. General building also saw a healthy 10.8% gain in 2013 over 2012. And, surprisingly, the sewer-and-waste market made a 10.2% comeback in 2013 over 2012, after two dismal years and amid fears that public funding for infrastructure was drying up.

The other markets covered by the ENR survey saw declines in revenue in 2013 from 2012. Industrial process fell the most, down 28.7%. Revenue from power projects fell 12.8%, but much of this decline can be traced to the absence of First Solar Inc., Tempe, Ariz., which reported more than $3 billion in solar-power construction revenue in last year's survey but did not respond to this year's survey.

Other declines include telecommunications (down 15.2% in 2013 from 2012), hazardous waste (9.2%), transportation (7.5%), manufacturing (2.2%) and water supply (0.9%).

The numbers are not as grim on the domestic side. Petroleum revenue from projects in the U.S. was up 21.1%, while the domestic general building market rose 12.5%. Sewer-and-waste project revenue in the U.S. was up 13.3%, water-supply project revenue rose 1.3% and transportation revenue was up 0.9%. ■

By Gary J. Tulacz

How To Read the Tables

Companies are ranked according to revenue for contracting services performed in 2013 (–\$ indicates \$). Those with subsidiaries are indicated by (S). For information on subsidiaries and where each firm ranked outside of the U.S., see www.ENR.com.

****Firms not ranked last year.** Some markets may not add up to 100% due to the omission of the miscellaneous "other" market category and rounding. N/A=Not available.

General Building is a category includes commercial buildings, office buildings, stores, educational facilities, government buildings, hospitals, medical facilities, hotels and casinos, apartments, housing, etc.

Hazardous Waste includes chemical and nuclear waste treatment, asbestos and lead abatement, etc.

Industrial Process comprises pulp and paper mills, steel mills, non-ferrous metal refineries, pharmaceutical plants, chemical plants and food and other processing plants, etc.

Manufacturing includes auto, electronic assembly, textile plants, etc.

Petroleum includes refineries, petrochemical plants, offshore facilities, pipelines, etc.

Power comprises thermal and hydroelectric powerplants, waste-to-energy plants, transmission lines, substations, cogeneration plants, etc.

Sewerage / Solid Waste includes sanitary and storm sewers, treatment plants, pumping plants, incinerators, industrial waste facilities, etc.

Telecommunications comprises transmission lines and cabling, towers and antennae, data centers, etc.

Transportation includes airports, bridges, roads, canals, locks, dredging, marine facilities, piers, railroads, tunnels, etc.

Water Supply includes dams, reservoirs, transmission pipelines, distribution mains, irrigation canals, desalination and potability treatment plants, pumping stations, etc.

- #3 in Pharmaceuticals
- #6 in Data Centers
- #7 in Commercial Offices
- #8 in Healthcare
- #11 in Green Construction
- #16 in General Building
- #18 in Industrial Process

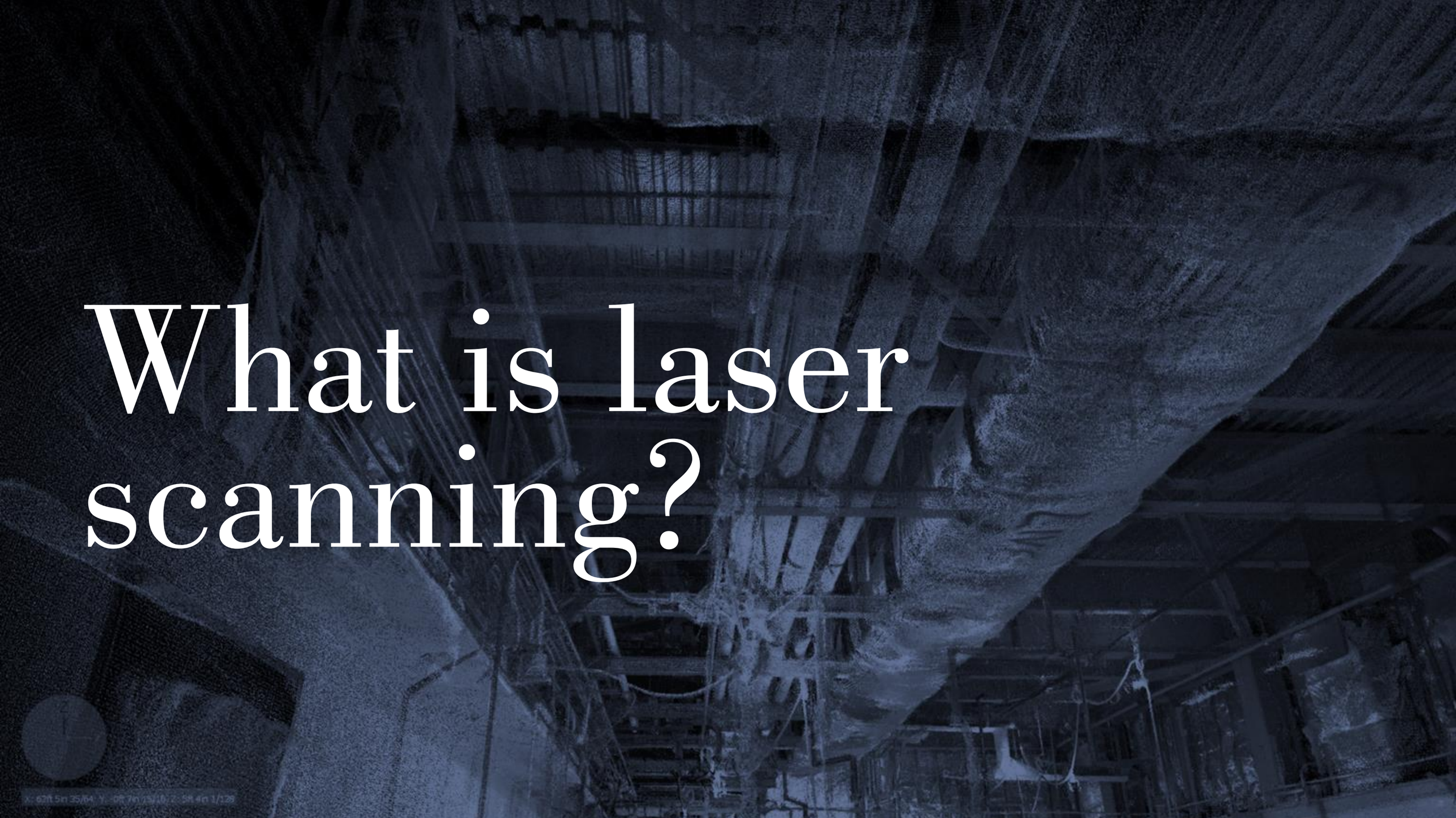
Core Values

integrity

enjoyment

uniqueness

ever forward



What is laser scanning?

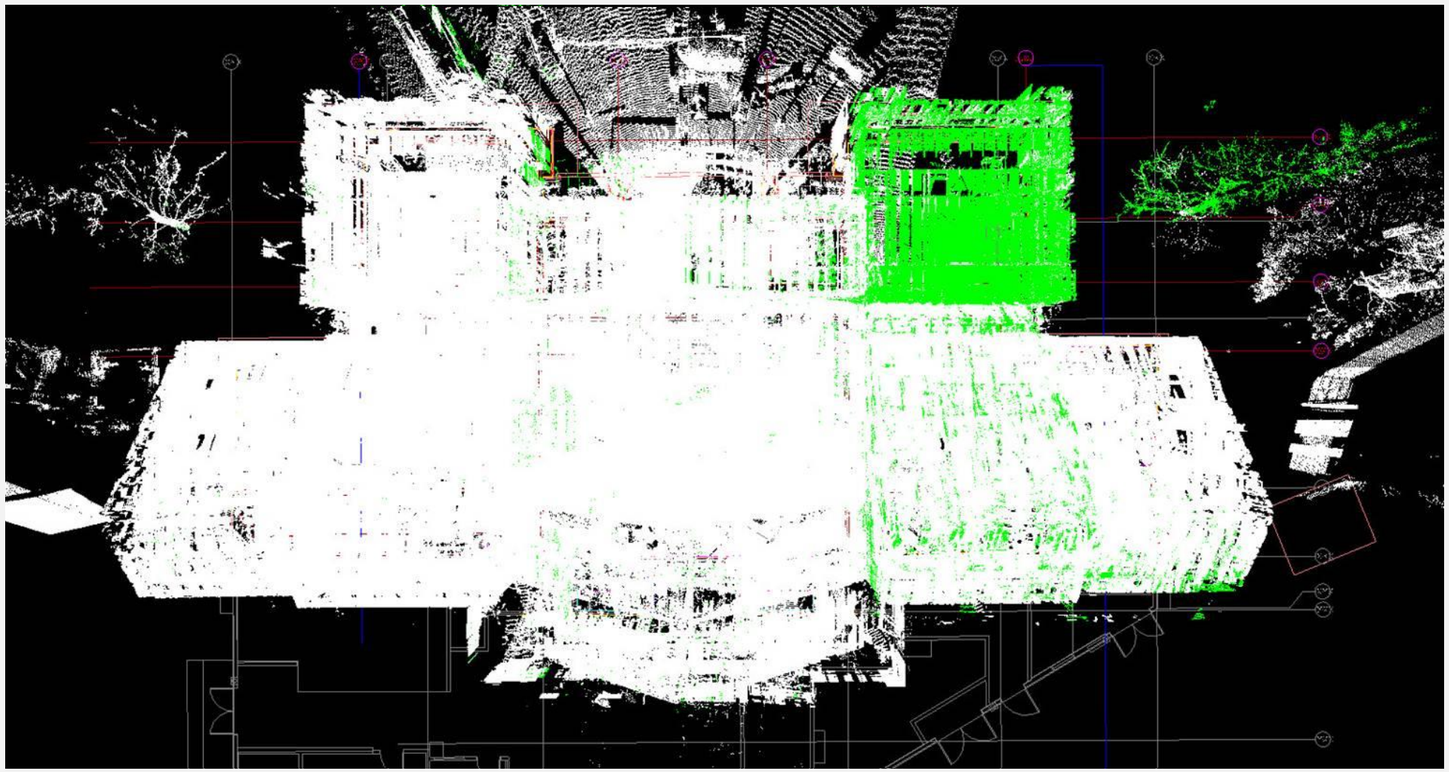
What is a laser scanner?

- Phase-based laser scanner
  - 1 million points per second
  - Accuracy to 1/8“
  - Class 1 Laser – Safe in all cases
  - Self-Leveling Inclinometer

How is 3D laser scanning done?

1. Turn on
2. Press the “scan” button
3. Move
4. Repeat steps 2-3 until complete

How to put scans together



- “Registration”
- Takes a day to learn
- A week to master

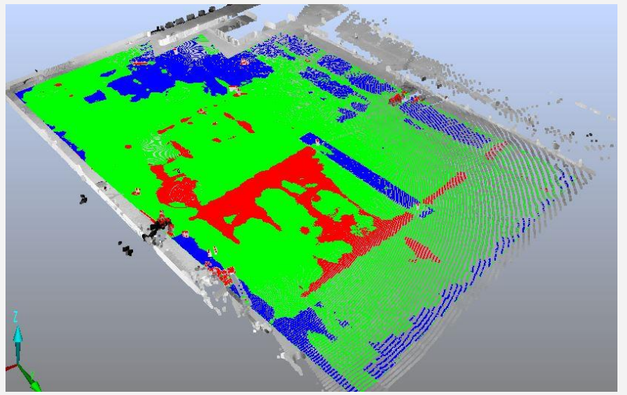
About Philip

- Worked for large GC, scanning for concrete flatness, deflection monitoring & beam camber
- Founded Rithm
- Joined ASTM E06
- Partnered with Faro Technologies

Rithm

How Rithm Started

$$
\begin{aligned}
f'(x_0) &= \lim_{h\to 0}\frac{f(x_0+h)-f(x_0)}{h} = \lim_{h\to 0}\frac{(x_0+h)^{1/2}-(x_0)^{1/2}}{h} \\
&= \lim_{h\to 0}\frac{[(x_0+h)^{1/2}-(x_0)^{1/2}]}{h}\frac{[(x_0+h)^{1/2}+(x_0)^{1/2}]}{[(x_0+h)^{1/2}+(x_0)^{1/2}]} \\
&= \lim_{h\to 0}\frac{(x_0+h)-x_0}{h[(x_0+h)^{1/2}+(x_0)^{1/2}]} = \lim_{h\to 0}\frac{h}{h[(x_0+h)^{1/2}+(x_0)^{1/2}]} \\
&= \lim_{h\to 0}\frac{1}{[(x_0+h)^{1/2}+(x_0)^{1/2}]} = \frac{1}{x_0^{1/2}+x_0^{1/2}} = \frac{1}{2x_0^{1/2}} = \tfrac{1}{2}x_0^{-1/2}
\end{aligned}
$$



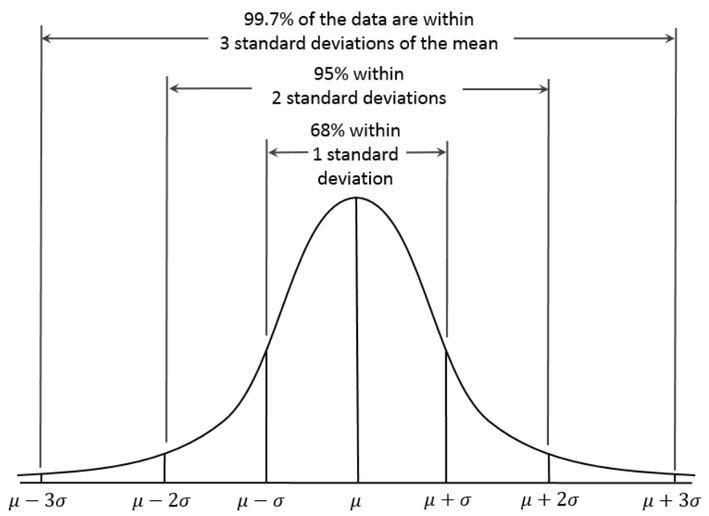
ASTM INTERNATIONAL
Standards Worldwide

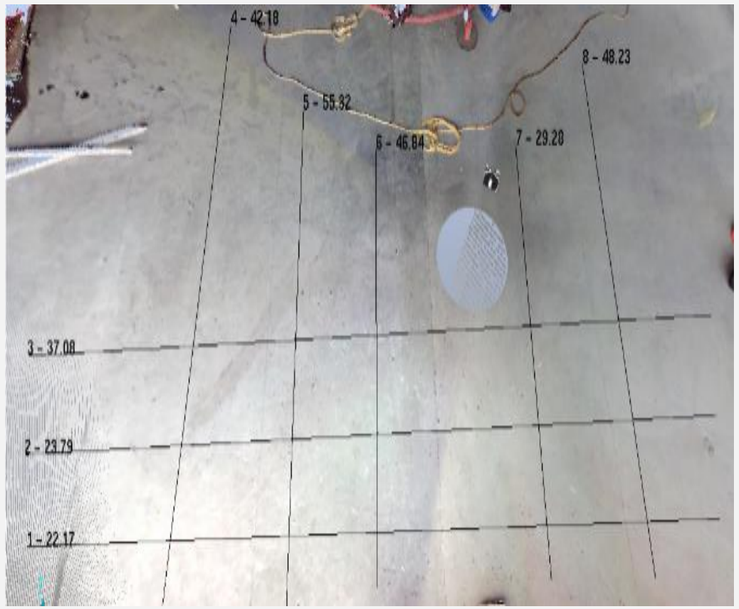
aci
American Concrete Institute®
Advancing concrete knowledge

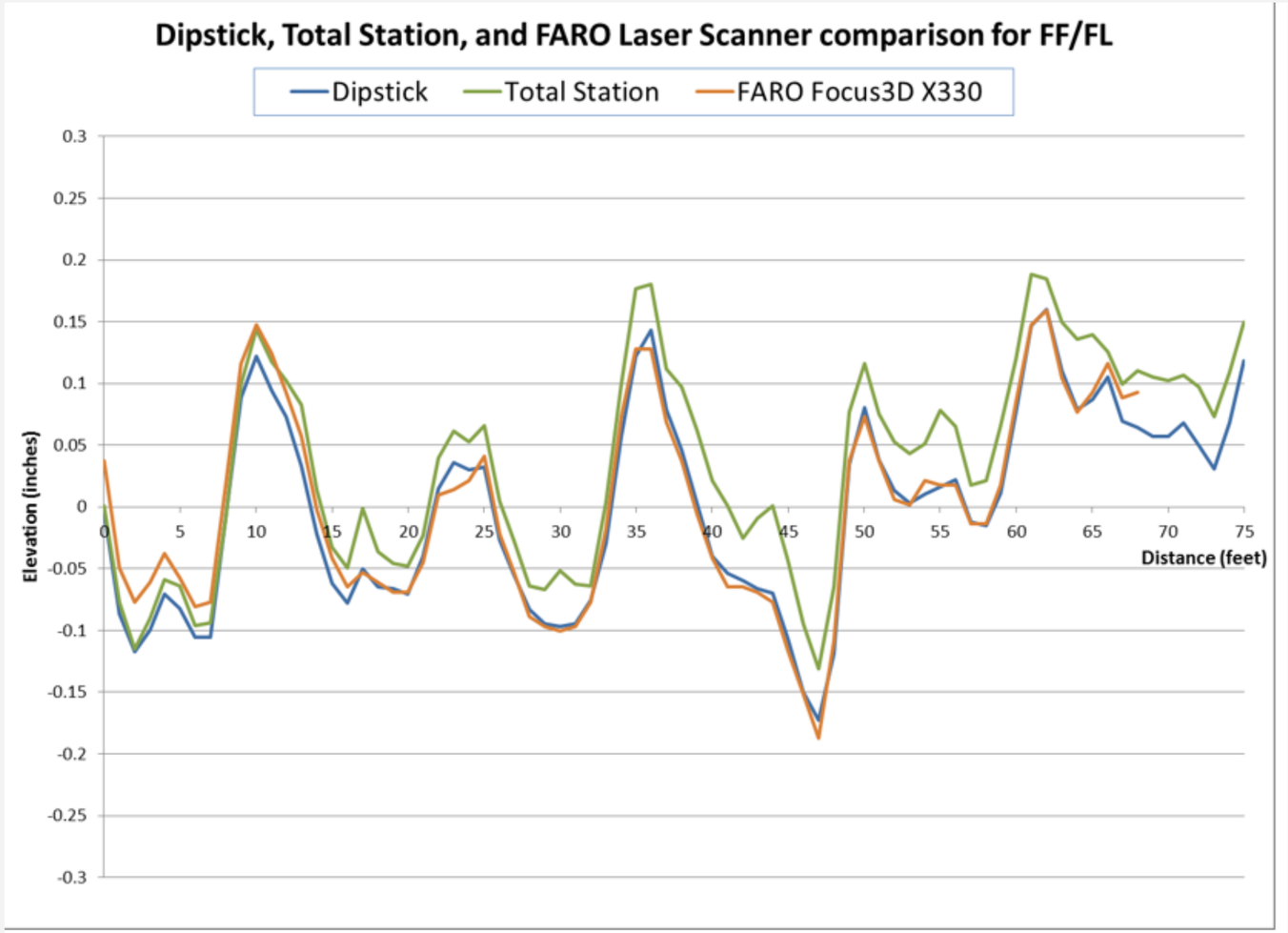
USIBD™
U.S. Institute of
BUILDING DOCUMENTATION

ICC
INTERNATIONAL
CODE COUNCIL®

Getting adoption with concrete contractors







	FARO	Total Station	Dipstick
FF Values	36.02	35.99	36.37
		FARO vs. Total Station	FARO vs. Dipstick
		0.08%	0.96%

Implementation

Our floor flatness journey

Concrete Laser Scanning

Implementation at DPR

CHALLENGES

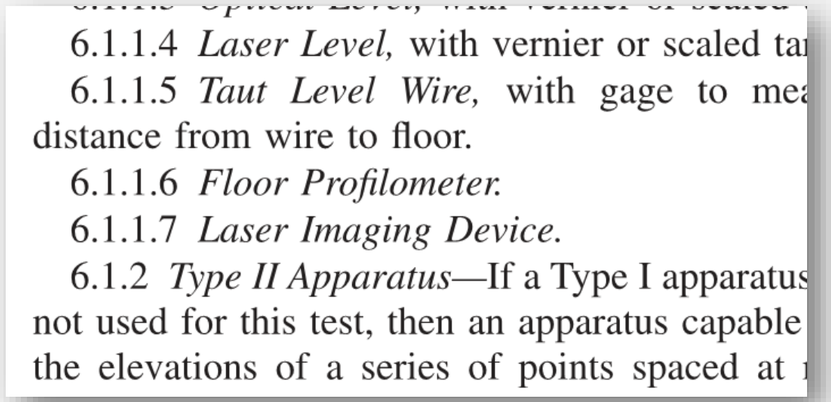
- Understanding the standards
- Accuracy of new methods
- Lack of trust
- Cost vs value

Concrete Laser Scanning

Implementation at DPR

NEXT STEPS

- Study current standards
  - Laser imaging device approved in 2014
  - Same requirements for test surface:
    - Sample measurement >11ft
    - no measurement within 2ft of slab boundary, CJ, block out, penetrations, etc.



6.1.1.4 *Laser Level,* with vernier or scaled ta
6.1.1.5 *Taut Level Wire,* with gage to mea
distance from wire to floor.
6.1.1.6 *Floor Profilometer.*
6.1.1.7 *Laser Imaging Device.*
6.1.2 *Type II Apparatus*—If a Type I apparatus
not used for this test, then an apparatus capable
the elevations of a series of points spaced at

Concrete Laser Scanning

Implementation at DPR

NEXT STEPS

- Study current standards
- Compare equipment function & cost
  - Dipstick
    - Less expensive, established
    - Single purpose equipment & data
  - Laser scanner
    - Multiple uses, lots of data
    - Higher cost, learning curve

Concrete Laser Scanning

Implementation at DPR

NEXT STEPS

- Study current standards
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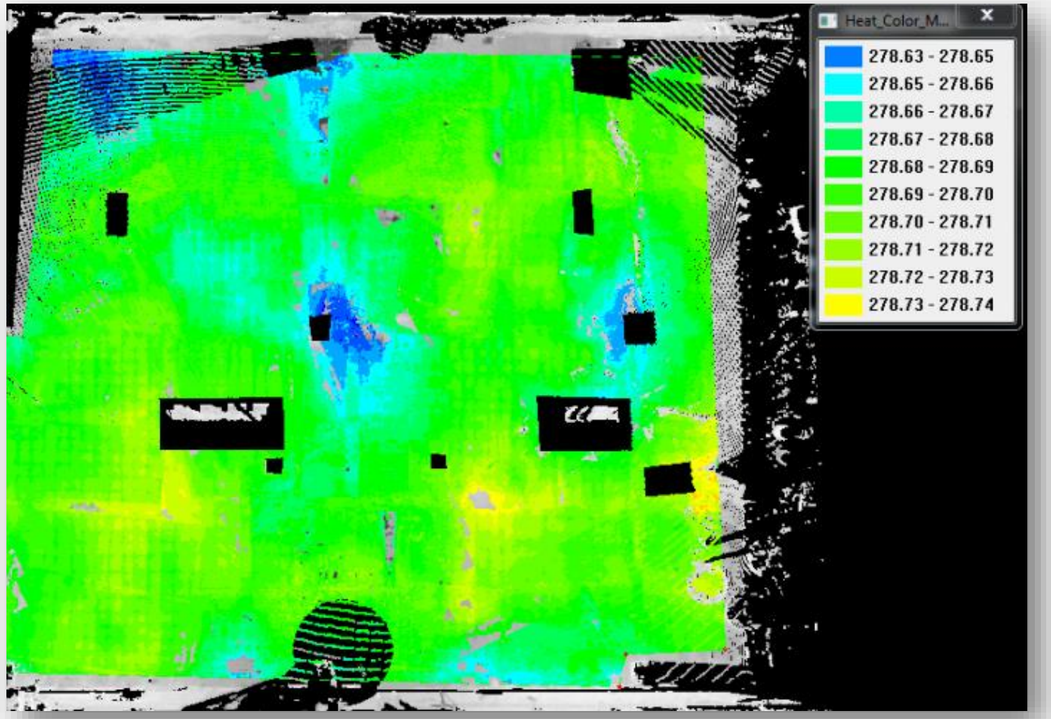
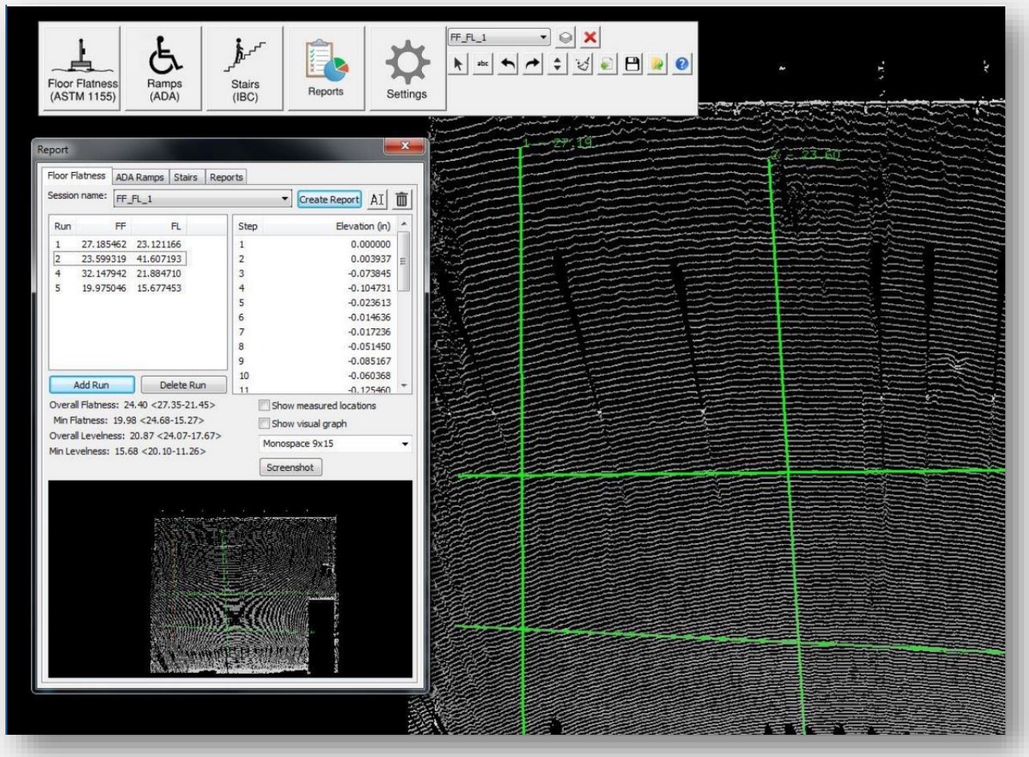


Concrete Laser Scanning

Implementation at DPR

NEXT STEPS

- Study current standards
- Compare equipment function & cost
- Test software & provide feedback

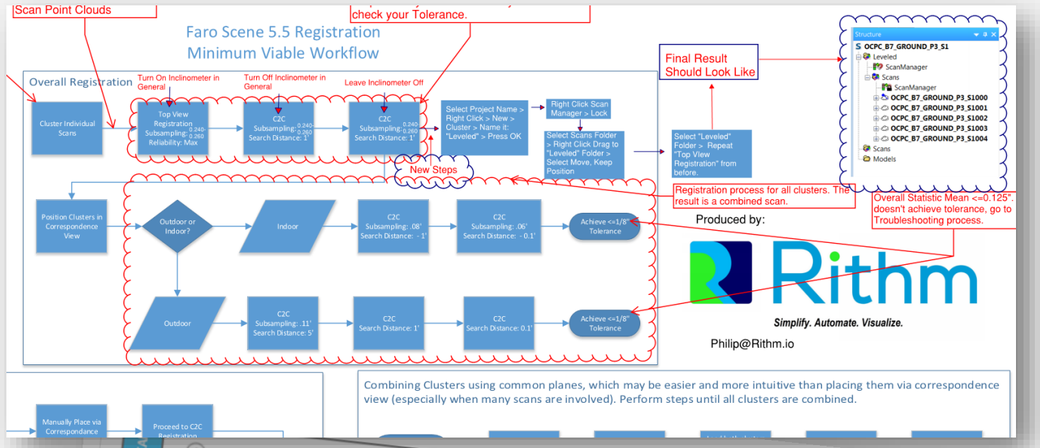


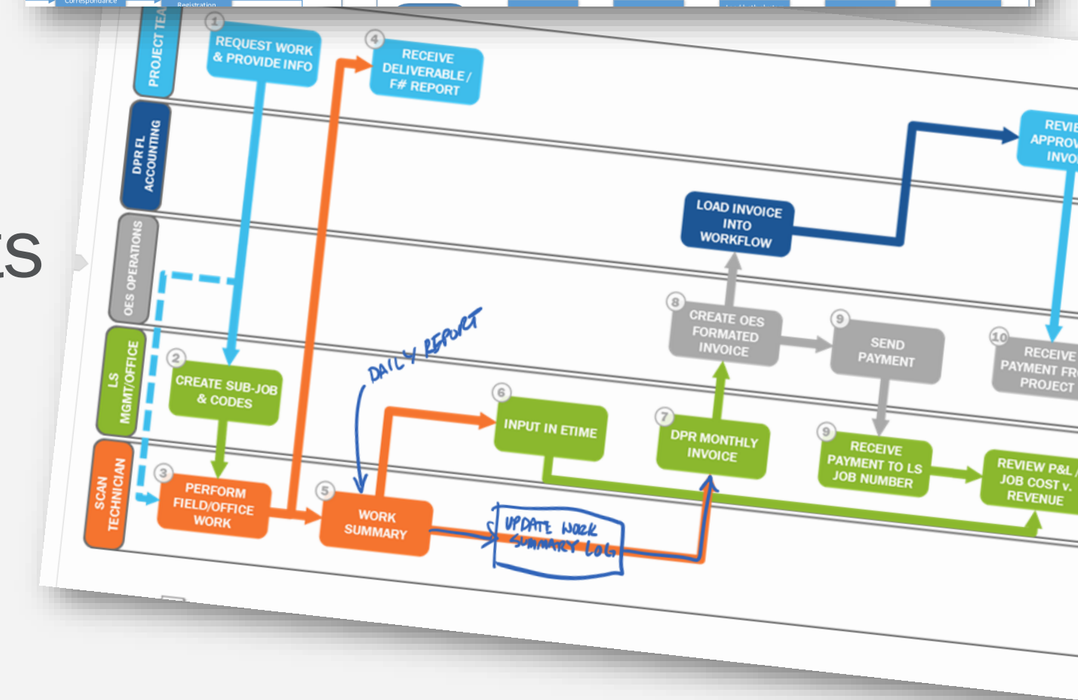
Concrete Laser Scanning

Implementation at DPR

NEXT STEPS

- Study current standards
- Compare equipment function & cost
- Test software & provide feedback
- Optimize workflows & duplicate results



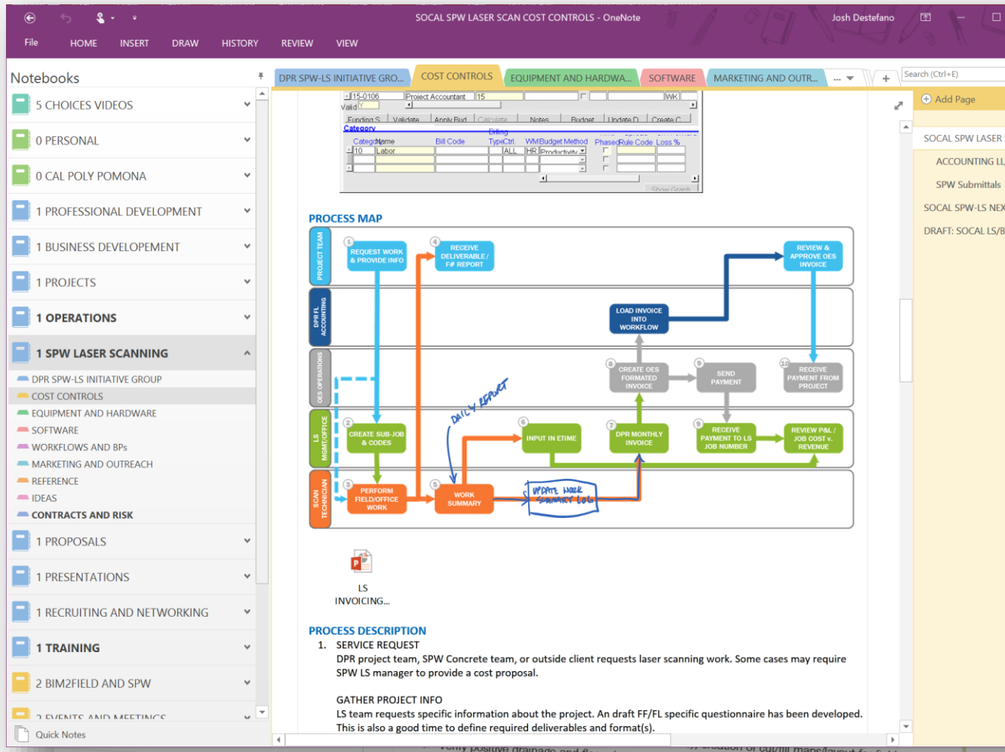


Concrete Laser Scanning

Implementation at DPR

NEXT STEPS

- Study current standards
- Compare equipment function & cost
- Test software & provide feedback
- Optimize workflows & duplicate results
- Document everything



Concrete Laser Scanning

Implementation at DPR

NEXT STEPS

- Study current standards
- Compare equipment function & cost
- Test software & provide feedback
- Optimize workflows & duplicate results
- Document everything
- Roll out

Concrete Laser Scanning

Implementation at DPR

DPR CONSTRUCTION

FF/FL Laser Scan
POUR INFORMATION REQUEST

	REQUIRED FIELD
Project Name	
Building	
Level	
Pour/Placement #	
Type of Slab (SOMD, SOG, etc.)	
Pour Date	
Area SF	
Start Time	
Pour Duration	
Finish Time	
Walkable Time	
Specified FF Number	
Specified FL Number	
Minimum FF Number	
Minimum FL Number	
Survey Control Point Established?	
Arch CAD Floor Plan File Provided?	
Pour Sequencing Plan Provided?	
Project Code	
Phase Code	

DPR CONSTRUCTION

SOCAL SPW LASER SCANNING
4665 MACARTHUR COURT, 100
NEWPORT BEACH, CA 92660
949-955-3771

DATE:
JOB NAME: OCPC
ADDRESS: Alton Pkwy & Barranca Pkwy
COMPANY: DPR Construction

LS JOB NUMBER: D1-16801- 01
MAIN PROJECT NO: D1-X15001-00
ORDERED BY:

WORK SUMMARY

LS TECHNICIAN: Ocean Van
EMPLOYEE NO.: 9994471

HRS	DESCRIPTION	LS PHASE CODE
	SCANNING	02-9152
	PROCESSING	02-9153

WORK SUMMARY

LS TECHNICIAN: Ocean Van
EMPLOYEE NO.: 9994471

HRS	DESCRIPTION	LS PHASE CODE
	SCANNING	02-9152
	PROCESSING	02-9153

VERIFICATION:

SIGNATURE DATE

PRINTED NAME PHONE EMAIL

*4 HOUR MINIMUM CHARGE AT APPROPRIATE RATE APPLIES FOR ALL MOBILIZATIONS TO SITE.

DPR CONSTRUCTION

BILLING TRANSMITTAL
INVOICE 16-002LS

TO: **BOB LOGAR**
OES EQUIPMENT LLC

ATTN: **Gul Dusi**
DPR Construction
4665 MACARTHUR COURT
NEWPORT BEACH, CA 92660
(949) 955-3771
guld@dpr.com

INVOICE DATE: **February 29, 2016**
JOB NAME: **OCPC CAMPUS PHASE 1**

JOB NUMBER: **D1-X15001-00**
ADDRESS: **15100 Barranca Parkway**
Irvine, CA 92618
BILLING PERIOD: **Thru February 29, 2016**

FROM: Josh DeStefano
RE: LASER SCANNING
SOCAL SPW LASER SCANNING
4665 MACARTHUR COURT, STE 100
NEWPORT BEACH, CA 92660
(949) 955-3771

SUMMARY OF SCOPE

DATE	HRS FIELD	HRS OFFICE	DESCRIPTION
2/10/16	2	3	Scanning for FF/FL & reporting at following areas:
2/11/16	2	3	Building 1, level 2, placement #1
2/13/16	2	3	Building 1, level 2, placement #2
2/16/16	2	2	Building 1, level 2, placement #3
2/17/16	2	2	Building 7, plaza level, placement #2
2/18/16	3	3	Building 7, plaza level, placement #1
2/18/16	3	3	Building 7, plaza level, placement #3
2/19/16	2	2	Building 1, level 3, placement #1
2/20/16	2	2	Building 1, level 3, placement #2
2/24/16	1	3	Building 7, level 2, placement #2
2/24/16	1	3	Building 1, level 3, placement #3
2/25/16	1	3	Building 7, level 2, placement #3
2/26/16	1	3	Building 1, level 4, placement #1
2/27/16	1	3	Building 7, level 3, placement #1
2/29/16	2	3	Building 4, level 2, placement #1
			Building 1, level 4, placement #2

27	hrs Faro Laser Scanning Rate	275	$7,425.00
41	hrs Technical Engineering Rate	145	$5,945.00
	TOTAL T&M AMOUNT		$13,370.00
	OES Processing Fee	-5.00%	-$668.50
	NET DUE		**$12,701.50**

PLEASE TRANSFER TO:

JOB NUMBER:	D1-B16801-00
PHASE CODE:	02-9010

Page 1 of 1

Concrete Laser Scanning

workflow

FF/FL REQUEST

- Provide general project information
- Advanced notice of concrete placement:
  - Prefer 1 week

PLACE & FINISH CONCRETE

- Real-time feedback, when will the surface be walkable?

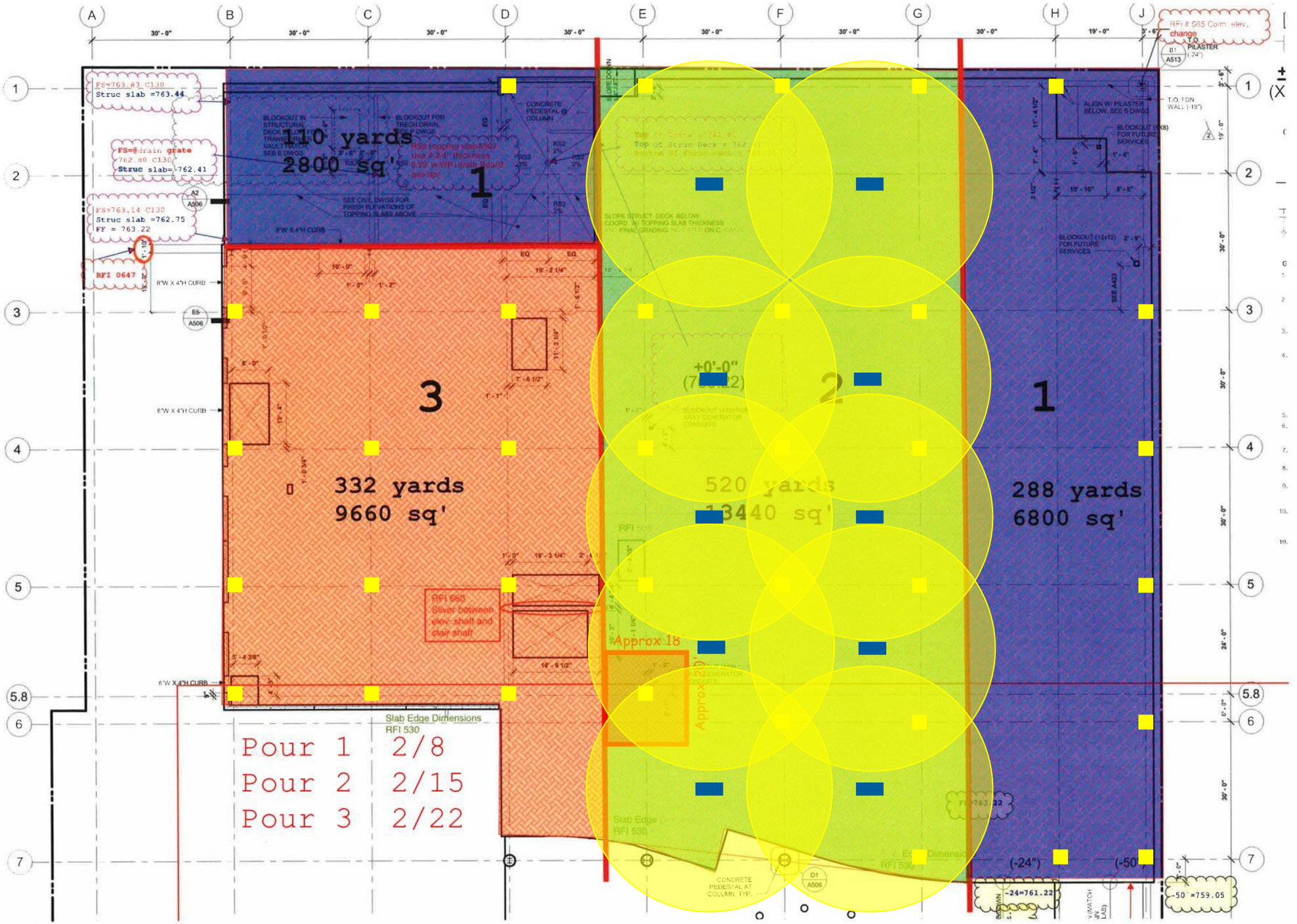
PERFORM SCAN

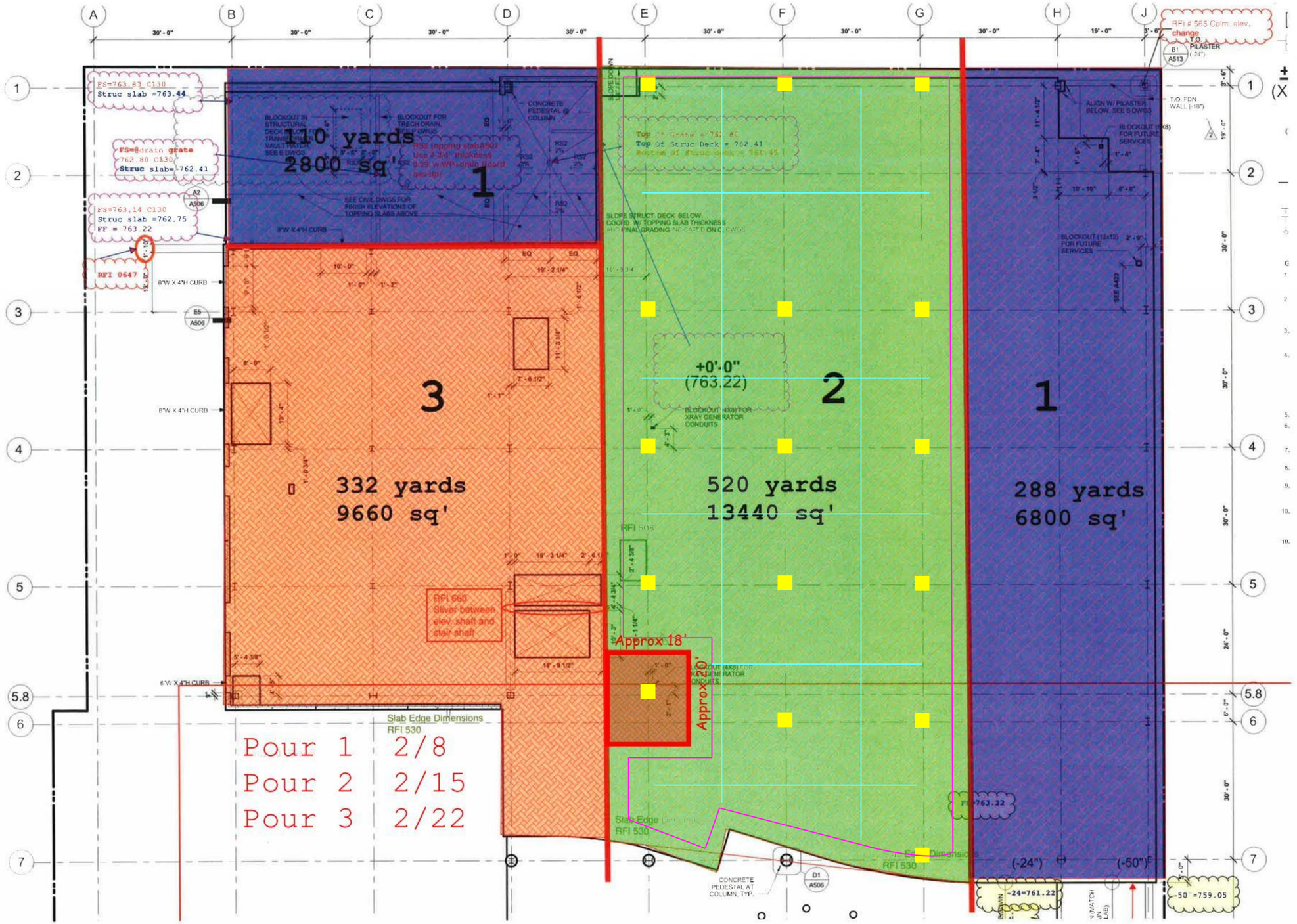
- Best practices during scanning:
  - Limit foot traffic
  - Remove debris, equipment & material

CREATE FF/FL REPORT

Report includes:

- Overall FF & FL
- Minimum FF & FL
- 90% confidence intervals (req. per ASTM E1155)
- Project specification “Pass/Fail” rating
- Test run details & exaggerated profiles


110 yards
2800 sq'
1
3
332 yards
9660 sq'
2
520 yards
13440 sq'
1
288 yards
6800 sq'
Approx 18'
Approx 20'
Pour 1 2/8
Pour 2 2/15
Pour 3 2/22


110 yards
2800 sq'
1
332 yards
9660 sq'
3
+0'-0"
(763.22)
520 yards
13440 sq'
2
288 yards
6800 sq'
1
RFI # 565 Corm. elev. change
RFI 0647
RFI 508
RFI 660
Sliver between elev. shaft and stair shaft
Approx 18'
Approx 20'
Slab Edge Dimensions
RFI 530
Pour 1 2/8
Pour 2 2/15
Pour 3 2/22
CONCRETE PEDESTAL AT COLUMN, TYP.
(-24")
(-50")

Results Comparison

Laser Scanning vs. Di[redacted]

[redacted]

Concrete Floor Flatness Testing, Inc.

11/3/2015

DPR Construction, A General Partnership, Southern California Regional Office
Attn: Kelvin Sam
4665 MacArthur Court, Suite 100
Newport Beach, CA 92660

Re: Norris Healthcare Center Health Sciences Campus
2204 East Alcazar Street
Los Angeles, CA 90033

Subject: Concrete F# Number Measurement / Concrete Floor Profiling

On 11-3-15, [redacted] performed F-Number measurement for the concrete floors at the project listed above. Testing was performed in accordance with ASTM E1155. The test sections, calculations, graphs and floor map are enclosed for your records.

The test data indicates the Combined F-number run values for Deck, Level1Plaza are:

- Floor Flatness = **FF39.36**
- Floor Levelness = **FL11.50**

Thank you for choosing [redacted] to service your concrete floor flatness and levelness testing needs. Please feel free to contact me should you have any questions regarding your F-Number measurement reports.

Sincerely,
[redacted]
President

2585 Crestview Drive, Newport Beach CA 92663
Office (949) 514-7238
email: mmoore@f-numbers.com

Results Comparison

Laser Scanning vs. Dip Stick

[redacted]

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Thank you for choosing [redacted] to service your concrete floor flat
levelness testing needs. Please feel free to contact me should you
questions regarding your F-Number measurement reports.

Sincerely,

[redacted]

Floor Flatness / Floor Levelness Inspection Results

Per ASTM 1155 Specifications

Inspection Information	
Project	
Location	USC NHC L1 PLAZA
Pour Date	
Date Measured	1/27/2016
Measured Area	1/21/2016
Type of Run Selection	

Contract Specifications				
Reference	Overall Flatness	Minimum Flatness	Overall Levelness	Minimum Levelness
CSI Division 03	35	17	20	15

Overall Results		
Measured Flatness (FF)	39.93	
FF 90% Confidence		Measured Levelness
Measured Flatness Test	38.43 - 41.43	FL 90% Co
Minimum Flatness (FL_min)	PASS	
FF_min 90% Confidence	22.73	
Minimum Flatn		

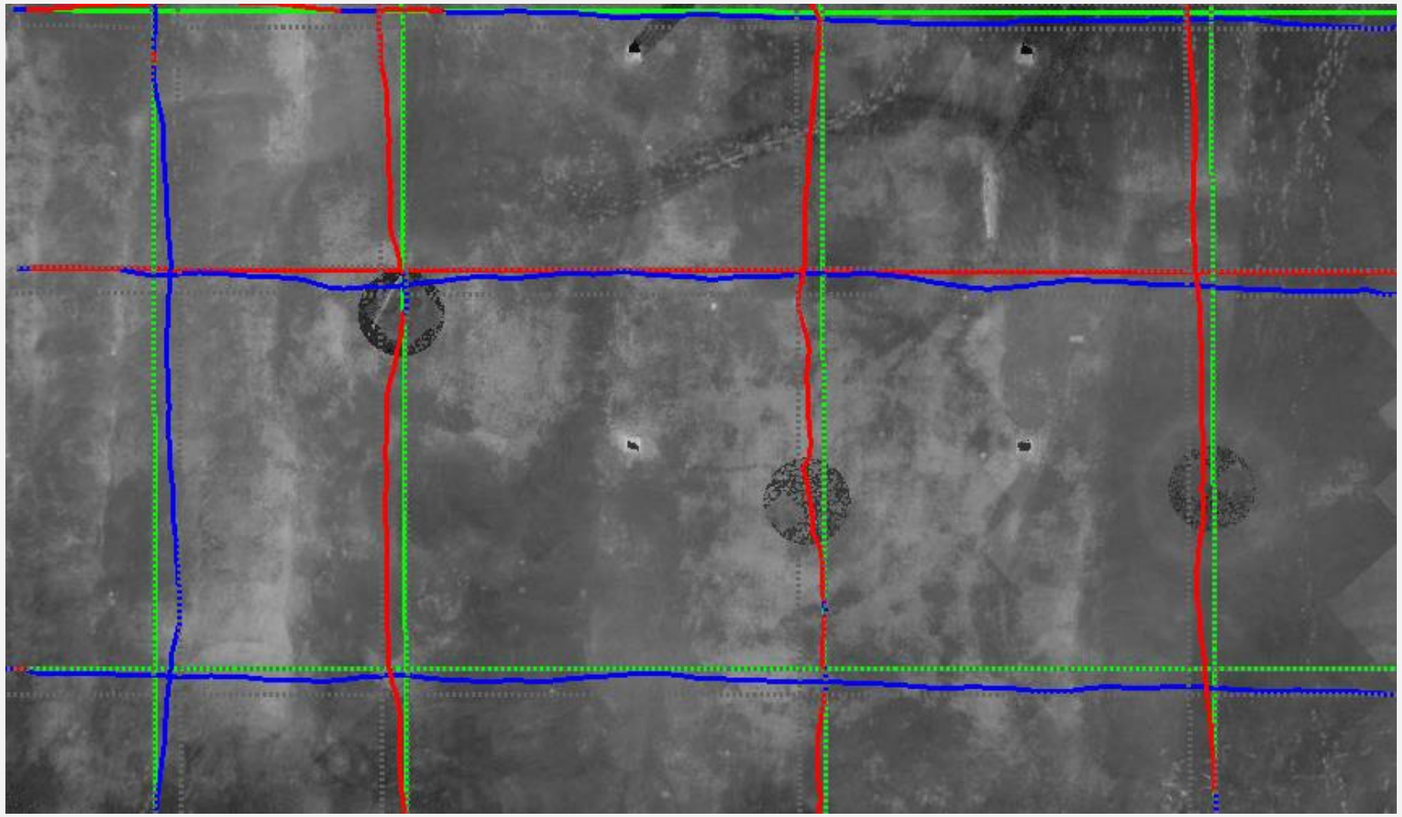

85/6
F-Number reports to date / projects

What future does laser scanning have in the concrete industry?

Limitations of Current Process

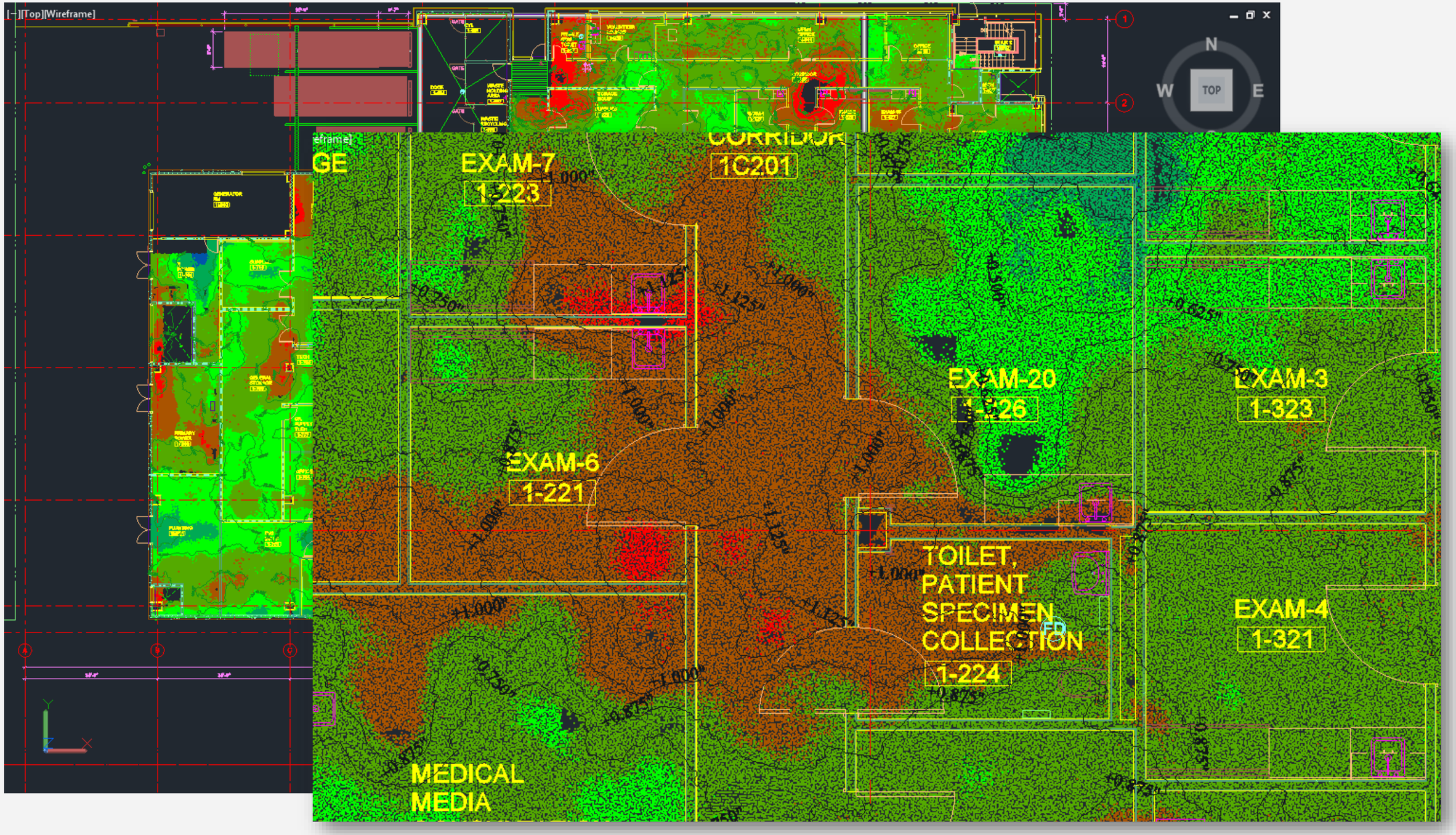
Descriptive text and content

- Does not capture what is in between runs
  - Miss high/slows
  - 1-1/2” of shim on extra-deflecting slabs



How might this technology improve the concrete quality control process?

- Does not capture what is in between runs
  - Miss high/slows
  - 1-1/2” of shim on extra-deflecting slabs
- Not truly “repeatable” in a practical sense
  - Cannot do runs in the exact same area
  - People are only going to do so many and not fully take an average due to time constraint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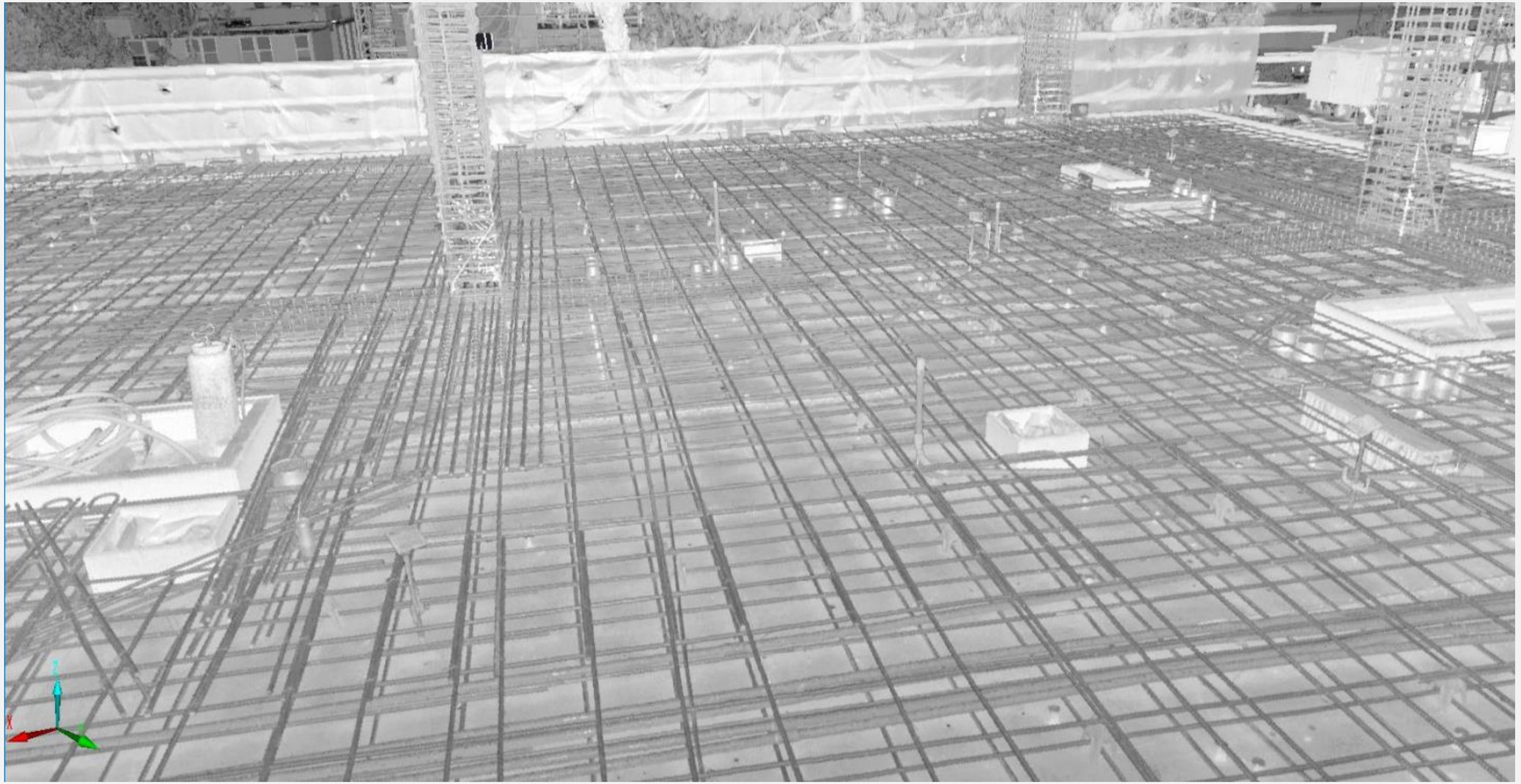
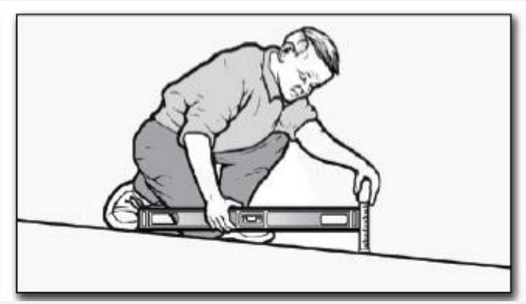
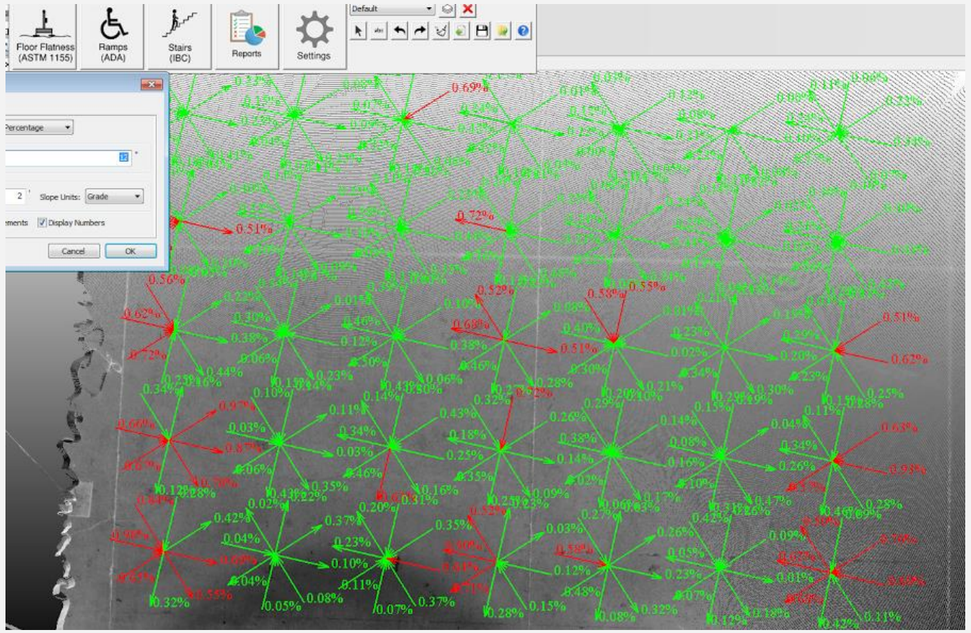
EXAM-7
1-223
CORRIDOR
1C201
EXAM-20
1-226
EXAM-3
1-323
EXAM-6
1-221
TOILET,
PATIENT
SPECIMEN
COLLECTION
1-224
EXAM-4
1-321
MEDICAL
MEDIA

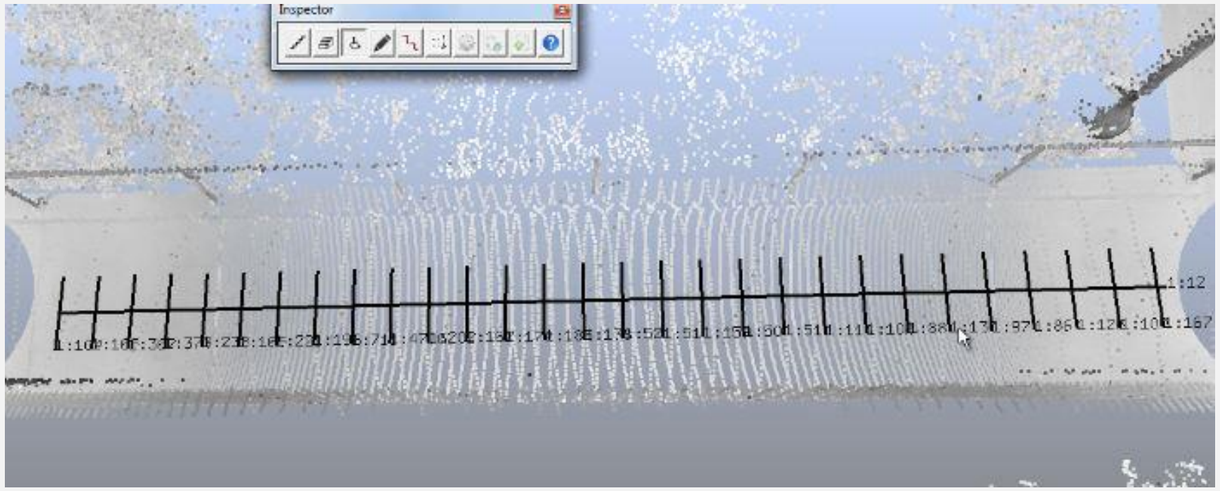




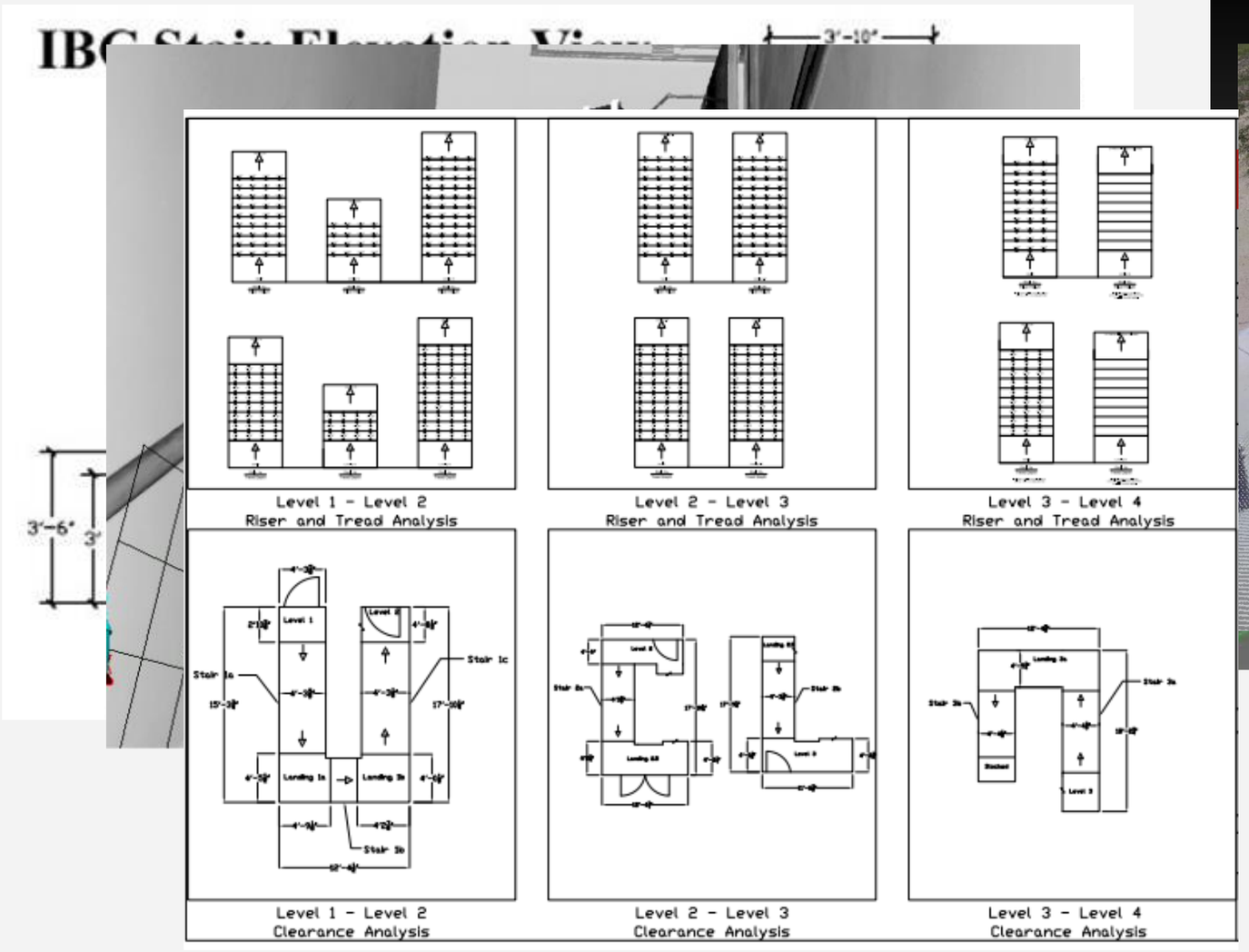


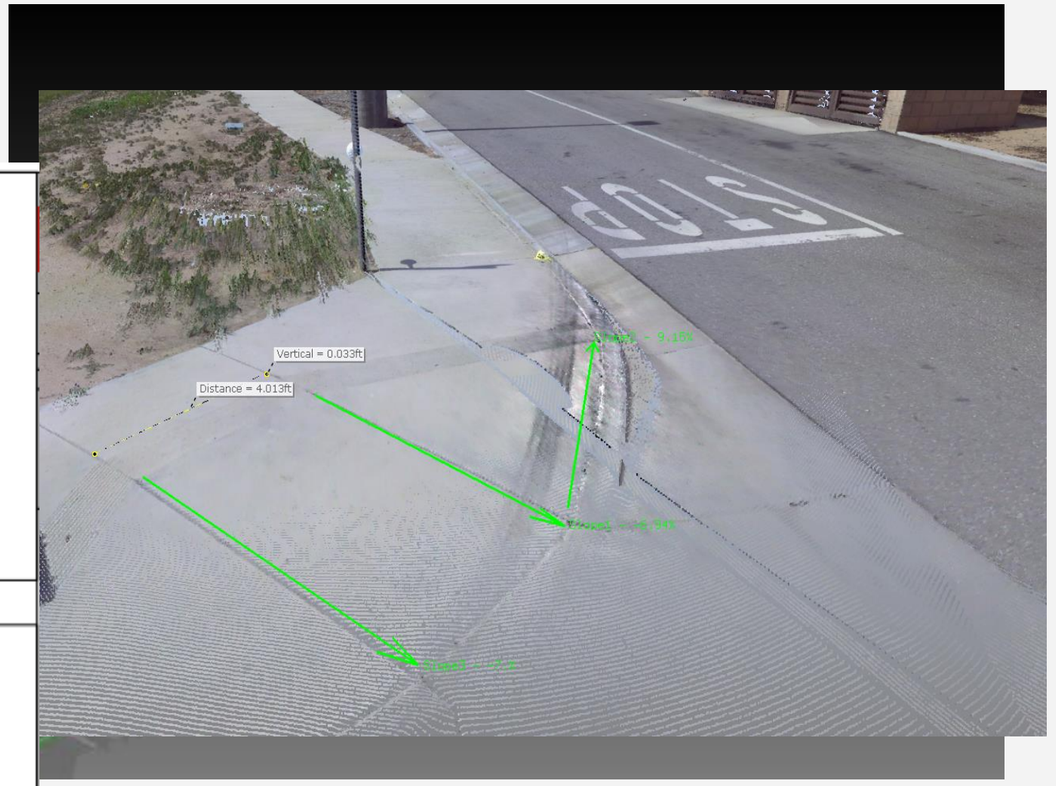
Why?

- Pass Inspection
- Prevent Litigation



Code Compliance – Stairs, Ramps

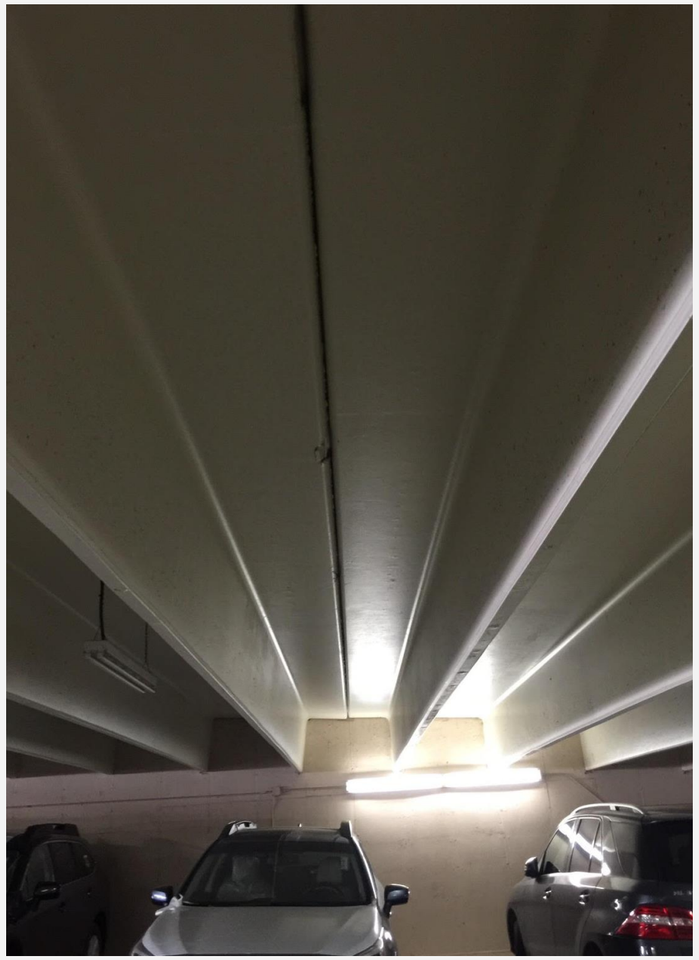


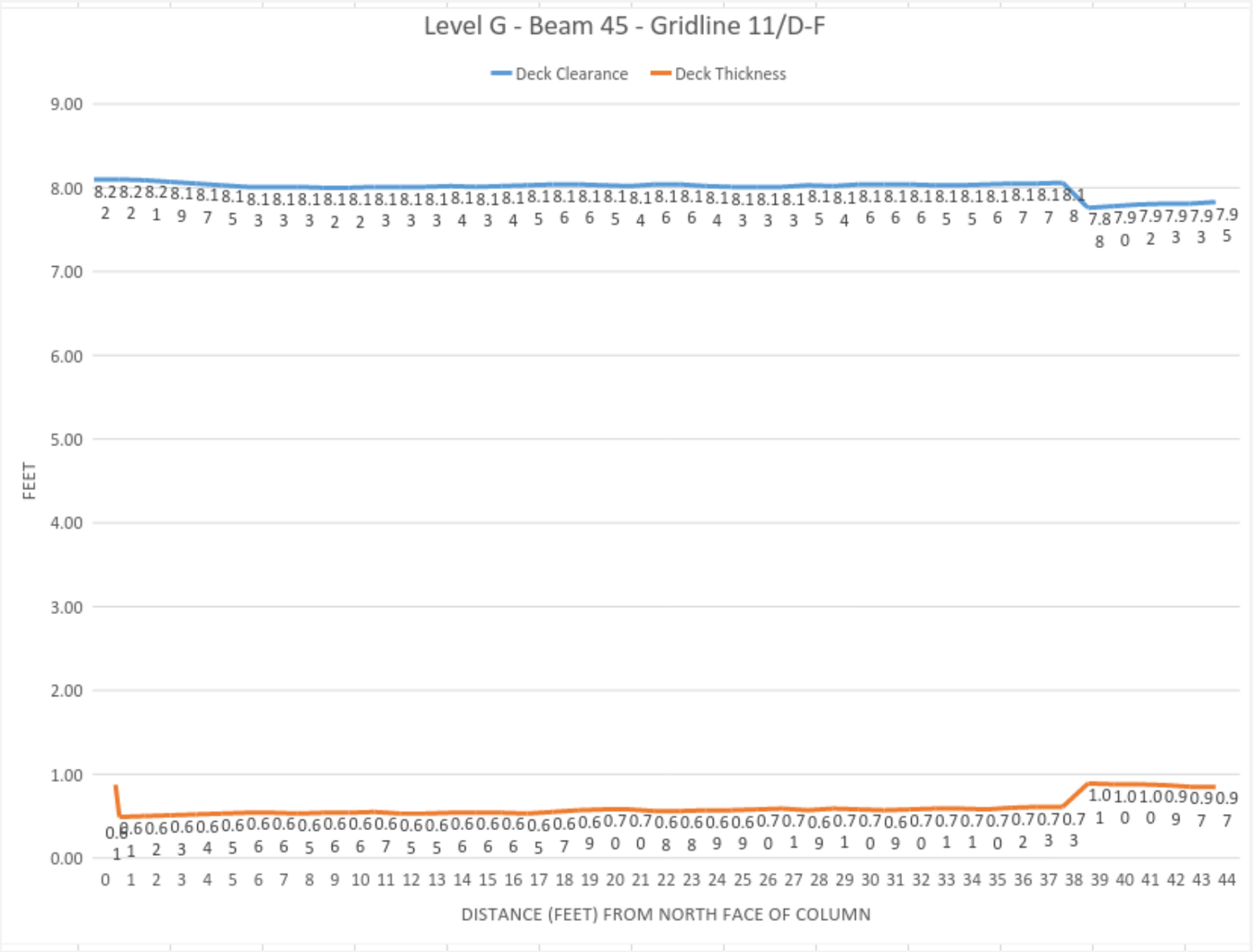


UC Berkeley Lower Sproul
Fire-Marshall Initiated Stair Survey
Computer Vision – AutoStair Detection

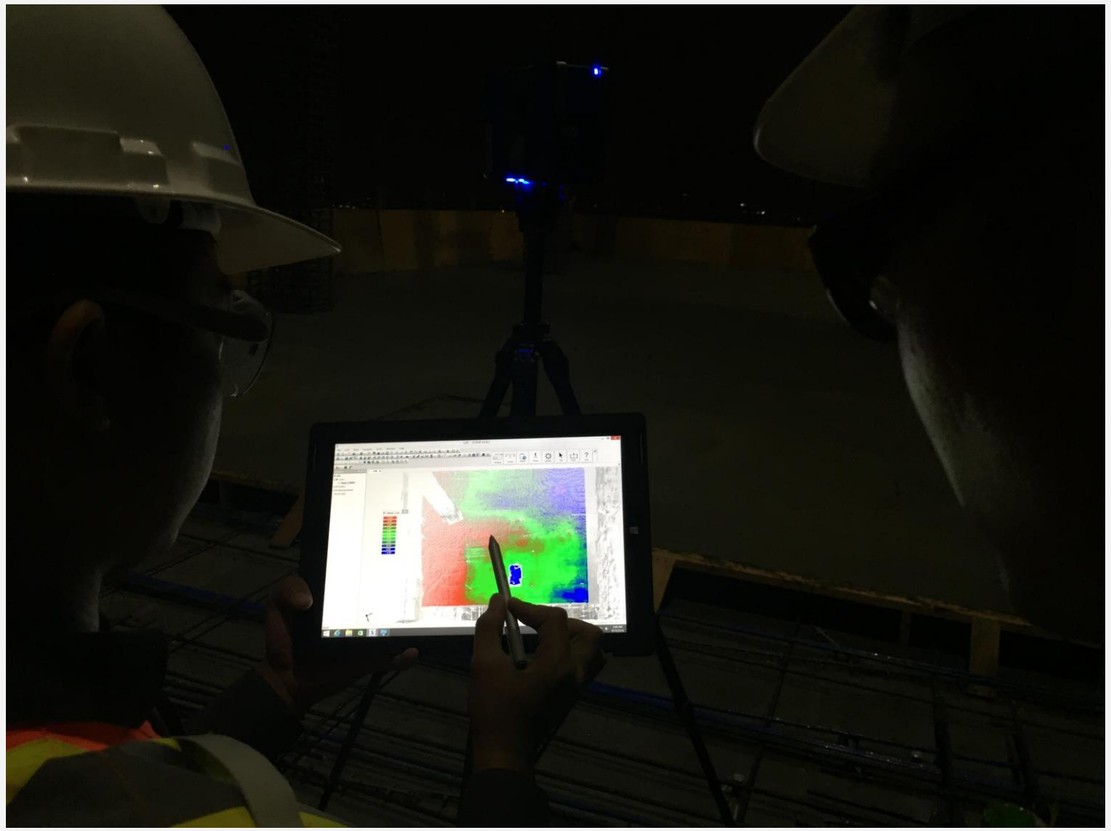
ICC INTERNATIONAL CODE COUNCIL®

Parking Garage Compliance

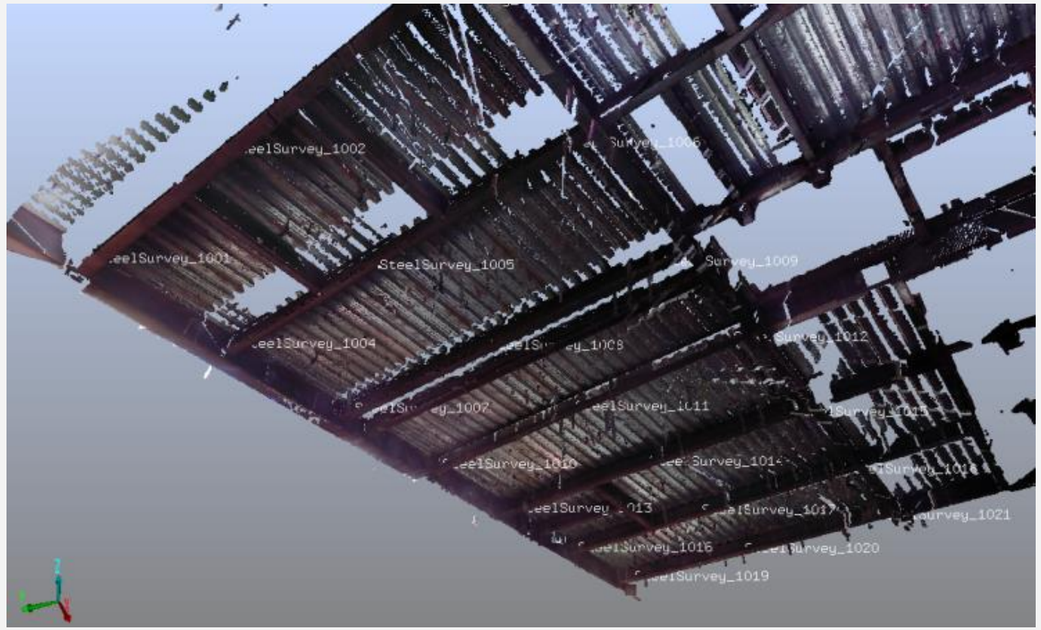




What if you could calculate concrete tolerances while it's still workable?



Building Survey



Courtesy of McCarthy Building Companies

What happens when our basic assumptions change?

"...since all of the infinite potential profiles to be seen by the traffic can not possibly be measured."

contract flatness and levelness tolerances on those floor installations primarily intended to support the operation of fixed-path vehicle systems (for example, narrow aisle warehouse floors).

NOTE 2—When the traffic patterns across a floor are random, (as is generally the case) evaluation of the floor's F_F Flatness and F_L Levelness will necessarily involve a random sampling of the surface, since all of the infinite potential profiles to be seen by the traffic can not possibly be measured. In those instances when the traffic across a floor will be confined to specific paths, however, the requirement for random sampling is eliminated, since the floor can indeed be inspected exactly as it will be seen by all of the traffic. In these special cases, rather than inferring the condition of the traffic paths from a random sample, it is far more useful to measure each of the traffic paths directly using continuous recording floor profilometer configured to run exactly in the traffic wheel paths. Such direct simulation measurements eliminate the inherent uncertainties of statistical sampling and provide profile information immediately applicable to the correction of the surface in way of the future traffic.

6. Apparatus

6.1 Point Elevation Measurement Device:

Industry standards?

"Measurement is the first step that leads to control and eventually to improvement."

— *H. James Harrington*

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Beam Erection
Tolerances

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CODE COUNCIL®

What might a future standard look like?

- More repeatable
  - Basically making the 2D become 3D
- Take advantage of all the information
- can be met reasonably by a typical contractor
- A standard score typical to FF/FL for pass/fail
- Be able to be met using current tools
- Be easily relatable to old standard, I.e. Same score

Contact information

Feedback or questions

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Questions & Discussion