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
- Understand the current discussions revolving around the development of new ACI standards that leverage 3D laser scanning

Agenda

new ways to measure floor flatness

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

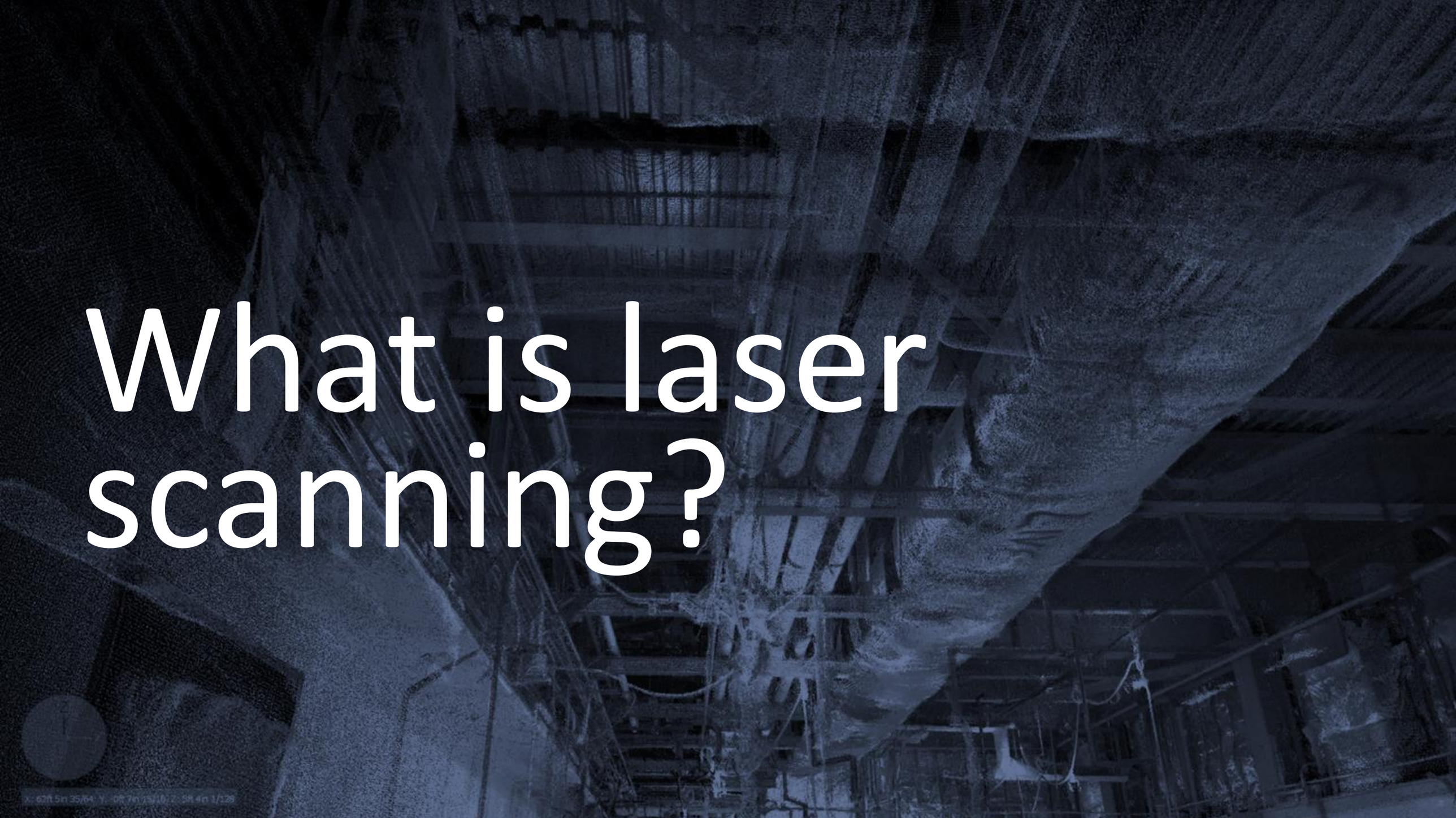
Introductions

Get to know your presenters

PRODUCT MANAGER

Philip Lorenzo

- Rithm founder
- Chair of Technology US Institute of Building Doc.
- ASTM 1155 Committee (2014 Revision)
- UC Berkeley Guest Lecturer
- ACI Laser Scanning Committee



What is laser scanning?

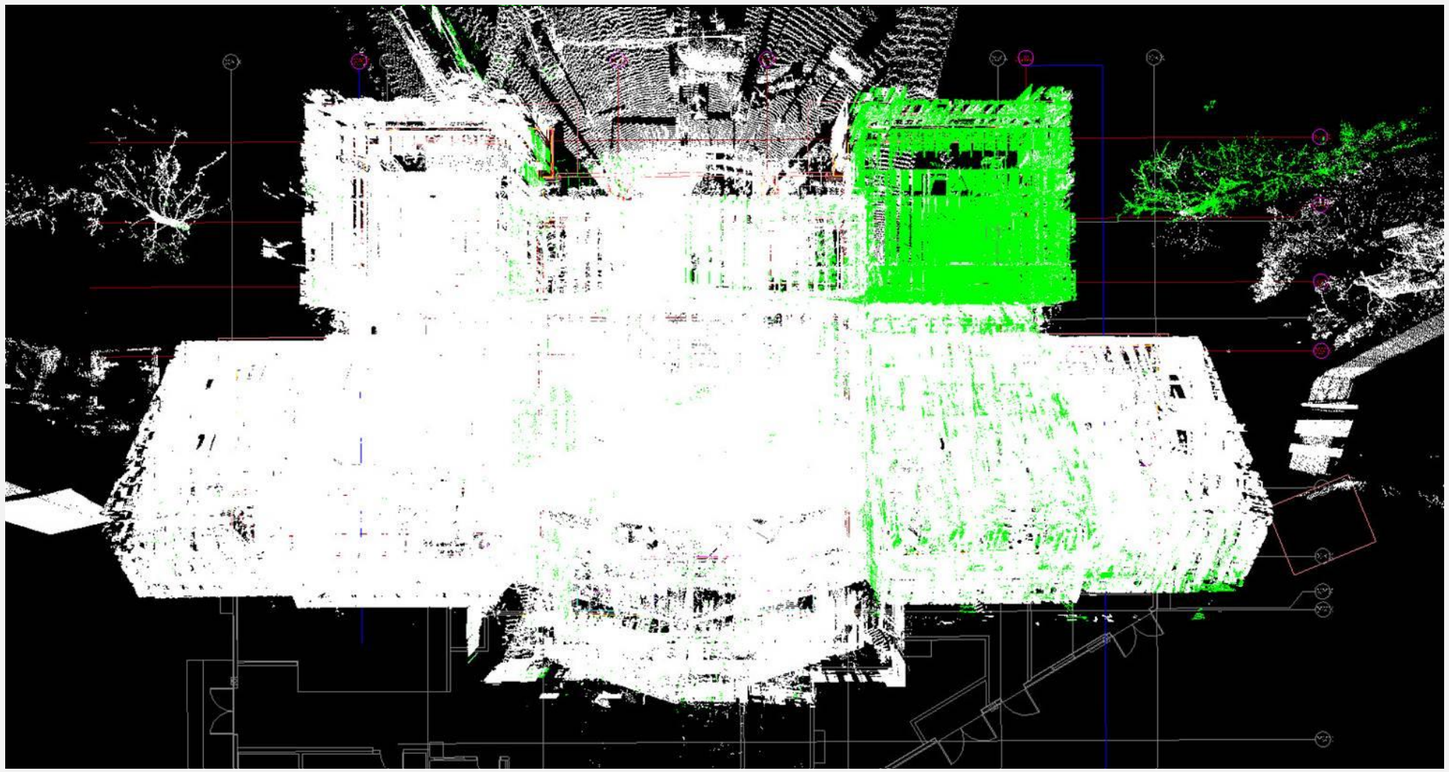
What is a laser scanner?

- 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

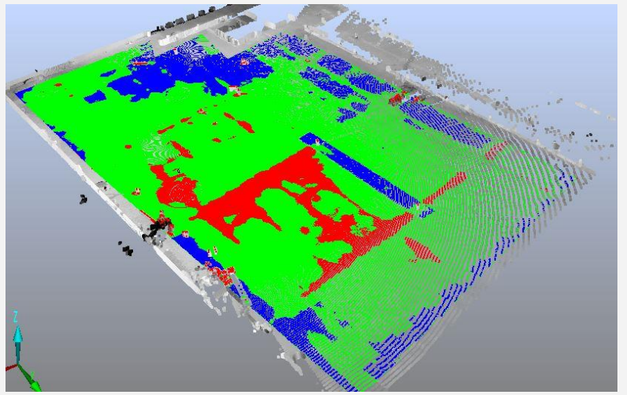
About Philip

- 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

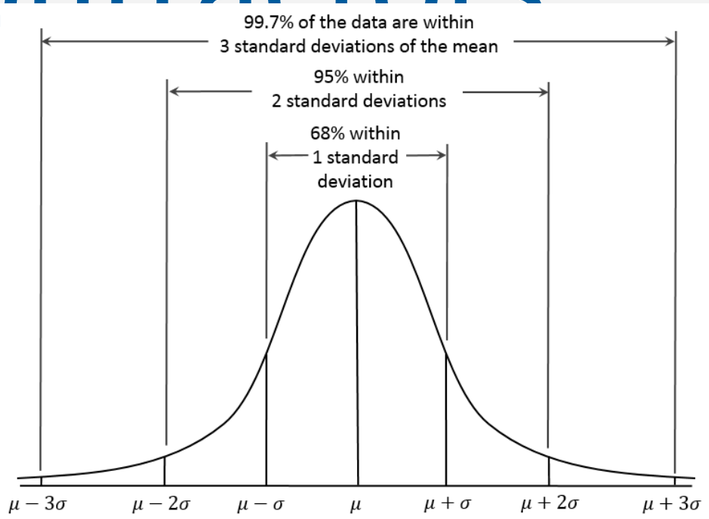
USIBD™
U.S. Institute of
BUILDING DOCUMENTATION

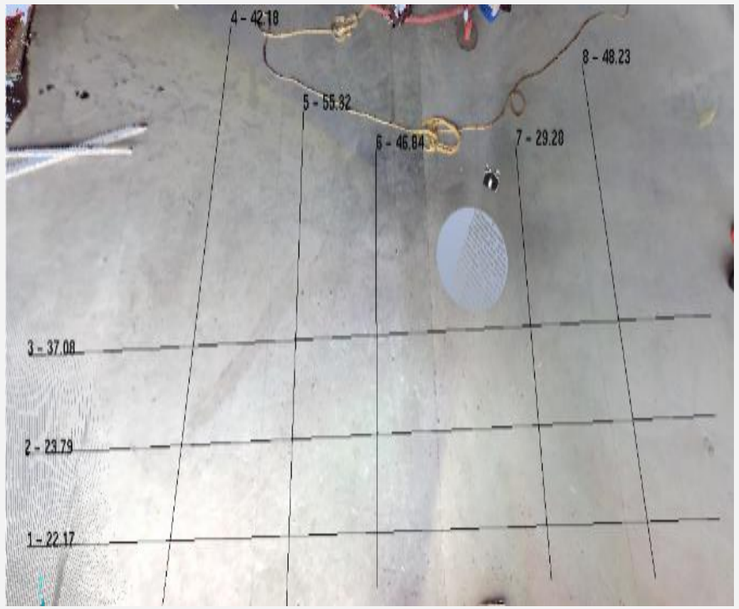
ICC
INTERNATIONAL
CODE COUNCIL®

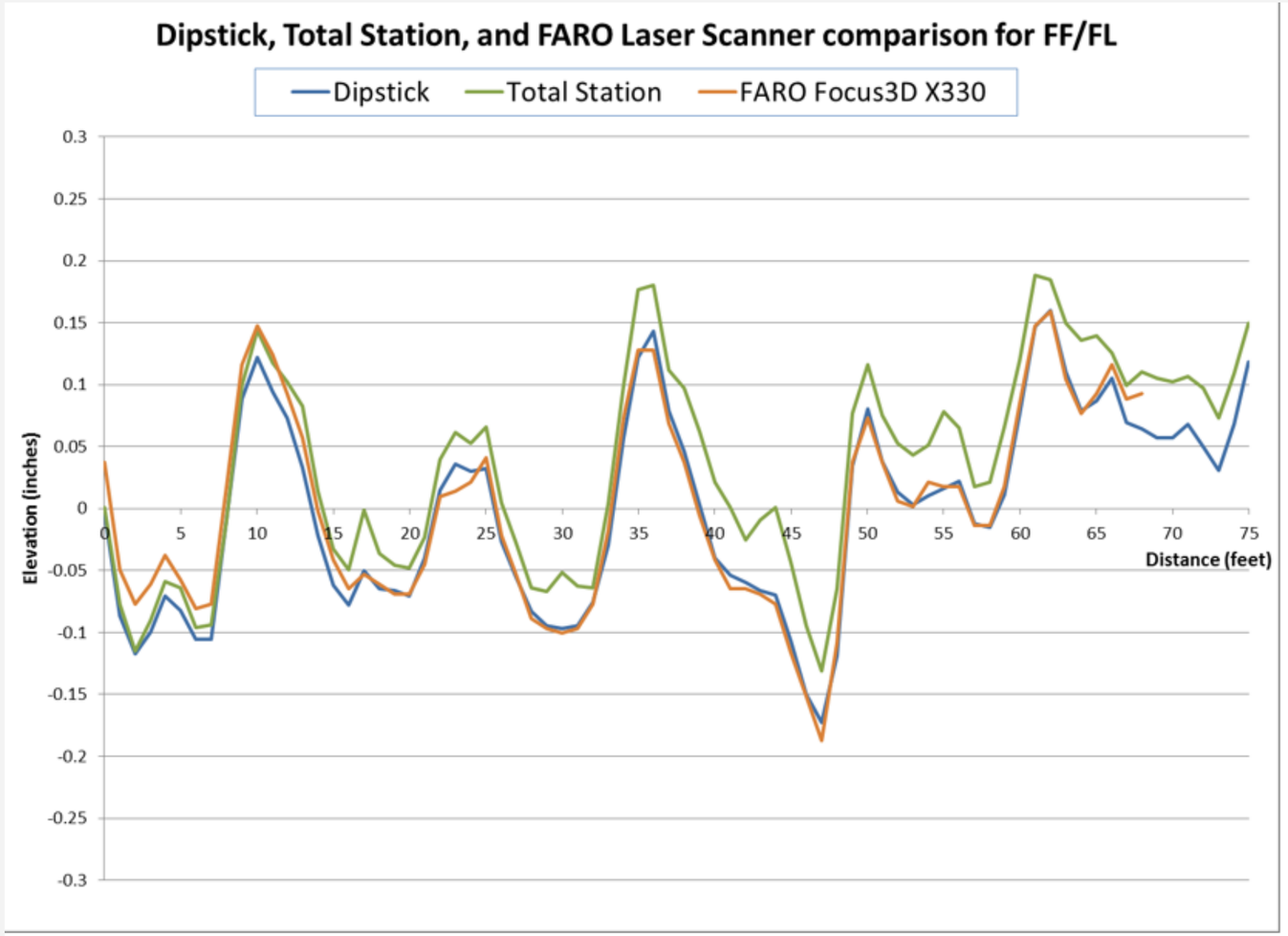
About Rithm

- Concept started
- Join ASTM 1155 Committee
  - 2014 Revision – “Laser Imaging” as valid apparatus
- Adoption across industry
  - Map across US
  - List of talks, publications, etc.
  - Faro
  - Laser FF
- DPR Construction
  - Adoption in SoCal

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

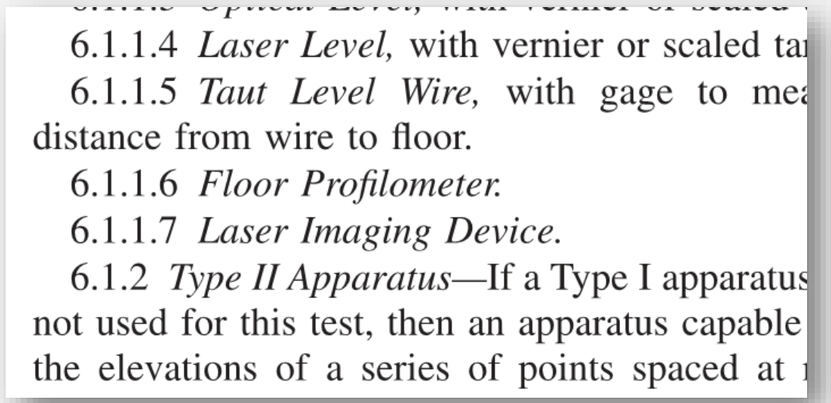
- Understanding the standards
- Accuracy of new methods
- Lack of trust
- Cost vs value

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

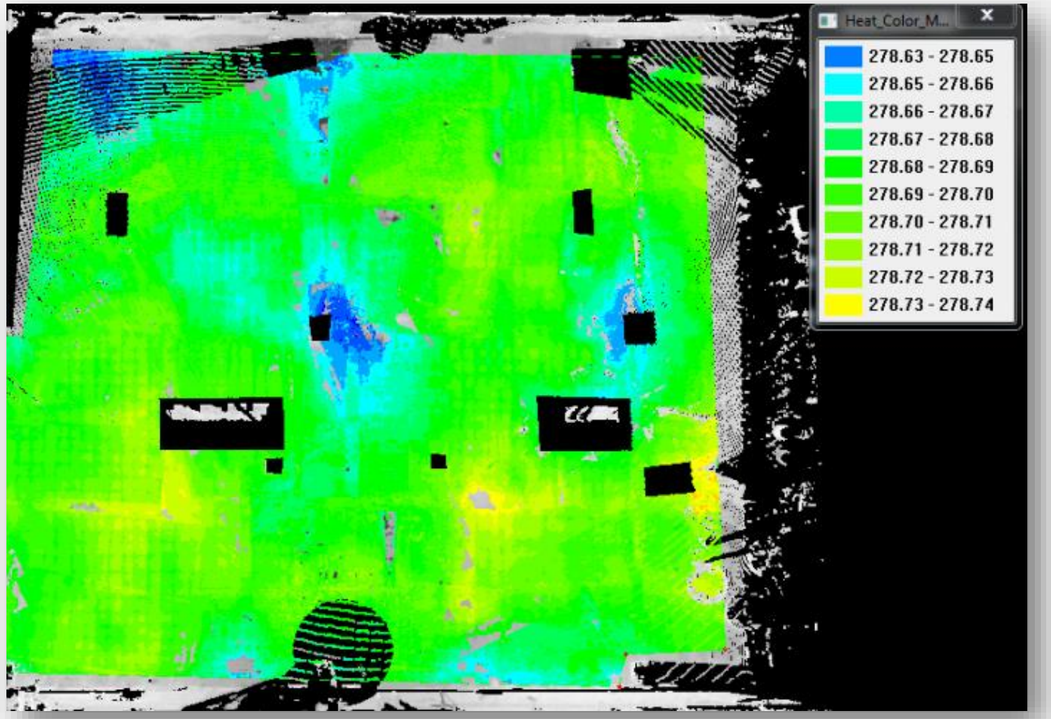
- Study current standards
- Compare equipment function & cost
  - Dipstick
    - Less expensive, established
    - Single purpose equipment & data
  - Laser scanner
    - Multiple uses, lots of data
    - Higher cost, learning curve

Concrete Laser Scanning

Implementation at DPR

NEXT STEPS

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

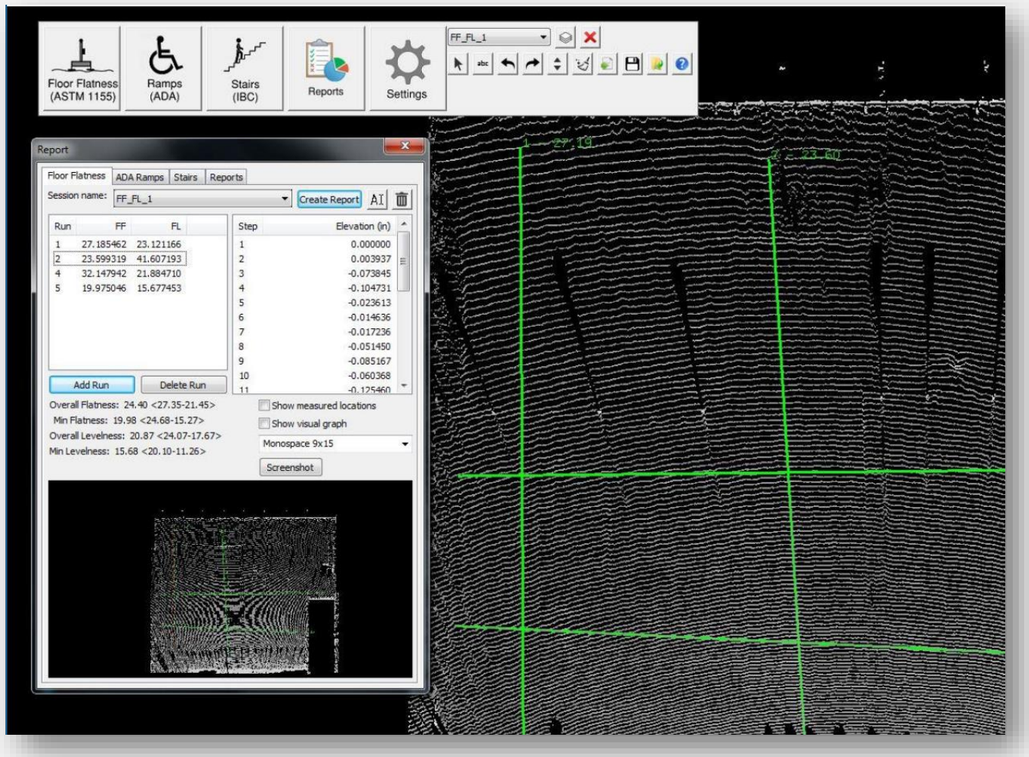


Concrete Laser Scanning

Implementation at DPR

NEXT STEPS

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

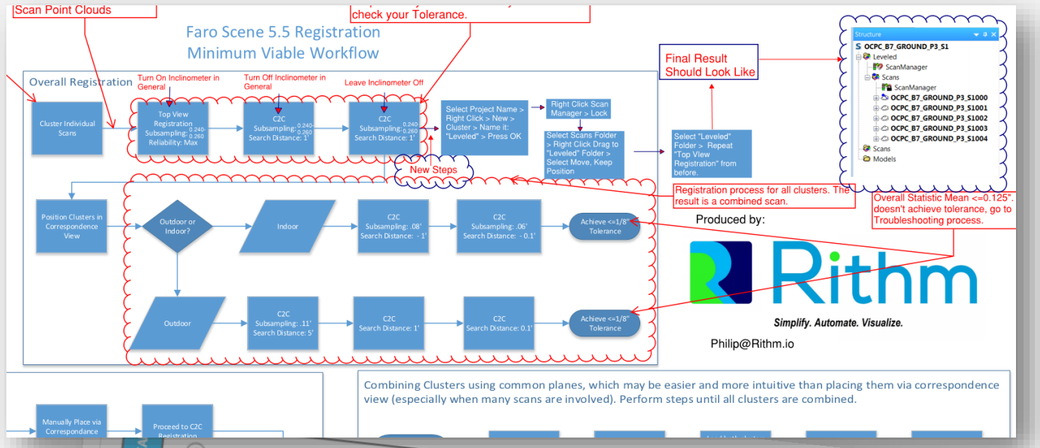


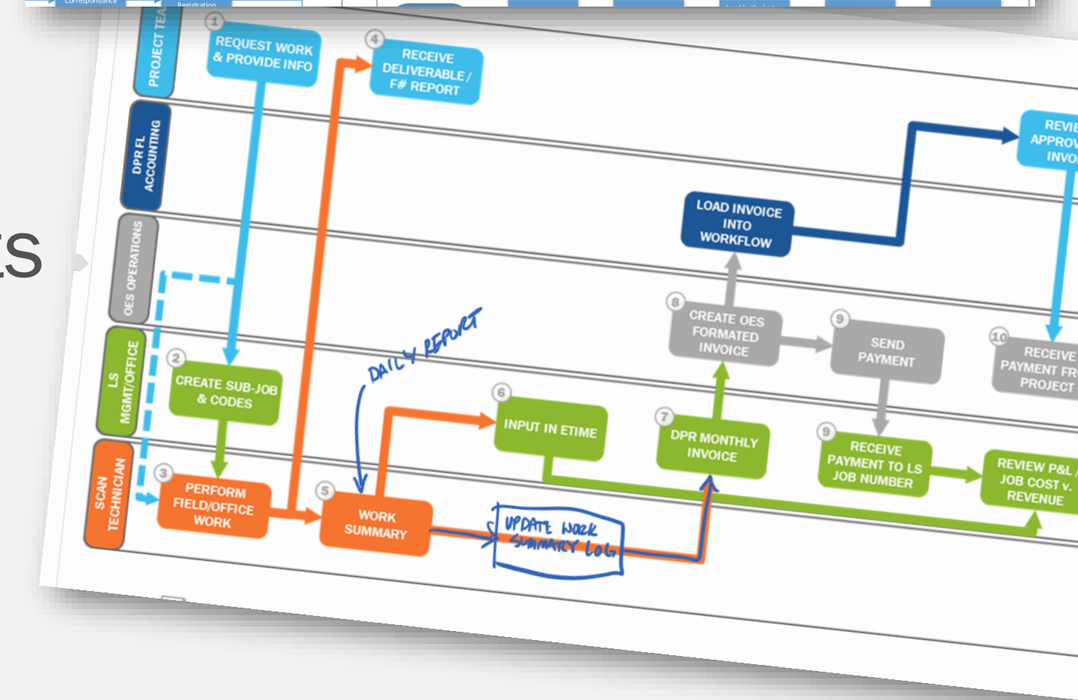
Concrete Laser Scanning

Implementation at DPR

NEXT STEPS

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



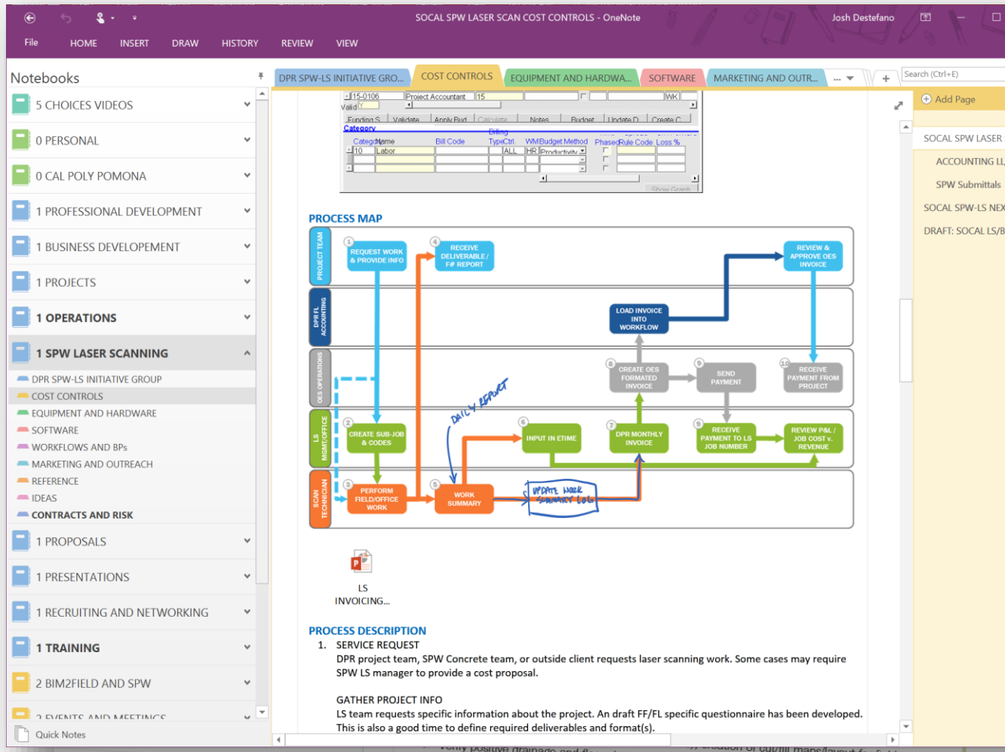


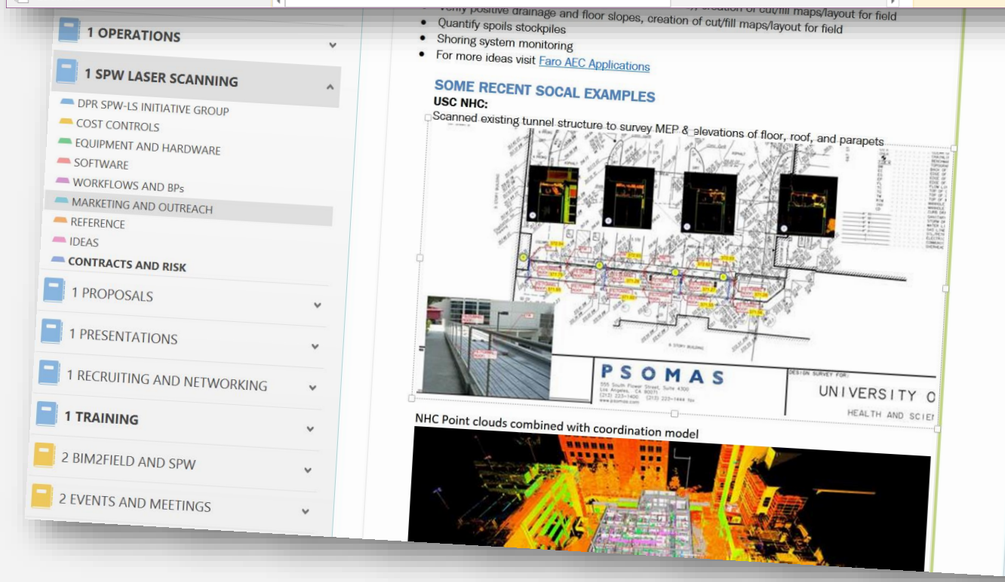
Concrete Laser Scanning

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: _____ LS JOB NUMBER: D1-16801- 01
JOB NAME: OCPC
ADDRESS: Alton Pkwy & Barranca Pkwy MAIN PROJECT NO: D1-X15001-00
COMPANY: DPR Construction 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

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**

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

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?

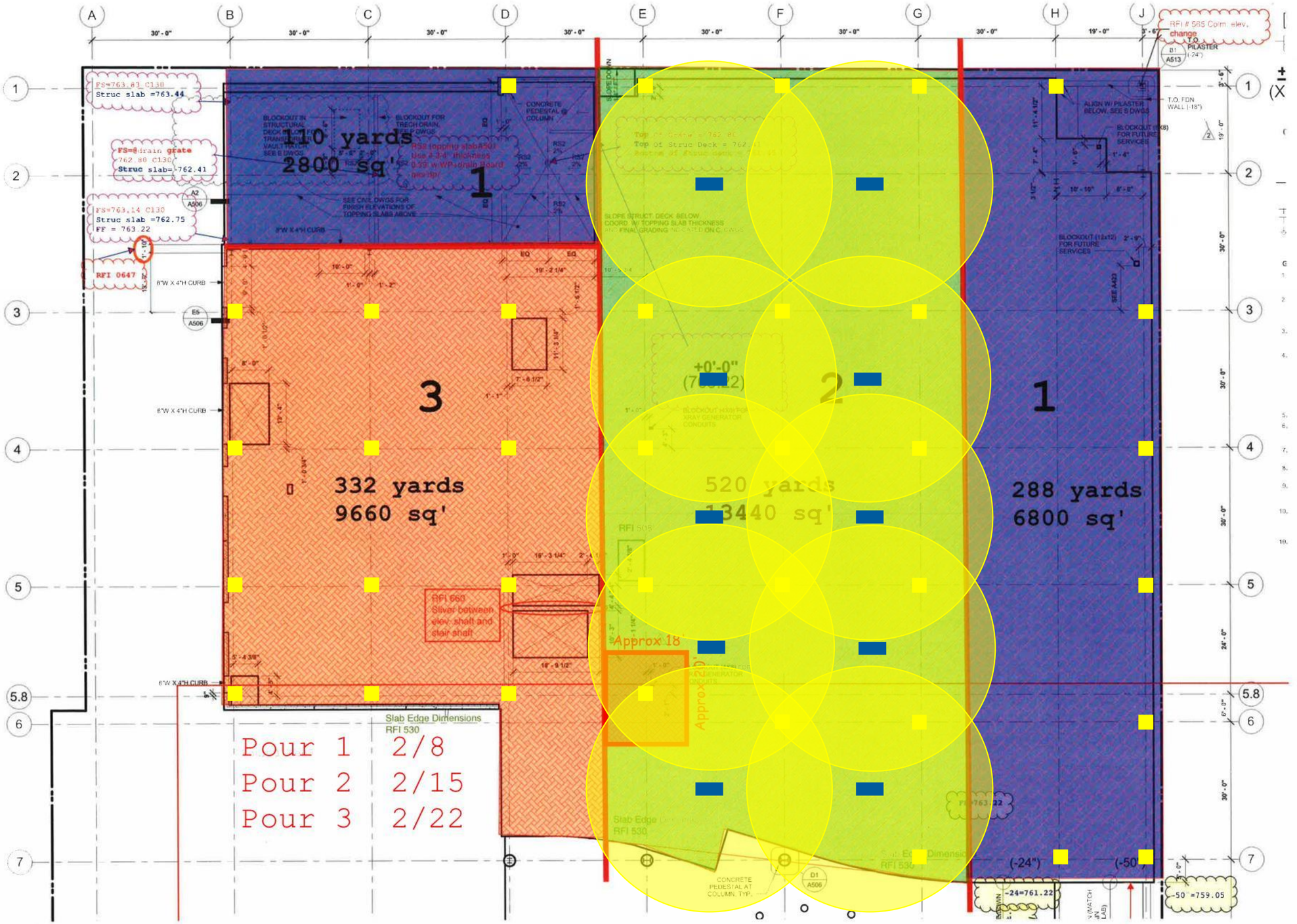
PERFORM SCAN

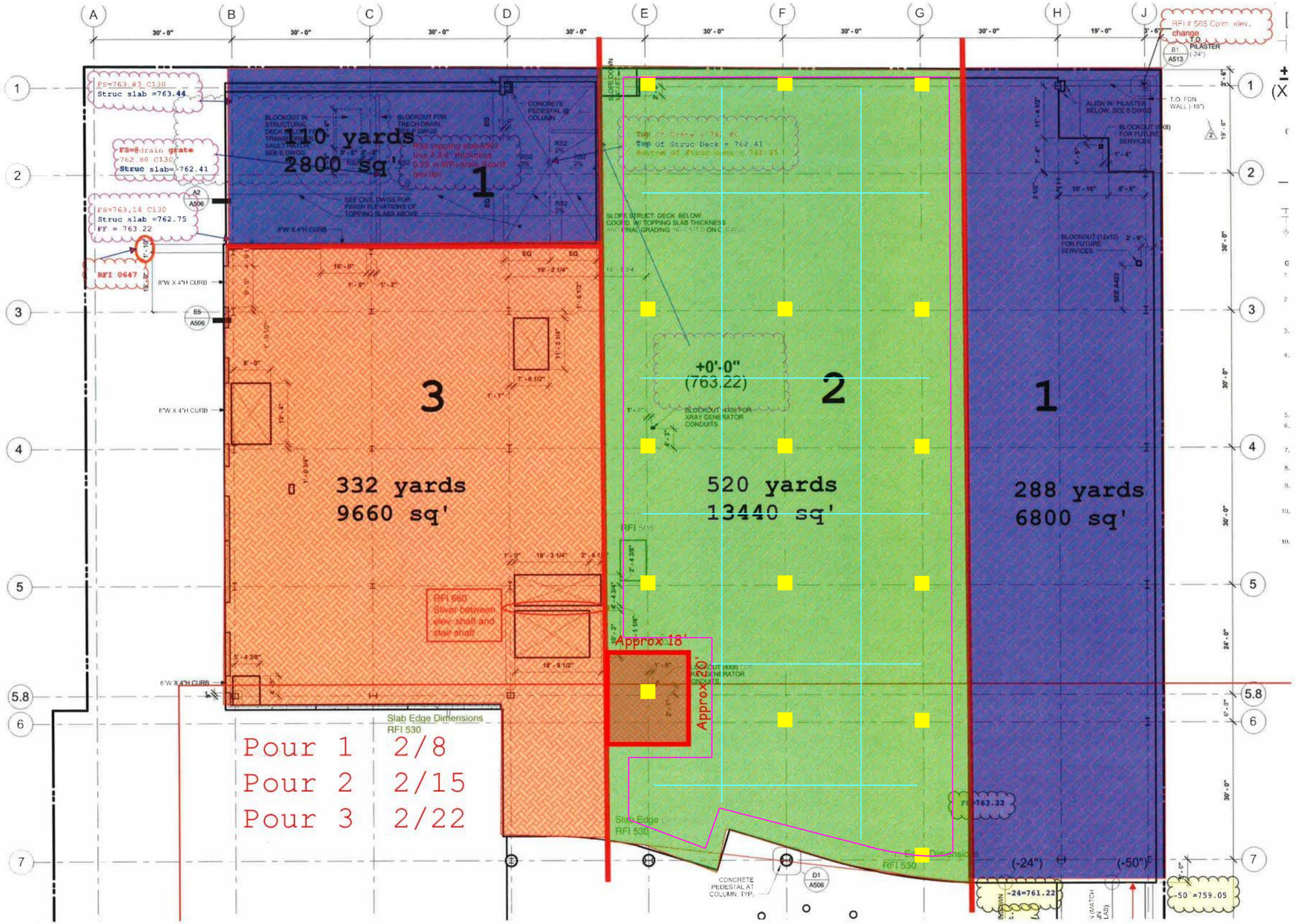
- Best practices during scanning:
  - Limit foot traffic
  - Remove debris, equipment & material

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'
Pour 1 2/8
Pour 2 2/15
Pour 3 2/22
Slab Edge Dimensions
RFI 530
RFI 660
Sliver between elev. shaft and stair shaft
Approx 18'
Approx 20'
RFI 0647
RFI # 585 Conn. elev. change
Struc slab =763.44
Struc slab =762.41
Struc slab =762.75
FF = 763.22
8"W X 4"H CURB
CONCRETE PEDESTAL AT COLUMN, TYP.
T.O. PILASTER
T.O. FDN WALL (-18")
(-24")
(-50")
-24"=761.22
-50 =759.05


110 yards
2800 sq'
1
332 yards
9660 sq'
3
+0'-0"
(763.22)
520 yards
13440 sq'
2
288 yards
6800 sq'
1
Struc slab =763.44
Struc slab =762.41
Struc slab =762.75
FF = 763.22
RFI 0647
RFI 660
Sliver between elev. shaft and stair shaft
RFI 508
Approx 18'
Approx 20'
Slab Edge Dimensions
RFI 530
Pour 1 2/8
Pour 2 2/15
Pour 3 2/22
RFI # 565 Conc. elev. change
T.O. PILASTER
T.O. FDN WALL (-18")
Top of Struc Deck = 762.41
SLOPE STRUCT. DECK BELOW
8"W X 4"H CURB
CONCRETE PEDESTAL AT COLUMN, TYP.
(-24")
(-50")
-24=761.22
-50 =759.05

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

Subject: Concrete F# Number Measurement / Concrete Floor Profiling

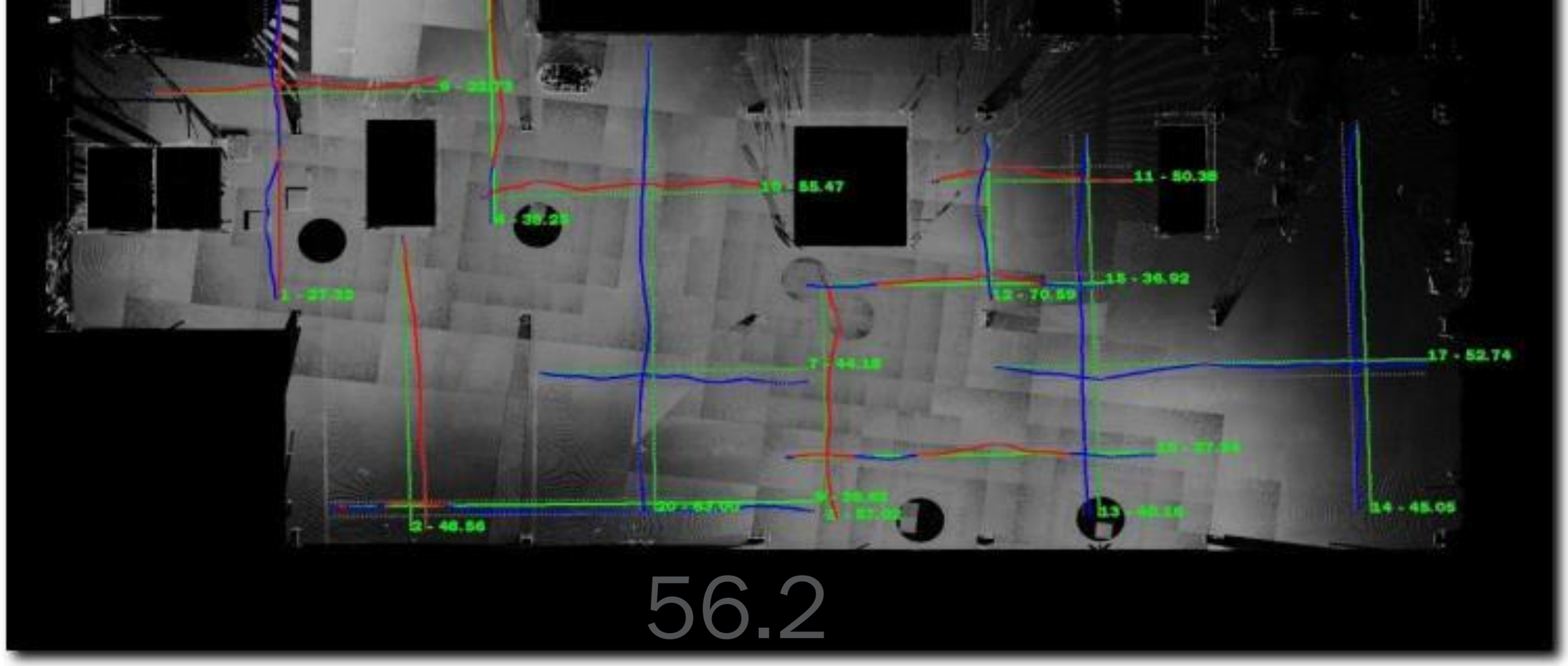
On 11-3-15, [redacted] performed F-Number measurement for the concrete floors at the project listed above. Testing was performed in accordance with ASTM E1155. The test sections, calculations, graphs and floor map are enclosed for your records.

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,



Inspection Information

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

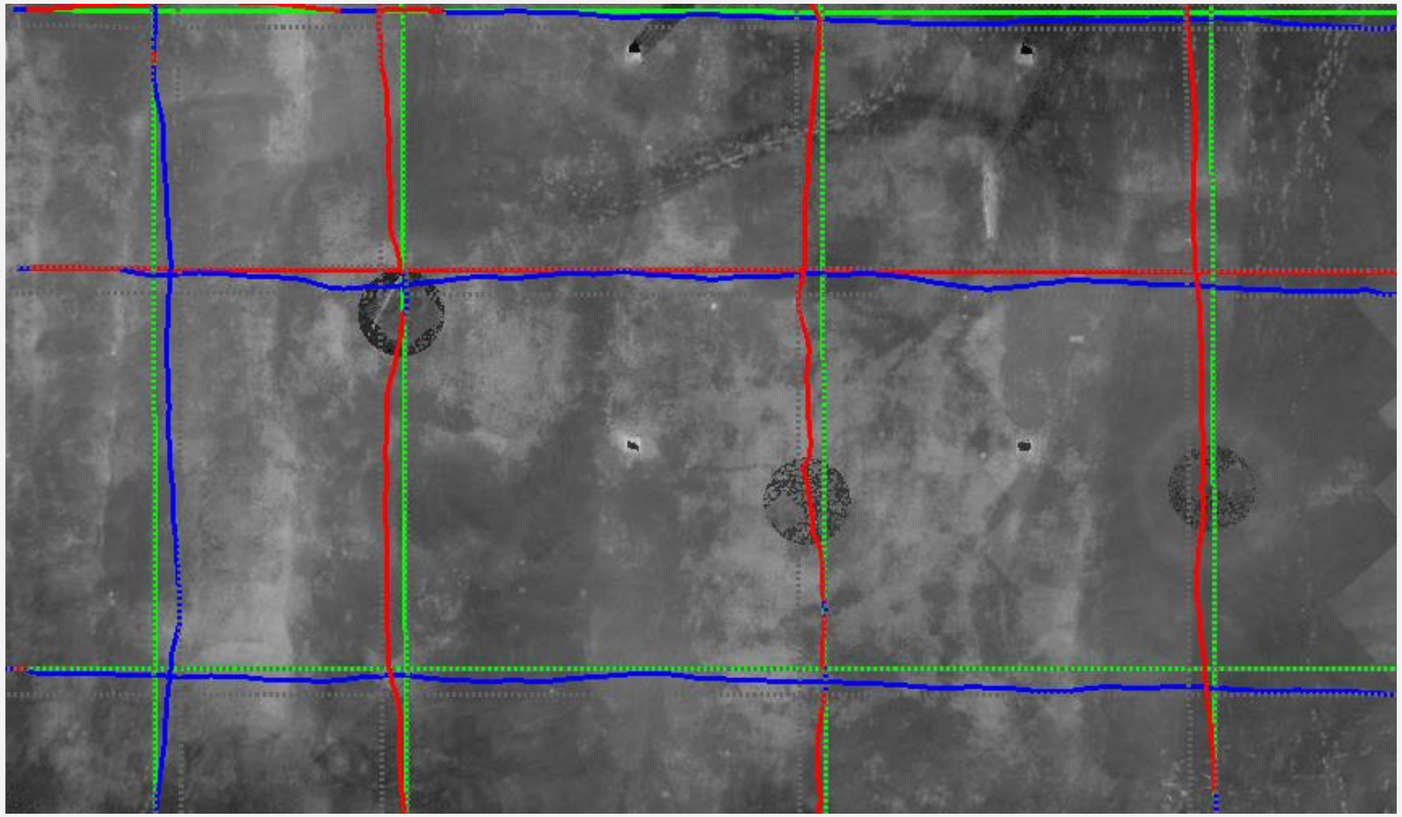

85/6
F-Number reports to date / projects

What future does laser scanning have in the concrete industry?

Limitations of Current Process

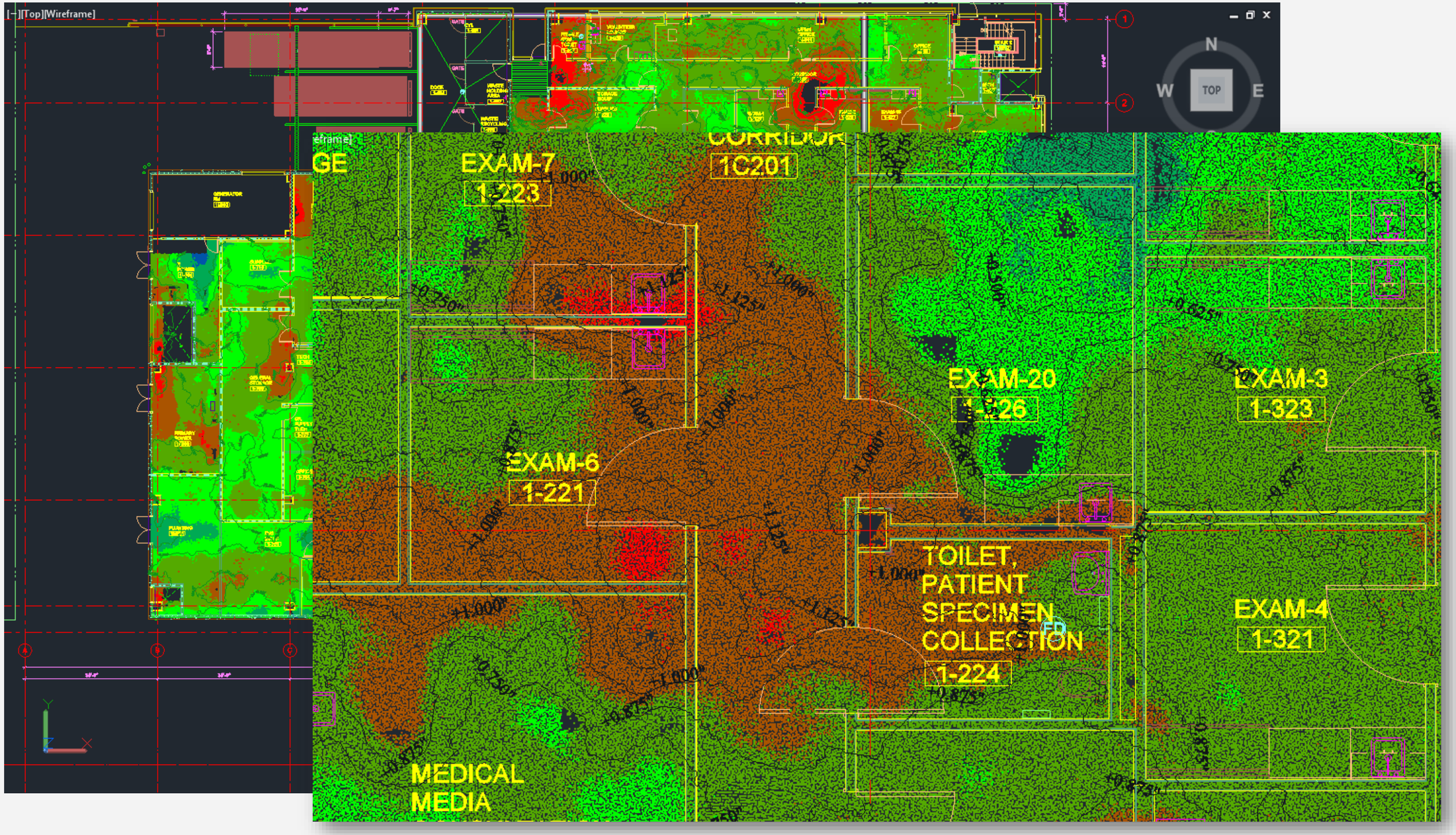
Descriptive text and content

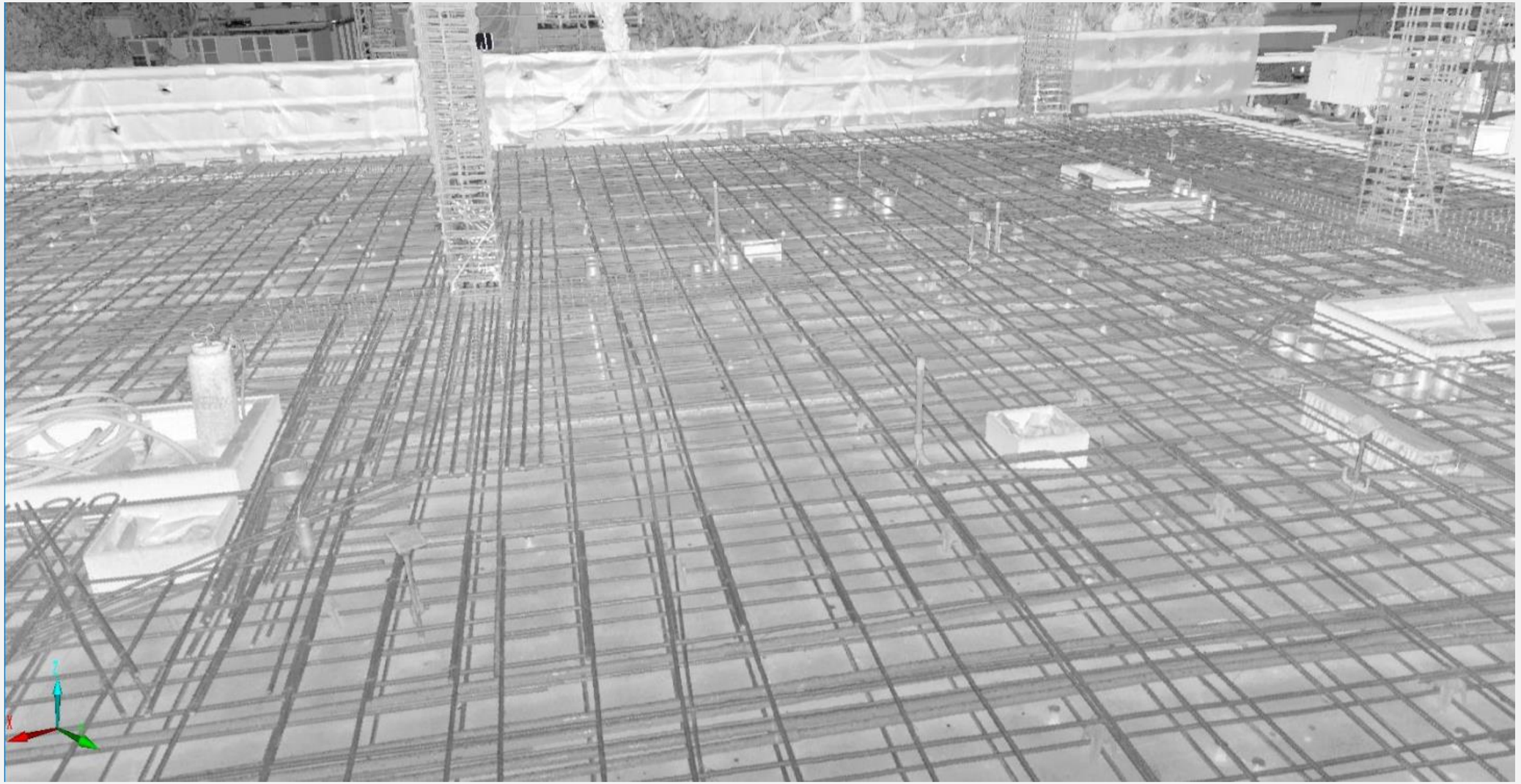
- Does not capture what is in between runs
  - Miss high/slows
  - 1-1/2” of shim on extra-deflecting slabs

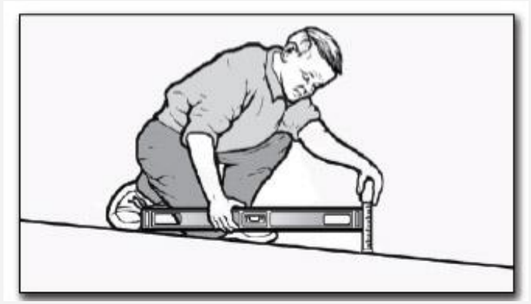


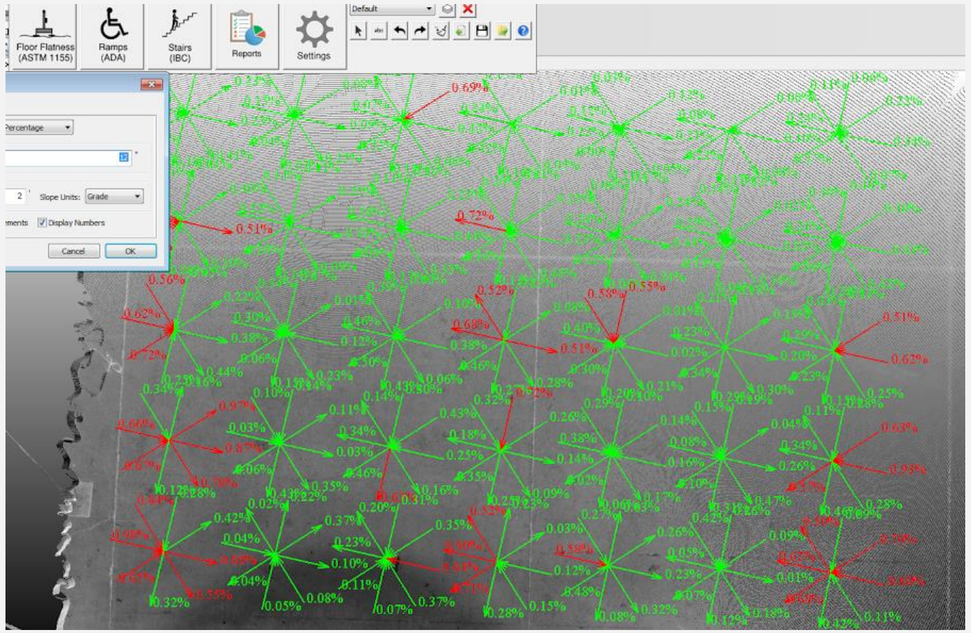
How might this technology improve the concrete quality control process?

- 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


[−][Top][Wireframe]
N
W
TOP
E
GE
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

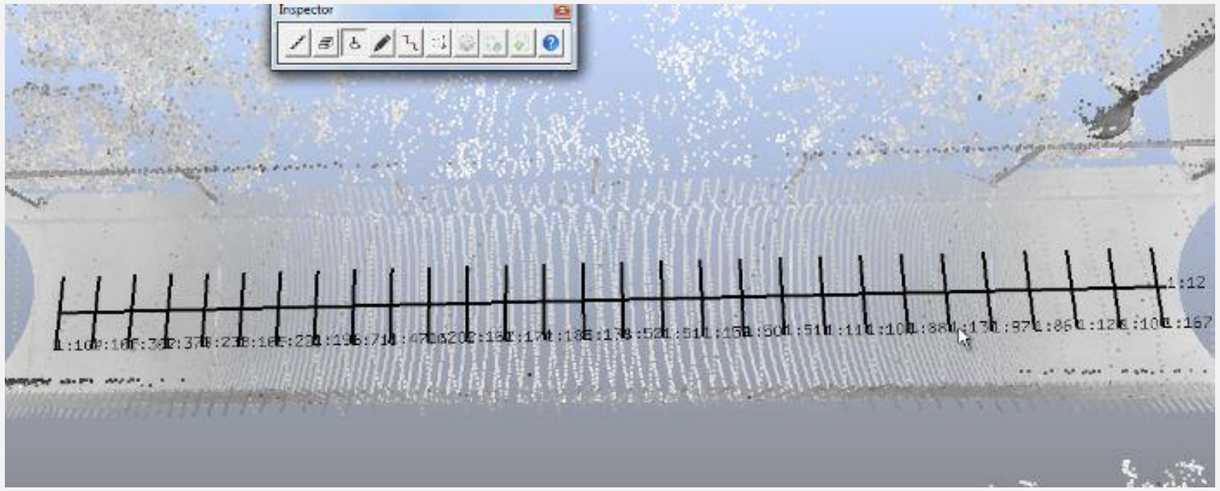




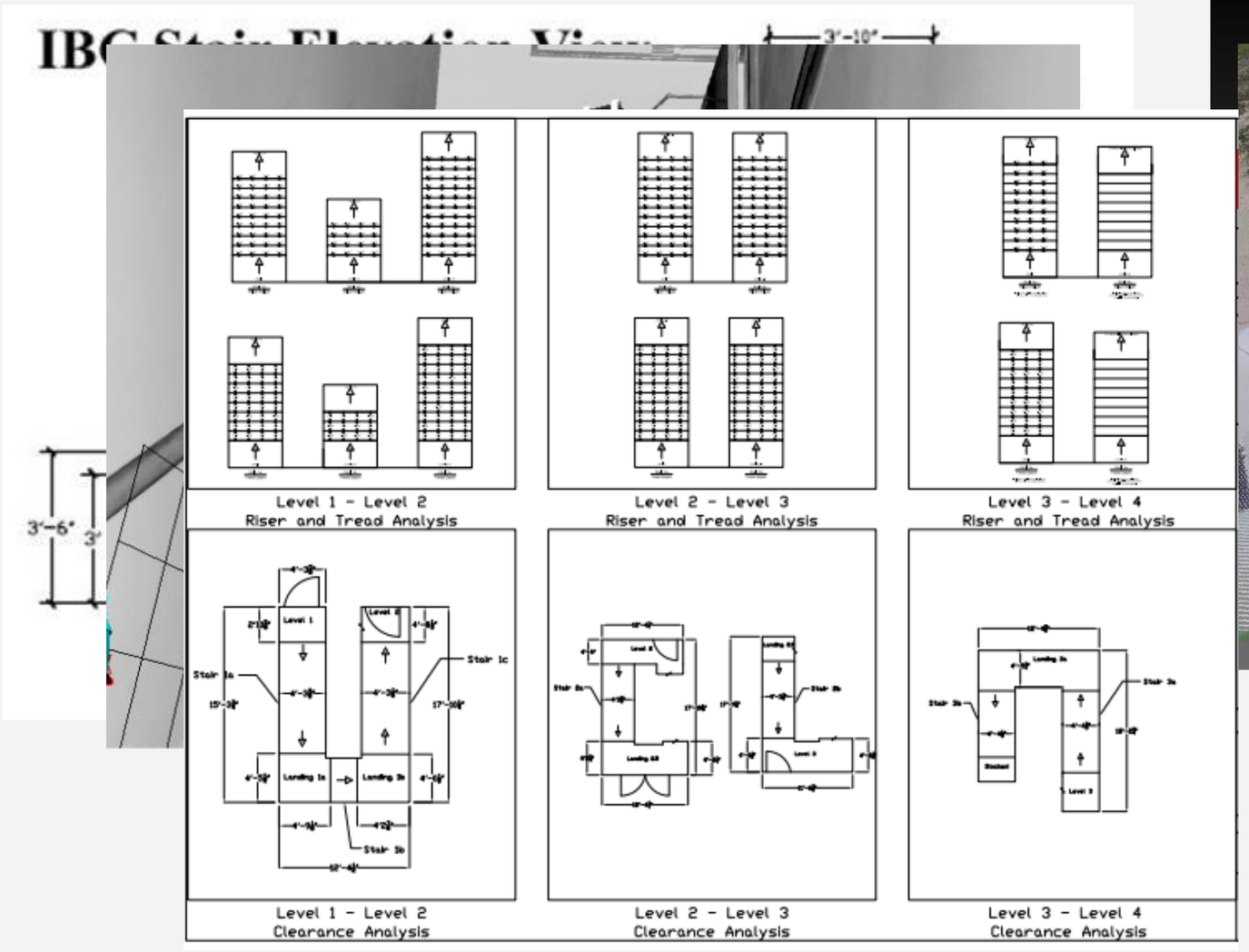


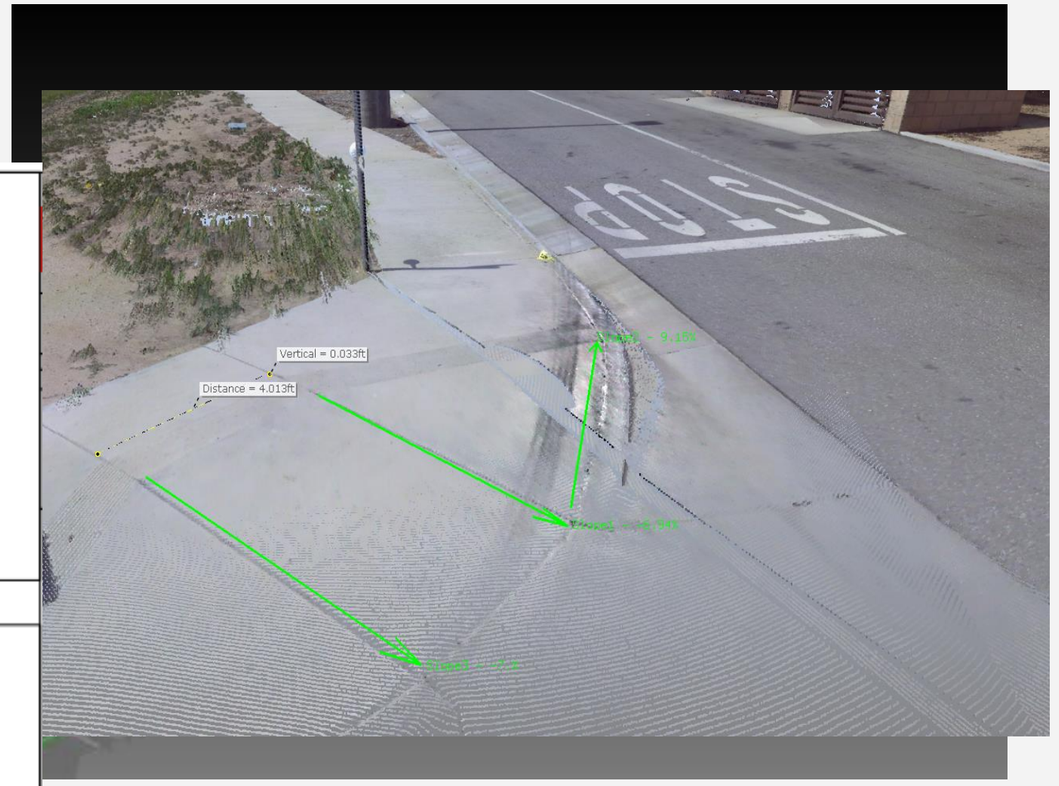
Why?

- Pass Inspection
- Prevent Litigation



Code Compliance – Stairs, Ramps

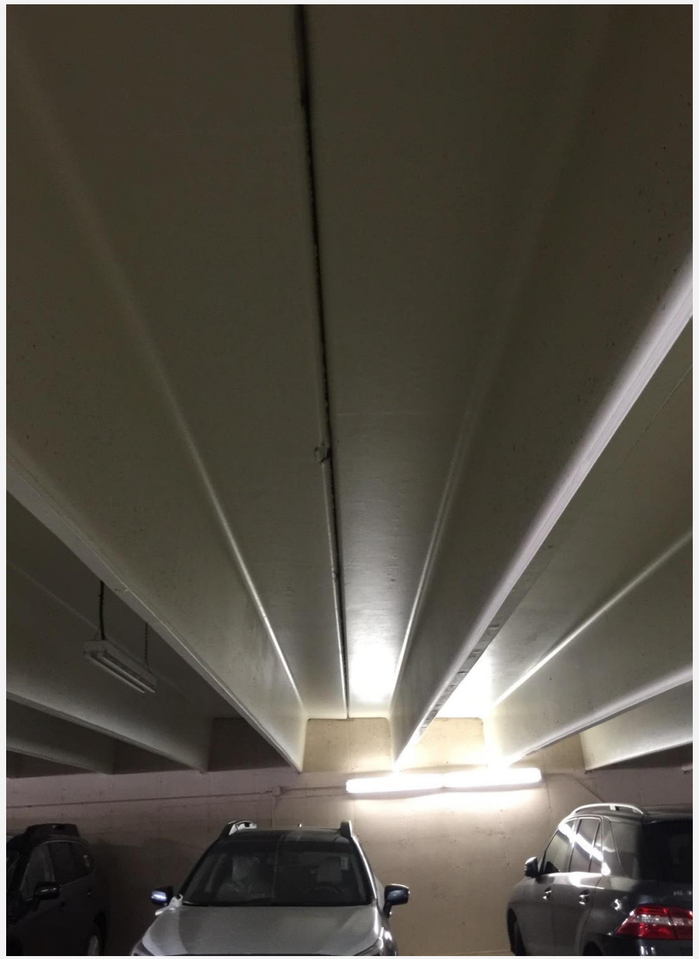


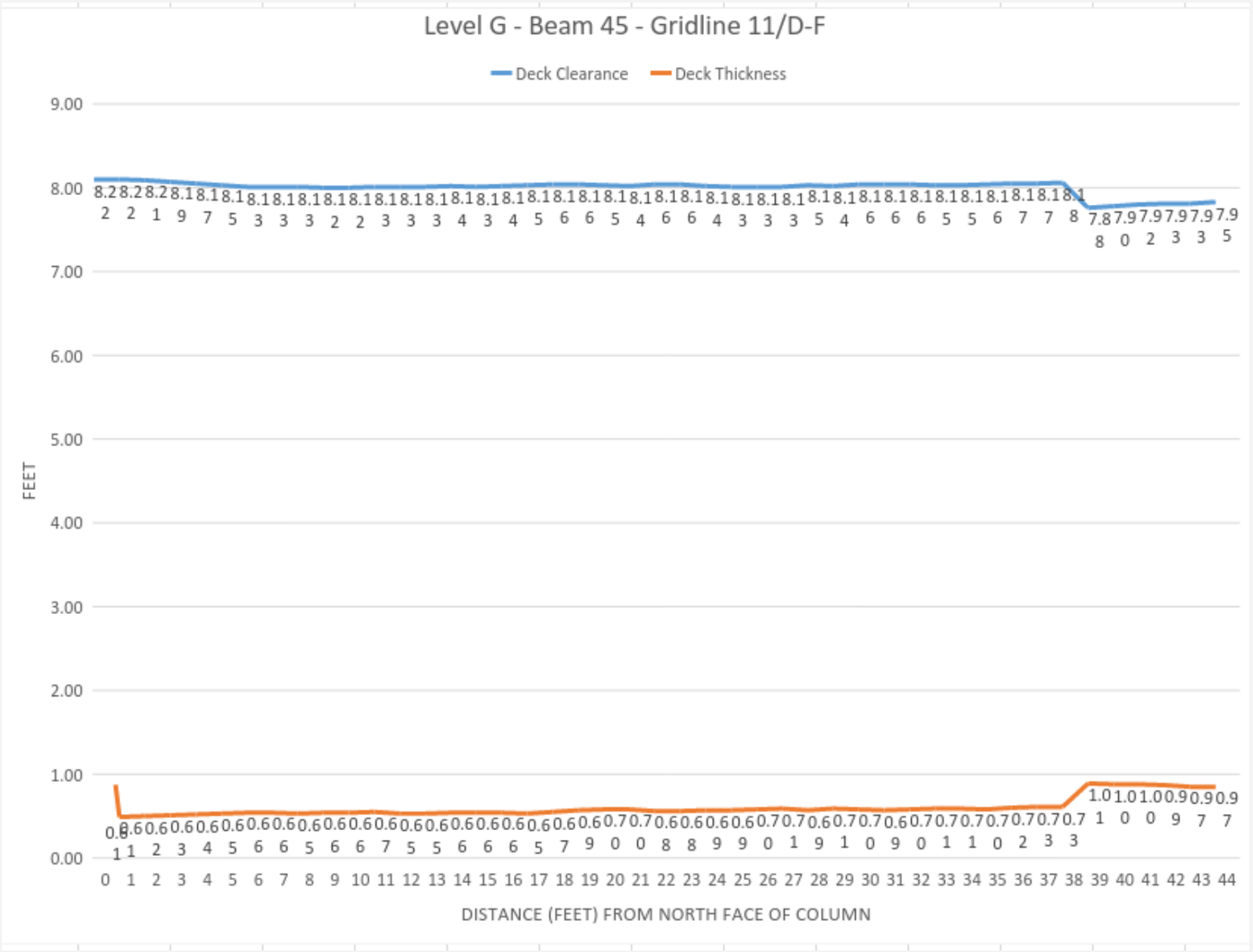


UC Berkeley Lower Sproul
Fire-Marshall Initiated Stair Survey
Computer Vision – AutoStair Detection

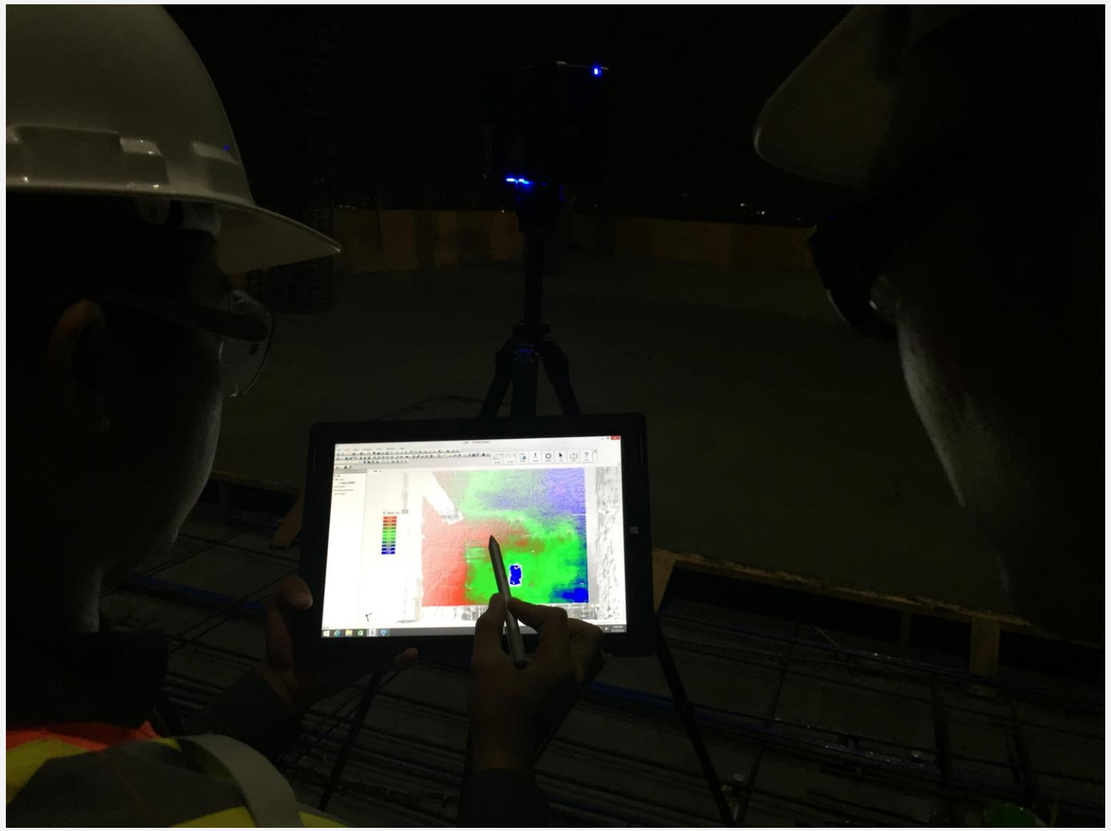
ICC INTERNATIONAL CODE COUNCIL®

Parking Garage Compliance

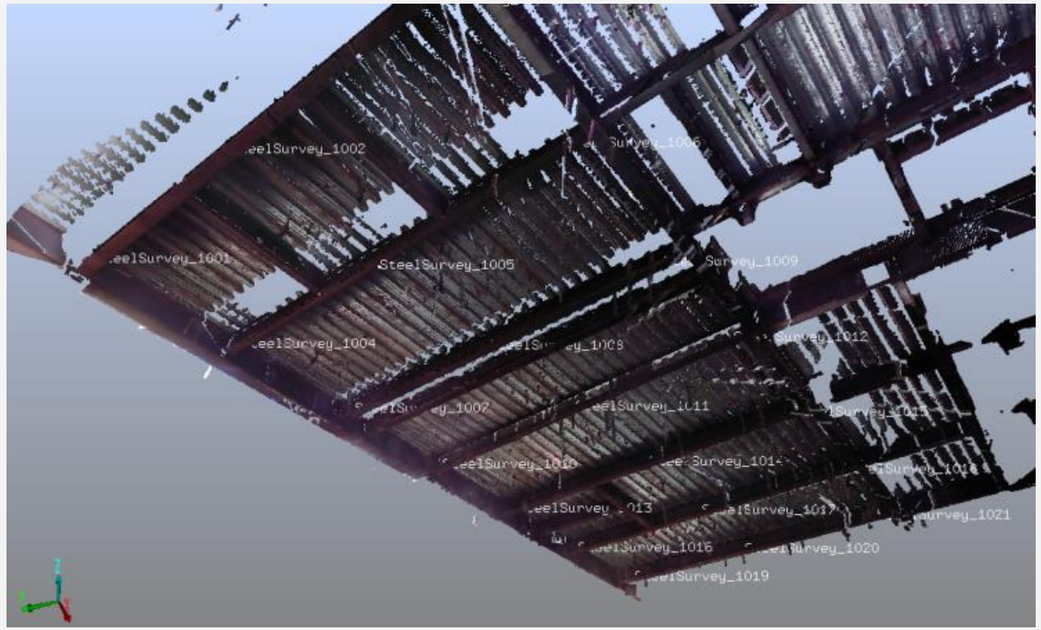




What if you could calculate concrete tolerances while it’s still workable?



Building Survey



Courtesy of McCarthy Building Companies

What happens when our basic assumptions change?

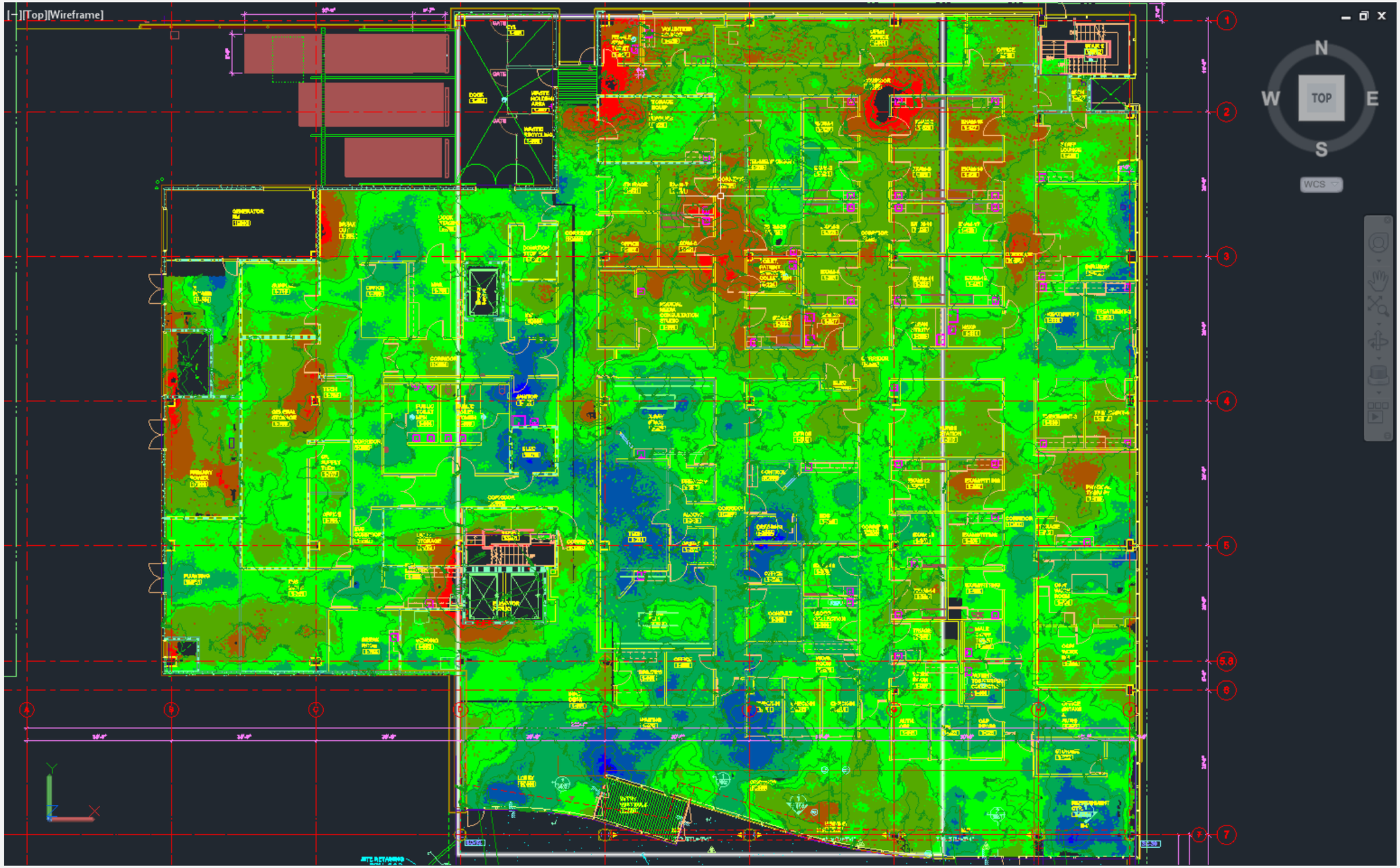
"...since all of the infinite potential profiles to be seen by the traffic can not possibly ne measured."

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:


[–][Top][Wireframe]
N
W
TOP
E
S
WCS

Source of a problem?

"Measurement is the first step that leads to control and eventually to improve[illegible]"

— *H. Jar[illegible]ngto[illegible]*

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Tolerances

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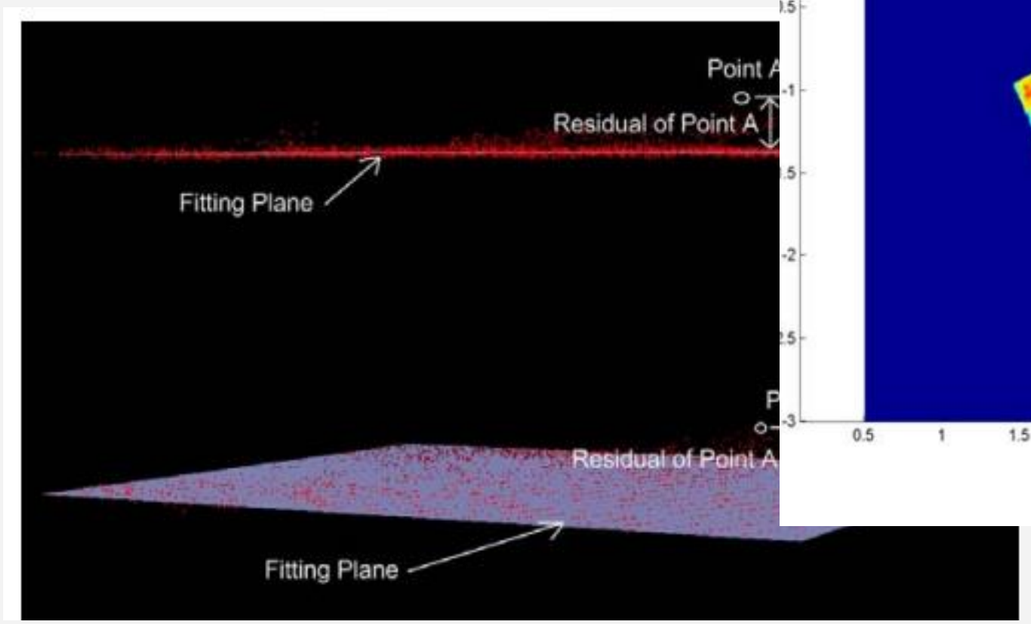
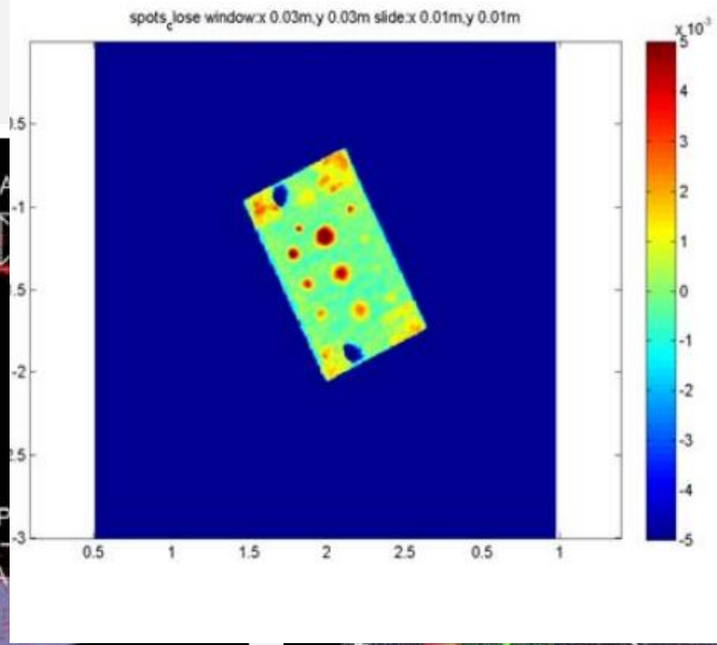
What might a future standard look like?

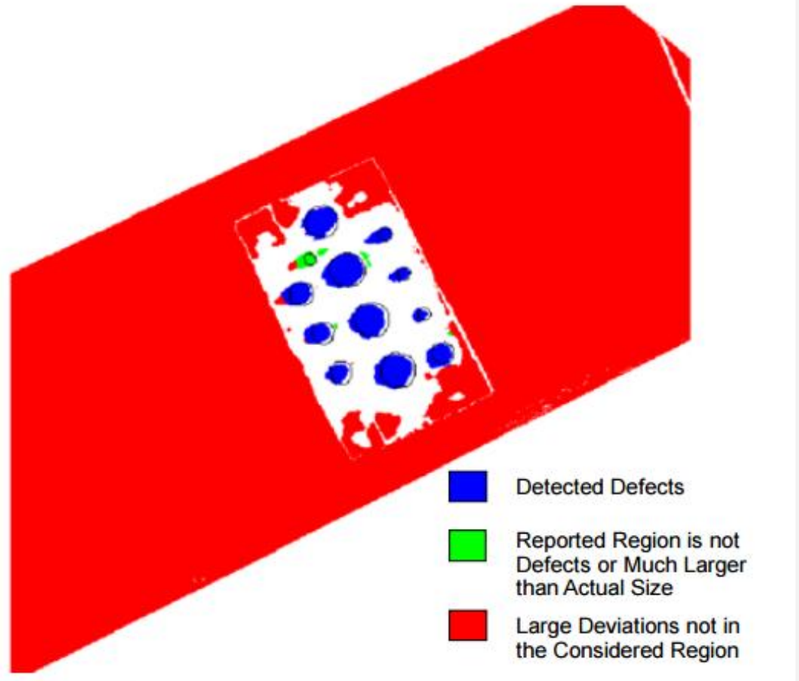
- More repeatable
  - Basically making the 2D become 3D
- Take advantage of all the information
- can be met reasonably by a typical contractor
- A standard score typical to FF/FL for pass/fail
- Be able to be met using current tools
- Be easily relatable to old standard, I.e. Same score

Partnering with Universities

ce plane at that window's center, all of which are combined to form the deviation image.







Pingbo Tang, PhD, Arizona

Call to Action

- Fund research
- Participate in discussion for new standards
- Allow your projects to be tested and investigated
- Adopt the technology!

Questions & Discussion