Digitalization Of Construction:

What Does It Mean And How To Do It?

Martin Fischer

- Stanford University
  - Kumagai Professor in the School of Engineering
  - Professor, Civil & Environmental Engineering
  - Director, Center for Integrated Facility Engineering (CIFE)
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- National Academy of Construction
- Royal Swedish Academy of Engineering Sciences
- Technical Committee, PPI

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Data

Process

Results

No data
No process
No results


Lazy

“Are you working for the information?
Or is the information working for you?”

Kathleen Liston

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Where is your data?

Justo E. Cabrera / jcabrera@macrodin.com / www.macrodin.com

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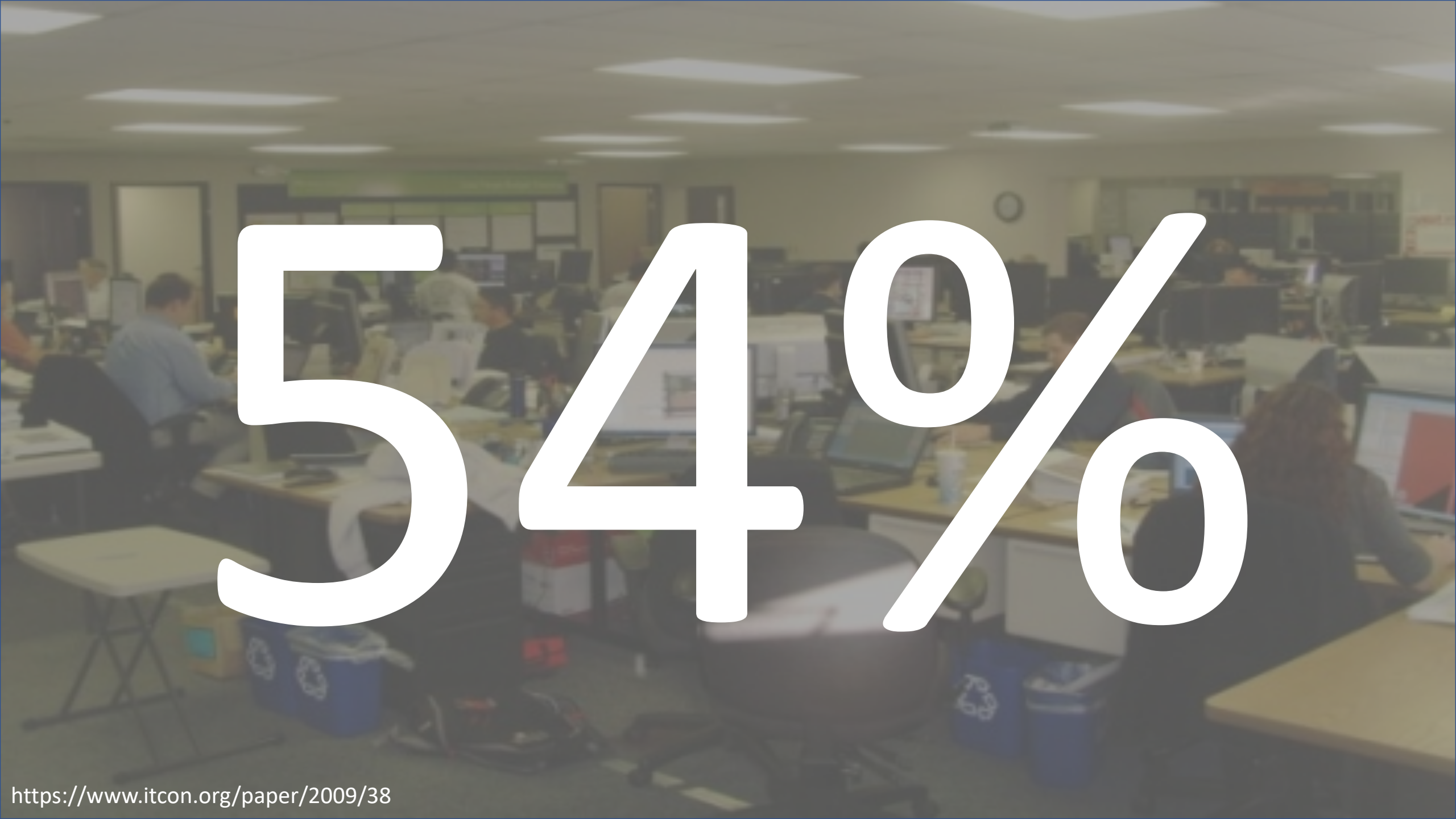
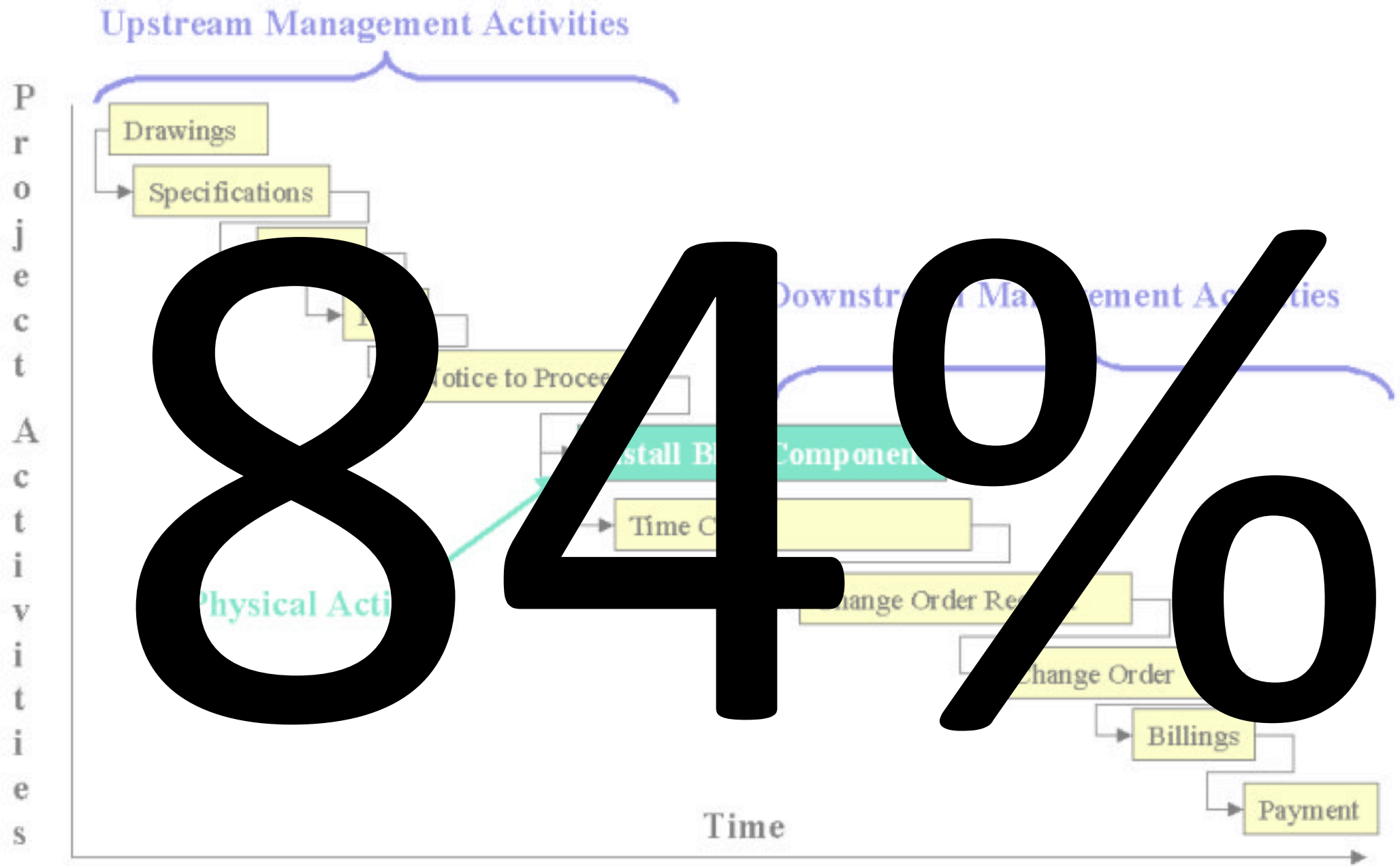


https://www.itcon.org/paper/2009/38



84%

Barrón, Alex and Fischer, Martin (2001), Potential Benefits of Internet-Based Project Control Systems – A Study On Monthly Progress Billings Processing, CIFE TR127, https://stacks.stanford.edu/file/druid:dz310yj8617/TR127.pdf

Everyone is picking the low-hanging fruit

https://heartclosetblog.com/2016/11/29/uncomplicated-thoughts-low-hanging-fruit/

No data
No process
No results

You can’t do much without information.

You can’t do anything well without good information.

How much better is your information today vs. last year?

How much better will your information be in a year?

The combination of emerging technologies creates unprecedented opportunities for breakthrough performance

- Mobile
- Cloud / Parallelization
- Location / Dimensional Control
- Machine Learning / Artificial Intelligence
- Robotics / Additive Manufacturing
- Internet of Things (IoT)
- Virtual Reality / Augmented Reality
- Etc.

Self-organizing and self-optimizing production systems

Establishing the demand

- VR
- Optimization

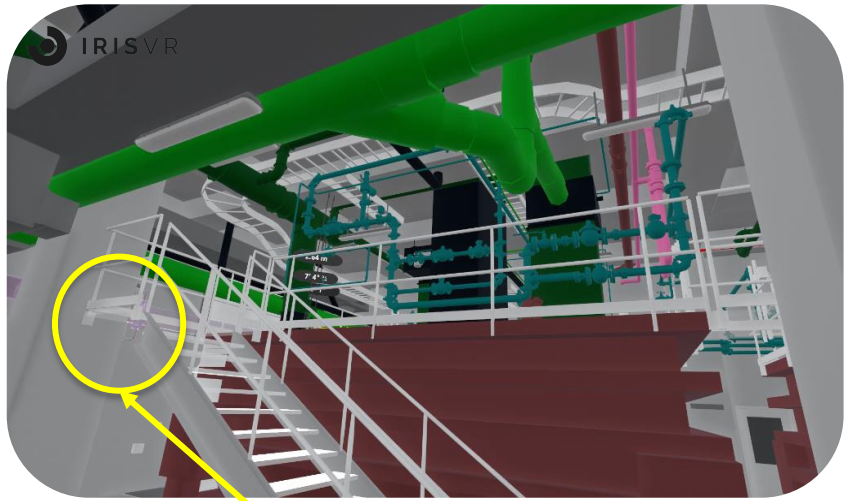
VR Implementations

Troubleshooting

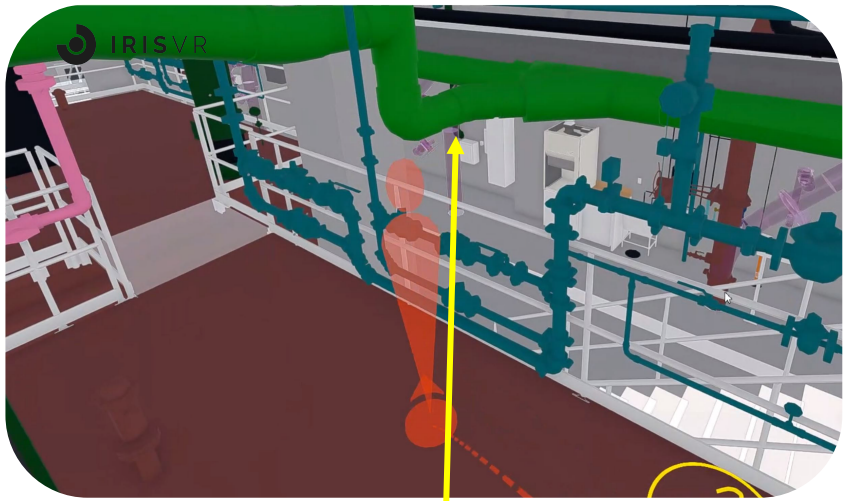
MWH&WEBCOR

MWH CONSTRUCTORS & WEBCOR BUILDERS
A CONSTRUCTION JOINT VENTURE

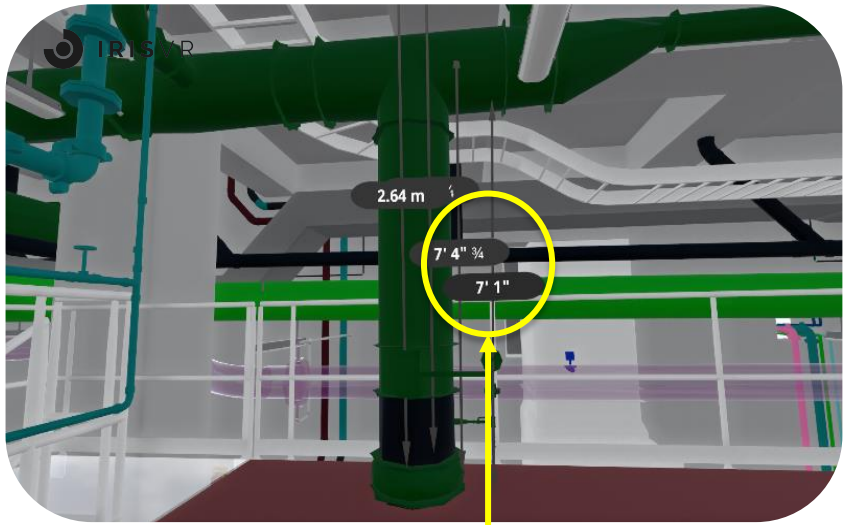
Application: Reviewing the Mechanical Process Room



Missing stairwell support is identified



Avatar's head seemed too close to ducts



Floor height is measured as 7.1 ft

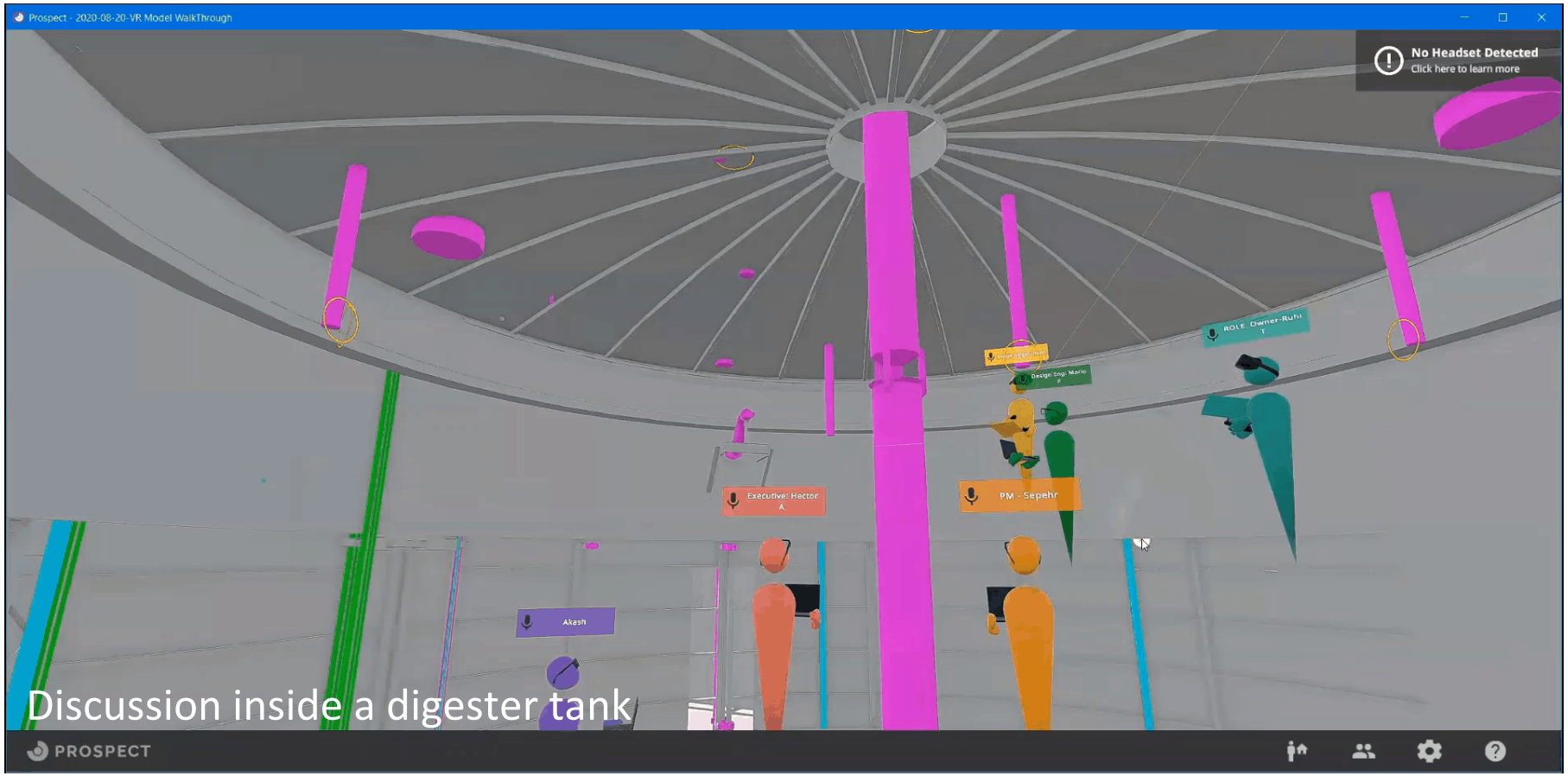
VR Implementations

Design Coordination

MWH&WEBCOR

MWH CONSTRUCTORS & WEBCOR BUILDERS
A CONSTRUCTION JOINT VENTURE

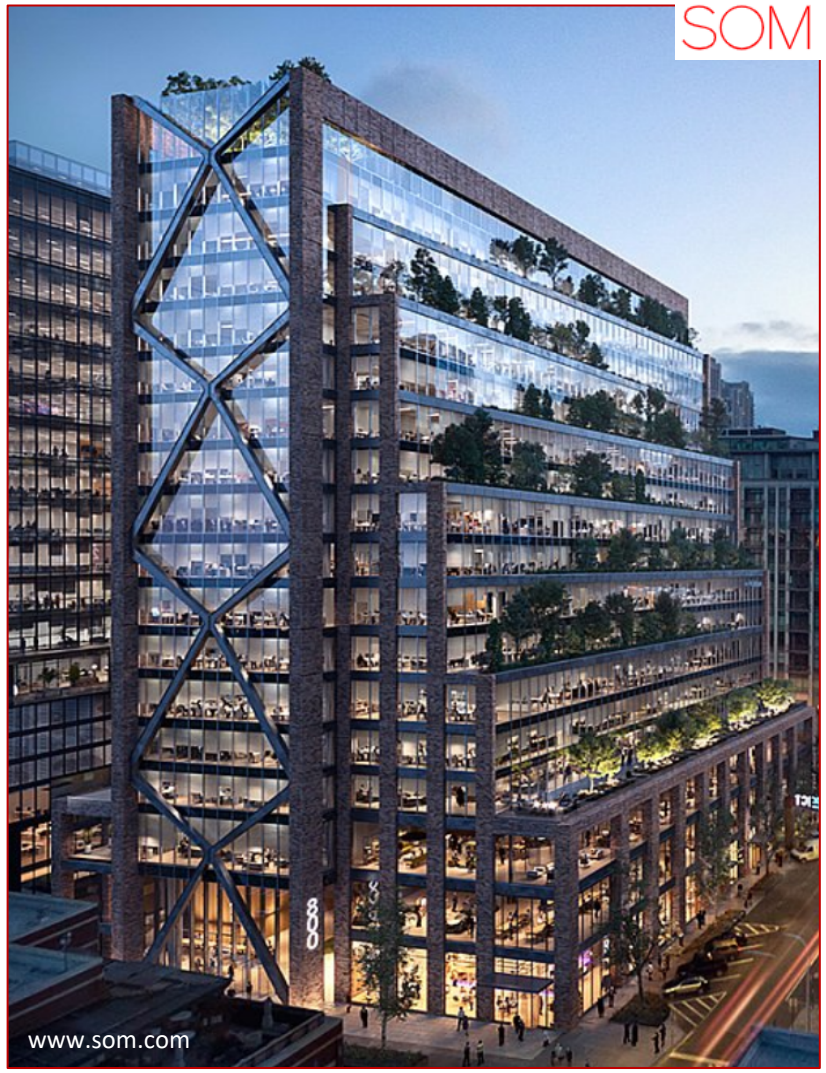
Application: Conducting a live VR meeting and presenting to 50 people at the JV



Discussion inside a digester tank

- Seven people from different disciplines:
  - VDC
  - BIM
  - Engineering
  - Project Management

Examples of Structural Optimization in Industry Today

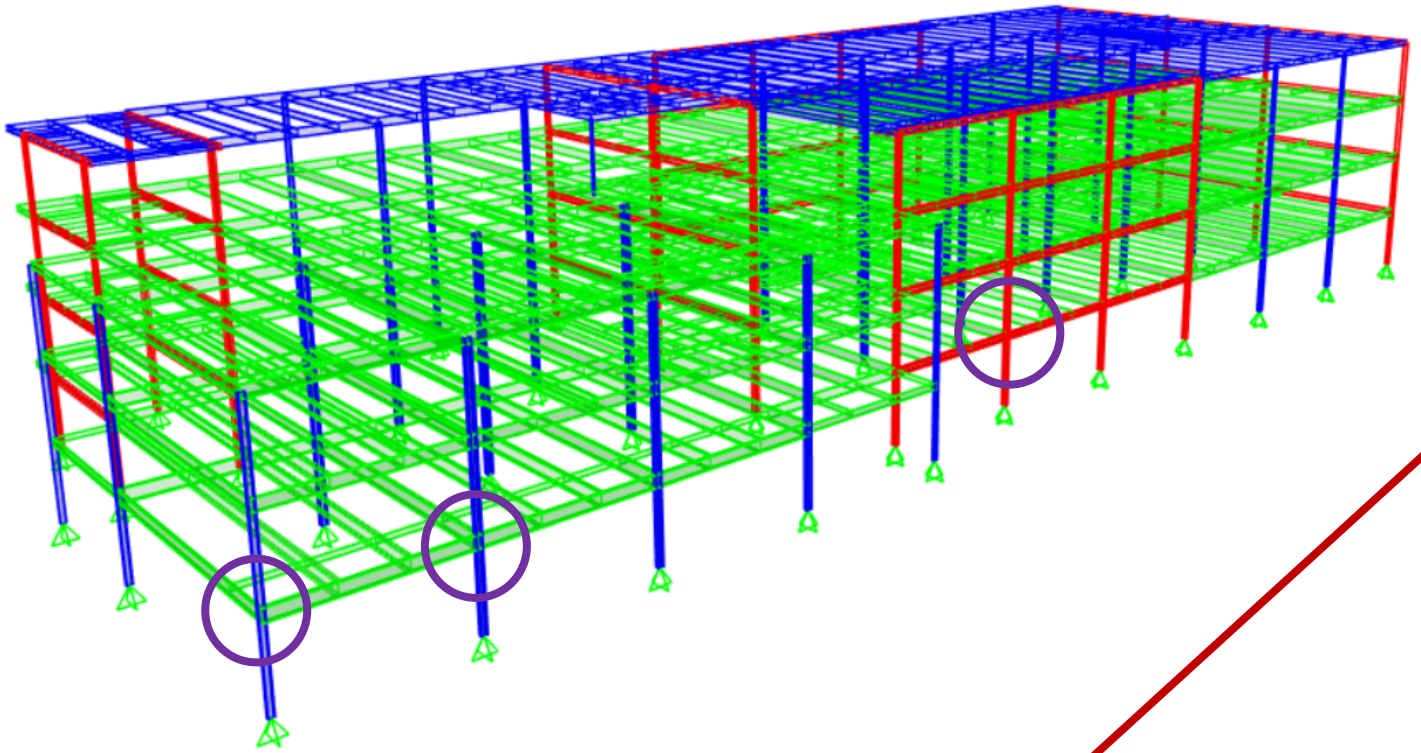


CHICAGO 800 WEST FULTON MARKET 2021

SHENZHEN CITIC FINANCIAL CENTER 2019

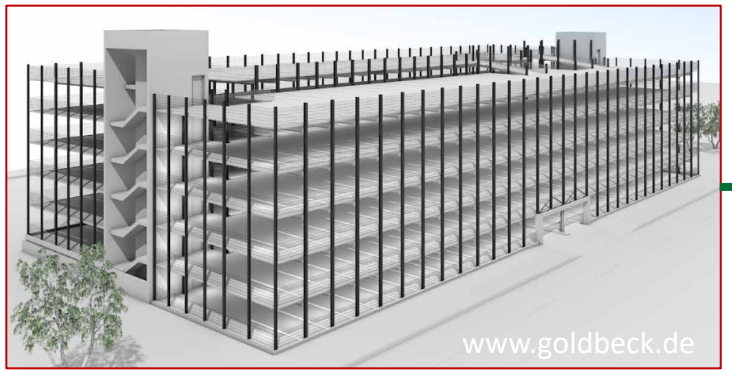
BEIJING INTERNATIONAL PLAZA 2016

Structural Optimization of Conventional Steel Buildings



Automated design of systems

- Non-Composite Gravity
- Composite Gravity
- Moment Frame
- Connections

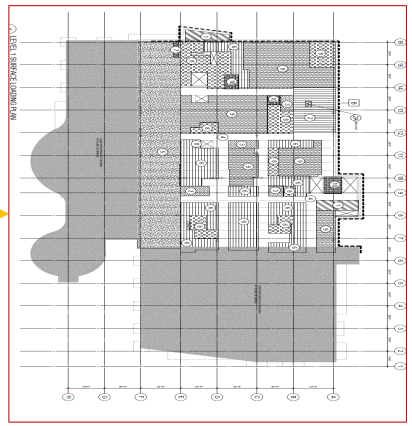


BIM

Optimization Algorithm

http://www.seismicresilience.org.nz/

Converged Structure

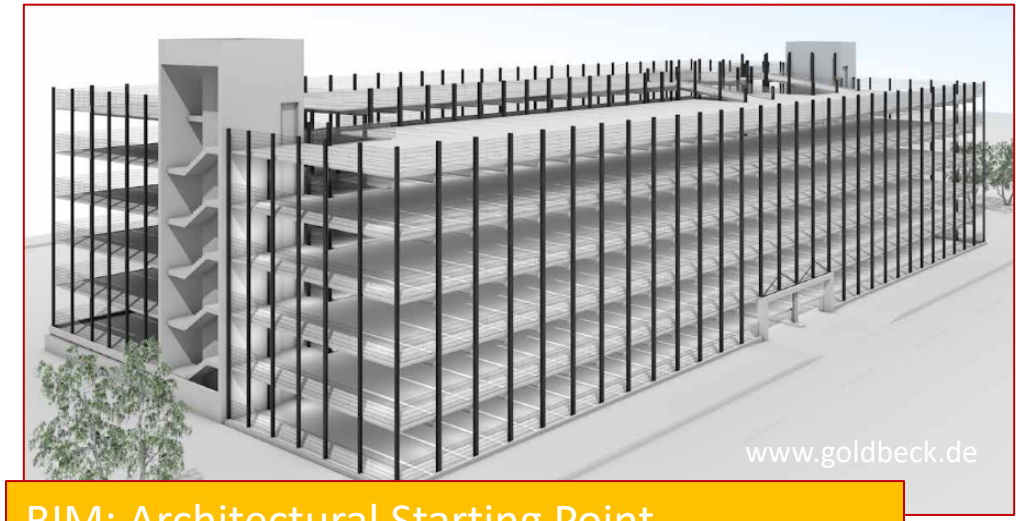


Drawings

Filippo Ranalli

The Structural Optimization Formulation

Building Structure



BIM: Architectural Starting Point

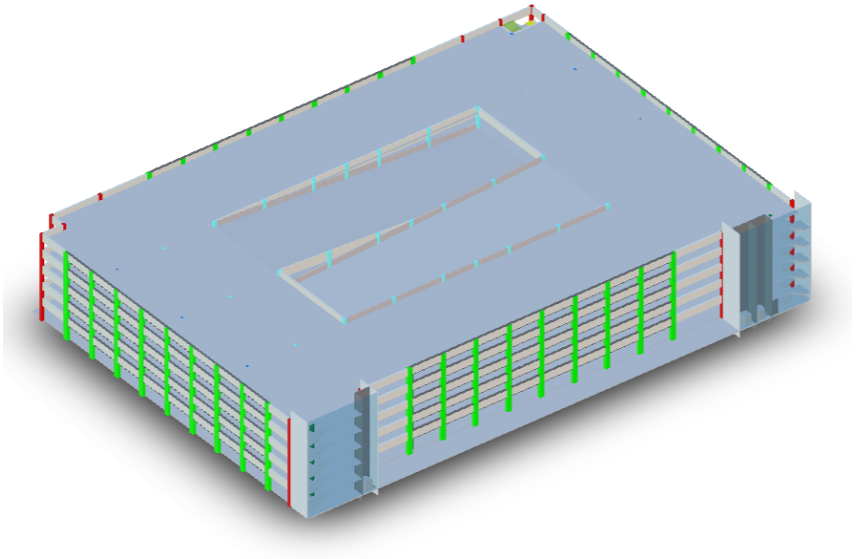
The Objective:
Minimize total installed cost and maximize constructability

The Constraints:
- Architectural
  - Aesthetics
  - Program
- Functionality
- Structural
  - Strength
  - Stiffness
  - Constructability
  - Ductility

The Design Task:
- Gravity frame member sizes
- Lateral frame member sizes
- Gravity and connection detailing

Benefits of Structural Optimization

- 10-20% material, fabrication and erection cost savings
- 40-100x faster structural design time
  - take on concurrent projects
  - focus on innovation (such as Performance-Based Engineering) or
  - Improve other aspects of design
- Improved structural safety from automated redundant calculations
- Evaluation of 1000s of feasible scenarios vs. 1 or 2



Precast Schedule Optimization Workshop Results

9/7/2018

CLARK PACIFIC

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ALICE TECHNOLOGIES

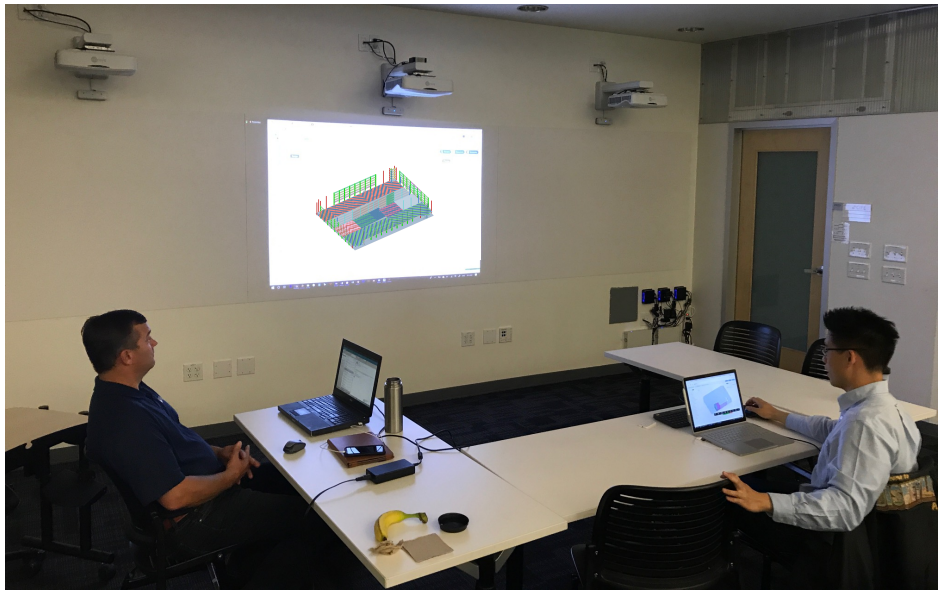
Precast Schedule Optimization Workshop

WHO:
Clark Pacific Team: Roy Griffith, Jon Mohle, Bobby Roumiguiere, Mark Palmer
Stanford Team: Martin Fischer, Yan-Ping Wang
ALICE Technologies: Dimitris Farmakis

WHAT:
To analyze multiple construction strategies for the CSUS precast concrete structure in terms of cost and schedule

WHEN: September 4-6

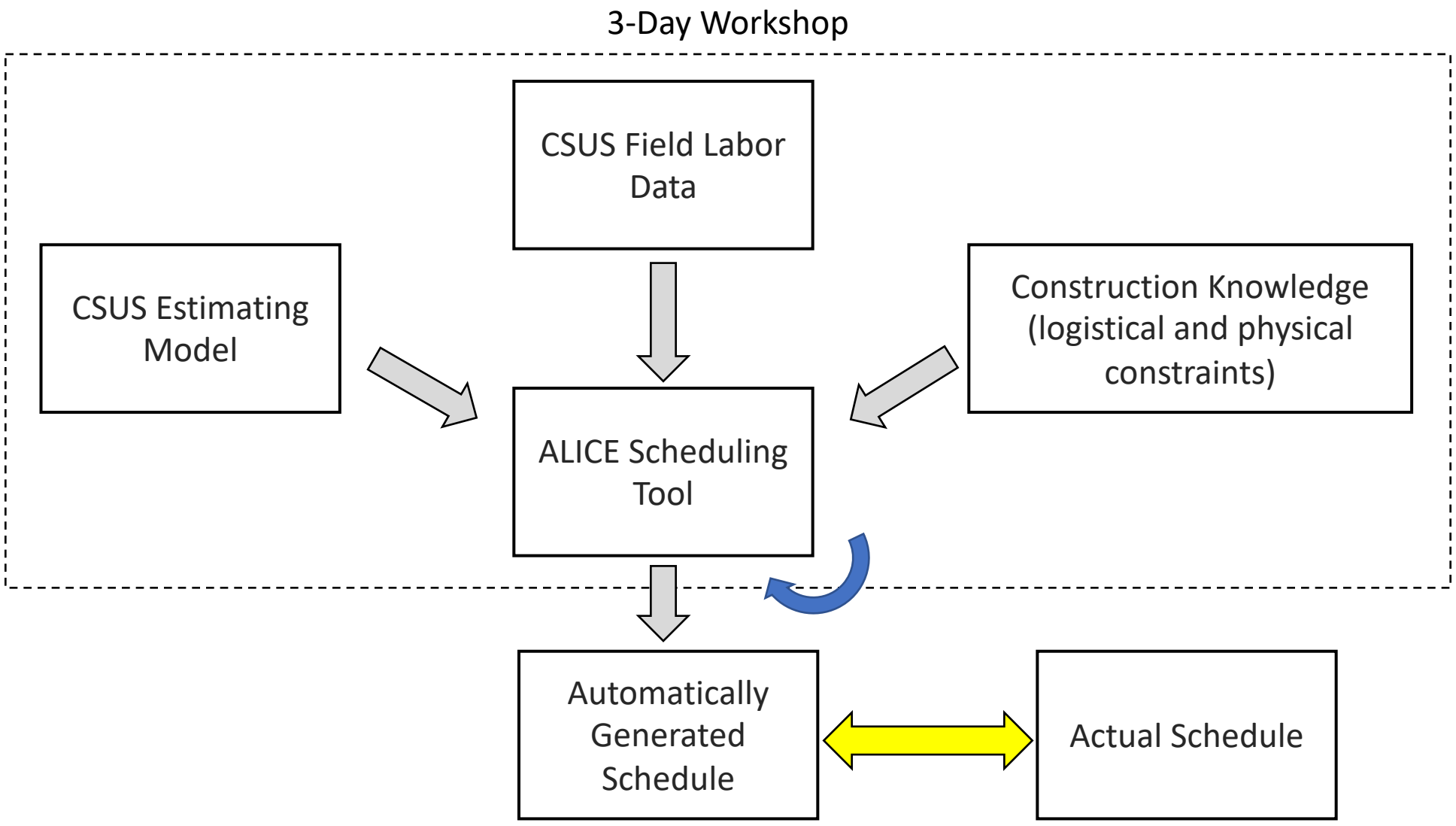
WORKSHOP ENVIRONMENT: Stanford CIFE iRoom



METRICS:
4 Construction Strategies Analyzed 56 Construction Schedules Evaluated 500+ Construction Schedules Generated
1 day for initial strategy, ½ day for each additional strategy
10 minutes for generating a new schedule

CLARK PACIFIC ALICE TECHNOLOGIES CIFE CENTER FOR INTEGRATED FACILITY ENGINEERING

Schedule Optimization Process

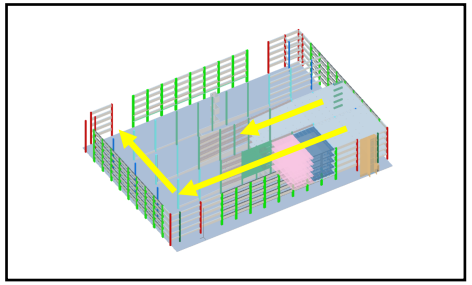


Construction Strategy Comparison

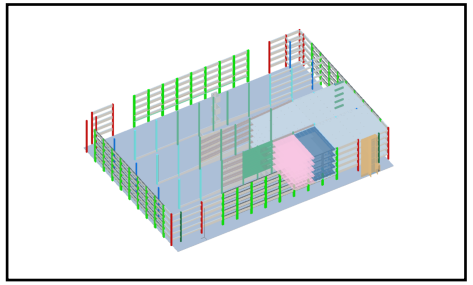
Objective(s)

The main objective of this workshop was to analyze 4 different construction strategies for precast parking structures, apply to the CSUS precast scope, and compare against actuals:

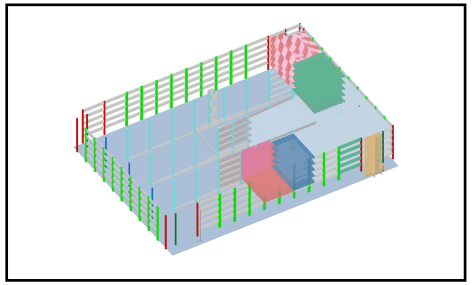
0 – Baseline - Actual



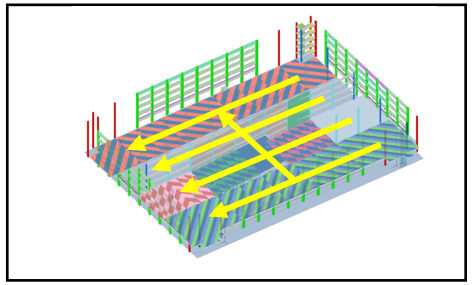
1 – Baseline - ALICE



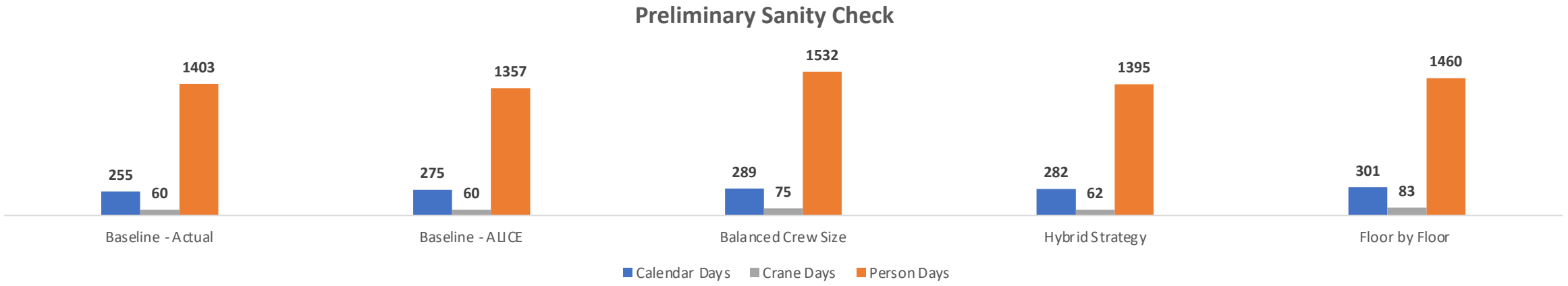
2 - Balanced Crews



3 - Hybrid Strategy



4 - Floor by Floor



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ALICE TECHNOLOGIES

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Establishing the supply

- IoT
- Robotics

We are finally able to set up feedback loops!

https://www.theguardian.com/lifeandstyle/wordofmouth/2013/dec/10/child-fussy-eater-what-not-to-say-dinner-table

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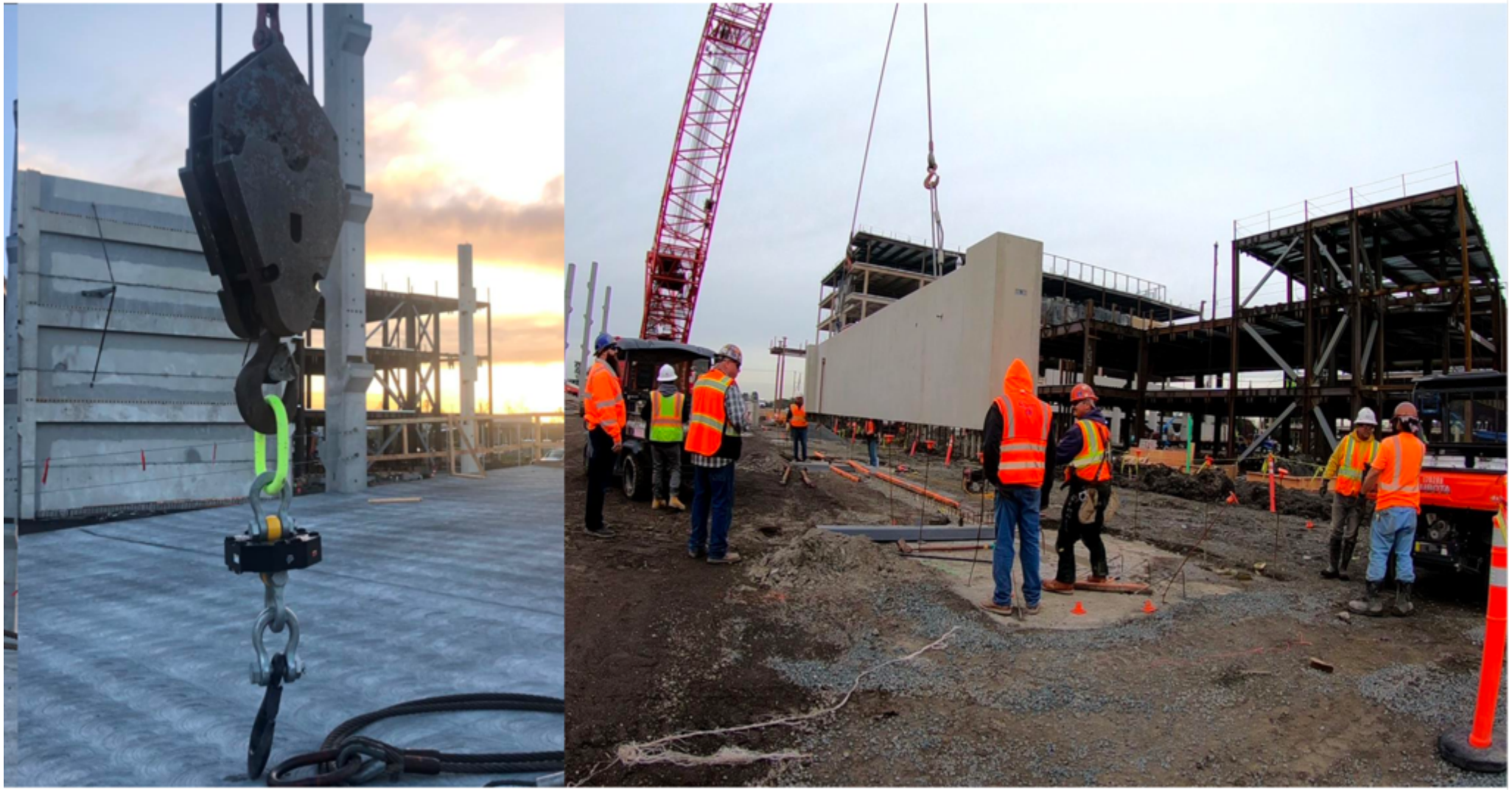
… **digital** feedback loops



Pictures courtesy Clark Pacific

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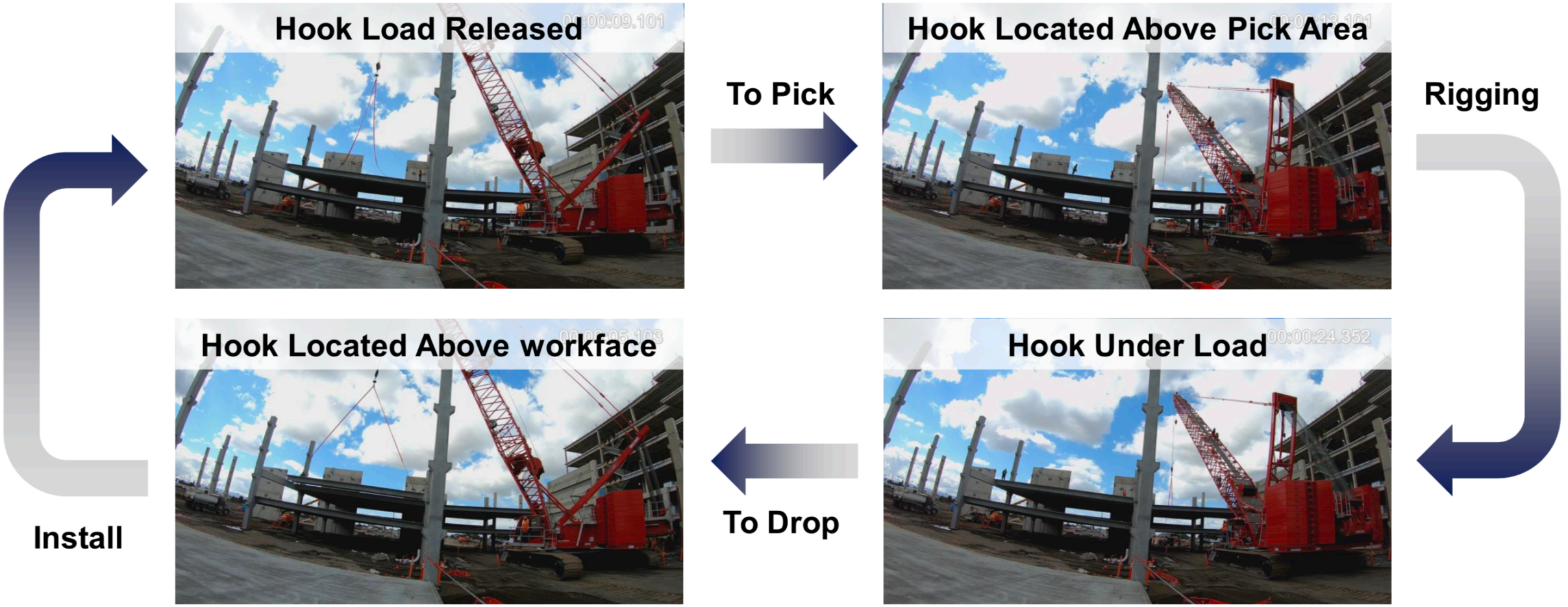
4-Step Installation Cycle

Total Cycle Time = To Pick + Rigging + To Drop + Installation



Work by Yan-Ping Wang and Rui Liu in collaboration with Clark Pacific and Versatile Natures

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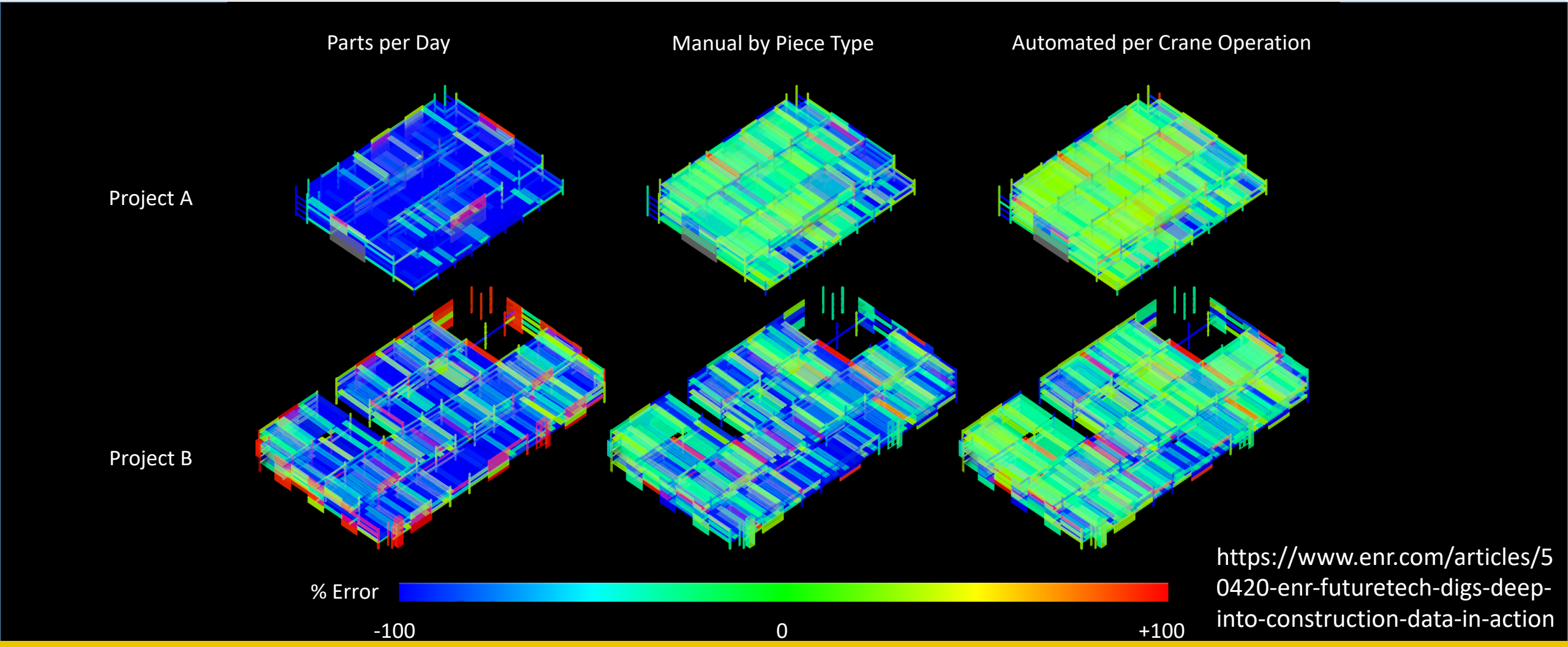
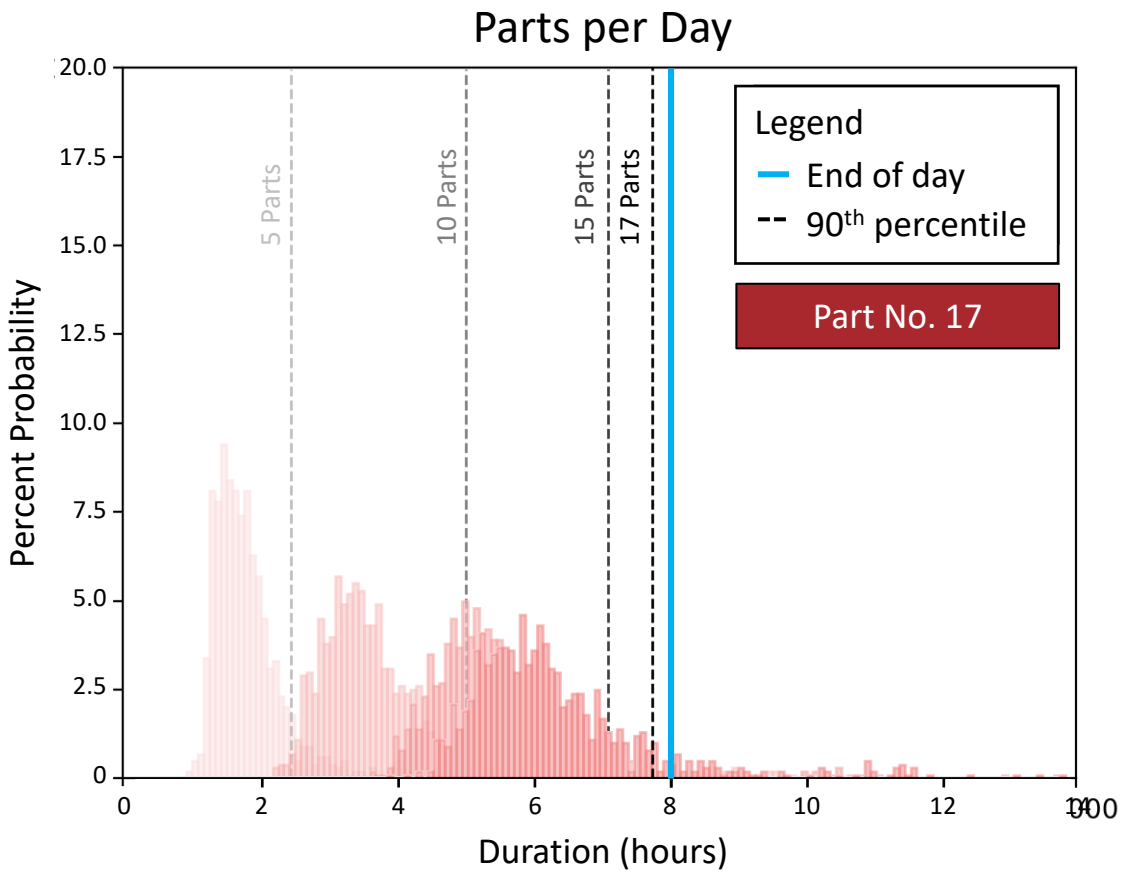
Reducing schedule error with granular data – 2 Case Studies

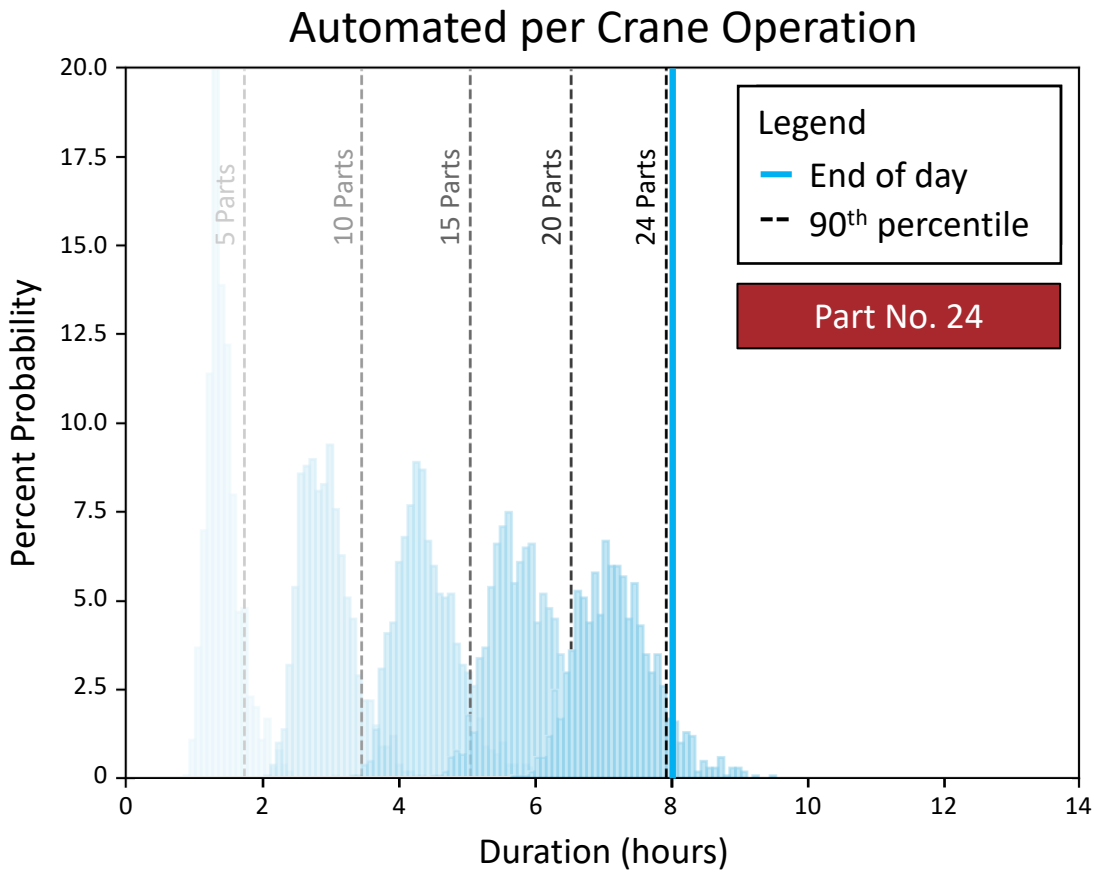


https://www.enr.com/articles/50420-enr-futuretech-digs-deep-into-construction-data-in-action

Automated data collection per crane operation → 45.4% to 52.6% less error in cycle time estimation

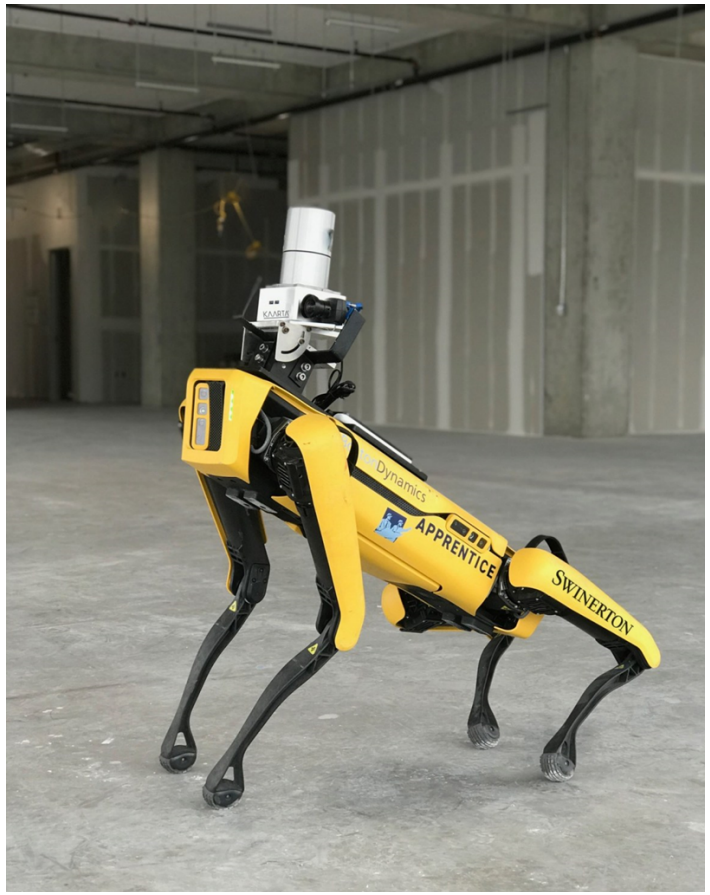
Reducing Buffer Size by Reducing Uncertainty – 1 Day Case Study

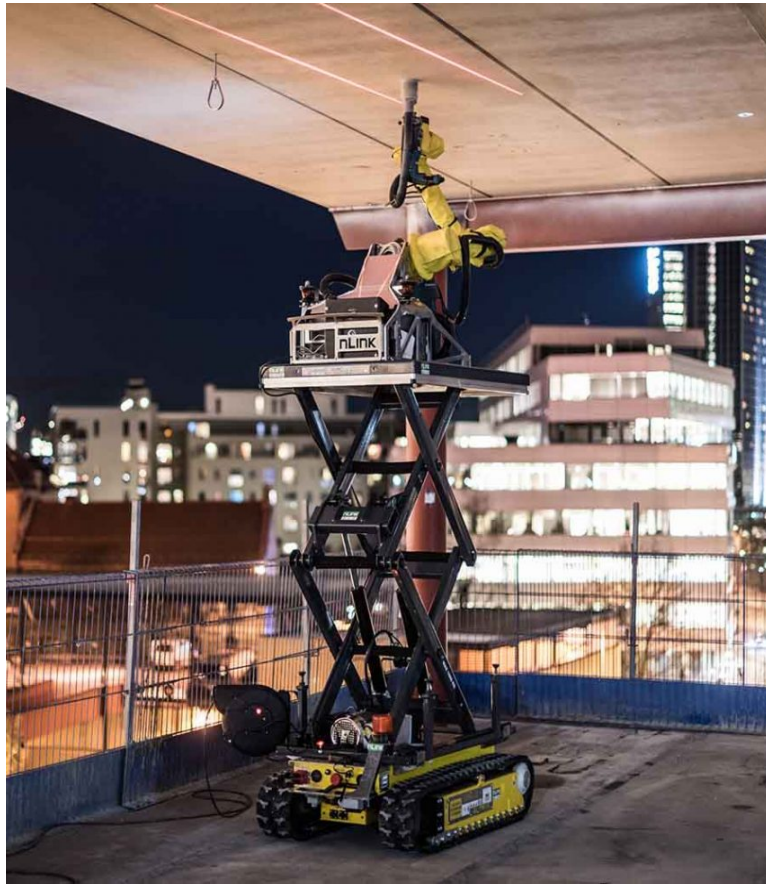




7 more parts planned at 90% percent chance of achieving schedule target

Construction robots are being tested on sites





https://ieeexplore.ieee.org/document/9152871

Robotic Data Collection for Streamlining Payments

- Robotic data capture on three projects in CA, TX, and HI

- Piloted applications of robot-captured data:
  - Production tracking
  - Streamlining payments
  - Quality control
  - Automated progression of schedule
  - Air quality monitoring

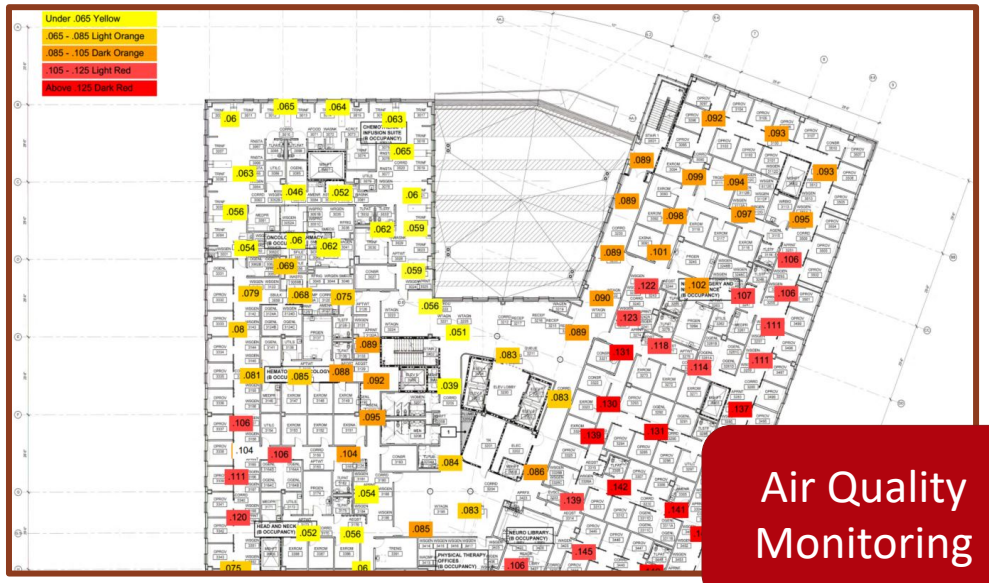
	Manual	Robotic
Payment cycle	85 days[1]	7-14 days
Time saving (laser scans)	-	10-15 hours/month/floor*
Data types captured	1/trip	4/trip**

*40,000 sq. ft. building floor, 2 scans per week

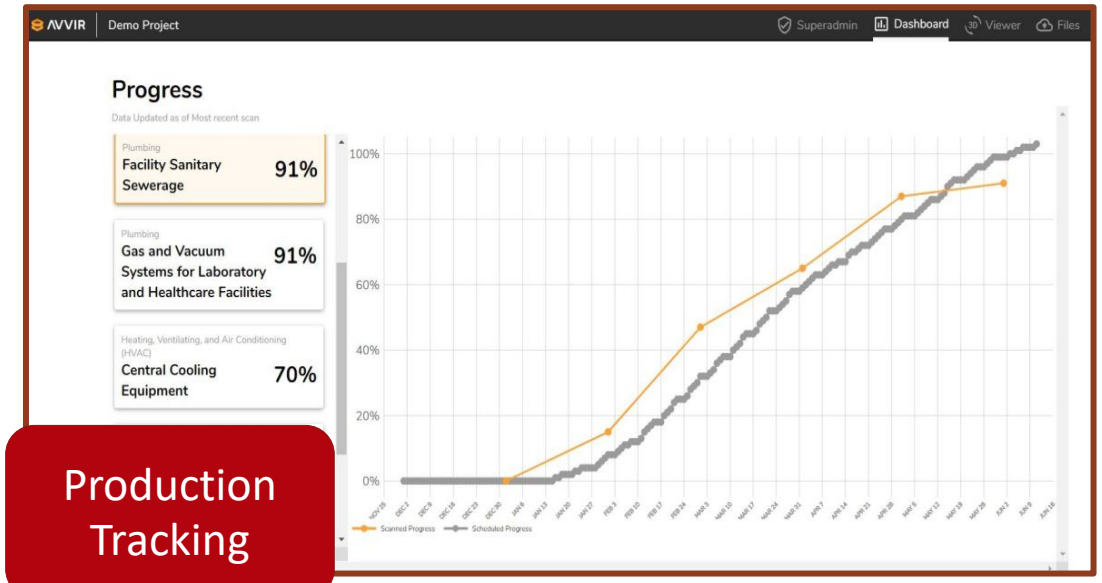
** laser scan, 360° photos, environmental data, digital photos

SWINERTON

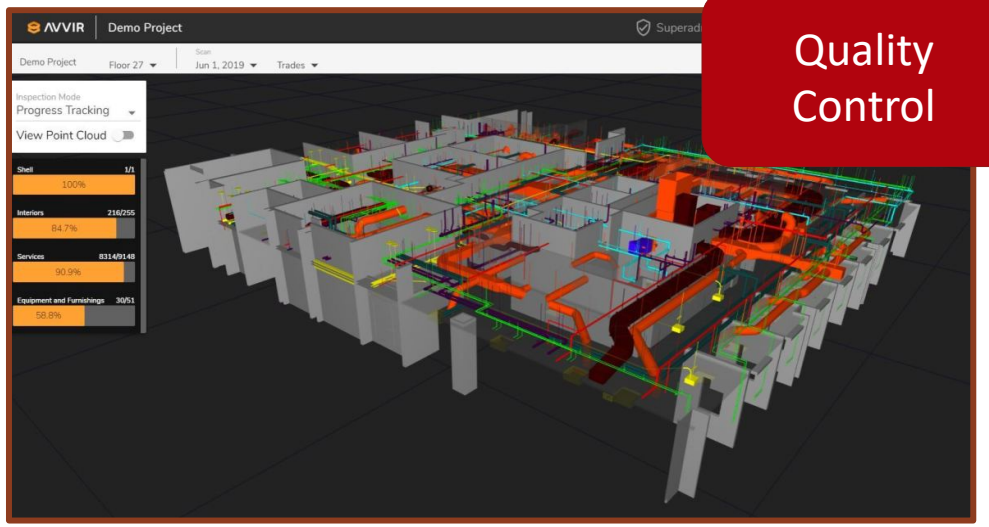
https://www.bostondynamics.com/spot/applications/swinerton



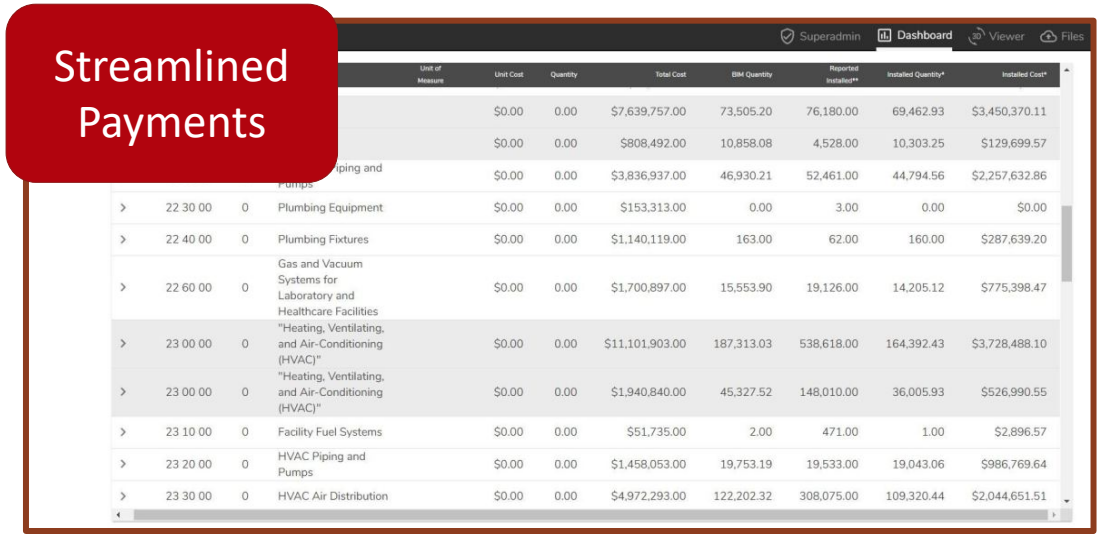
Air Quality Monitoring



Production Tracking



Quality Control



				Unit Cost	Quantity	Total Cost	BIM Quantity	Reported Installed**	Installed Quantity*	Installed Cost*
				$0.00	0.00	$7,639,757.00	73,505.20	76,180.00	69,462.93	$3,450,370.11
				$0.00	0.00	$808,492.00	10,858.08	4,528.00	10,303.25	$129,699.57
			Piping and Pumps	$0.00	0.00	$3,836,937.00	46,930.21	52,461.00	44,794.56	$2,257,632.86
>	22 30 00	0	Plumbing Equipment	$0.00	0.00	$153,313.00	0.00	3.00	0.00	$0.00
>	22 40 00	0	Plumbing Fixtures	$0.00	0.00	$1,140,119.00	163.00	62.00	160.00	$287,639.20
>	22 60 00	0	Gas and Vacuum Systems for Laboratory and Healthcare Facilities	$0.00	0.00	$1,700,897.00	15,553.90	19,126.00	14,205.12	$775,398.47
>	23 00 00	0	"Heating, Ventilating, and Air-Conditioning (HVAC)"	$0.00	0.00	$11,101,903.00	187,313.03	538,618.00	164,392.43	$3,728,488.10
>	23 00 00	0	"Heating, Ventilating, and Air-Conditioning (HVAC)"	$0.00	0.00	$1,940,840.00	45,327.52	148,010.00	36,005.93	$526,990.55
>	23 10 00	0	Facility Fuel Systems	$0.00	0.00	$51,735.00	2.00	471.00	1.00	$2,896.57
>	23 20 00	0	HVAC Piping and Pumps	$0.00	0.00	$1,458,053.00	19,753.19	19,533.00	19,043.06	$986,769.64
>	23 30 00	0	HVAC Air Distribution	$0.00	0.00	$4,972,293.00	122,202.32	308,075.00	109,320.44	$2,044,651.51

Streamlined Payments

SWINERTON

Stanford | ENGINEERING
Civil and Environmental Engineering

Robotic drilling saved time and improve health and safety for four subcontractors

Reduced task time by 11%

Cut muscle strain hours from 60% to 1.3%

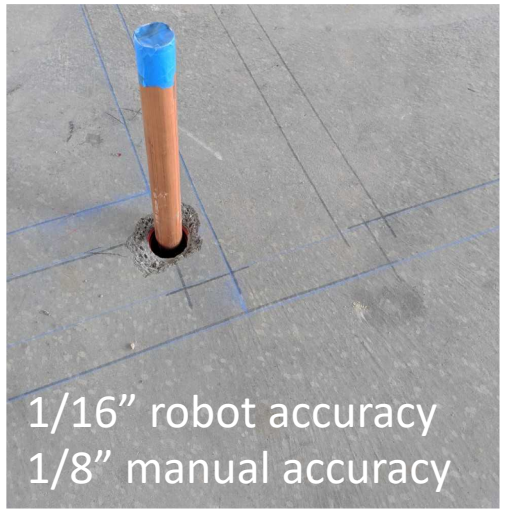
Reduced rework from 5% to 3%

Improved accuracy from 10 mm to 3.3 mm

Collected 10 kg of dust/1000 holes which saved 3 h of cleaning per zone (750 m^2)

Increased total costs by 13%

Robotic layout increases the information transfer to the field from 3D models, improves accuracy, and provides instant work reports



Information is getting more …

- accurate (correct)
- reliable
- consistent
- timely (up-to-date)
- complete
- granular
- relevant
- computer-interpretable

Project teams can better match demand and supply

Levels of digitalization

- **Prescription** "What should be done"
- **Prediction** "What will happen"
- **Explanation** "Why is it happening"
- **Description** "What is happening"

Inspired from Competing on Analytics: The New Science of Winning Heavily (2007)

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Self-organizing and self-optimizing production systems

No data
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No results

Digitalization Of Construction:

What Does It Mean And How To Do It?

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- National Academy of Construction
- Royal Swedish Academy of Engineering Sciences
- Technical Committee, PPI

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