AUTODESK. UNIVERSITY

Bridge Inspection with Aerial Robots: An End-to-End Automated Workflow

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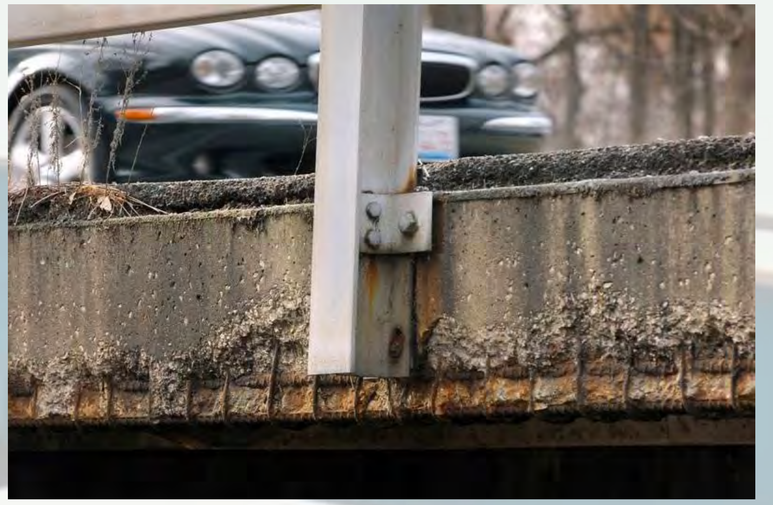
Yoshihiko Fukuchi | Autodesk Inc.

U.S. Infrastr. Rehab Opportunity



77% of bridges are atleast 40 years old

1 out of 11 bridges in the U.S. is structurally deficient

Illinois has +2,200 Structurally Deficient Bridges

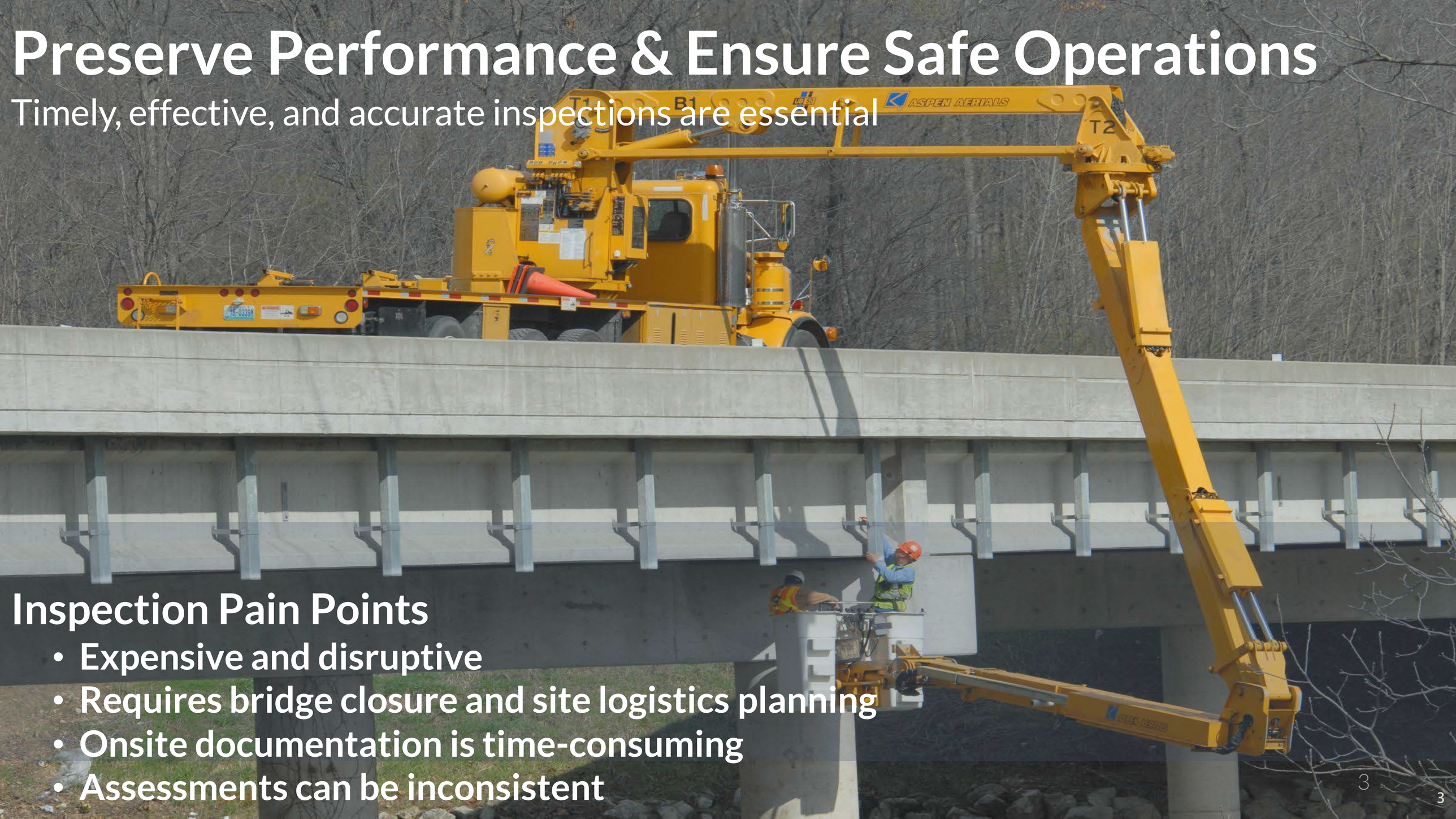
188 million trips/day
across structurally deficient bridges

$123 billion
to rehab all of the structurally deficient bridges in the U.S.

ASCE Report Card (2017), Roads&Bridges (2017)

Preserve Performance & Ensure Safe Operations

Timely, effective, and accurate inspections are essential



Inspection Pain Points

- Expensive and disruptive
- Requires bridge closure and site logistics planning
- Onsite documentation is time-consuming
- Assessments can be inconsistent

3

Requirements for Enhanced Condition Assessment

- Standard procedures for documenting, communicating, and following up on bridge inspectors' recommendation
- Unified system for managing bridge maintenance (store and retrieve data remotely)
- Improve inspection documentation, timeliness, and accuracy
- Provide inspectors with resources necessary for inspection at their fingertips

Picture from: Zink J. and Lovelace, B. (2016) " MnDOT UAS Project Presentation"

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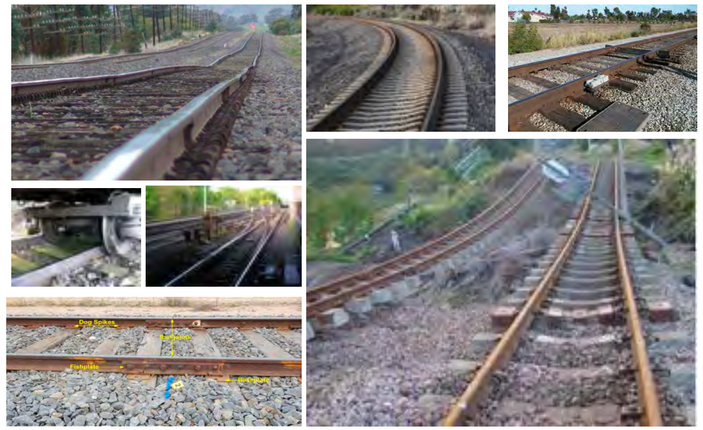
Source: Zink, J. "MNDOT's new Software for Bridge Inspection and Management", IBC-12-76

Opportunity: Visual data captured but not actionable

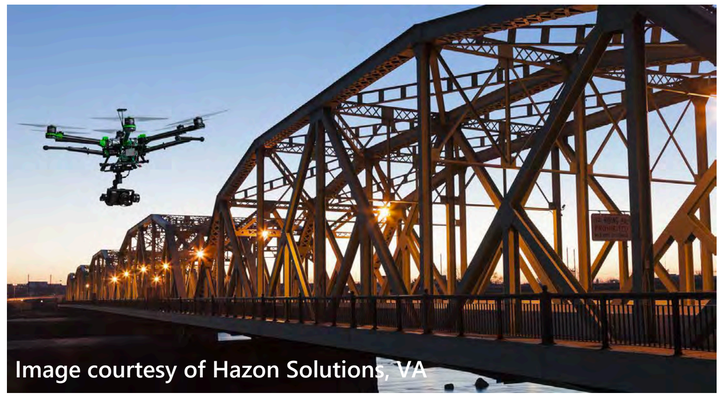


Inspection Photologs
Varied Frequency

Automated Visual Capture
High Frequency

Time-Lapse Camera
High Frequency

Action Cameras
Low Frequency



Camera Drones
High Frequency

Laser Scanning
Low Frequency

Reality Capture and Data Analytics

- Faster and cheaper compared to Inspection Vehicles, Man Lifts, Rope Access, and Ladders
- Reduce the need for expensive access and traffic control measures

- Cloud-based analysis reduces the need for onsite engineer visits

60% cost saving when drone is used (Minnesota DOT)

Japanese MLIT Story

Robotic-driven visual inspection of infrastructure assets

Initiatives for the use field robots and AI in infrastructure management

Yasushi NITTA, Ph.D.
Director for Construction Equipment and Safety Planning Office, Policy Bureau,
Ministry of Land, Infrastructure, Transport and Tourism, Japan

Hiroyuki MORIKAWA
Team leader, Advanced Technology Team,
Public Works Research Institute (National R&D Agency)

国土交通省

Making Japan the showcase of the advanced robots

Next five years is focused on implementation of Robot Revolution

- Invest a total of 100 billion yen for robotics-related-projects.
- Increase the market size of robotics to 2.4 trillion yen.
- Establish a new experiment field for robots.

＜Infra-Maintenance, Disaster response, Construct

＜インフラ維持管理, 災害対応, 建設施工＞

- Adoption rate 30% of Intelligent construction technology for productivity and labor-saving.
  →情報化施工技術の普及率を30%に！
- Introduction of Robots for visual checking and repairing 20% of important/old infrastructures.
  →重要/老朽化インフラの目視点検や補修の20%にロボット・センサーを導入！
- Construction efficiency of unmanned construction no way inferior to manned construction in scene of disaster. →災害現場において有人施工と遜色ない効率を実現！

＜Manufacturing service（ものづくり）＞

＜Nursing and medical field（医療介護）＞

＜Agriculture（農業）＞

Next-Generation Robots for Infrastructure

- Accurately inspecting areas where people cannot see to ensure the soundness of facilities: **Maintenance Robots**.
- Supporting emergency measures and prompt and accurate grasping of affected areas dangerous to enter: **Disaster Response Robots**.


UAV


Wheeled robots

*Parallel to this recruitment, as a support measure for new technologies being developed.


Underwater robots

Implementation Flow

Technical seeds

Key Areas Clarified

Site needs

Technology development promotion

2014 - 2015

Development/Improvement

Public recruit-ment

Site verification (Verification of site appropriateness)

Assess-ment

2016 -

Development/ Improvement

Trial introduction assessment

2017 -

Full-scale introduction

Site/Field "See, Repair, and reinforce" social infrastructure (**build a next-gen infrastructure**)

5 key areas are designated for site verification/assessment and development support as next-generation robots for infrastructure.

I. Maintenance

(1) Bridges

(2) Tunnels

(3) Dams, River

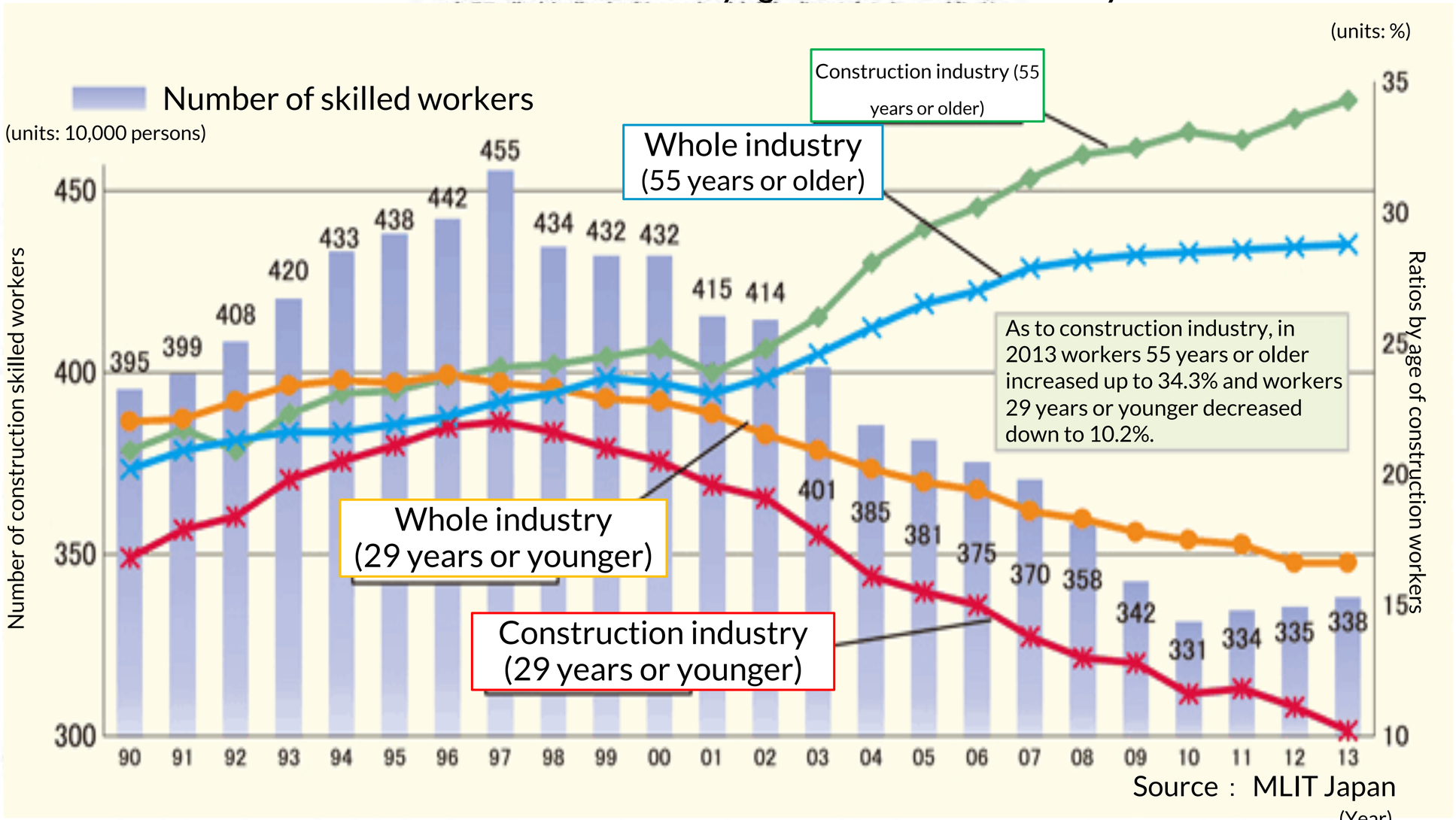
II. Disaster Support

(4) Damage surveys (Landslides, eruptions, tunnel collapses)

(5) Emergency recovery from disasters (Landslides, eruptions)

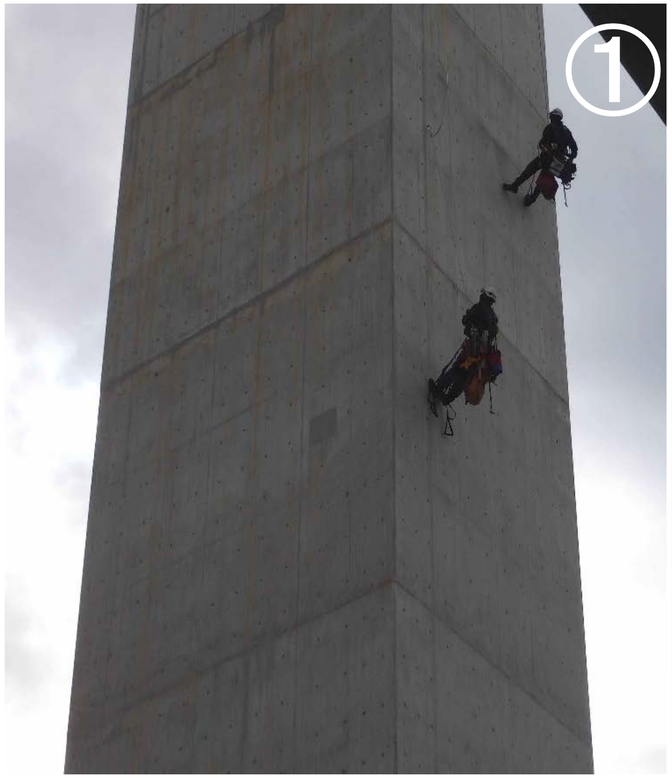
Decrease in manpower in construction industry

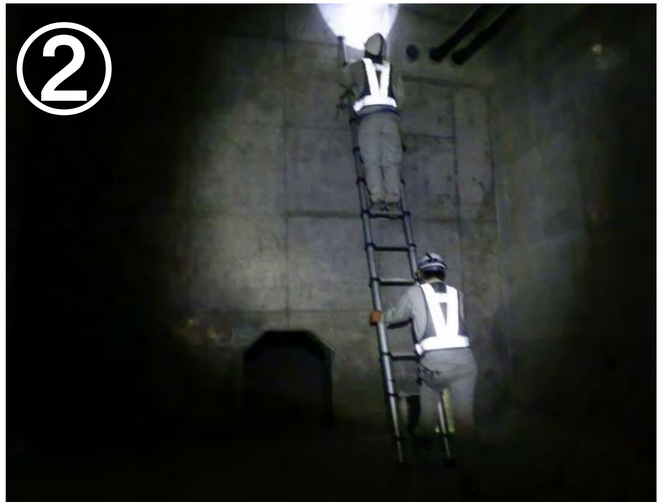
Number of construction skilled workers and ratio by age of construction industry workers



Data: Formulated by MLIT based on labor force survey (Ministry of Internal Affairs and Communications)

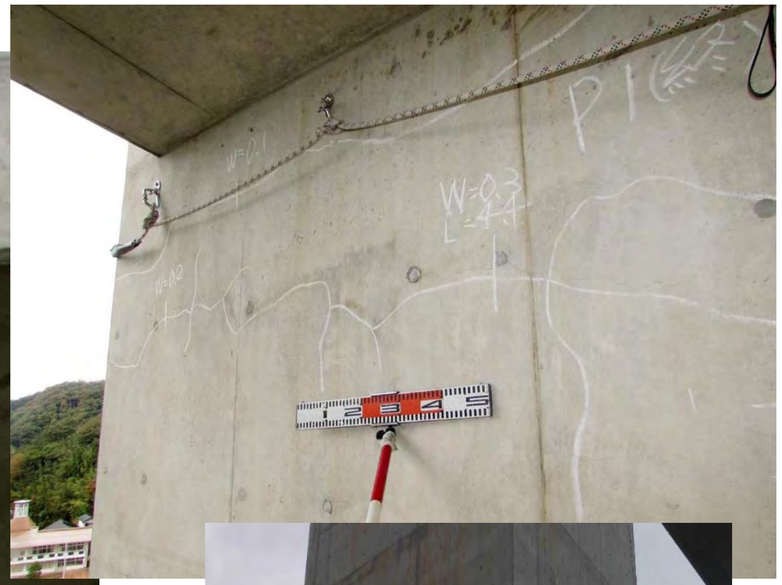
Bridge inspection work(Height 50m, Span 100m, girder height10m)





① Rope access status
② Inspection inside the box girder with ladder
③Inspection with a large bridge inspection vehicle

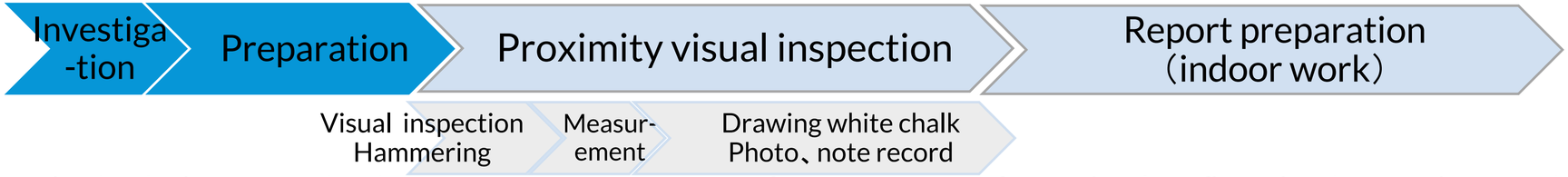
Rope access inspection



Photos taken close-up by using a rope will later become a report after organizing the positional relationship.

Introduction step of tunnel inspection robot

【Current procedure 】

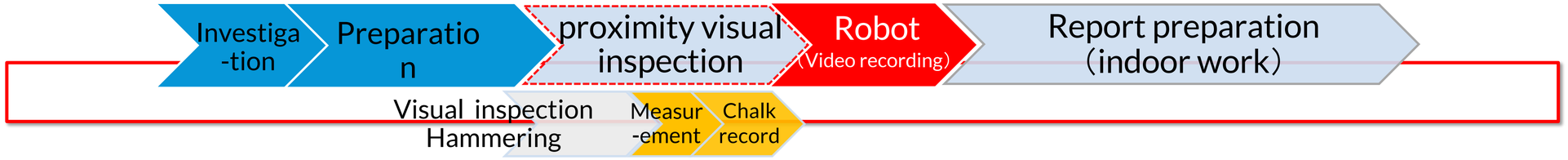


In the current close visual inspection by the inspector, the checker approaches the reach of the hand and performs visual confirmation, hammering sound (hammer etc.), measurement and recording at the site (chalking and photo shooting, record to the pad)

Present scope of on-site evaluation

【Robot procedure】

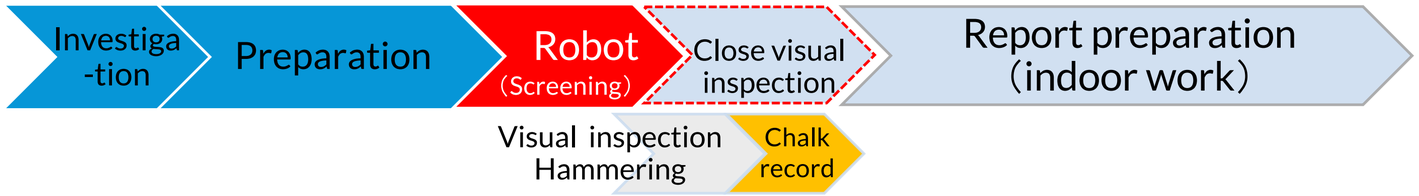
Detection accuracy is lower than visual inspection, but variations above a certain level can be reliably detected.



Although close visual inspection by inspectors is the same way, improvement in efficiency can be realized by omitting photographing and omitting measurement and choking by a person for the deformation that can be sufficiently measured by the robot.

【Robot procedure（near future）】

The level of detection accuracy is equal to that of proximity visual inspection.



In the close visual inspection after screening by the robot, an inspector approaches the problem part as a target, and visual confirmation and hammering sound are performed. By omitting photography and choking (except minor variations), substantial efficiency improvement is realized.

Proposed government budget starting 2018

- MLIT promotes the introduction of artificial intelligence that supports person's judgment in inspection of structures at the introduction of robot, which is the key to improving productivity.
- For this purpose, we will develop "teacher data" accumulating correct judgments of civil engineers and promote private AI development.

【Goal】

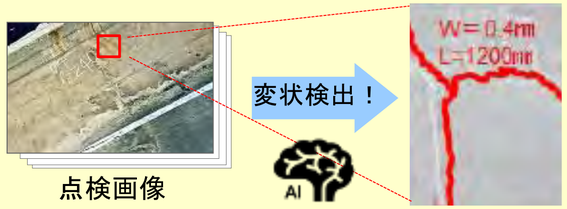
Improving efficiency of human inspection

Present

●インフラの点検画像をロボットにより取得

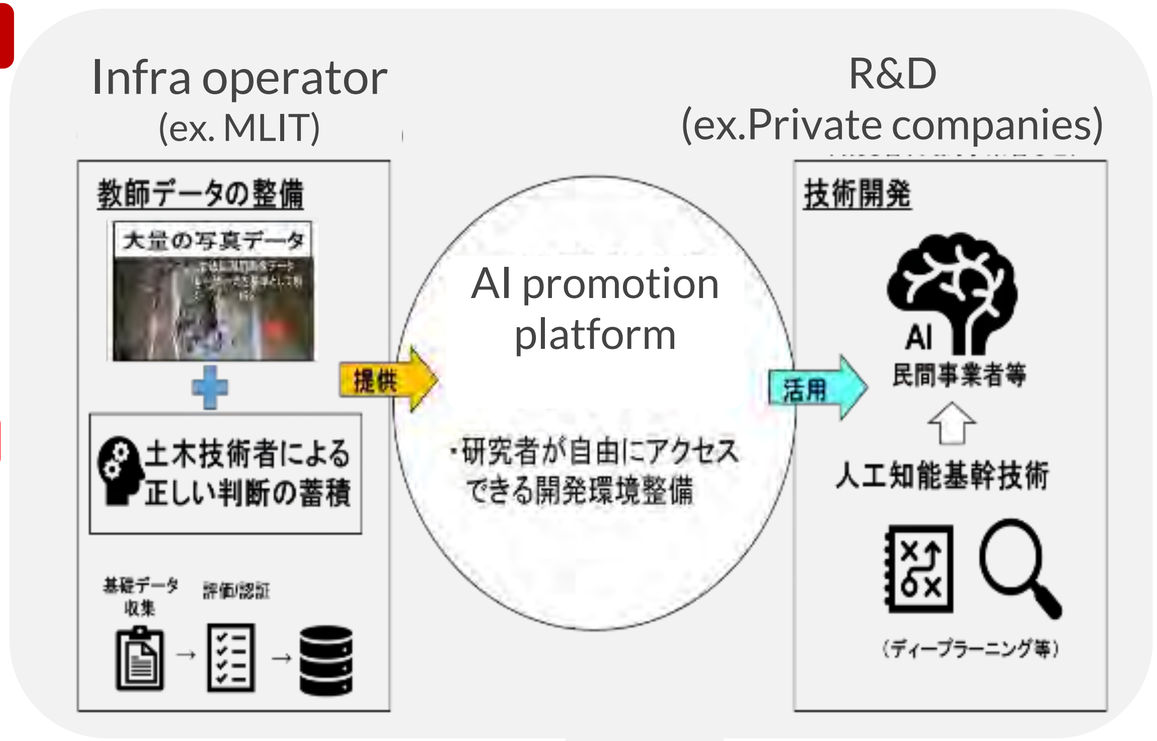
Efficiency of human decision making by AI

将来

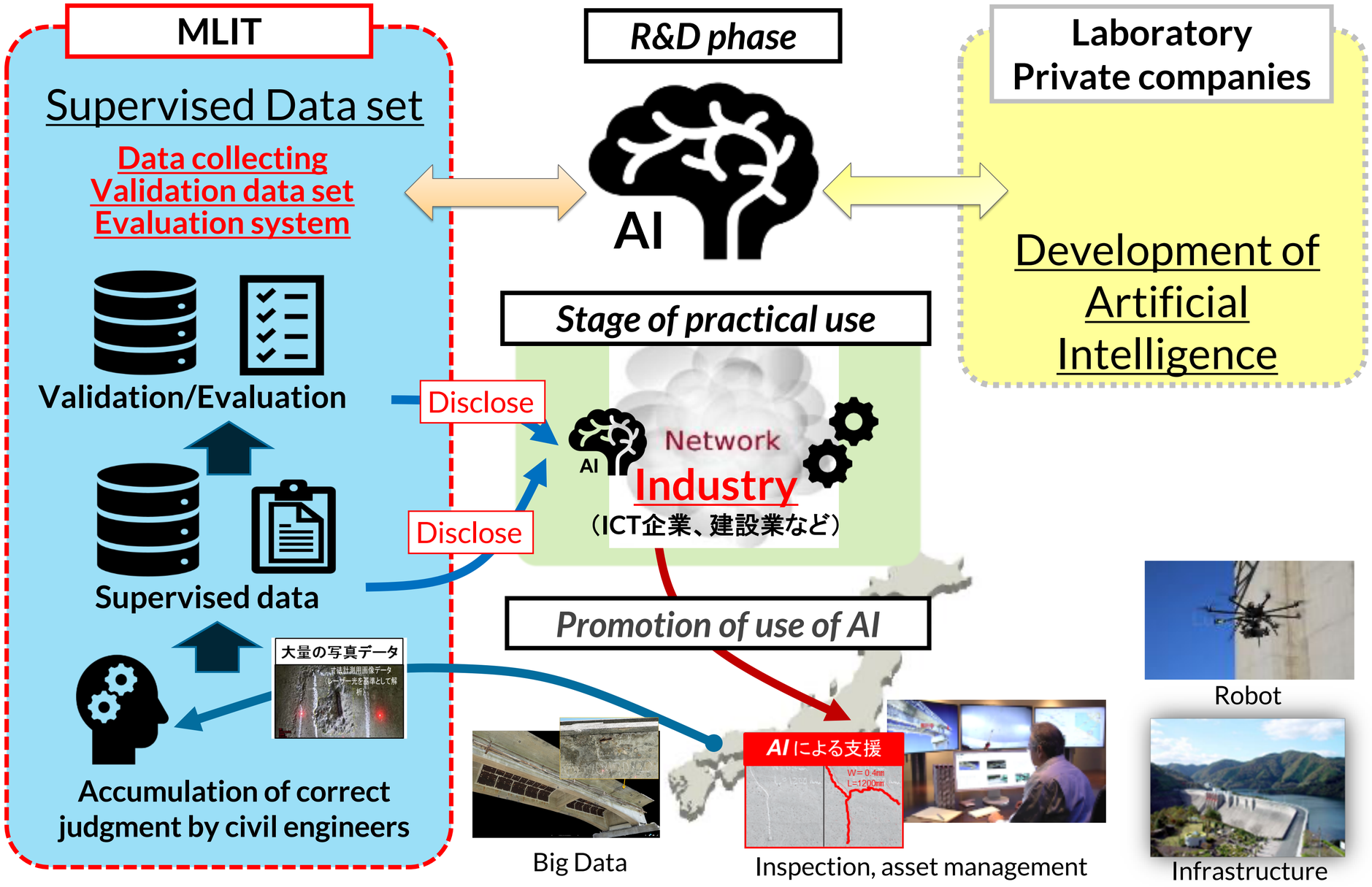


●変状の自動抽出により点検員の「判断」を支援

【Policy outline】

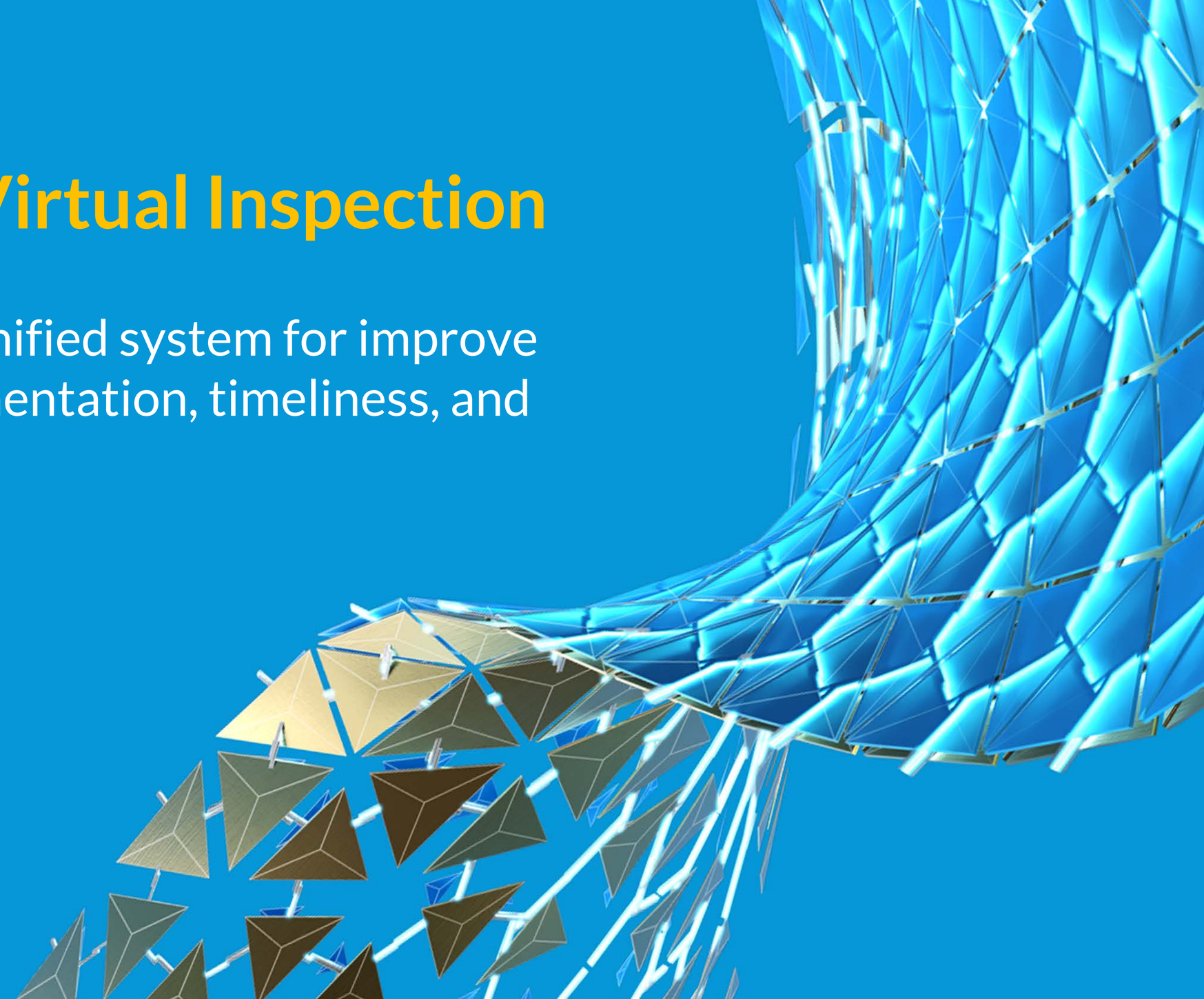


Teacher data development to promote AI development



Visual and Virtual Inspection

Reconstruct- A unified system for improve inspection documentation, timeliness, and accuracy time



Reconstruct- Infrastructure Inspection Solution

Integrated with AUTODESK® **BIM 360**™ *and built on Autodesk FORGE*

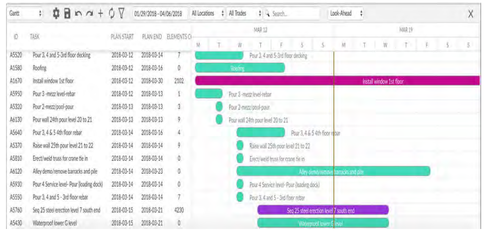
#1 Historical Record

Reality Capture

#2 Visual Inspection

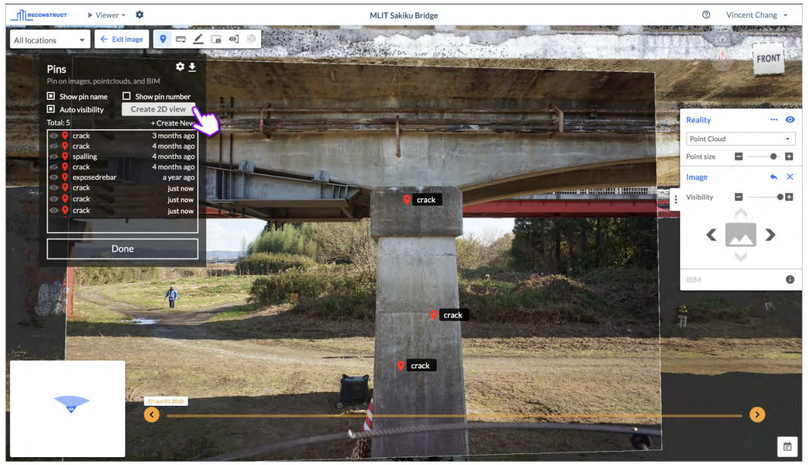
+ Drawings and Models

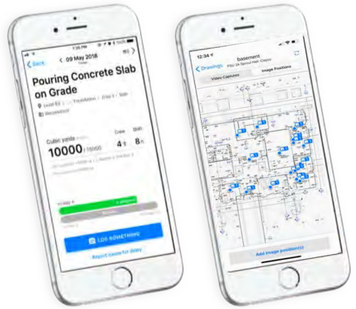
#3 Work Order Tracking



+ Schedule

Reconstruct





Visual & Virtual- A new approach to infrastructure inspection

Multi-Modal Capture

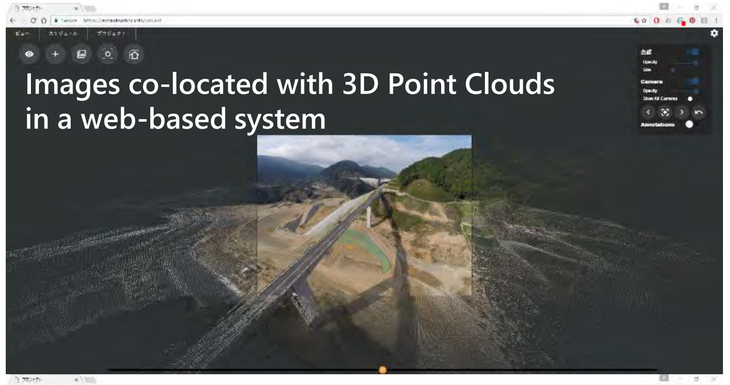
- Images, videos (still and 360)
- Using drones, hand-held cameras, web cams, scanners

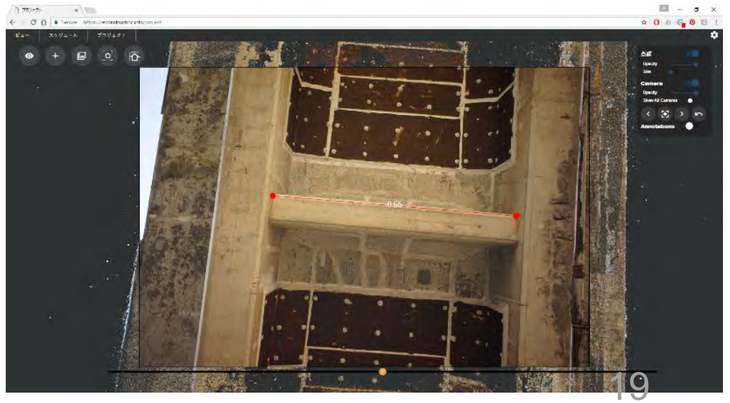
Web-based Visualization & Collaboration

- All-needed data accessible online
- Correlated and linked
  - Captured images, reconstructed 3D point cloud, CAD/BIM, inspection manual/procedure, reports, etc.
- Office & Field (Mobile) communication, collaboration

System-wide Analytics and Reporting

- Over time, across bridge types
- Templated, customized reports
- Progression & comparison – 4D Reality Model and all correlated reports and other data

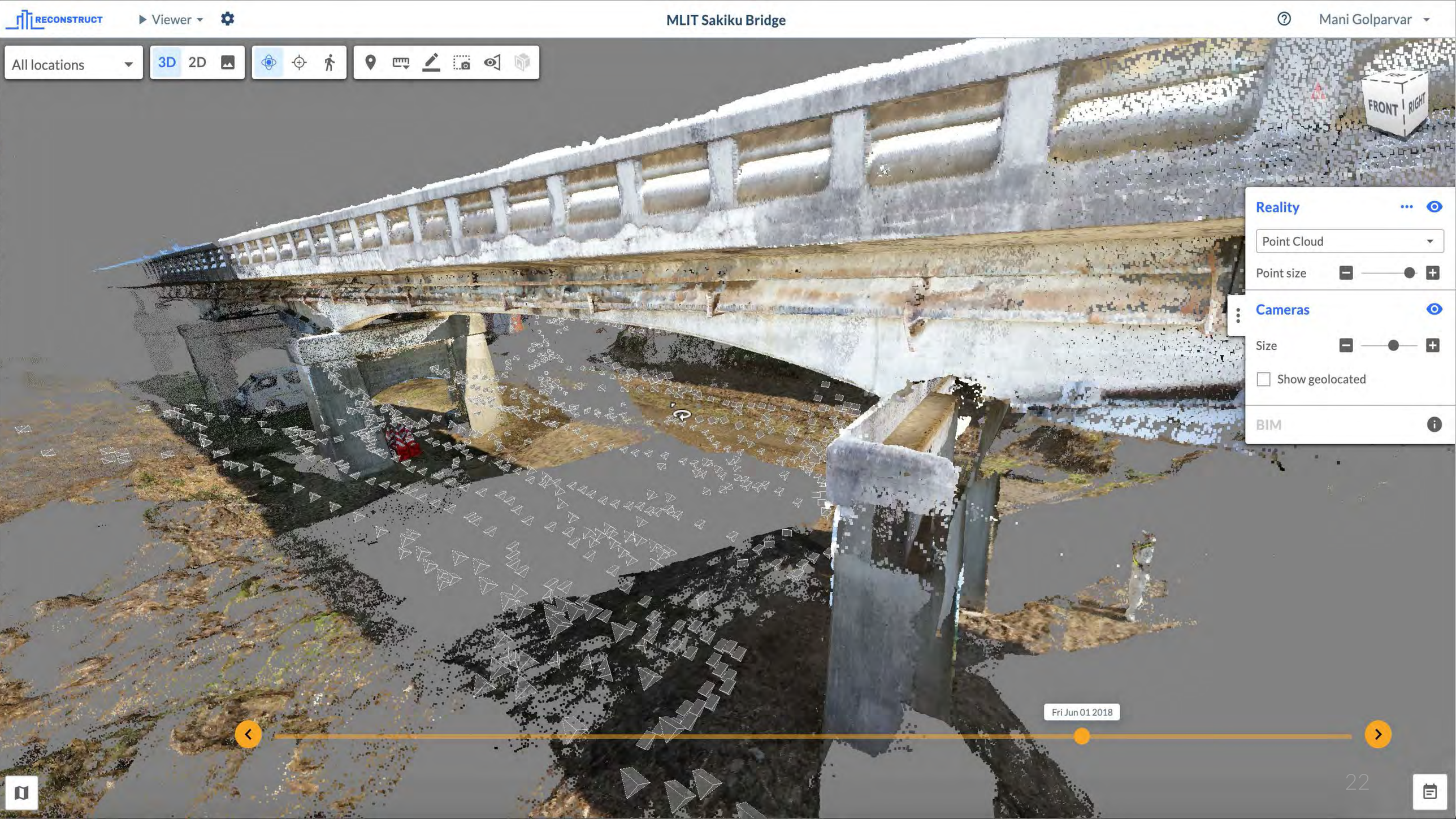




Generate Point Clouds from Images/Videos

Still images from drones and videos from 360° cameras

Conduct Inspection (measure/document defects in 3D)


RECONSTRUCT
Viewer
MLIT Sakiku Bridge
Mani Golparvar
All locations
3D
2D
FRONT
RIGHT
Reality
Point Cloud
Point size
Cameras
Size
Show geolocated
BIM
Fri Jun 01 2018
22

Visual Inspection workflow

Data Collection

- Capture Visual Data

(Use Reconstruct guideline)

Automatic Processing

- Import 2D/3D design and align against reality models

- Process Data into Point Cloud

(Reconstruct- automated)

Inspection & Analysis

- Perform Virtual Walk and identify with PINs locations that need improvement
- Document defect type, severity in each PIN
- Pins includes image mark-up

(Use Reconstruct system – interactive)

Report generation & Sharing

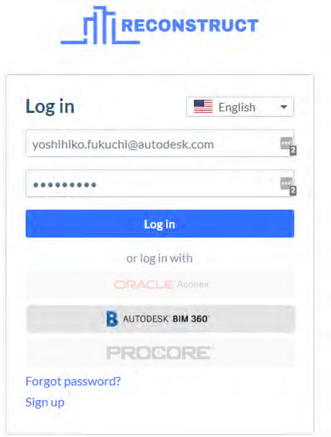
- Export PINS and images from Reconstruct and upload report (or CSV) into Work Order Management System or MLIT forms
- (URLs to Reconstruct exact location of PINs can be provided in Work Order System

(Reconstruct- automated)

Secure Storage & Online Access

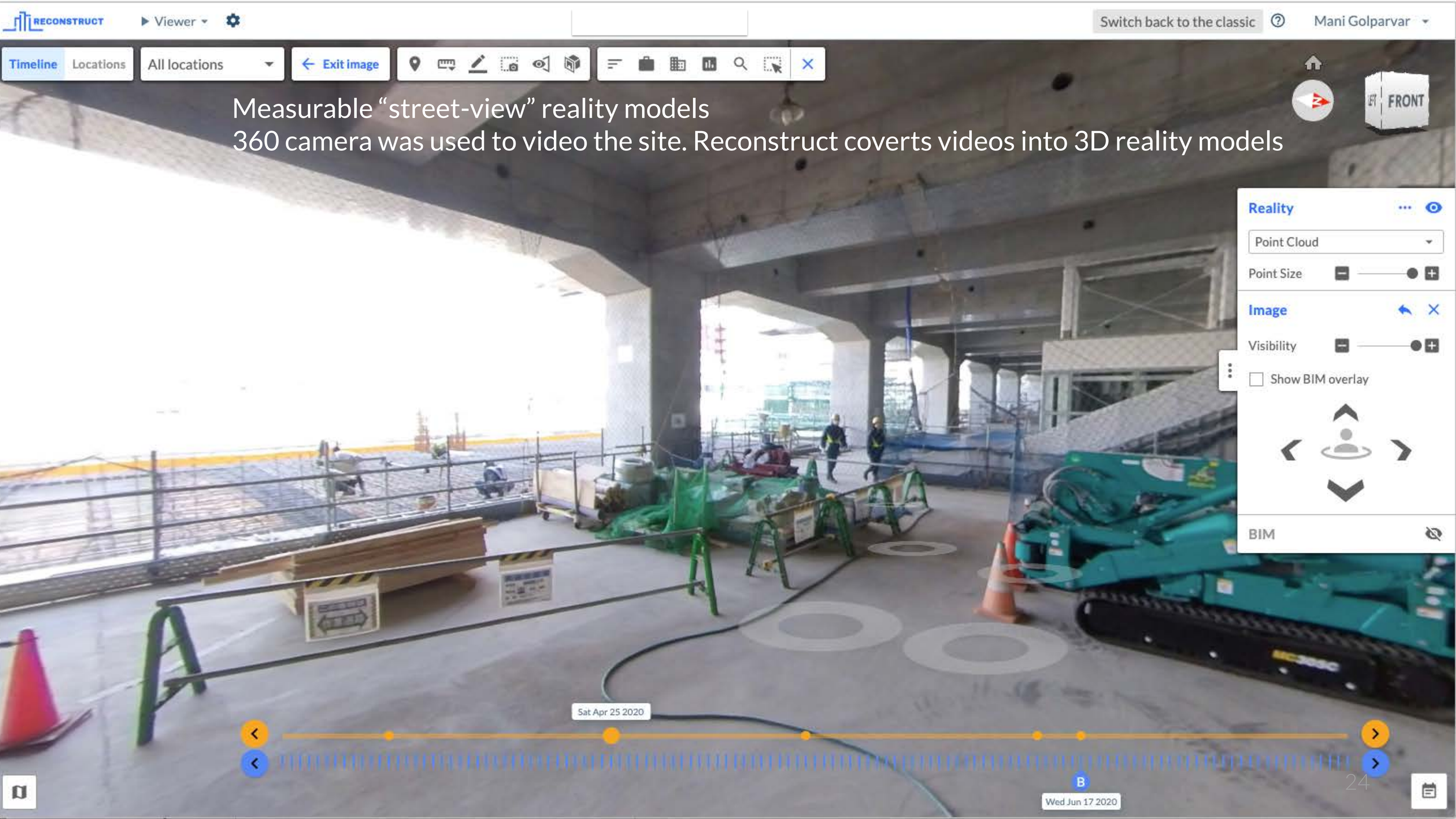
- Web-based System
- Unlimited Access for Users with Different Roles and Access Levels

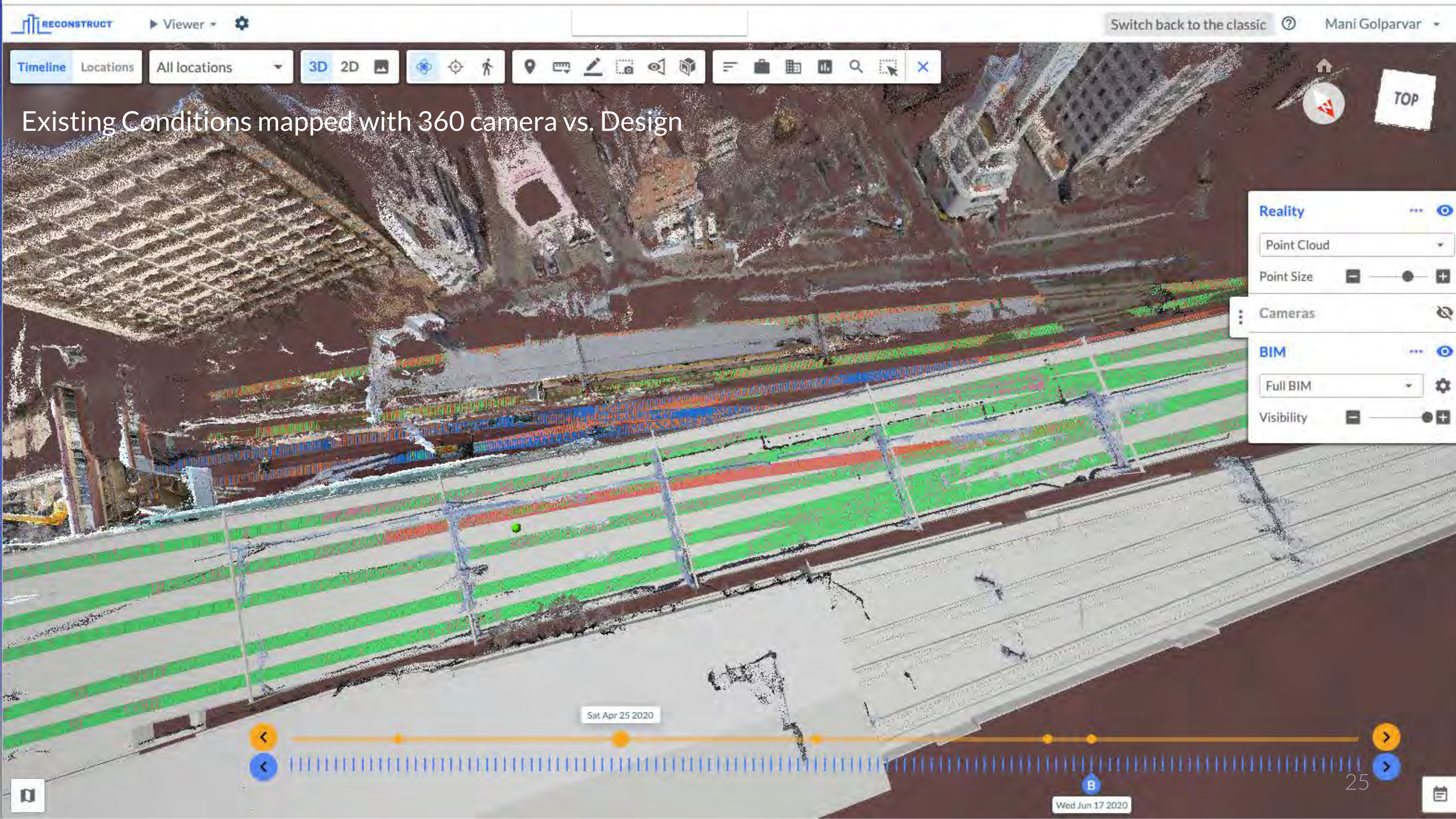
(Reconstruct- automated)

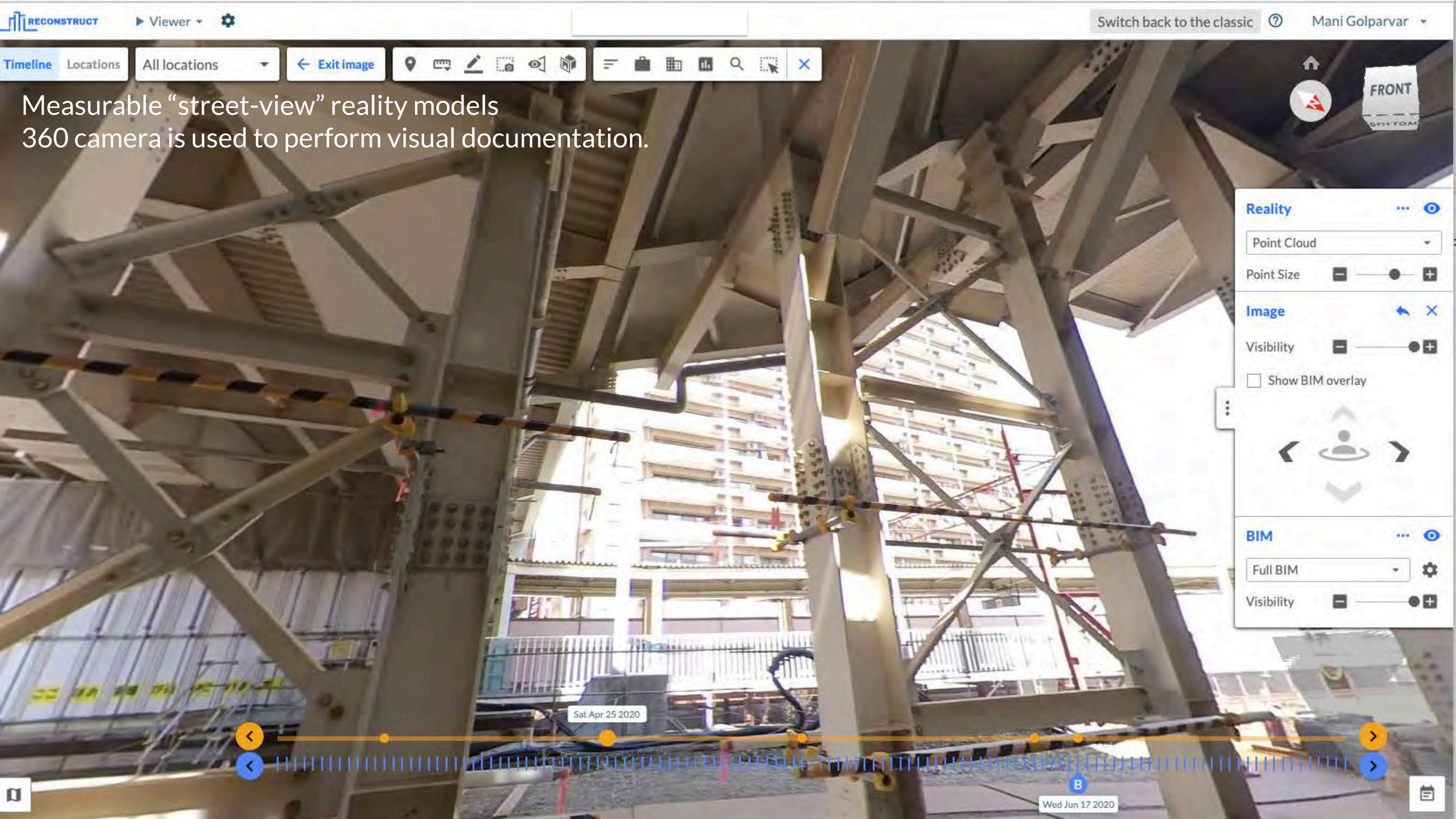


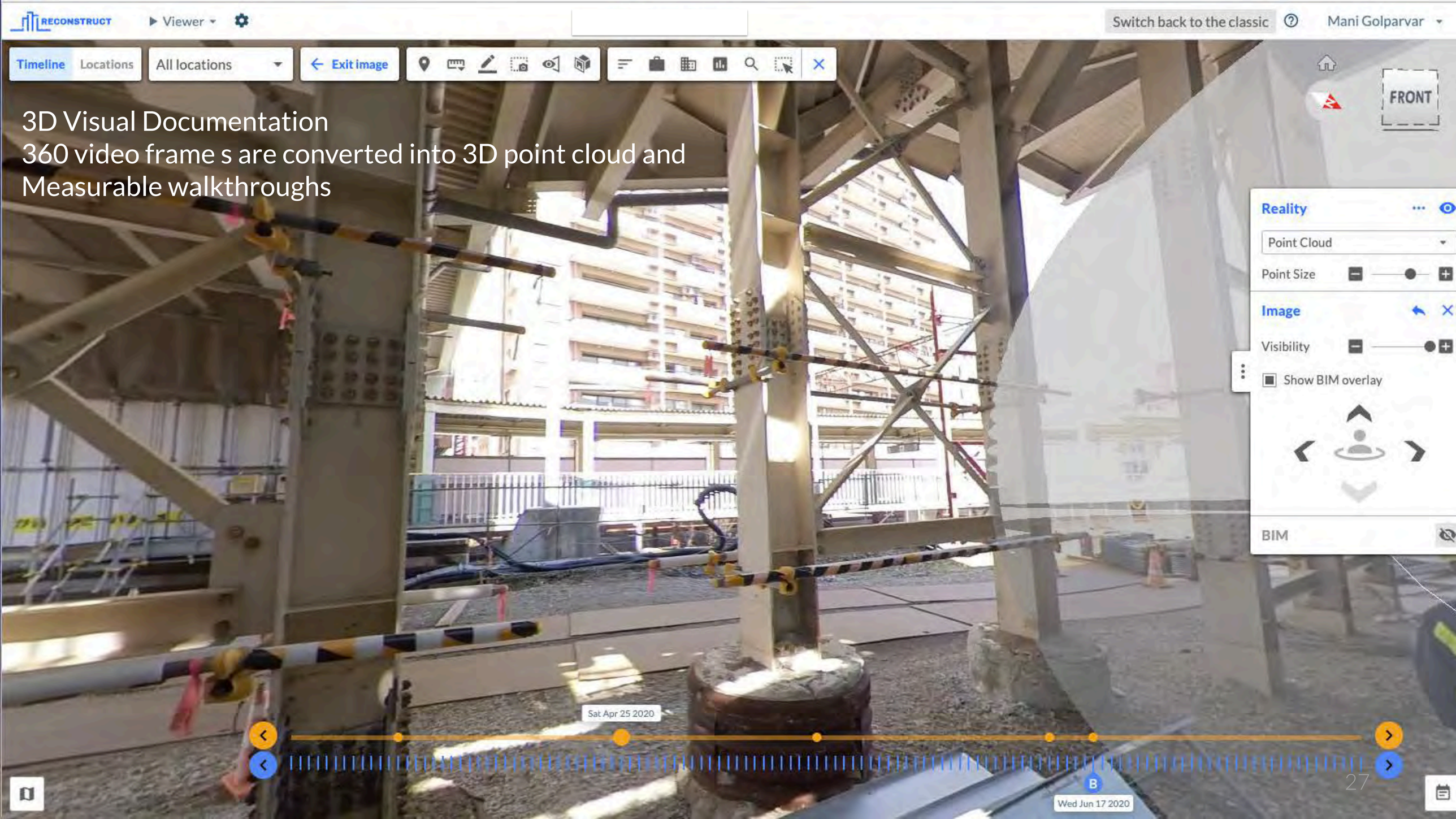
To be released soon

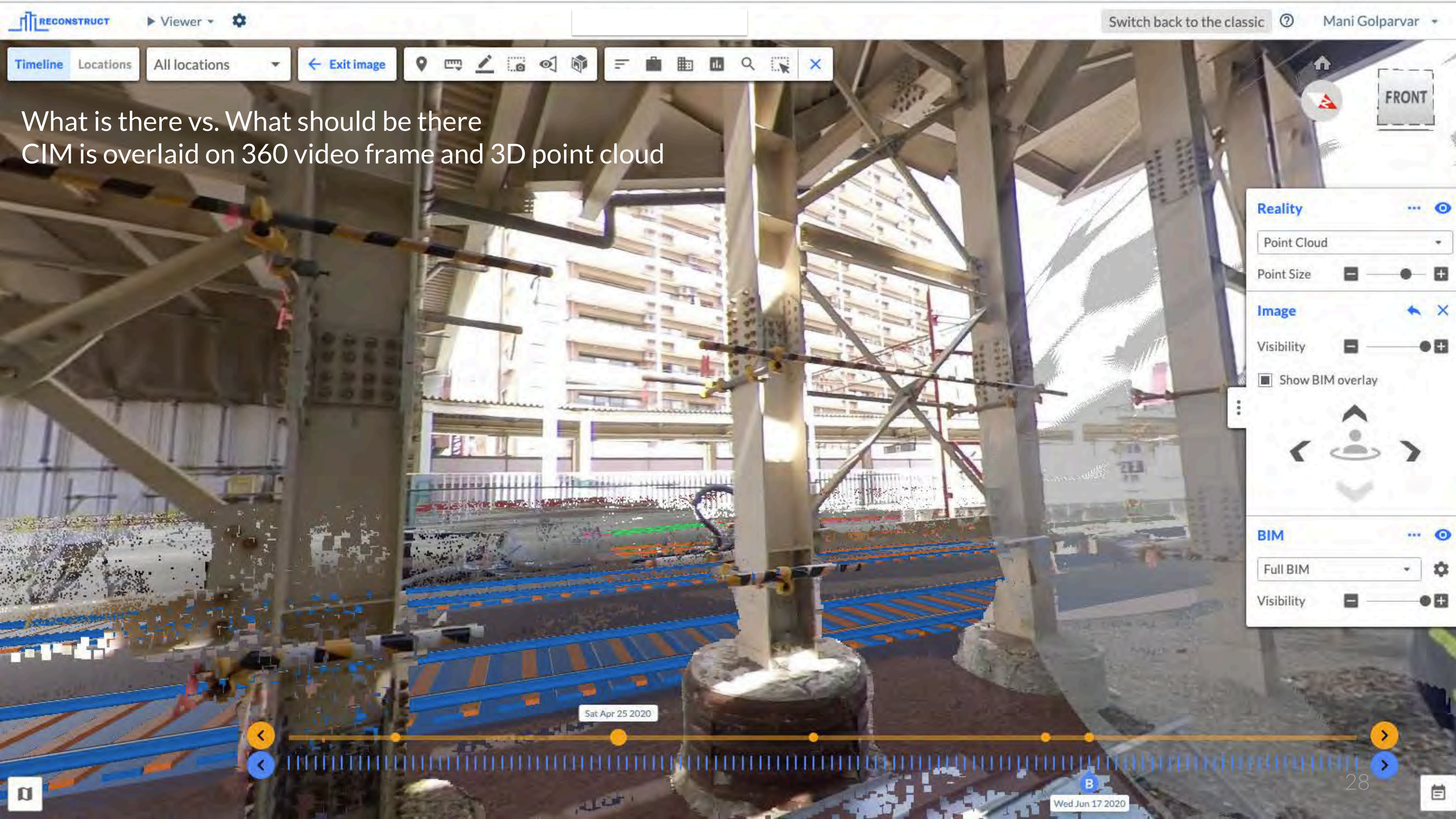
- Web-based System
- Long term Data Management
- ISO19650 compliant


RECONSTRUCT
Viewer
Switch back to the classic
Mani Golparvar
Timeline
Locations
All locations
Exit image
Measurable “street-view” reality models
360 camera was used to video the site. Reconstruct coverts videos into 3D reality models
FRONT
Reality
Point Cloud
Point Size
Image
Visibility
Show BIM overlay
BIM
Sat Apr 25 2020
B
Wed Jun 17 2020
24


RECONSTRUCT
Viewer
Switch back to the classic
Mani Golparvar
Timeline
Locations
All locations
3D
2D
Existing Conditions mapped with 360 camera vs. Design
TOP
Reality
Point Cloud
Point Size
Cameras
BIM
Full BIM
Visibility
Sat Apr 25 2020
B
Wed Jun 17 2020


RECONSTRUCT
Viewer
Switch back to the classic
Mani Golparvar
Timeline
Locations
All locations
Exit image
Measurable “street-view” reality models
360 camera is used to perform visual documentation.
FRONT
Reality
Point Cloud
Point Size
Image
Visibility
Show BIM overlay
BIM
Full BIM
Visibility
Sat Apr 25 2020
Wed Jun 17 2020


RECONSTRUCT
Viewer
Switch back to the classic
Mani Golparvar
Timeline
Locations
All locations
Exit image
3D Visual Documentation
360 video frame s are converted into 3D point cloud and
Measurable walkthroughs
FRONT
Reality
Point Cloud
Point Size
Image
Visibility
Show BIM overlay
BIM
Sat Apr 25 2020
B
Wed Jun 17 2020


RECONSTRUCT
Viewer
Switch back to the classic
Mani Golparvar
Timeline
Locations
All locations
Exit image
What is there vs. What should be there
CIM is overlaid on 360 video frame and 3D point cloud
FRONT
Reality
Point Cloud
Point Size
Image
Visibility
Show BIM overlay
BIM
Full BIM
Visibility
Sat Apr 25 2020
B
Wed Jun 17 2020

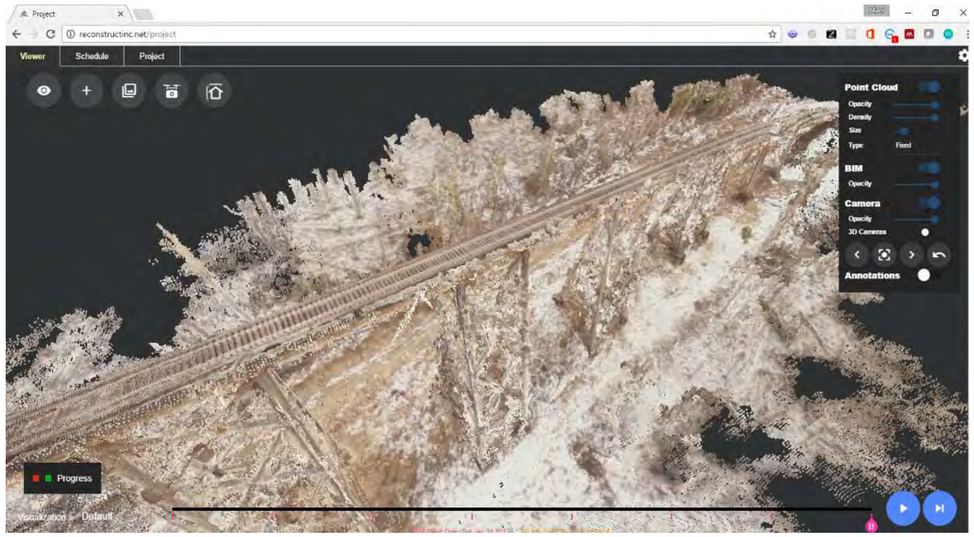
Inspection & Analysis

- **Visual inspection in images**
  - Find image based on current view or 3D point
  - Deep zoom to see fine details

- **Measurement**
  - Length, angle, area, and coordinates
  - 3D measure directly on images

- **Document**
  - Mark up images
  - Pin defect location, type (crack vs. spalling vs. exposed rebar), severity (low to high risk) and add notes

- **Change over time**
  - See model and images at various points in time



Report Generation and Sharing

- **Save and share viewpoints, annotations, and measurements**
  - Online Documentation
  - Email
  - Text Messages

- **Attach reports and other files to 3D locations**

Creating Desired Report Views

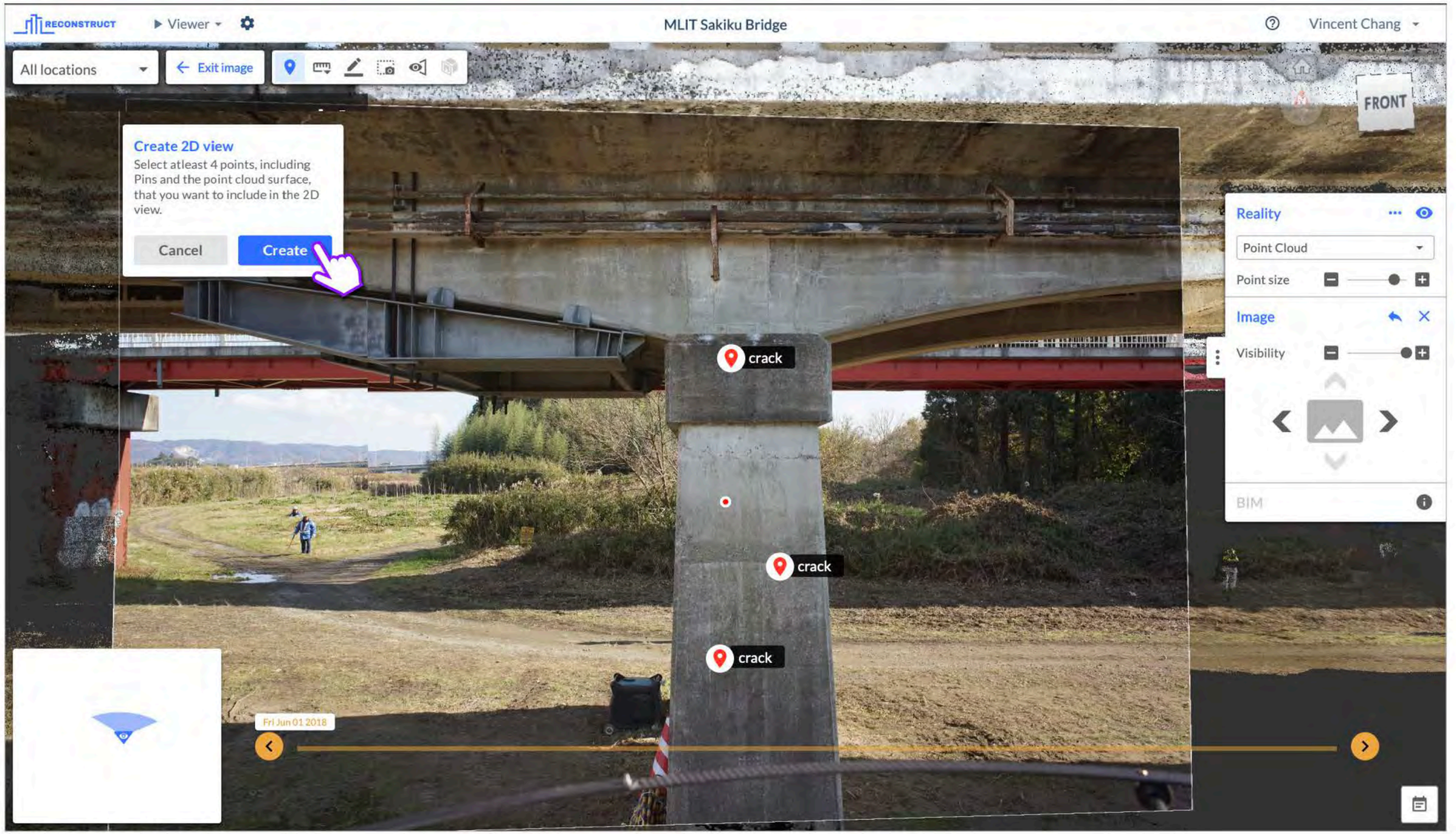
Create 2D view

Creating Desired Report Views

Selecting 4 points in total to create 2D view

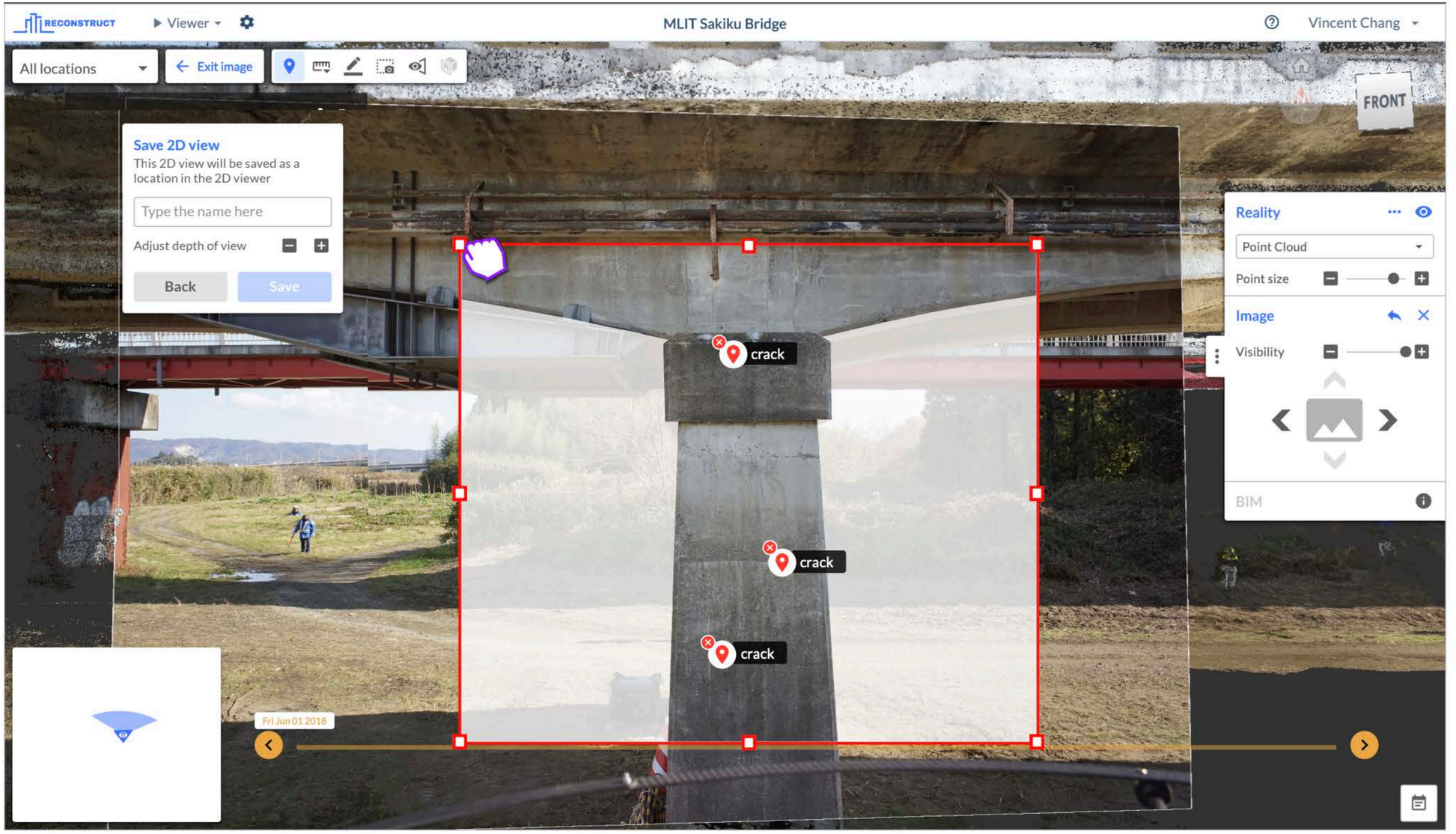
Creating Desired Report Views

4 points selected. Create 2D view.



Creating Desired Report Views

Adjust the view to the desired size. Enter the name of the view.

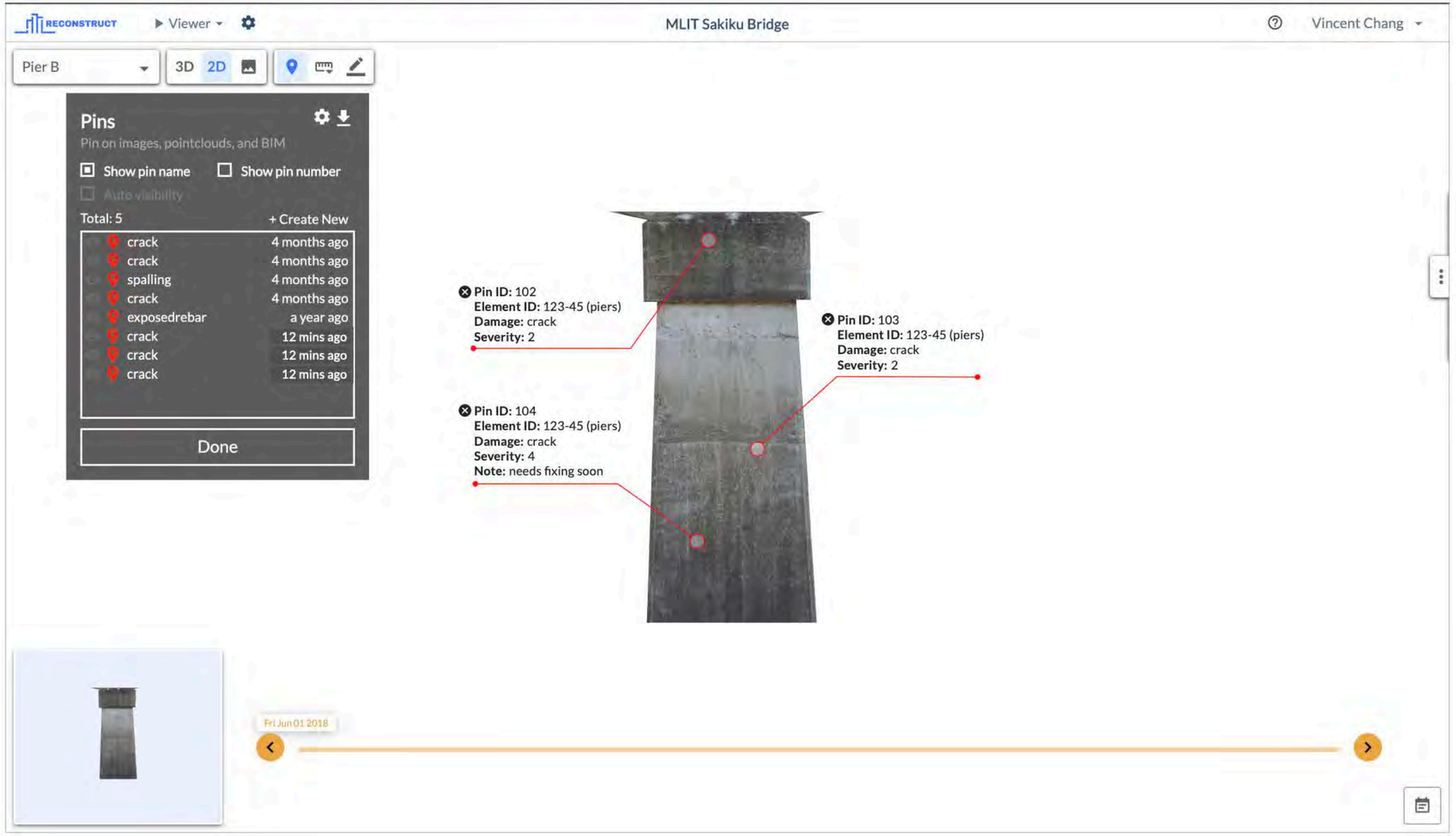


Creating Desired Report Views

This is `Pier B` in 2D

Creating Desired Report Views

This is `Pier B` in 2D with callouts



Generate inspection forms (example: Japanese MLIT official reports)

データ記録様式(その9) 損傷図
Form9: Damage figure(Figure of Damage)

径間番号 Span number

起点側 start point 緯度latitud 度longitu

終点側 Arrival poin 緯度latitud 度longitu

橋梁ID Bridge ID

フリガナ 橋梁名 Bridge name

路線名 Route name

管理者 Administrator name

橋梁コード Bridge Code

損傷図 Damage figure

Defect: Crack
Severity: 3
Note: Surface area is about 10 cm2

Defect: Crack
Severity: 4
Note: Surface area is about 10 cm2

Defect: Spalling
Severity: 2
Note: Spalling is about 10 cm2

Defect: Spalling
Severity: 3
Note: Spalling is about 10 cm2

East Elevation Orthographic View

径間番号 Span number

起点側 start point

終点側 Arrival poin

橋梁ID Bridge ID

路線名 Route name

管理者 Administrator name

橋梁コード Bridge Code

写真番号 Photo number

部材名 Part name

要素番号 element number

損傷の種類 type of damage

損傷程度 degree of damage

1

前回損傷程度

Crack

メモ

Our approved vendor's crack sealant to be applied.

Reconstruct is the basis of Japanese National Guideline for Bridge Inspection-
Japan Ministry of Land, Infrastructure, Transport and Tourism (MLIT)

Online Access & Secure Storage

Accessibility

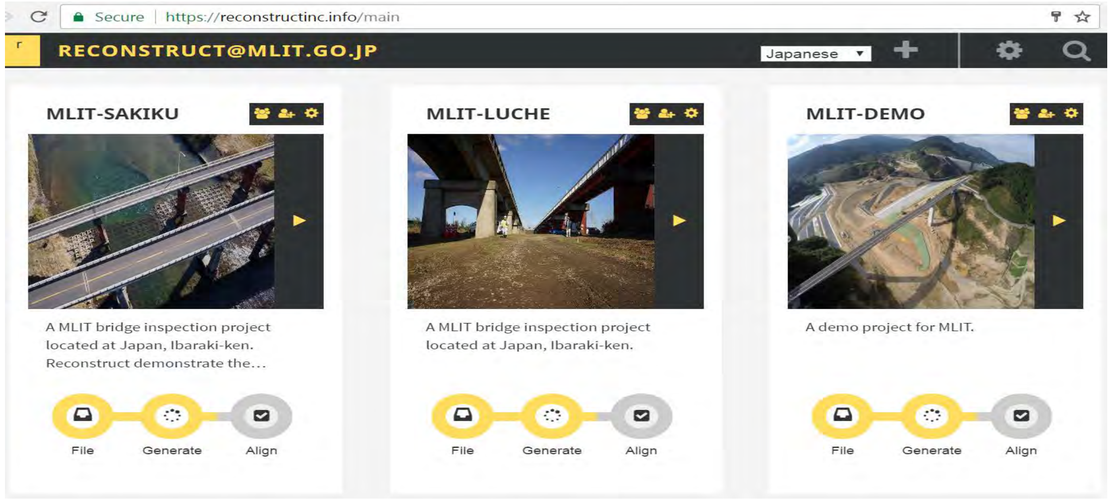
- Access to all infrastructure assets, organized by date, location, or identified issues via a dashboard

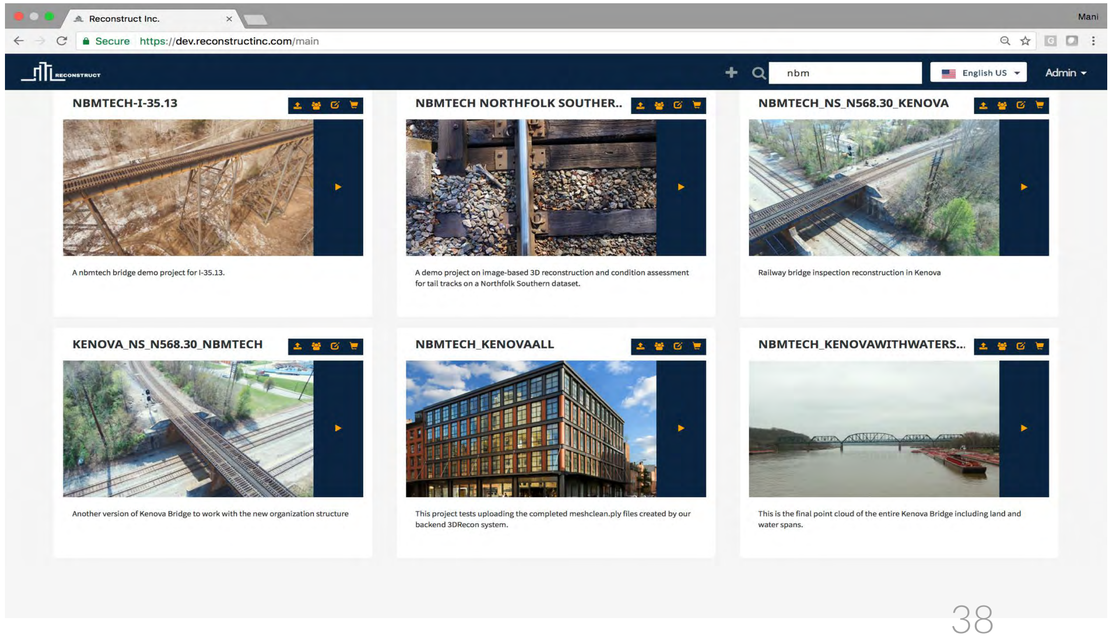
Cloud data security

- Data in cloud, available online & mobile

Customization

- Standards and practices
- Migration of existing data (optional)





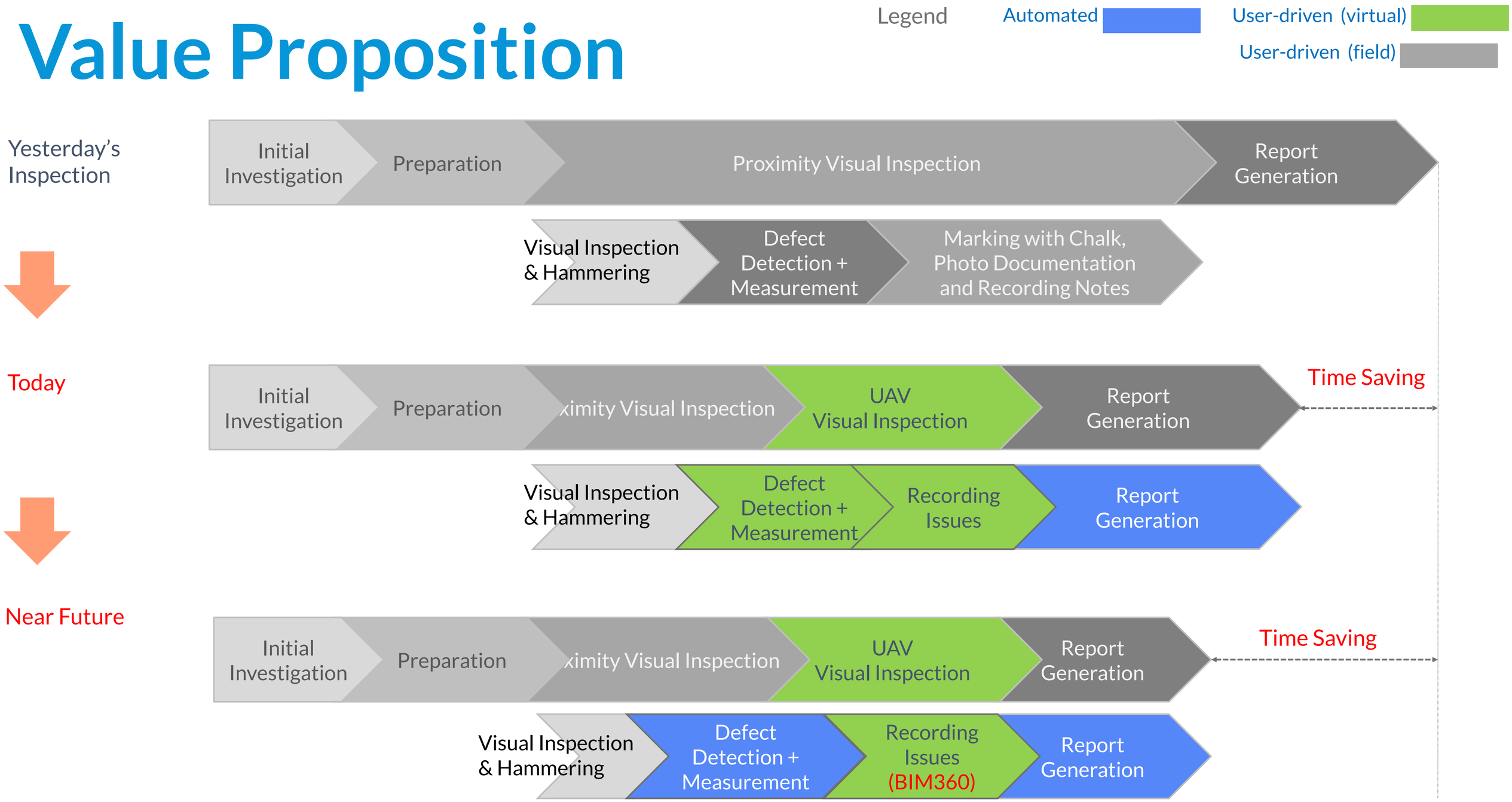
Later inspections

- **Update data on previously identified issues**
  - Identify key locations to take additional high-resolution photos
- **Compare 3D models and images across time**
- **Add/edit maintenance data**


Spans 3-5 East Side, Fredericksburg Bridge, VA


Column #7, Fredericksburg Bridge, VA

Value Proposition

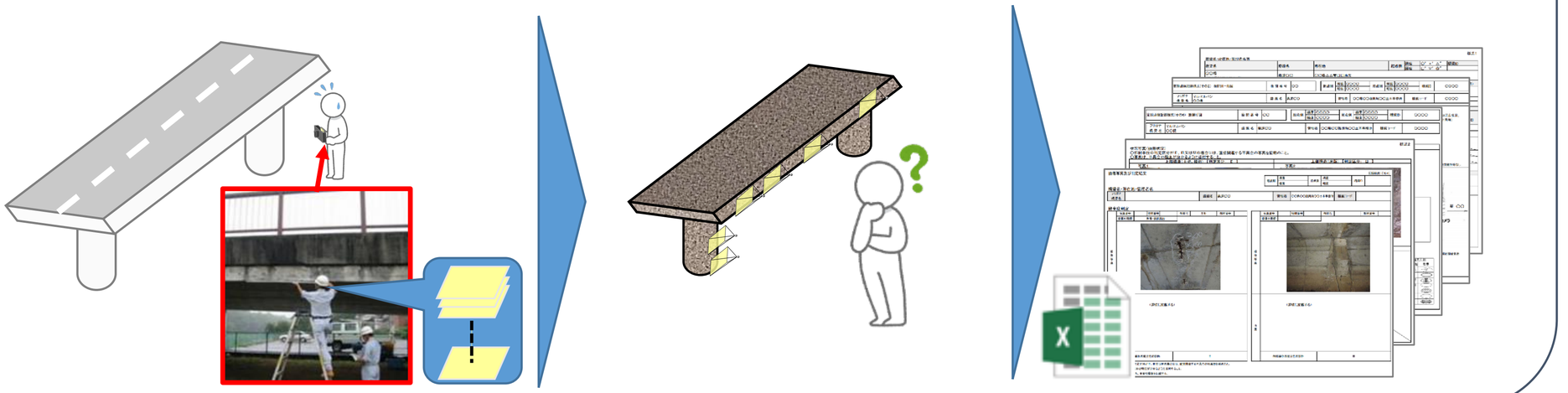


Reconstruct Inspection Solution

STEP1：現地での損傷確認及び画像撮影
On-site damage confirmation and imaging

STEP2：損傷内容、位置を画像より判断
Judgment of the damage type and location from images

STEP3：把握した内容を点検帳票として整理
Organize the contents as bridge inspection report forms



Visual Data Management

- 4D Reality Models (point cloud)
- Localized Images – images associated with *specific locations/points* on bridge
- Measurement & Annotation on Images
- Deep zoom capability to see details in high-res images
- “Time Travel” – point cloud and images over time
  - Compare and detect changes
  - Correlate with inspection logs and other documents

Cloud data security

- Data in cloud, available online & mobile

Customization

- Standards and practices of your agency
- Migration of existing data (optional)

Takeaways

- **Unified system for managing bridge maintenance**
  - Reduce manual and duplicate entry of inspection data
  - Spend less time manipulating data and preparing reports
  - Reduce time to perform, enter, and review inspection
  - Reduce time to manage and communicate recommendations

- **Improve inspection documentation, timeliness, and accuracy**
- **Provide inspectors with resources necessary for inspection at their fingertips**

Picture from: Zink J. and Lovelace, B. (2016) " MnDOT UAS Project Presentation"

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Source: Zink, J. "MNDOT's new Software for Bridge Inspection and Management", IBC-12-76

AUTODESK. UNIVERSITY

Bridge Inspection with Aerial Robots: An End-to-End Automated Workflow

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