Practical Tools for the Construction Sector in Digital Twin

Round 1 – Quality Control Digital Twin Applications

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 958310

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CONSTRUCTION PHASE DIGITAL TWIN MODEL

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Agenda

- **Introduction:** COGITO project innovations and goals
- **1st Poll**: What is your experience with Digital Twin?
- **Quality Control Data Acquisition**: Visual Data Pre-Processing for contributing visual data (2D and 3D) to the project Digital Twin
- **Geometric Quality Control**: GeometricQC for automatically control geometric quality against defined specifications
- **Visual Quality Control**: VisualQC for automated defects detection in pictures acquired on site
- **DigitAR:** On-site Augmented Reality-based Digital Twin information visualisation and decision making
- **Digital Command Centre – DCC**: Off-site Digital Twin information visualisation
- Questions and Answers
- **2nd Poll**: Will the tools answer your needs?
- Wrap up & conclusions

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Introduction

Project Innovations and Goals

Giorgos Giannakis

Hypertech SA

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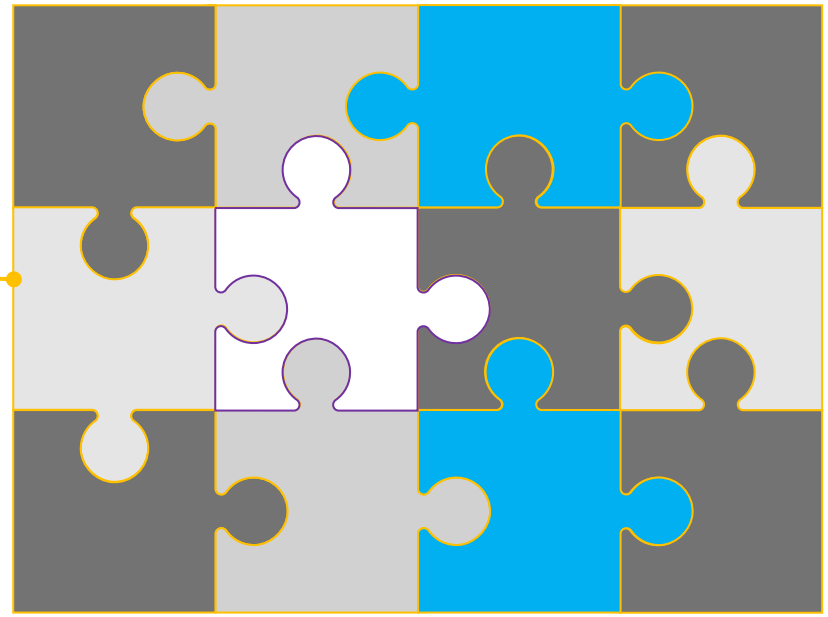
COGITO in a nutshell

Problem

- The construction phase has so far been overlooked by the Digital Twin community;
- Lack of commonly agreed standards and low interoperability among collected data reveal a major drawback to the enterprises' digital transformation.



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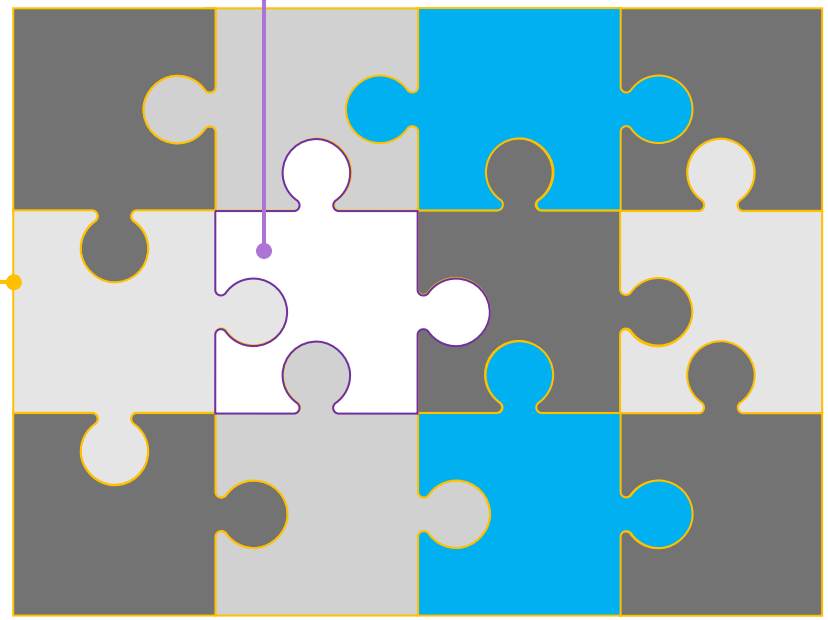
Need

- Going beyond "static" Building Information Modelling (BIM) is required by leveraging technologies like IoT, Cloud Computing and Artificial Intelligence;
- Construction projects require collaboration between many parties -> transparent platforms for digital data handling are needed;
- Automated progress and resource tracking, automated quality assessment, safety measures planning, and hazardous areas detection -> need for a COnstruction-phase diGItal Twin mOdel (COGITO).



COGITO

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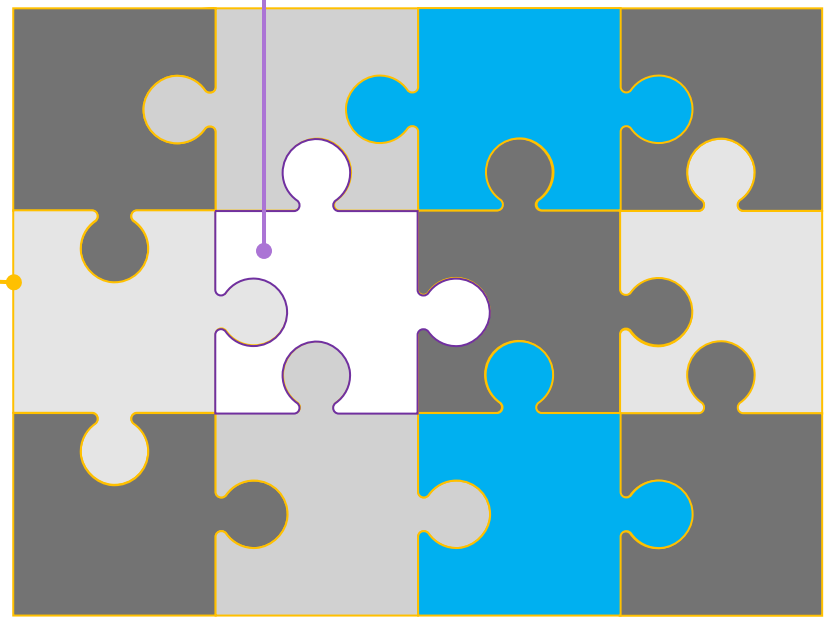
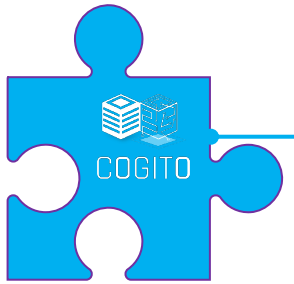


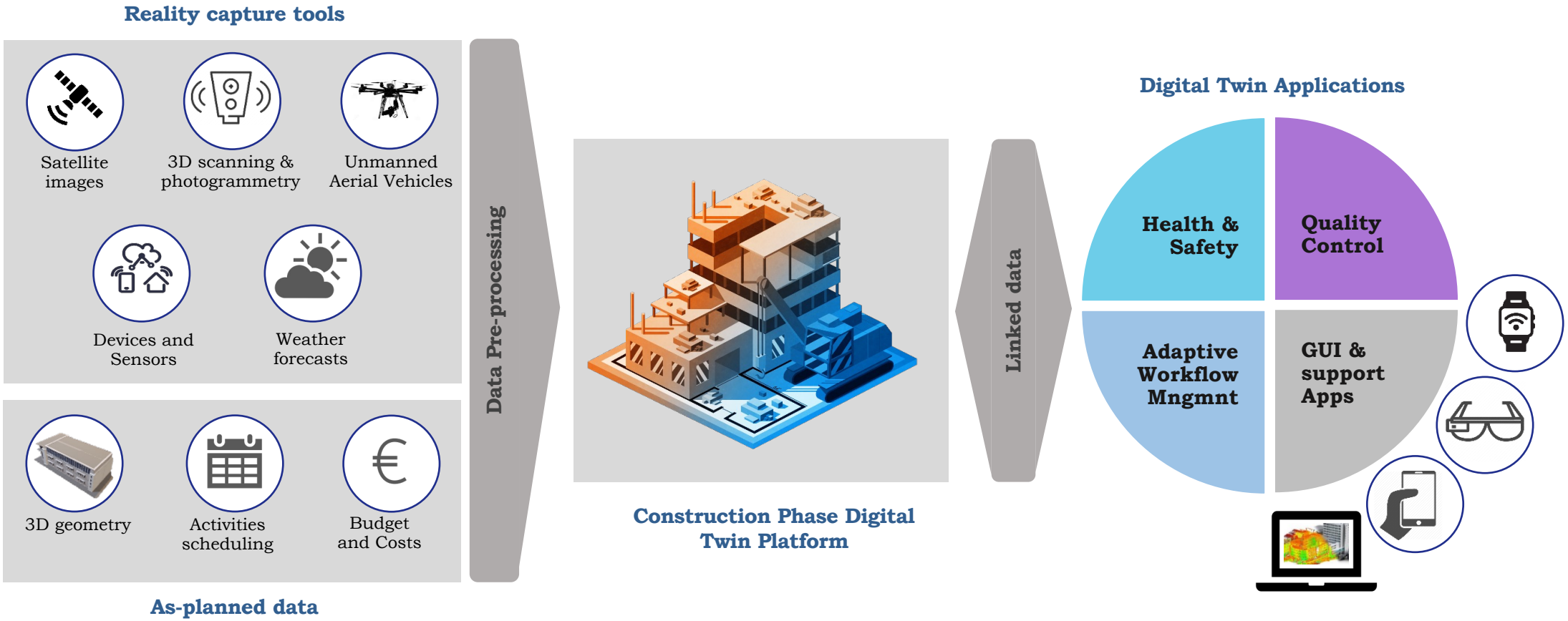
Solution

- Development and delivery of (1) a transparent digital data management platform and (2) digital Construction 4.0 toolbox that contributes to productivity improvement and increased safety.



COGITO

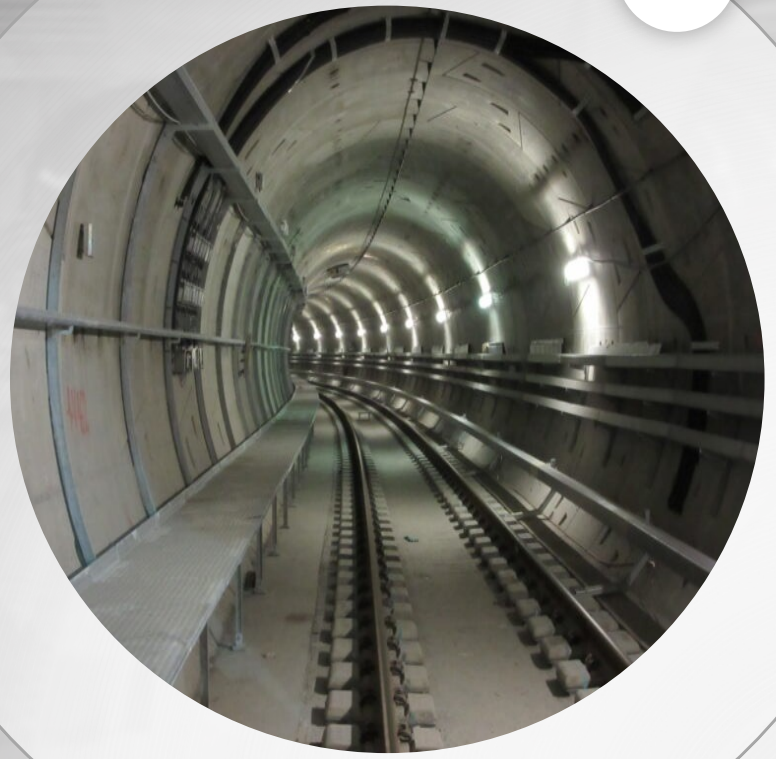
COGITO Innovations



COGITO Goals

Objective 1
Delivery of a Construction Digital Twin platform

COGITO Goals



Objective 1
Delivery of a Construction Digital Twin platform

Objective 2
Delivery of digital tools for Quality Control and Workflow Management

COGITO Goals

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Objective 3
Delivery of digital tools for Health and Safety Management

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Objective 4
Demonstration on actual construction sites to quantify the benefits of the COGITO tools

COGITO Goals

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Objective 5
Research, design and promotion for standardization data exchange formats

COGITO Goals

Objective 1
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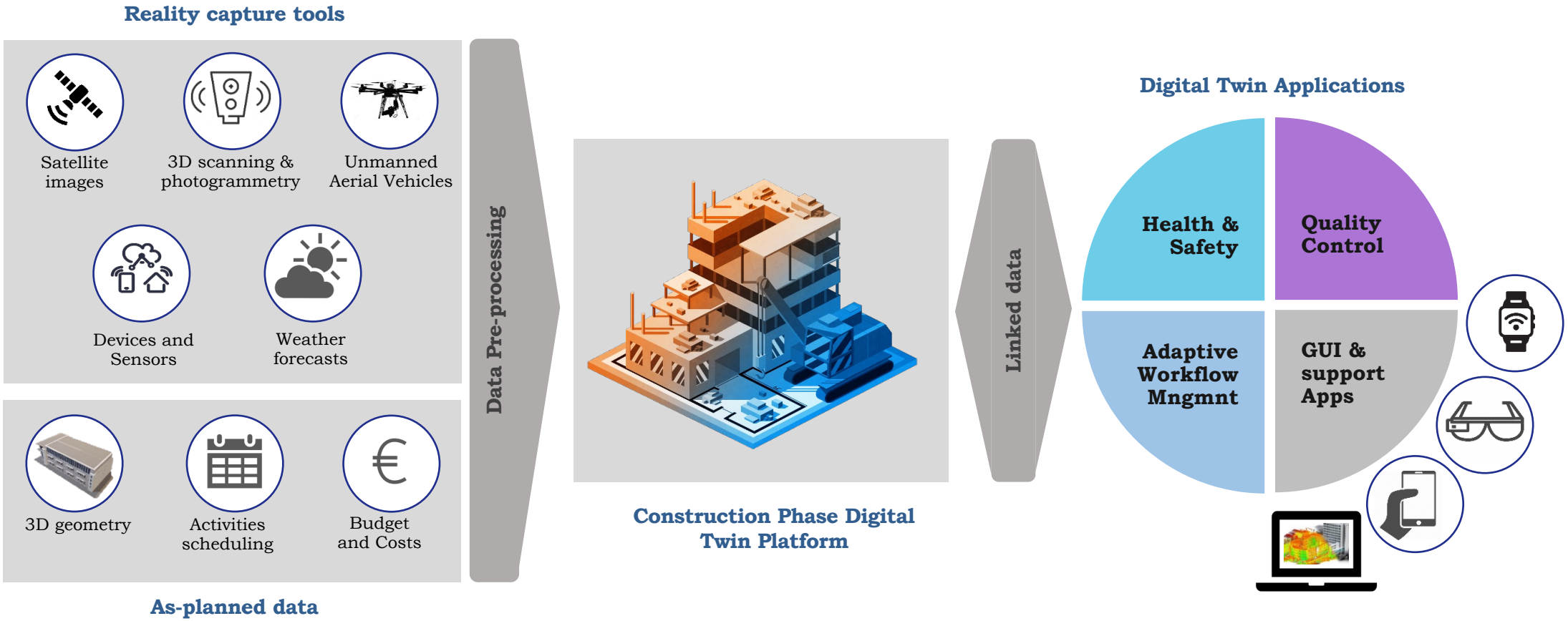
Objective 5
Research, design and promotion for standardization data exchange formats

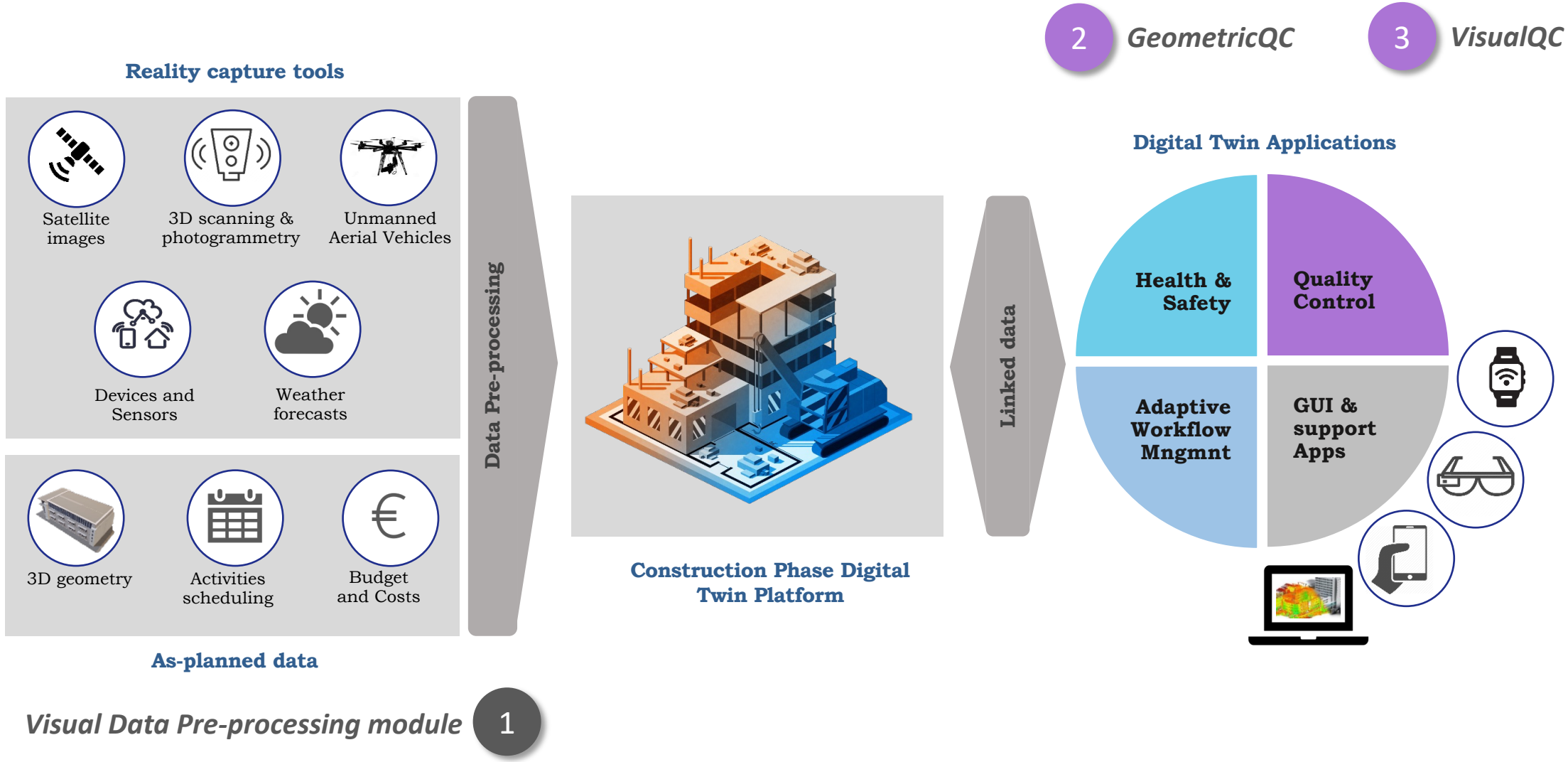
Objective 6
Promotion of the COGITO solution's adoption through intense dissemination

COGITO Quality Control

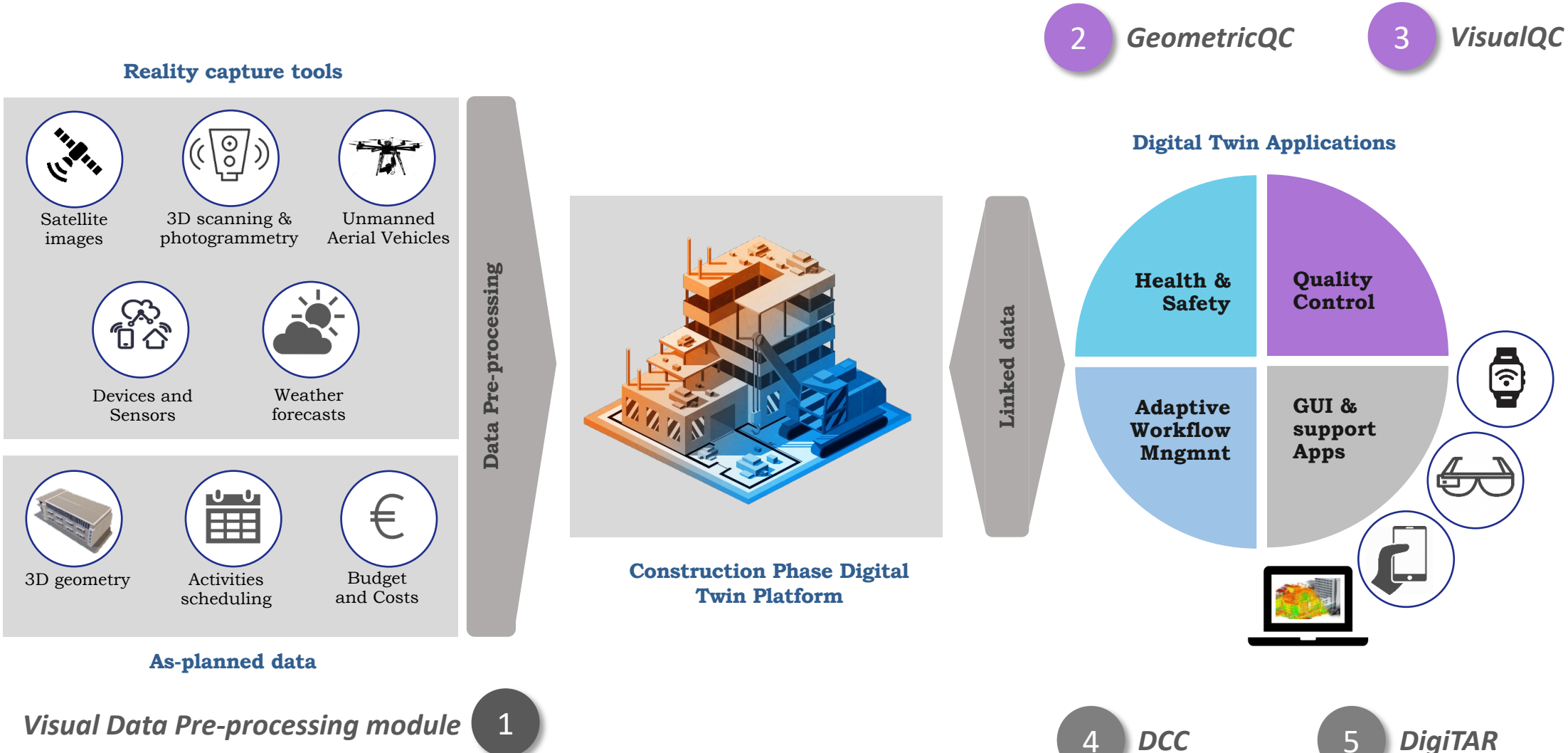


Visual Data Pre-processing module 1

COGITO Quality Control



COGITO Quality Control



1st Poll

What is your experience with Digital Twin?

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Quality Control Data Acquisition

Visual Data Pre-Processing for contributing visual data to the DT

Thanos Tsakiris

CERTH

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Visual Data Pre-processing Tool Scope

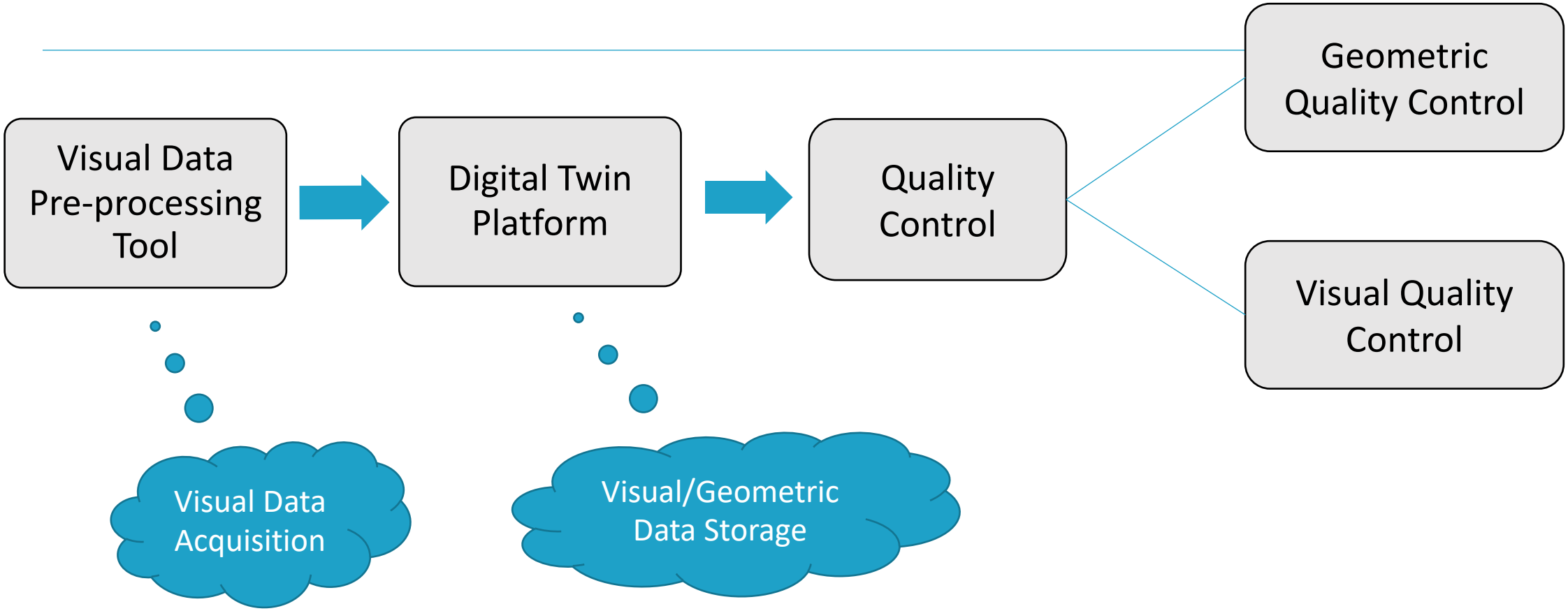
Uploading

Easy uploading of the visual data that can be collected through various data sources / devices.

Pre-processing

It is essential to pre-process the visual data before feeding them to the Quality Control algorithms (Geometric or Visual QC tools) in order to achieve more accurate results.

Architecture



Visual Data Acquisition

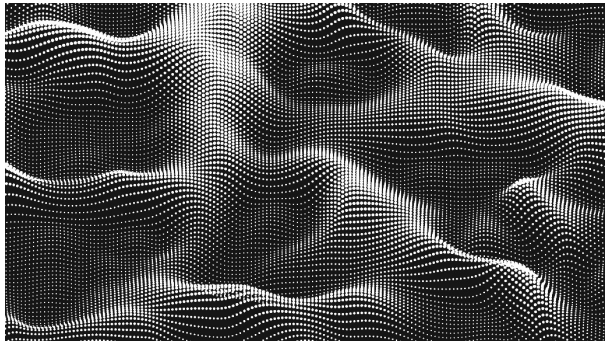
Two types of visual data:

1. Images (2D)

- Cameras
- Smartphones
- HoloLens
- Drones

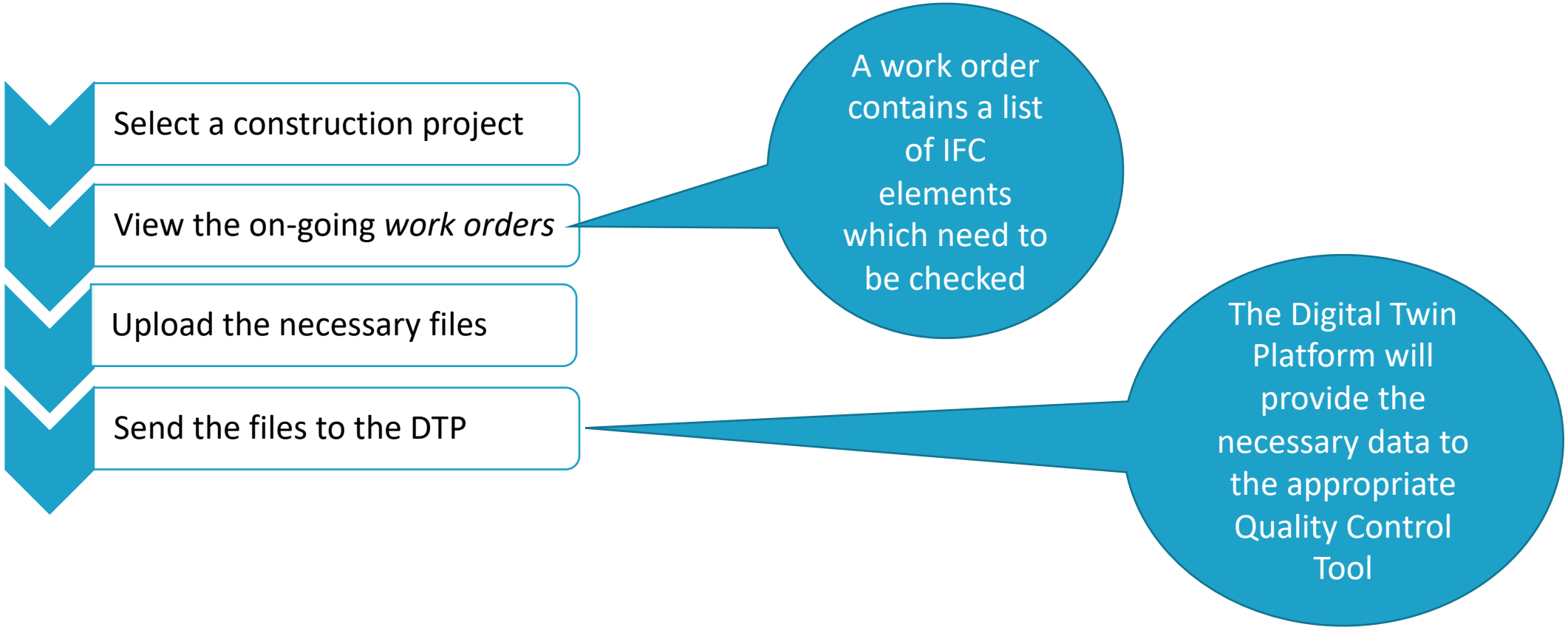
2. Point clouds (3D)

Laser Scanners



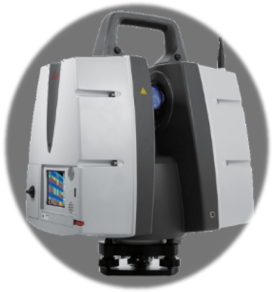
Visual Data Pre-processing Tool

A user of the Visual Data Pre-processing Tool needs to follow these steps:



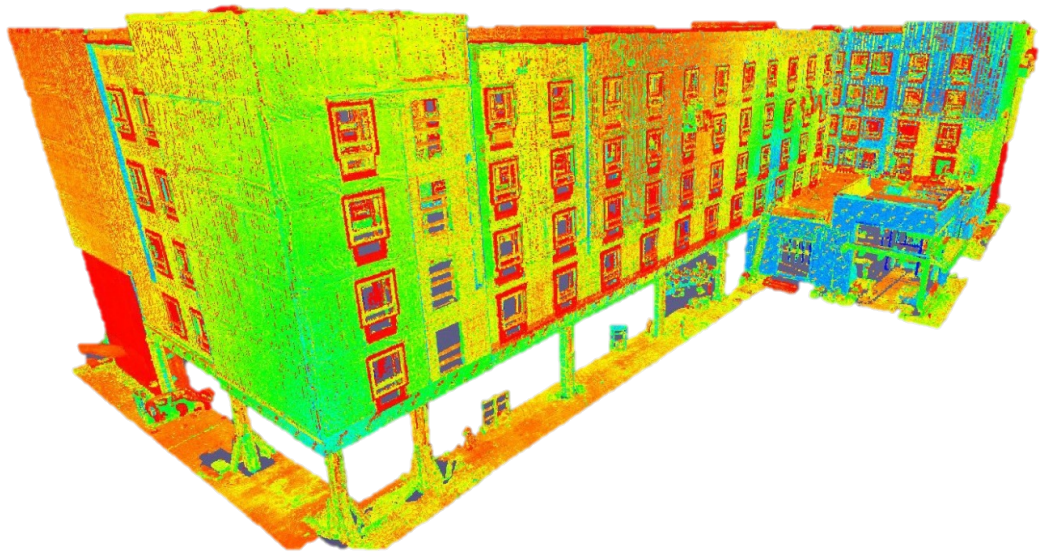
Use Case – Geometric QC

Scan the required IFC elements using a laser scanner



Upload the point cloud files (E57 or PLY format)

Assign the capturing timestamp to each point cloud



Use Case – Visual QC

An image can be captured either manually or by using some static device (ex. IP camera)

- Photograph the required IFC elements
  - Upload the images (JPG or PNG format)
    - Process the image if needed

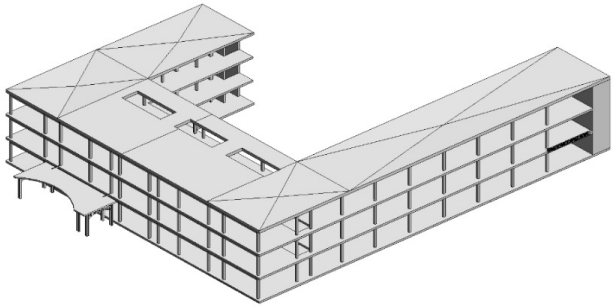
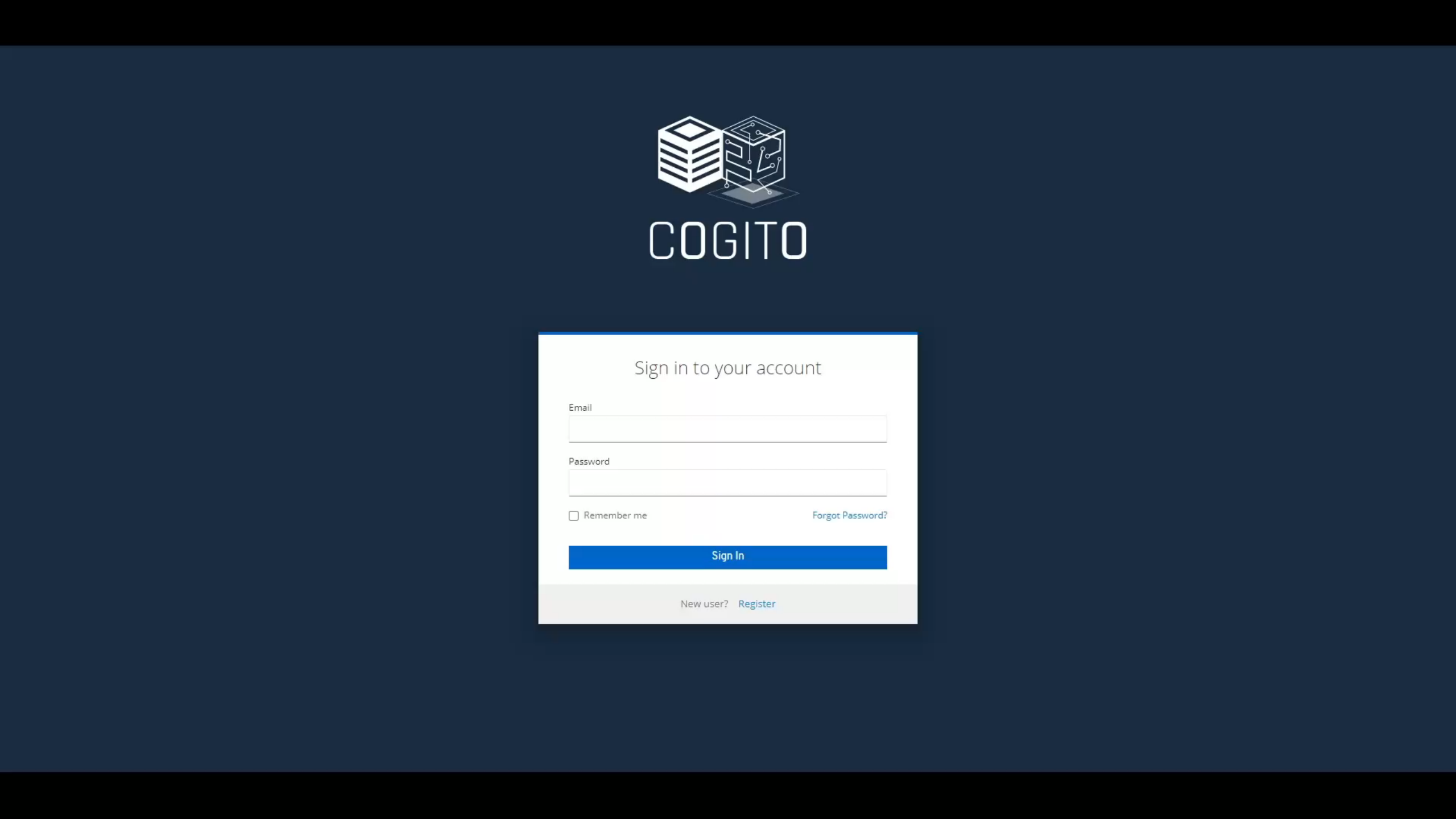


Image Processing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Sign in to your account
Email
Password
Remember me
Forgot Password?
Sign In
New user?
Register

Geometric Quality Control

GeometricQC for automatically control geometric quality against defined specifications

Martin Bueno

University of Edinburgh

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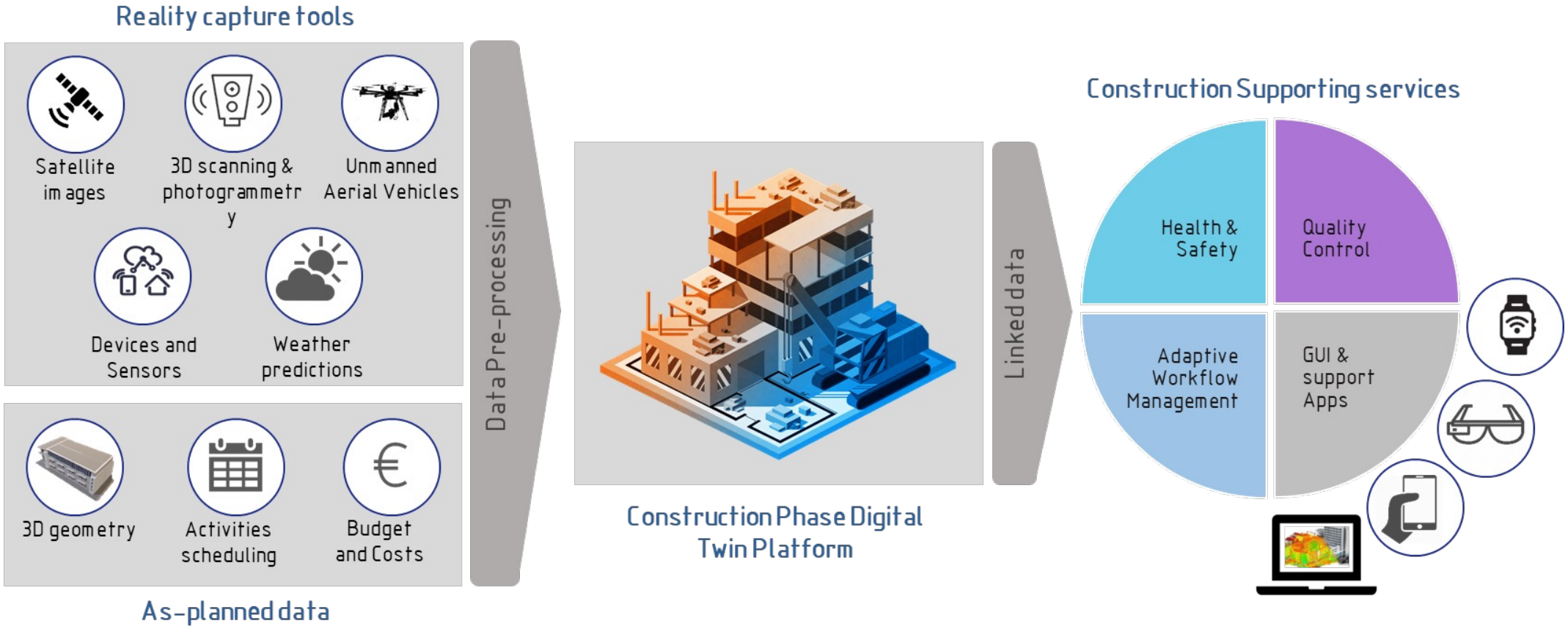
Use Case - Geometric QC

- Automated geometric tolerance compliance control



Use Case - Geometric QC

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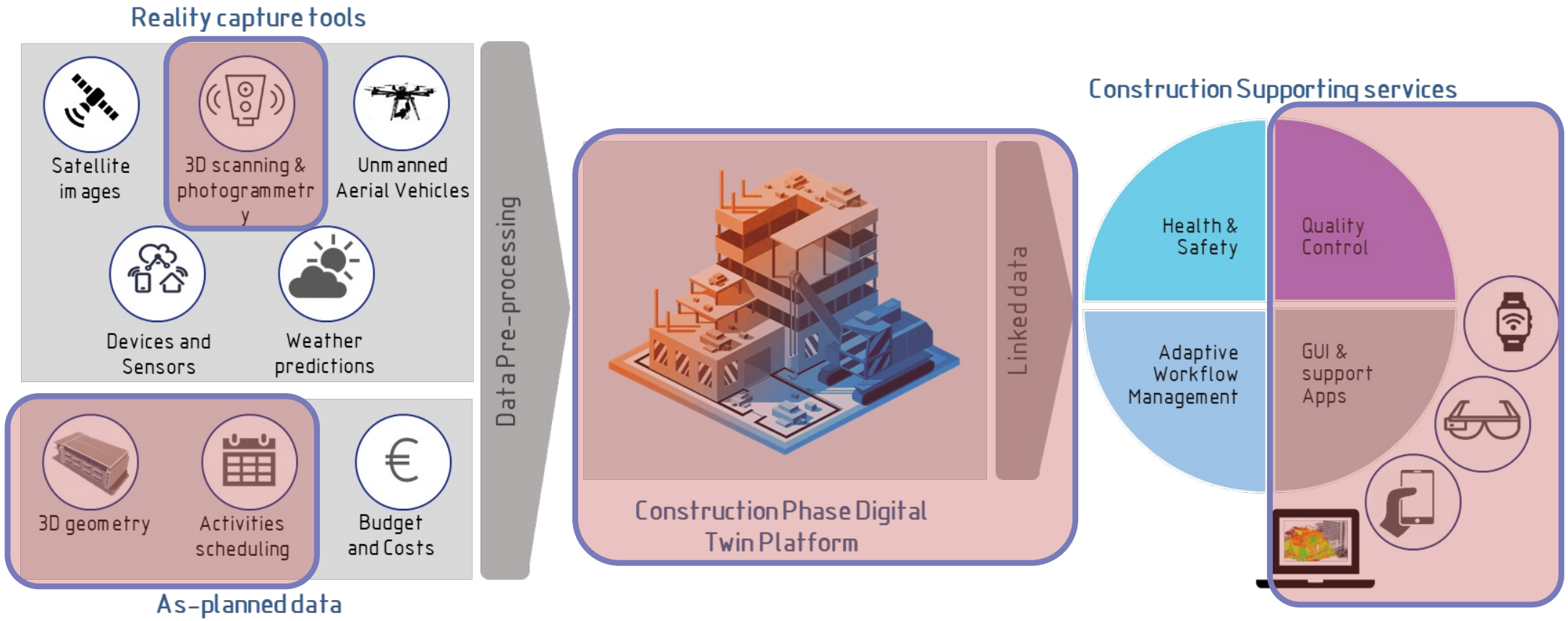
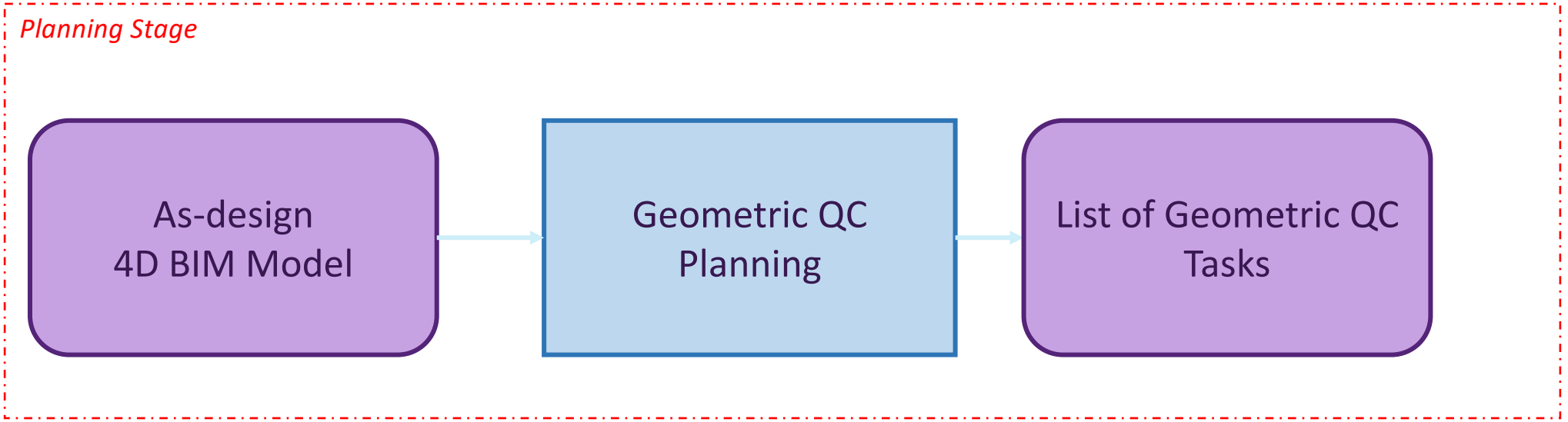


Use Case - Geometric QC

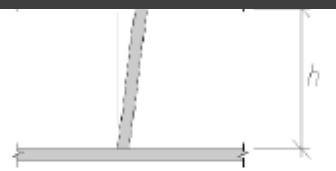
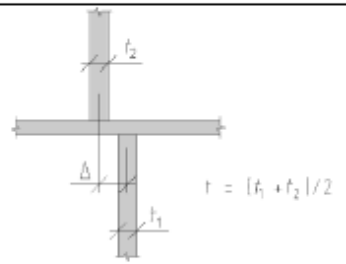
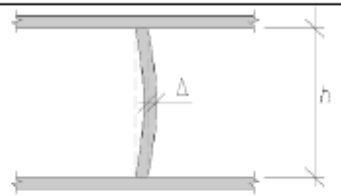
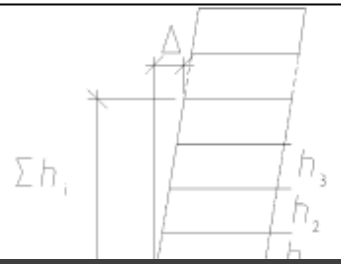


What QC needs to be conducted? And when?

Geometric QC Planning

What QC needs to be conducted? And when?

1. Digital Dictionary of *QC Rules* (i.e. Specifications)

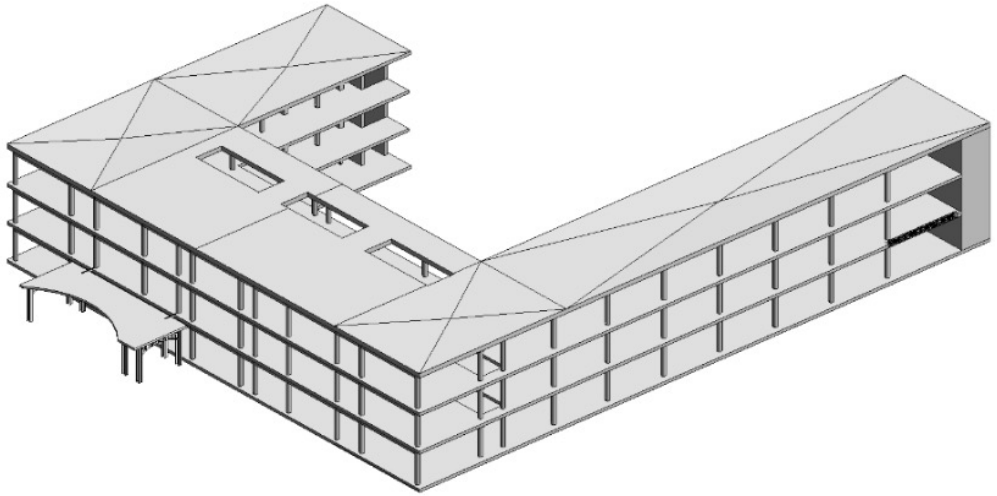
	 *h* - free height	multi-storey building *h* ≤ 10 m *h* > 10 m	15 mm or *h*/400 25 mm or *h*/600
b		Deviation between centres	The larger of *t*/30 or 15 mm but not more than 30 mm
c		Curvature of a column or wall between adjacent storey levels	The larger of *h*/300 or 15 mm but not more than 30 mm
d		Location of a column or a wall at any storey level, from a vertical line through its intended centre at base level in a multi-storey structure	The smaller of 50 mm or $\Sigma h_i/(200\ n^{1/2})$

Geometric QC Planning

- What QC needs to be conducted? And when?
  1. Digital Dictionary of *QC Rules* (i.e. Specifications)

  2. Set of *QC Rule Instances*:
     - At each location in the as-design BIM model where the *Rule Context* is encountered, an *Instance* of the corresponding rule applies.

Geometric QC Planning



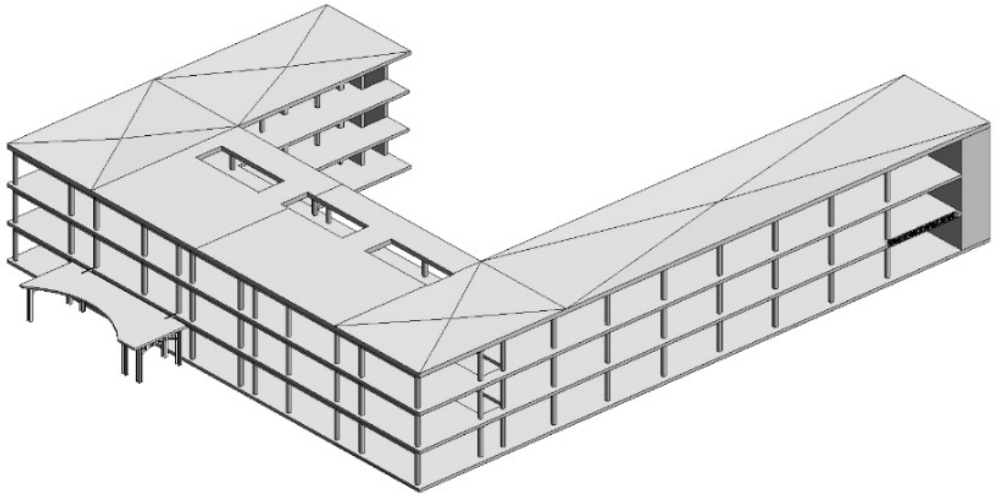
Components:

- 357 Concrete beams
- 195 Concrete columns
- 6 Concrete Walls
- 5 Concrete Slabs

Relationships:

- Adjacency within storey (horizontal)
- Physical connection
- Above/Below (i.e. stacked)
- Storey adjacency (vertical)

Geometric QC Planning



Components:

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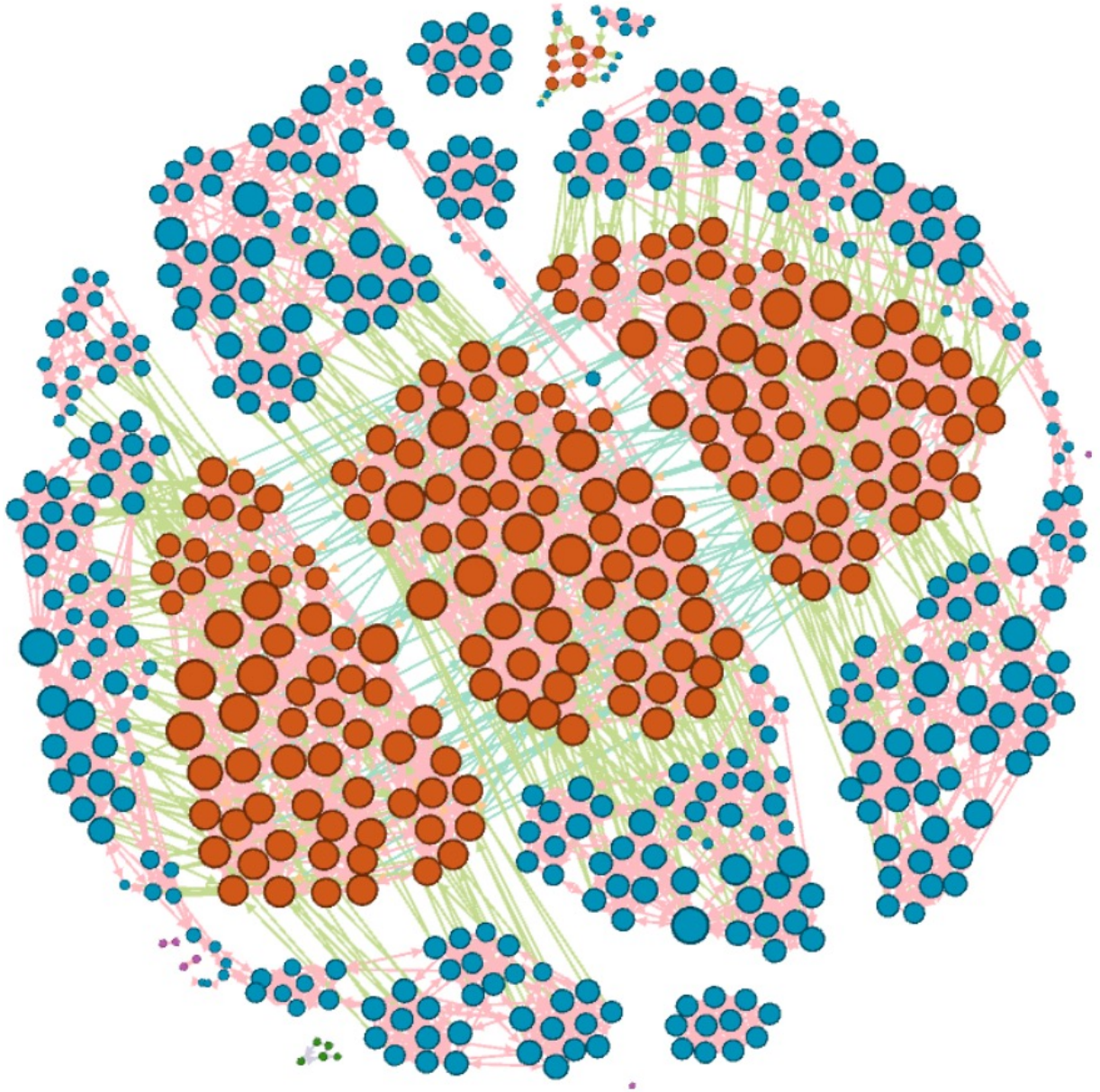
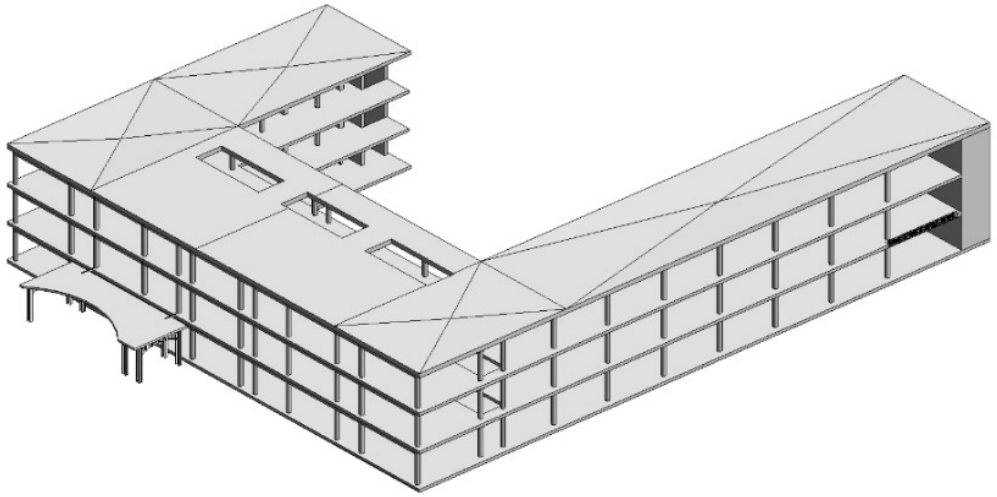
Relationships:

- 6,013 Adjacency within storey (horizontal)
- 407 Physical connection
- 252 Above/Below (i.e. stacked)
- 5 Storey adjacency (vertical)

Geometric QC Planning





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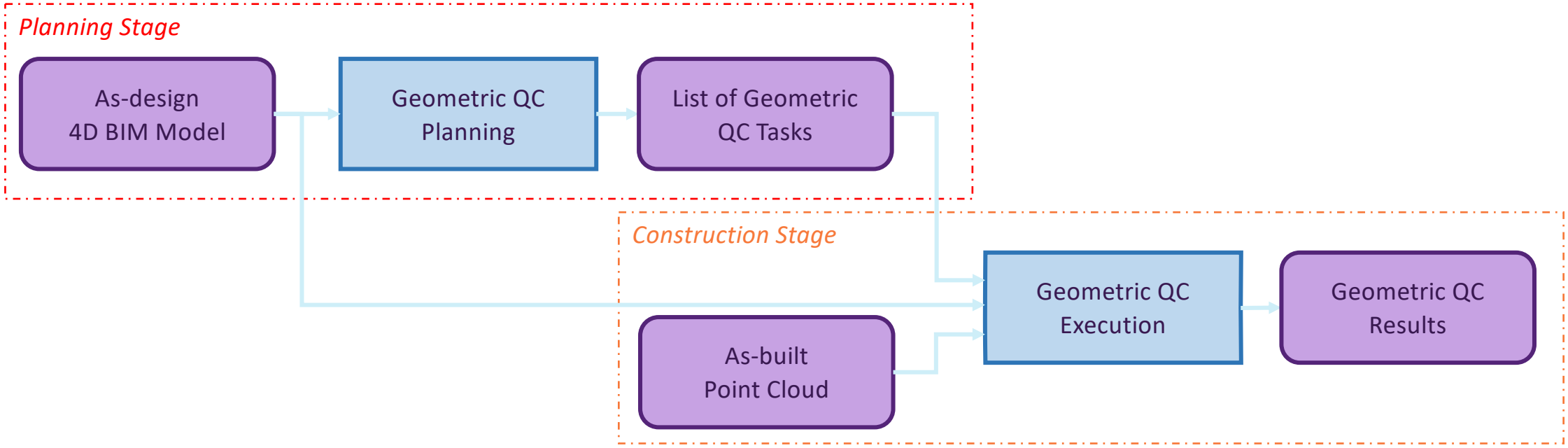
Geometric QC Planning

QC Rule ID	Description	Count
QC_1	Inclination of a column/wall	195
QC_2	Deviation between centres of stacked columns/walls	126
QC_3	Curvature of a column/wall between adjacent storey levels	195
QC_4	Location of a column/wall at any storey level w.r.t base level	126
QC_5	Location of a beam-to-column connection	396
QC_6	Position of bearing axis of support	357
QC_7	Cross-sectional dimensions	551
QC_8	Lap-joints	11
QC_9	Free space between adjacent columns/walls	3,039
QC_10	Horizontal straightness of beams	357
QC_11	Distance between adjacent beams	1,737
QC_12	Inclination of a beam/slab	362
QC_13	Level of adjacent beams	1,737
QC_14	Level of adjacent floors at supports	5
QC_15	Orthogonality of a cross-section	557
	Total:	**9,751**

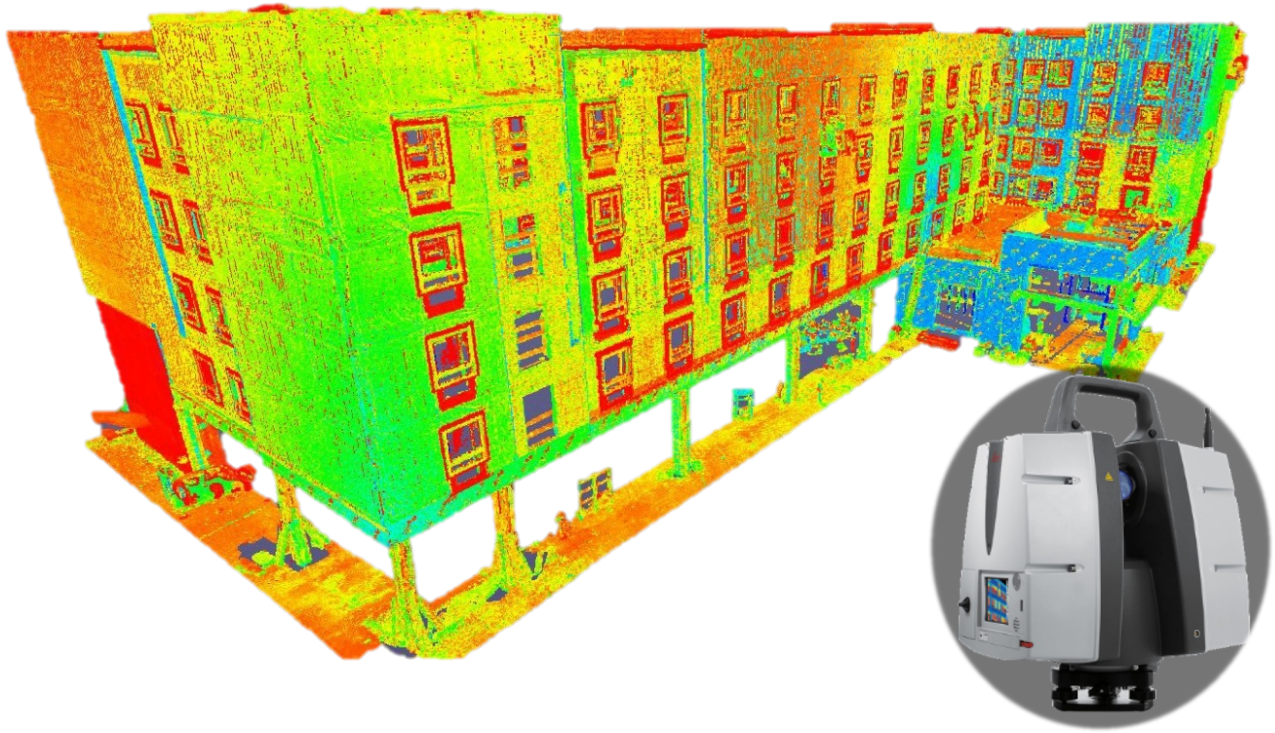
Use Case - Geometric QC



Which QC rule instances are passed, failed, or couldn't be controlled? And why?

Geometric QC Execution

- Which QC rules are passed, failed, not controlled? And why?
  1. As-built element geometry (pose)



Geometric QC Execution

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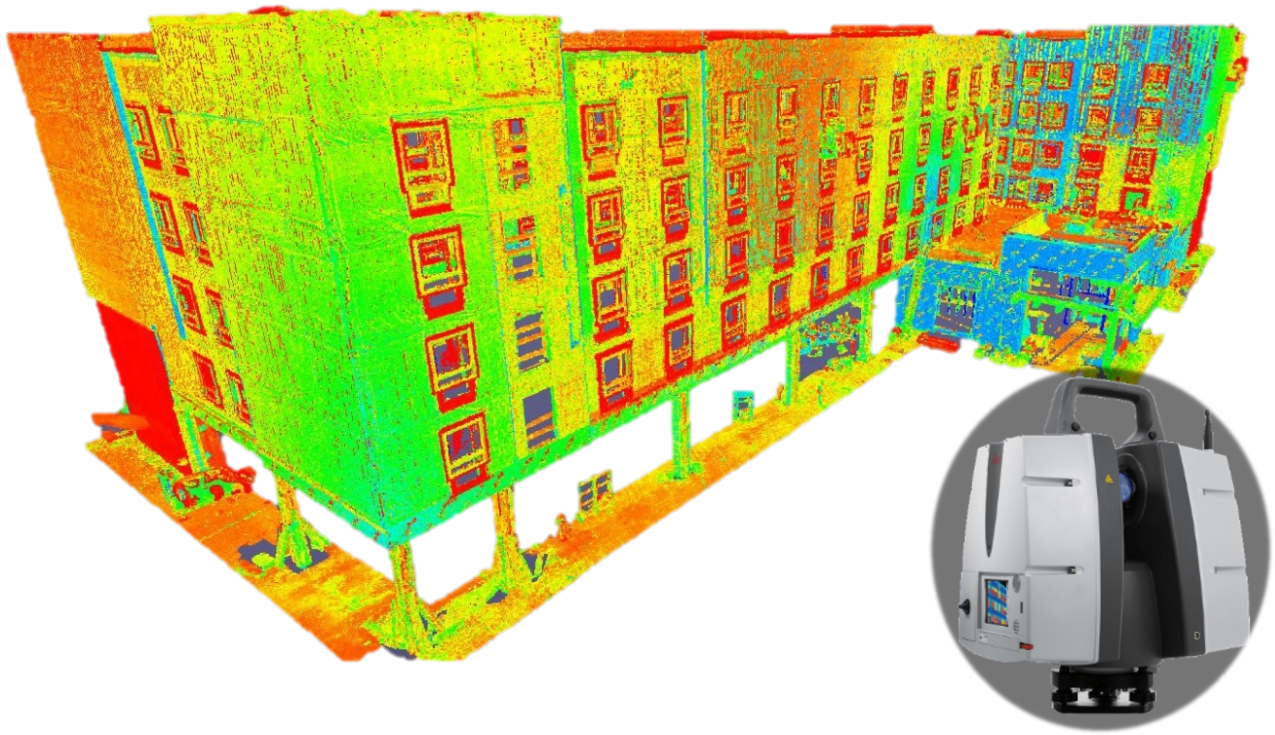
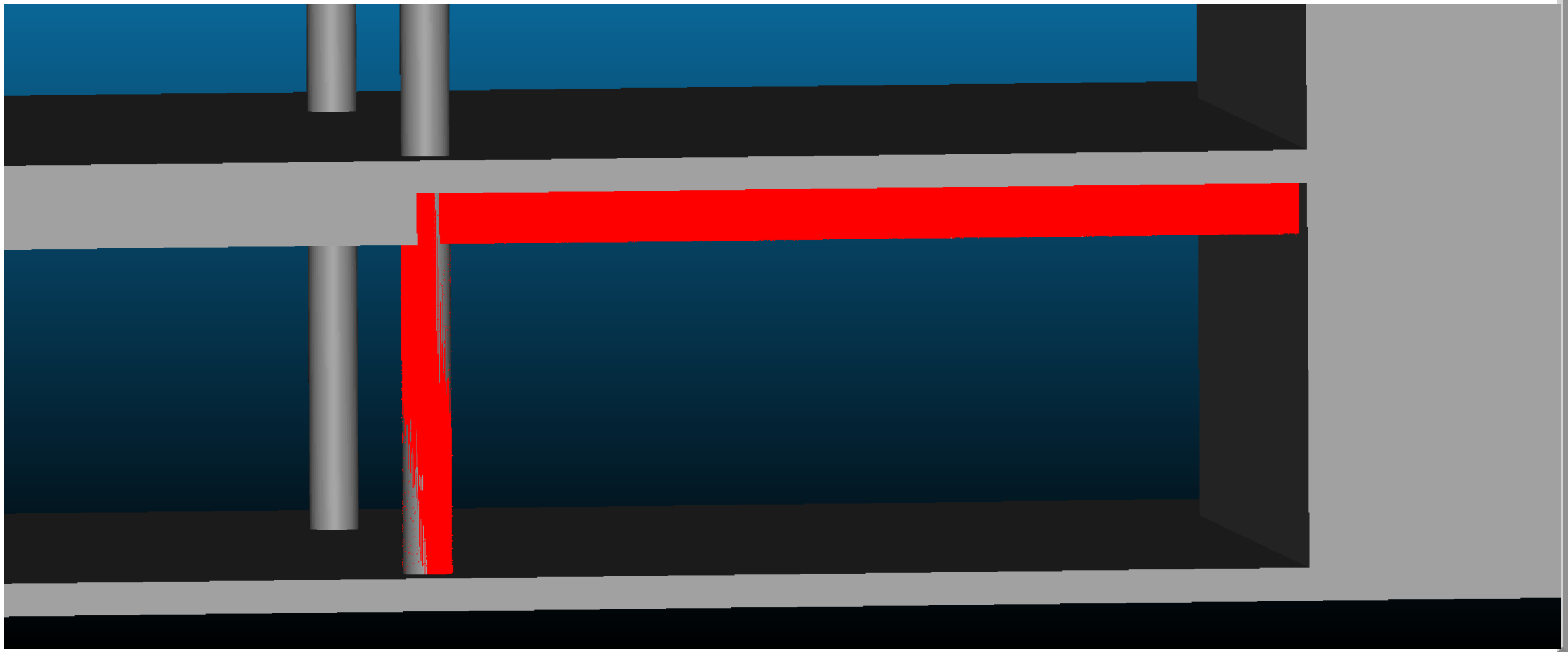


Geometric QC Execution

Which QC rules are passed, failed, not controlled? And why?

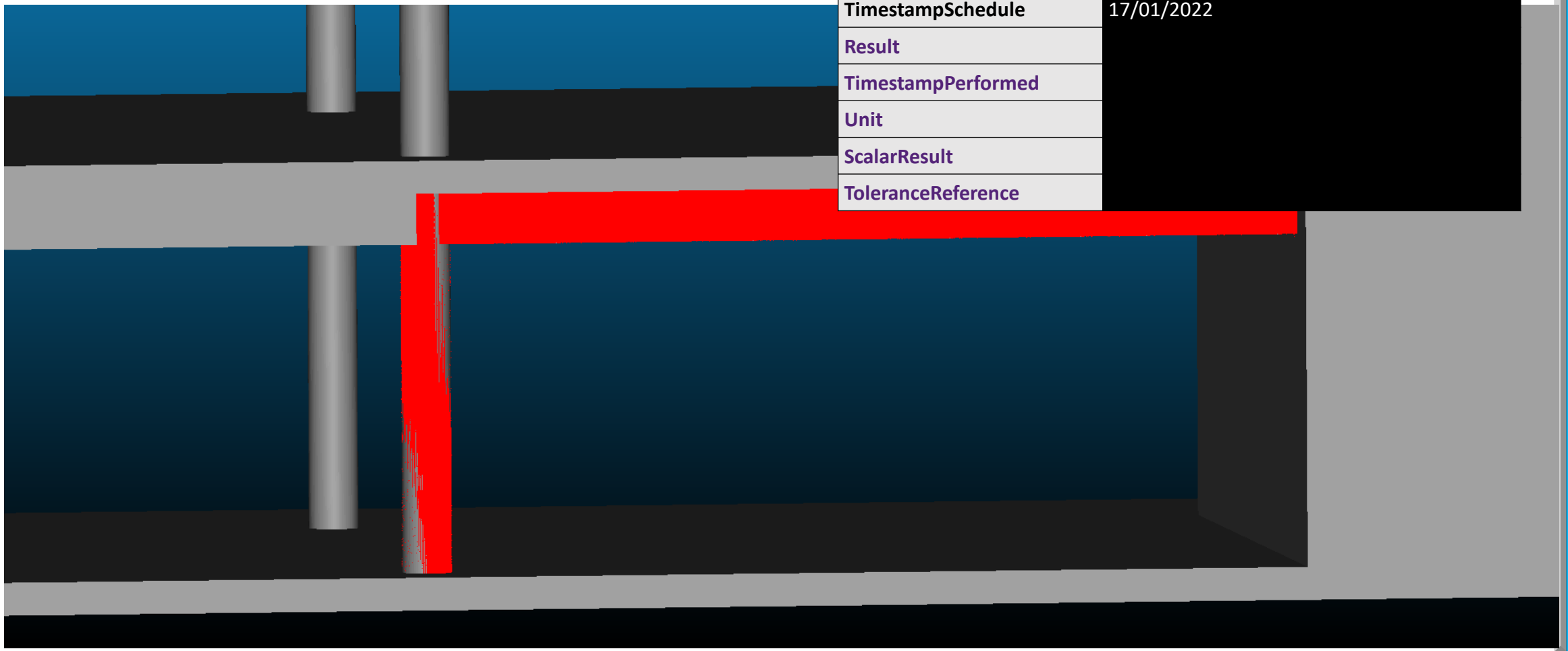
1. As-built element geometry (pose)
2. Apply *code* of pre-established *QC rule Instances* using as-built element geometry

Geometric QC Execution



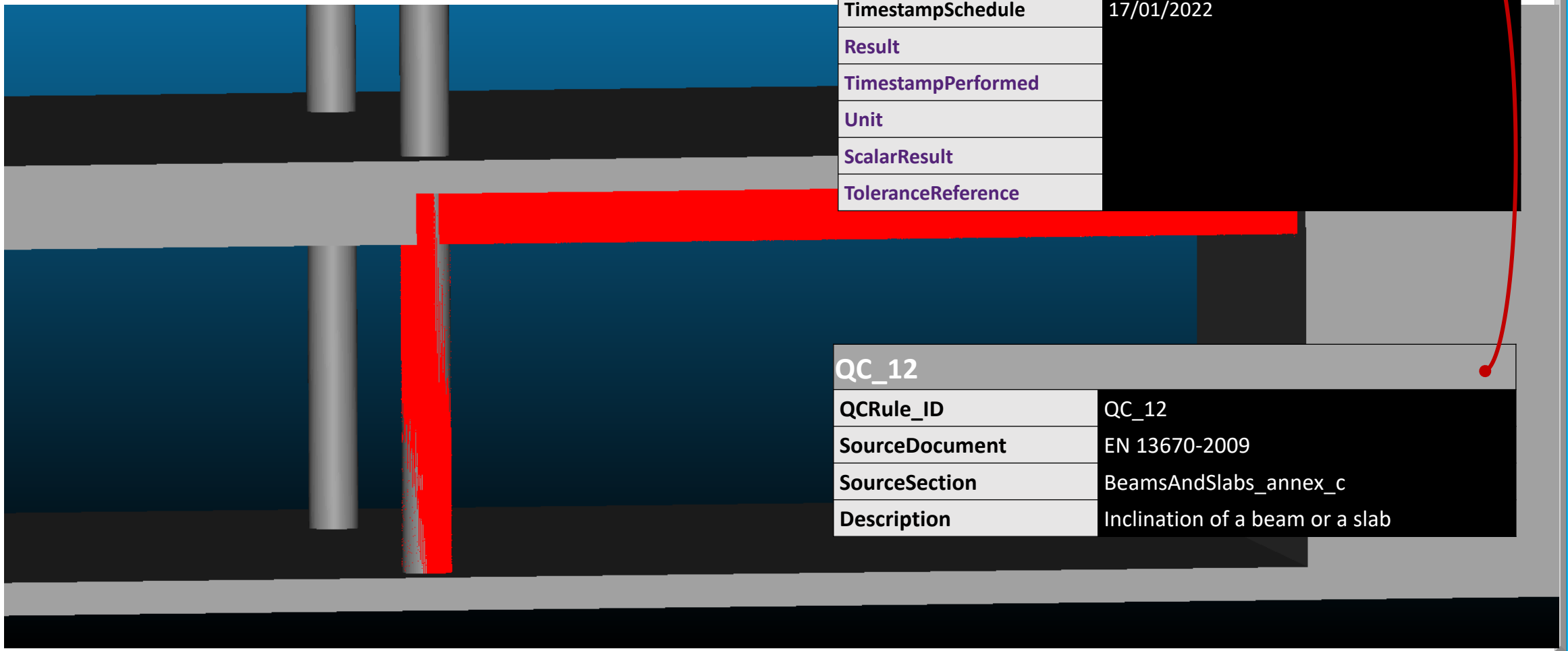
Geometric QC Execution

QC2406	
QC_UID	Rst_advanced_sample_project_QC2406
Dictionary_ID	QC_12
Involved_Components	[1WrzGm1SD2ev45B?OWQ3EP]
TimestampSchedule	17/01/2022
Result	
TimestampPerformed	
Unit	
ScalarResult	
ToleranceReference	



Geometric QC Execution

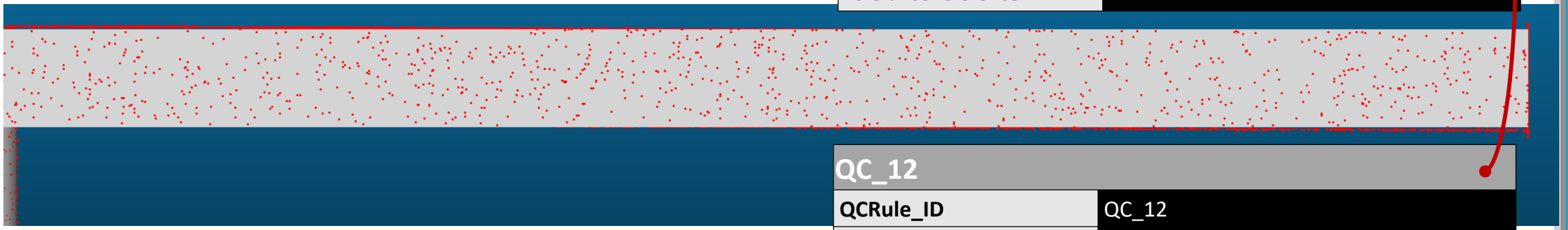
QC2406	
QC_UID	Rst_advanced_sample_project_QC2406
Dictionary_ID	QC_12
Involved_Components	[1WrzGm1SD2ev45B?OWQ3EP]
TimestampSchedule	17/01/2022
Result	
TimestampPerformed	
Unit	
ScalarResult	
ToleranceReference	



QC_12	
QCRule_ID	QC_12
SourceDocument	EN 13670-2009
SourceSection	BeamsAndSlabs_annex_c
Description	Inclination of a beam or a slab

Geometric QC Execution

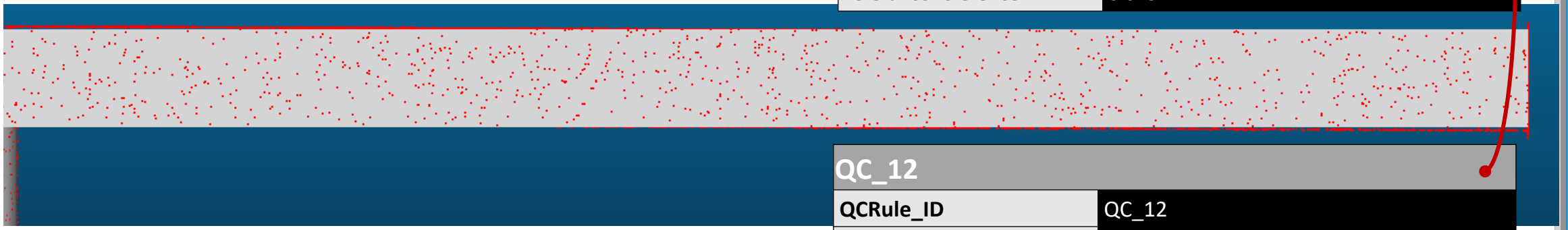
QC2406	
QC_UID	Rst_advanced_sample_project_QC2406
Dictionary_ID	QC_12
Involved_Components	[1WrzGm1SD2ev45B?OWQ3EP]
TimestampSchedule	17/01/2022
Result	
TimestampPerformed	
Unit	
ScalarResult	
ToleranceReference	



QC_12	
QCRule_ID	QC_12
SourceDocument	EN 13670-2009
SourceSection	BeamsAndSlabs_annex_c
Description	Inclination of a beam or a slab

Geometric QC Execution

QC2406	
QC_UID	Rst_advanced_sample_project_QC2406
Dictionary_ID	QC_12
Involved_Components	[1WrzGm1SD2ev45B?OWQ3EP]
TimestampSchedule	17/01/2022
Result	Fail
TimestampPerformed	02/02/2022
Unit	[distance, metres]
ScalarResult	0.088
ToleranceReference	0.025



QC_12	
QCRule_ID	QC_12
SourceDocument	EN 13670-2009
SourceSection	BeamsAndSlabs_annex_c
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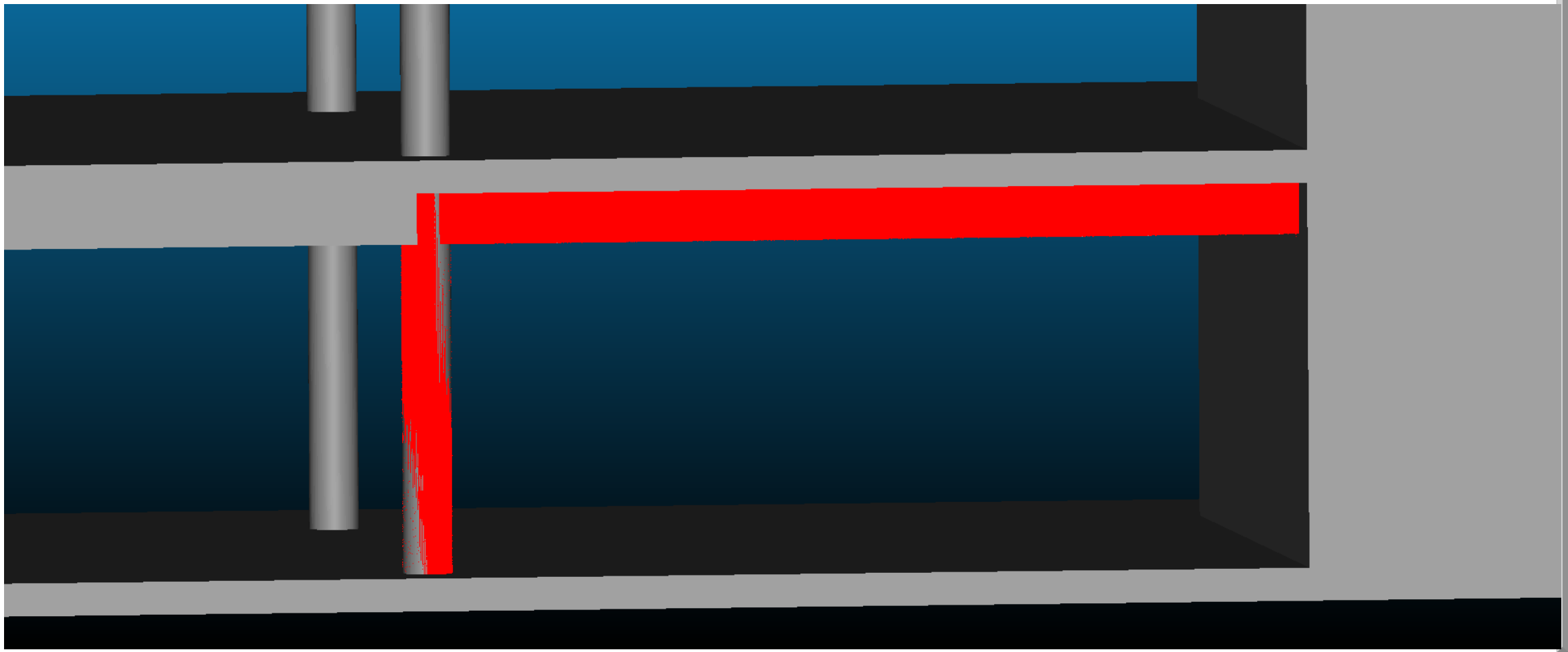

Geometric QC Execution

QC2416	
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Dictionary_ID	QC_5
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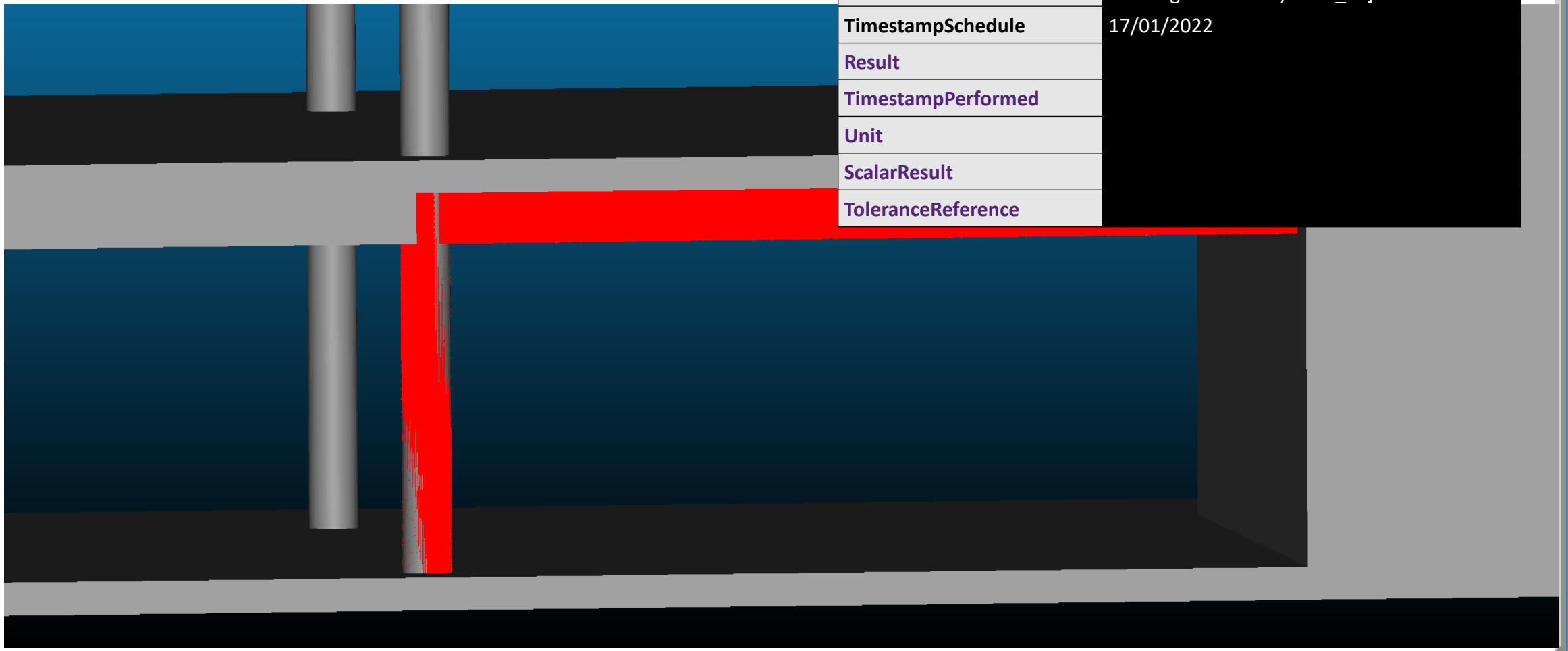
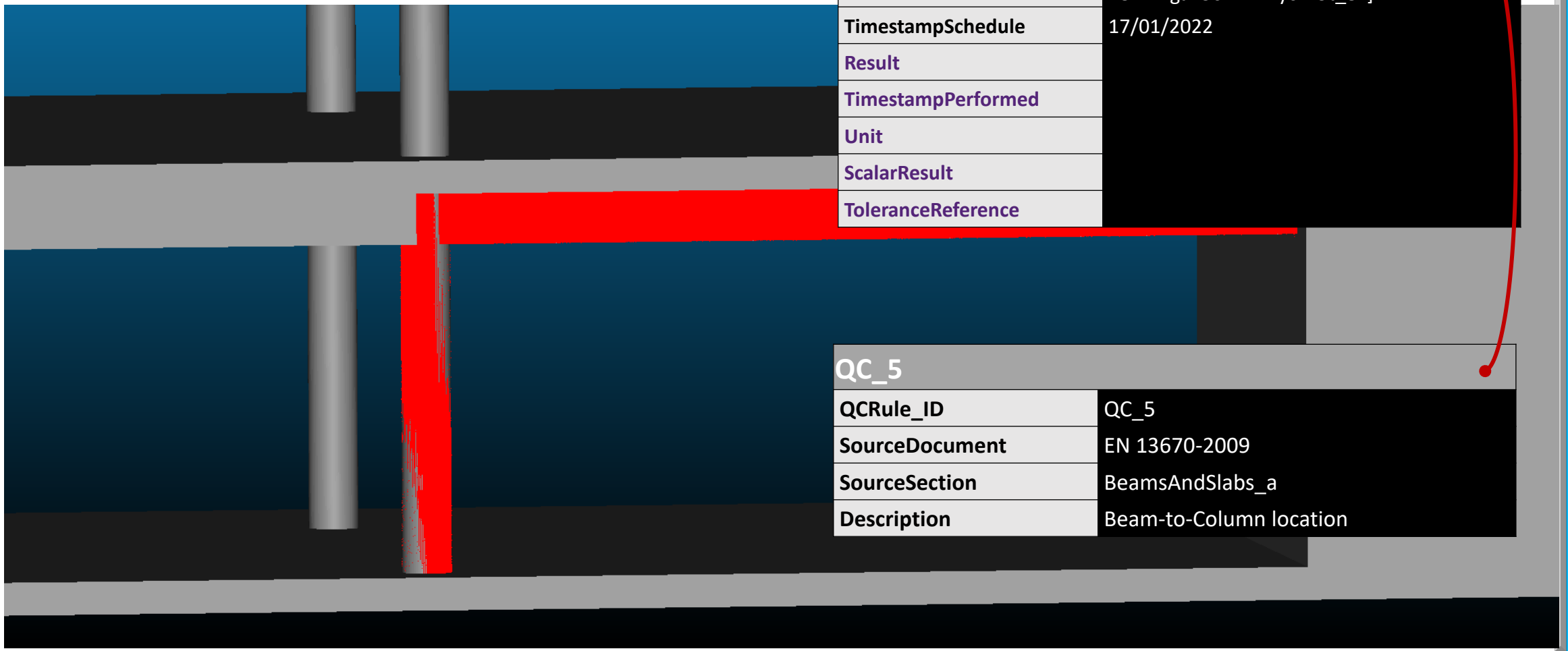
TimestampSchedule	17/01/2022
Result	
TimestampPerformed	
Unit	
ScalarResult	
ToleranceReference	



Geometric QC Execution

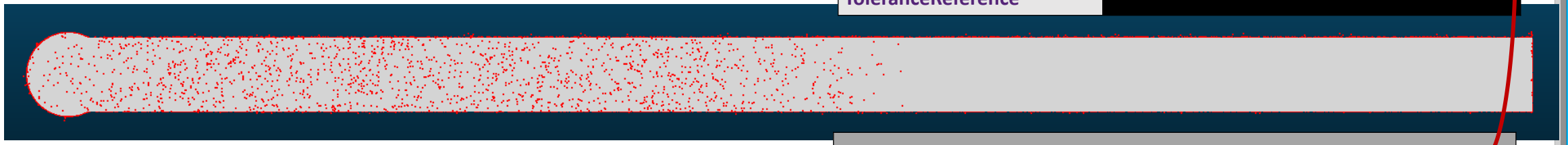
QC2416	
QC_UID	Rst_advanced_sample_project_QC2416
Dictionary_ID	QC_5
Involved_Components	[1WrzGm1SD2ev45B?OWQ3EP, 18YHwga450Mw4Fy6M5t_8F]
TimestampSchedule	17/01/2022
Result	
TimestampPerformed	
Unit	
ScalarResult	
ToleranceReference	



QC_5	
QCRule_ID	QC_5
SourceDocument	EN 13670-2009
SourceSection	BeamsAndSlabs_a
Description	Beam-to-Column location

Geometric QC Execution

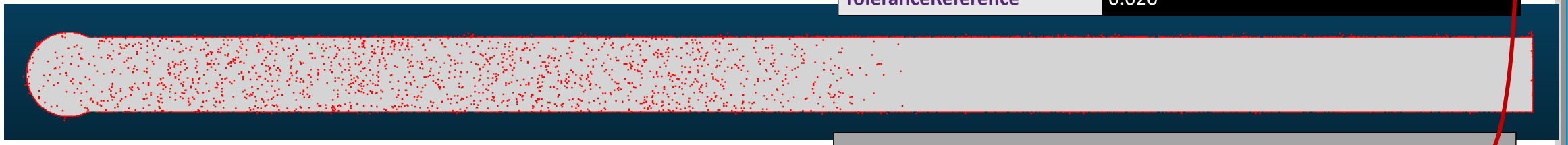
QC2416	
QC_UID	Rst_advanced_sample_project_QC2416
Dictionary_ID	QC_5
Involved_Components	[1WrzGm1SD2ev45B?OWQ3EP, 18YHwga450Mw4Fy6M5t_8F]
TimestampSchedule	17/01/2022
Result	
TimestampPerformed	
Unit	
ScalarResult	
ToleranceReference	



QC_5	
QCRule_ID	QC_5
SourceDocument	EN 13670-2009
SourceSection	BeamsAndSlabs_a
Description	Beam-to-Column location

Geometric QC Execution

QC2416	
QC_UID	Rst_advanced_sample_project_QC2416
Dictionary_ID	QC_5
Involved_Components	[1WrzGm1SD2ev45B?OWQ3EP, 18YHwga450Mw4Fy6M5t_8F]
TimestampSchedule	17/01/2022
Result	Pass
TimestampPerformed	02/02/2022
Unit	[distance, metres]
ScalarResult	0.010
ToleranceReference	0.020



QC_5	
QCRule_ID	QC_5
SourceDocument	EN 13670-2009
SourceSection	BeamsAndSlabs_a
Description	Beam-to-Column location

COGITO

CONSTRUCTION PHASE
DIGITAL TWIN MODEL

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Visual Quality Control

VisualQC for automated defects detection in pictures acquired on site

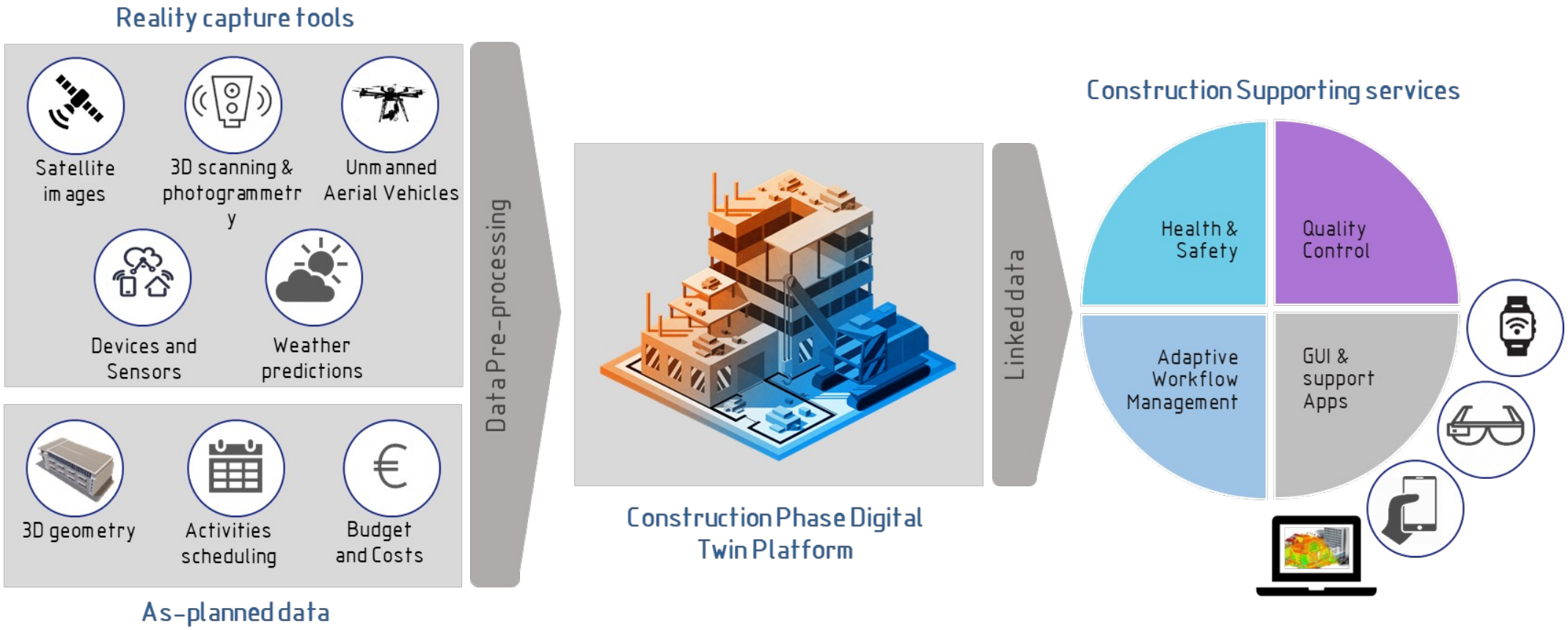
Thanos Tsakiris

CERTH

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 958310

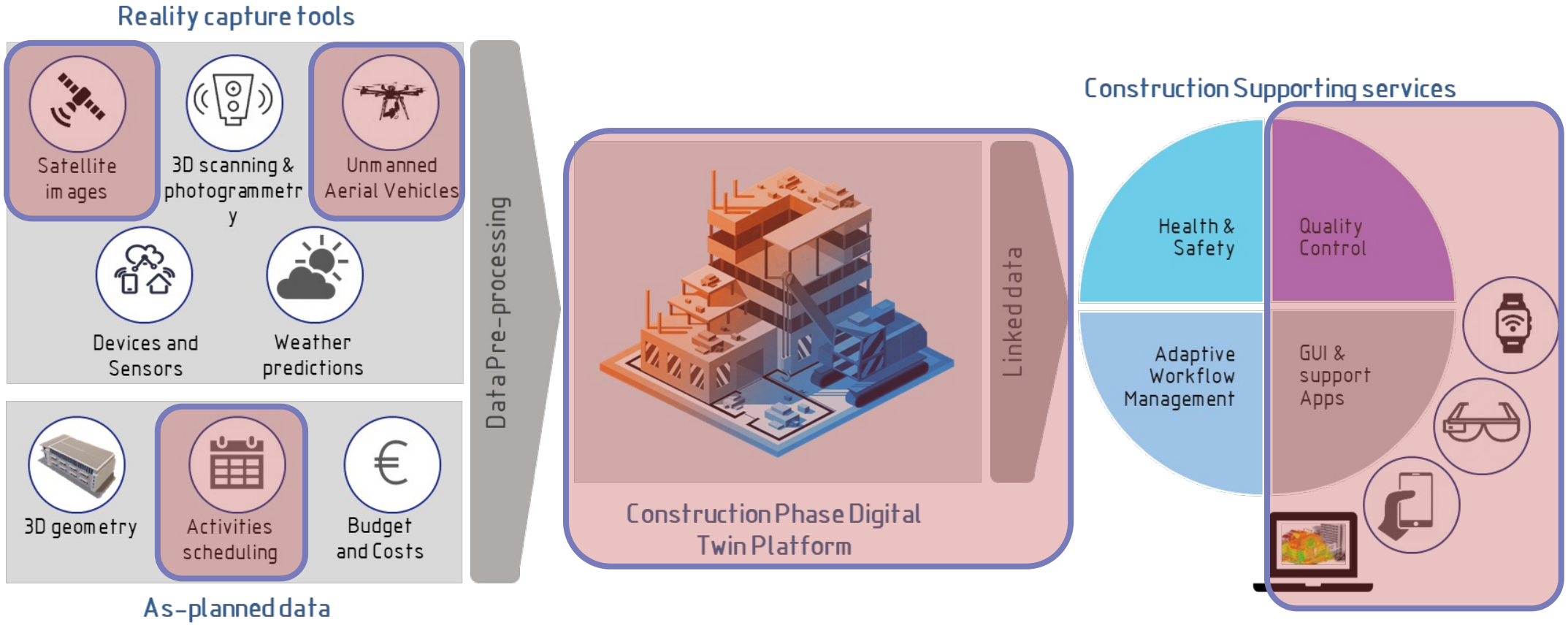
Use Case - Visual QC

- Automated visual inspection and defect detection

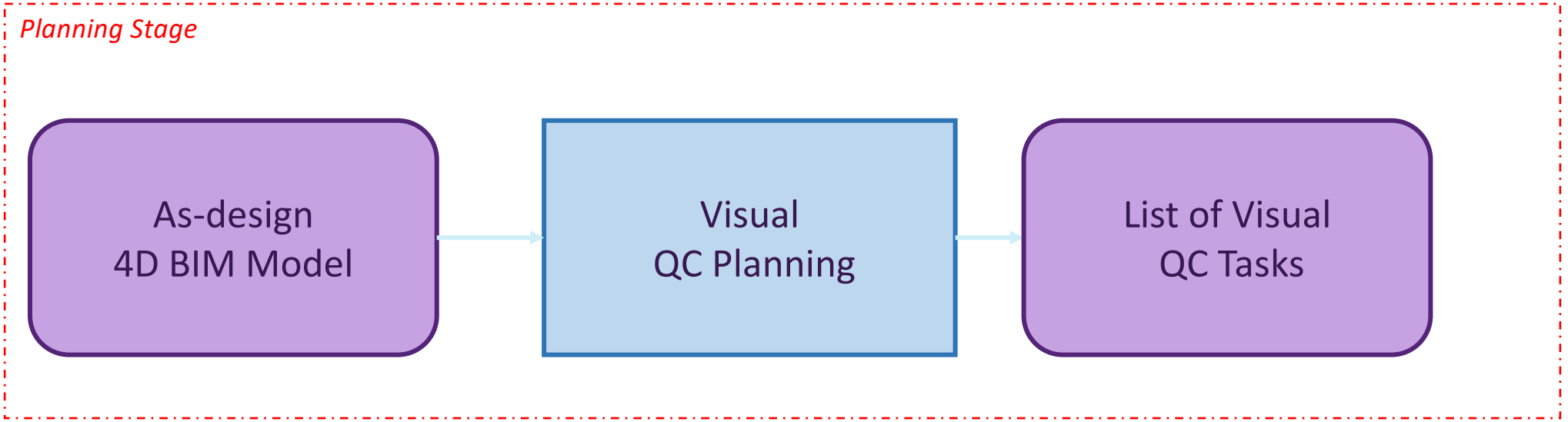


Use Case - Visual QC

- Automated visual inspection and defect detection



Use Case - Visual QC



What QC needs to be conducted? And when?

Visual QC Planning

What QC needs to be conducted? And when?

Visual QC Planning

What QC needs to be conducted? And when?

Based on the element material→ 2 Categories:

Visual QC Planning

What QC needs to be conducted? And when?

Based on the element material→ 2 Categories:

1. Concrete defects

Visual QC Planning

What QC needs to be conducted? And when?

Based on the element material→ 2 Categories:

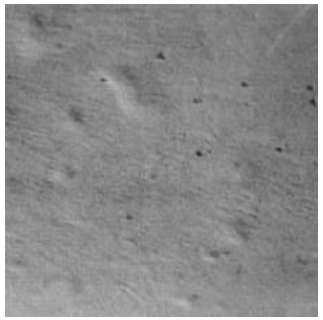
1. Concrete defects
2. Steel defects

Visual QC Planning

1. Concrete surface defects
    1. Crack

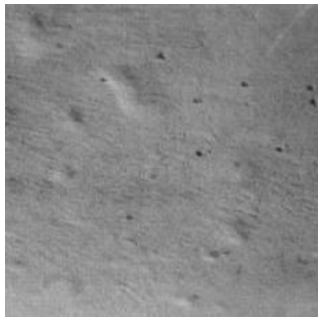
Visual QC Planning

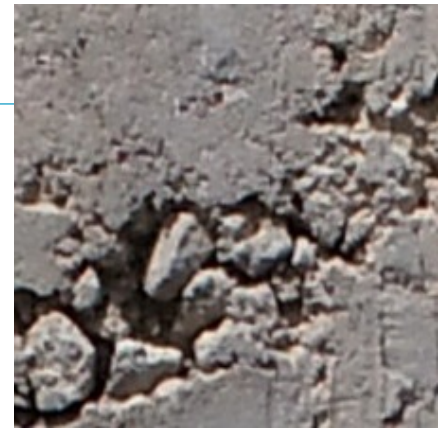
1. Concrete surface defects
    1. Crack
    2. Blistering



Visual QC Planning

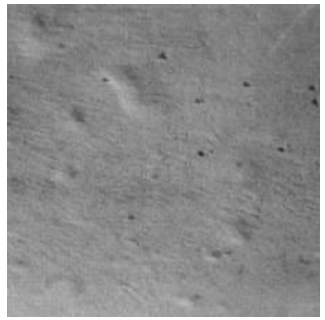
1. Concrete surface defects
    1. Crack
    2. Blistering
    3. Honeycomb

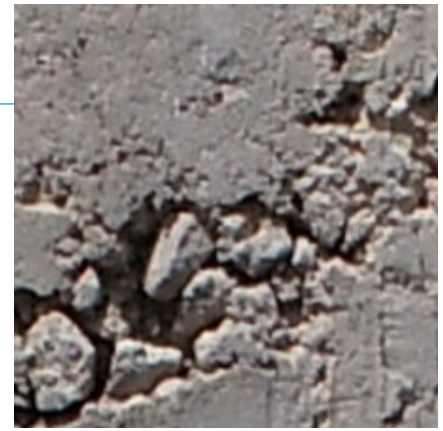




Visual QC Planning

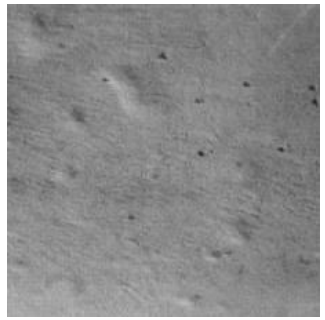
1. Concrete surface defects
    1. Crack
    2. Blistering
    3. Honeycomb
    4. Efflorescence

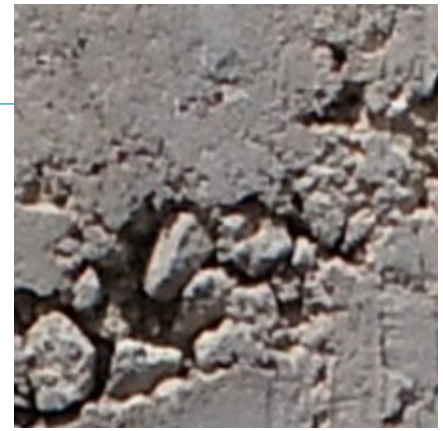




Visual QC Planning

1. Concrete surface defects
    1. Crack
    2. Blistering
    3. Honeycomb
    4. Efflorescence
    5. Hole



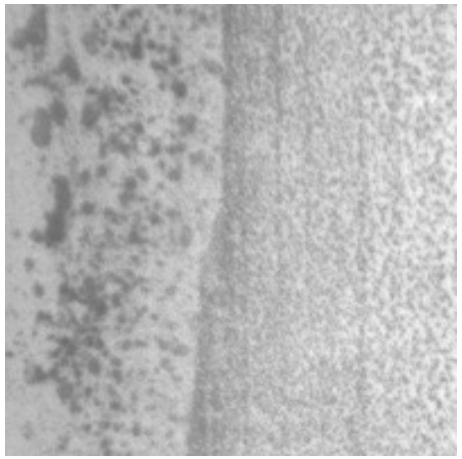


Visual QC Planning

2. Steel surface defects
    1. Rail track damage

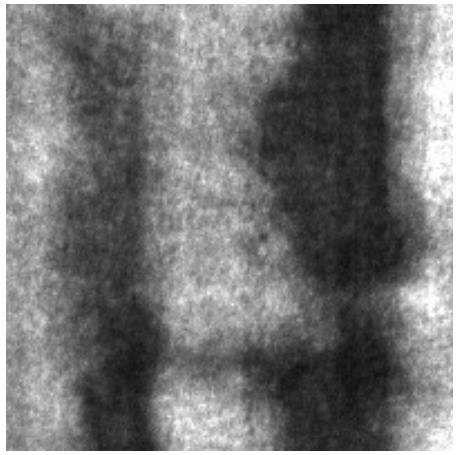
Visual QC Planning

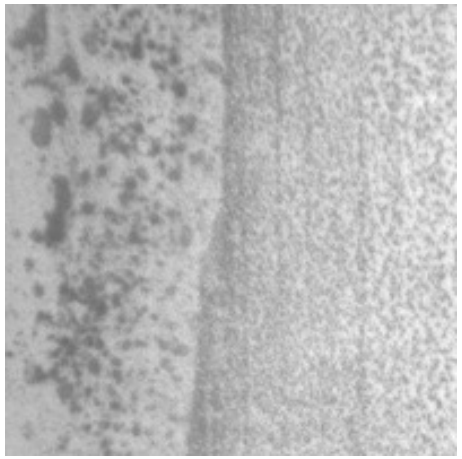
2. Steel surface defects
    1. Rail track damage
    2. Pitted surface



Visual QC Planning

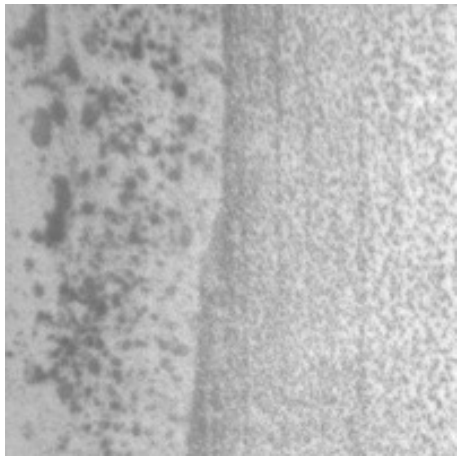
2. Steel surface defects
    1. Rail track damage
    2. Pitted surface
    3. Patch



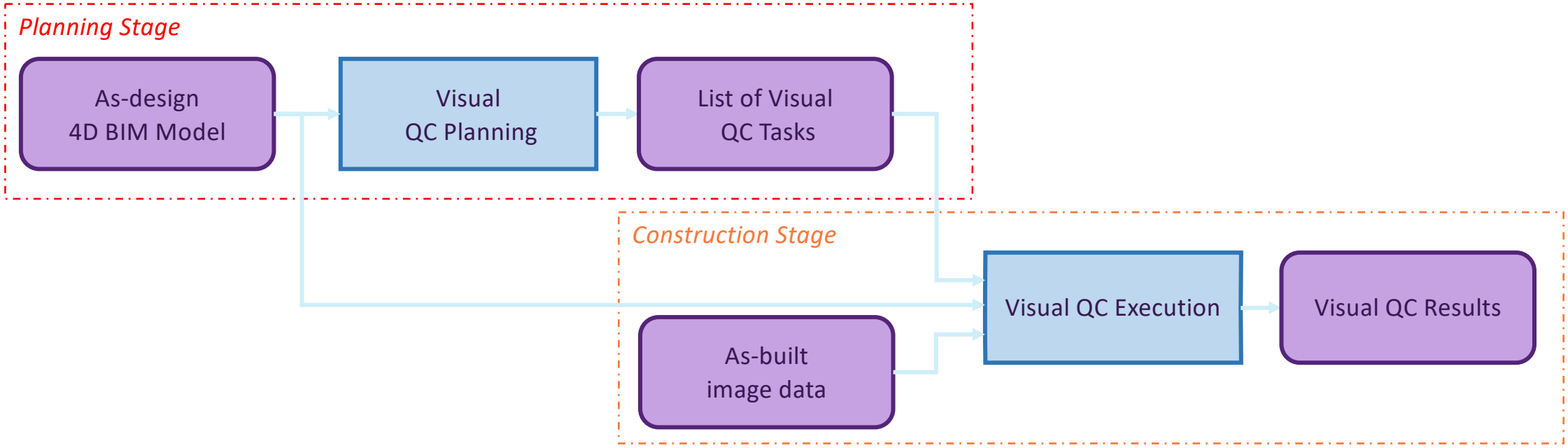


Visual QC Planning

2. Steel surface defects
    1. Rail track damage
    2. Pitted surface
    3. Patch
    4. Scratch



Use Case - Visual QC



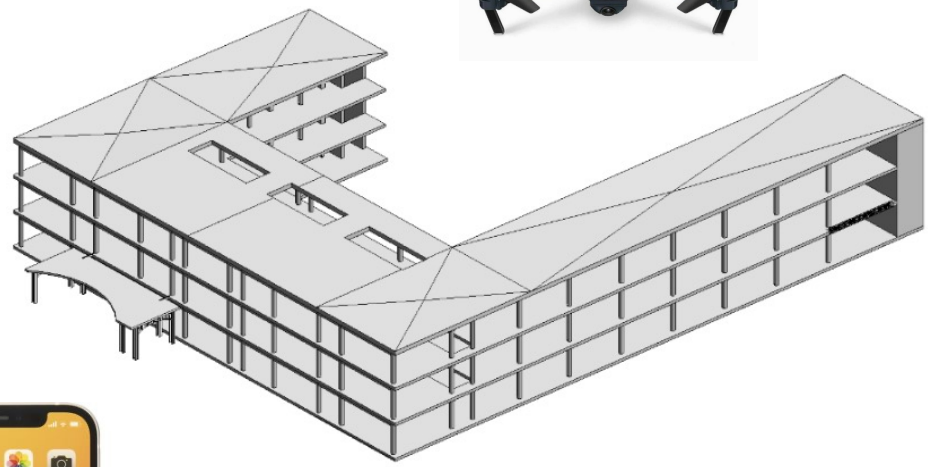
Is a defect detected in each image or not?

Which defect type is detected?

Related to an IFC element (decision based on the material type - concrete or steel)

Visual QC Execution

- What is the QC result for a specific element, based on a specific image?
  - Passed: No defect detected



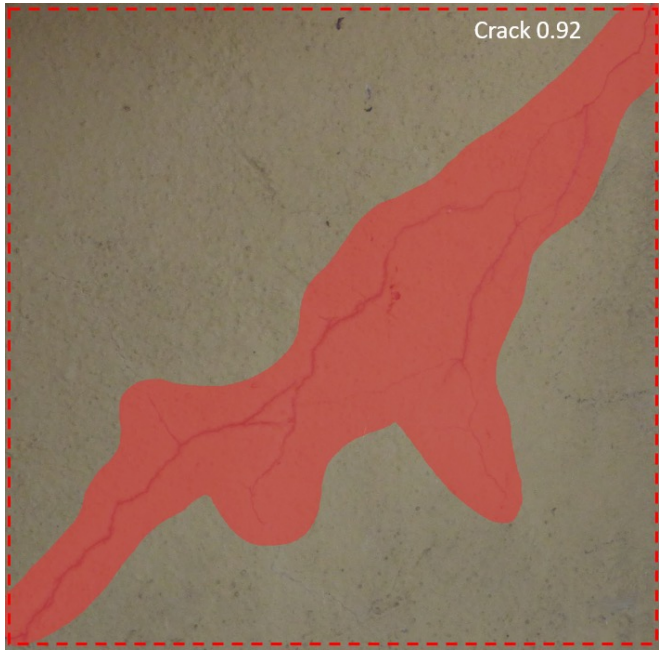
Visual QC Execution

- What is the QC result for a specific element, based on a specific image?
  - Passed: No defect detected
  - Failed: Defect detected

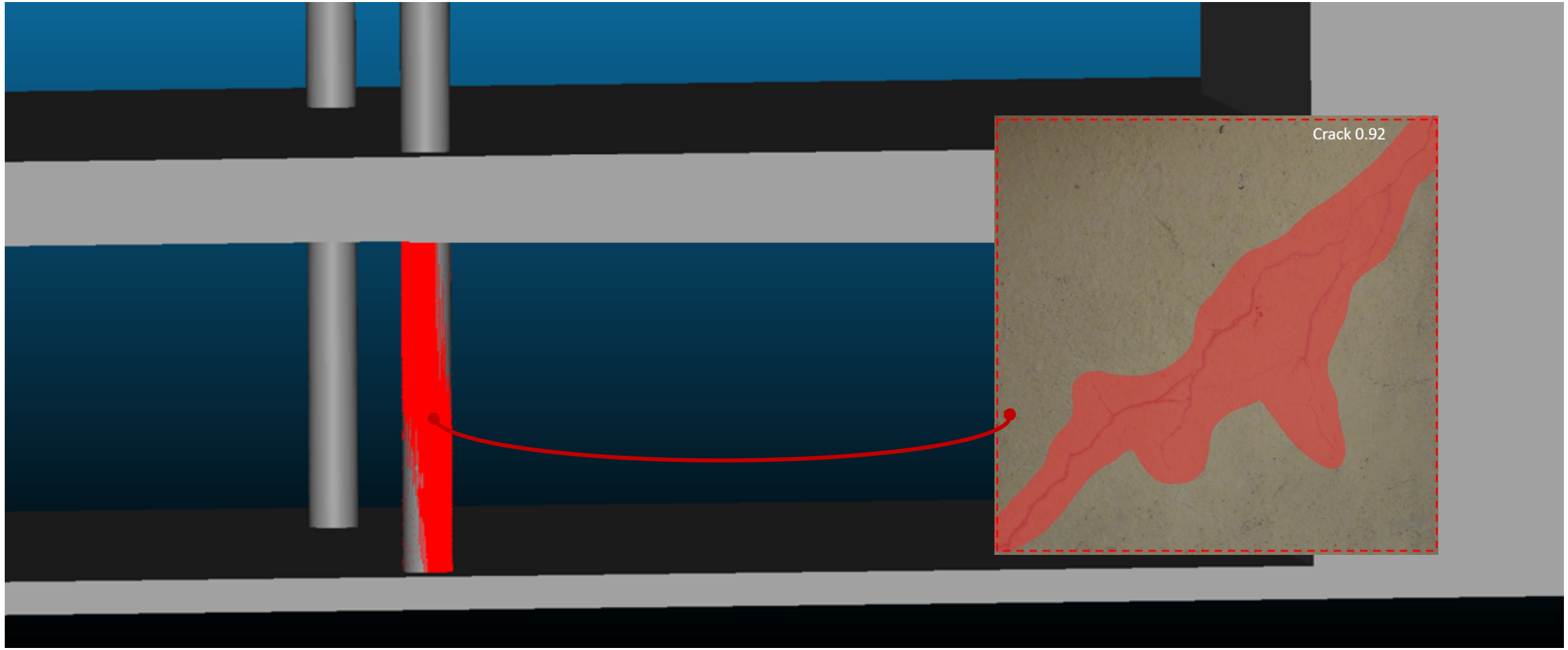
Visual QC Execution

- What is the QC result for a specific element, based on a specific image?
  - Passed: No defect detected
  - Failed: Defect detected
  - Undefined: Unknown surface material

Visual QC Execution

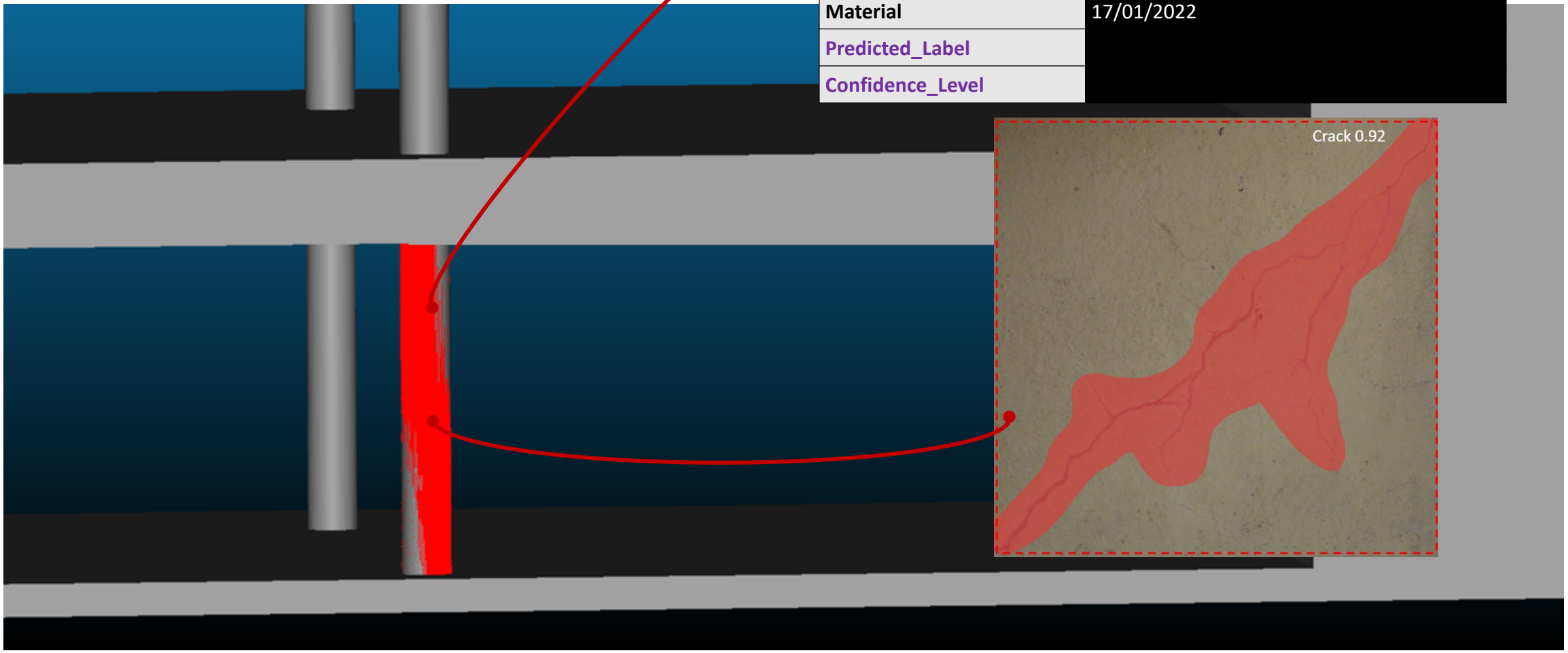


Visual QC Execution



Visual QC Execution

QC2416	
QC_UID	Rst_advanced_sample_project_QC2416
Building_Component	QC_5
Global_ID	[1WrzGm1SD2ev45B?OWQ3EP, 18YHwga450Mw4Fy6M5t_8F]
Material	17/01/2022
Predicted_Label	
Confidence_Level	



DigiTAR

On-site Augmented Reality-based Digital Twin information visualisation and decision making

Thanos Tsakiris

CERTH

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 958310

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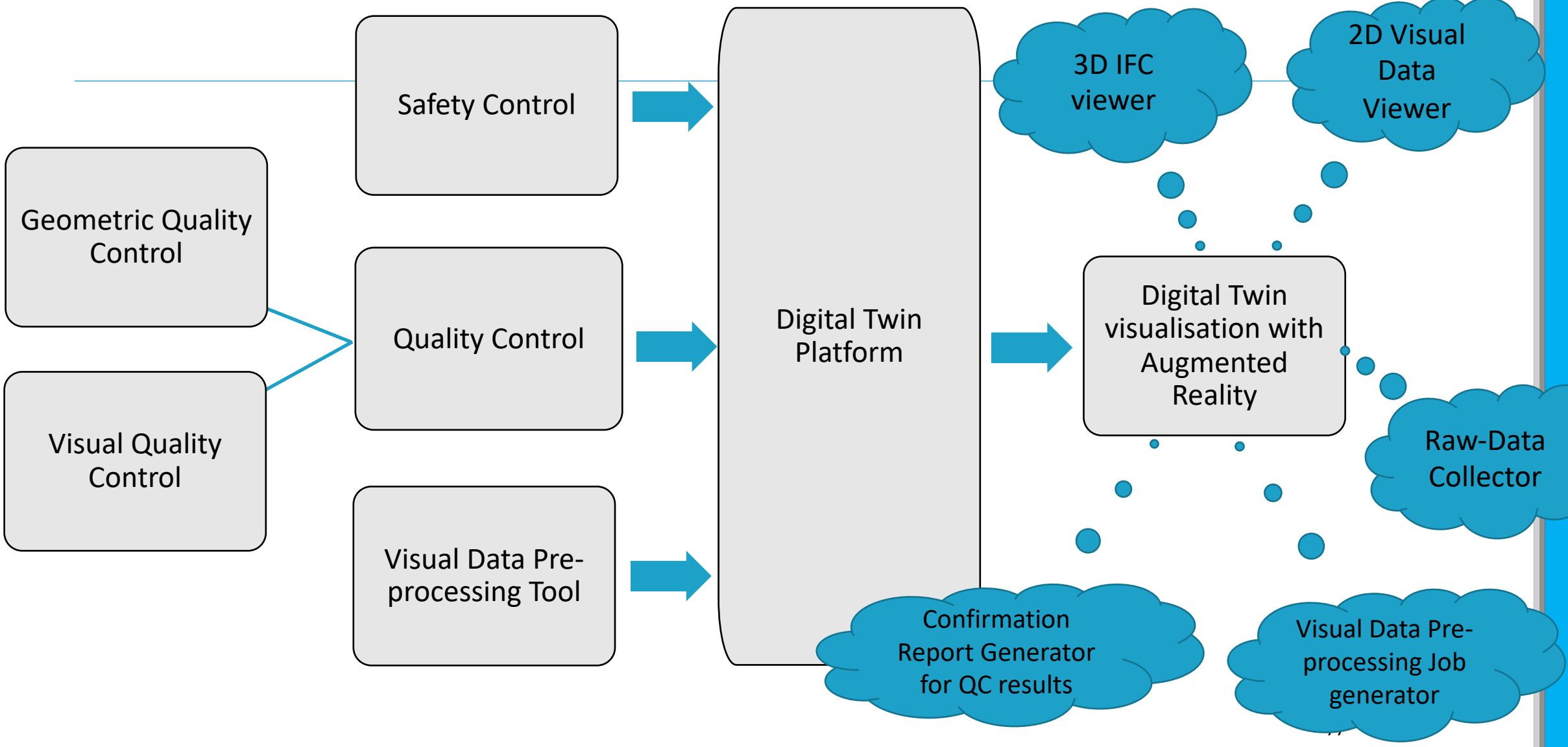
Digital **T**win visualisation with **A**ugmented **R**eality

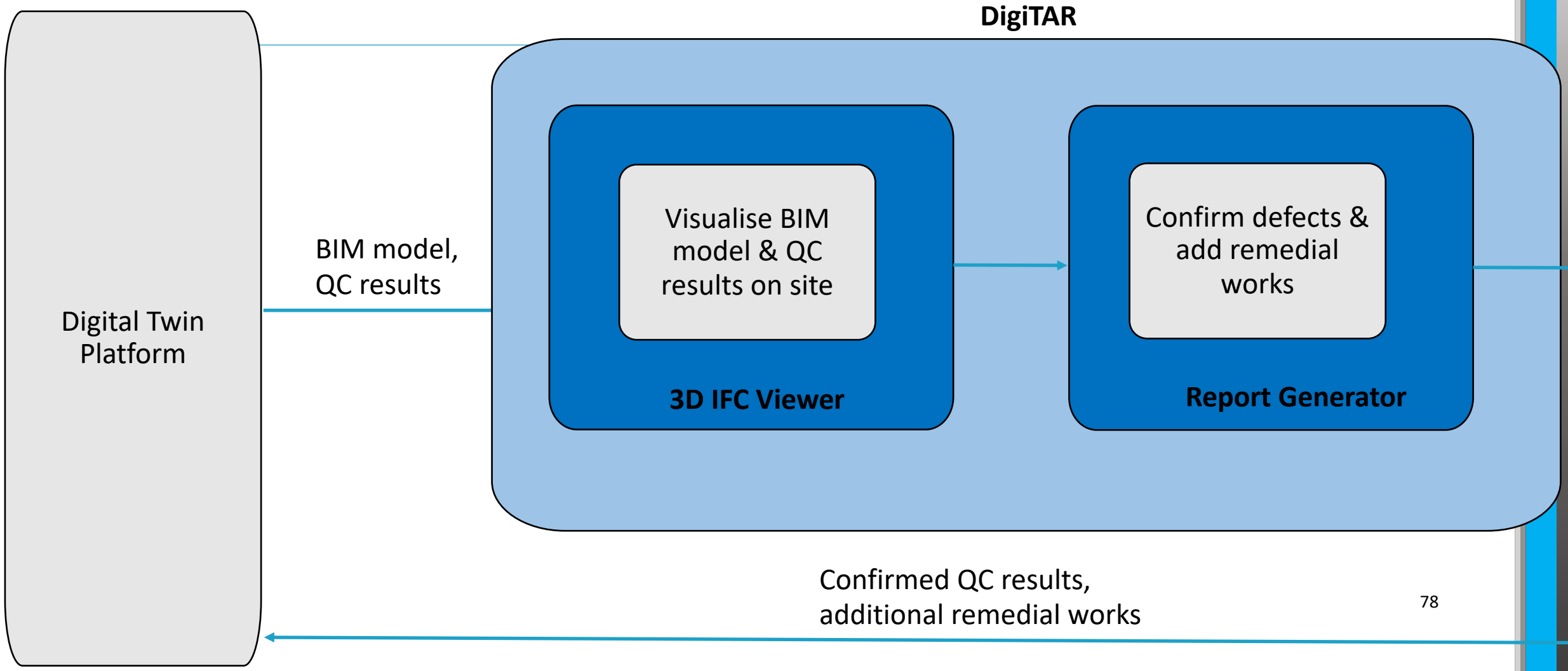
Scope of the DigiTAR tool (HoloLens app)

1. Visualise the results of the Quality Control (QC) components (Geometric and Visual)
2. Visualise potential construction site hazards (Health and Safety issues)
3. Collect as-built data and implement part of the Visual Data Pre-processing on-site

Architecture



DigiTAR Workflow: Quality Control mode



DigiTAR Tool

The user of the DigiTAR Tool needs to follow these steps for the Quality Control mode:

- Login to the application
- Select a construction project
- Select the Quality Control mode
- Receive the IFC model and QC results from the DTP
- Perform registration to align the 3D BIM model to the real world
- View the Geometric and Visual QC results
- Confirm/Reject the QC results and add remedial works if needed

The 3D IFC Viewer of the DigiTAR tool requires both the geometry representation of the BIM model (OBJ file) and the IFC file.

The Digital Twin Platform will provide the necessary data from the appropriate Quality Control Tool

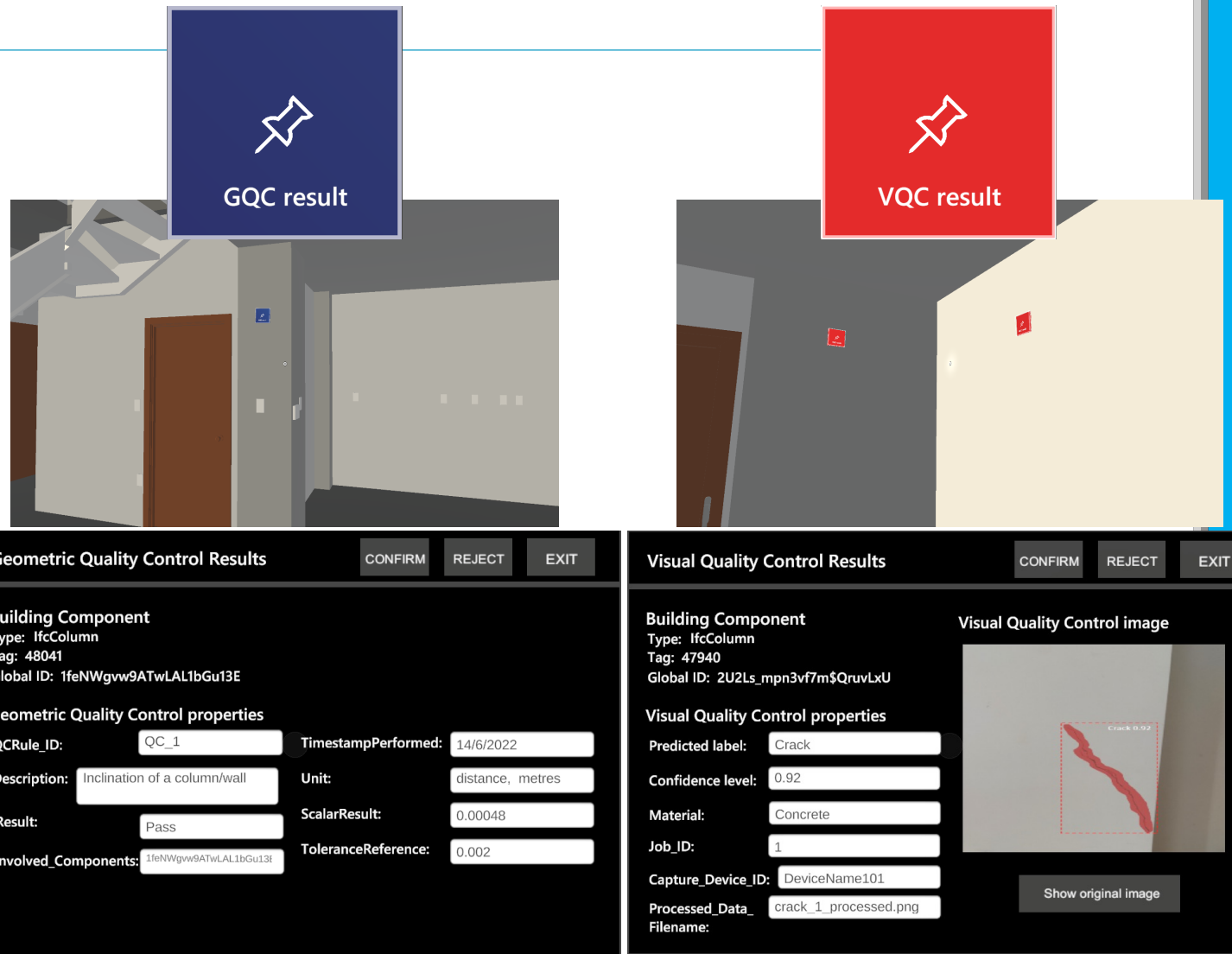
Use Case –QC results visualization

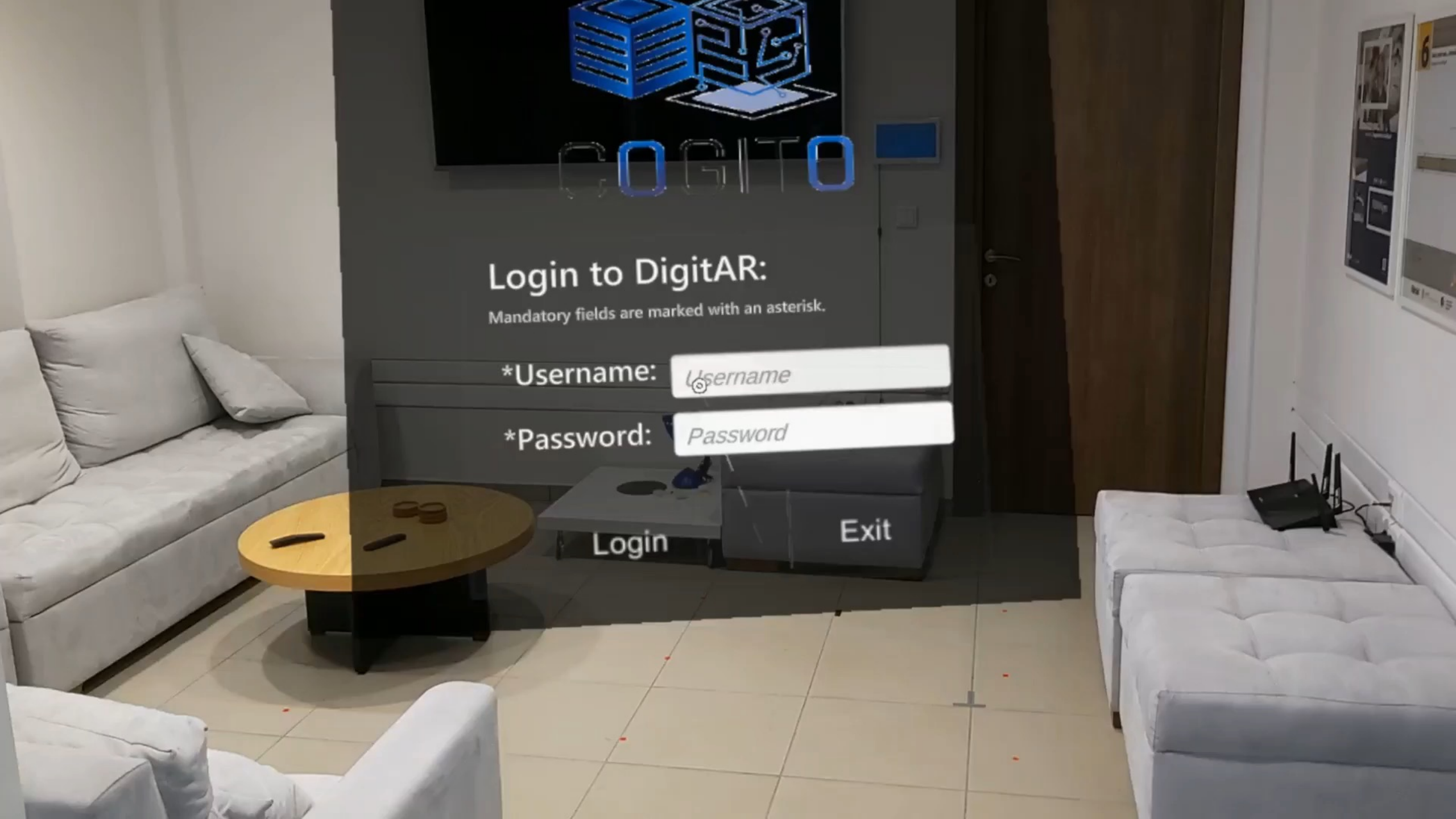
Visualise the 3D BIM model of the construction site

Receive and parse the QC results and the involved IFC components

Assign 3D QC tags to each involved IFC component (blue color for “Pass” QC result and red for “Fail” QC result)

Provide confirmed QC results and additional remedial works




COGITO
Login to DigitAR:
Mandatory fields are marked with an asterisk.
*Username:
Username
*Password:
Password
Login
Exit

COGITO

CONSTRUCTION PHASE
DIGITAL TWIN MODEL

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Digital Command Centre - DCC

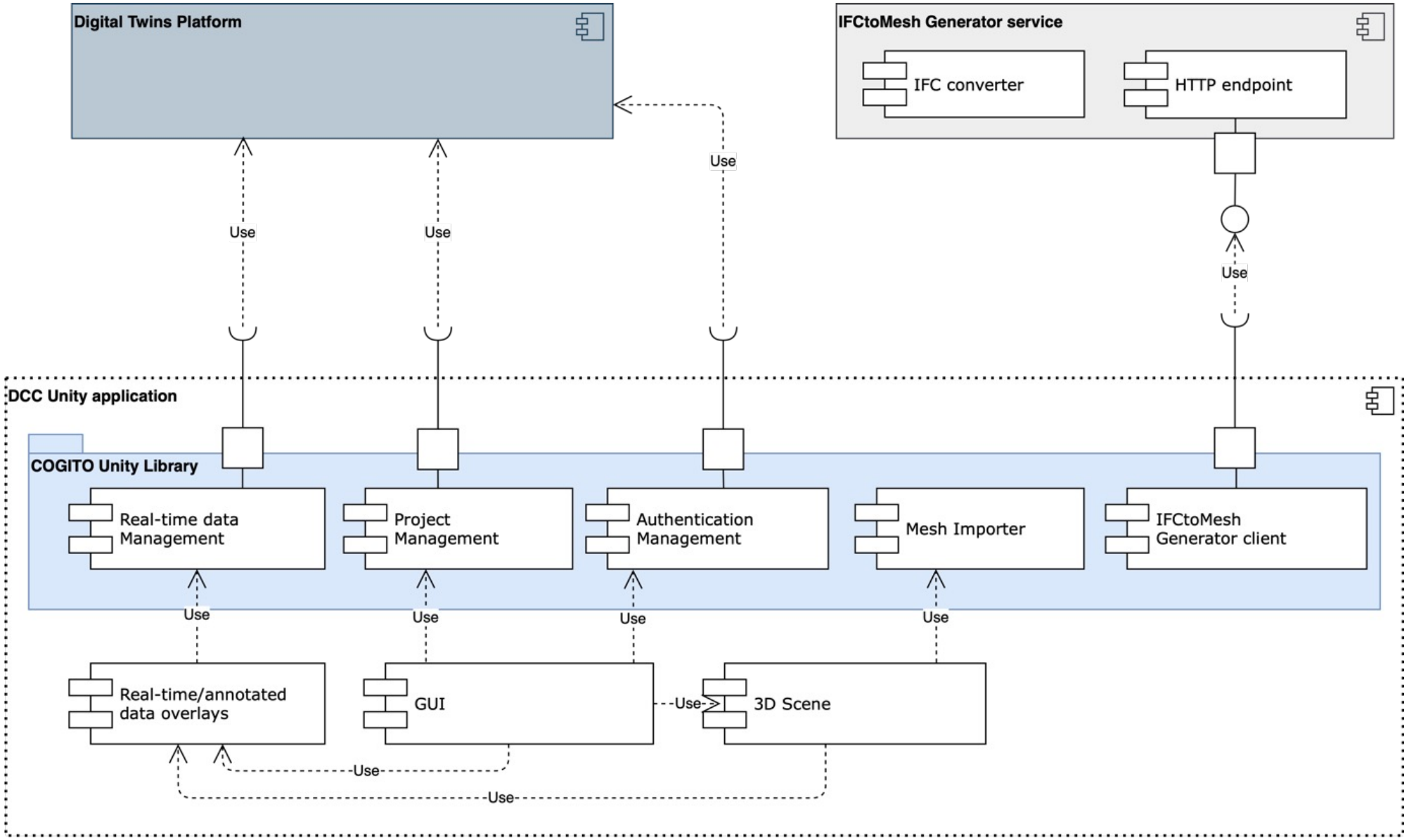
Off-site Digital Twin information visualisation

Giorgos Giannakis

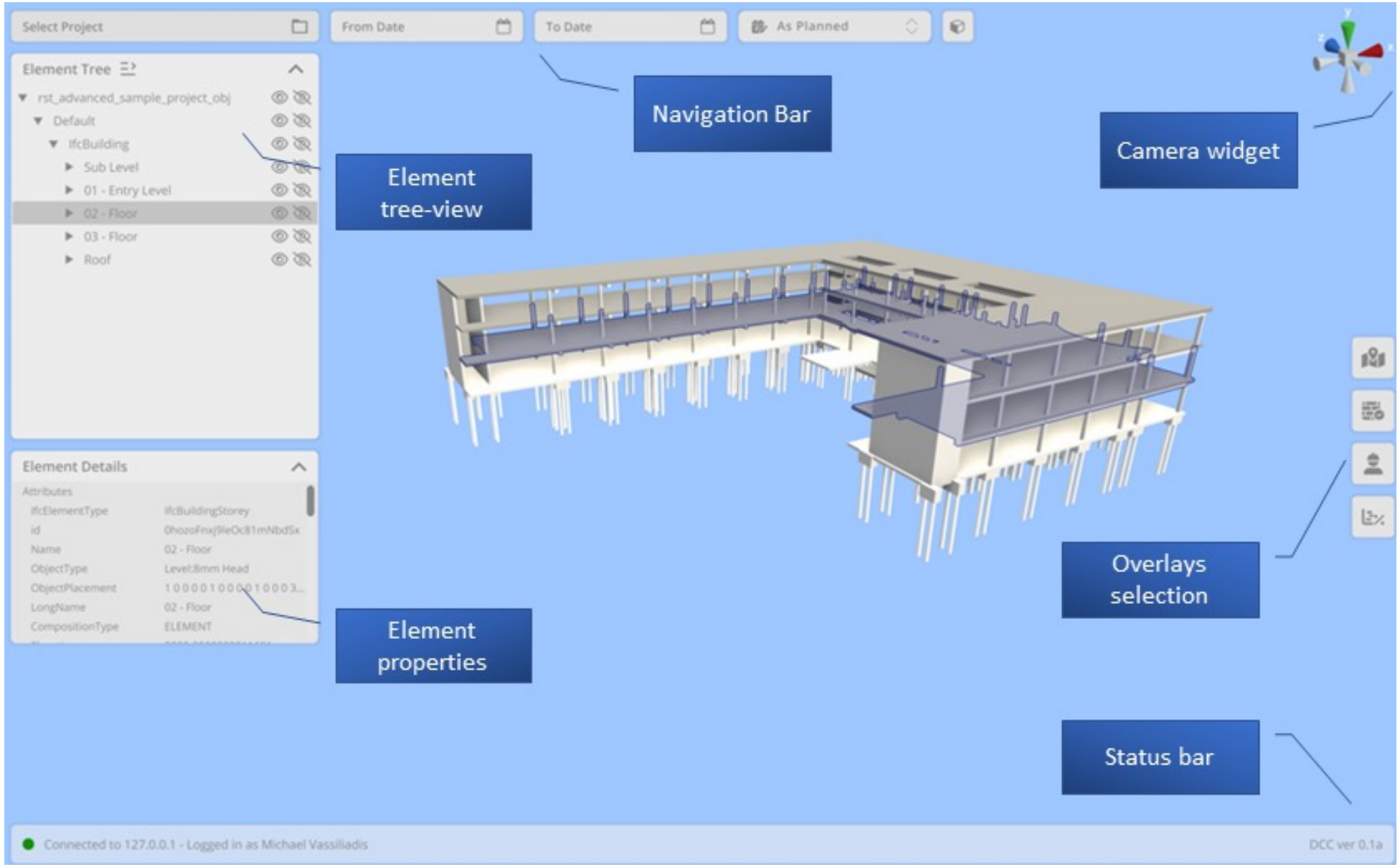
Hypertech SA

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 958310

DCC Architecture

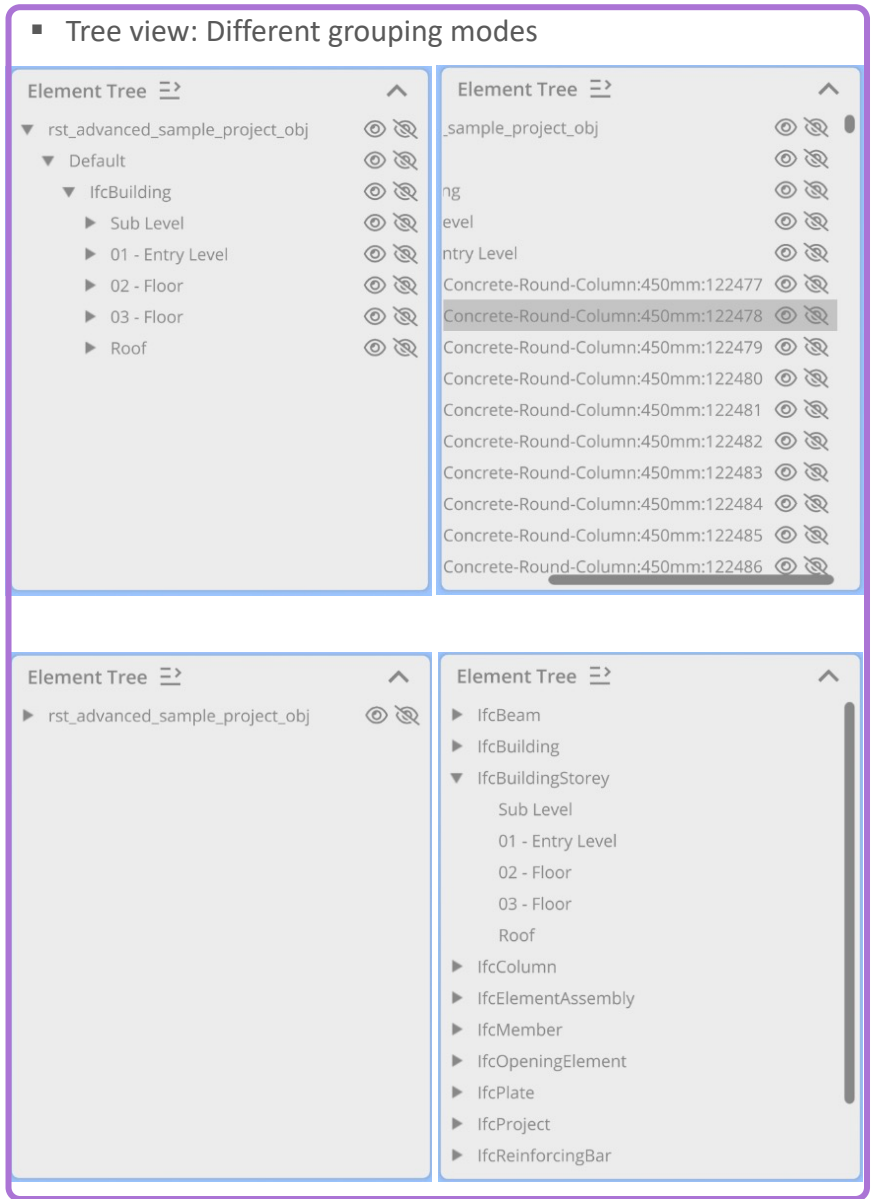


DCC – Web Application UI



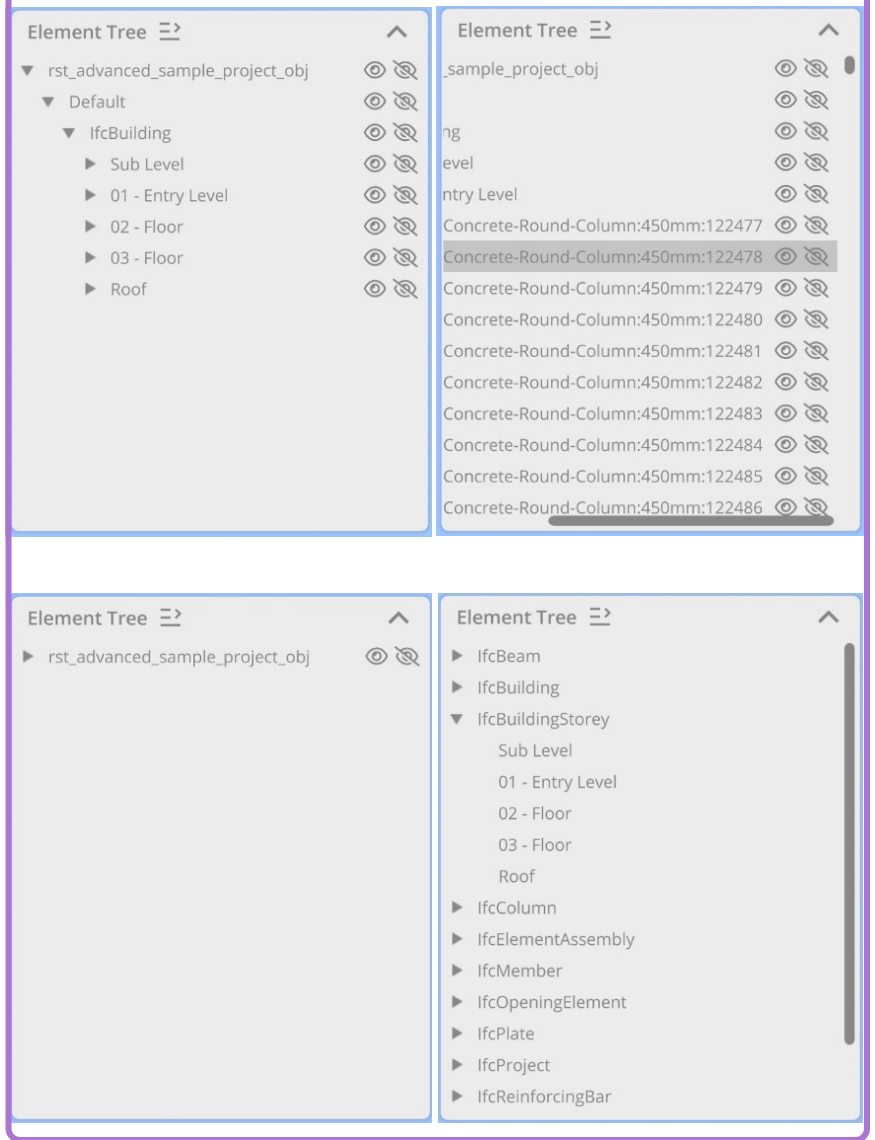
DCC – Web Application UI

- Tree view: Different grouping modes

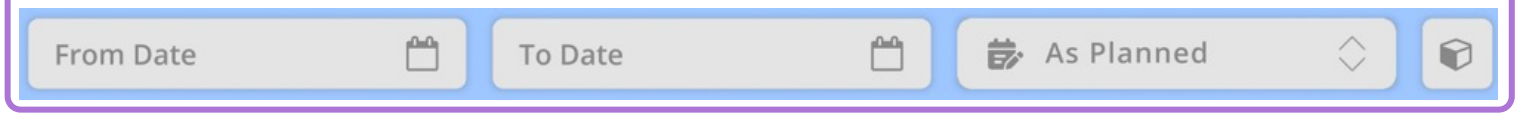


DCC – Web Application UI

- Tree view: Different grouping modes

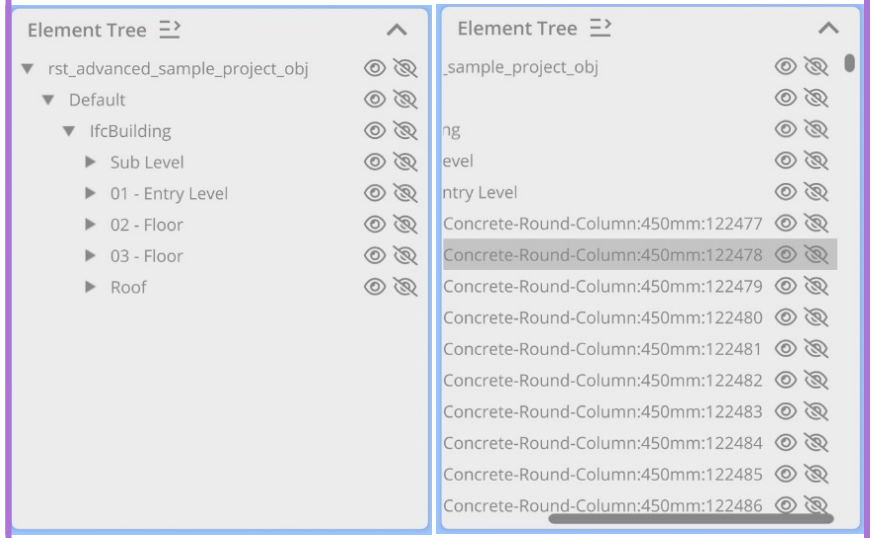


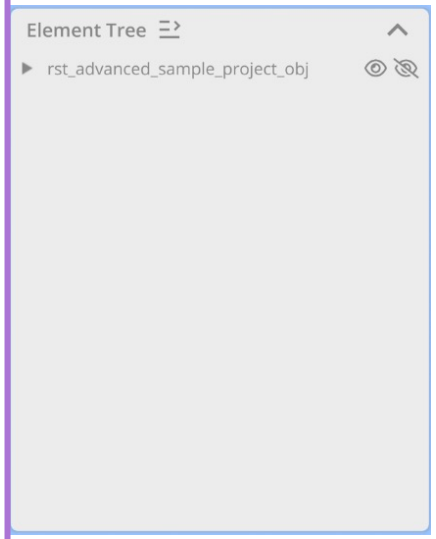
- Data filter menu – start/end data and as-planned or as-built

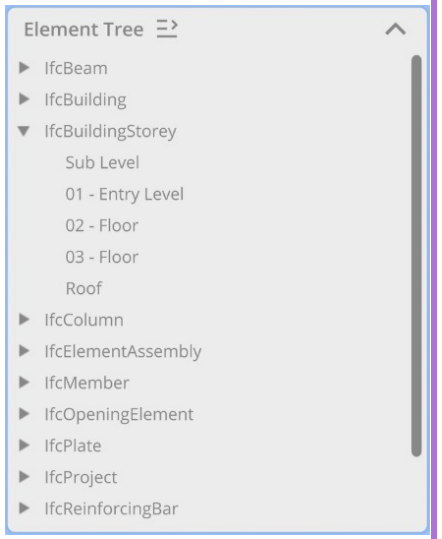


DCC – Web Application UI

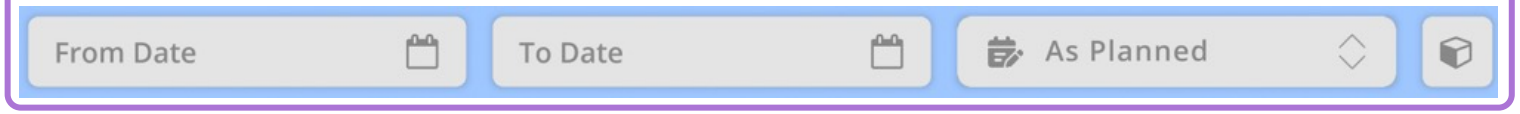
- Tree view: Different grouping modes



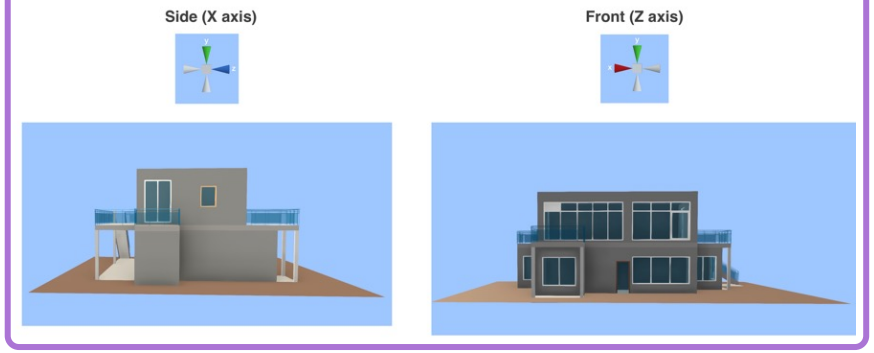




- Data filter menu – start/end data and as-planned or as-built

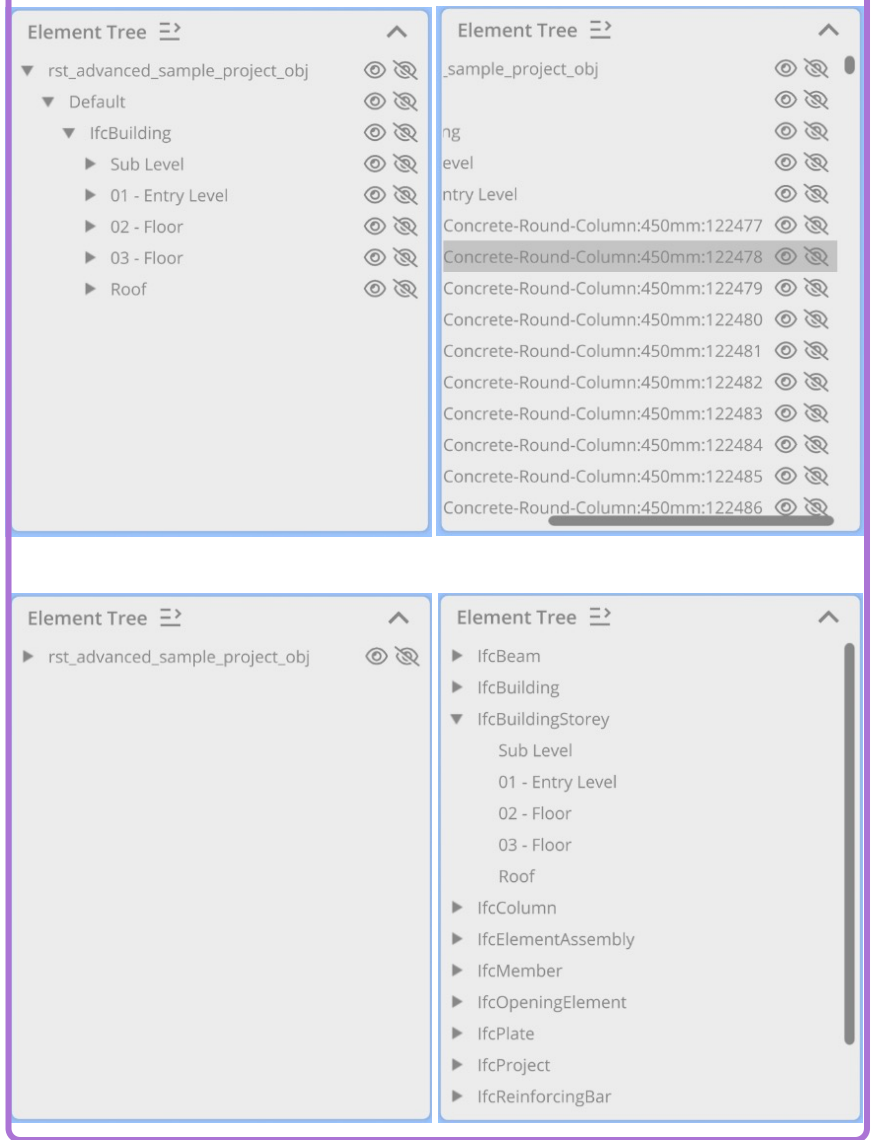


- Camera widget

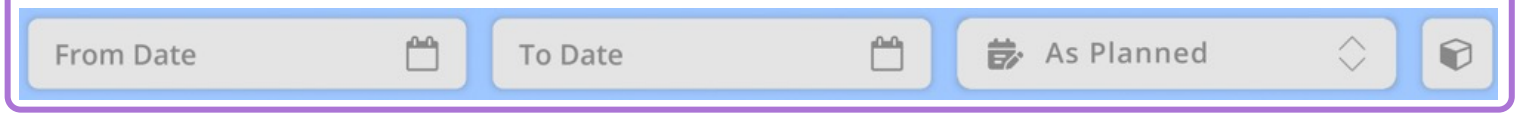


DCC – Web Application UI

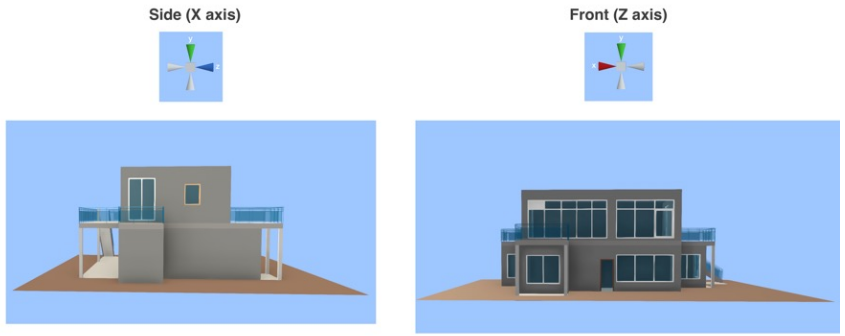
- Tree view: Different grouping modes



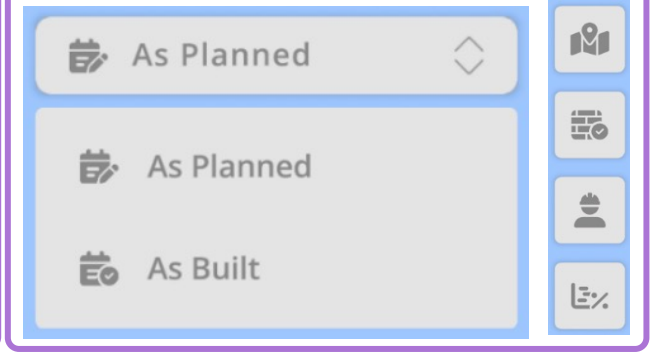
- Data filter menu – start/end data and as-planned or as-built



- Camera widget

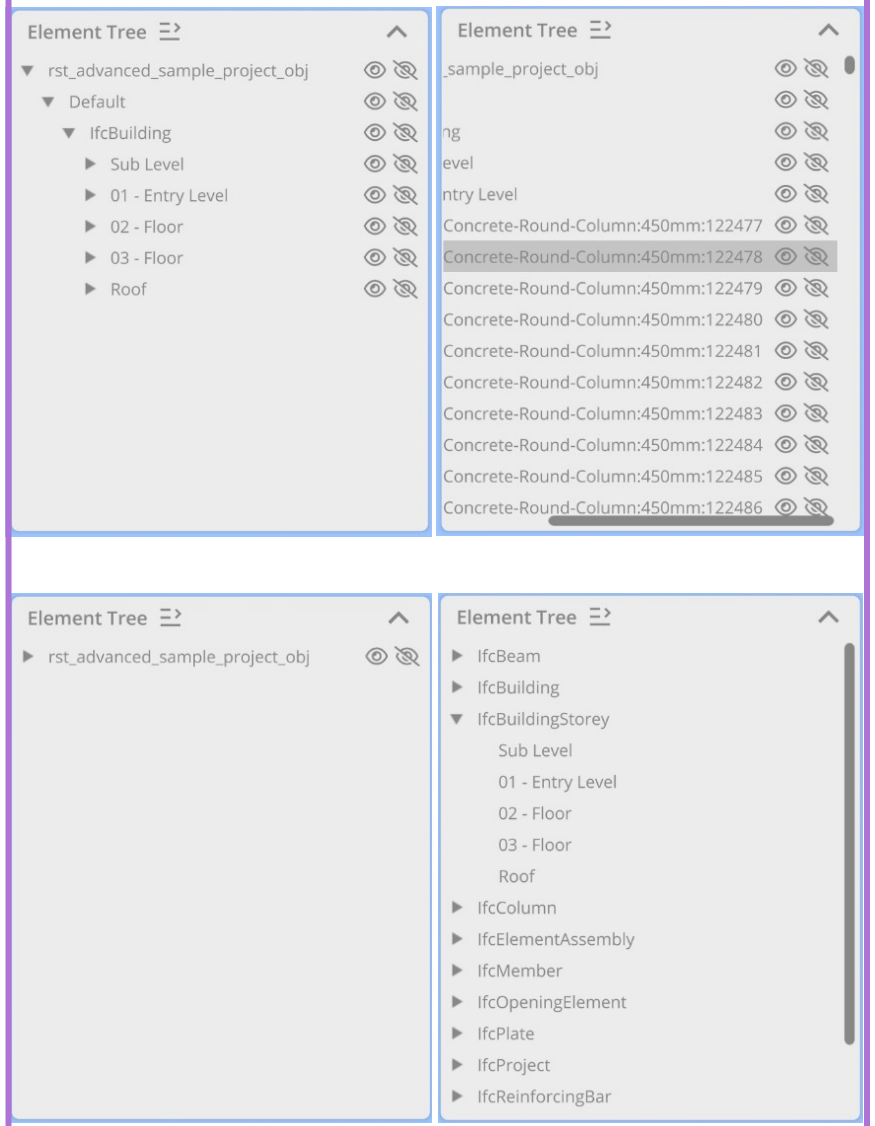


- Data overlays

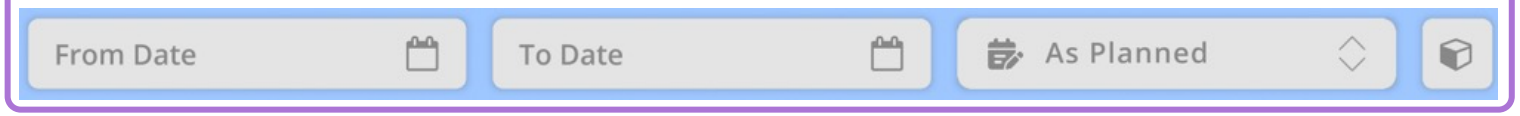


DCC – Web Application UI

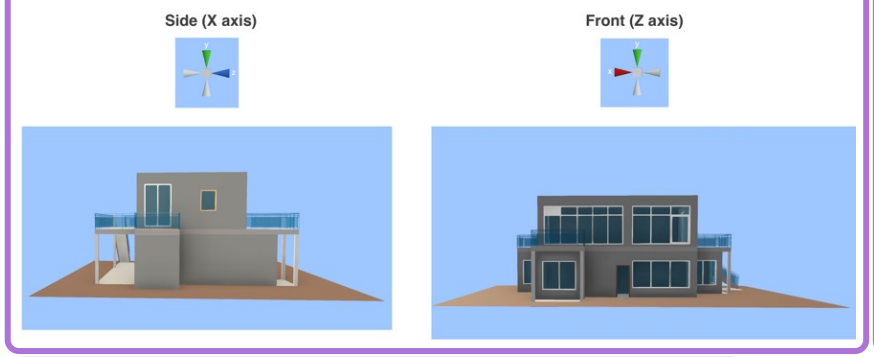
- Tree view: Different grouping modes



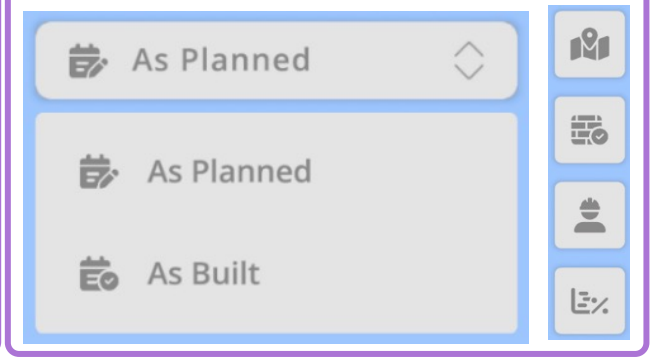
- Data filter menu – start/end data and as-planned or as-built



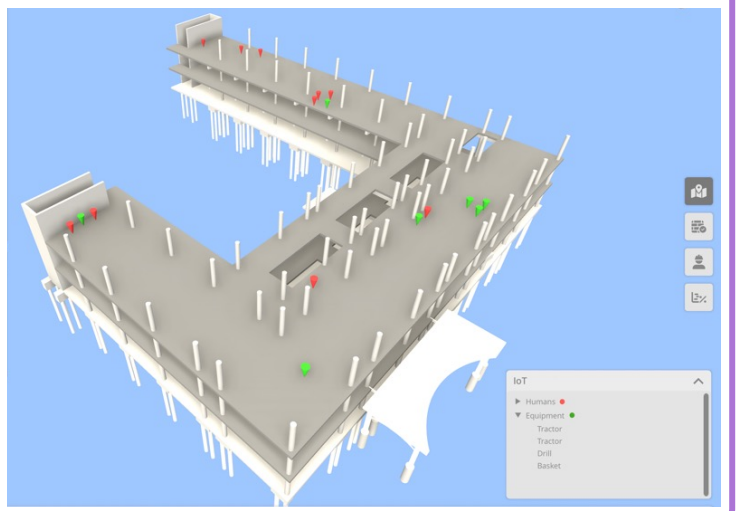
- Camera widget



- Data overlays

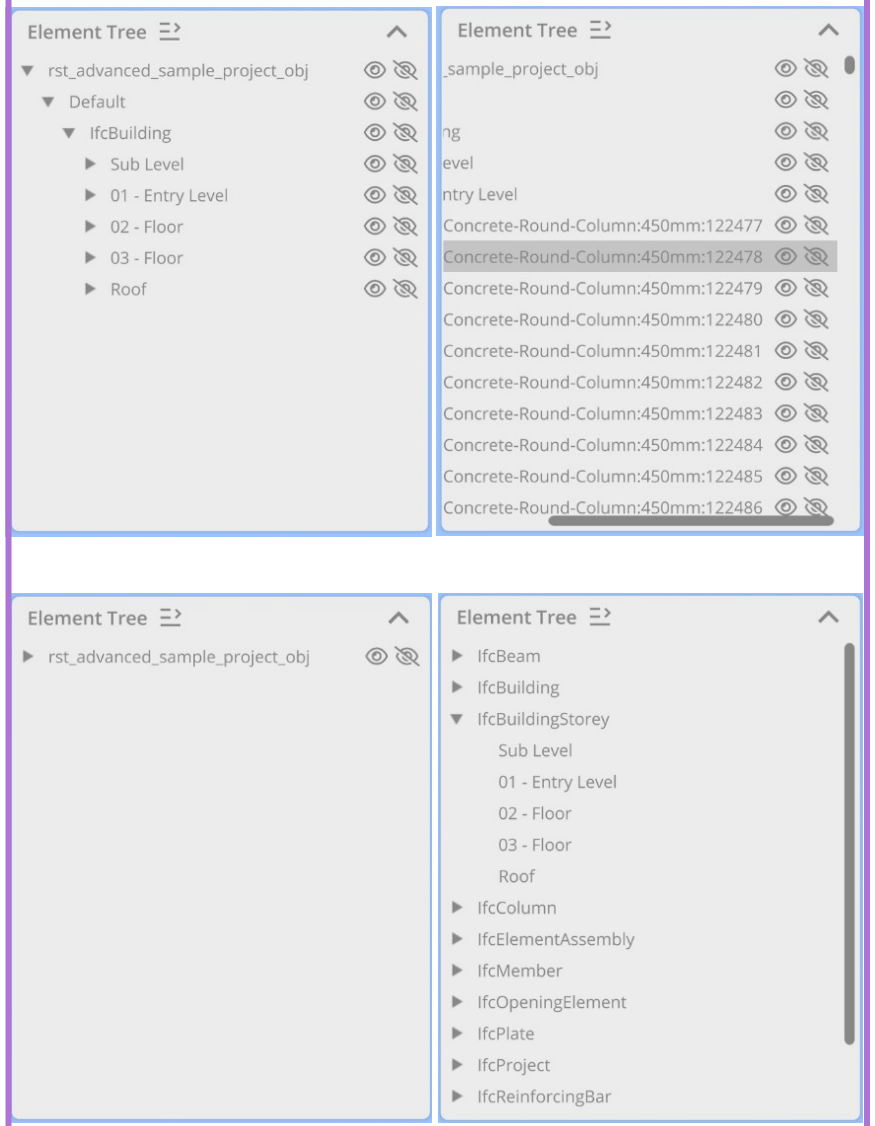


- Construction with IoT overlay enabled

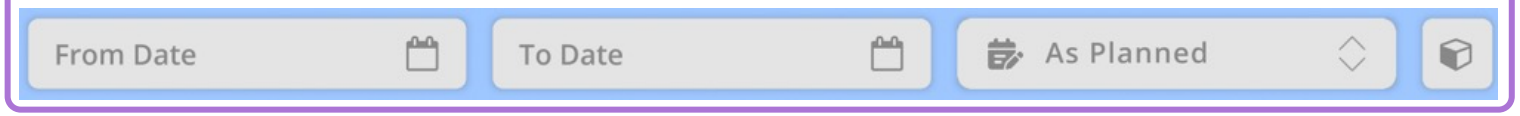


DCC – Web Application UI

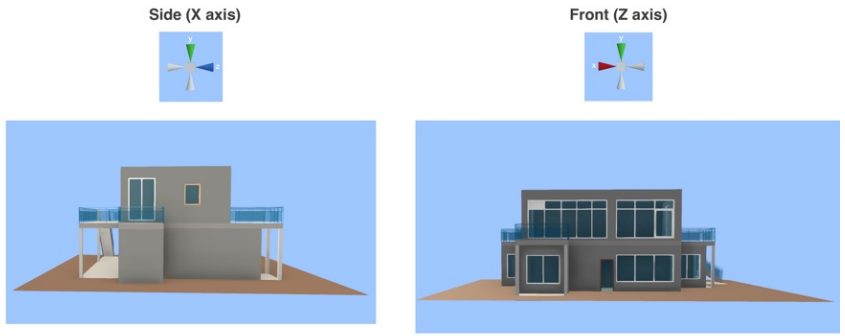
- Tree view: Different grouping modes



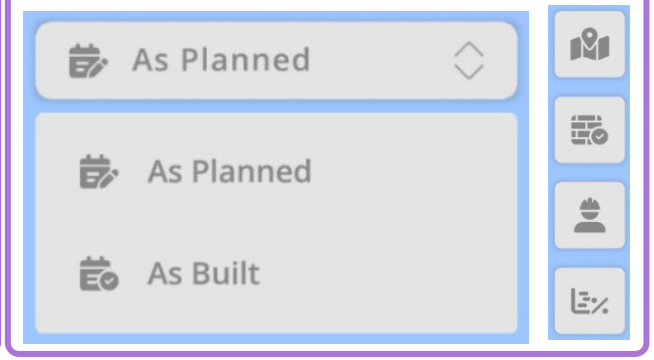
- Data filter menu – start/end data and as-planned or as-built



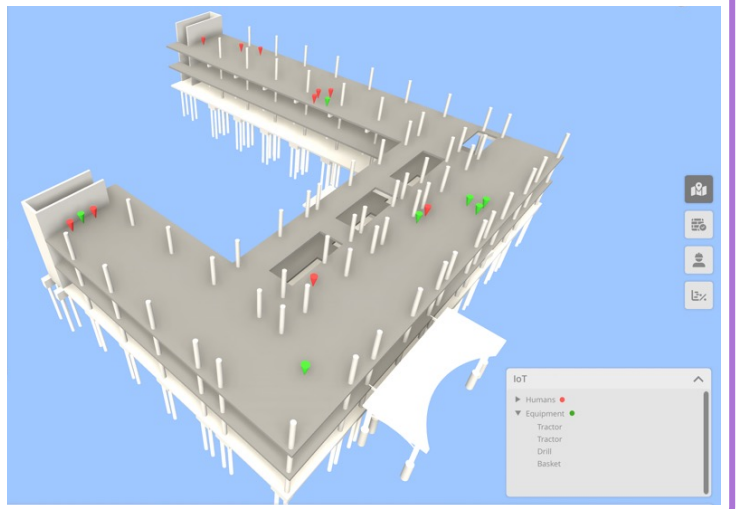
- Camera widget



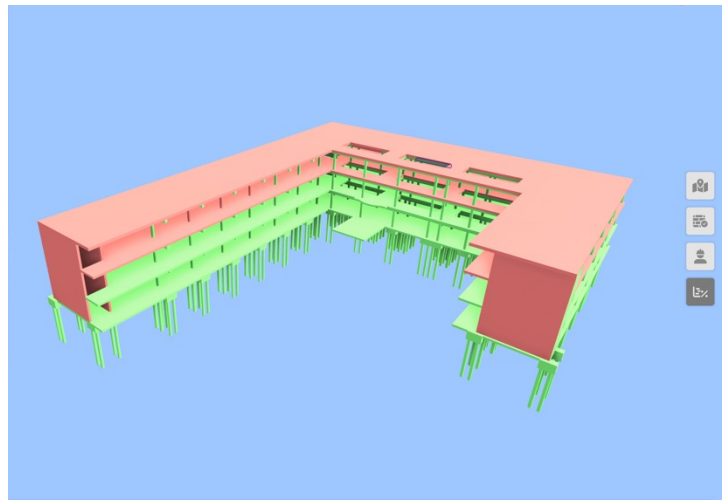
- Data overlays



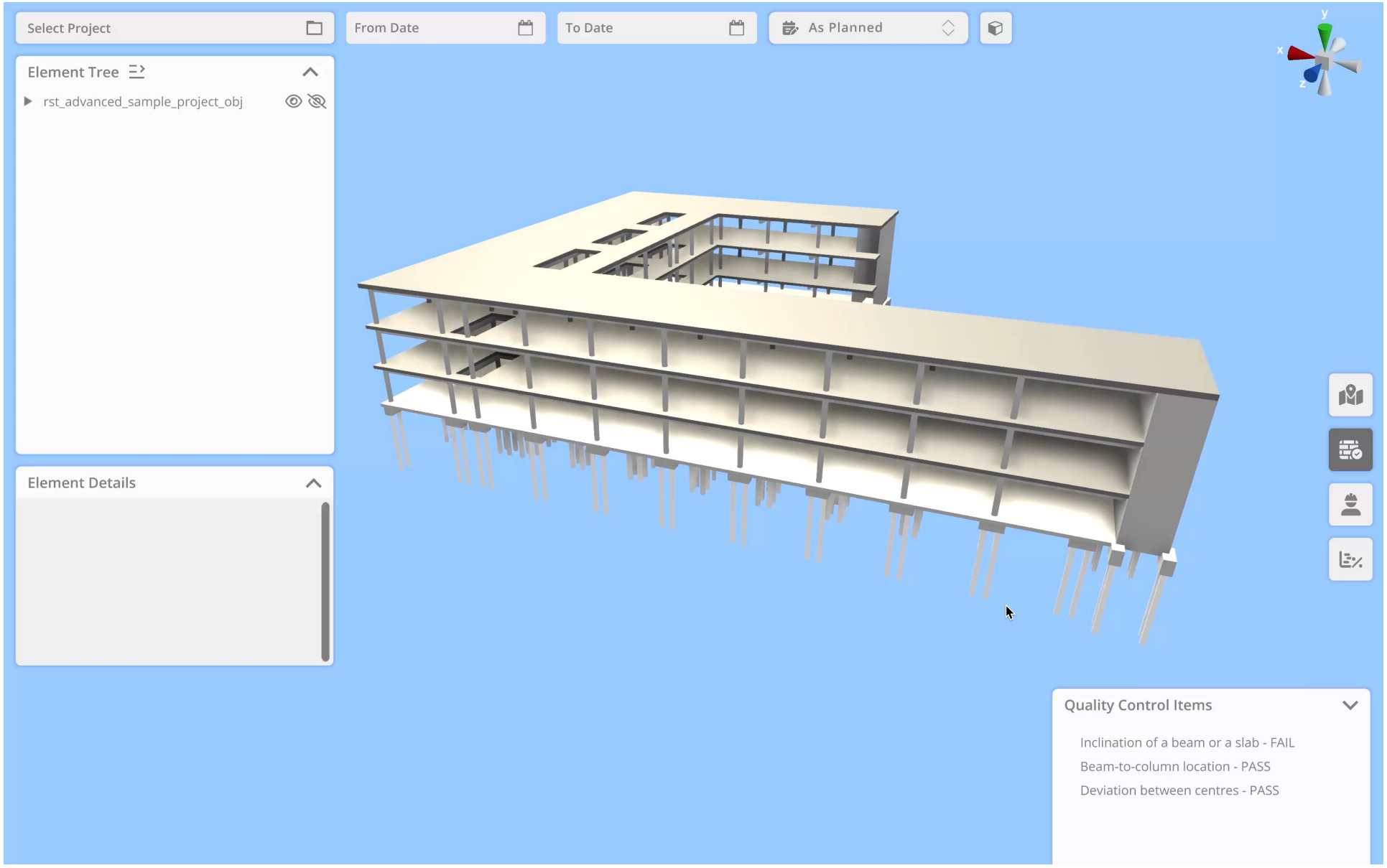
- Construction with IoT overlay enabled



- Construction with work progress overlay enabled



GeometricQC results in DCC



- Construction with quality control overlay enabled

2nd Poll

Will the tools answer your needs?

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 958310

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Questions & Answers

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