

AI/ML Driven Innovation for High Precision Construction, Inspections, and Management

Kevin Han & Abhinav Gupta

Center for Nuclear Energy Facilities and Structures

Dept. of Civil, Construction, and Environmental
Engineering

NC State University

kevin_han@ncsu.edu | agupta1@ncsu.edu

Center for Nuclear Energy Facilities & Structures

CNEFS

Sustainability



Resiliency and Severe Accident Management



Reducing Cost of Building New Plants



CNEFS

Center for Nuclear Energy Facilities & Structures

Department of
Civil Engineering

Department of
Nuclear Engineering

Abhinav Gupta
Kevin Han
Giorgio T. Proestos
Ashly Cabas Mijares
Jim Rispoli

Nam Dinh
Kostadin Ivanov
Mihai A. Diaconeasa
Xu Wu

CNEFS Faculty

Faculty



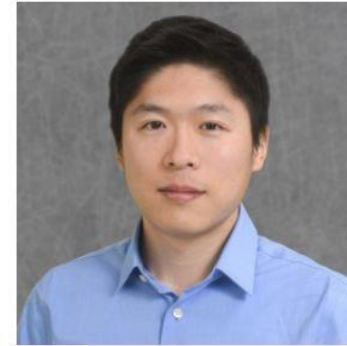
› Abhinav Gupta,
Professor and Director
of CNEFS



› Mihai A. Diaconeasa,
Assistant Professor



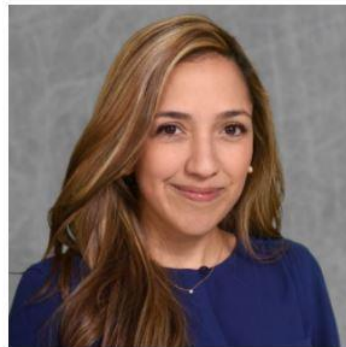
› Nam Dinh, Professor



› Kevin Han, Assistant
Professor



› Kostadin Ivanov,
Professor and Head of
Nuclear Engineering



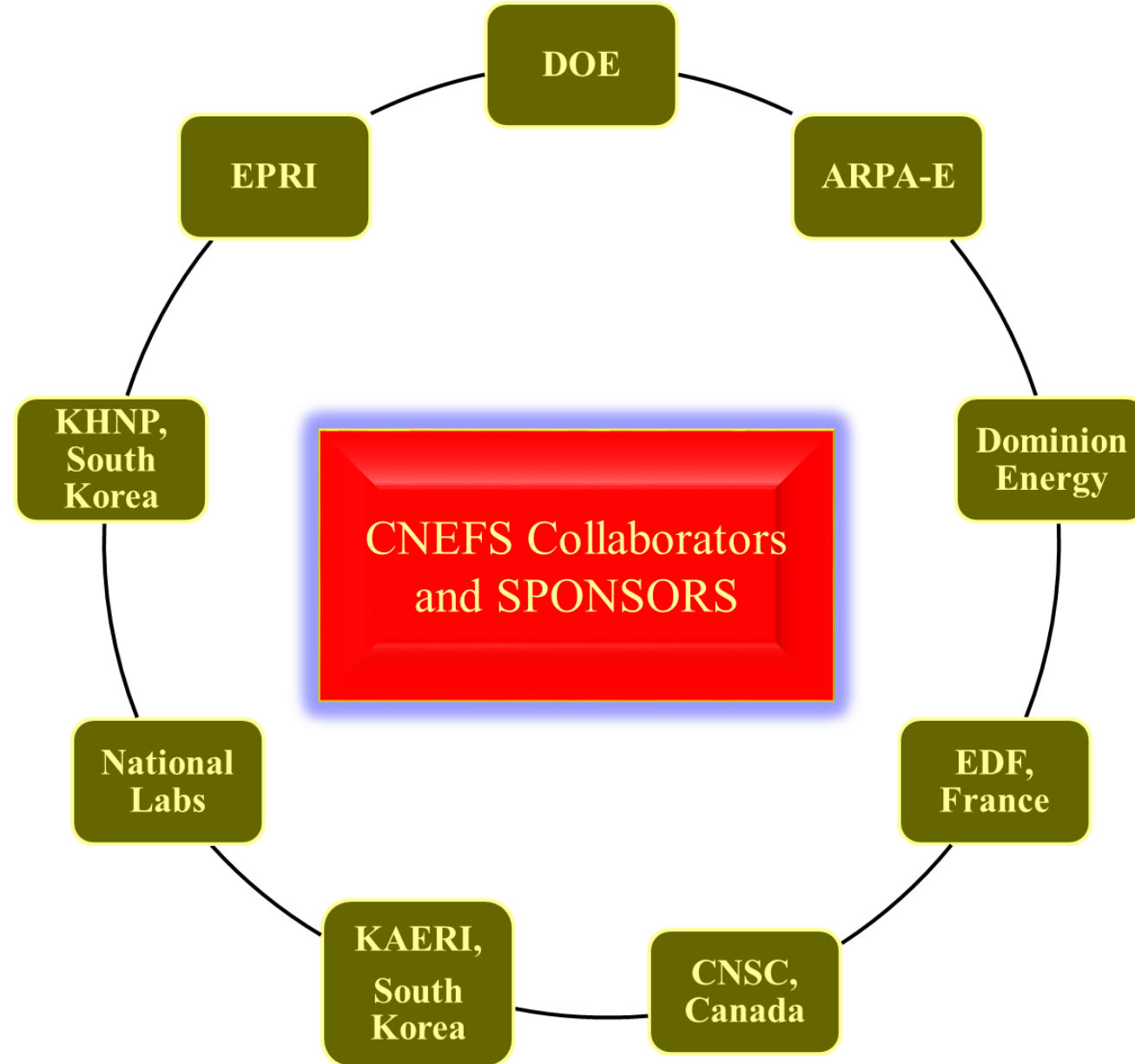
› Ashly Cabas Mijares,
Assistant Professor



› Giorgio T. Proestos,
Assistant Professor



› Jim Rispoli, Professor
of Practice



Facilitated by Support From

- VTR Project at INL
 - Digital Engineering for Integrated Design and Construction
 - *Chris Ritter, Lee Nelson and Digital Engineering team at INL*
- ARPA-E
 - Development of Construction Performance Modeling & Simulation
 - *Rachel Slaybaugh and rest of ARPA-E team*

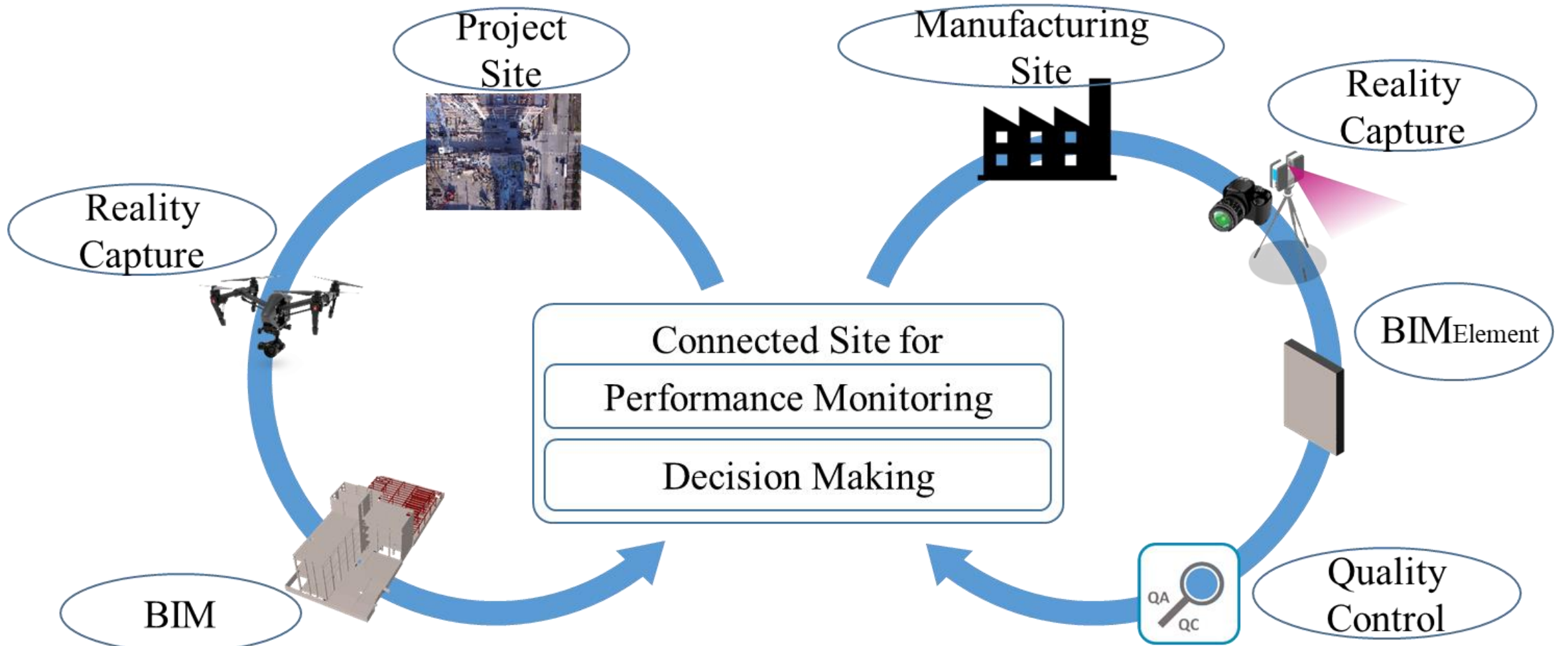
What happened at VC Summers...

- Construction plans and schedules not reflective of on-site reality.
- Project management integration was poor. Approvals of changes through paperwork between construction supervisors, inspectors, decision makers, regulators, and owners.
- Lack of communication and information flow at all levels. Very slow pace and lack of understanding of the real issue at all stages.
- Design changes not showing up in EPC or in construction drawings.
- Mismatch in as-design and as-built.
- Lack of real-time info for oversight.

What We Do...

- Provide near real-time on-site & off-site progress/quality monitoring
- Improve communication of **performance and changes** among all stakeholders through integrated digital modeling
 - Project management integration & streamlined decision making for changes
- Model performance (as-built) against construction plan (as-design)
 - No mismatch in as-design and as-built
- Improve interoperability between design software and BIM
 - Design changes showing in EPC and in construction drawings

Holistic Approach to Performance Management at Project Site and Off- Site Facilities

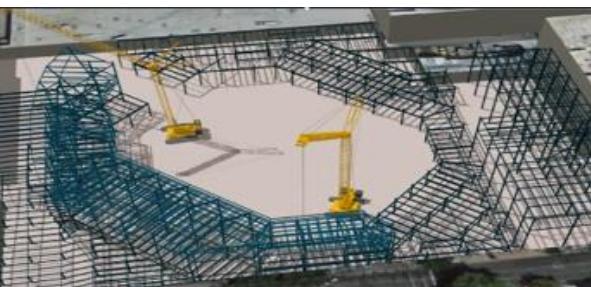


Virtual QA/QC and Workflow

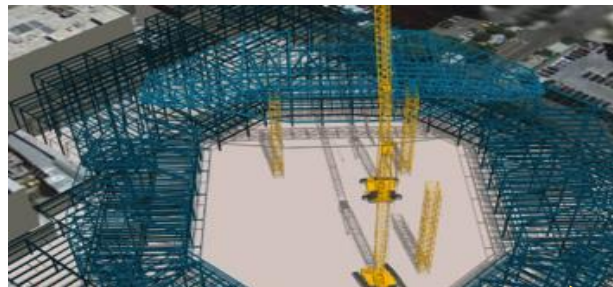
- NQA-1 standards for key components that require visual inspection
- Quality assessment method that ensures compatibility of modular components
- Workflow, standards, and quality of digital information exchange for CPMS

Integrated Information Models for Production Control

- As-built Documentation
- Performance Monitoring (Progress, Safety, and Quality)
- Contractor Hand-Over



t



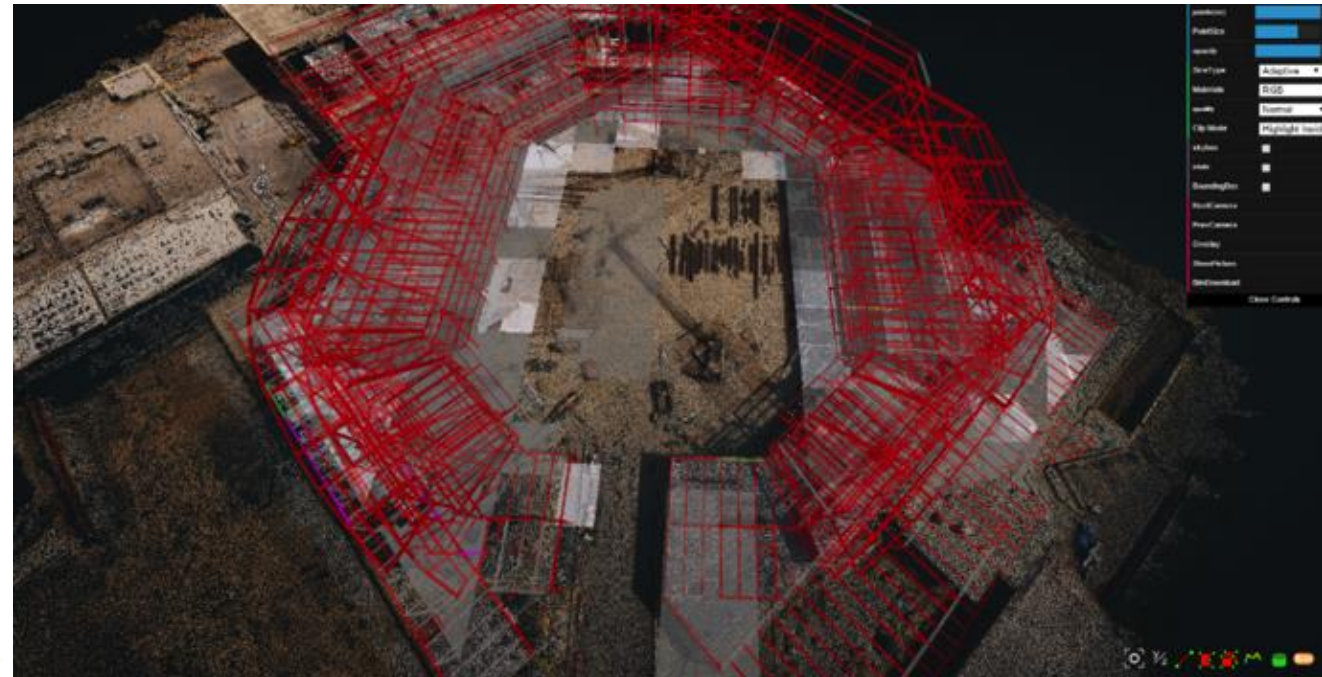
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Virtual Comparison: 4D As-built Model (Progress) vs 4D BIM (Plan)

Prototype – Virtual Environment for Performance Monitoring

The image displays a virtual environment interface for performance monitoring. The central focus is a 3D visualization of a building under construction, showing a tall tower and a base with various construction elements. The interface includes several control panels and data displays:

- Top Left Panel:** A dropdown menu with '1' selected, and checkboxes for 'BIM' (checked), 'Image' (checked), and 'Mesh/PointCloud' (unchecked).
- Top Right Panel:** A box displaying performance metrics: 'FPS: 59 fps' and 'RP: 53,547,861'.
- Bottom Left Panel:** A dropdown menu with '3909073' selected, and text indicating 'Name: Basic_Wall' and 'Size: Concrete_-_6"'. Below this is a small 3D viewer showing a white rectangular prism.
- Bottom Center Panel:** A timeline slider with 'Start' on the left and 'February 2018' on the right.

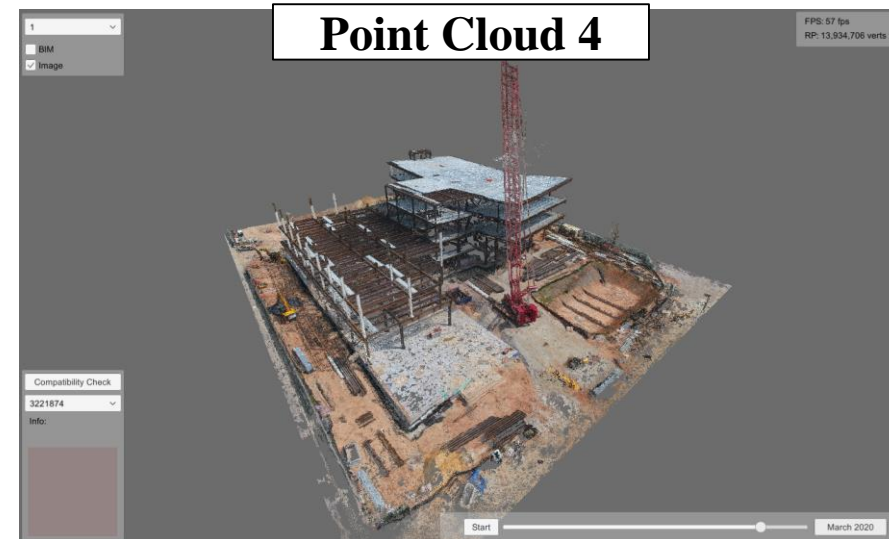
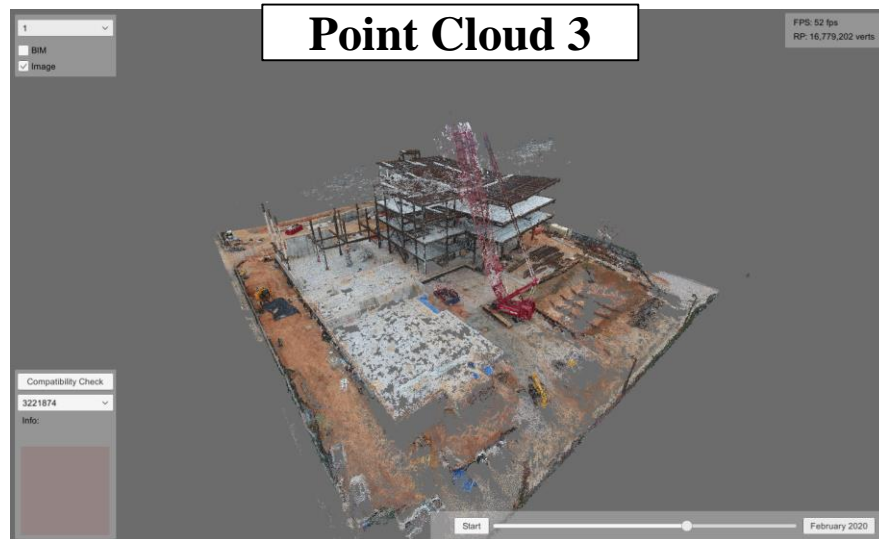
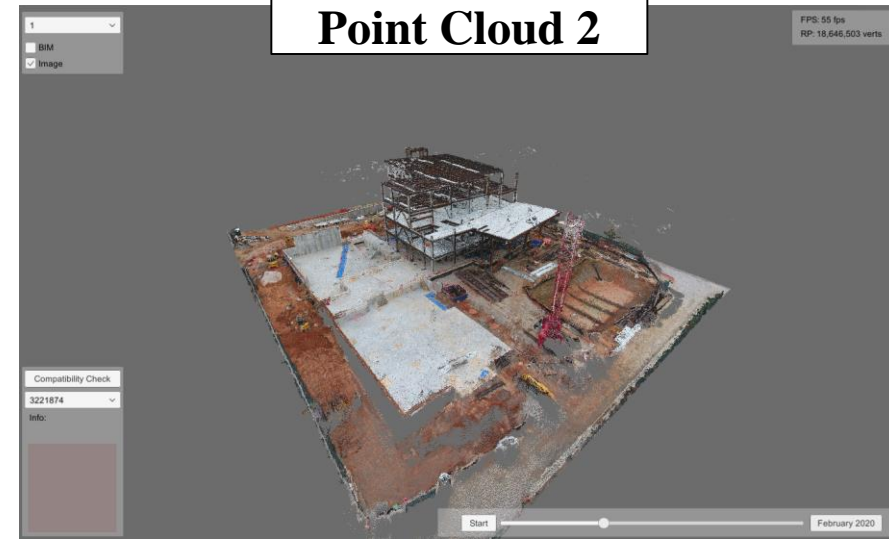
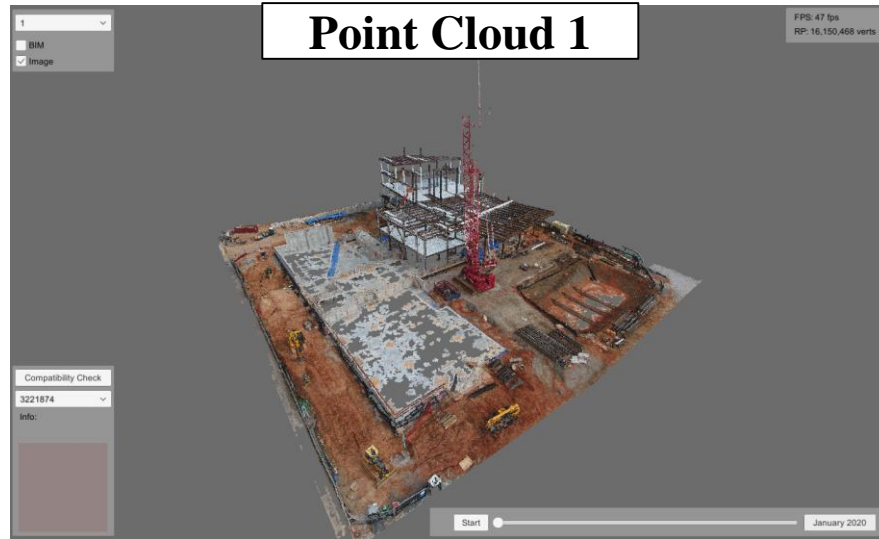
Annotations and labels are placed around the interface:

- 1. Image selection** points to the top left dropdown.
- 2. Image and BIM controllers** points to the 'BIM' and 'Image' checkboxes.
- 3. Mesh and pointcloud controllers** points to the 'Mesh/PointCloud' checkbox.
- 4. BIM element selection** points to the bottom left dropdown.
- 5. BIM element information** points to the 'Name' and 'Size' text.
- 6. BIM element viewer** points to the small 3D viewer.
- 7. Timeline** points to the bottom center slider.
- 8. FPS and RP information** points to the top right performance metrics box.

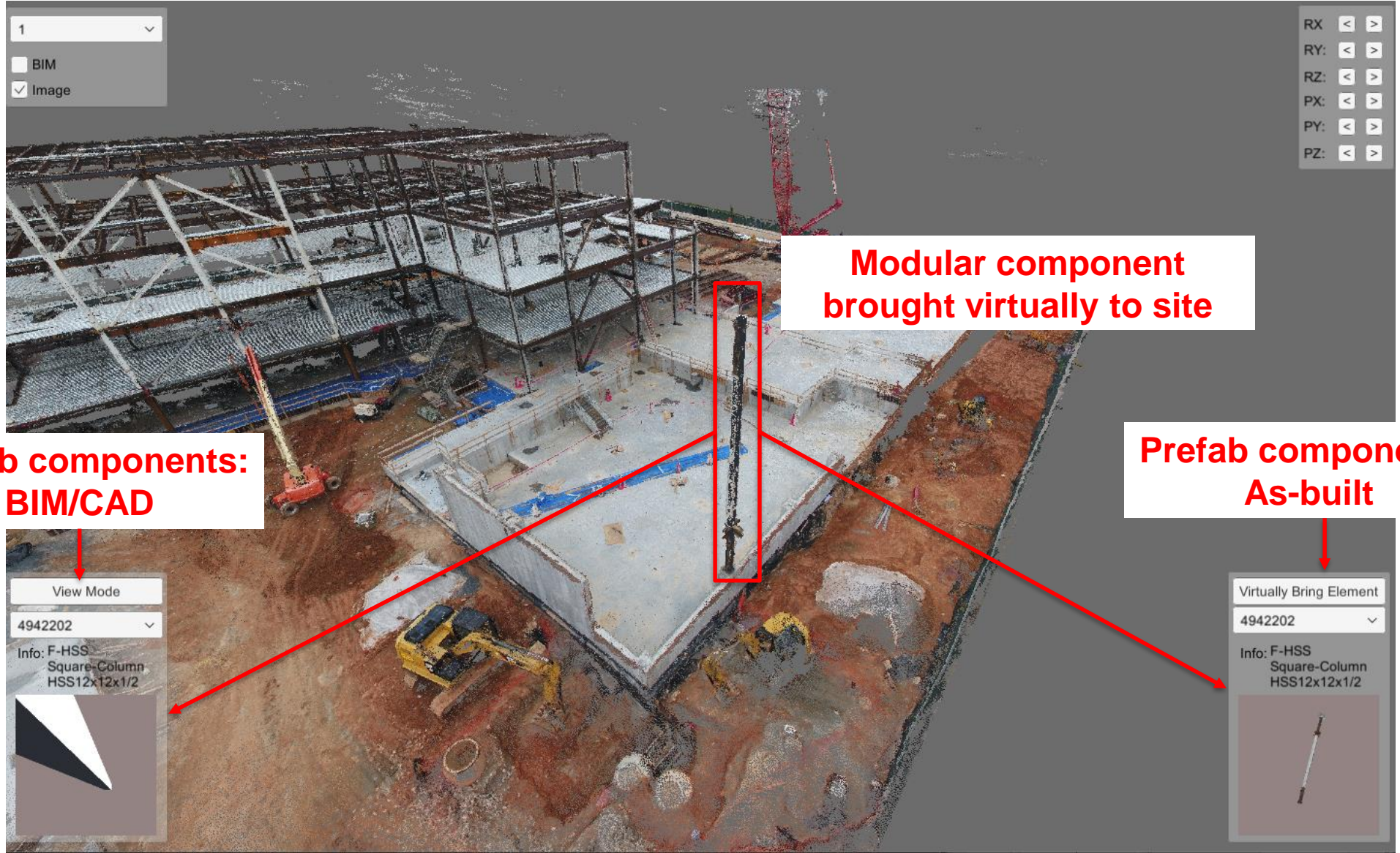
Additional text includes:

- Prefab components: As-built & BIM/CAD** in red text with a red arrow pointing to the bottom left panel.
- 4D visualization** in red text with a red arrow pointing to the 3D model.

Prototype – 4D as-built model for capturing progress



Prototype – Virtually bring modular component to assess



Modular component brought virtually to site

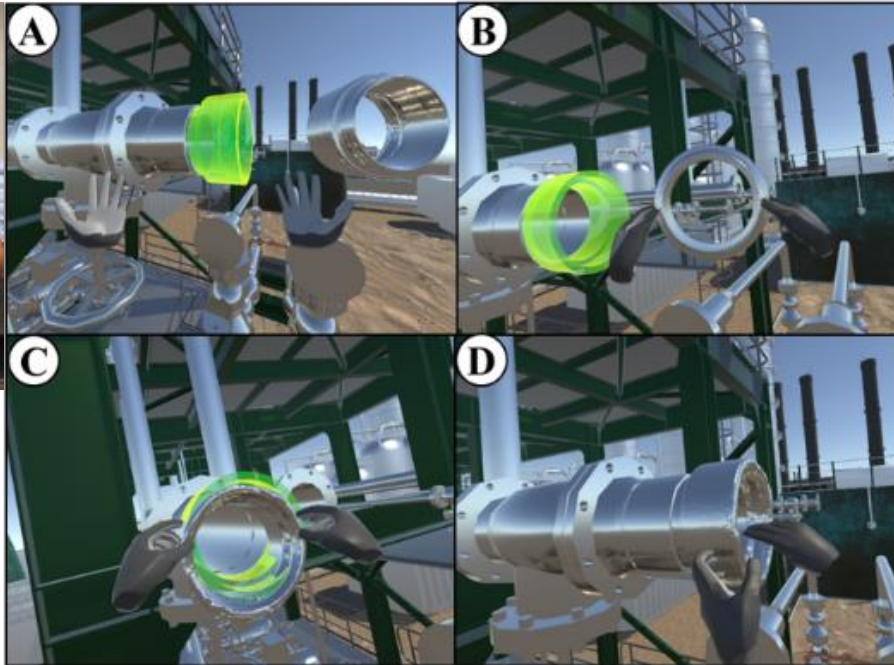
Prefab components: BIM/CAD

Prefab components: As-built

View Mode
4942202
Info: F-HSS
Square-Column
HSS12x12x1/2

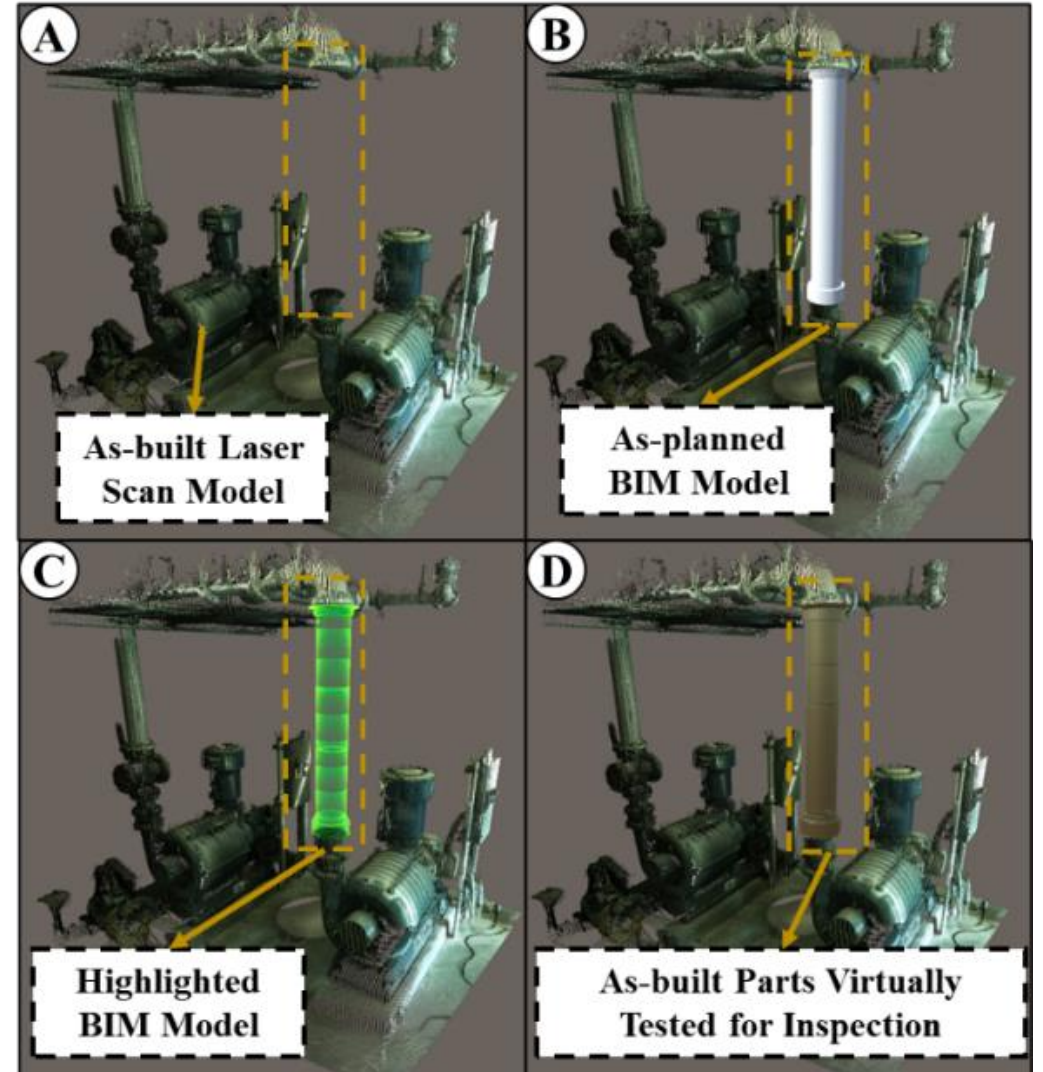
Virtually Bring Element
4942202
Info: F-HSS
Square-Column
HSS12x12x1/2

VR for Virtually Managing QA/QC in Supply Chain

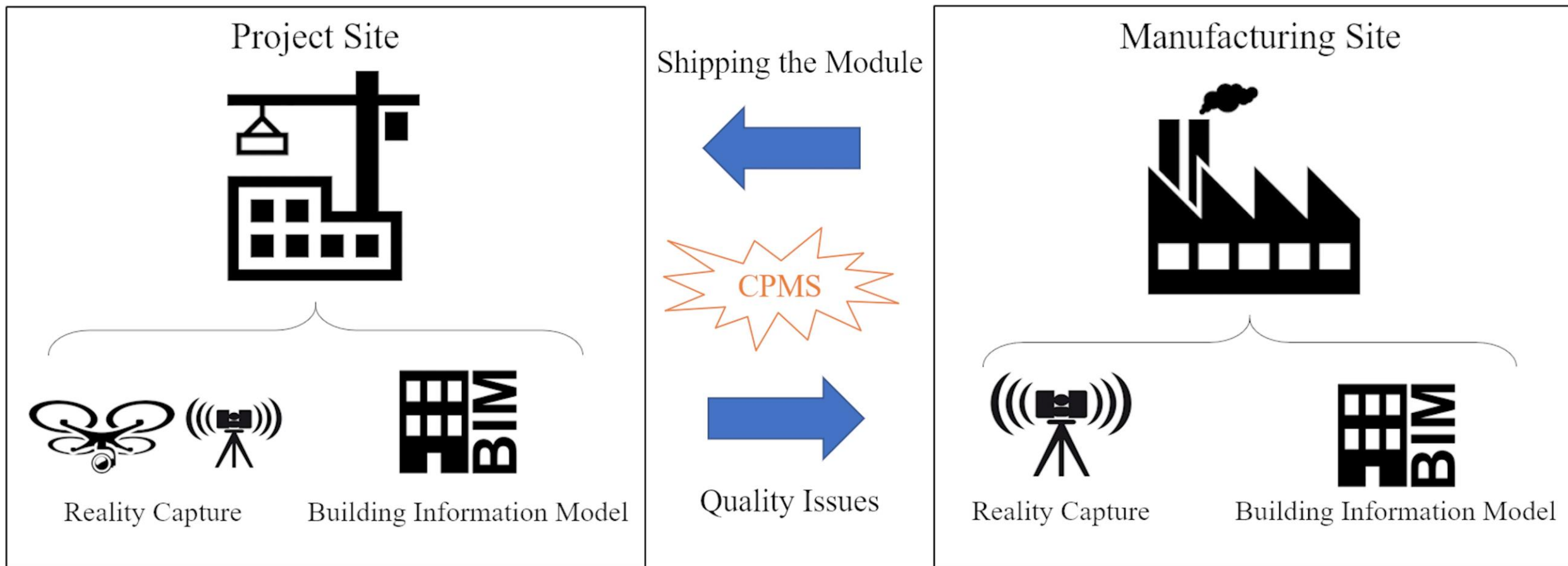


Manual Virtual Inspection

Automatic Virtual Inspection



Construction Performance Modeling and Simulation

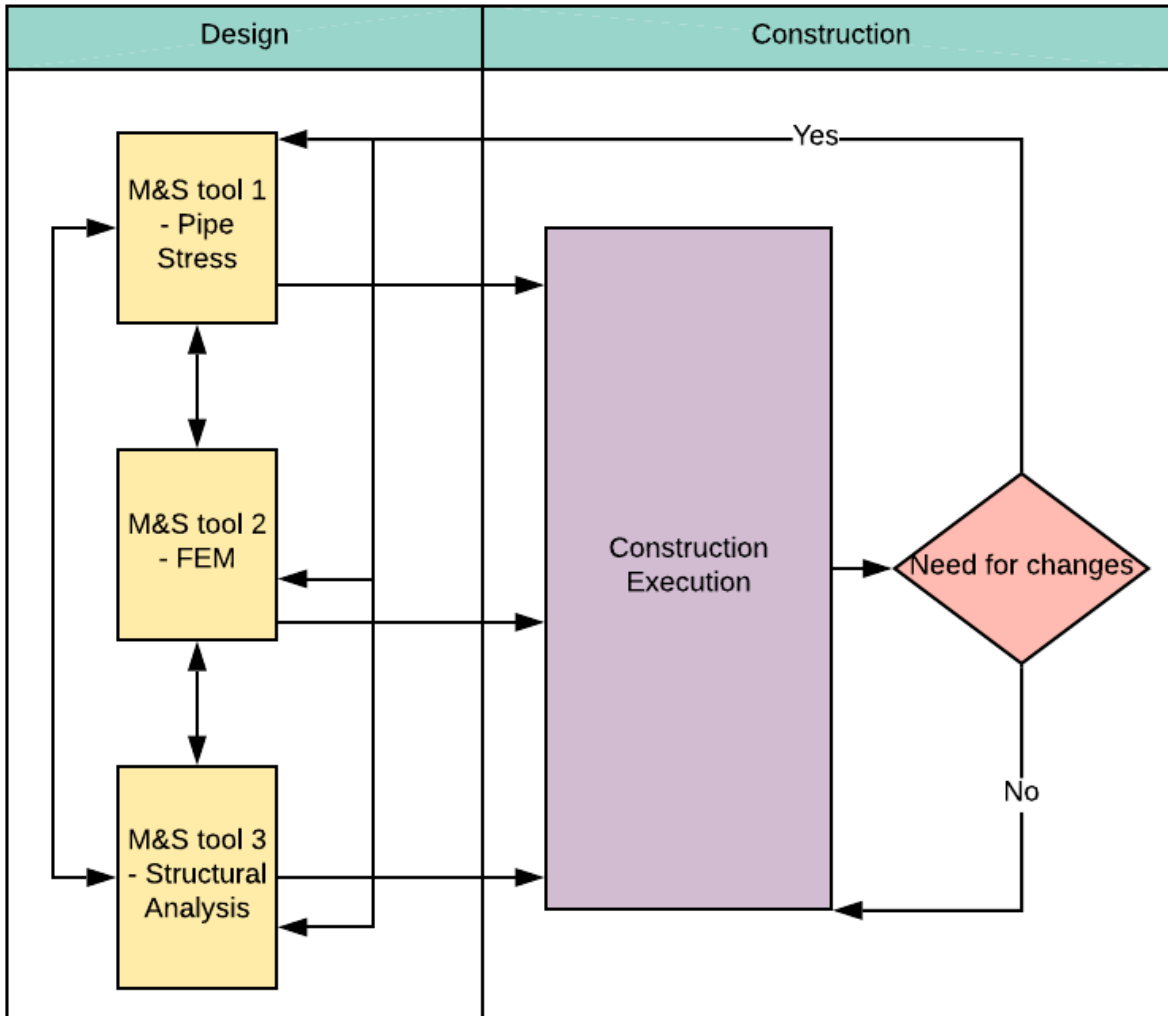


Risk-informed Approach to Increase Tolerance

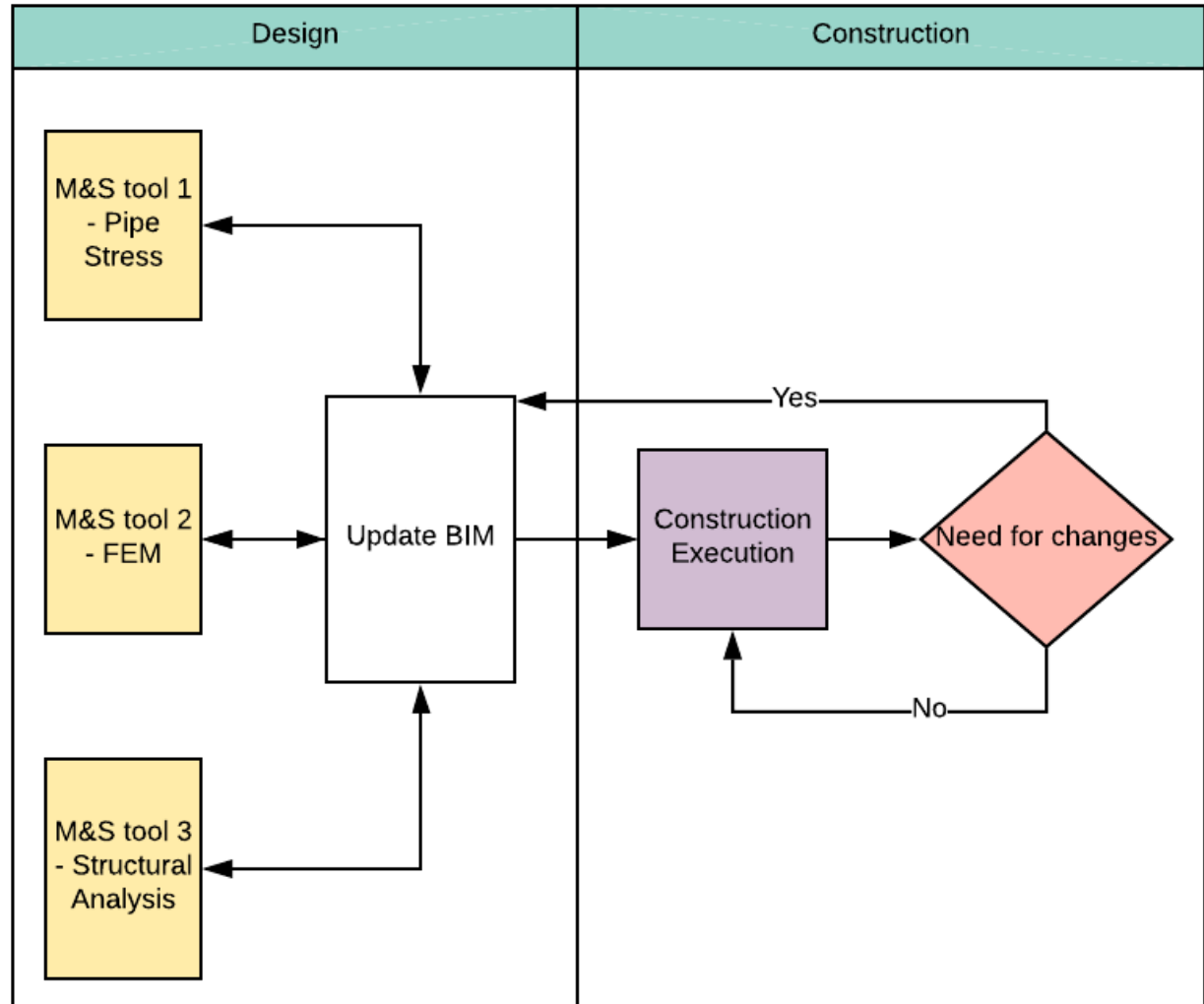
- Assessment of risk construction tolerance exceeds mechanical tolerance
- Update 4D BIM to reflect as-built condition
- Convert 4D BIM models into structural models
 - Automated approach currently under investigation
- Assess risk and determine acceptability of risk

Integrated Approach to Design and Construction

Problems in Practice

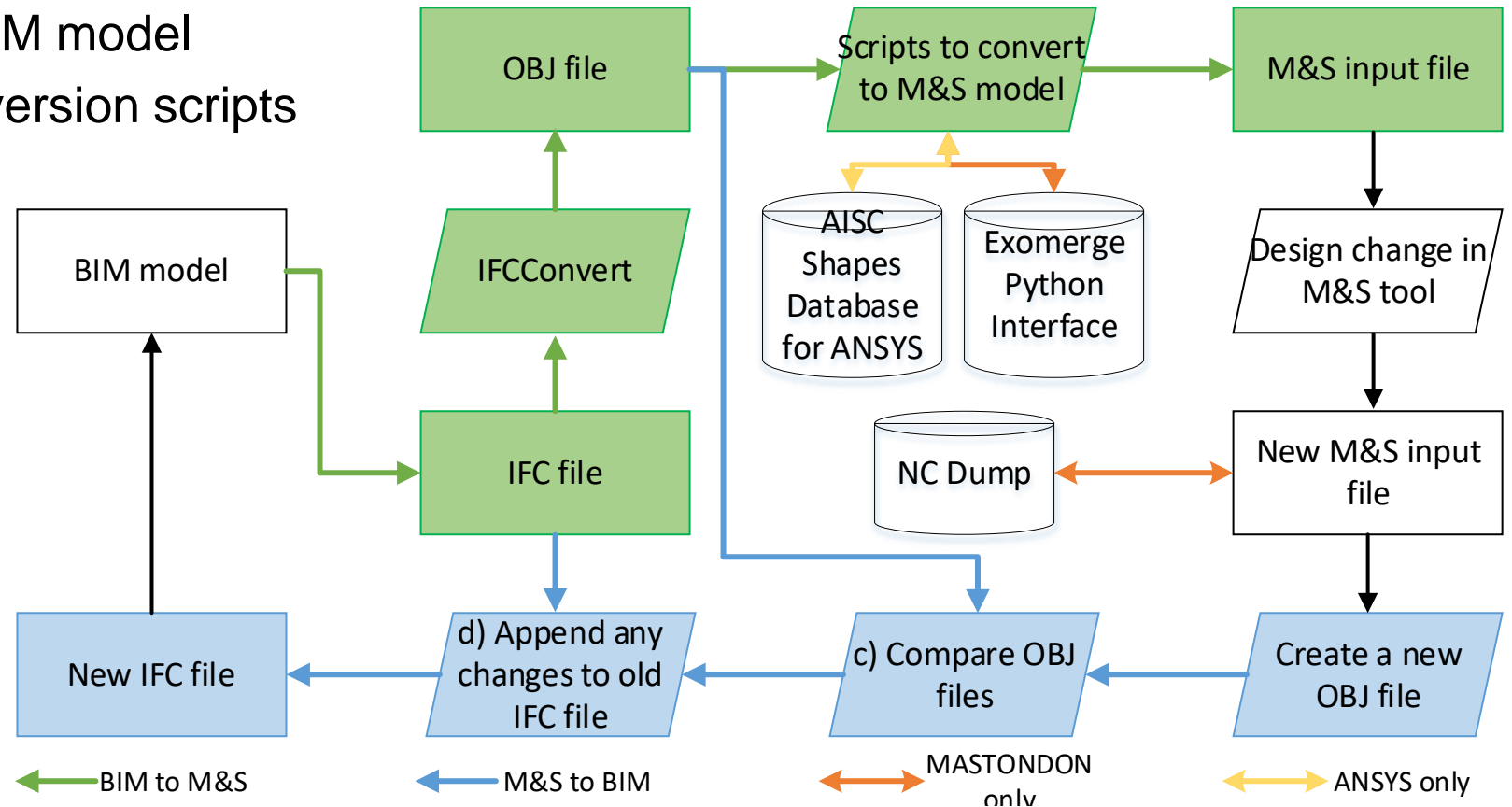


Our Approach

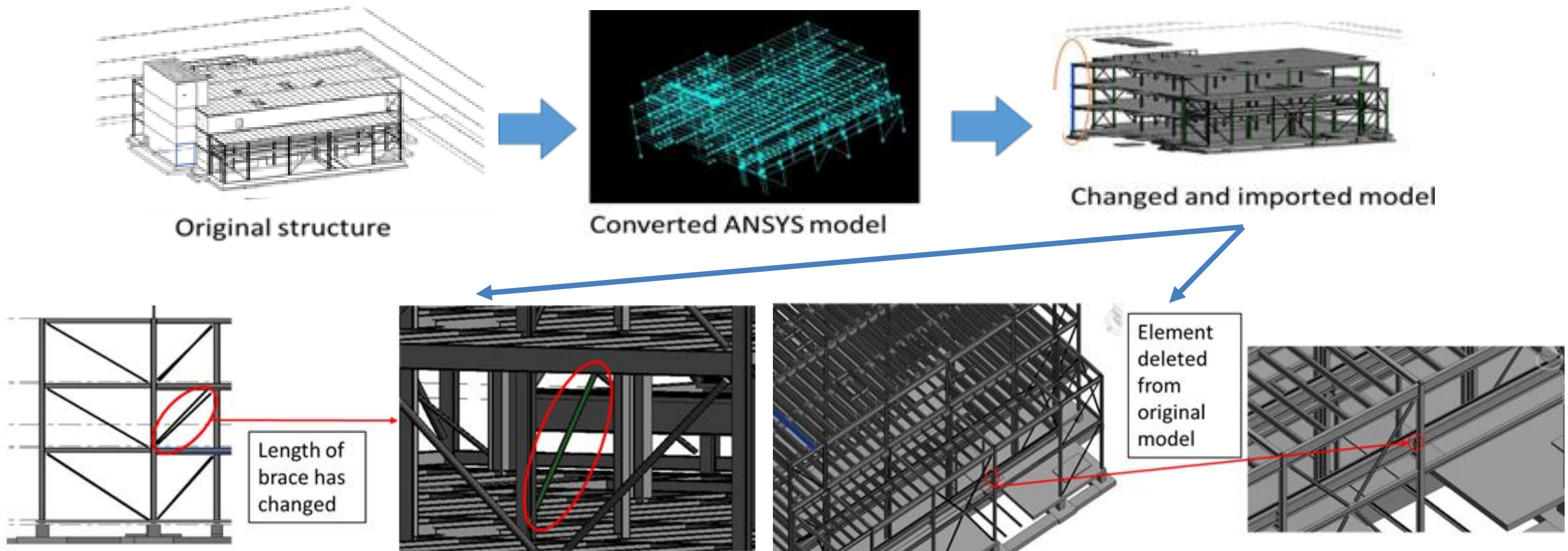


Interoperability between Design and BIM Software

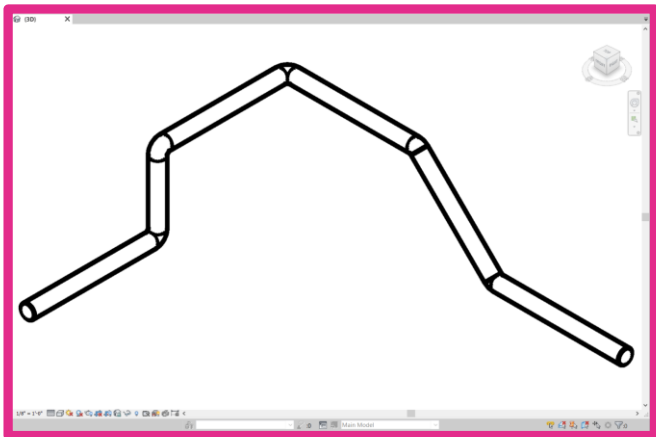
- Automated approach from BIM model (Revit and AVEVA E3D to FEM (ANSYS))
 - ANSYS Mechanical APDL is used for FEM tool
 - Revit 2020 used for BIM model
 - Python3 used for conversion scripts
 - IFC version 4



Structural Model & BIM



Piping Stress Model & BIM



BIM: Revit Piping



```

1 ISO-10303-21;
2 HEADER;
3
4 /*****
5 * STEP Physical File produced by: The EXPRESS Data Manager Version 5.02.010
6 * Module: EDMstepFileFactory/EDMstandAlone
7 * Creation date: Thu Mar 12 03:22:36 2020
8 * Host: CCEXP-048
9 * Database: C:\Users\nccrowde\AppData\Local\Temp\7A3
10 * Database version: 5507
11 * Database creation date: Thu Mar 12 03:22:35 2020
12 * Schema: IFC2X3
13 * Model: DataRepository.ifc
14 * Model creation date: Thu Mar 12 03:22:35 2020
15 * Header model: DataRepository.ifc_HeadedModel
16 * Header model creation date: Thu Mar 12 03:22:35 2020
17 * EDMUser: sdai-user
18 * EDMGroup: sdai-group
19 * License ID and type: 5605 : Permanent license. Expiry date:
20 * EDMstepFileFactory options: 020000
21 *****/
22 FILE_DESCRIPTION ('ViewDefinition [CoordinationView_V2.0]', '2:1');
23 FILE_NAME ('Project Number', '2020-03-12T03:22:36', (''), (''), 'The EXPRESS Dat
24 FILE_SCHEMA ('IFC2X3');
25 ENDDOC;
26
27 DATA;
28 #1= IFCORGANIZATION ($, 'Autodesk Revit 2019 (ENU)', '0.0.0');
29 #5= IFCAPPLICATION ($1, '2019', 'Autodesk Revit 2019 (ENU)', 'Revit');
30 #6= IFCARTESIANPOINT ((0., 0., 0.));
31 #9= IFCARTESIANPOINT ((0., 0., 0.));
32 #11= IFCDIRECTION ((1., 0., 0.));
33 #13= IFCDIRECTION ((-1., 0., 0.));
34 #15= IFCDIRECTION ((0., 1., 0.));
35 #17= IFCDIRECTION ((0., -1., 0.));
36 #19= IFCDIRECTION ((0., 0., 1.));
37 #21= IFCDIRECTION ((0., 0., -1.));
    
```

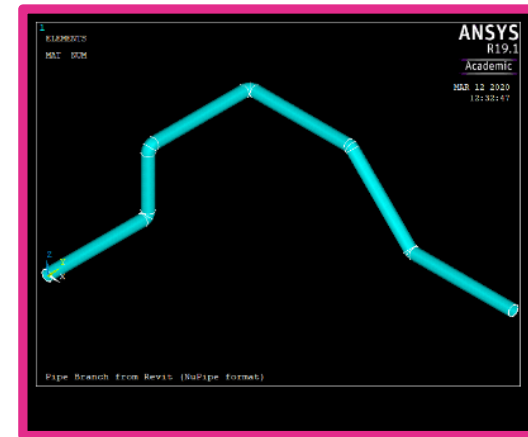
IFC File



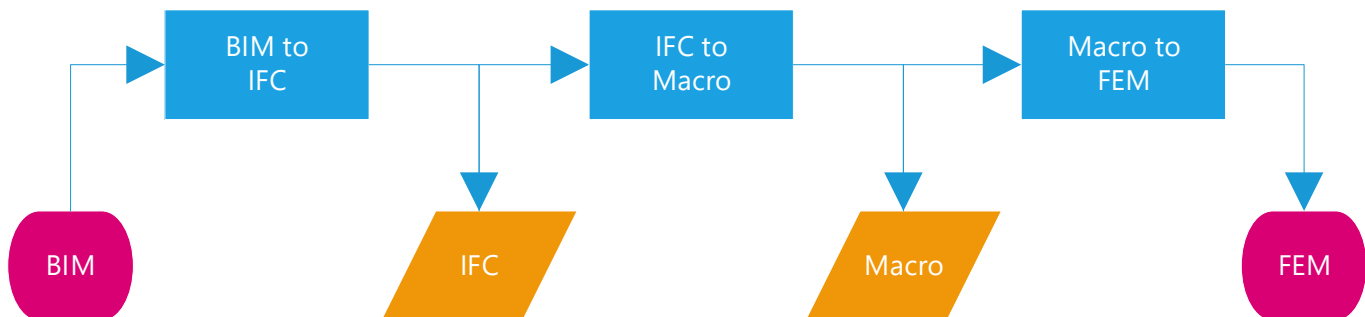
```

1 /clear
2 /title, Pipe Branch from Revit (RUpipe format)
3 /UNITS= IN,FE
4 /ENTER PRE-PROCESSOR
5 /PROP7
6
7 /*****
8 * Define Element Type
9 /define Element Type
10 et,1,pipe16
11 et,2,pipe18
12
13 /*****
14 * Define Material Properties
15 mp,ex,1,30E6
16
17 /*****
18 * Define Real Properties
19 /define Real Properties
20 ID = (6+I)/12
21 ID = (5+95/128)/12
22 TX = (OD-ID)/2
23
24 /*****
25 * Assign Real properties to Elements
26 /assign Real properties, MAT, DCON, RPROP, CO, TX
27 /PSECT
28 ,1 , , , , CO, TX
29
30 /*****
31 * Generate Pipe Model
32 RSMON,1,0,0,0,0,0,0
33 RSM,0,0, 5.000000000000007, 0,0
34 RSM,0,0, 0.0, 3.000000000000005
35 RSM,, ,0.276041666666667, 0
36 RSM,0,0, 4.899999999999986, 0,0
37 RSM,, ,0.276041666666667, 0
38 RSM,5.000000000000007, 0,0, 0,0
39 RSM,, ,0.276041666666667, 0,0
40 RSM,2.899999999999982, 0,0, -3.000000000000024
41 RSM,, ,0.276041666666667, 0,0
42 RSM,4.899999999999977, 0,0, 0,0
43 RSM,, ,0.276041666666667, 0,0
    
```

FEM Macro



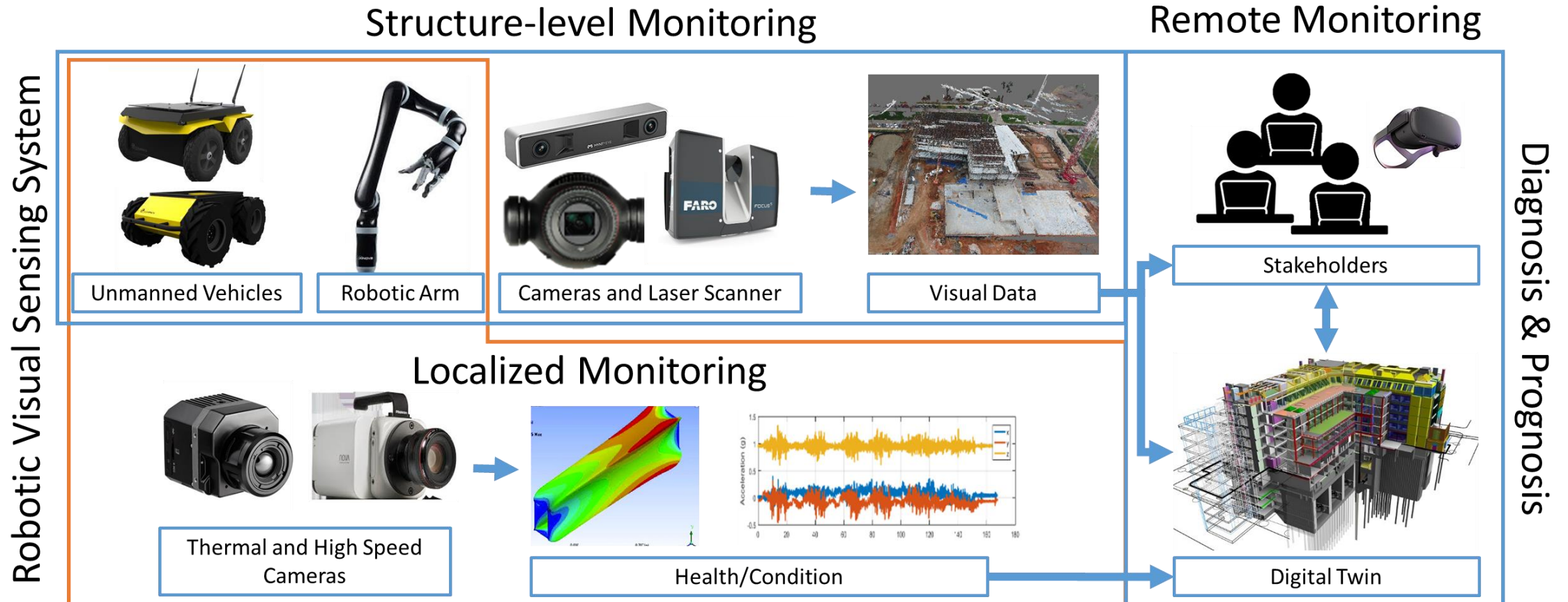
FEM: ANSYS Piping



- From BIM model to FEM analysis
- Completely automated file conversion and model generation

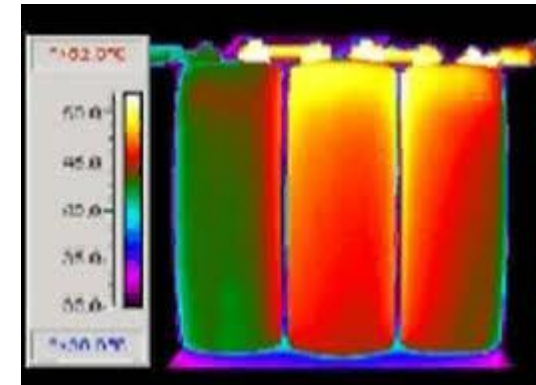
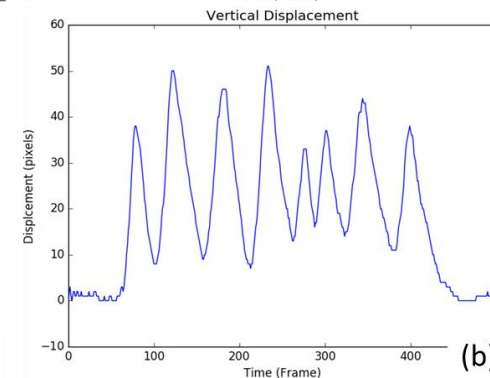
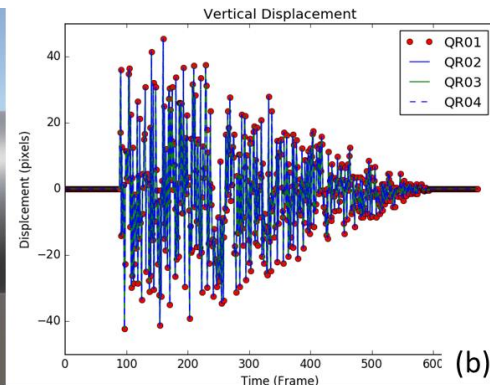
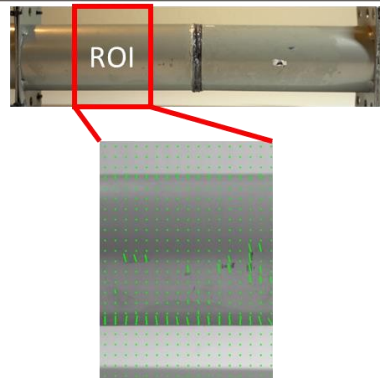
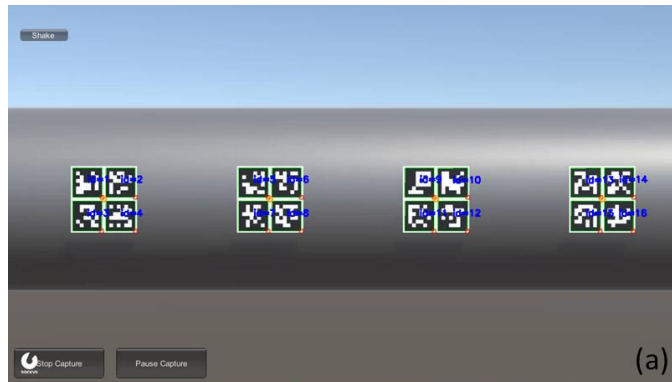
Visual Sensing Integration with Digital Twins

- Continuous monitoring during transportation using multi-sensory system & integration with “Construction” and “Design” models through DT



Continuous Monitoring during Transportation

- Target-based (and also target-less for less accuracy) sensing for vibration
- Automated object recognition to detect any movement
 - Integrated sensing system (high-speed and thermal cameras and accelerometers)



<https://www.nrel.gov/docs/fy16osti/66960.pdf>

Questions