

# The Pathway to Complete Digital Twins in Construction: Where Are We Now and Where Are We Going?

Robert Cox, Ph.D.  
Associate Director and Associate Professor

Energy Production & Infrastructure Center (EPIC)  
UNC Charlotte





## Agenda

- Defining a Digital Twin
- Beginning the Digital Twin journey
- Example use cases for tolerance management
- Future directions



## EPIC Digital Engineering Efforts – Advanced Construction

### Characterized by:

- All digital design
- Automated component production by supply chain
- Repeatable component dimensions
- Reliable assembly by OEM
- Cost competitive
- High production rates
- Achieved in a regulated environment designed for safety



# NRIC

National Reactor  
Innovation Center

### Characterized by:

- Single design (no two airports alike)
- Local fabrication
- No complete digital design
- Diminishing supply chain

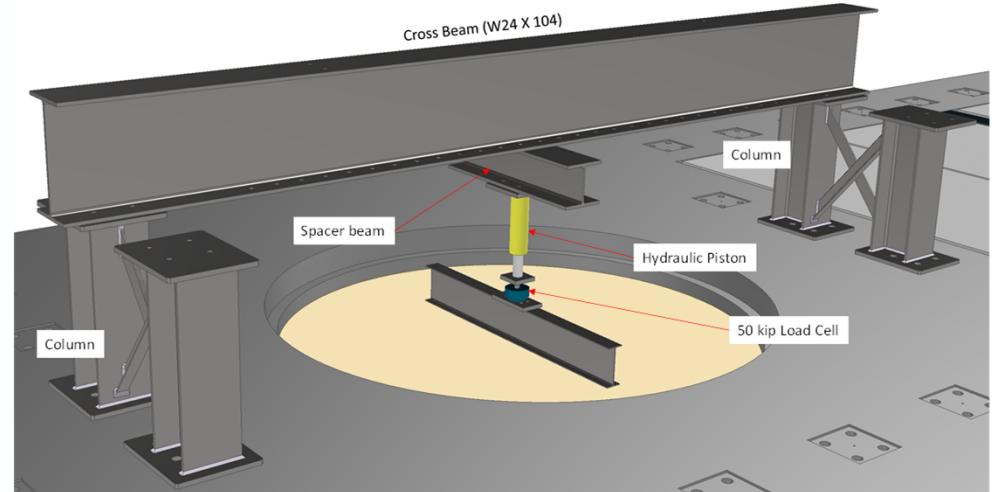




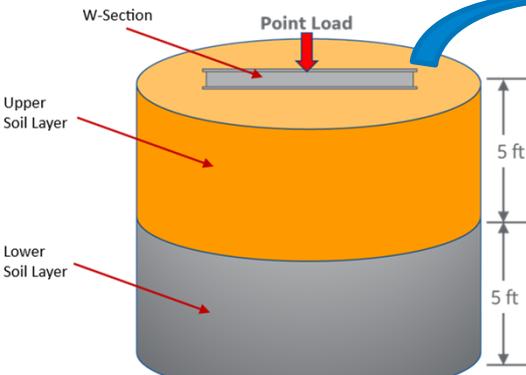
# What Constitutes a Digital Twin?



*Is this a “Twin”?*



### Soil Conditions Modeled

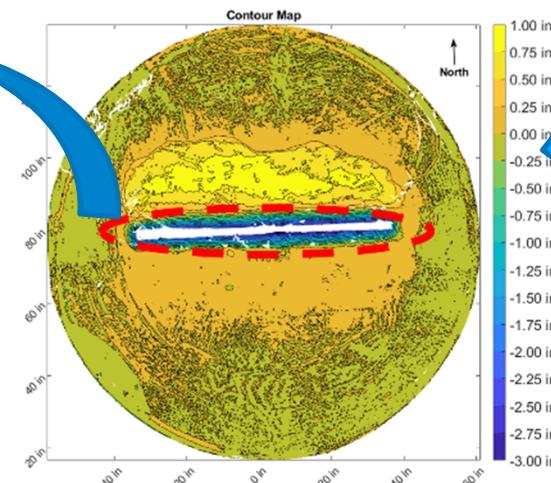
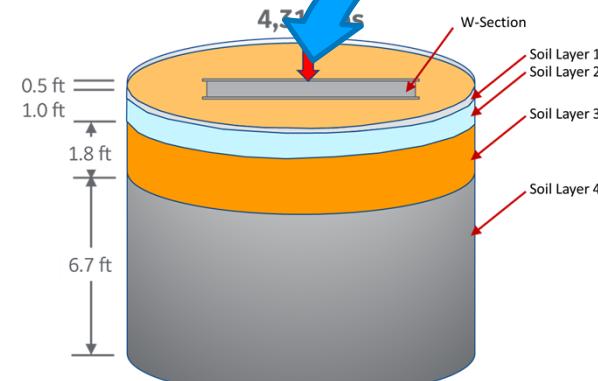
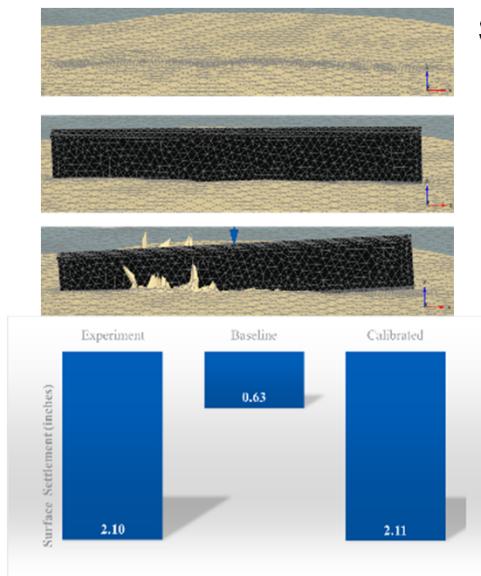


### System Loaded in The Lab



Model & Predictions Don't Agree!

### Soil Model Updated

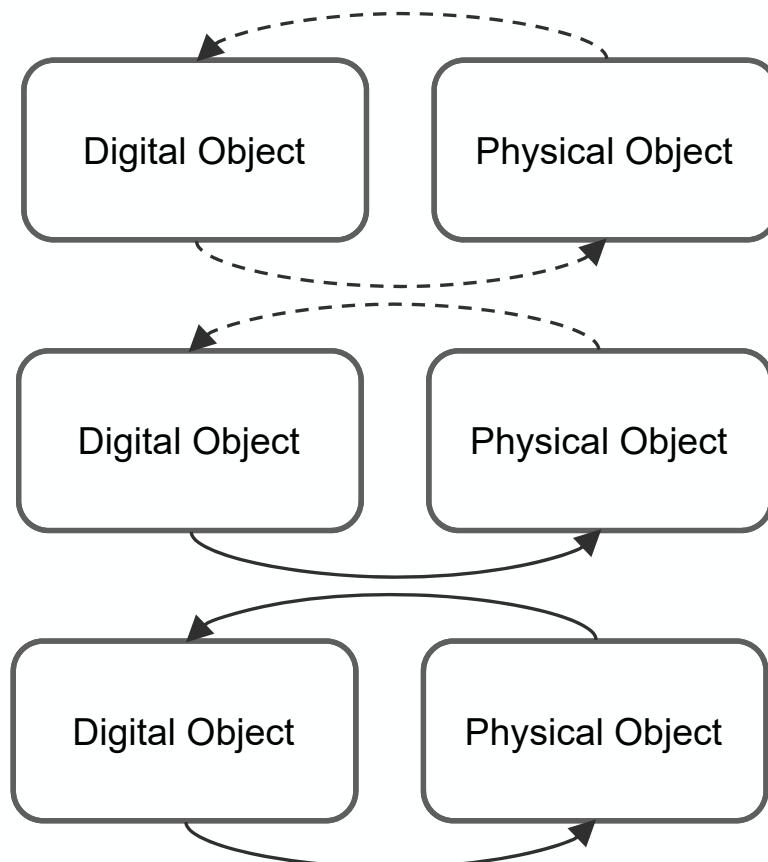


Settlement Measured

***Is this calibrated model a “Twin”?***



## Progressing from Models to Twins



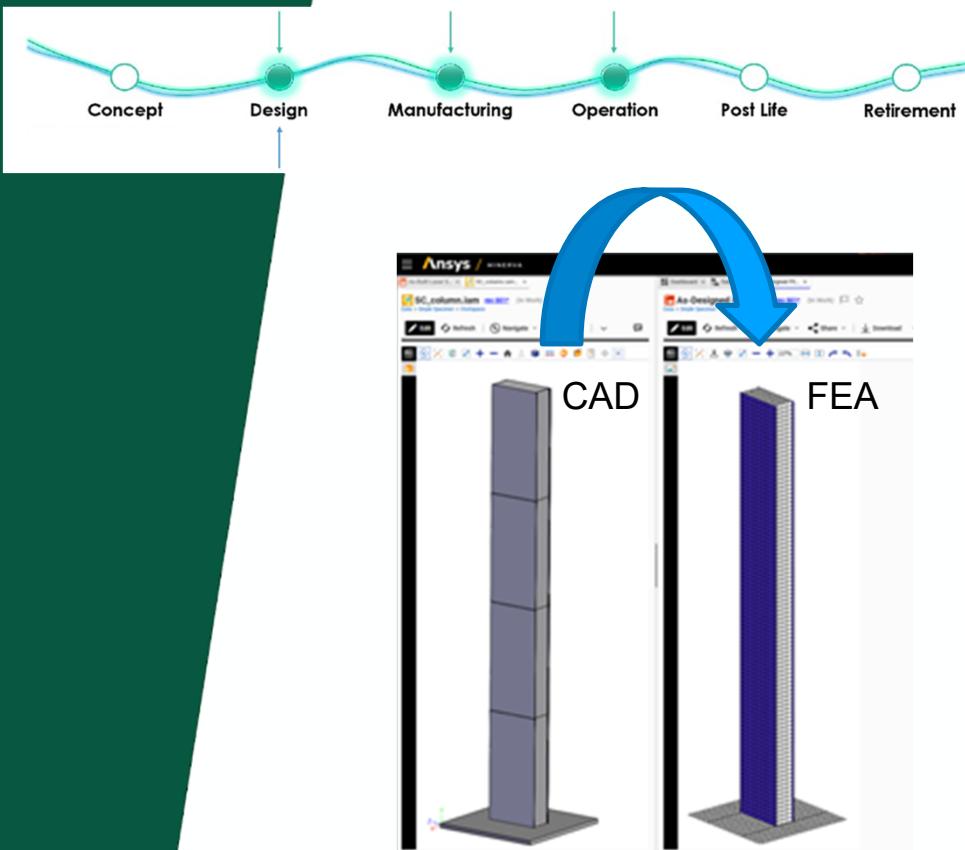
***Digital Models***

***Digital Shadows***

***Digital Twins***



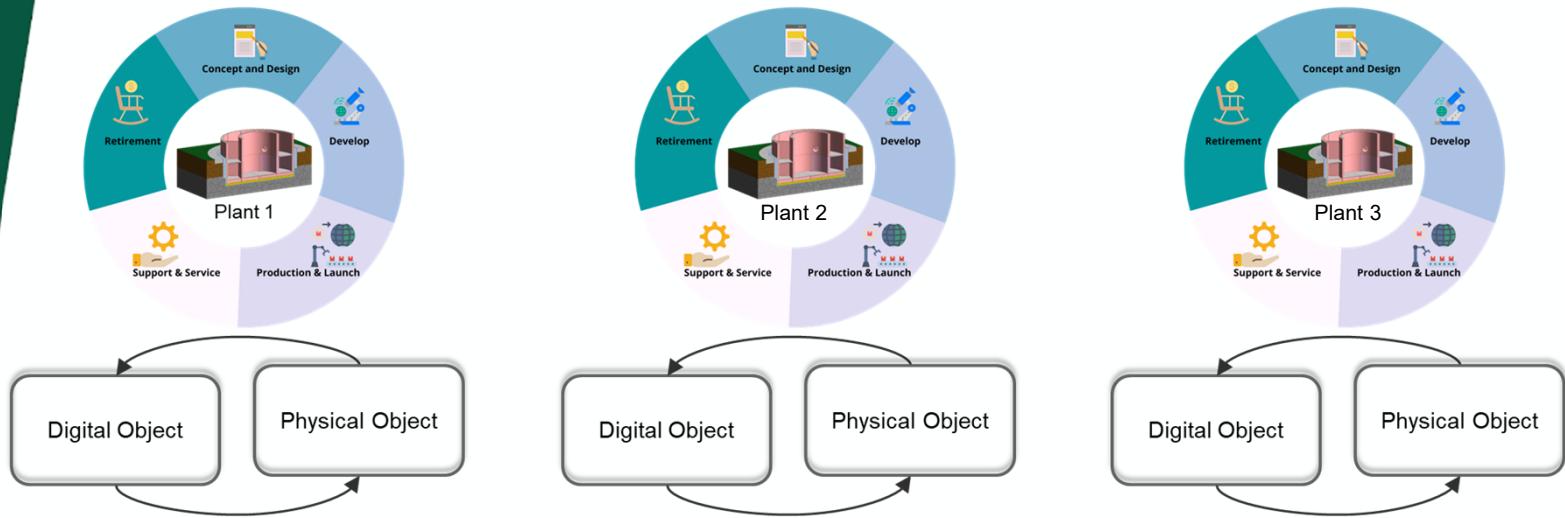
## Advancing PLM Using Digital Thread



- Adopt a ***model-based systems engineering (MBSE)***
- Two key steps:
  - Data untethers from documents
  - Models link to each other using a common framework
- Linkage occurs throughout lifetime
- Example:
  - Steel Composite Structure



# Digital Twin Utilizes PLM For Each Individual System

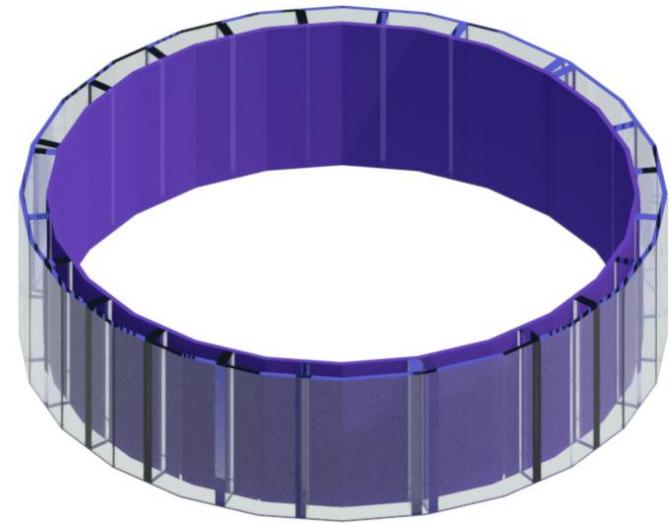


- ***Physical system and digital system are so closely connected, they adapt together***
- ***PLM is used for each individual instance, not general product families***



## Lessons Learned & Emerging Opportunities

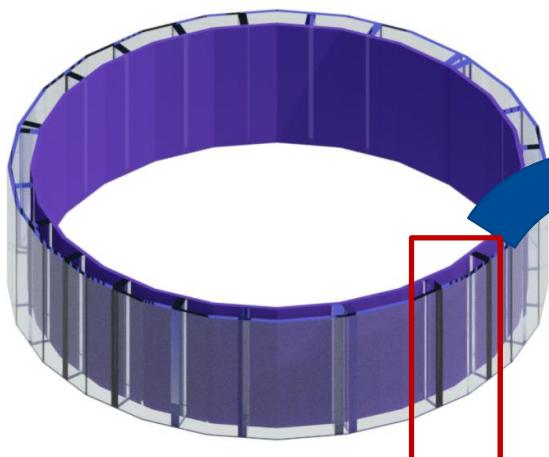
- Outdated design processes
- Managing documentation packages
- Fully exploiting the benefits of modularity
- Improved decision-making during construction



***Managing Tolerance as Modules are Placed***



# Dynamic Product Navigation Enabled By BIM



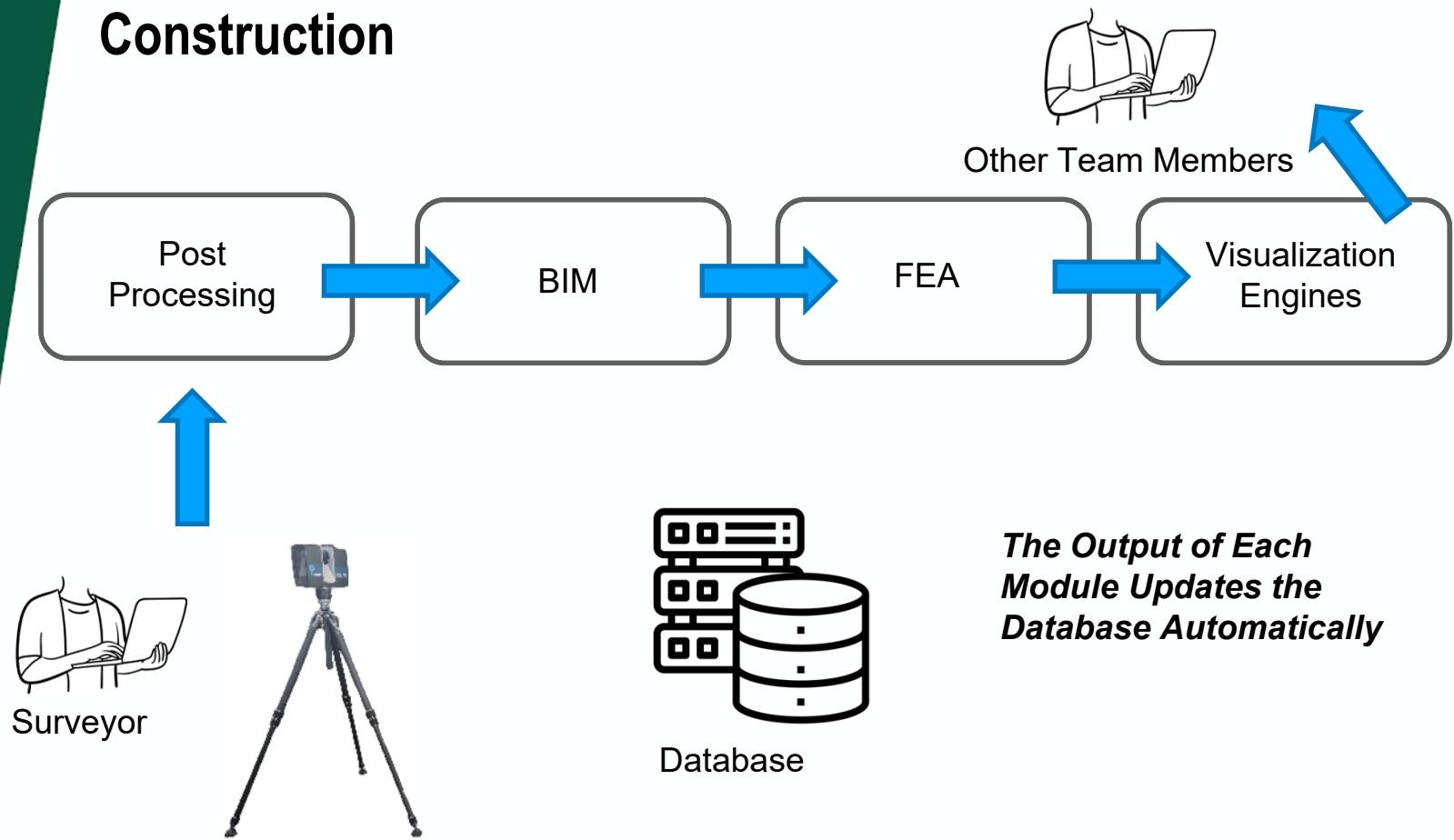
The screenshot shows a CAD document interface for 'Beam4941.stl' (rev A\*). The interface includes a navigation tree on the left with categories like 'Attachments', 'Engineering Mod', 'Fabrication Mod', 'Erection Mod', 'Casting Mod', and 'Test Mod'. The 'Attachments' tab is selected, showing a table of files:

Name	Rev	Branch	State	Date Modified	Modified By	Classification
Engineering Calcs	001	Default	Uncontrolled	2022-11-14 12:16:19	Ansys Admin	Folder
CAD	001	Default	Uncontrolled	2022-11-14 12:16:53	Ansys Admin	Folder
BOM	001	Default	Uncontrolled	2022-11-17 16:18:07	Ansys Admin	Folder
Material Reports	001	Default	Uncontrolled	2022-11-17 16:18:07	Ansys Admin	Folder
IFC	001	Default	Uncontrolled	2022-11-17 16:18:07	Ansys Admin	Folder

Users can drill down on available data as desired

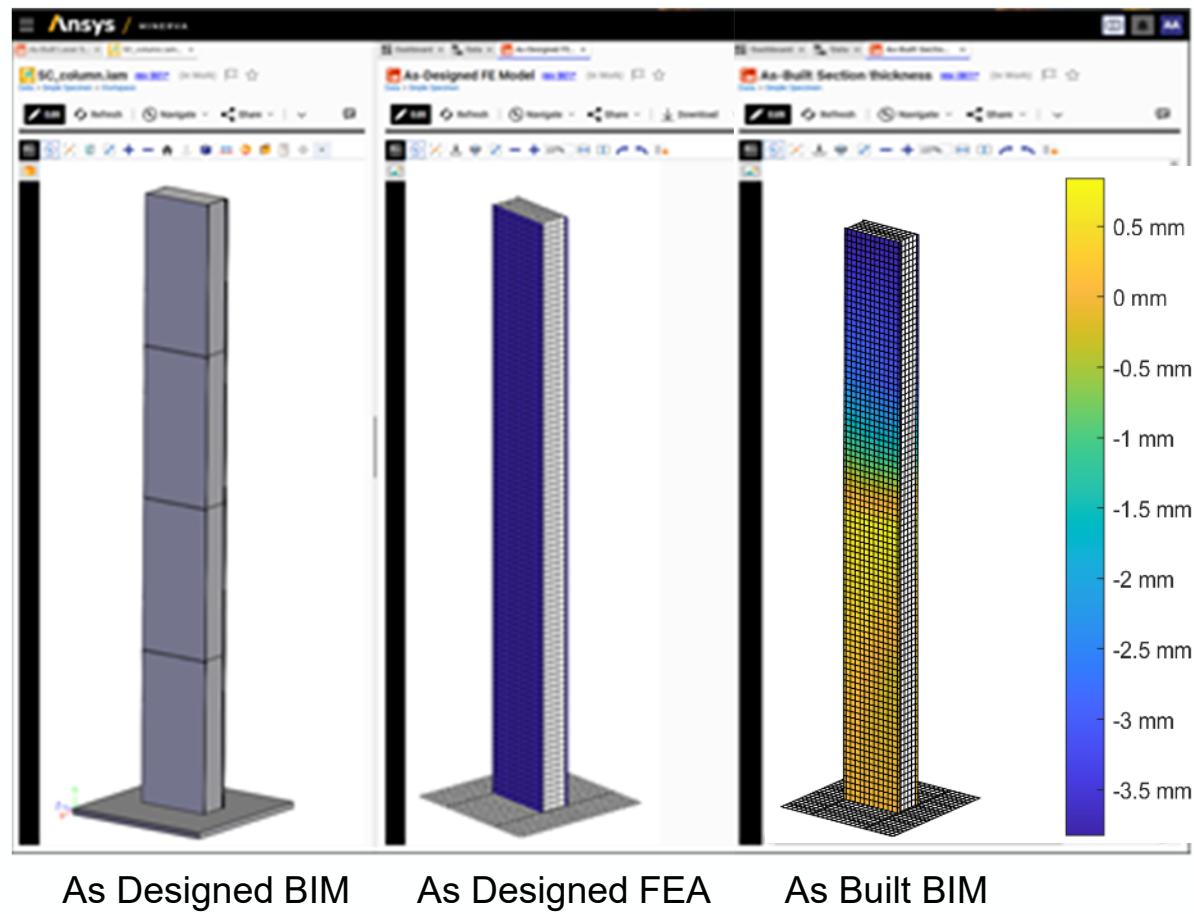


## Example Benefit of the Single Source of Truth in Construction



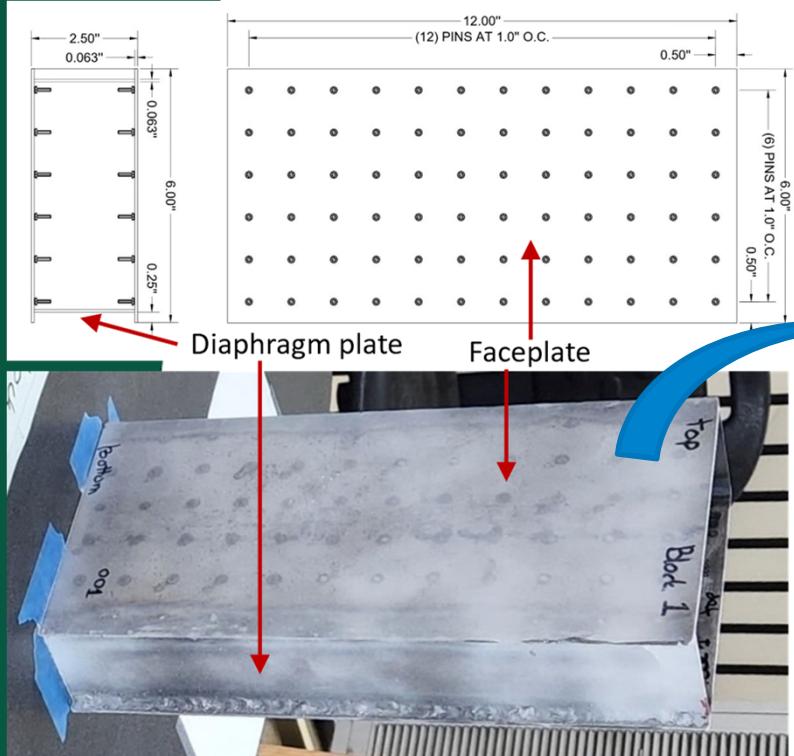


## Towards a Single-Source of Truth





# Using a Single-Source of Truth

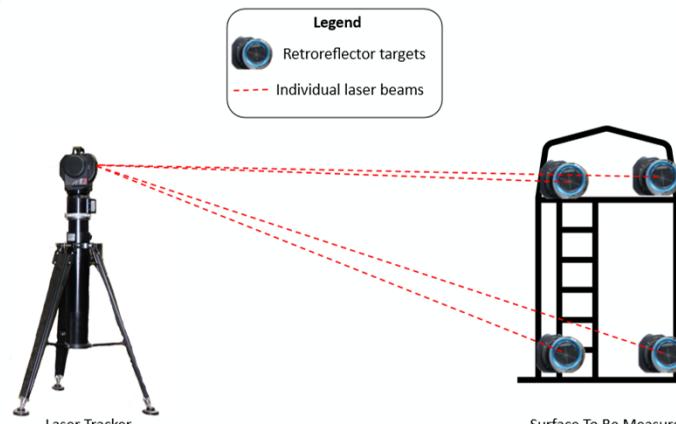


A screenshot of a software interface showing a table of data items. The table has columns for Name, Label, Data Type, and Data Source. A blue arrow points from the 'Faceplate' callout in the image above to the 'a\_length' row in the table, which is highlighted with a red border. The table data is as follows:

Name ↗	Label	Data Type	Data Source [...]
a_a	a	Float	
a_c	c	Float	
a_cad	CAD	Item	<a href="#">CAD</a>
a_crosssectional...	Cross Sec. Area	Float	
a_d	d	Float	
a_e	e	Float	
a_grossarea	Gross Area	Float	
a_grosssurfacear...	Gross Surf Area	Float	
a_grossvolume	Gross Volume	Float	
a_grossweight	Gross Weight	Float	
a_id	ID	String	
a_intermittent	Intermittent	Boolean	
a_isexternal	Is External	Boolean	
a_l	l	Float	
<b>a_length</b>	<b>Length</b>	<b>Float</b>	
a_loadbearing	Load Bearing	Boolean	
a_material	Material	Text	
a_matrix	Matrix	String	
a_n	n	Float	
a_netarea	Net Area	Float	
a_netsurfacearea	Net Surf Area	Float	

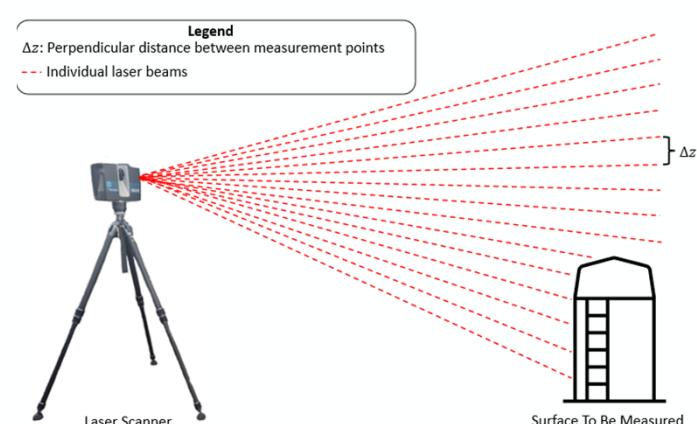


# Today's Technologies: Scans & Tracking



A diagram illustrating a Laser Tracker setup. On the left, a 'Laser Tracker' is mounted on a tripod. Two red dashed lines represent 'Individual laser beams' originating from the tracker and hitting 'Retroreflector targets' attached to a 'Surface To Be Measured' object on the right. A legend in the top right corner identifies the 'Retroreflector targets' as a blue circle with a white center and the 'Individual laser beams' as red dashed lines.

- Tracks locations of individual points with high accuracy
- Low resolution
- Updates geometry quickly in the field

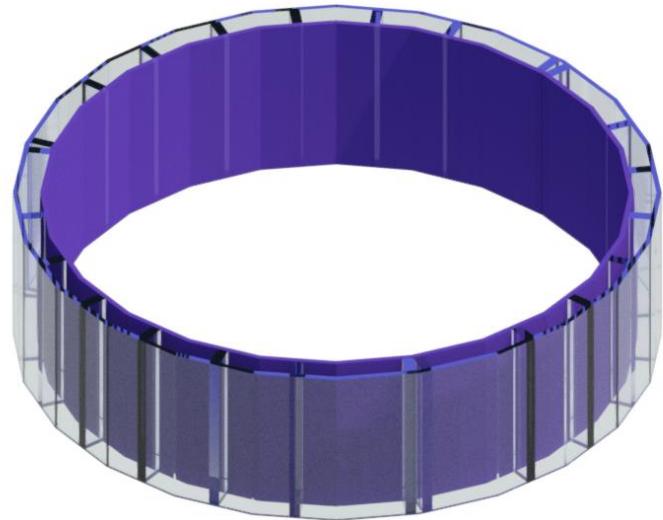


A diagram illustrating a Laser Scanner setup. On the left, a 'Laser Scanner' is mounted on a tripod. Multiple red dashed lines represent 'Individual laser beams' originating from the scanner and hitting 'Retroreflector targets' attached to a 'Surface To Be Measured' object on the right. A legend in the top right corner identifies the 'Individual laser beams' as red dashed lines and the 'Perpendicular distance between measurement points' as  $\Delta z$ .

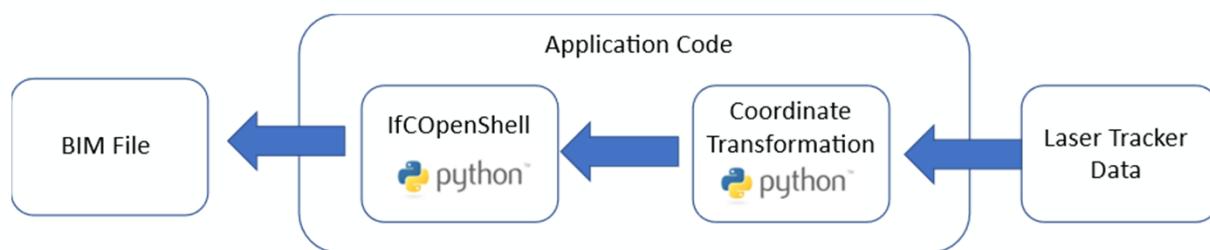
- Creates dense point cloud to profile the surface contour of an object
- High resolution
- High processing time
- Often requires manual intervention



## Laboratory Example: Tolerance Management

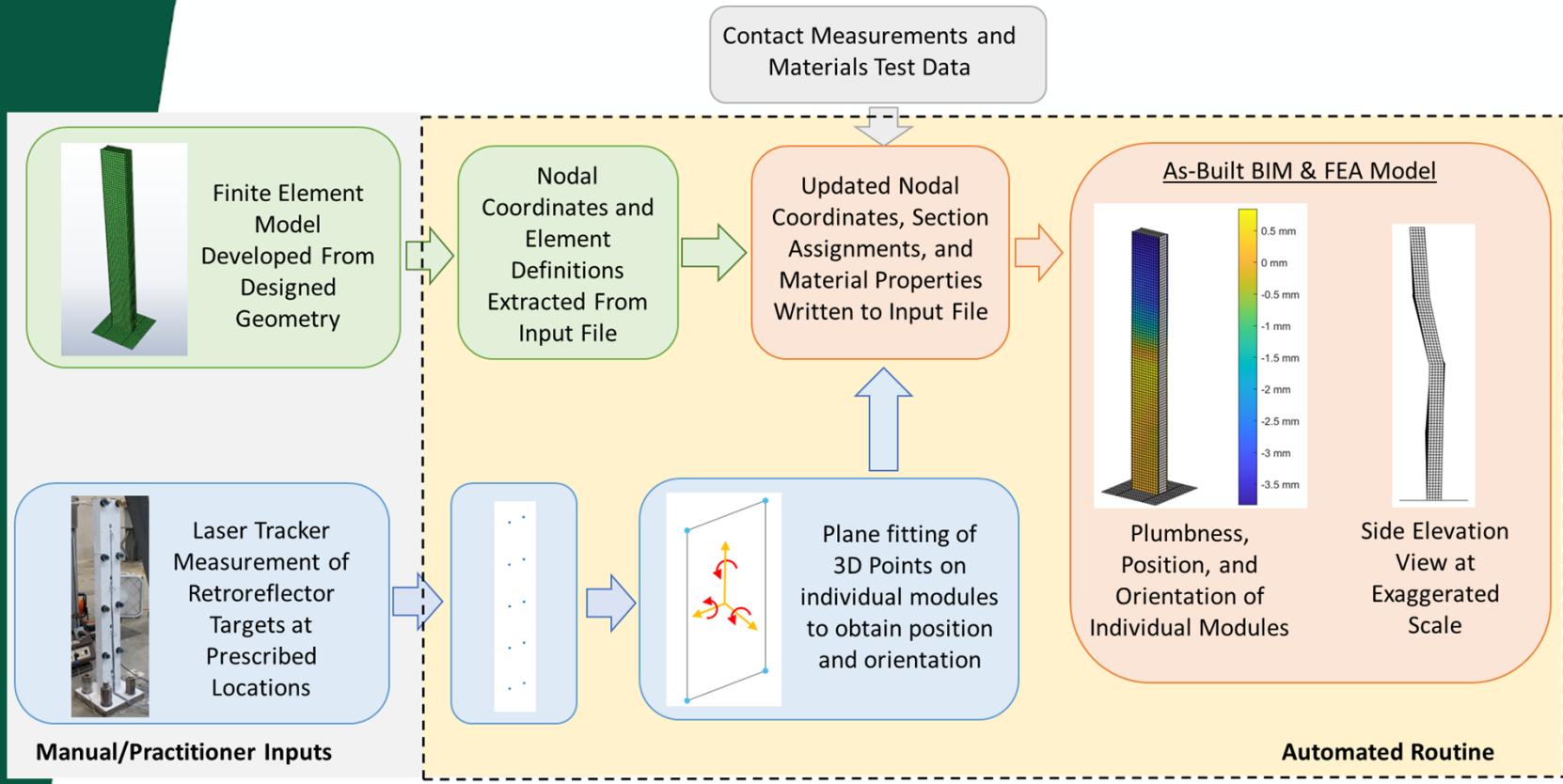


***Managing Tolerance as  
Modules are Placed***



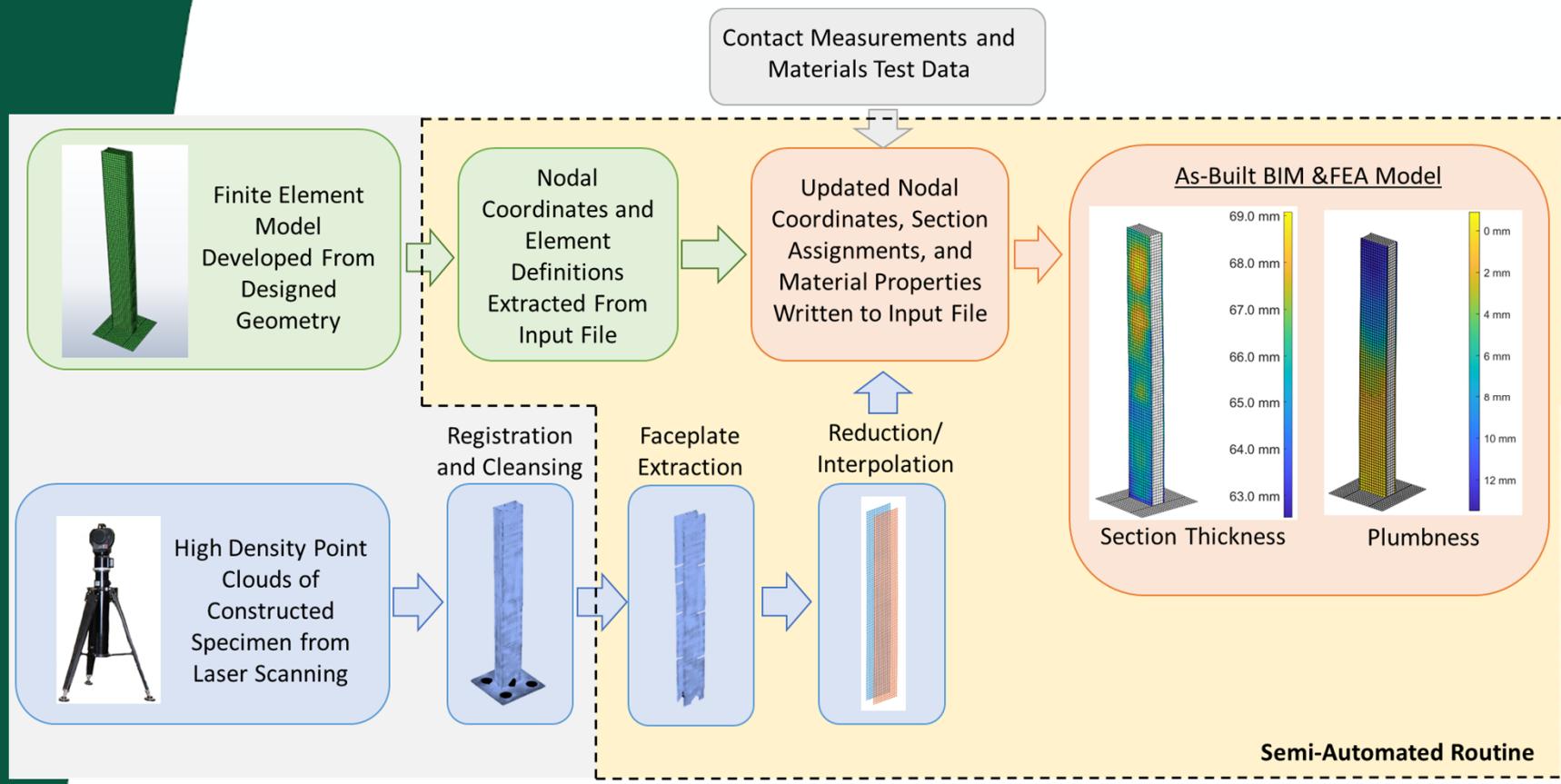


# Automated Model Updating Via Laser Tracker



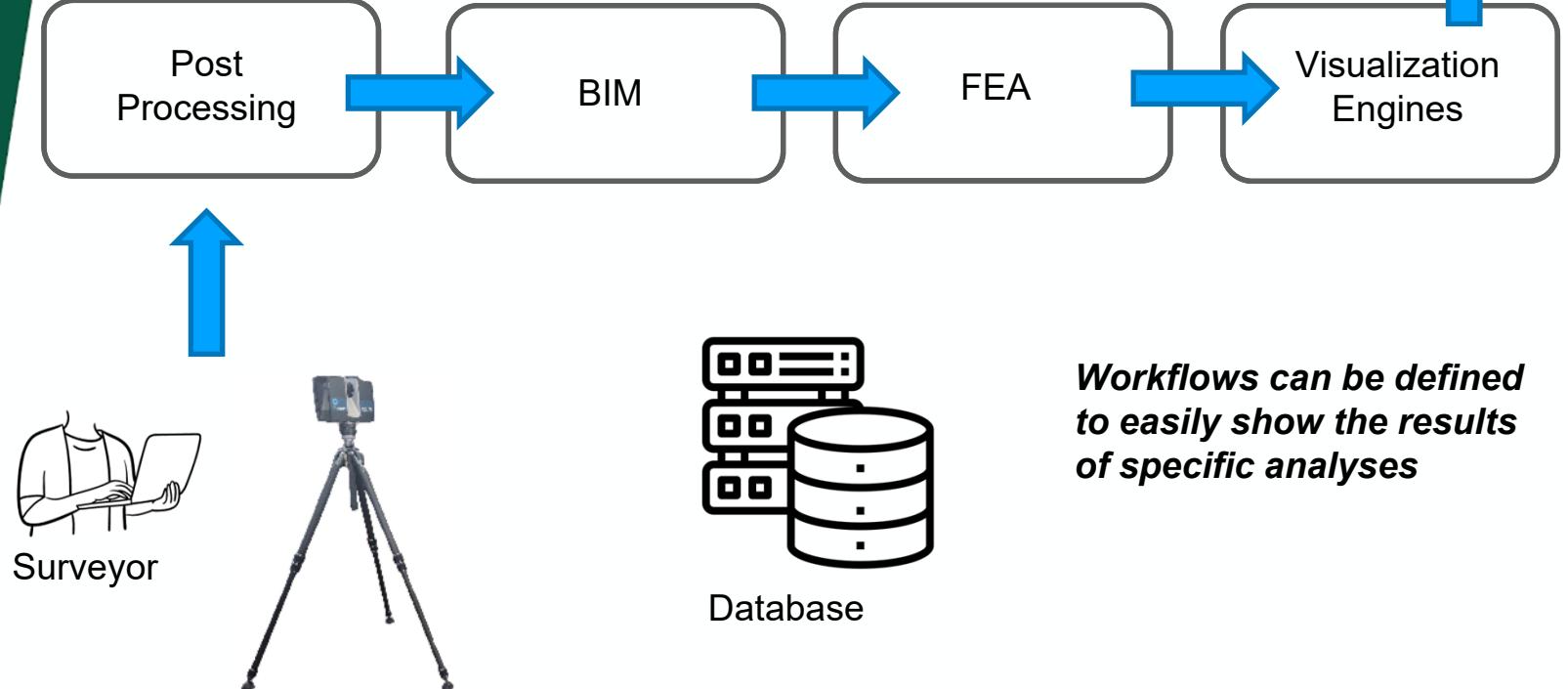


# Semi-Automated Model Updating Via Laser Scan





# Regulatory Interface?





## Gaps to Address

- Behavioral challenges in the industry – trust in data
- ***Rapid*** feature extraction and cleansing of laser scans and approaches for seamless integration with construction
- Better understanding of how to fully exploit modularity

# The Pathway to Complete Digital Twins in Construction: Where Are We Now and Where Are We Going?

Robert Cox, Ph.D.  
Associate Director and Associate Professor

Energy Production & Infrastructure Center (EPIC)  
UNC Charlotte

