BIM-based Integration of Virtual and Physical Building Components

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Preamble

- Penn State:
  - Over 82,000 students on 24 'Commonwealth' campuses across PA
  - Main campus is University Park with about 45,000 students
  - University Park is located in Central PA (3-4hrs from Philadelphia, Washington DC, New York, Pittsburgh, Cleveland, etc.)
- Architectural Engineering:
  - One of 12 Depts/Programs in College of Engineering
  - About 500 students (400 UG and 100 PG)
  - About 25 faculty (7 of whom are adjunct)
  - Department was 100 years in 2010 !!!
- Degree Programmes:
  - 5 year B.A.E
  - Integrated B.A.E./M.A.E + Integrated B.A.E./M.S.
  - M.S., M.Eng., Ph.D. in Architectural Engineering

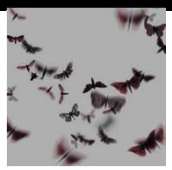
AE Dept.'s Latest Claim to Fame:

$129m Energy Efficient Buildings Research Grant

Outline

- Introduction
- BIM @ Penn State
- Previous Integration Efforts
- The Cyber-Physical Systems Approach
- Enabling Technologies
- System Architecture
- Triggers for Bi-directional Coordination
- Deployment Scenarios
- Conclusions

Definitions



- What is BIM?
  - Butterflies in Motion?
  - Building Information Management?
  - Building Information Modelling?
- Building Information Modelling:
  - 'a modeling technology and associated set of processes to produce, communicate and analyze building models'
    - Eastman et al, 2007
  - 'a digital representation of physical and functional characteristics of a facility…'
    - NBIMS, 2009

Professor Gifford Albright
July, 1968

Early BIM Pioneer?

MODCON:
Man-Machine System for the Optimum Design and Construction of Buildings

Vision (1961):
'a computer operation with both verbal and graphic printout that will allow an architect, engineer and others to sit down together and quickly conceive, design and specify a building on the basis of total performance criteria'

BIM Education at Penn State

- Students use AutoCAD in 1st year drawing course
- Revit now used in 2nd and 3rd years for building modelling
- Integrated BIM Studio in 4th year links AE students (construction, lighting/electrical, mechanical & structural options) with architecture and landscape architecture students.
- BIM/IPD Thesis - an option in 5th year capstone project

BIM/IPD Thesis

- 3 Student Groups of 4 – one from each option
- Projects: NY Times Building, Millennium Science Complex (PSU), Ice Hockey Arena (PSU)
- Replicates real world experience
- Students' collaboration skills and technical knowledge (depth and breadth) greatly enhanced
- Final presentations to large industry jury…
- Penn State has won 4 national awards: AIA (x2), NCARB, Autodesk

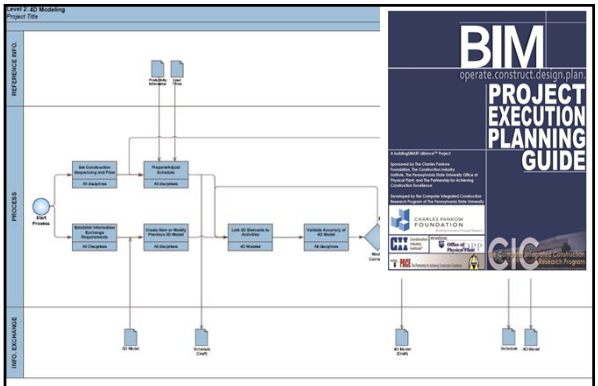
Immersive Construction (ICon) Lab at Penn State

INTEGRATING BIM INTO ACADEMIA … INTEGRATING ACADEMIA WITH BIM

BIM

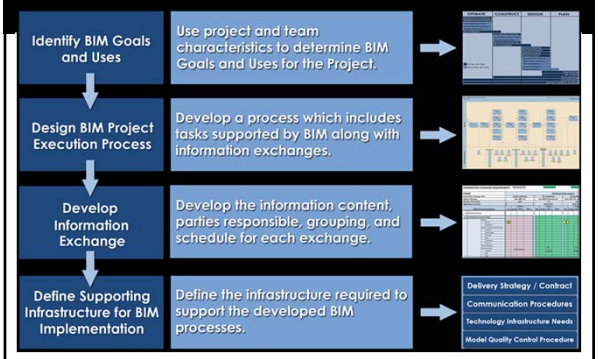
Architecture	Landscape Architecture	Mechanical, Structural, Lighting/Electrical Engineering	Construction Engineering

BIM Implementation Guides
(www.bim.psu.edu)



Project Execution Planning
(www.bim.psu.edu)

BIM Project Execution Planning Procedure



BIM for Owners Guide

- Maximize benefits of BIM to owners
- Link BIM to operation/FM
- Huge potential for lifecycle asset management

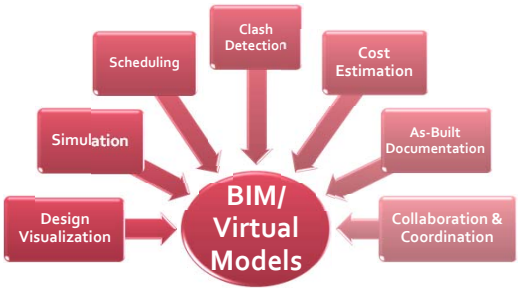
BIM Planning Procedures

Additional Information at **bim.psu.edu**

Research Example

Integration of Physical and Virtual Building Components

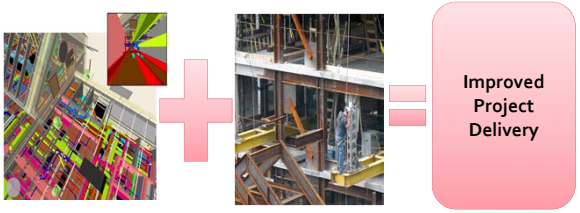
Potential of BIM/Virtual Models



Physical Construction

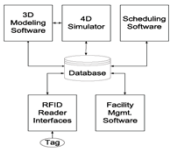
- Physical Construction
  - Components to be tracked
  - Activities to be monitored
  - Processes to be controlled
  - Systems to be manipulated
  - All these need information from the virtual model.

Integration of BIM/Virtual Models with the Physical Construction

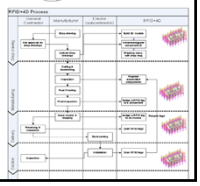


Previous Integration Efforts

- BIM and Building Components
  - RFID tags
  - (Hammad and Motamedi, 2009)

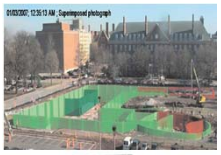


- 4D CAD and Steel Components
  - RFID tags
  - (Chin et al, 2008)

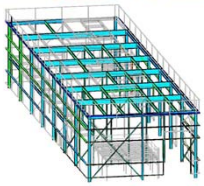


Previous Integration Efforts

- 4D CAD and Physical Construction
  - Digital camera
  - (Golparvar-Fard et al.,2009)

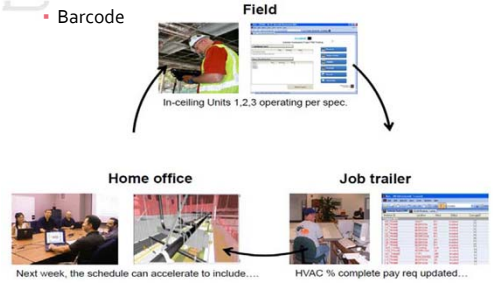


- 3D CAD and Physical Construction
  - 3D Laser scanner
  - (Boche et al., 2008)



Previous Integration Efforts

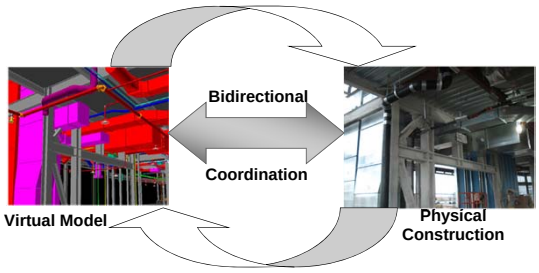
- Industry: Field BIM and Physical Construction
  - Barcode



Need for Improvement

- Limited mechanisms for real-time bi-directional coordination between virtual models and the physical building components;
- Lost opportunity for the use of sensors and other embedded instrumentation to track and control the construction process/constructed facility.

Cyber-Physical Systems Approach



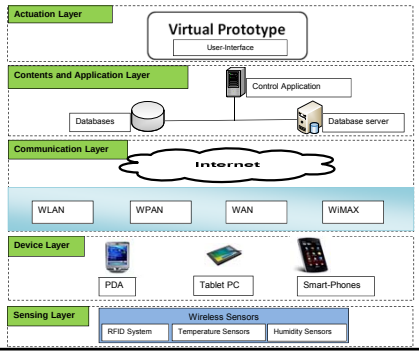
Support for CPS Requirements

Cyber-Physical System Integration Requirements	Previous Approaches			
	RFID + VM	Photography + VM	Laser Scan +VM	Photogram. + VM
Communicate design information	L	L	L	L
Capture and document as-built information	M	L	M	L
Track construction progress	M	M	M	M
Control building components in the constructed facility	L	L	L	L

Enabling Technologies

- Virtual models
- Wireless sensors and RTLS/RFID tags
- Cameras
- 3D Laser scanners
- Mobile devices (tablet PC, PDA)
- Mobile communications networks

System Architecture

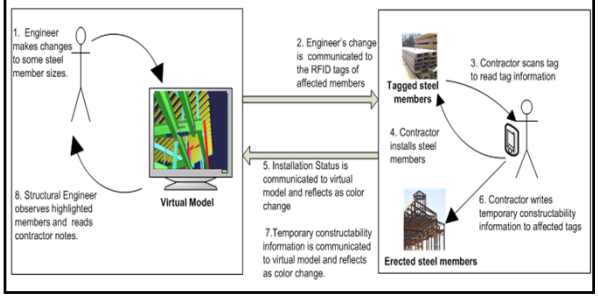


Triggers for Bi-directional Coordination

- Design Changes
- Capture and document construction changes and as-built information
- Track construction progress
- Temporal conditions required for constructability
- Control components and sub-systems

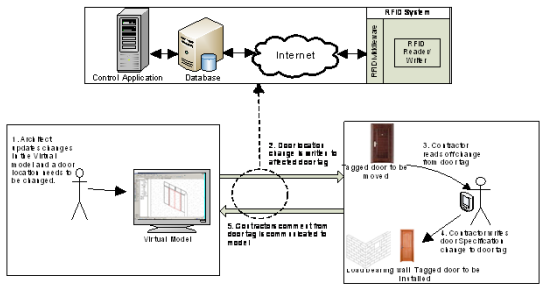
Deployment Scenario - 1

- Steel Placement



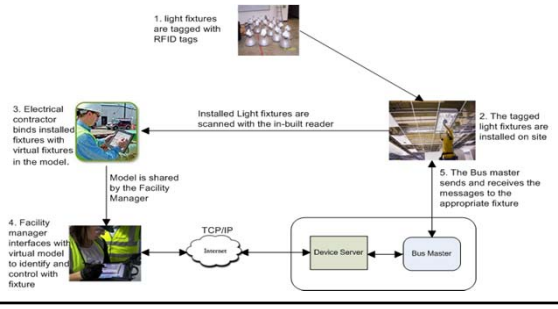
Deployment Scenario - 2

- Changes on Retrofit Site



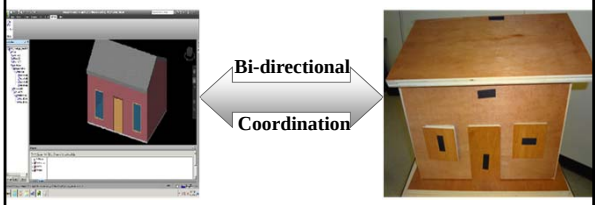
Deployment Scenarios

- Light Fixture Tracking and Control



Experimental Approach

- Bi-directional coordination

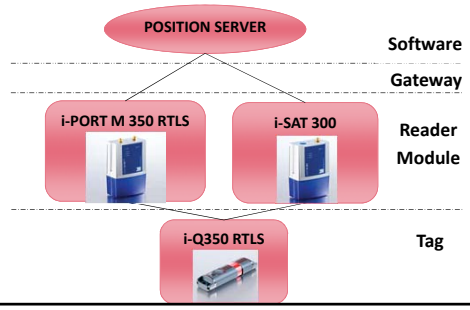


Virtual Model

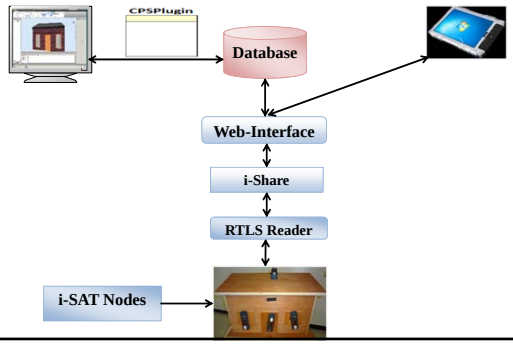
Detachable Physical Components

Key Enabling Technology

- Real-time location sensing system (RTLS)

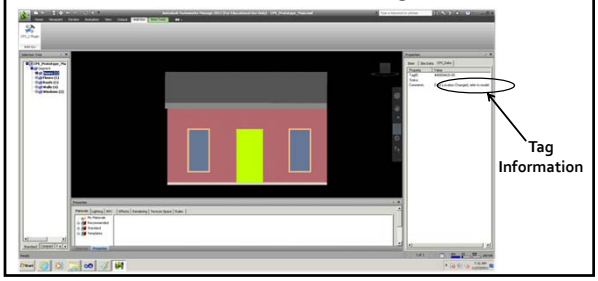


Overview of Prototype System



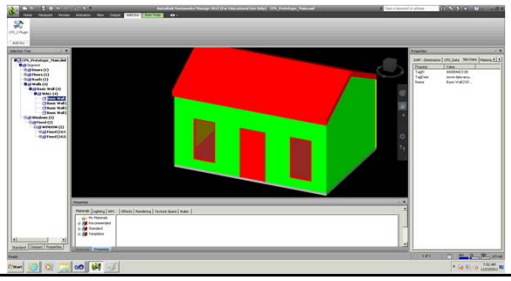
Results

- Element highlighted and property updated with information from RTLS tag



Results

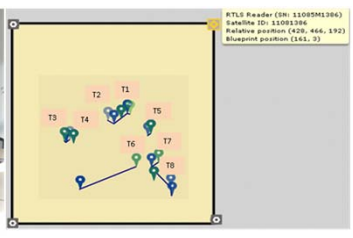
- Door and Roof element status changed to 'uninstalled' (red)



Results

- Indoor test

Indoor site

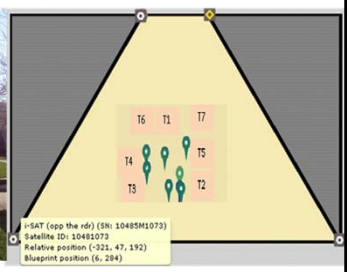


Indoor site blueprint

Results

- Outdoor test

Outdoor site



Outdoor site blueprint

Wider Implications

- Real-time information exchange between site and design office
- Reduction of construction risks as activities and processes can be more closely monitored and controlled
- Accurate as-built models useful for:
  - Facility operation and management
  - Deconstruction/decommissioning
- Improved opportunities for sustainable construction practices through:
  - Minimizing delays and waste on site
  - Energy Management
- Etc.

Conclusions

- Real-time bi-directional coordination b/w virtual models and physical components needed
- Current mechanisms offer limited support for CPS (Cyber-Physical Systems)
- Approach presented here addresses this
- Laboratory and field test results positive…
- Many potential benefits in construction process tracking and active component control

Thank You!

Questions