Virtual Construction: VR-Enabled Project Delivery
CII Research Team TC-02

Stephen Mulva, CII
Dan Gibson, Black & Veatch
Max Eklund, Fluor

Theme:
Win Together to Share Success NOW!

Year: 2019
Date: Aug. 28-31
Location: The Broadmoor
Colorado Springs, CO
Overview of CII

**History**
- Founded in 1983 by 28 organizations; now 145
- Organized Research Unit (ORU) of the Cockrell School of Engineering (CSE) at the University of Texas at Austin (UT)
- First structured owner-contractor-academic research collaboration for the constructed project
- Merged Fiatech (technology group) into CII in January 2018

**Strategy: Increase Impact and Reach**
- Amplify the scale of financial returns emanating from capital projects and lifecycle management
- Catalyze our industry with inventive business processes, organizational structures, and technological developments
- Expand CII’s global reach
- Expand industry sector representation
CII Strategic Initiatives

- **Funded Studies**
  - AI for Advanced Work Packaging
  - Integrated, Collaborative Delivery
  - Workforce 2030

- **Membership & Comms**
  - C-Suite Engagement
  - Membership Campaign

- **Technology**
  - Digital Structured Project Delivery
  - Technology Path to the Future

- **Deployment**
  - DP1 (Project Assurance)
  - NextGen Benchmarking

- **Sectors**
  - Key Business Objectives

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Virtual Construction: VR-Enabled Project Delivery
The Jetsons (1962-1963)

Flying Cars

Video Calls

Wearables

Flat Screens

Jet Packs

Wireless Endoscopic Robots

Internet Learning
CII Technology Path to the Future

Technology that exists

Academia & Science

Industry & Engineering

Technology that we can imagine but does not exist
Digital Delivery

- CII Technology Committee Strategic Initiatives
  - Technology Path to the Future
  - Digital Structured Project Delivery

Source: McDermott
A digital rendering of Pemex’s PB-Litoral
A production platform in the Bay of Campeche
Welcome to the Future!

Let’s invest now – building VR into SOPs

Empower workforce

Attract, train, and retain next gen workforce
What Will You Learn Today?

- Performance Measurements
- Implementation Guidance
- Cost-Benefit Analysis
- Virtual and Mixed-Reality Demos
Vision for the Future
Stephen Mulva, CII

Virtual Construction: VR-Enabled Project Delivery
What is the future of VR in construction?

- Collaborative Communication / Design & Issue Resolution
- Modify and Manipulate Model Data in VR
- Safety Planning & Site Logistics
- Schedule Optimization & Progress Monitoring
Research Development
Stephen Mulva, CII

Virtual Construction: VR-Enabled Project Delivery
Research Team TC-02

THE UNIVERSITY OF TEXAS AT AUSTIN

- Principal Investigator: Dr. Fernanda Leite
- Graduate Student: Bing Han

INDUSTRY TEAM MEMBERS

- Chair: Predrag Jokovic, Hatch
- Dan Gibson, Black & Veatch
- Peter Robar, Fluor Corporation
- Todd Sutton, Zachry Corp
- Dave Tyner, Autodesk, Inc.
Summary of Results

**IMPROVEMENTS IN DESIGN AND WORK PACKAGING REVIEW TASKS**

**IMPLEMENTATION GUIDEBOOK**

“WHAT’S THE ROI OF ONE LIFE?”

Virtual Reality Implementation Guide
for Construction Projects
Final Report TC-02

Virtual Construction: VR-Enabled Project Delivery
Existing VR Applications

ENTERTAINMENT

SERIOUS APPLICATIONS
VR in the Construction Industry

- Desktop-based VR
- Game engine-based VR
- Immersive VR
Immersive Virtual Reality (IVR)

DEFINITION
A computer-generated virtual simulation that is experienced through Head Mounted Displays (HMD) and other input/output devices.
Immersive Virtual Reality

KEY FEATURES
Block the real world, provides immersive experience in virtual world
Augmented Reality (AR)

Overlay virtual world on the real world based on software settings, e.g., location information.
Mixed Reality (MR)

KEY FEATURE
Overlay virtual world on the real world based on technology understanding of the real world
Immersive vs. Desktop-based Virtual Reality User Tests
Stephen Mulva, CII

Virtual Construction: VR-Enabled Project Delivery
Demo & User Test
User Test Participants

PARTICIPANTS’ INDUSTRY EXPERIENCE

Novices: 11 participants
- No industrial experience: 6
- Below 1 year: 2
- 1-3 years: 3

Experts: 12 participants
- 3 years+ industrial experience
User Test Results

Design Error Detected (Mean)

Significant Influence from Experience and Device
($P = 0.038, 0.002$ in Linear Regression Analysis)

- Novices: 2.40 (Desktop-based VR), 5.83 (Immersive VR)
- Experts: 5.00 (Desktop-based VR), 6.75 (Immersive VR)

Error example: support height not consistent with pipe spool height
User Test Results

Mistakes in Sequence (Mean)

Significant Influence from Device
(P = 0.012 in Linear Regression Analysis)

- Novices: 5.17 (Desktop-based VR), 6.30 (Immersive VR)
- Experts: 3.50 (Desktop-based VR), 6.63 (Immersive VR)
User Test Results

Recalled Items (Mean)

No Significant Influence from Experience or Device

- Novices: 15.80
- Experts: 13.50

Experts vs. Novices:
- Desktop-based VR: 17.80
- Immersive VR: 16.50

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Traditional Workflow

3D Models

Information

Feedback

Practitioners
Immersive VR-included Workflow

Model & Information Feedback → Immersive VR → Feedback

Visualization & Interaction

3D Models

Practitioners

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Key Factors for Implementation

- Selection of Implementation Scenario
- 3D Model Quality
- VR Model Functions
- User Experiences with VR
Immersion VR
Implementation Guide for the Construction Industry
Stephen Mulva, CII

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What do I do?

Implementation Guidebook for Immersive Virtual Reality

BUILD A PROGRAM PEOPLE WILL LOVE

IMPLEMENTATION GUIDEBOOK

- Planning
- Tools Selection
- Training
- Model Preparation
- Opportunities

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Strategy and Use Cases

Implementation Strategy and Use Cases

Hardware and Software Selection

Training of Users and Developers

3D Model Preparation for the Immersive VR Environment

Integration and Further Developments

Virtual Construction: VR-Enabled Project Delivery
Hardware and Software

Implementation Strategy and Use Cases

Hardware and Software Selection

Training of Users and Developers

3D Model Preparation for the Immersive VR Environment

Integration and Further Developments

Virtual Construction: VR-Enabled Project Delivery
Training Programs

Implementation Strategy and Use Cases

Hardware and Software Selection

Training of Users and Developers

3D Model Preparation for the Immersive VR Environment

Integration and Further Developments

Virtual Construction: VR-Enabled Project Delivery
Model Preparation

Implementation Strategy and Use Cases

Hardware and Software Selection

Training of Users and Developers

3D Model Preparation for the Immersive VR Environment

Integration and Further Developments

Virtual Construction: VR-Enabled Project Delivery
Future Developments

Implementation Strategy and Use Cases

Hardware and Software Selection

Training of Users and Developers

3D Model Preparation for the Immersive VR Environment

Integration and Future Developments
Black & Veatch
Pipe Routing App
Dan Gibson, Black & Veatch

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Mixed Reality – B&V Example

CONCEPT:
Develop a solution to reduce time
to collect non-model design data for SB-Pipe
and Conduit routing

*Design on the fly*
Mixed Reality – Benefits

- Provide simultaneous comparison
- Empower the workface to create
- Provide a quick turnaround solution
Fluor Safety Training Program
Max Eklund, Fluor
Fluor VR Safety Training - Fluor Life Critical Campaign

Life Critical focuses on the operations we execute that have the greatest potential for serious injury or fatality,

- Working at height
- Motorized heavy equipment
- Motor vehicle operation
- Material handling
- Confined space entry
- Cranes and rigging
- Trenching and excavations
- Electrical work
- Hazardous energy control / line breaking

Life Critical promotes our single most important goal - Protecting the lives of workers
Fluor VR Safety Training - Working at Height

1. Put on your HSE Equipment
   You start off with your gloves on and put on your hardhat, safety glasses and select a scenario.

2. Work At Height
   Working at height starts off up on a platform with an open area in the handrail for material delivery.

3. Tie off Lanyard
   Before you can start, you must tie off your lanyard.

4. Move tripping hazards
   Ensure that you move any tripping hazards before proceeding.

5. Falling objects
   Learn about falling objects and they impacts they can have.

6. Spot the hazard
   Take some time and spot hazards in the scene.
## Cost-Benefit Analysis

<table>
<thead>
<tr>
<th>Costs</th>
<th>Benefits</th>
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<tbody>
<tr>
<td>- Hardware</td>
<td>- &quot;What’s the ROI? One life&quot;</td>
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<tr>
<td>- Software Description</td>
<td>- Efficient Craft Coordination</td>
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<tr>
<td>- Software Implementation</td>
<td>- Increased Scope of Contract</td>
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<td>- Software Maintenance</td>
<td>- Reduced RFI's</td>
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<td>- Training Services</td>
<td>- Precise Progress Tracking</td>
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<td>- Content Curation</td>
<td>- Reduced Change Orders</td>
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<td>- Workspace</td>
<td>- Faster Project Delivery</td>
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<td>- Increased Product Quality</td>
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<td>- Match Commodity Trending</td>
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<td>- Reduced Rework</td>
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<td>- Faster Understanding on Design</td>
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<td>- Better Visualization for Reviewer</td>
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<td>- Reduced Travel Expenses</td>
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<td>- Improved Recall Rate</td>
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<td>- Fewer Personnel on Site</td>
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<td>- Longer Memory Retention</td>
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Virtual Construction: VR-Enabled Project Delivery
Key Lessons

- Hardware cost minimal; invest in people
- Be intentional when selecting use cases for VR/AR/MR
- Empower the workforce
Questions?

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