4D CAD and Collaboration

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Overview of Presentation

- Vision for the AEC industry
- Overview of CIFE
- Examples of 4D CAD use and cooperative R&D
- Develop
  - Framework for *Virtual Design and Construction* (VDC)
  - Starting point for *your VDC strategy*, including your role in cooperative R&D
  - Understanding of *ongoing cooperation* between CRC-CI and CIFE as part of ICALL
AEC Industry Perspective

- The Construction Industry *contributes* a lot to society
- It *costs* too much
- High world-wide *demand*
- *Envision* safe, fast, low cost, high value, sustainable ... construction
- Create *opportunities* for *people* in the industry and society
- Develop a “robust and viable research and *innovation* capability”
AEC Problem: Declining Productivity (1964-1998)

(Constant $ of contracts / work hours of hourly workers)

For 40 years, incremental, local innovations have not improved stagnant or declining productivity trends for AEC.

• Articulate *strategic business objectives* for delivery and use of physical assets that are aggressive but achievable

• **Compete today** and **evolve for tomorrow**

• **Manage** the project and the business to maximize measurable business objectives, e.g.,

  • Safety
  • Scope
  • Cost
  • Schedule
  • Sustainability
## Design-Construction Practice \(\rightarrow\) Goals

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<thead>
<tr>
<th></th>
<th>Practice: 2004</th>
<th>Goal: 2015</th>
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<tbody>
<tr>
<td><strong>Schedule</strong></td>
<td>1-6 y Design</td>
<td>1 y Design</td>
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<tr>
<td></td>
<td>~1.5 y Construct</td>
<td>&lt; .5 y Construct</td>
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<tr>
<td></td>
<td>Variance 5-100%</td>
<td>Variance 1-5%</td>
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<tr>
<td><strong>Cost</strong></td>
<td>Variance 5-30%</td>
<td>Variance 1-5%</td>
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<tr>
<td><strong>Function</strong></td>
<td>Large Variance</td>
<td>Very small variance</td>
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<tr>
<td></td>
<td>Good?</td>
<td>Great</td>
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<td></td>
<td>Productivity impact?</td>
<td>++ productivity</td>
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<tr>
<td><strong>Safety</strong></td>
<td>Good</td>
<td>Better</td>
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<tr>
<td><strong>Sustainability</strong></td>
<td>Poor</td>
<td>Life-cycle cost 25% (\downarrow)</td>
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<td><strong>Globalization</strong></td>
<td>Some</td>
<td>&gt;= 50% of supply and sales</td>
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Will we get there with current practice?

Can this project be built?
Orchestrate the team’s collective intelligence ...
Virtual prototypes
Multiple screens
Interactive
Role of Universities and Research Centers

- Be practical and scientific
- Cooperative R&D with industry
- Formalize and test the new methods needed to achieve breakthrough goals
- Educate future and current practitioners
CIFE Overview

• Started in 1988
  - Vision: build buildings ahead of time in the computer
• Industry sponsors
  - Private and public owners
  - AEC service providers
  - Software/hardware
• Virtual Design and Construction (VDC) Tools
  - Building Information Modeling (3D+) since 1988
  - 4D modeling since 1993
  - Virtual reality and multi-screen interfaces since 1996
  - Develop the foundation and prototypes for various modeling, analysis, simulation, visualization tools
• Professional education: VDC Certificate Program
  http://scpd.stanford.edu/scpd/programs/certs/civilEng.htm
• Stanford classes on VDC
Address practical problems with scientific methods

• ... “and to be able to say, with justification, that we are leading-edge world’s best practice.” John McCarthy, Chair CRC-CI

• CIFE’s role
  - Establish leading edge vs. bleeding edge
  - Document best possible practice
  - Generate R&D agenda
  - Carry out R&D

• R&D creates the future
Virtual Design and Construction (VDC)

Use of multi-disciplinary \textit{performance} models of design-construction projects, including

- \textit{Product} (i.e., facilities), e.g., BIM
- \textit{Organization} of the design-construction-operation team
- \textit{Work Processes}
- \textit{Economic Impact} (i.e., model of both cost and value of capital investments)

in support of (explicit, public) \textit{business objectives}. 
Components of VDC

- **Product Model**
- **Process Model**
- **Organization Model**

\[\text{3D Model} \rightarrow \text{Schedule} \rightarrow \text{Organization/Process Model} \rightarrow \text{4D Model}\]
Development plan

By 2015

- Many small building projects
- A few major strategic projects
- Dramatically shorter design and construction, etc. (CIFE breakthrough goals)
- What process/technology changes?

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<td>Strategic projects</td>
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<td>Small projects</td>
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The CIFE vision for AEC companies

• By 2006
  - Operate with a strategic plan to implement VDC incrementally
  - Use first (visualization) stage of VDC confidently
  - Staff each project with four VDC trained engineers

• By 2015
  - Owners have built and commissioned at least three large buildings (ground break to high value operation) within six months and routinely expect reliable Construct-within-6 performance
  - Contractors routinely deliver reliable schedule, costs and quality
  - Designers routinely design sustainable projects and produce rapidly constructible plans using VDC methods
3 Levels of VDC

1. Visualization (assume *manual* integration)
   - Routinely model and visualize all “expensive” elements of the product, organization and process
   - Get input from all stakeholders when it matters
   - Manage with model-based methods
   - Incrementally enhance current business goals
   - Requires project justification only

2. Integration (*computer based*)
   - Product, organization & process models “interoperate”, i.e., notify, highlight, control, propagate, parameterize
   - Single data entry
   - Incrementally enhance business goals
   - Requires corporate, multi-project support

3. Automation
   - Automated design and (CNC) manufacturing
   - Do high-quality work really fast all the time
   - Enables breakthrough project performance
   - Requires corporate, multi-project support
VDC Examples

- GSA: Largest facility owner in the U.S.
  - A public client driving towards virtual prototyping and adoption of building information standards
- Hospital addition
  - GC showing the value of visualization and early communication
- Walt Disney Imagineering
  - A private client driving towards 4D visualization
- Senate Properties
  - A public client enabling sharing of building information
- Terminal 5
  - A private client enabling integration of the project and automation in support of DMA (design, manufacture, assemble)
3D-4D Pilot Program: Collaboration between CIFE and GSA Office of the Chief Architect

Pioneer Courthouse, Oregon
Base-isolation construction sequencing
Response to historic preservation challenges; visualization & coordination

GSA Central Office, DC
Sustainability and energy simulations

Regional Office Bldg, DC
Tenant space planning (swing space, construction phasing)

Border Station Prototypes
Design and structural options (materials, prefabrication, construction assemblies)

26 Federal Plaza, New York
Laser scanning of existing plaza, parking, and utilities
3D coordination for design
4D issues in construction
A better informed client: How to expand and operate a hospital at the same time
Benefits of 4D Model on Good Samaritan Hospital, Phoenix

- Improved communication from GC to owner, city, subs
- Hospital CEO showed 4D model to entire hospital staff
- Improved safety (e.g., cranes are in direct flight path of helicopters)
- For GC: Immediately won a second $200 M project from this client (cost of 4D model ~$40 k)
Cooperative R&D and technology transfer: Paradise Pier at Disney’s California Adventure™

Cooperative R&D on 4D modeling and deployment of 4D models by WDI R&D and CIFE from 1998 to 2001 (from Design Development to Opening Day), followed by tech transfer

Work out logistics in a virtual environment to strategize accurately for the field. Refabricating Architecture
Make the outcome more predictable:
4D CAD model for Paradise Pier
Is this a good schedule?
Benefits of 4D Models on Paradise Pier

• Preconstruction
  - Unprecedented stakeholder involvement (200+ in 2 months)
  - More precise specifications

• Bidding
  - Bids within 2% of each other
  - Contractors understood scope and challenges within 48 hours, could use rest of time to work on bid

• Construction
  - Reduced change orders (potential for further reduction)
Due to the great success of 4D modeling on Paradise Pier, all WDI project managers immediately adopted 4D models.

Yeah right ... almost!

2001 to 2003:
- Lot’s of lunches with respected project managers -> a few became believers and were willing to give 4D CAD a try

Spring 2003:
- Stanford VDC students built 4D model for Space Mountain retrofit in about 100 hours

Fall 2003:
- Article in Forbes magazine with WDI President stating that 3D and 4D models are part of their everyday toolset

Now:
- 3D/4D models are used on every significant project on the practitioners’ own initiative
Stanford class CEE 243 “Virtual Design and Construction” with mini-internships

- **Obayashi**
  - Tokyo main train station track move
- **Swinerton**
  - Template hospital
- **CCC**
  - Ammonia Plant
- **Webcor**
  - Roof construction for new Renzo Piano Academy of Sciences building
- **Walt Disney Imagineering**
  - Demolish, rebuild Space Mountain
A collective web of information: Schematic design of HUT600

Mechanical Designer

Structural Engineer

Architect

General Contractor

New method: Quilt, don’t weave. Refabricating Architecture

Early User Input through Visualization

President of HUT: "The first row is too close to the speaker"
Test your mechanical system before you buy it

Virtual building model enabled CFD simulation, which provided the decision basis to select the - initially - more expensive displacement cooling system because of its better life cycle performance.

Snapshots courtesy of Granlund, Helsinki, Finland
• Integrated project team from the start
• High quality user input early in the project
• Greatly improved decision basis for many of the big life cycle decisions
• Process, organization, technology roadmap for virtual prototyping and sharing of building information models
Design, manufacture, assemble: The building is at once both virtual and actual.
Strive to minimize the amount of field assembly
Approach and Benefits for DMA on T5

- Drawing batch size aligned with work package batch size
- Complete Work Package drawings produced on a 5-day lead time ("On Demand")
- Co-creation reduced the need for CYA checking and rework
- Onsite RFI’s reduced by 80%
- Material orders tailored to work packages
- Smaller orders take up less space and were consumed more often
"I dream of the seamless integration of CAD design information with quantity and price information." — Construction 2020
• **Component:** Identify IFC building component
  - \#36 = IFCCOLUMN ('0UUQlH_cfDK8ZpiuvuFeFA', \#6, 'Col-012', $, $, \#52, \#49, $);
  - \#53 = IFCMATERIAL ('Concrete in Situ');
  - \#54 = IFCRELASSOCIATESMATERIAL ('1tmoGhhA57SeWs3Ap5p3k1', \#6, $, $, (#36), \#53);

• **Match against Activities**
  % activity(Component, Type, Activity, Productivity, P_unit).
  - activity('column', 'in-situ rc', 'place reo', 5.50, 'ton').
  - activity('column', 'in-situ rc', 'place formwork', 0.67, 'sqm').
  - activity('column','in-situ rc','pour conc', 0.90, 'cum').
  - activity('column','in-situ rc','cure conc', 168.00, 'unit').
  - activity('column','in-situ rc','strip formwork',0.33,'sqm').
• Resources
  - ea_resources(Gid, Storey, ‘pour conc', 'conc pump', 1) :-
    element_activity(Gid, Storey, _, ' pour conc ',_,_),
    storey(_,_, Storey, Elevation),
    Elevation > 3000, Elevation < 15000.

• Sequence
  - activity('column','in-situ rc', 'place reo', 'place formwork').
  - activity('column','in-situ rc', 'place formwork', 'pour conc').
  - activity('column','in-situ rc', 'pour conc', 'cure conc').
  - activity('column','in-situ rc', ‘cure conc', 'strip formwork').
  - activity('column','in-situ rc', 'strip formwork‘, ‘’).
Online meeting between Stanford and Melbourne (Australia), Tampere (Finland), Berlin (Germany), Basel (Switzerland), and Washington, DC
Together with Stanford’s Computer Science Department, CIFE has pioneered methods to enable group interactions with building information models through multiple views.

- **Multiple screens**
- **Multiple views**
  - Product, Organization, Process
  - Functions, Forms, Behaviors
- **Unified control**
  - Multiple screens, applications
Understand, appreciate, and organize complexity to focus on quality and speed.

Comparison of project scenarios with two 4D models, project schedule, and the CIFE Time Controller.
Controllable factors (you decide)
- Modeled Scope: build VDC models for expensive parts of your project
- Managed Scope: model-based management methods
- Organization design strategy
- Coordination activity
- Prediction basis: computer-based models
- Design versions

Measurable process improvement (you measure regularly)
- Field material delivery
- Decision latency (Decision-making promptness)
- Response latency (Decision-making no earlier than necessary)
- Field-generated Requests for Information
- Rework volume

2015 Breakthrough goals
How will you work in 2015?

2005 ... 2015?

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Key References:
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