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

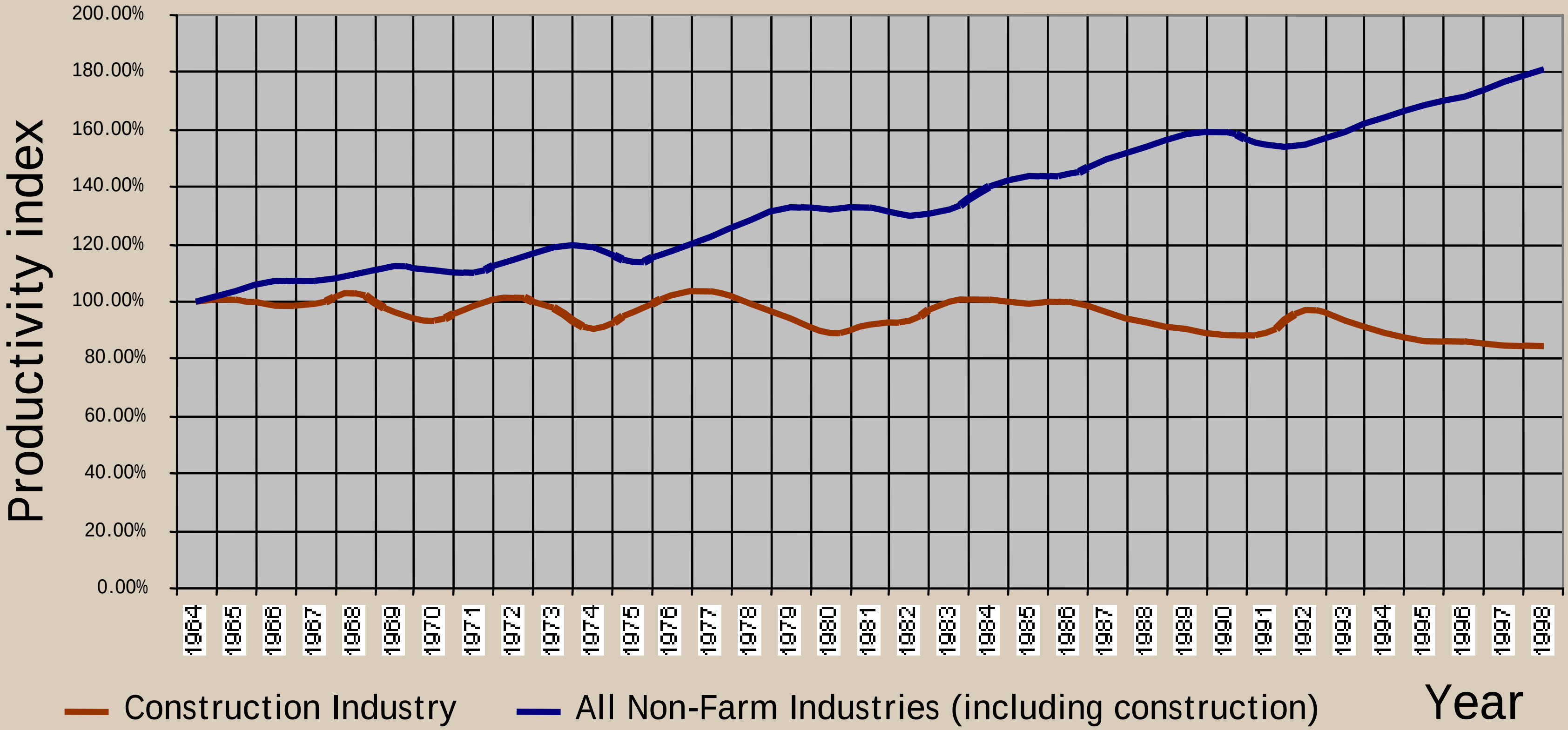
ICALL
International Construction Research Alliance

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)



Sources: US Bureau of Labor Statistics, US Dept. of Commerce, compiled by Paul Teicholz

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

Challenges of every company

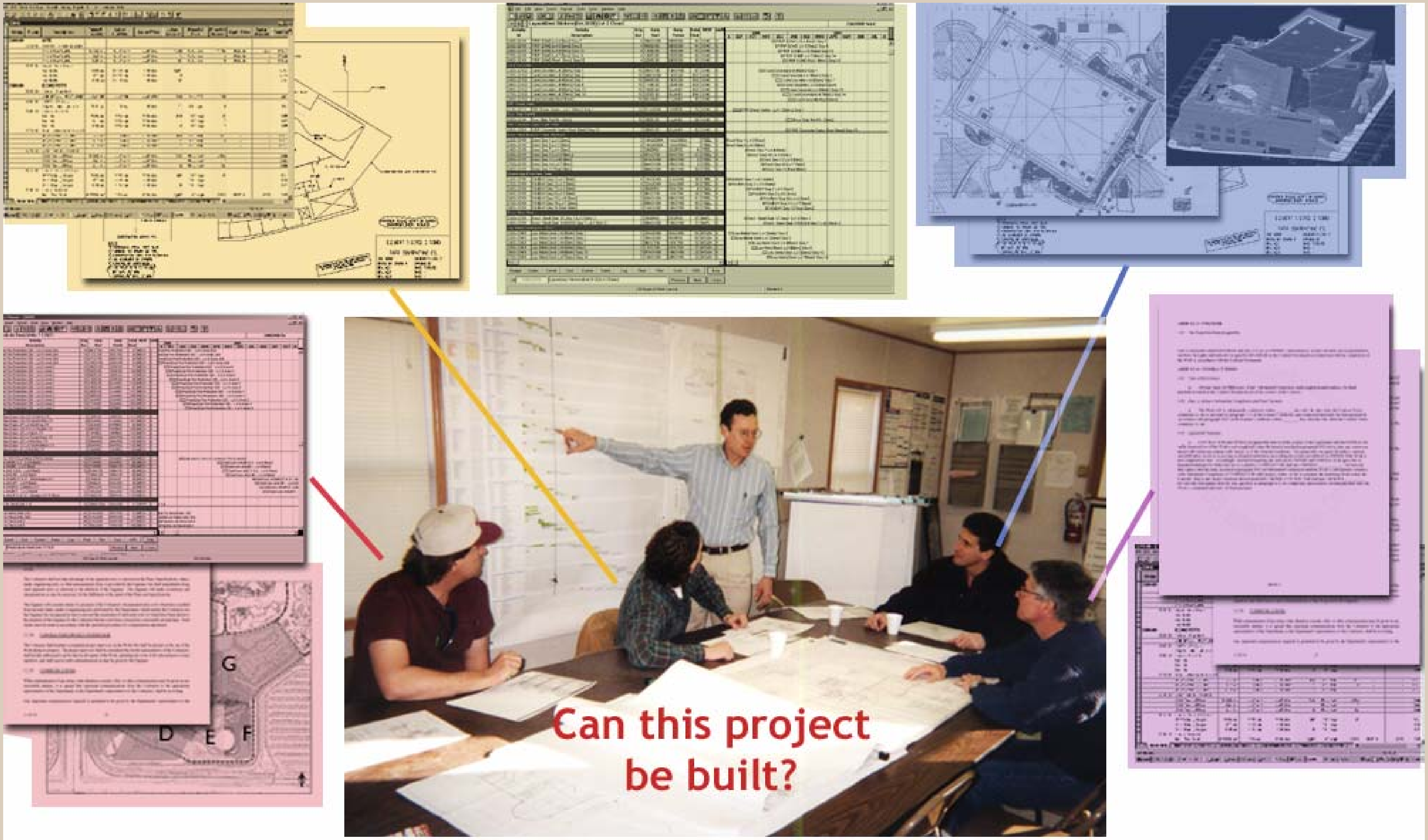
- **Articulate** *strategic business objectives* for delivery and use of physical assets that are aggressive but achievable
- **Compete today** *and* **evolve for tomorrow**
- **Manage** the project and the business to maximize measurable business objectives, e.g.,
  - Safety
  - Scope
  - Cost
  - Schedule
  - Sustainability

CIFE 2015 Breakthrough Goals

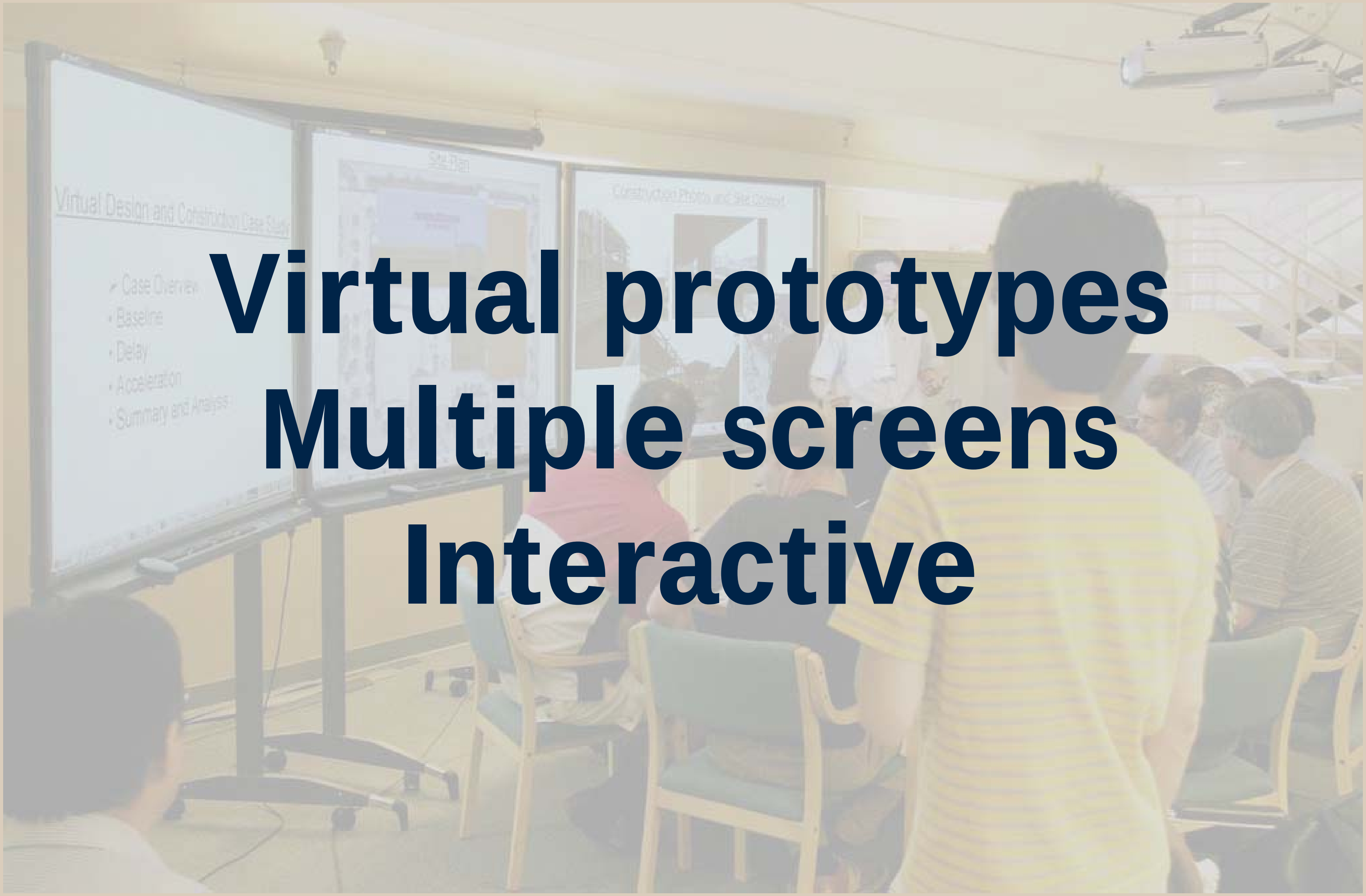
Design-Construction Practice → Goals

	Practice: 2004	Goal: 2015
Schedule	1-6 y Design ~1.5 y Construct Variance 5-100%	1 y Design < .5 y Construct Variance 1-5%
Cost	Variance 5-30%	Variance 1-5%
Function	Large Variance Good? Productivity impact?	Very small variance Great ++ productivity
Safety	Good	Better
Sustainability	Poor	Life-cycle cost 25% ↘
Globalization	Some	>= 50% of supply and sales

Will we get there with current practice?



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 *performance* models of design-construction projects, including

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

in support of (explicit, public) *business objectives*.

Components of VDC

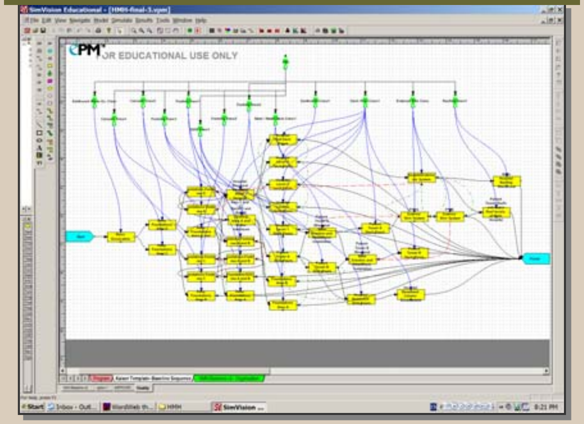
- Product Model
- Process Model
- Organization Model

→ 3D Model
→ Schedule
→ Organization/Process Model

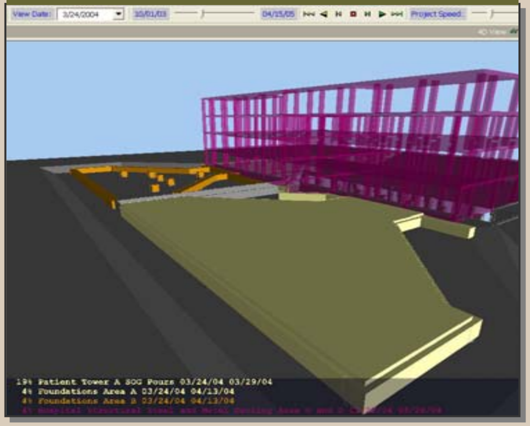
3D Model + Schedule } 4D Model

3D Model

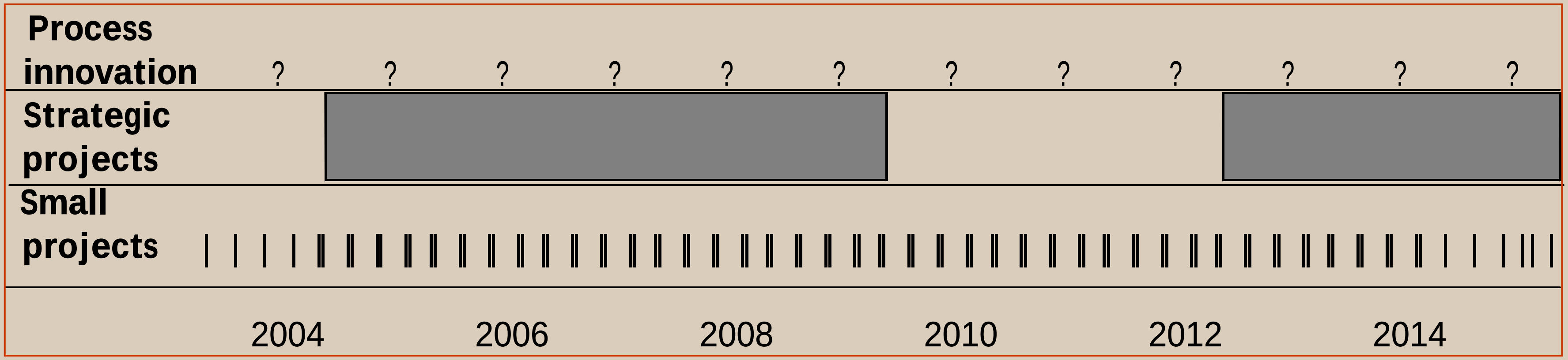
Organization/Process



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?

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

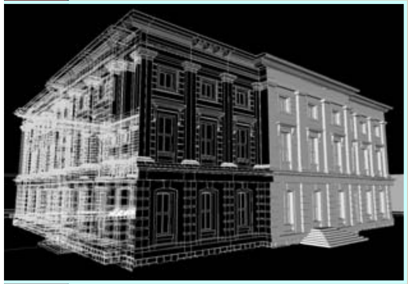
3 Levels of VDC

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



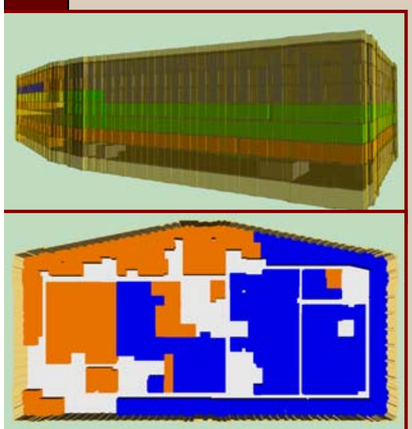
Pioneer Courthouse, Oregon

Base-isolation construction sequencing

Response to historic preservation challenges; visualization & coordination

GSA Central Office, DC

Sustainability and energy simulations

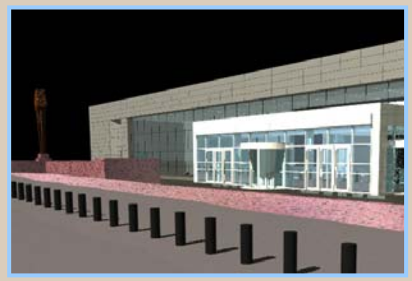


Regional Office Bldg, DC

Tenant space planning (swing space, construction phasing)

Border Station Prototypes

Design and structural options (materials, prefabrication, construction assemblies)



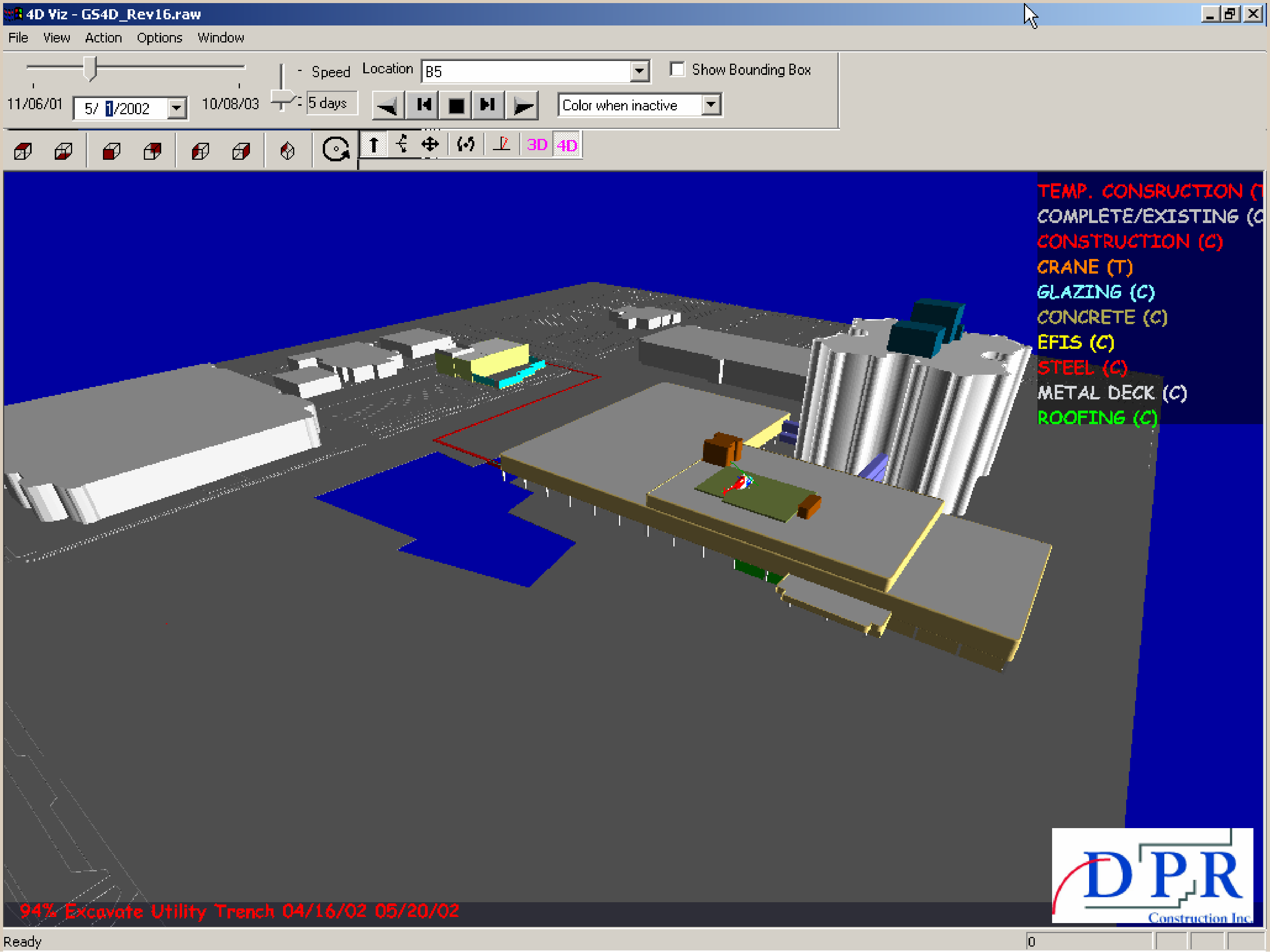
26 Federal Plaza, New York

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

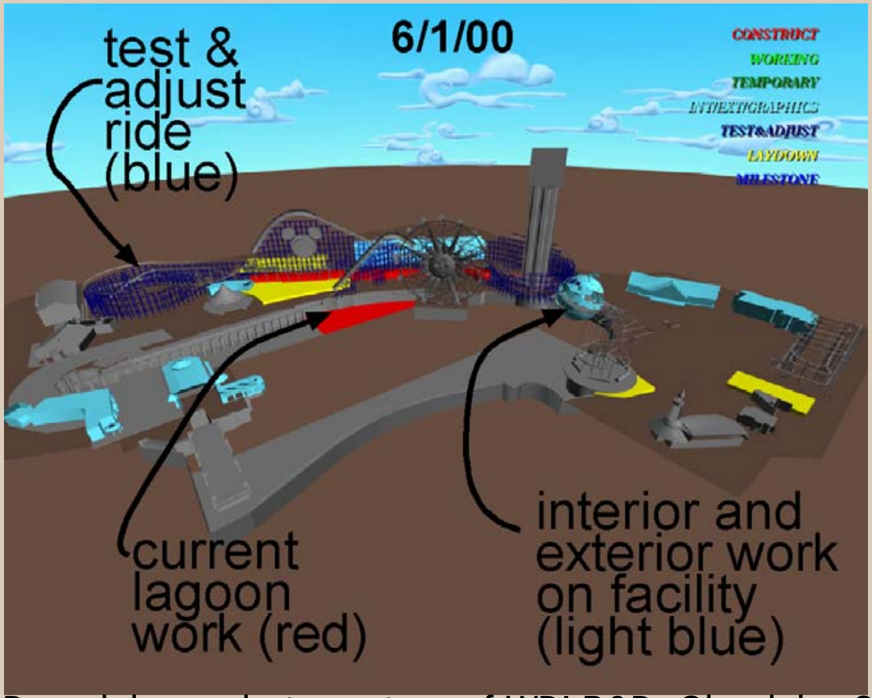


Benefits of 4D Model on Good Samaritan Hospital, Phoenix

- 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™

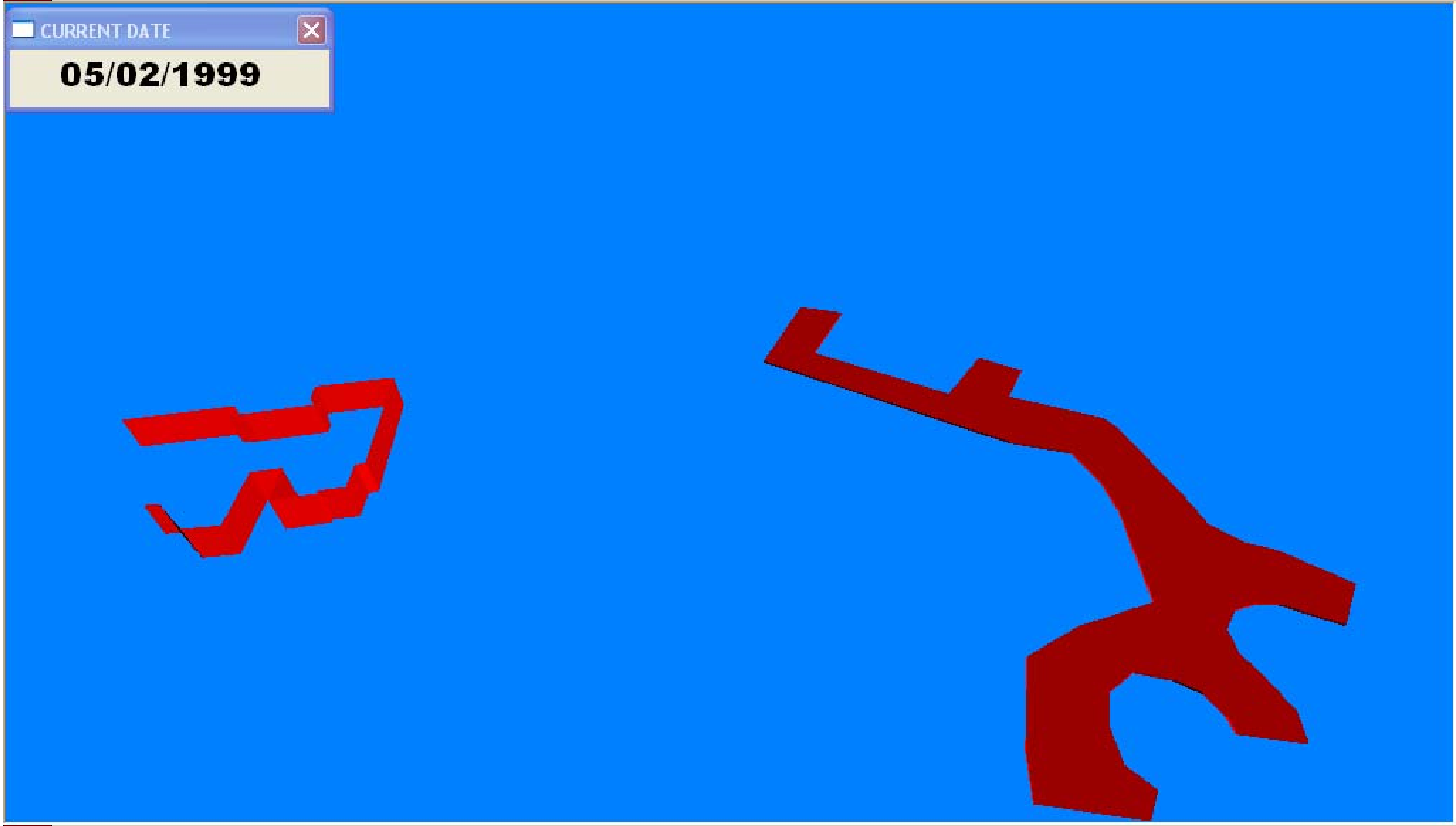
Cooperative R&D on 4D modeling and deployment of 4D models by WDI R&D and CIFE from 1998 to 2001 (from Design Development to Opening Day), followed by tech transfer



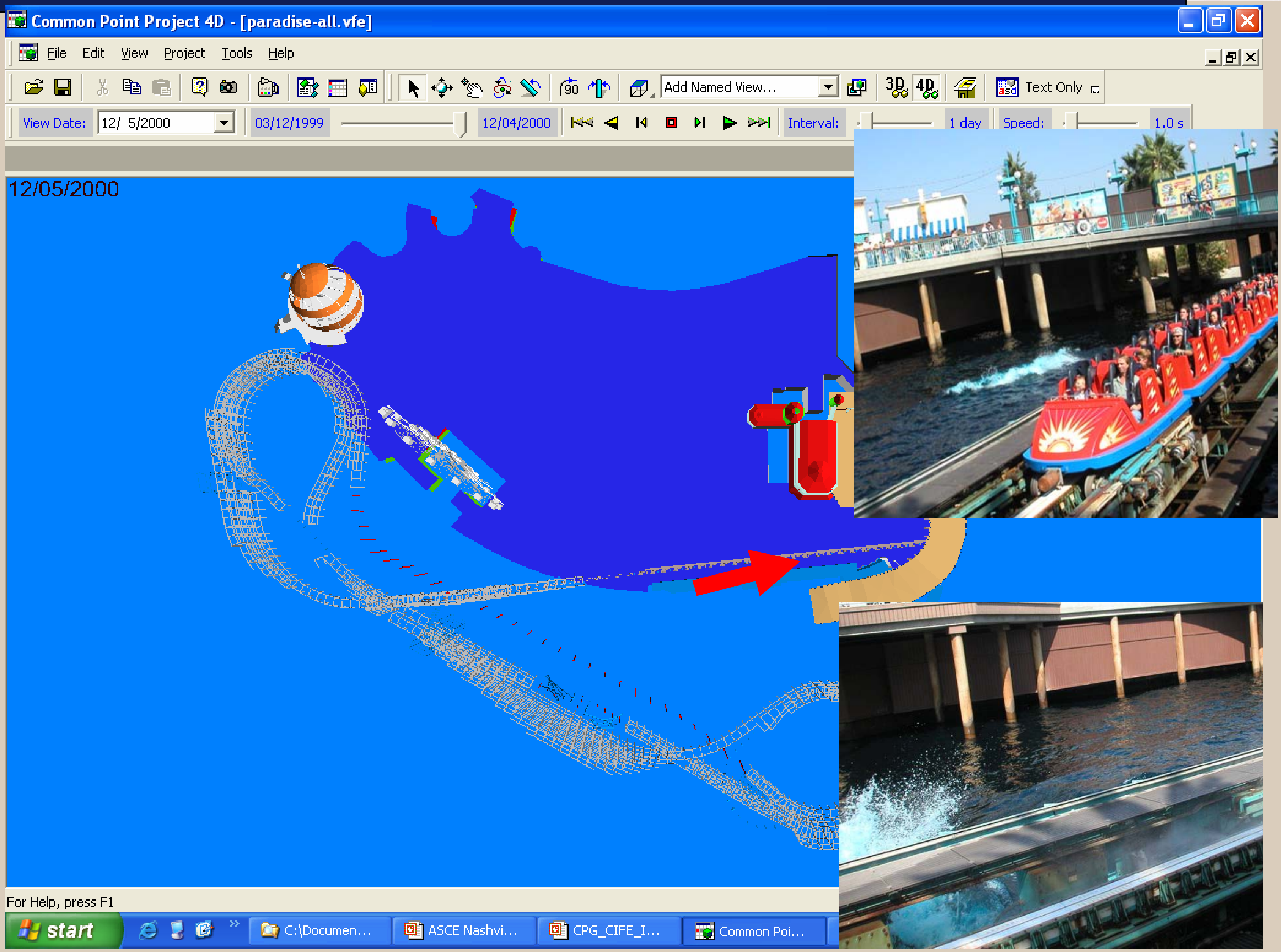
4D model snapshot courtesy of WDI R&D, Glendale, CA

Work out logistics in a virtual environment to strategize accurately for the field.

Make the outcome more predictable: 4D CAD model for Paradise Pier



Is this a good schedule?



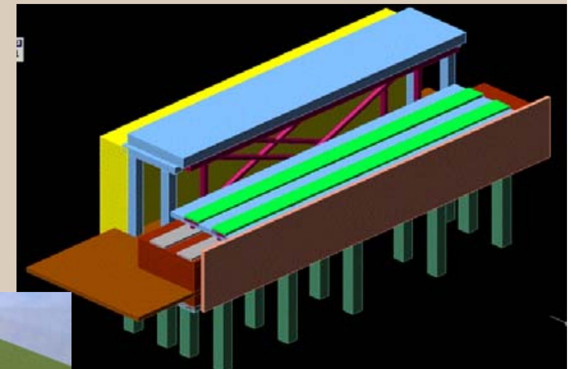
Benefits of 4D Models on Paradise Pier

- 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)

Trajectory of 4D Modeling at WDI

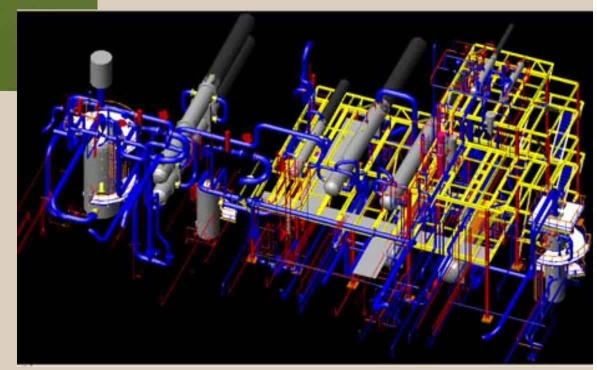
- Due to the great success of 4D modeling on Paradise Pier, all WDI project managers immediately adopted 4D models
- Yeah right … almost!
- 2001 to 2003:
  - Lot's of lunches with respected project managers -> a few became believers and were willing to give 4D CAD a try
- Spring 2003:
  - Stanford VDC 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

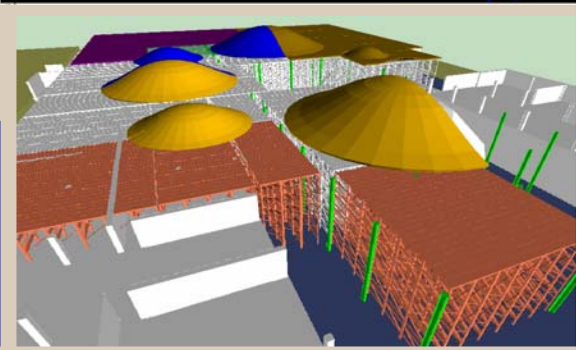


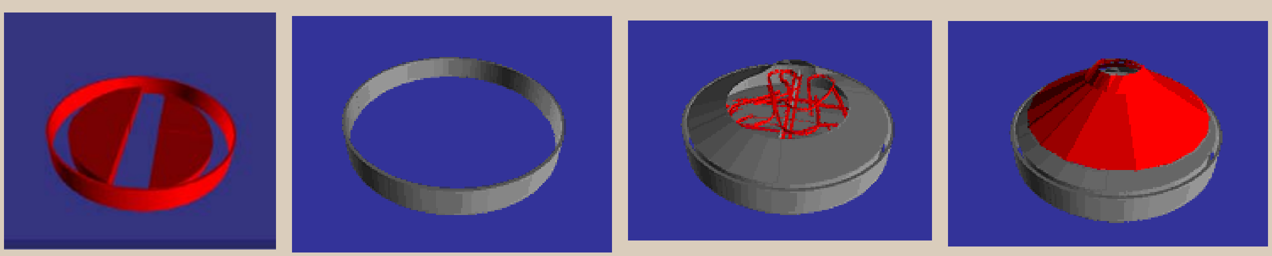
- Obayashi
  - Tokyo main train station track move
- Swinerton
  - Template hospital

- CCC
  - Ammonia Plant

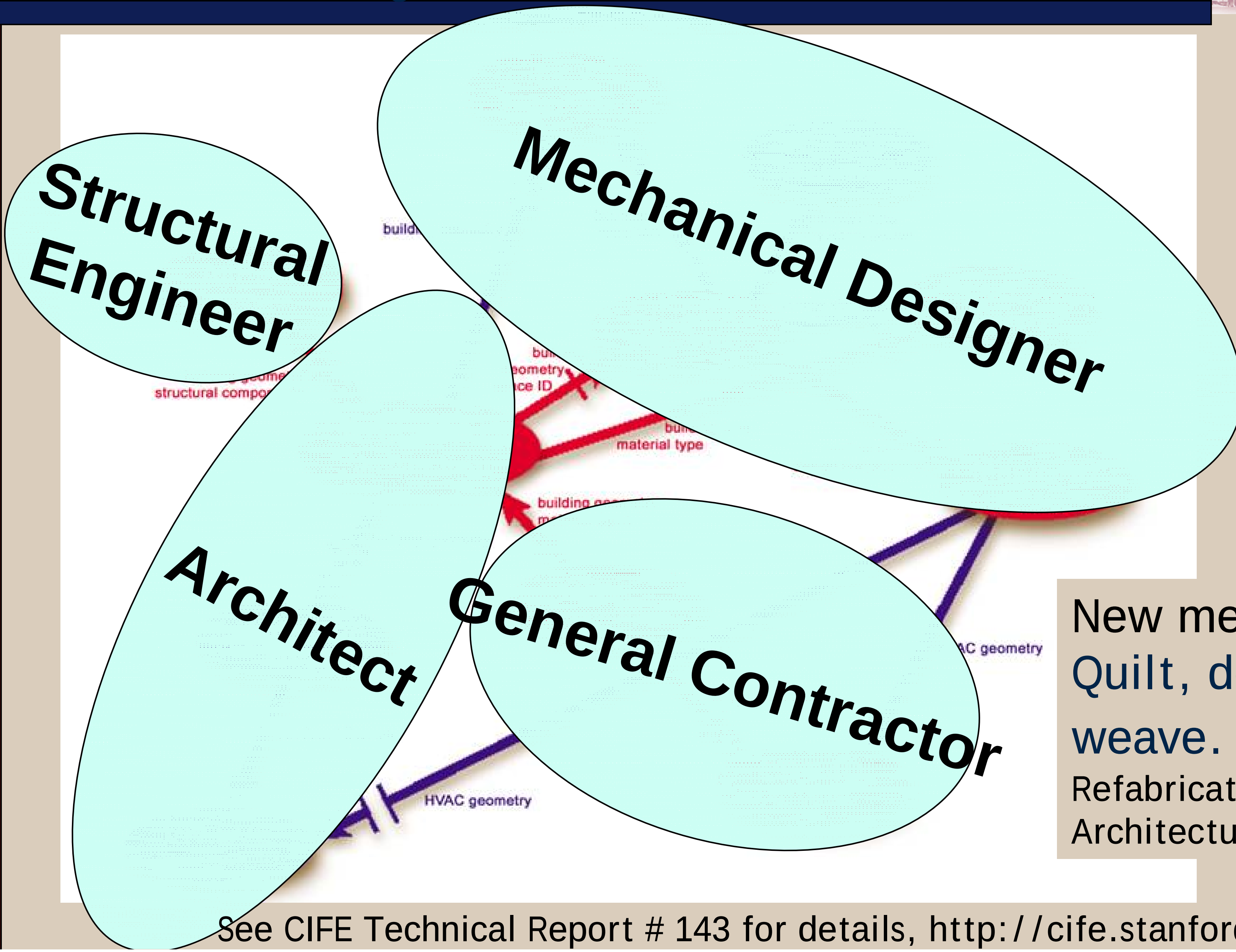


- Webcor
  - Roof construction for new Renzo Piano Academy of Sciences building
- Walt Disney Imagineering
  - Demolish, rebuild Space Mountain





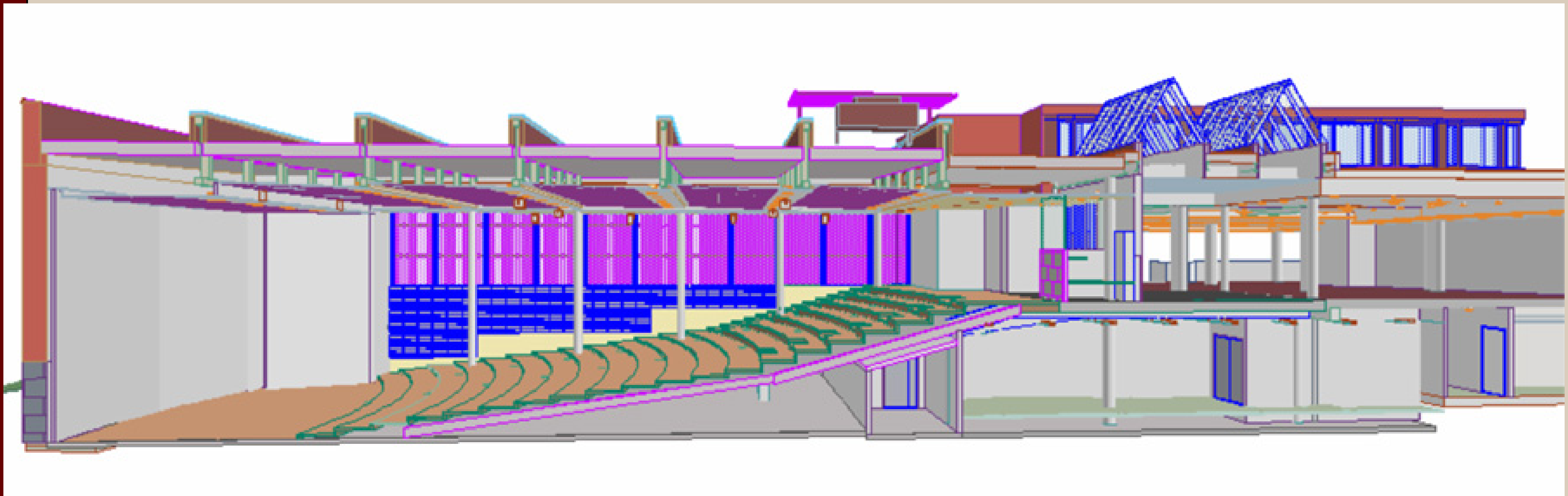
A collective web of information: Schematic design of HUT600

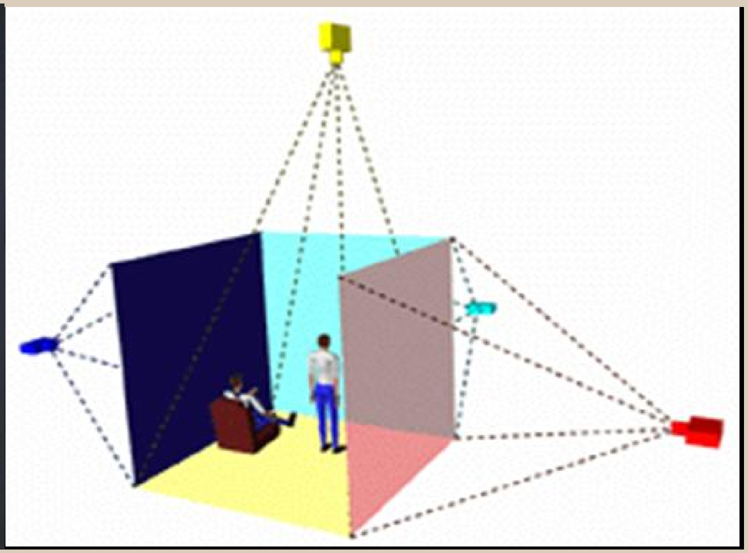


New method:
Quilt, don't weave.
Refabricating Architecture

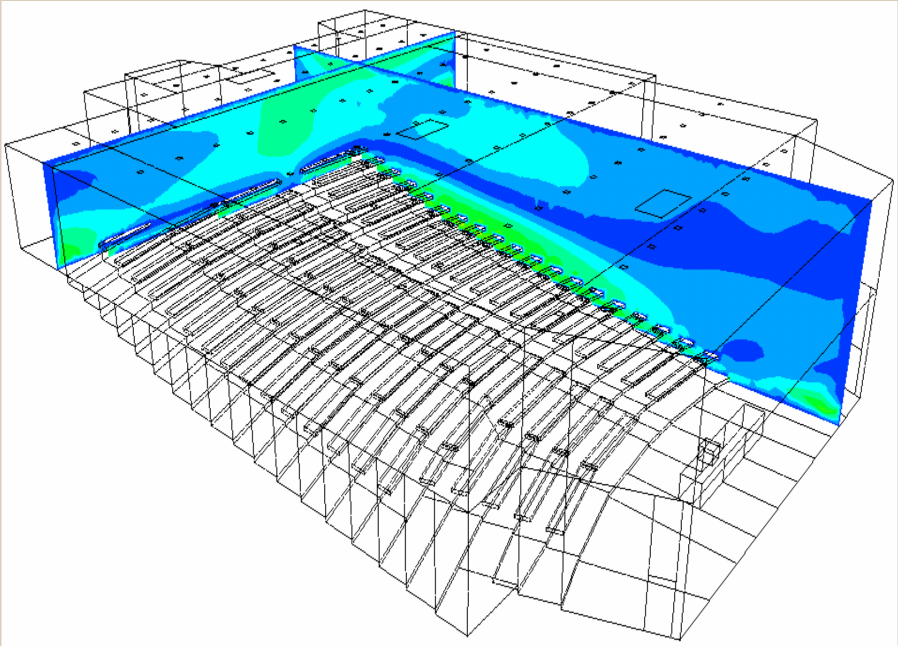
See CIFE Technical Report # 143 for details, http://cife.stanford.edu

Early User Input through Visualization

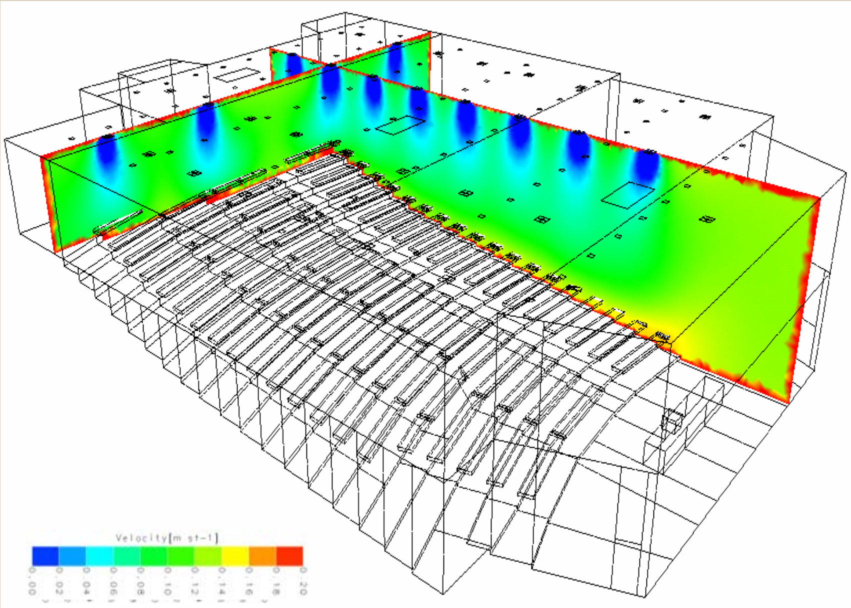




Test your mechanical system before you buy it



displacement cooling



mixed cooling

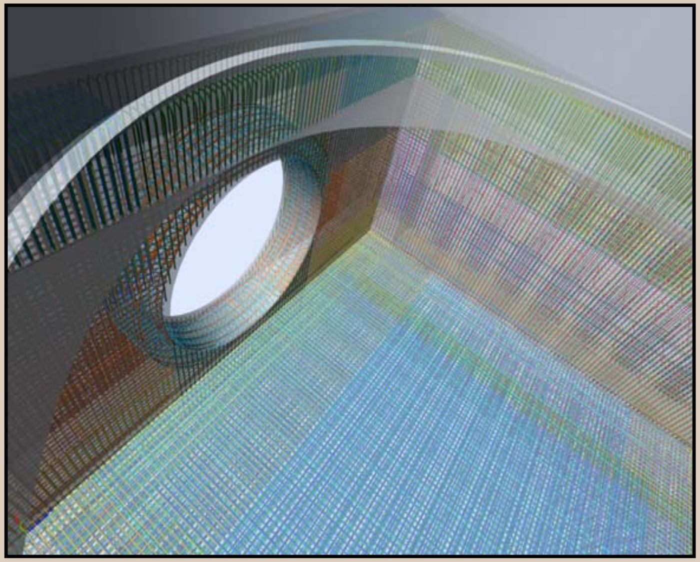
Virtual building model enabled CFD simulation, which provided the decision basis to select the – initially - more expensive displacement cooling system because of its better life cycle performance.

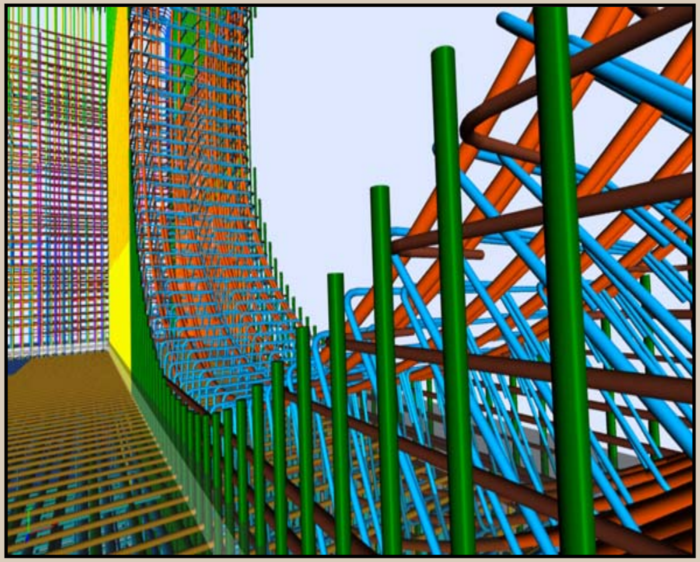
Snapshots courtesy of Granlund, Helsinki, Finland

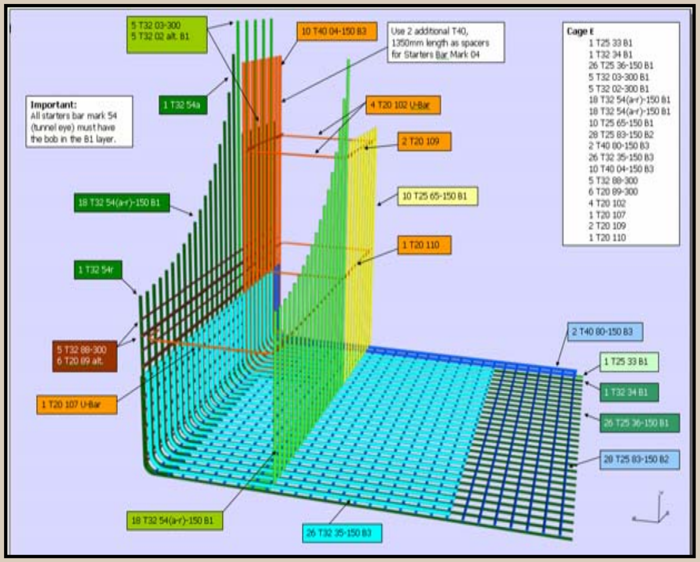
Value of Virtual Prototyping and Information Sharing for Senate Properties (HUT600 Client)

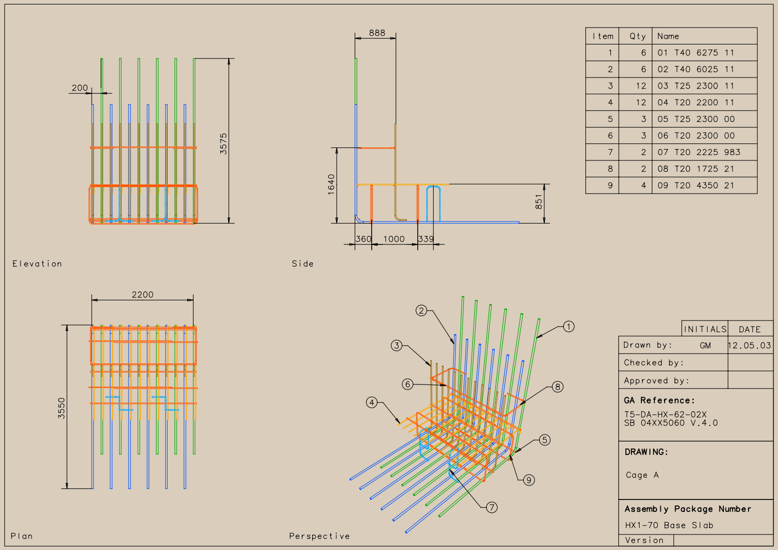
- Integrated project team from the start
- High quality user input early in the project
- Greatly improved decision basis for many of the big life cycle decisions
- Process, organization, technology roadmap for virtual prototyping and sharing of building information models

Design, manufacture, assemble: The building is at once both virtual and actual





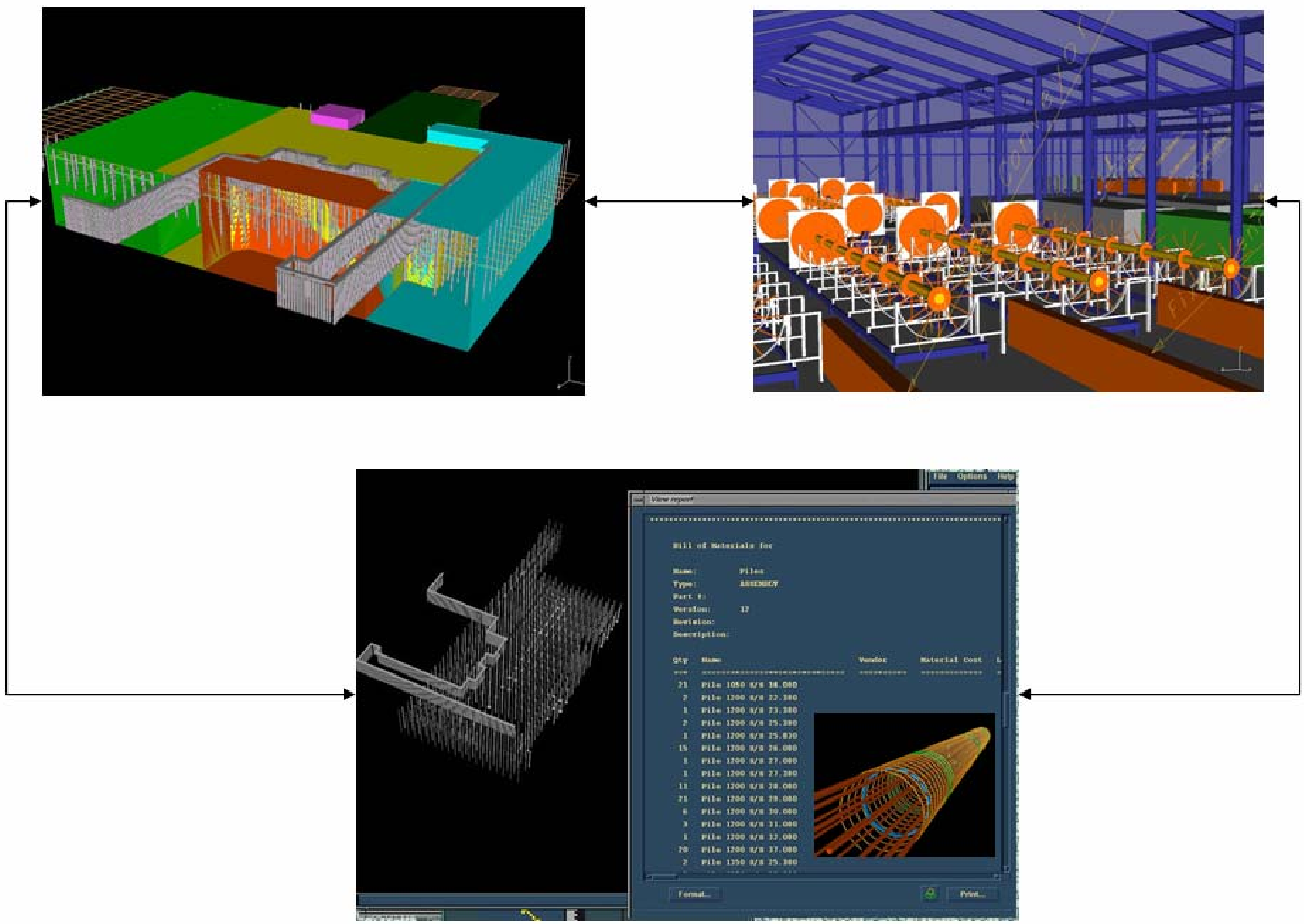




Item	Qty	Name
1	6	01 T40 6275 11
2	6	02 T40 6025 11
3	12	03 T25 2300 11
4	12	04 T20 2200 11
5	3	05 T25 2300 00
6	3	06 T20 2300 00
7	2	07 T20 2225 983
8	2	08 T20 1725 21
9	4	09 T20 4350 21

Pictures courtesy of Strategic Project Solutions, San Francisco, CA

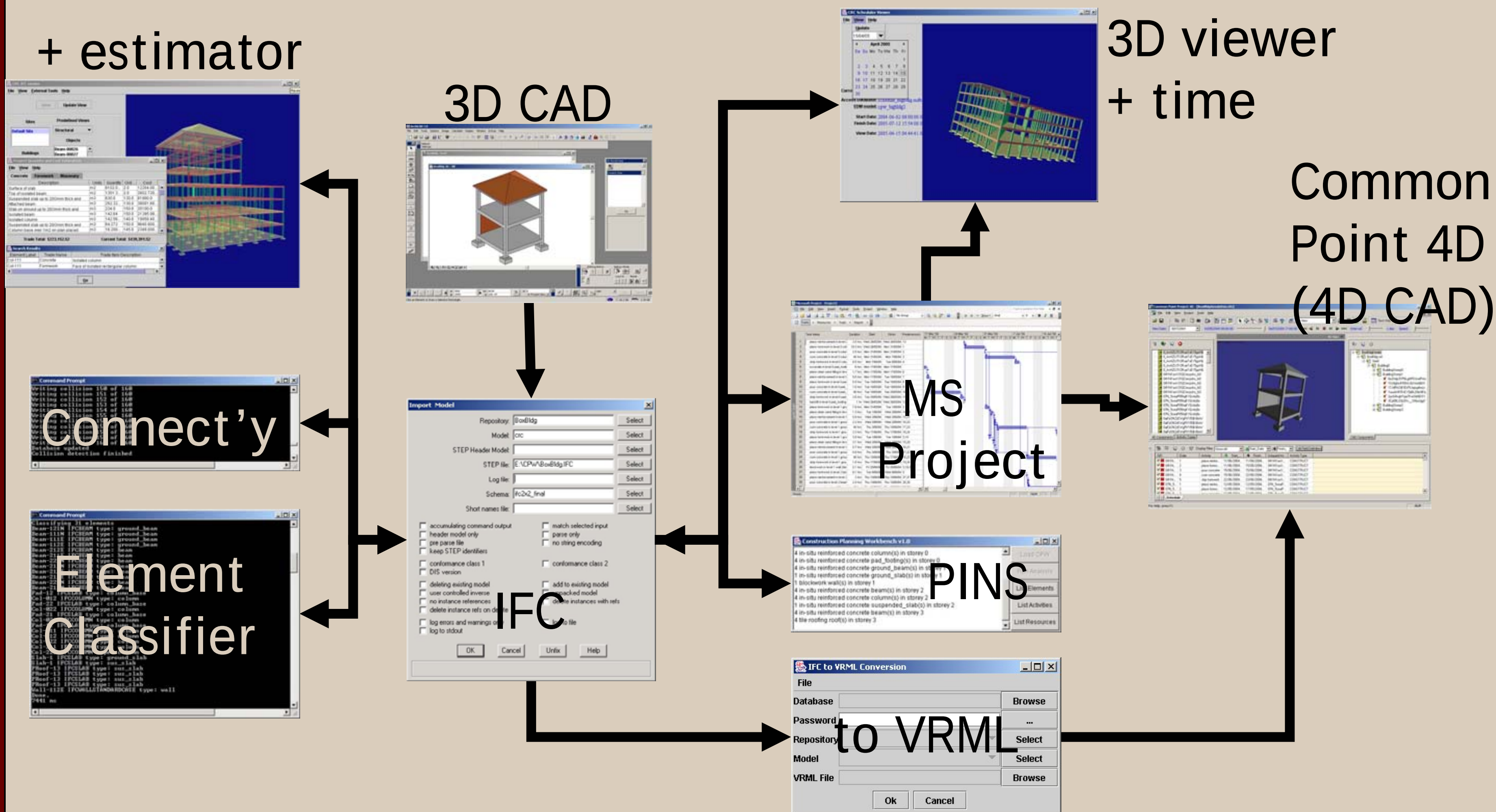
Strive to minimize the amount of field assembly



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

Construction Planning Workbench: Collaboration between CRC-CI & CIFE



"I dream of the seamless integration of CAD design information with quantity and price information." Construction 2020

CARS

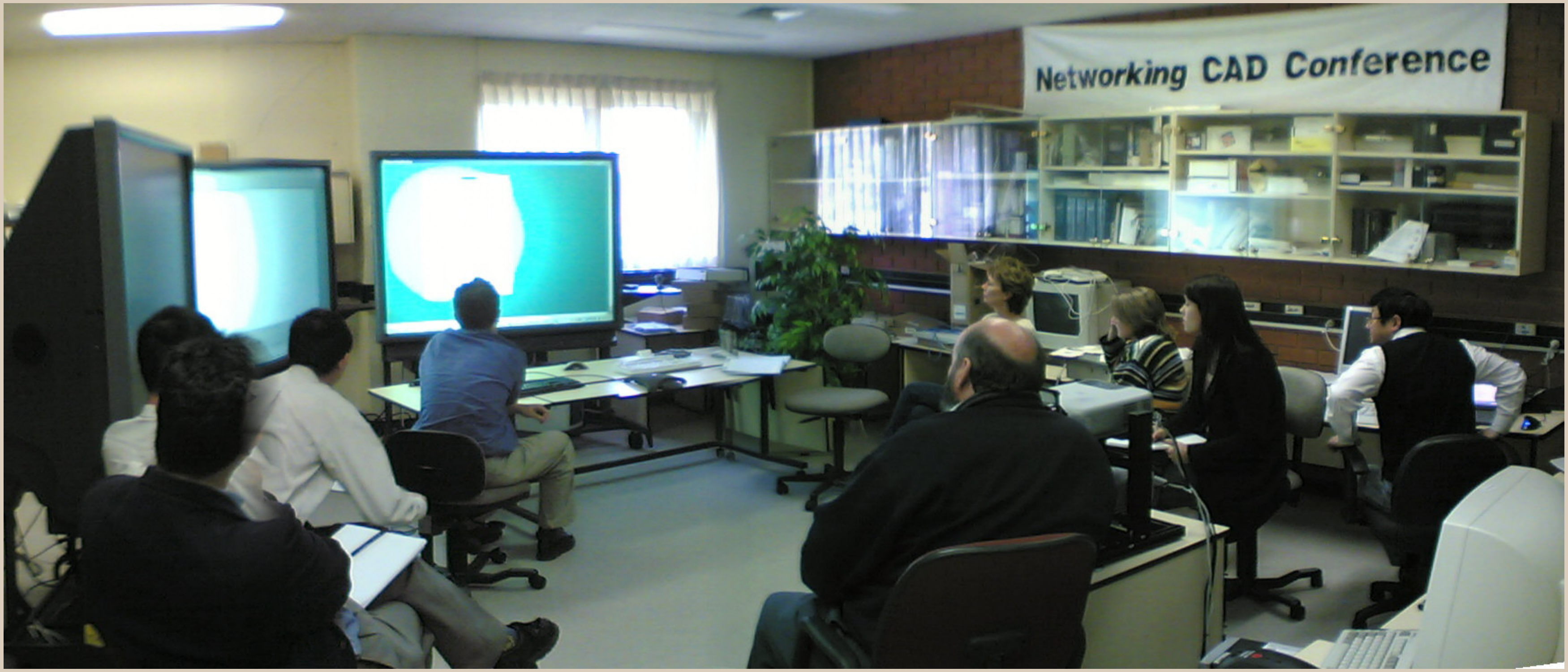
- Component: Identify IFC building component
  - #36 = IFCCOLUMN ('0UUQlH_cfDK8ZpiuvuFeFA', #6, 'Col-012', $, $, #52, #49, $);
  - #53 = IFCMATERIAL ('Concrete in Situ');
  - #54 = IFCRELASSOCIATESMATERIAL ('1tmoGhhA57SeWs3Ap5p3k1', #6, $, $, (#36), #53);
- Match against Activities

  % 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').

CARS

- 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‘, ‘’).

Global R&D Collaboration

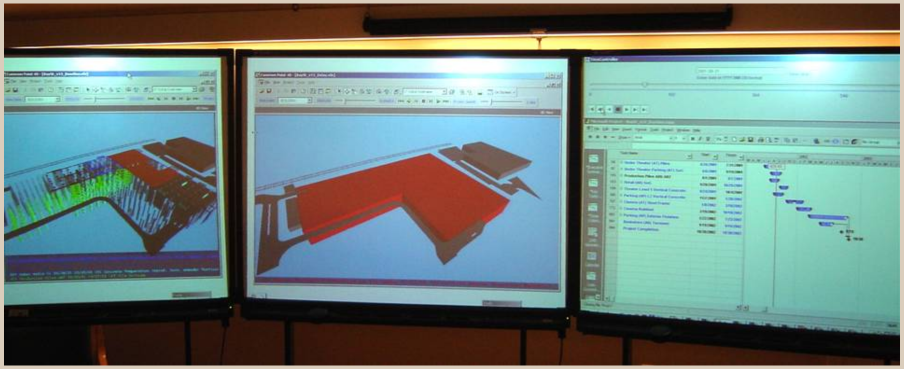


Online meeting between Stanford and Melbourne (Australia), Tampere (Finland), Berlin (Germany), Basel (Switzerland), and Washington, DC

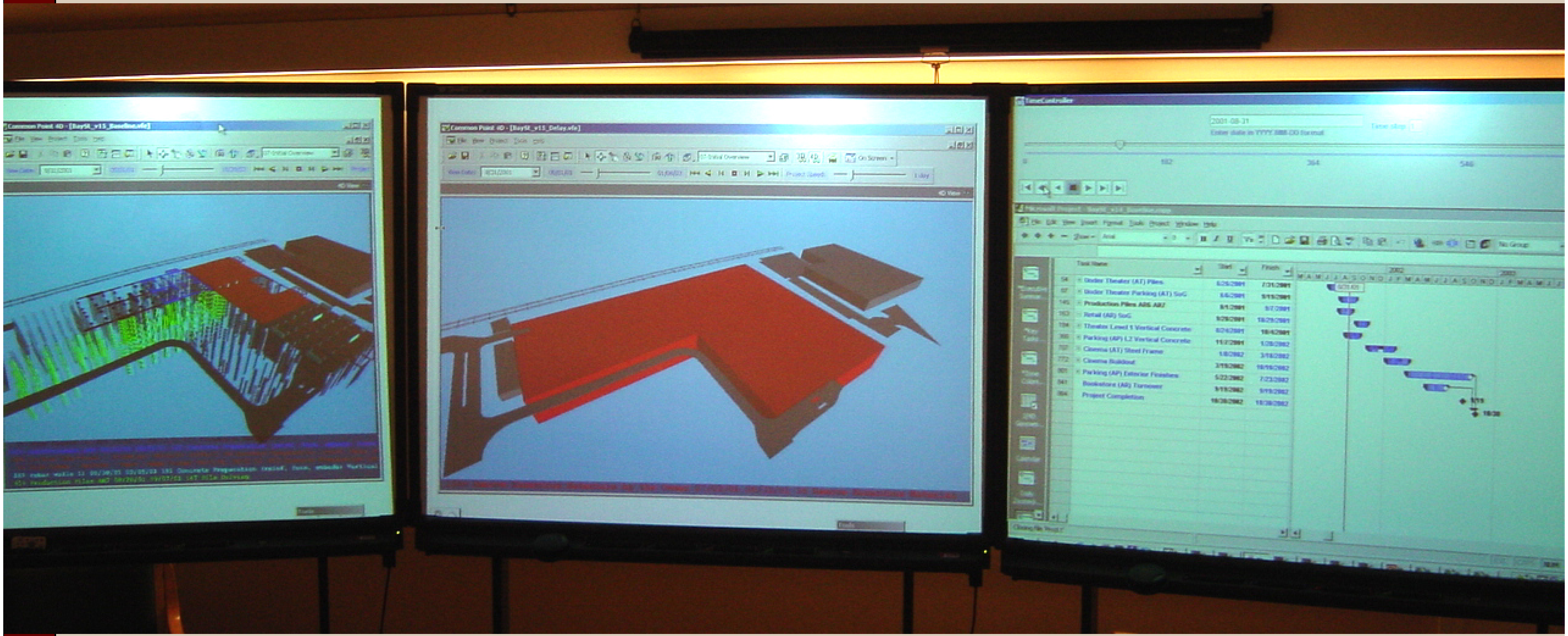
CIFE Interactive Workspace (iRoom)

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

Method to Achieve Breakthrough Goals

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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http://cife.stanford.edu

Key References:

Hampson/Brandon, Construction 2020, CRC-CI.

Kieran/Timberlake, Refabricating Architecture, McGraw-Hill.