OWNERS:
Dimitra, Joanna

ADVISOR:
Renate

CENTRAL TEAM 2011
UNIVERSITY OF CALIFORNIA, LOS ANGELES

Chelsea  Lindsey  Imke  Marina  Andres  Sebastian  Mads  Karol

E    E    CM    E    CM    LCFM    MEP    A
PROJECT SITE

University of California
Los Angeles
SITE CONDITIONS

- Warm, moderate, dry climate
- Yearly precipitation – 13”
- Avg. max temperature < 80°F
- Avg. min temperature > 45°F
HAZARDS

• Earthquakes
  o Highly seismic area

• Air quality
  o Smog

• NO Flooding Concerns
• NO Snow
• NO Freezing
# DECISION MATRIX

<table>
<thead>
<tr>
<th>points</th>
<th>owner preference</th>
<th>sculpture</th>
<th></th>
<th>concrete</th>
<th></th>
<th>orthogonal</th>
<th></th>
<th>concrete</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>design (interior)</td>
<td>12,5</td>
<td>4</td>
<td>55</td>
<td>4</td>
<td>44</td>
<td>3</td>
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<td>design (exterior)</td>
<td>14</td>
<td>5</td>
<td>67</td>
<td>3</td>
<td>40</td>
<td>3</td>
<td>35</td>
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<td>constructability</td>
<td>8</td>
<td>4</td>
<td>30</td>
<td>3</td>
<td>21</td>
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<td>initial cost</td>
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<td>24</td>
<td>3</td>
<td>26</td>
<td>4</td>
<td>28</td>
<td>3</td>
<td>27</td>
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<tr>
<td>life cycle cost</td>
<td>11,5</td>
<td>3</td>
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<td>36</td>
<td>3</td>
<td>37</td>
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<td>sustainability</td>
<td>14</td>
<td>4</td>
<td>51</td>
<td>3</td>
<td>46</td>
<td>3</td>
<td>40</td>
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<tr>
<td>quality of space</td>
<td>14</td>
<td>5</td>
<td>65</td>
<td>3</td>
<td>44</td>
<td>2</td>
<td>33</td>
<td>3</td>
<td>35</td>
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<tr>
<td>usability after earthquake</td>
<td>18</td>
<td>4</td>
<td>72</td>
<td>3</td>
<td>50</td>
<td>3</td>
<td>61</td>
<td>2</td>
<td>43</td>
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</table>

**Result**

<table>
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<tr>
<th>steel</th>
<th>concrete</th>
<th>orthogonal</th>
<th>steel</th>
<th>concrete</th>
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<tbody>
<tr>
<td>100</td>
<td>402</td>
<td>306</td>
<td>303</td>
<td>270</td>
</tr>
</tbody>
</table>
ARCHITECTURE
IDEA

DIRECT SOUTH SUN  CULTURAL CONTEXT  OWNER WISH

ARCHITECTURE
MAIN CORRIDOR

ARCHITECTURE
STRUCTURAL OVERVIEW

EXTERIOR STRUCTURAL SHELL
HSS TRUSS SYSTEM - GRAVITY AND LATERAL RESISTING SYSTEM
STRUCTURAL DESIGN SHIFT

SPRING QUARTER TASKS
- Modeling/Analysis
- Truss Design
- Connection Details

Architecture Design – Winter Quarter
SCULPTURAL INSPIRATION

DESERT BLOOM, MORONGO CASINO - CA

BIRDS NEST, BEIJING

SOUMAYA ART MUSEUM, MEXICO CITY

OVERALL APPEARANCE OF TRUSS SHELL

STEEL MEMBER TYPE

CONNECTION DETAILS
**BUILDING LOADS**

- **EQ 124 kips**
  - 30 psf DL + 20 psf LL + 2.8 psf PV Panels

- **EQ 62 kips**
  - 63 psf DL + 80 psf LL
  - 63 psf DL + 100 psf LL

- **HVAC=8.2 kips**

- **SEISMIC LOAD:**
  - Los Angeles, CA
  - $S_s = 1.779g$, $S_1 = 0.609g$
  - Base Shear V = 186 kips

- **SANDY SOIL:** 5ksf

- **WATER TABLE:** 15ft
SHELL DESIGN OVERVIEW

RED = PRE-FAB TRUSSES

3D VIEW OF TRUSS SHELL
STRUCTURAL DESIGN ITERATIONS

Architecture – April 11

Structural – April 11
GROUND

TRUSS:
- Members - HSS 8x8x1/2
- Columns - HSS 12x12x5/8

COLUMNS:
- Single Column - W14x283

GIRDERS:
- Perimeter Girders - W27x84

FLOOR BEAMS:
- Auditorium - W24x68
- North/South - W21x55
- East/West - W16x26
- Corridor - W21x68
COLUMNS:
- Single Column - W14x283

GIRDERS:
- Perimeter Girders - W27x84

FLOOR BEAMS:
- Auditorium - W27x84
- North/South - W27x84
- East/West - W21x68
- Catwalk - W27x129
GIRDERS:
- Exterior Girders – HSS12x12x5/8
- Interior Girders - W27x84

ROOF JOISTS:
- Steel Joists – Vulcraft 48LH17

HORIZONTAL BRACING:
- Truss System - HSS8x8x1/2

COLUMNS:
- Single Column - W14x283
LOAD PATH

Roof

1st Floor

Ground Floor

Basement Wall

8'

15'

15'

15'
BASEMENT DESIGN

TRUSSES
Frame into Basement Walls & Grade Beams

HYCRETE
Waterproofing Concrete Admixture
RETAINING WALL

Elevation with reinforcement

Section cut with reinforcement

3D view of retaining wall
FOUNDATION DESIGN

Isolated Spread Footing - 9’x9’
Retaining wall - 22” wide
Grade Beams - 22” wide & 30” deep
Isolated Spread Footing - 9’x9’
Base plate - 18”x18”
Basement wall - 20” wide
MODELING PROCESS

ETABS

Revit

Revit
BIM COORDINATION CHALLENGES

Structural interfering with glass curtain panel

Structural interfering with MEP

Created a separate offset model so the team could view structure within panels

Moved structural beams and girders down 18”
ETABS NON-LINEAR ANALYSIS

1989 Loma Prieta Earthquake

**Fault Normal**

**Fault Parallel**

**ETABS Analysis Input**
- 12 Load Cases
- 100% and 30% Acceleration Contributions
- $\xi=5\%$
DESIGN DEVELOPMENT

Final Roof Plan

Initial ETABS Analysis – large roof deflections
Design Change with ETABS - Additional Truss Bracing
MOMENT & SHEAR DIAGRAMS

Moment Diagram

Shear Diagram
## ETABS ANALYSIS RESULTS

<table>
<thead>
<tr>
<th></th>
<th>ROOF</th>
<th>FIRST FLOOR</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Moment Diagram</strong></td>
<td><img src="image" alt="Auditorium 48LH17" /></td>
<td><img src="image" alt="South-west side W27x84" /></td>
</tr>
<tr>
<td><strong>Max. Moment (k.ft)</strong></td>
<td>581.1</td>
<td>856.3</td>
</tr>
<tr>
<td><strong>Demand/Capacity Ratio</strong></td>
<td>0.92</td>
<td>0.94</td>
</tr>
<tr>
<td><strong>Max. Shear (k)</strong></td>
<td>194.4</td>
<td>384.3</td>
</tr>
<tr>
<td><strong>Max. Deflection (in)</strong></td>
<td>9.8</td>
<td>4.4</td>
</tr>
</tbody>
</table>
TIME HISTORY ANALYSIS RESULTS

Loma Prieta Scaled Earthquake Record
\( M_w = 6.9 \quad \Delta t = 0.005 \text{ sec} \)

<table>
<thead>
<tr>
<th>Mode</th>
<th>Period (sec)</th>
</tr>
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<tbody>
<tr>
<td>1</td>
<td>0.2458</td>
</tr>
<tr>
<td>2</td>
<td>0.2083</td>
</tr>
<tr>
<td>3</td>
<td>0.1743</td>
</tr>
<tr>
<td>4</td>
<td>0.1560</td>
</tr>
<tr>
<td>5</td>
<td>0.1396</td>
</tr>
</tbody>
</table>

Max Floor Drift

<table>
<thead>
<tr>
<th>ETABS – Non Linear Analysis</th>
<th>( 0.495'' )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Max Allowable</td>
<td>3.6''</td>
</tr>
<tr>
<td>Max Reduced</td>
<td>0.72''</td>
</tr>
</tbody>
</table>
COLUMN BASE CONNECTION

BASEPLATE DESIGN:
- Welds 1/16” smaller than tube thickness
- 6 bolts per baseplate
Columns @ Café Corner extended to Basement Slab

BASEPLATE
Restoring Moment Provided by Exterior Trusses
FIRST FLOOR CONNECTION

LW concrete
6.25” depth

Vulcraft 3VLI20

Slab Extended to HSS Columns
ROOF CONNECTION

Vulcraft 1.5BA22
(Acoustical decking for educational facilities)
ON-SITE CONNECTION

HSS Splice

- Hollow Section
- Bolt
- Weld
- Flange-Plate
ENERGY SOURCES

- Electricity from on campus cogeneration plant
- Steam from on campus cogeneration plant
- Chilled water from on campus chillers
- Annual solar resource 211 kWh/ft²/yr
Sloped walls not room bounding
SOFTWARE LIMITATIONS

Simplification for approximate volumes
SOFTWARE LIMITATIONS

Simplified analytical model
SOFTWARE LIMITATIONS

Air gaps
PROBLEM SOLVING

Revit
BIM

dxf

Rhino
Geometry

3DS

SketchUp
New geometry

gbXML

IES<VE>
Analytical model
ANALYTICAL MODEL

- Office
- Student office
- Corridor / Transition
- Small Classroom
- Computer Lab
- Large Classroom
- Server
- Auditorium
- Cafeteria
- Storage
- Restroom
- Plenum
ANNUAL ENERGY CONSUMPTION

- Heating: 2.0 kWh/SF
- Cooling: 8.0 kWh/SF
- DHW: 0.5 kWh/SF
- Lights: 1.5 kWh/SF
- Pumps/fans: 4.0 kWh/SF

Suncool: 14.5 kWh/SF
Standard: 16.8 kWh/SF
MODELING

Main shaft

Auditorium

- Supply air
- Return air
- Exhaust air
• Hard to mount from inside
• Hard to control room airflows individually
RETURN AIR

Occupied zone

18''

15'-0''

6'-6''
PV PANELS
BIM IMPLEMENTATION PLAN

- Models
- Model check
- Content plan
- 3D Coordination
BIM IMPLEMENTATION PLAN

Quantities

Schedule

Estimate
FACILITATING SPACIAL COORDINATION

Structural

Mechanical

Architectural

Revit linked integrated model
3D COORDINATION

Structural

Mechanical

Architectural

Navis: Coordinated model
PREFABRICATION – STRUCTURAL STEEL

- HSS 12x12 & HSS 8x8 members in pre-fabricated assemblies
- Bolted connections for diagonal HSS 8x8 braces

40ft “high”
8ft “out”

TRUSS Assembly

16ft
STEEL ERECTION SEQUENCE

Phase I

Prefabricated unit

Phase I erection

Phase II

Phase II erection

N

CM
SITE LAYOUT

TRAFFIC IN/OUT

MOBILE CRANE MOVES AROUND SITE DURING ERECTION
<table>
<thead>
<tr>
<th>Heaviest load/reach</th>
<th>Capacity</th>
</tr>
</thead>
<tbody>
<tr>
<td>30 USt</td>
<td>35 USt</td>
</tr>
<tr>
<td>80 ft</td>
<td>95 ft</td>
</tr>
</tbody>
</table>
TRANSPORTING PREFAB ELEMENTS

Height (16’), Width (10’), Length (53’), and Weight Limits (80K lbs) OK
PREFABRICATION – CURTAIN WALL

Unitized panel modules

Work points
Mullions rotate in ‘section’ by bending. Brackets rotate in ‘plan’.
• Early Occupancy of Computer Labs
• Worked intensely with Steel & Curtain wall subcontractors
TOTAL COST (2011 DOLLARS): $7.12 MILLION
TOTAL COST (2015 DOLLARS, ASSUMING 1.5% INFLATION): $7.56 MILLION
GOING NATIVE

- Local companies/construction materials

<table>
<thead>
<tr>
<th>Company Type</th>
<th>Distance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Concrete/civil contractor</td>
<td>9.2 miles</td>
</tr>
<tr>
<td>Steel fabricator</td>
<td>13.3 miles</td>
</tr>
<tr>
<td>Equipment rental</td>
<td>26.7 miles</td>
</tr>
<tr>
<td>MEP Supplier</td>
<td>20.7 miles</td>
</tr>
<tr>
<td>Curtain Wall Contractor</td>
<td>14.5 miles</td>
</tr>
</tbody>
</table>
RENT CALCULATION

Architectural Design

Structural Design

MEP Design

CM – cost estimate for building

LCFM – cost estimate for LC

design

cost feedback

Team Central - SPV (special purpose vehicle)

Client

Goal: as low as possible
second loan for replacement
Savings of $2,525,293 (10%) over LC
• 30% private equity  
• same O+M cost  

• same building cost  
• without any management fees
LIFE CYCLE COST

LCC

- Replacement Cost 4%
- Risk Surcharge 3%
- Construction Cost 37%
- Other O&M Cost 29%
- Interest Payments 27%

- $677,730
- $5,977,044
- $6,480,499
- $8,059,076

Total: $25,000,000
SENSITIVITY OF TOTAL LCC

Mean of C7 vs Percentage Change of Inputs

@RISK Student Version
For Academic Use Only
CASH-FLOW LCC

life cycle cost

- replacement cost
- income rent building
- income rent cafe
- other operation and maintenance cost
- risk charge
- income pv system
- sum property cash flow p. year

Break even

Years
RISK MANAGEMENT – MAIN PROCESS

Cost Management

CM – cost estimate building
assumption

standard cost

LCFM – cost estimate LC
assumption

Risk Management

statistical distribution of assumption

most likely cost

safety for client and SPV
Risk Surcharge $ 231.585

Risk Surcharge Construction Stage

most likely value

Risk Surcharge $ 231.585
RISK MANAGEMENT – RESULTS IMPACT

Risk Surcharge $ 231,585

Top Risk
1. Steel Price
2. Earthquake
3. Building Permit
VALUE FOR MONEY - TVD

owner input to define cost cluster

client

A/E/M EP

feedback

cost

preference

budget

target cost

standard cost (RS Means)

linked
VALUE FOR MONEY - TVD

challenge: distribute clients preference into cost cluster

<table>
<thead>
<tr>
<th>cost</th>
<th>Facade design</th>
<th>Room design/quality</th>
<th>circulation area design</th>
<th>summ</th>
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<tbody>
<tr>
<td>A2020</td>
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<td>1,75</td>
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<td>B1020</td>
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<td></td>
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<td>1,65</td>
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<tr>
<td>B20</td>
<td>3,6</td>
<td>0,7</td>
<td>0,35</td>
<td>7,475</td>
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<tr>
<td>B30</td>
<td>0,6</td>
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<td>1,55</td>
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<tr>
<td>C10</td>
<td>1,75</td>
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<td>0,35</td>
<td>10,325</td>
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<td>1,4</td>
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<tr>
<td>C30</td>
<td>0,7</td>
<td></td>
<td></td>
<td>7,925</td>
</tr>
<tr>
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<td>0,35</td>
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<td>4,325</td>
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<td>0,7</td>
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<td>7,925</td>
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<td>D30</td>
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<td>7,6</td>
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<tr>
<td>D40</td>
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<td>9,1</td>
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<tr>
<td>E20</td>
<td></td>
<td></td>
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<tr>
<td>G20</td>
<td></td>
<td>0,7</td>
<td></td>
<td>1,475</td>
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</table>

Owner input

<table>
<thead>
<tr>
<th>Presentation</th>
<th>Facade design</th>
<th>Room design/quality</th>
<th>circulation area design</th>
<th>summ</th>
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</thead>
<tbody>
<tr>
<td>facade design</td>
<td>5</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>room design/quality</td>
<td>6</td>
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<tr>
<td>circulation area design</td>
<td>3</td>
<td></td>
<td></td>
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</table>
## CLIENT WEIGHTED CLUSTER - RESULT

<table>
<thead>
<tr>
<th>cluster</th>
<th>standard cost/target cost for cluster</th>
<th>in %</th>
<th>owners preference in %</th>
<th>additional budget</th>
<th>difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>B20</td>
<td>Exterior Enclosure</td>
<td>$1,102,946.00</td>
<td>19%</td>
<td>16,95</td>
<td>17,0%</td>
</tr>
<tr>
<td>C10</td>
<td>Interior Construction</td>
<td>$469,395.00</td>
<td>8%</td>
<td>18,275</td>
<td>18,3%</td>
</tr>
<tr>
<td>C30</td>
<td>Interior Finishes</td>
<td>$345,110.00</td>
<td>6%</td>
<td>9,275</td>
<td>9,3%</td>
</tr>
<tr>
<td>D10</td>
<td>Conveying</td>
<td>$68,858.00</td>
<td>1%</td>
<td>1,775</td>
<td>1,8%</td>
</tr>
<tr>
<td>D20</td>
<td>Plumbing</td>
<td>$78,560.00</td>
<td>1%</td>
<td>1,65</td>
<td>1,7%</td>
</tr>
<tr>
<td>D30</td>
<td>HVAC</td>
<td>$331,414.00</td>
<td>6%</td>
<td>9,125</td>
<td>9,1%</td>
</tr>
<tr>
<td>D40</td>
<td>Fire Protection</td>
<td>$122,500.00</td>
<td>2%</td>
<td>5,6</td>
<td>5,6%</td>
</tr>
<tr>
<td>D50</td>
<td>Electrical</td>
<td>$851,500.00</td>
<td>14%</td>
<td>10,175</td>
<td>10,2%</td>
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<tr>
<td>E10</td>
<td>Equipment</td>
<td>$22,707.00</td>
<td>0%</td>
<td>3,675</td>
<td>3,7%</td>
</tr>
<tr>
<td>E20</td>
<td>Furnishings</td>
<td>$62,910.00</td>
<td>1%</td>
<td>2,4</td>
<td>2,4%</td>
</tr>
<tr>
<td>G20</td>
<td>Landscaping Paving</td>
<td>$163,356.00</td>
<td>3%</td>
<td>2,175</td>
<td>2,2%</td>
</tr>
</tbody>
</table>

**sum all (RS Means)** $5,957,499.00

**sum** $1,458,750.00
TVD – EXAMPLE

- Kone MonoSpace for $112,000
- Additional budget $27,000
- MEP/C M
- standard: hydraulic elevator for $68,000
- greater accessibility
- client
- new choice
- feedback
- cost
- preference
- target cost
- linked

EXAMPLE
**TEAM PROCESS COORDINATION**

**Smaller increments of coordination are better for Feedback**

WHAT???? – I can’t believe....

Could you look at this...

Let’s resolve this...

[Images of team process coordination tools and examples]
LESSONS LEARNED

“If you think something is going to take one hour... plan on four”
   - Chelsea

“The success of an avant-garde design lies in the trials of infinite iterations”
   - Lindsey

“On design - steal from the best, and invent the rest”
   - Marina

“You will get only as much as others want to give you”
   - Karol

“If we have to learn from them, they have to learn from us...”
   - Sebastian

“If experience is the sum of the mistakes made, this course has made us all very experienced.”
   - Mads

“Honest efforts to do your best have to be their own reward”
   - Imke

“You must compromise”
   - Andres
THANK YOU!

Renate Fruchter
Joanna Huey
Dimitra Loannidou
Glenn Katz

Björn Wündsch
Matthias Ehrlich

Willem Kymmell
Humberto Cavallin
David Bendet
Jan Słyk

John Nelson
Dennis Kwan
Cole Roberts

Greg Luth
Erik Kneer
Helmut Krawinkler
Eric Borchers
Eduardo Miranda

Josh Odelson
Mike Pearson
Jeffrey Vaglio
Katie Eslick
Dustin Rothwell