Team Pacific

- A
- E
- E
- E
- C
- C
- MEP
- LCFM

Universities:
- Stanford University, California
- CSU Chico, California
- UW Madison, Wisconsin
- Bauhaus University, Germany
- WUoT, Poland
Site - San Francisco State University

Lake View

San Francisco State Campus

Our Site

Seismic Challenge
Clockwork
Branching Patterns
Site Location
Second Floor

- Instructional Labs
- Classes and Seminar Rooms
- Toilets
Third Floor

- **Faculty Offices**
- **Faculty Lounge**
- **Terrace**
- **Toilets**
Section

130'

100'

5', 8', 6', 10', 14'
## Loads & Soil Profile

<table>
<thead>
<tr>
<th>Live Load</th>
<th>psf</th>
</tr>
</thead>
<tbody>
<tr>
<td>Office</td>
<td>50</td>
</tr>
<tr>
<td>Classroom</td>
<td>40</td>
</tr>
<tr>
<td>Storage (light)</td>
<td>125</td>
</tr>
<tr>
<td>Large Classroom</td>
<td>60</td>
</tr>
<tr>
<td>Lobby</td>
<td>100</td>
</tr>
<tr>
<td>Construction</td>
<td>20</td>
</tr>
<tr>
<td>Corridors</td>
<td>80</td>
</tr>
</tbody>
</table>

### Soil Conditions
- Well sorted fine to medium sand
- Bearing Capacity: 3500psf
- Not in Liquefaction Zone
- Water Table: 14ft below grade

### Seismic Loads
- $S_{ds} = 1.349$ Site Class D
- $S_{d1} = 1.085$
- Seismic controls over wind
Clockwork

Challenges:
• Irregular floors
• Lack of continuous frames or walls for lateral system
• Spanning Auditorium
# Clockwork

<table>
<thead>
<tr>
<th></th>
<th>ConXtech Moment Frame</th>
<th>Reinforced Concrete</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Gravity System</strong></td>
<td>Steel</td>
<td>Concrete</td>
</tr>
<tr>
<td><strong>Lateral System</strong></td>
<td>ConXtech Steel Moment Frame</td>
<td>Concrete Special Moment Frame</td>
</tr>
<tr>
<td><strong>Floor System</strong></td>
<td>Concrete Metal Deck</td>
<td>Flat Slab</td>
</tr>
</tbody>
</table>
System 1 – ConXtech Frame
Floor 1

- **Challenge:** Create simple floor system for irregular floor plan

**Auditorium**
- Auditorium beam: W44x335

**Typical girder**
- W18x50

**Typical filler beam**
- W12x22

**Column**
- HSS16x16x5/8
System 1 – ConXtech Frame
Floor 2

Bridged Entrance (supported on street side)

Typical filler beam W12x22

Largest Cantilever

Typical girder W18x50
System 1 – ConXtech Frame  
Floor 3

- Typical filler beam W10x19
- Typical girder W16x50
System 1 – ConXtech Frame
Lateral System

Challenge: Place lateral system with few continuous frames

Traditional Moment Frame

ConXtech

Short Frames in East-West Direction

More frames are possible

Base Shear V= 360k
# ConXtech frame

## Pros
- Simplified Moment Connections
- Less Welding
- Faster Erection Time
- Allows For Open Floor Plans
- Center Has Regular Floor Plan
- Short Cantilevers

## Cons
- Irregular Floor Plan
- Drift
- Large Auditorium Span
- Lack of Continuous Columns
System 2 – Concrete
Floor 1

8” slab required. 16” x 16” typical columns

10DT32 with 128-S Strand Pattern
System 2 – Concrete
Lateral System Concrete Moment Frame

Base Shear V = 465k
System 2 – Concrete

<table>
<thead>
<tr>
<th>Pros</th>
<th>Cons</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Cheaper material</td>
<td>• Large auditorium span</td>
</tr>
<tr>
<td></td>
<td>• Constructability</td>
</tr>
<tr>
<td></td>
<td>• Performance</td>
</tr>
<tr>
<td></td>
<td>• Poor repairability after earthquake</td>
</tr>
<tr>
<td></td>
<td>• Column transfer over auditorium</td>
</tr>
</tbody>
</table>
Foundation Solutions

- Retaining Wall
- Strip Footings along Exterior
- Spread Footings for Interior Columns

*Diagram*

- #7 @ 6” c-c
- 30in
- 10ft
- 10ft
- 2ft
- 12ft
- 1.5ft
- 2.5ft
- 2.5ft
- 9ft
- 4ft
Site Access

Exit Routes

Our Site

Approach to Site

SFSU Campus
Site Logistics

- Parking Areas (32 Spaces)
- Crane Location #2
- Sloped elevated Road
- Laydown Area: 2500 S.F.
- Storage for Tools and Equipment
- Access Road: 20’ wide 50’ radius 6000 S.F.
- Mobile Crane
- Recycling/Waste
- Storage for Tools and Equipment
Sequence
ConXtech
## Schedule

**ConXtech**

<table>
<thead>
<tr>
<th>Task Name</th>
<th>Duration</th>
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<tbody>
<tr>
<td>SFSU Building</td>
<td>240 days</td>
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<tr>
<td>Site Preparation</td>
<td>203 days</td>
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<tr>
<td>Clear &amp; Grub Site</td>
<td>5 days</td>
</tr>
<tr>
<td>Site Mobilization</td>
<td>5 days</td>
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<tr>
<td>Site Improvement</td>
<td>13 days</td>
</tr>
<tr>
<td>Substructure</td>
<td>50 days</td>
</tr>
<tr>
<td>Foundations</td>
<td>20 days</td>
</tr>
<tr>
<td>Basement Construction</td>
<td>30 days</td>
</tr>
<tr>
<td>Shell</td>
<td>48 days</td>
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<tr>
<td>Superstructure</td>
<td>13 days</td>
</tr>
<tr>
<td>Superstructure Complete</td>
<td>0 days</td>
</tr>
<tr>
<td>Exterior Enclosure</td>
<td>30 days</td>
</tr>
<tr>
<td>Roof</td>
<td>20 days</td>
</tr>
<tr>
<td>Interior</td>
<td>107 days</td>
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<tr>
<td>Stairs</td>
<td>15 days</td>
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<tr>
<td>Interior Construction</td>
<td>59 days</td>
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<td>Interior Finishes</td>
<td>38 days</td>
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<td>Services</td>
<td>93 days</td>
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<td>Fire Protection</td>
<td>31 days</td>
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<td>Electrical</td>
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<tr>
<td>Plumbing</td>
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<td>HVAC</td>
<td>49 days</td>
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<tr>
<td>Conveying</td>
<td>17 days</td>
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<tr>
<td>Equipment &amp; Furnishings</td>
<td>50 days</td>
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<tr>
<td>Equipment</td>
<td>25 days</td>
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<tr>
<td>Furnishings</td>
<td>25 days</td>
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<tr>
<td>Building Complete</td>
<td>0 days</td>
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</tbody>
</table>

**Structure erected**

**Instructional Labs Complete**

**Duration : 240 days**

**Completion Date : 8/30/16**

**Project Complete**
Schedule

Duration: 267 days
Completion Date: 10/6/16
Estimates

$7,870,000

$8,110,000

Shell

Services

Interiors

Substructure

ConXtech

Concrete MF
Houses
Houses

San Francisco House

San Francisco Quarter

San Francisco School of Engineering
Sketch-Up Model

Lake Merced

30’

76’
Site Location
Second Floor

- Large Classrooms
- Faculty Offices
- Auditorium
- Toilets

Dimensions:
- 76' x 76'
- 50' x 26'
- 26' x 50'
- 26' x 26'
First Floor

- Instructional Lab
- Server Room
- Administration
- Toilets
Third Floor

Faculty Lounge
Faculty Offices
Small Classrooms
Toilets
Student Open Space Office
Section a-a
# Houses

<table>
<thead>
<tr>
<th></th>
<th>Steel Moment Frame</th>
<th>Eccentrically Braced Frame</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Gravity System</strong></td>
<td>Steel</td>
<td>Steel</td>
</tr>
<tr>
<td><strong>Lateral System</strong></td>
<td>Steel Moment Frame</td>
<td>EBF</td>
</tr>
<tr>
<td><strong>Floor System</strong></td>
<td>Concrete Metal Deck</td>
<td>Concrete Metal Deck</td>
</tr>
</tbody>
</table>
System 1
Steel Moment Frame

3 @ 13'

2 @ 38'
System 1
Floor 1

Typical Column: W14x82

Typical Girder: W21x68

Typical Filler Beam: W14x38

Auditorium
System 1
Floor 2

Typical Girder: W21x68

Auditorium Girder: W24x76

Typical Filler Beam: W14x38

Typical Column: W14x82
System 1
Steel Moment Frame

Column: W14x257

Base Shear $V = 390k$
# System 1

**Steel Moment Frame**

<table>
<thead>
<tr>
<th>Pros</th>
<th>Cons</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Regular Shape</td>
<td>• Auditorium Span 50ft</td>
</tr>
<tr>
<td>• Short Cantilevers</td>
<td>• Drift</td>
</tr>
<tr>
<td>• Open Bays For Windows</td>
<td>• Long Typical Spans: 38ft</td>
</tr>
</tbody>
</table>
System 2 – Eccentrically Braced Frame

Challenges:
- Spanning Auditorium
- Placing Lateral System
System 2
Floor 1

Typical Girder: W21x68

Typical Filler Beam: W14x82

Auditorium

Typical Column: W14x38

Typical Column Around Auditorium: W12x87
System 2
Floor 2

Typical Girder: W21x68

Auditorium Girder: W24x76

Typical Filler Beam: W14x38

Typical Column: W14x82
EBFs

Initial Sizing:

Columns: W14x193

Beams: W14x132
Roof: W14x68

Brace: HSS10x10x5/8

Possible Locations for Additional Frames if Necessary

Base Shear V= 390k
## System 2 – EBF

<table>
<thead>
<tr>
<th>Pros</th>
<th>Cons</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Regular Shape</td>
<td>• Auditorium Span 50ft</td>
</tr>
<tr>
<td>• Short Cantilevers</td>
<td>• EBF Along Auditorium</td>
</tr>
<tr>
<td>• Brace Along Exterior</td>
<td>• EBFs Block Windows</td>
</tr>
<tr>
<td>• Regular Frames of 38ft</td>
<td></td>
</tr>
</tbody>
</table>
Site Logistics

- **Crane Location #2**
- **Laydown Area**: 2500 S.F.
- **Sloped elevated Road**
- **Storage for Tools and Equipment**
- **Access Road**: 20’ wide, 50’ radius, 6000 S.F.
- **Mobile Crane**
- **Parking Areas (24 Spaces)**
- **Recycling/Waste**
Sequence
Moment Frame & EBF
Schedule
Moment Frame

- Structure erected
- Instructional Labs Complete
- Project Complete

Duration: 263 days
Completion Date: 9/30/16
Schedule

EBF

Duration: 249 days
Completion Date: 9/12/16

Project Complete
Instructional Labs Complete
Structure Erected
Equipment

Wheel Loader:
JCB 426 HT
2.5 CY Bucket

Excavator:
JCB JS 260
1.5 CY Bucket

Mobile Crane:
Grove TM 8690

Other Equipment
Aerial Lifts
Forklift
Trucks
MEP Inspiration

San Francisco Federal Building

- Natural Ventilation
  - Mechanical Backup
- Daylight
  - Reduce Heating
Natural Ventilation
Clockwork: Windows

- Manual operable Windows
Natural Ventilation
Houses: Windows

FLOOR 2

FLOOR 3

Manual operable
Windows
Smart Windows

- Architect: “no shading devices”
- Hot Days: (tinted) reflect solar Heat away from Building
  Cold Days: (transparent) allow solar Heat into Building
- Reduce Energy Bills by 30%

Cold Days

Hot Days
Mechanical System Distribution
Clockwork

FLOOR 1

FLOOR 2

FLOOR 3

Server Room
Portable A/C Unit

Active Chilled Beams
Mechanical System Distribution

Houses

FLOOR 1

FLOOR 2

FLOOR 3

Server Room
Portable A/C Unit

Active Chilled Beams
Details on Chilled Beams

- Thermostats (individual Control)

- Sensor on each Chilled Beam
  - Provide only the required Heating/Cooling
  - Linked to Thermostats
  - Dewpoint Temperature Control
## MEP Options & Decisions

<table>
<thead>
<tr>
<th></th>
<th>Forced-Air Heat Pump</th>
<th>Hybrid System</th>
<th>Active Chilled Beams</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Sandwich Height</strong></td>
<td>3 ft</td>
<td>3 ft</td>
<td>1.5 ft</td>
</tr>
<tr>
<td><strong>Lifetime</strong></td>
<td>20 years</td>
<td>&gt; 18 years</td>
<td>20 years</td>
</tr>
<tr>
<td><strong>Cost</strong></td>
<td>High Installation</td>
<td>High Installation</td>
<td>Reduced Installation</td>
</tr>
<tr>
<td><strong>Maintenance</strong></td>
<td>Low</td>
<td>High</td>
<td>Very Low (if any)</td>
</tr>
<tr>
<td><strong>Energy Efficiency</strong></td>
<td>Baseline</td>
<td>&gt; Baseline</td>
<td>&gt; Hybrid</td>
</tr>
<tr>
<td></td>
<td></td>
<td>&lt; Chilled Beams</td>
<td></td>
</tr>
</tbody>
</table>
MEP Options & Decisions

5"-7" Formed Metal Deck

1'-1.5' Beams
1.5' Chilled Beam Venting

19'-2"

13.0'

1.5' Underfloor Venting

Total "Sandwich" Heights: 12.5'

2" NWT Topping

10DT24 3' Std Overhead Ducts

2" NWT Topping

8" Hollowcore
<table>
<thead>
<tr>
<th></th>
<th>Forced-Air Heat Pump</th>
<th>Hybrid System</th>
<th>Active Chilled Beams</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sandwich Height</td>
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<td>Maintenance</td>
<td>Low</td>
<td>High</td>
<td>Very Low (if any)</td>
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<tr>
<td>Energy Efficiency</td>
<td>Baseline</td>
<td>&gt; Baseline</td>
<td>&gt; Hybrid</td>
</tr>
<tr>
<td></td>
<td></td>
<td>&lt; Chilled Beams</td>
<td></td>
</tr>
</tbody>
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Comparison
Building Program Fit

Owner Requirements
Clockwork
Houses

- Faculty Offices
- Department Chair's Office
- Senior Administration
- Administrative Assistants
- Faculty Lounge
- Student Offices
- Auditorium
- Large Classrooms
- Small Classrooms
- Seminar Rooms
- Instructional Labs
- Server Room
- Technical Support
- Storage Rooms
- restrooms
## Life Cycle Benchmarks

<table>
<thead>
<tr>
<th>Ratio</th>
<th>Clockwork</th>
<th>Houses</th>
<th>Goals</th>
</tr>
</thead>
<tbody>
<tr>
<td>Circulation Area / Usable Floor Area</td>
<td>0.28</td>
<td>0.28</td>
<td>as small as possible</td>
</tr>
<tr>
<td>Usable Floor Area / Gross Floor Area</td>
<td>0.84</td>
<td>0.87</td>
<td>&gt; 0.6</td>
</tr>
<tr>
<td>Circulation Area / Gross Floor Area</td>
<td><strong>0.23</strong></td>
<td>0.24</td>
<td>as small as possible</td>
</tr>
</tbody>
</table>
## Risk List

<table>
<thead>
<tr>
<th>Phase</th>
<th>Risk Name</th>
<th>Description</th>
<th>Affected Aspect</th>
<th>Max. Cost Reduction</th>
<th>Most Likely</th>
<th>Max. Cost Increase</th>
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</thead>
<tbody>
<tr>
<td>Planning and Construction</td>
<td>Steel Price</td>
<td>Price Changes</td>
<td>Cost of Steel</td>
<td>65%</td>
<td>100%</td>
<td>150%</td>
</tr>
<tr>
<td></td>
<td>Concrete Price</td>
<td>Price Changes</td>
<td>Cost of Concrete</td>
<td>80%</td>
<td>100%</td>
<td>120%</td>
</tr>
<tr>
<td></td>
<td>Soil-Condition</td>
<td>Problems with Excavation and Foundation</td>
<td>Excavation and Foundation Cost</td>
<td>95%</td>
<td>100%</td>
<td>110%</td>
</tr>
<tr>
<td>Operation and Maintenance</td>
<td>MEP System Performance</td>
<td>MEP System works better/worse than expected</td>
<td>Heating and Cooling Cost</td>
<td>80%</td>
<td>100%</td>
<td>200%</td>
</tr>
<tr>
<td></td>
<td>Water Price</td>
<td>Price Changes</td>
<td>Water Cost</td>
<td>90%</td>
<td>100%</td>
<td>115%</td>
</tr>
<tr>
<td></td>
<td>Electricity Price</td>
<td>Price Changes</td>
<td>Electricity Price</td>
<td>90%</td>
<td>100%</td>
<td>130%</td>
</tr>
</tbody>
</table>
Risk Matrix

- **A-Risks** (High Likelihood, High Impact):
  - Building Costs
  - Steel Price

- **B-Risks** (Medium Likelihood, Medium Impact):
  - Electricity Price

- **C-Risks** (Low Likelihood, Low Impact):
  - Material Quality
  - Earthquake
  - Concrete Price

- **Risk Matrix Grid**:
  - X-axis: Severity / Impact
  - Y-axis: Likelihood

- **Risk Sources**:
  1. Material Quality
  2. Earthquake
  3. Concrete Price
  4. MEP System
  5. Electricity Price
  6. Building Costs
  7. Steel Price
# Clockwork vs. Houses

<table>
<thead>
<tr>
<th></th>
<th>Clockwork</th>
<th></th>
<th>Houses</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>ConXtech</td>
<td>RC</td>
<td>Steel MF</td>
<td>EBF</td>
</tr>
<tr>
<td><strong>Total Cost</strong></td>
<td>$7,870,000</td>
<td>$8,110,000</td>
<td>$7,380,000</td>
<td>$7,170,000</td>
</tr>
<tr>
<td><strong>Construction Duration</strong></td>
<td>240 days</td>
<td>267 days</td>
<td>263 days</td>
<td>249 days</td>
</tr>
<tr>
<td><strong>Completion Date</strong></td>
<td>8/30/16</td>
<td>10/6/16</td>
<td>9/30/16</td>
<td>9/12/16</td>
</tr>
</tbody>
</table>
Estimates: Compared

- ConXtech: $8,000,000
- Concrete MF: $7,500,000
- Steel MF: $7,000,000
- EBF: $7,000,000

ConXtech is the highest estimate, followed by Concrete MF, Steel MF, and EBF.
Total Value Design

- Goal: Provide valuable Cost Information as Input to Design
- Level 1: General Cost Guidelines
- Level 2: Comparative Assembly Costs
- Level 3: Total Building Value Tracking
  - Regular Intervals (easily repeatable)
  - Visual

### Comparison Table

<table>
<thead>
<tr>
<th></th>
<th>Clockworks</th>
<th>Houses</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>ConXtech</td>
<td>Concrete MF</td>
</tr>
<tr>
<td>A Substructure</td>
<td>$460,000</td>
<td>$470,000</td>
</tr>
<tr>
<td>B Shell</td>
<td>$2,700,000</td>
<td>$2,930,000</td>
</tr>
<tr>
<td>C Interiors</td>
<td>$1,070,000</td>
<td>$1,070,000</td>
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<tr>
<td>D Services</td>
<td>$2,950,000</td>
<td>$2,950,000</td>
</tr>
<tr>
<td>G Building Sitework</td>
<td>$700,000</td>
<td>$700,000</td>
</tr>
<tr>
<td>Total Project Estimate</td>
<td><strong>$7,870,000</strong></td>
<td><strong>$8,110,000</strong></td>
</tr>
</tbody>
</table>
Native Challenge

- Natural Ventilation
- Water Reuse
- Maximum Daylight
- Use of Native Materials for Interior
- Smart Windows

Looking Ahead:
- Heat and Power Unit
LEED Strategies
Sustainable Performance

- Natural Ventilation
- Maximum Occupant Comfort
- Smart Windows
- Maximum Daylight
- Minimal Site Disturbance During Construction

- Water Reuse
- Native Materials for Interior
- Bicycle Racks
- Heat and Power Unit
- Vertical Axis Wind Turbine
## LEED Certification

<table>
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<tr>
<th>LEED Rating Categories</th>
<th>Yes</th>
<th>No</th>
<th>Maybe</th>
<th>Possible Points</th>
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<tbody>
<tr>
<td>Sustainable Site</td>
<td>17</td>
<td>1</td>
<td>8</td>
<td>26</td>
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<tr>
<td>Water Efficiency</td>
<td>3</td>
<td>0</td>
<td>7</td>
<td>10</td>
</tr>
<tr>
<td>Energy &amp; Atmosphere</td>
<td>15</td>
<td>5</td>
<td>17</td>
<td>35</td>
</tr>
<tr>
<td>Materials &amp; Resources</td>
<td>7</td>
<td>1</td>
<td>6</td>
<td>14</td>
</tr>
<tr>
<td>Indoor Environmental Quality</td>
<td>10</td>
<td>1</td>
<td>4</td>
<td>15</td>
</tr>
<tr>
<td>Innovation &amp; Design Process</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>6 bonus</td>
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<tr>
<td>Regional Priority Credits</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>4 bonus</td>
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<tr>
<td><strong>Silver Accredited</strong></td>
<td><strong>52</strong></td>
<td>8</td>
<td>42</td>
<td><strong>50-59</strong></td>
</tr>
</tbody>
</table>
Team Process - Communications
# Team Process - Production

## Task List

<table>
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<th>What</th>
<th>By</th>
<th>For</th>
<th>By When</th>
<th>Estimated Time Needed to Complete</th>
<th>Date/Time Completed</th>
<th>Completion Status</th>
<th>Actual Time</th>
<th>File Name(s)</th>
<th>File Location(s)</th>
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**IPD Production Plan**
Team Progress

Good Interdisciplinary Collaboration

What Worked
Lessons Learned

Did this change?
I didn’t see that wave

Clustered Team Dynamics

Fully Integrated Team Dynamics
Decision Matrix

- Aspects:
  - Aesthetics, “Wow”-Effect
  - User Experience
  - Functionality / Flexibility / Space Efficiency
  - Earthquake Performance
  - Structural Symmetry
  - Building and Life Cycle Costs
  - Construction Time / Constructability / Prefabrication
  - Energy Efficiency
  - MEP Implementation
  - Natural Ventilation and Light
  - Sustainability and Compliance with NATIVE
## Decision Matrix

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<tr>
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<td>Anirudh (owner)</td>
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Team Pacific presents ...

CLOCKWORK
Team Pacific would like to thank:

Renate Fruchter
Bjorn Wundsch
Anirudh Rao
Greg Luth
Professor Krawinkler
Eric Borchers
Henry Tooryani
Professor Kolderup
Dennis Kwan