Team Process

We are all one

Learning Experience

Respect

Open Communication

Team Organization Flow and Responsibilities

Two weekly team meetings
2 initial weeks = 33 hours
9 weeks = 86 hours

More than 50% of time optimization

- meeting hours
- productivity

Challenges Champions

BIM Champion

Project Manager

P A C I F I C
Team Communication and Workflow

Daily communication

Brainstorm Ideas

miro

Meetings

Initial Planning

Final Planning

Team Document Management

Workflow

Organization

Model Files

Task interdependence

Nialli™ Visual Planner
Team Design and BIM Collaboration

1. BIM execution plan
   BIM pull plan / weekly LOD target

2. Weekly clash detection
   Clash detection to meet LOD target

   **Instructions on Discord**

   - Clash detection to meet LOD target
   - Issue-driven
   - Remove clash right away

3. Subgroup clash detection
   Issue-driven

4. VR clash detection
   Remove clash right away
This walkway is challenging!
Let’s check the braces!
Let’s check clash Detection
Rounded building will cost more!
Look closer guys!
This rounded walkway looks nice!
We have some clashes with STR-MEP
This rounded walkway looks nice!
Rounded building will cost more!
Look closer guys!
Let’s check the braces!
This walkway is challenging!
We have some clashes with STR-MEP
This rounded walkway looks nice!
Hands together! Let’s go TEAM!
Location on site
Climate conditions

- Annual temperature distribution.

- Monthly precipitation.

- Annual relative humidity.

💧 Average humidity: 75%
Sun / wind analysis

-Sun path.

-Sunshine hours.

-Average wind speed.
Soil Conditions:
Well sorted fine to medium sand
Bearing Capacity: 3500 psf
Not in Liquefaction Zone
Water Table: 14' below grade

Earthquake:

1. Risk Category: III
ASE7-16: "Buildings and other structures that represent a substantial hazard to human life in the event of failure"

2. Seismic site class: C
Very dense soil and soft rock (Vs = 386 m/s)
THE LINK
Big Idea

Resilient
It is Strong

Extension of Nature
It is Sustainable

Learning and connecting
It connects

Technology, Future and Innovation
It is Advanced

THE LINK

Strong and resilient as a chain, connecting all of us, our knowledge and ideas for this Big building that will LINK all around it.

Your team is as strong as your weakest member!

TEAM

It makes everything possible
Architecture
Big Idea

Conventional floor plan → Open-floor plan → Rethinking floor plan → Collaboration landscape
Conceptual 3D model
3d Video
3D model - Stairs
Floor Plan - 1

- Small Classroom 96.39 m²
- Small Classroom 36.36 m²
- Large Classroom 75.06 m²
- Toilet
- Entrance

Auditorium 162.73 m²
Floor Plan 0

- Student office: 600 m²
- Seminar room: 1520 m²
- Entrance

Legend:
- Faculty office: 17.95 m²
- Faculty office: 18.59 m²
- Faculty office: 19.39 m²
- Toilet: 12.95 m²
- Seminar room: 1520 m²
Structural Engineering
Loads

**Gravity Loads / Dead**
*Type of Structure and Finishing*
- Steel - 490pcf
- Wood - 35pcf
- Concrete - 150cpf

**Live Loads / Occupancy**
*ASCE 7-16*
- Classroom/Office - 50psf
- Lobbies and entrance - 100psf
- Corridors - 80psf
- Stair/Elevator - 100psf
- Storage - 125psf
- Roof - 20psf

**Environmental Loads**
- Wind
- Seismic

Equivalent Lateral Force Procedure – ASCE 7-16

Seismic Loads > Wind Loads
Seismic design and detailing requirements are more restrictive than wind requirements
Base Isolation System – Steel design

- Reduce displacements and forces
- Reduces foundation costs
- Reduces damages after an event
- Expensive system
Floor Plans – Grids Floor –2 and –1

- HSS 12" X 12" X 3/8"
- W16X57
- W10X33
- W24X84
- Concrete Shear Wall
- Braces
Floor Plans – Grids Floor 0 - Ceilings

- FACULTY LOUNGE (1000)

Materials:
- HSS 12" X 12" X 3/8"
- W16/57
- W10/33
- W24/84
- Concrete Shear Wall
- Braces
Steel Braced System

Gravity Load

Lateral Load
**Krawinkler Fuses and Rocking walls – Wood design**

- Dissipation of Energy
- The fuses can be replaced
- PT self-centering
- Reduce drift

---

**Structural Systems - Krawinkler Fuses**

**Krawinkler Fuses**
Structural Systems – Wood Design

Glulam and Cross Laminated Timber CLT
Composed by Glulam columns and beams and CLT Rocking walls
With basic member sizes:

Connections

- Spline Connection
- Half Lap Connection
- Floor Ledger Connection
- Concrete Hold Down

Post installed on site to suit conditions. Allow tolerance for leveling SSL plate or grout.
Wood Design - Floor Plan -2

- Columns (12"x12")
- Column (12"x20")
- Beams (8"x20")
- Beams (8"x30")
- Rocking walls (8")
- Isolated Foundation 8"x8"x2"
Wood Design

Wood structure with Rocking walls

- Beams roof (6”x24”)
Loads Path

Wood Rocking wall System

Gravity Load

Lateral Load

Compression

Tension
Foundation Systems

Soil Conditions:

- Well sorted fine to medium sand
- Bearing Capacity: 3500 psf
- Water table

Consideration for both Structural Systems

Isolated RC Footing
The design is not yet defined
Fire Resistance - Protection

**Steel**
- Spray insulation
- Intumescent paint
- Fire Resistant Boards
- Concrete encasement

**CLT**
"Moen-Wood "Fire-Resistant Laminated Lumber with Fire-Resistant Column-Beam Connection"
Gravity System:
- HSS Columns & W shapes Beams
- Composite Metal Deck

Lateral System
- Base Isolation
- Concrete Shear Wall
- BRF (Buckling Restrained Braced Frames)

Gravity System:
- Glulam columns & beams
- Composite CLT

Lateral System
- CLT Rocking Walls
- Krawinkler Fuses
## Structural Systems Comparison

<table>
<thead>
<tr>
<th></th>
<th>Steel</th>
<th>Wood</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Cost</strong></td>
<td>$$$$</td>
<td>$</td>
</tr>
<tr>
<td><strong>Carbon Footprint</strong></td>
<td><img src="image" alt="Trees" /></td>
<td><img src="image" alt="Trees" /></td>
</tr>
<tr>
<td><strong>Parametric Design</strong></td>
<td><img src="image" alt="Smiley" /></td>
<td><img src="image" alt="Smiley" /></td>
</tr>
<tr>
<td><strong>Prefabrication</strong></td>
<td><img src="image" alt="Smiley" /></td>
<td><img src="image" alt="Smiley" /></td>
</tr>
<tr>
<td><strong>Structure Weight</strong></td>
<td><img src="image" alt="KG KG" /></td>
<td><img src="image" alt="KG" /></td>
</tr>
<tr>
<td><strong>Material Reuse</strong></td>
<td><img src="image" alt="Check" /></td>
<td><img src="image" alt="Check" /></td>
</tr>
</tbody>
</table>
Mechanical
Electrical
Plumbing
Shading simulation- Conclusions

Expected big sun loads in central part of the building

Parametric design in the process of roof creation
Sun analysis - Results

Daylight factor:

-1 Floor

0 Floor

1st Floor
Decision matrix for HVAC secondary system:

<table>
<thead>
<tr>
<th>The Link</th>
<th>NV</th>
<th>CAV</th>
<th>VAV</th>
<th>Air Conditioners</th>
<th>Fan Coils (ceiling)</th>
<th>Fan Coils (windows)</th>
<th>Chilled beams</th>
<th>Radiant ceilings</th>
<th>Radiant floors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initial cost</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>Maintenance cost</td>
<td>5</td>
<td>3</td>
<td>4</td>
<td>3</td>
<td>4</td>
<td>2</td>
<td>3</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Loudness</td>
<td>3</td>
<td>2</td>
<td>3</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>Advanced</td>
<td>3</td>
<td>2</td>
<td>3</td>
<td>2</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>Resilience</td>
<td>4</td>
<td>4</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>Heating Efficiency</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Cooling Efficiency</td>
<td>4</td>
<td>3</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>3</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Comfort</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>2</td>
<td>4</td>
<td>2</td>
<td>4</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Aesthetic</td>
<td>5</td>
<td>3</td>
<td>3</td>
<td>1</td>
<td>3</td>
<td>1</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>Humidity control</td>
<td>2</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>3</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Service life</td>
<td>5</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>sum</td>
<td>39</td>
<td>34</td>
<td>38</td>
<td>32</td>
<td>40</td>
<td>32</td>
<td>35</td>
<td>33</td>
<td>35</td>
</tr>
</tbody>
</table>

Primary system:
Wind Heat Pump

Secondary system:
VAV+ Fan coils (support)

Ventilation:
Primary: Natural Ventilation
Secondary: VAV system
Tree of ducts - 2nd floor

- Column

- Structural wall
Tree of ducts - 1st floor

- Column
- Structural wall
Tree of ducts - 0 floor

1st Floor

- Column

- Structural wall
Preliminary PV assumptions

- Lightning --> 10 kW
- Projectors, screens --> 17 kW
- AHU --> 10 kW
- Server room --> 4 kW
- Heat pump --> 5 kW
- 60 computers + printers --> 16 kW
- Toilet dryers --> 9 kW

71 kW --> 50 kW  (not every equipment will be used in same time- 0.7 usage factor)

Assumption: Electricity is mainly operating in building for 13 h/day

Number of operating hours in year: 4745 h

Energy spending during the year: 4745 h * 50 kW = 237 000 kWh

Energy required from public grid: 237 000 kWh - 147 000 kWh = 90 000 kW

Energy provided by PV panels: 147 000 kWh/an (Assumed solar panel yield: 19%)
STV analysis

Steel construction

<table>
<thead>
<tr>
<th>Impact</th>
<th>Target</th>
<th>Project</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbon (kgCO2e)</td>
<td>3 714 897</td>
<td>2 727 563</td>
<td>73%</td>
</tr>
<tr>
<td>Energy (MJ)</td>
<td>120 509 807</td>
<td>33 425 175</td>
<td>28%</td>
</tr>
<tr>
<td>Water (kgH2O)</td>
<td>73 347 945</td>
<td>476 814 379</td>
<td>650%</td>
</tr>
<tr>
<td>Ozone (kgCFC11)</td>
<td>-</td>
<td>8,36E-02</td>
<td>-</td>
</tr>
</tbody>
</table>

Assumptions:

- Toilet Flow Rate: 1.6 gal/flush
- Urinal Flow Rate: 1.0 gal/flush
- WC Sink Flow Rate: 1.4 gal/min
- Lab Sink Flow Rate: 0.0 gal/min
- Kitchen Sink Flow Rate: 2.0 gal/min
- Shower Flow Rate: 1.8 gal/min
- Landscaping Water Use: 150 gal
- Rainwater Collection: 300 000 gal

Timber construction

<table>
<thead>
<tr>
<th>Impact</th>
<th>Target</th>
<th>Project</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbon (kgCO2e)</td>
<td>3 714 897</td>
<td>2 278 547</td>
<td>61%</td>
</tr>
<tr>
<td>Energy (MJ)</td>
<td>120 509 807</td>
<td>29 331 513</td>
<td>24%</td>
</tr>
<tr>
<td>Water (kgH2O)</td>
<td>73 347 945</td>
<td>456 456 717</td>
<td>636%</td>
</tr>
<tr>
<td>Ozone (kgCFC11)</td>
<td>-</td>
<td>6,61E-02</td>
<td>-</td>
</tr>
</tbody>
</table>
Construction Management
How are we going to plan a sustainable Construction site for both idea?

On site soil Soil management
Wearable safety assist devices
Waste management/ Scheduling

Concrete  Sheetrock
Metal      Cardboard
Plastic    Wood
Landfill
1. N State Dr is a dead end (side road)  
2. Winston Dr has a traffic count of 874 cars/day.  
3. Lake Merced Blvd has a traffic count of 4097 cars/day.  
4. Only access is from N State Rd which has a width of 30 ft.
Major Suppliers

- **Project site**
- **Timber Fabricator**
- **Steel Fabricator**
- **Concrete Supply Factory**
- **Pre-Fab**
- **Equipment Lease**
Can we automate the crane selection and placement process?

For each (X, Y) inside site boundaries, the lifting radius is calculated (R).

This process is repeated for every crane in the database.

Safety checks & clearances calculated.

For each theta available, Boom length is calculated (L).

Weight allowable from crane load charts is found.

Crane Database
(11 cranes)
Case Study - Applying My-Lift on The LINK

Characteristic | Value
--- | ---
Length | 21.5 ft.
Height | 56 ft.
Weight | 26,000 lbs.

Heaviest crane lift
CLT Shear Wall

User Input Module

User Output Module
# Details of the Selected Crane

**AC-Demag 120 (All-terrain)**

<table>
<thead>
<tr>
<th>Item</th>
<th>Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximum gross capacity (t)</td>
<td>120</td>
</tr>
<tr>
<td>Maximum Boom length (ft.)</td>
<td>196.9</td>
</tr>
<tr>
<td>Maximum Radius (ft.)</td>
<td>170.6</td>
</tr>
<tr>
<td>Maximum Operating Angle (theta)</td>
<td>76</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Lift Parameter</th>
<th>Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>X, Y (ft)</td>
<td>217, 31</td>
</tr>
<tr>
<td>Boom Length (ft)</td>
<td>135.2</td>
</tr>
<tr>
<td>Operating Theta</td>
<td>45</td>
</tr>
<tr>
<td>Allowable Weight (lbs)</td>
<td>32,800</td>
</tr>
</tbody>
</table>

2 cranes (on both sides of the building)
Crane Selection VR troubleshoot

Proposed position/types

Analyze and Troubleshoot

Finalize

Safety issue
Efficiency
Constructability
Site Layout - Excavation / Structure work

- Site
- Office/Labor trailer
- Excavation Line
- On Site soil storage for backfill
- Waste yard
- Material storage

Major Waste
- Concrete
- Metal
- Wood

Soil storage 25,000CF

Mobile Crane 197feet/3.1 Klbs.

Secured minimum width for Trucks to go around (12')
Site Layout - Structure work Steel/ Timber

Major Waste
>Concrete
>Metal
>Wood

In site carry in capacity
44 feet * 8 feet 6 inches

Concrete Pump
90 feet
3,200 CF/hour (max)

Mobile Crane
197 feet / 3.1 Klbs

Trajectory analysis

Site
Office/Labor trailer
Building Footprint
Waste yard
Material storage

Site Entrance
Material Handling Assembly area (Steel/ Timber)
BIM Model

RSMeans data from Gordian®

Assemblies Cost

Suppliers

Quotes from vendors & subs

Model Take-off

Quantities

Pricing

TVD - The Link - The Process

TVD tool
TVD - The Link - BIM Information Integration

Arch BIM Model

Steel & Timber Structure BIM Model

MEP BIM Model

Dynamo

Model Take-off

- Foundations
- Slabs
- Columns/Framing
- Walls
- Doors
- Ducts
TVD – The Link Construction Cost Tracking

Base Isolation
21,200 sf. Curtain Wall
High Services Cost

$12,000,000
$1,900,000
$11,100,000
$10,200,000
$9,300,000
$8,400,000
$7,500,000
$6,600,000
$5,700,000
$4,800,000
$3,900,000
$3,000,000
$2,100,000
$1,200,000

RS-Means Original
The Crit
Winter Presentation

Link (Timber)
Link (Steel)

Model at 100%
Fog Catcher, PV Solar System

$12,300,000
$11,600,000

Curtain Wall -> X-Series Wall
Glass Roof -> Roof Structure
Bigger Timber Elements

Target
TVD - The Link - Detailed Cost Breakdown

Cheaper floor and roof construction in case of timber framing by $400K

Less $300K for CLT Shear Walls + Krawinkler fuses than base isolation

Target

$12.3 million

$11.6 million
# Time Schedule - The Link - Timber vs. Steel

## Pacific 2021 Schedule

**Select a period to highlight at right.**

<table>
<thead>
<tr>
<th>ACTIVITY</th>
<th>PLAN START</th>
<th>DURATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mobilization</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Site Preparation</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>Excavation &amp; Grading</td>
<td>5</td>
<td>3</td>
</tr>
<tr>
<td>Foundations</td>
<td>8</td>
<td>4</td>
</tr>
<tr>
<td>Superstructure Shell</td>
<td>12</td>
<td>10</td>
</tr>
<tr>
<td>Exteriors (Skin façade)</td>
<td>19</td>
<td>6</td>
</tr>
<tr>
<td>MEP (Rough-In + Trim-out)</td>
<td>19</td>
<td>12</td>
</tr>
<tr>
<td>Interiors (Finishing)</td>
<td>25</td>
<td>10</td>
</tr>
<tr>
<td>Equipment &amp; Furnishings</td>
<td>34</td>
<td>2</td>
</tr>
<tr>
<td>Commissioning</td>
<td>36</td>
<td>2</td>
</tr>
<tr>
<td>Landscaping</td>
<td>36</td>
<td>3</td>
</tr>
<tr>
<td>Punchlist &amp; Closeout</td>
<td>39</td>
<td>2</td>
</tr>
</tbody>
</table>

### Mobilization
- **PLAN START:** 1
- **DURATION:** 2 weeks

### Site Preparation
- **PLAN START:** 3
- **DURATION:** 2 weeks

### Excavation & Grading
- **PLAN START:** 5
- **DURATION:** 3 weeks

### Foundations
- **PLAN START:** 8
- **DURATION:** 4 weeks

### Superstructure Shell
- **PLAN START:** 12
- **DURATION:** 10 weeks

### Exteriors (Skin façade)
- **PLAN START:** 19
- **DURATION:** 6 weeks

### MEP (Rough-In + Trim-out)
- **PLAN START:** 19
- **DURATION:** 12 weeks

### Interiors (Finishing)
- **PLAN START:** 25
- **DURATION:** 10 weeks

### Equipment & Furnishings
- **PLAN START:** 34
- **DURATION:** 2 weeks

### Commissioning
- **PLAN START:** 36
- **DURATION:** 2 weeks

### Landscaping
- **PLAN START:** 36
- **DURATION:** 3 weeks

### Punchlist & Closeout
- **PLAN START:** 39
- **DURATION:** 2 weeks

---

### Finish Foundations
- **Finish Exteriors (Thanksgiving):**
- **Duration:** 40 weeks

### Rain Season (Dec to Feb)
- **Duration:** 1 week delay
- **(Christmas, New Year’s)**

### Crane to site

### Timber shell longer - 4 weeks

### Wood CLT Walls

---

### Start early June to avoid Rain Season

### Pacific 2021 Schedule

**Select a period to highlight at right.**

<table>
<thead>
<tr>
<th>ACTIVITY</th>
<th>PLAN START</th>
<th>DURATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mobilization</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Site Preparation</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>Excavation &amp; Grading</td>
<td>5</td>
<td>3</td>
</tr>
<tr>
<td>Foundations</td>
<td>8</td>
<td>4</td>
</tr>
<tr>
<td>Superstructure Shell</td>
<td>12</td>
<td>6</td>
</tr>
<tr>
<td>Exteriors (Skin façade)</td>
<td>16</td>
<td>6</td>
</tr>
<tr>
<td>MEP (Rough-In + Trim-out)</td>
<td>16</td>
<td>12</td>
</tr>
<tr>
<td>Interiors (Finishing)</td>
<td>22</td>
<td>10</td>
</tr>
<tr>
<td>Equipment &amp; Furnishings</td>
<td>31</td>
<td>2</td>
</tr>
<tr>
<td>Commissioning</td>
<td>33</td>
<td>2</td>
</tr>
<tr>
<td>Landscaping</td>
<td>33</td>
<td>3</td>
</tr>
<tr>
<td>Punchlist &amp; Closeout</td>
<td>36</td>
<td>2</td>
</tr>
</tbody>
</table>

### Mobilization
- **PLAN START:** 1
- **DURATION:** 2 weeks

### Site Preparation
- **PLAN START:** 3
- **DURATION:** 2 weeks

### Excavation & Grading
- **PLAN START:** 5
- **DURATION:** 3 weeks

### Foundations
- **PLAN START:** 8
- **DURATION:** 4 weeks

### Superstructure Shell
- **PLAN START:** 12
- **DURATION:** 6 weeks

### Exteriors (Skin façade)
- **PLAN START:** 16
- **DURATION:** 6 weeks

### MEP (Rough-In + Trim-out)
- **PLAN START:** 16
- **DURATION:** 12 weeks

### Interiors (Finishing)
- **PLAN START:** 22
- **DURATION:** 10 weeks

### Equipment & Furnishings
- **PLAN START:** 31
- **DURATION:** 2 weeks

### Commissioning
- **PLAN START:** 33
- **DURATION:** 2 weeks

### Landscaping
- **PLAN START:** 33
- **DURATION:** 3 weeks

### Punchlist & Closeout
- **PLAN START:** 36
- **DURATION:** 2 weeks

### Finish Foundations
- **Finish Exteriors (Thanksgiving):**
- **Duration:** 37 weeks

### Rain Season (Dec to Feb)
- **Duration:** 1 week delay
- **(Christmas, New Year’s)**

### Crane to site

### Finish of Shell

### Steel, Composite Slab

### 1 week delay
- **(Christmas, New Year’s)**

### Finish Services (Before Christmas)
COME TOGETHER
VIDEO
Big Idea

**Come Together**

- **Anyone and Everyone Together**
  - Accessibility for disabled
  - Respect for everyone's senses

- **Come Together to Grow Together**
  - Skill sharing
  - Collaboration
  - Connecting industry - university

- **Always Hold On Together**
  - Resilient to earthquakes
  - Fully functional during pandemics

**Embrace everyone**
Architecture
Concept
Building flow

Regular use

Emergency exit

Pandemic use
Floor Plan -2
Floor Plan 0
Floor Plan 1
BIM 3D model
Structural Engineering
Structural System – PT Concrete Design

Post Tension Slab – Base Isolation

**Pros**
- Flat Slabs
- Work easily with Grid
- Possibility for Aesthetical Arch.
- Flexibility on design

**Cons**
- Complexity of work
- Reduces prefabrication
Concrete that Sequester Carbon

Concrete produced using CO2 injection on the mixture, sequestering the carbon when it hardens

31700sft = - 60000kg CO2 in the air = 70 acres forest
Structural System Evaluation

Sofistik Analysis on position of shear walls and circular shape structural behavior

- $T = 1.77 \text{ sec}$
- $T = 0.96 \text{ sec}$
- $T = 0.39 \text{ sec}$
Concrete – PT Design

**Floor plans (Member sizes and positions)**
Continuous member size and position

- **Columns (12"x12")**
- **Shear walls (8"x20')(8"x8')**
- **PT - Slab (8"-10")**
The structural system (shear wall positions) aligned with facade elements
Load Path - Concrete

Concrete – PT Design with shear walls

Gravity Load

Lateral Load

Compression

Tension
Structural System – Steel

Steel with braces and moment frames

Roof Design

Lateral System Design:
Moment Frame + Braces
Gravity Loads

Gravity Loads / Dead Loads
Steel - 490pcf
Concrete Composite Slab - 150cpf

Live Loads / Occupancy - ASCE 7-16
Classroom/Office - 50psf
Lobbies and entrance - 100psf
Corridors - 80psf
Stair/Elevator - 100psf
Roof - 20psf

Preliminary Design:
Columns: (Too large)
HSS 14X14
HSS12X12

Beams: (Too small)
W10X26
W12x35
W24X84

Etabs Linear Static Analysis

Load Combination:
1. 1.4 DL
2. 1.2DL + 1.6LL
3. 1.2 DL + EQ

By calculation and simplification, we assume DL = 100 psf and LL = 75 psf (roof = 20 psf)

Gravity Design:
Columns:
HSS 14 X 14 X 1/2
HSS 10 X 10 X 5/16

Beams:
W10 x 39
W14 x 53
W33x130
Typical Floor Plan
Typical Floor Plan - Ceilings

- W 14 x 53
- W 10 x 39
- HSS 10 x 10 x 5/16
- HSS 8 x 8 x 1/4
- Braces
Load Path - Steel

Steel Design – Braces and Moment Frames

Gravity Load

Lateral Load
Structural System – Steel

Etabs Analysis for implementing Lateral System

<table>
<thead>
<tr>
<th>Case</th>
<th>Mode</th>
<th>Period (sec)</th>
<th>UX</th>
<th>UY</th>
<th>UZ</th>
<th>RZ</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modal 1</td>
<td>0.779</td>
<td>0.468</td>
<td>0.47</td>
<td>0</td>
<td>0.063</td>
<td></td>
</tr>
<tr>
<td>Modal 2</td>
<td>0.631</td>
<td>0.501</td>
<td>0.499</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Modal 3</td>
<td>0.352</td>
<td>0.037</td>
<td>0.034</td>
<td>0</td>
<td>0.029</td>
<td></td>
</tr>
<tr>
<td>Modal 4</td>
<td>0.245</td>
<td>0.407</td>
<td>0.542</td>
<td>0</td>
<td>0.051</td>
<td></td>
</tr>
<tr>
<td>Modal 5</td>
<td>0.202</td>
<td>0.57</td>
<td>0.428</td>
<td>0</td>
<td>0.001</td>
<td></td>
</tr>
<tr>
<td>Modal 6</td>
<td>0.145</td>
<td>0.398</td>
<td>0.562</td>
<td>0</td>
<td>0.04</td>
<td></td>
</tr>
<tr>
<td>Modal 7</td>
<td>0.121</td>
<td>0.549</td>
<td>0.385</td>
<td>0</td>
<td>0.066</td>
<td></td>
</tr>
<tr>
<td>Modal 8</td>
<td>0.109</td>
<td>0.048</td>
<td>0.505</td>
<td>0</td>
<td>0.447</td>
<td></td>
</tr>
<tr>
<td>Modal 9</td>
<td>0.102</td>
<td>0.514</td>
<td>0.226</td>
<td>0</td>
<td>0.261</td>
<td></td>
</tr>
</tbody>
</table>
Troubleshooting: Columns are more slender than other 14’ height columns.
Load Case – Pushover Analysis

Target Displacement: \[ \delta = C_0C_1C_2S_a\frac{\tau^2}{4\pi^2} \]

DBE level: 8.494 in  
MCE level: 12.752 in

Pushover Mass: DL + 0.25LL

Directions for Pushover Analysis

DBE-Dir1  DBE-Dir2  MCE-Dir1  MCE-Dir2

Immediate Occupancy  Life Safety  Collapse Prevention
Increase the interior columns’ size from HSS10X10X5/16 to HSS14X14X1/2

Immediate Occupancy
Life Safety
Collapse Prevention
Structural System – Steel Diagrid

Steel Design – Diagrid

**Pros**
- Structurally and aesthetically effective
- Diagonal members carry gravity loads as well as lateral forces
- Provides bending & shear rigidity
- Different arrangements can be done

**Cons**
- Designing can be very complicated
- Prefabrication may increase costs
- Difficult to predict global stiffness demand
Structural System – Steel Diagrid

**Floors 2 and -1**

- Columns (12"x12")
- Steel Beams W18x65
- Composite Slab 5"
- Cables

**Legend:**
- Truss
- Diagrid members Presented floor
- Diagrid members Previous floor
- Tension Ring
Structural System – Steel Diagrid

Floors 0, 1 and Ceiling

- Columns (12"x12")
- Steel Beams W18x65
- Composite Slab 5"
- Cables
- Diagrid members Presented floor
- Diagrid members Previous floor
- Truss
- Tension Ring
Load Path - Diagrid

Steel Design – Diagrid

Gravity Load

Lateral Load
The structural system will be aligned with a second facade concept
Foundation Systems

Soil Conditions:

Initial Consideration
Isolated RC Footing
The design is not yet defined

Well sorted fine to medium sand
Bearing Capacity 3500 psf
Water table
Structural Design Overview Come Together

**Gravity System:**
- Concrete Columns
- Post Tensioning Slabs

**Lateral System**
- Base Isolation
- Concrete Shear Wall
- Inner and outer walls

**Gravity System:**
- HSS Columns & W shapes Beams
- Composite Metal Deck

**Lateral System**
- Base Isolation
- BRF (Buckling Restrained Braced Frames)
- Moment Frames

**Gravity System:**
- HSS Columns & W shapes Beams
- Composite Metal Deck

**Lateral System**
- Base Isolation
- Diagrid System
## Structural Systems Comparison

<table>
<thead>
<tr>
<th></th>
<th>Concrete - PT</th>
<th>Steel</th>
<th>Steel (Diagrid)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Cost</strong></td>
<td>$$$$</td>
<td>$$$$</td>
<td>$$$$</td>
</tr>
<tr>
<td><strong>Carbon Footprint</strong></td>
<td>🌳</td>
<td>🌳🌳</td>
<td>🌳🌳</td>
</tr>
<tr>
<td><strong>Parametric Design</strong></td>
<td>😞</td>
<td>😊😊</td>
<td>😊😊</td>
</tr>
<tr>
<td><strong>Prefabrication</strong></td>
<td>😞</td>
<td>😊😊</td>
<td>😊😊</td>
</tr>
<tr>
<td><strong>Structure Weight</strong></td>
<td>KG KG KG</td>
<td>KG KG</td>
<td>KG KG</td>
</tr>
<tr>
<td><strong>Material Reuse</strong></td>
<td>✗</td>
<td>✅</td>
<td>✅</td>
</tr>
</tbody>
</table>
Shading simulation - Conclusions

Parametric design in the process of creating a facade and roofing.
Sun analysis - Results

Daylight factor:

-1 Floor

0 Floor

1st Floor
HVAC Solutions - building division

Continous people presence
Temporary peoples presence
Without peoples presence
HVAC Solutions - building division

Continous people presence

Temporary peoples presence

Without peoples presence
### HVAC Solutions

#### Decision matrix for HVAC secondary system:

<table>
<thead>
<tr>
<th>Come together</th>
<th>NV</th>
<th>CAV</th>
<th>VAV</th>
<th>Air Conditioners</th>
<th>Fan Coils (ceiling)</th>
<th>Fan Coils (windows)</th>
<th>Passive chilled beams</th>
<th>Radiant ceilings</th>
<th>Radiant floors</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Initial cost</strong></td>
<td>5</td>
<td>3</td>
<td>2</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td><strong>Maintenance cost</strong></td>
<td>5</td>
<td>3</td>
<td>4</td>
<td>3</td>
<td>4</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td><strong>Ability to create drafts</strong></td>
<td>3</td>
<td>2</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>2</td>
<td>5</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td><strong>Heating Efficiency</strong></td>
<td>4</td>
<td>3</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>3</td>
<td>4</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td><strong>Cooling Efficiency</strong></td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>3</td>
<td>3</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td><strong>Noise</strong></td>
<td>4</td>
<td>2</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>2</td>
<td>5</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td><strong>Comfort</strong></td>
<td>3</td>
<td>3</td>
<td>4</td>
<td>2</td>
<td>3</td>
<td>2</td>
<td>4</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td><strong>Aesthetic</strong></td>
<td>5</td>
<td>3</td>
<td>3</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td><strong>Humidity control</strong></td>
<td>2</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>3</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td><strong>Service life</strong></td>
<td>5</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>5</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td><strong>sum</strong></td>
<td>33</td>
<td>30</td>
<td>35</td>
<td>31</td>
<td>33</td>
<td>26</td>
<td>35</td>
<td>39</td>
<td>39</td>
</tr>
</tbody>
</table>

**Primary system:**
- Ground heat pump

**Secondary system:**
- Radiant ceilings + Passive chilled beams

**Ventilation:**
- Primary: Natural Ventilation
- Secondary: VAV system
Tree of ducts - 2nd floor

- Column
- Structural wall

-2nd Floor
Tree of ducts - 1st floor

- Column
- Structural wall

-1st Floor
Floor sandwich – Radiant Ceiling

Option #1

air grille

radiant ceiling
Floor sandwich - Chilled Beams

Option #2 with chilled beams
Preliminary PV assumptions

- Lightning --> 8 kW
- Projectors, screens --> 17 kW
- AHU --> 9 kW
- Server room --> 4 kW
- Heat pump --> 5 kW
- 60 computers + printers --> 16 kW
- Toilet dryers --> 8 kW

67 kW --> 47 kW (not every equipment will be use in same time - 0.7 usage factor)

Assumption: Electricity is mainly operating in building for 13 h/day

Number of operating hours in year: 4745 h

Energy spending during the year: 4745 h * 50 kW = 223 400 kWh

Energy provided by PV panels: 190 400 kWh/an (Assumed solar panel yield: 19%)

Energy required from public grid: 223 400 kWh - 190 400 kWh = 33 000 kW

(57 000 kWh less than The Link)
Steel construction

<table>
<thead>
<tr>
<th>Impact</th>
<th>Target</th>
<th>Project</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbon (kgCO2e)</td>
<td>3 714 897</td>
<td>2 819 332</td>
<td>76%</td>
</tr>
<tr>
<td>Energy (MJ)</td>
<td>120 509 807</td>
<td>33 940 814</td>
<td>28%</td>
</tr>
<tr>
<td>Water (kgH2O)</td>
<td>73 347 945</td>
<td>478 555 105</td>
<td>652%</td>
</tr>
<tr>
<td>Ozone (kgCFC11)</td>
<td>-</td>
<td>8,42E-02</td>
<td>-</td>
</tr>
</tbody>
</table>

Concrete construction

<table>
<thead>
<tr>
<th>Impact</th>
<th>Target</th>
<th>Project</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbon (kgCO2e)</td>
<td>3 714 897</td>
<td>2 586 544</td>
<td>89%</td>
</tr>
<tr>
<td>Energy (MJ)</td>
<td>120 509 807</td>
<td>30 326 540</td>
<td>25%</td>
</tr>
<tr>
<td>Water (kgH2O)</td>
<td>73 347 945</td>
<td>476 828 396</td>
<td>650%</td>
</tr>
<tr>
<td>Ozone (kgCFC11)</td>
<td>-</td>
<td>9,28E-02</td>
<td>-</td>
</tr>
</tbody>
</table>

Assumptions:
- Toilet Flow Rate: 1.6 gal/flush
- Urinal Flow Rate: 1.0 gal/flush
- WC Sink Flow Rate: 1.4 gal/min
- Lab Sink Flow Rate: 0.0 gal/min
- Kitchen Sink Flow Rate: 2.0 gal/min
- Shower Flow Rate: 1.8 gal/min
- Landscaping Water Use: 150 gal
- Rainwater Collection: 500 000 gal
Construction Managers
Site Layout - Excavation / Structure work

- Site
- Office/Labor trailer
- On Site soil storage for backfill
- Waste yard
- Material storage

Site Entrance
- Excavation Line
- Extra shore wall

- Concrete Pump
  - 90 feet
  - 3,200 CF/hour (max)

- Soil storage
  - 25,000 CF

Major Waste:
- Concrete
- Metal
- Wood

Work with mobile cannot be carried out on a pouring day
Site Layout - Structure work PT concrete / Steel

Major Waste
>Concrete
>Steel
>Wood

Site
Office/Labor trailer
Building Footprint
Waste yard
Material storage

Site Entrance
Material Handling
Assembly area (Steel)

Site
Office/Labor trailer
Building Footprint
Waste yard
Material storage

9500CF/floor (Concrete)
95pieces/floor (Steel)

Mobile Crane
197feet/3.1 Klbs
Case Study - Applying My-Lift on Come Together

User Input Module
- Heaviest Lift: AHU (4,000 lbs)
- Furthest Lift: HSS Column (1,800 lbs)
- Liebherr LTF (1060)

User Output Module

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Location</td>
<td>X=229 ft. Y=104 ft.</td>
</tr>
<tr>
<td>Height</td>
<td>56 ft.</td>
</tr>
<tr>
<td>Weight</td>
<td>1,800 lbs.</td>
</tr>
</tbody>
</table>

Furthest crane lift
- HSS Column
### Details of the Selected Crane

#### Liebherr LTM (1090-4.1)

<table>
<thead>
<tr>
<th>Lift Parameter</th>
<th>Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>X, Y (ft)</td>
<td>119, 35</td>
</tr>
<tr>
<td>Boom Length (ft)</td>
<td>164</td>
</tr>
<tr>
<td>Operating Theta</td>
<td>29</td>
</tr>
<tr>
<td>Allowable Weight (lbs)</td>
<td>7,000</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Item</th>
<th>Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximum gross capacity (t)</td>
<td>90</td>
</tr>
<tr>
<td>Maximum Boom length (ft.)</td>
<td>164</td>
</tr>
<tr>
<td>Maximum Radius (ft.)</td>
<td>176</td>
</tr>
<tr>
<td>Maximum Operating Angle (theta)</td>
<td>82</td>
</tr>
</tbody>
</table>

2 cranes (on both sides) ↔ The LINK

1 crane (placed centrally) ↔ Come Together
TVD – Come Together Construction Cost Tracking

- **Base Isolation**: Circular slabs & walls
- **High Shell Cost**

**Target**

- **RS-Means Original**: $11,600,000
- **The Crit**: $11,200,000
- **Winter Presentation**:
  - CT (Concrete)
  - CT (Braces)
  - CT (Diagrid)

**Model at 100%**
- Fog Catcher, PV Solar System
- $13,000,000
- $13,200,000
- $12,400,000
- $12,540,000
- $12,100,000

- **Curtain Wall** -> **X-Series Wall**
- **Acoustical Ceiling** -> **Exposed Slabs**
- **Cheaper Interiors Cost (20% less footprint)**
Cheaper floor and roof construction in case of Concrete by $300K - $500K
The LINK vs. Come Together

**The LINK**
- $3.8 M

**Come Together**
- $4.2 M

- Higher shell cost by 400K
- Circular Slabs with increased Labor and Formwork costs
- Bigger-sized Steel Sections (W18×65 vs. W16×57 and W10×33)
- Higher Concrete Quantities (Extra 4,000 sf.)
- Higher Exterior Walls Quantities (24,200 sf. vs. 21,200 sf.)

**The LINK**
- $1.2 M

**Come Together**
- $1.7 M

- Lower Interiors cost by 500K
- Reduced interior footprint by 20%
- Lower Interior Walls Quantities (18,500 sf., half the quantity of the LINK)
- Mix of Acoustical Ceilings & Exposed Slabs
- Cheaper floorings and wall finishes.
Time Schedule – Come Together - Concrete vs. Steel

**Concrete**
- mobilization: 1 week
- site preparation: 2 weeks
- excavation & grading: 4 weeks
- foundations: 3 weeks
- superstructure shell: 13 weeks (longer - 5 weeks)
- exteriors (skin/finish): 8 weeks
- MEP (rough-in + trim-out): 8 weeks
- interiors (finish): 10 weeks
- equipment & furnishing: 2 weeks
- commissioning: 2 weeks
- landscaping: 3 weeks
- punchlist & closeout: 2 weeks

**Steel, Composite Slab**
- mobilization: 1 week
- site preparation: 2 weeks
- excavation & grading: 4 weeks
- foundations: 3 weeks
- superstructure shell: 8 weeks
- exteriors (skin/finish): 8 weeks
- MEP (rough-in + trim-out): 14 weeks
- interiors (finish): 10 weeks
- equipment & furnishing: 2 weeks
- commissioning: 2 weeks
- landscaping: 3 weeks
- punchlist & closeout: 2 weeks

**Start early June to avoid Rain Season**
- Finish Foundations
- Finish of Shell
- Finish Interiors (Mid-Feb)
- Concrete shell longer - 5 weeks
- 1 week buffer (Christmas, New Year's)

**Rain Season (Dec to Feb)**
- 41 weeks
- 45 weeks
<table>
<thead>
<tr>
<th>Criteria</th>
<th>Link - Timber</th>
<th>Link - Steel</th>
<th>CT - Concrete</th>
<th>CT – Steel (Braces)</th>
<th>CT – Steel (Diagrid)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cost</td>
<td>$11.6 M</td>
<td>$12.3 M</td>
<td>$12.1 M</td>
<td>$12.4 M</td>
<td>$12.54 M</td>
</tr>
<tr>
<td>Time</td>
<td>40 weeks</td>
<td>37 weeks</td>
<td>45 weeks</td>
<td>41 weeks</td>
<td>42 weeks</td>
</tr>
<tr>
<td>Prefabrication Potential</td>
<td>Medium, mid-sized local market in Bay Area</td>
<td>High, big market in Bay Area</td>
<td>Low, nearly zero relying on cast in place concrete in site</td>
<td>High, big market in Bay Area</td>
<td>High, big market in Bay Area</td>
</tr>
<tr>
<td>Modularity &amp; Constructability</td>
<td>Regular elements, similarity across spaces</td>
<td>Regular elements, similarity across spaces</td>
<td>Circular elements, not as much similarity, site congestion</td>
<td>Circular elements, not as much similarity</td>
<td>Circular elements, not as much similarity</td>
</tr>
<tr>
<td>Total</td>
<td>10</td>
<td>11</td>
<td>5</td>
<td>9</td>
<td>8</td>
</tr>
</tbody>
</table>
LCF
Life Cycle Financial Management
Importance of Life Cycle Costs

- Initial investment
- Garbage and wastewater
- Insurance
- Infrastructural Facility Management
- Maintenance
- Energy
- Repair costs
- Risk
Importance of LCC for the Owner

Come Together is 20,700 $ cheaper than The LINK
Comparing the profitability of the options

<table>
<thead>
<tr>
<th>Option</th>
<th>Profitability</th>
</tr>
</thead>
<tbody>
<tr>
<td>The Link Timber</td>
<td>10.3%</td>
</tr>
<tr>
<td>The Link Steel</td>
<td>8.9%</td>
</tr>
<tr>
<td>Come Together Concrete</td>
<td>10.3%</td>
</tr>
<tr>
<td>Come Together Steel</td>
<td>9.9%</td>
</tr>
<tr>
<td>Come Together Steel Diagrid</td>
<td>9.6%</td>
</tr>
</tbody>
</table>
Importance of LCC for the project company

Come Together is 1.43% more profitable than The Link.

Rent The Link: $1,240,000
Rent Come Together: $1,260,000

*Options are chosen based on the comparability of construction costs
Risk management

- Construction risk
- Liquidity Risk
- Management
- O & M
- Vandalism
- Force Majure
Decision making

1. Specification
2. 2–3 Criteria
   - Specific weighting
3. 5 Categories
   - Specific weighting
4. Decision
Decision Matrix weighting

- **Design**: 30%
- **Challenges**: 20%
- **Sustainability**: 10%
- **Construction**: 0%
- **Profitability**: 0%

- **Owner**
- **Team**
Decision Matrix Scoring

- The Link Timber
- The Link Steel
- Come Together Concrete
- Come Together Steel
- Come Together Steel Diagrid
Choosing the winner

- The Link Timber: 3.5
- The Link Steel: 3.4
- Cometogther concrete: 3.4
- Come Together Steel: 3.6
- Come Together Steel Diagrid: 3.8

The winner is Come Together Steel Diagrid with a score of 3.8.
Thank you!