Team Central Winter Presentation

03/15/2019
Team Central

MEP - Xiaoxi
Stanford - China

SE - Gabe
Stanford - US

CM - Aakanksha
Stanford - India

CM - Harry
Loughborough - UK

SE - Kostas
DTU - Greece

LCFM - Tim
Bauhaus - Germany

AR - Weronika
WAPW - Poland
Our Client

Andrej Kurent
Sohan Mone
Eeshan Shah
Norayr Badasyan
Vikash Soni
Project Challenges

Carbon Negative  Industrialized Construction & Prefabrication  IT
Los Angeles, US

Engineering School at UCLA

Public-Private-Partnership
Earthquake Risk Category 3
Assuming >500 total occupants

Wind Speed, Snow Loads not limiting factors in design
Wildfire Risk
Climate Zone 9

Temperature
- Summer 1% design temperature: 93 °F
- Winter 99% design temperature: 37 °F
- Max: 75 °F, Min: 70 °F

Relative Humidity
- Summer - dehumidification
- Winter - humidification
- 55%

Precipitation
Semi-arid area, scarce rainfall
Most rainfall from Dec. to Mar.

Sunshine
3,200 hours of sunshine per year
More than 50% of the time skies are clear or partly cloudy.

Inspiration
Big Idea

Green oasis

Modularity

Timber
Addressing Challenges

- Timber structure
- Trees Inside
- PV panels
- Standardized spans
- Modular offices
- Smart Sensors
- Adjustable Shading
Bird’s Eye View South-West
Street view
Level -1 ( -9 ft el)

- auditorium
- lab
- small classroom
- cafe
- bathrooms
- storage
- mech. shaft
- elevator
- Indoor circulation
Student Lounge
Soil Conditions

5 ksf Bearing
Site Class C
Very Dense Soil

-15 ft Water Table

Strip foundation
## Earthquake Design

<table>
<thead>
<tr>
<th>Design Code Reference Document</th>
<th>ASCE7-10</th>
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<tbody>
<tr>
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<td>Site Class</td>
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Source: www.usgs.gov (Retrieved: 03/12/19)
# Building live loads

## Live Loads

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<tr>
<td>Offices</td>
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<tr>
<td>Computer Labs</td>
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<tr>
<td>Auditorium/Large Classroom</td>
<td>60</td>
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<tr>
<td>Lobby</td>
<td>100</td>
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<tr>
<td>Small Classroom</td>
<td>40</td>
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<tr>
<td>Corridors - 1st floor</td>
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<tr>
<td>Corridors - above 1st floor</td>
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<tr>
<td>Stairs</td>
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<tr>
<td>Storage</td>
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Advantages of timber:

- Increased Speed of Construction
- Raw Material is Fully Finished
- Carbon Sequestering
- Weather Versatility
- Light Weight and Strong
- Offsite Construction
- Reduced Labor Costs
- Tolerances in Millimeters
- Improved Safety
1st Structural Solution
Superstructure:
Gravity: GLT moment frames
Lateral: CLT pivoting walls

Substructure:
Baseement: Concrete podium
Foundation: Strip footings
<table>
<thead>
<tr>
<th>Typical Elements</th>
<th>Section [inch]</th>
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<td>16x32</td>
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<td>9.5x13 [ft]</td>
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<td>Footprint</td>
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<td>10.5x22</td>
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- GLT: Glued Laminated Timber
- CLT: Cross-Laminated Timber

Level 1 (4ft)

Footprint: 133' x 133'
## Typical Elements

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</table>

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**Diagram:**

- Level 2 (17ft)
- Footprint
- 133’
- 19’
- 9.5’
CLT Fused Pivoting wall

- Fail-safe GLT columns
- Alternating pivot-points
- Upward movement resisted by PT rod
- Downward movement mobilizing the fuses
- PT rod anchored in underlying concrete wall
Gravity load path diagram

- Lateral load
- Beam’s transfer load
- Compression force
- Tension force
Auditorium: formation

- Tendons of P.T.
- Concrete slabs

P.T. concrete beams

Dimensions:
- 66.5 ft
- 47.5 ft
Main basement: -9ft
Foundation: -11ft
Auditorium and labs: -14ft
Foundation: -16ft
2nd Structural Solution
Superstructure:
- **Gravity:** GLT moment frames
- **Lateral:** BRBF

Substructure:
- **Basement:** Concrete podium
- **Foundation:** Strip footings
Atrium Conceptualization
Atrium - Structural Core

- Structural core
- Cantilevers
- Large beams - ties

19'

133'

133'

133'
Level -1 (-9ft & -14ft)

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<td>GLT BRBF Bay: 19x13 [ft]</td>
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**Footprint**

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**Level 1 (4 ft)**
## Level 2 (17 ft)

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</table>
GLT Buckling restrained braced frames

- Diagonals: 8.5x8.25” GLT
- Butterfly steel fused plates for additional ductility
Gravity load path diagram

- **Gravity load**
- **Beam’s transfer load**
- **Compression force**
- **Tension force**
Lateral load path diagram

- Lateral load
- Beam’s transfer load
- Compression force
- Tension force

Dimensions:
- 13’
- 13’
- 13’
- 13’
- 9.5’
- 19’
- 133’
Main basement: -9 ft
Foundation: -11 ft
Auditorium and labs: -14 ft
Foundation: -16 ft
Central Atrium - Air Quality

Air Quality Index in LA Over the Past 10 years

Central Atrium - Concerns

Recorded Highest & Lowest Temperature from 2010 to 2018

Average Monthly Rainy Days Over the Year
Central Atrium - Close Options

Option 1
Movable Skylight

Option 2
Glass Wall
Central Atrium - Life Cycle Cost

Construction → Maintenance → Replacement

Life Cycle Cost ($)

- Open Atrium: $1,541
- Close w/ Skylight: $1,544
- Close w/ Glass Wall: $1,549
Central Atrium - Life Cycle Cost

Process

Construction

Maintenance

Replacement

Life Cycle Cost ($)

Open Atrium

Close w/ Skylight

Close w/ Glass Wall

1,550
1,548
1,546
1,544
1,542
1,540
1,538
1,536
1,541
1,544
1,549

×10000
Big Idea
Inspiration
Big Idea

Building in a spotlight

Skylights

V-shaped columns
Addressing Challenges

- Overhang
- Daylighting Design
- Integrated PV facade

- Smart Sensors
**Design process**

**PROBLEMS**
- Radial grid
- V columns not compatible with the program
- Irregular rooms + no daylight in inner parts

**OPTIMIZATION**
- Adding skylights
- Discussing the position of the V-shape columns
- Simplifying plans
Bird’s Eye View from South-West
Level 1 (0 ft el)

- Seminar room
- Small classroom
- Big classroom
- Circulation
- Mech. shaft
- Bathroom
- Elevator
Level 2 (14 ft el)

- Office
- Department chair’s office
- Senior administrative
- Administrative assistants
- Student offices
- Faculty lounge/collaboration
- Shaft
- Bathroom
- Elevator
Level -1 (-14 ft el)

- storage
- auditorium
- lab
- collaboration space
- shaft
- bathroom
- elevator
Ground floor
Faculty lounge
Concrete V Columns

Superstructure:
- **Gravity**: V Columns, Steel Frame
- **Lateral**: Base Isolation with Steel Moment Frame

Substructure:
- **Basement**: Concrete podium
- **Foundation**: Strip footings
## Typical Elements

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<tbody>
<tr>
<td><strong>Concrete column</strong></td>
<td>18x18</td>
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<tr>
<td><strong>Steel girder</strong></td>
<td>W14x120</td>
<td>58</td>
</tr>
<tr>
<td><strong>Steel beam</strong></td>
<td>W14x30</td>
<td>30</td>
</tr>
<tr>
<td><strong>Composite Deck</strong></td>
<td>2&quot; metal deck with 3.25&quot; LW concrete slab</td>
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<td>Typical Elements</td>
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</tbody>
</table>
Concrete V columns - Section cuts

Level 2

Level -1

Level 1

135.5' 135.5'

116'

116'

116'

116'
Lateral resisting system

- Isolators on column’s base
- 37 Isolators in total

Conventional design - enhanced performance
Foundation

Basement level: -14ft

Foundation level: -16ft
Gravity load path diagram

- **Gravity load**
- **Beam’s transfer load**
- **Compression force**

Dimensions:
- 135.5’
- 16’
- 14’
Lateral load path diagram

- Lateral load
- Beam's transfer load
- Compression force
- Tension force

Dimensions:
- 135.5’
- 16’
- 14’
Superstructure:
- **Gravity:** Steel Frame with Steel V’s
- **Lateral:** Steel BRBF

Substructure:
- **Basement:** Concrete podium
- **Foundation:** Strap footings
# Basement (-14ft)

## Typical Elements

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<td>BRBF</td>
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First floor (0 ft)

Typical Elements

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BRBF

Bay: 17x16 [ft]

Composite Deck

2" metal deck with 3.25" LW concrete slab
## Typical Elements

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![Diagram of the second floor layout](image-url)
Steel V columns - Section cuts

Level 2

Level 1

Level -1

116’
Basement level: -14ft

Foundation level: -16ft

<table>
<thead>
<tr>
<th>Typical Elements</th>
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<td>Foundation Wall</td>
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<td>116</td>
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</tbody>
</table>
Gravity load path diagram

Buckling Restrained Braced Frame (BRBF)

- Gravity load
- Beam’s transfer load
- Compression force
- Tension force
Buckling Restrained Braced Frame (BRBF)

Lateral load path diagram

135.5'
Primary System

Cogeneration Plant

Heating

Cooling

Mechanical Room

AHU

Mechanical Shaft

AHU

Electricity

Los Angeles Department of Water & Power

Water
## Small Classrooms & Offices
- **Flr-to-Flr Height:** 13/14 ft

### Option 1
- **Variable Air Volume (VAV)**
  - Cooling & Heating & Ventilation: Overhead Air Distribution

### Option 2
- **Active Chilled Beam (ACB)**
  - Cooling & Heating: Chilled/Hot water delivered to the coils in beams
  - Ventilation: Dedicated Outdoor Air System (DOAS)

## Auditorium & Large Classrooms
- **Flr-to-Flr Height:** 16/14 ft

### Displacement Ventilation
- [Diagram of Displacement Ventilation](image)
HVAC Design Basis

Summer Design Dry Bulb Temperature: 93 °F
Indoor Temperature Setpoint: 75 °F

Winter Design Dry Bulb Temperature: 37 °F
Indoor Temperature Setpoint: 70 °F

Indoor Relative Humidity: 55%

Ventilation as per California Title 24
3D Distribution Tree - Treehouse

Architectural Overlay

Structural Overlay

Supply Air

Return Air
Distribution Tree - Basement

- Supply Air
- Return Air
- Vertical Shaft
Distribution Tree - First Floor

- Supply Air
- Return Air
- Vertical Shaft
Floor Sandwich

GLT + VAV

Deck: 3"
GLT Beam: 15"
Return Duct: 12"
Supply Duct: 16"

Clear Space: 8'9"

GLT + ACB

Deck: 3"
GLT Beam: 15"
Return Duct: 10"
DOAS Duct: 12"

Clear Space: 9'3"

Flr-to-Flr Height: 13'

Slab: 5"
Displacement Ventilation

Deck

Beam

Return Air Plenum

16' Flr-to-Flr Height

12' Clear Space

Slab

Supply Air Plenum

1'
Smart Wooden Louver

Responsive Skin

PV Attached
3D Distribution Tree - Spotlight

- **Supply Air**
- **Return Air**

Architectural Overlay

Structural Overlay
Distribution Tree - First Floor

- Supply Air
- Return Air
- Vertical Shaft
Distribution Tree - Second Floor

- Supply Air
- Return Air
- Vertical Shaft
Floor Sandwich

Steel + VAV

Deck
GLT Beam
Return Duct
Supply Duct

3'' 14''

14'' 20''

14' Flr-to-Flr Height

5'' Slab

Clear Space 9'10''

Steel + ACB

Deck
GLT Beam
Return Duct
DOAS Duct

3'' 14''

10'' 12''

14' Flr-to-Flr Height

5'' Slab

Clear Space 10'4''
Mechanical System Rating

ACB

- Construction Cost: 1.5
- Environmental Impact: 2.0
- Comfort Down Draft: 0.5
- Space Needed: 0.5
- Energy Efficiency: 2.0
- Maintenance: 1.0

Rating: 4.8

VAV

- Construction Cost: 1.5
- Environmental Impact: 2.0
- Comfort Down Draft: 0.5
- Space Needed: 0.5
- Energy Efficiency: 2.0
- Maintenance: 1.0

Rating: 4.6
Sustainable Design - Daylighting

- Skylight
- Daylight Sensors
- Perimeter Zone
- Light Shelf
- Light Tubes

Above Ground

Underground
Glazing Area Design

Curtain Wall

Diffusing Glazing

Transparent

PV Panel

4"

7"

3"
Smart Buildings - Sensors

Thermostats

Acoustic Sensors

Occupancy Sensors

Air Quality Sensors

CO2 Sensors

Daylight Sensors
On-site Energy Generation

Electricity Generation: 370,000 kWh/yr

PV Area on the Roof

1 kWp System

<table>
<thead>
<tr>
<th>Month</th>
<th>Solar Radiation (kWh/m²/day)</th>
<th>AC Energy (kWh)</th>
<th>Value (%)</th>
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Sustainable Target Value

Carbon (kgCO2e)

Water (kgH2O)

Energy (MJ)

Treehouse VAV

Spotlight VAV

Treehouse ACB

Spotlight ACB
Challenges - Site and Design

- Develop Construction Practices & TVD
- Prepare Site Logistics Plan
- Develop Schedule
- Agile Cost-shift
Site Sensitivity Analysis

West
- Heavy Traffic
- Pedestrian Walkway
- Bus stop
- Trees

South
- Heavy Traffic
- Pedestrian Walkway
- Bus Stop
- Trees

North
- Children Health Care
- Trees

East
- Oncology Center
- Trees
- Traffic
Site Provision

Echo barrier H series with fabric filters

Mobile Dust Collector

Fire extinguishers/ANSUL R-102™ FIRE PROTECTION SYSTEM

Portable Trailers
Traffic Mitigation Plan

Heavy Vehicle Path

Light Vehicle Path
Integrated Supply Chain

CLT - Katerra - Oregon
Steel Supplier - California (LA)
Concrete Supplier - California (LA)
Site Equipment - California (LA)
Prefabrication Warehouse - California (LA)
Construction Methodology: THE STORY

Carbon Negative
Innovation
IT
### Concept Appraisal

**Opportunity Indicator ✓**
- Standardised Grid ✓
- Orthogonal Grid ✓
- Large Footprint Relative to Site Area ✓
- Flat roof ✓
- No Curves! ✓
- Deep Basement & foundations ✓
- Large Footprint Relative to Site Area ✓

**Challenge Indicator ✗**
- Numerous Trees ✗
- Restricted space in working areas ✗
- Complex Structure ✗
- Multi Spur ✗
- Complex Atrium cover ✗
- Deep Basement & foundations ✗
- Low Rise ✗
- Programme repetition ✗
- Easy for bottom up construction ✗

**Treehouse**
- Restricted space in working areas ✗
- Complex Structure ✗
- Multiple Spur ✗

**Spotlight**
- Simple form ✓
- Abundance of work faces ✗
- Non standardised bays ✗
- Non-orthogonal Grid ✗
- Complex Structure ✗
- Sloping roof line ✗

**Footprint Adjacent to public footpath & highway ✗**

**Abundance of work faces ✗**

**Multiple Spur ✗**

**Complex Atrium cover ✗**

**Deep Basement & foundations ✗**

**Low Rise ✗**

**Programme repetition ✗**

**Easy for bottom up construction ✗**

**Restricted space in working areas ✗**

**Complex Structure ✗**

**Non standardised bays ✗**

**Non-orthogonal Grid ✗**

**Flat roof ✓**

**No Curves! ✓**
Treehouse Construction Solutions
Construction Solutions

Spatial Timber

Volumetric Construction

Panelized Construction
26 Modular Opportunities
Volumetric
Progressive Site Logistics
Site Logistics

- Truck Route
- Truck Wash Pad
- Inventory
- Portable Trailer
- On-site vehicle Parking
- QA/QC and Safety Meeting Area
- Waste Segregation Yard
- Labor Units
- Labor Facilities
- Power Unit
- Streetlight
- Crane Radius
- Safety Exit
- Gate

Footprint
Progression

Excavation During Superstructure
### Traditional Stick Built

<table>
<thead>
<tr>
<th>Activity</th>
<th>Start</th>
<th>Finish</th>
<th>Duration</th>
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</thead>
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<tr>
<td>Site Setup</td>
<td>1</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Civils</td>
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<td>7</td>
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<td>Substructure</td>
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#### Prefabricated Methods

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<td>Civils</td>
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<td>7</td>
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<tr>
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</tr>
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</tr>
<tr>
<td><strong>Total</strong></td>
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<td>43</td>
<td>38</td>
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</table>
Agile Cost Shift (TVD)

Comparison

Concept 1
TOTAL COST = $8,680,952
DELTA = + $919,048

Concept 2
TOTAL COST = $9,755,436
DELTA = - $155,436
Concept Appraisal

Treehouse

Opportunity Indicator ✓

- Standardised Grid ✓
- Orthogonal Grid ✓
- Restricted space in working areas x
- Complex Atrium cover x
- Flat roof ✓

Challenge Indicator x

- Numerous Trees x
- Deep Basement & foundations x
- Large Footprint Relative to Site Area x
- Multiple Spors x

Spotlight

Opportunity Indicator ✓

- No Curves! ✓
- Low Rise ✓
- Programme repetition ✓
- Easy for bottom up construction ✓

Challenge Indicator x

- Large Footprint Relative to Site Area x
- Simple form ✓
- Abundance of work faces x
- Non standardised bays x
- Non-orthogonal Grid x
- Complex Structure x
- Sloping roof line x
Modular MEP

Flying Factories

Additive Manufacturing
Modular Construction
Flying Factories
Additive Manufacture
Site Logistics

Truck Route
Truck Wash Pad
Inventory
Portable Trailer
On-site vehicle Parking
QA/QC and Safety Meeting Area
Waste Segregation Yard
Labor Units
Labor Facilities
Power Unit
Streetlight
Crane Radius
Safety Exit
Gate
Progressive Site Logistics

Excavation

Superstructure

Footprint
### Concrete V - Columns

<table>
<thead>
<tr>
<th>Activity</th>
<th>Start</th>
<th>Finish</th>
<th>Duration</th>
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<tbody>
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<td>MEP</td>
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<td>33</td>
<td>5</td>
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<tr>
<td>Handover &amp; Commissioning</td>
<td>29</td>
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<td>5</td>
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<tr>
<td>MS: Handover</td>
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### Steel V - Columns

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<td>Civils</td>
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<td>Internals</td>
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<td>5</td>
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<tr>
<td>MS: Handover IT Office &amp; Labs</td>
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<tr>
<td><strong>Total</strong></td>
<td>1</td>
<td>38</td>
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</table>
Agile Cost Shift (TVD)

**Comparison**

- **Target Cost**
- **Concept 1**
- **Concept 2**

**Concept 1**
- **TOTAL COST** = $9,967,845
- **DELTA** = ($367,845.00)

**Concept 2**
- **TOTAL COST** = $9,501,900
- **DELTA** = + $98,100

**Concept 1 - $342 per SF**

**Concept 2 - $326 per SF**
Agile Cost Shift Approach

No Roof
- High Maintenance Cost
- Connection to the outside environment
- $0

Glass and asphalt Roof
- Low Maintenance Cost
- Sunlight and weather protection
- $27,424

Glass wall
- High Maintenance Cost
- Sunlight and partial weather protection
- $82,800
Agile Cost Timeline

Discipline Integration

Time Period

Jan  Feb  Mar

Retractable Glass Roof
$244,000
People Come First

In house training
Smart Safety Meetings
BIM Tracking
Fire and Noise Sensors

Smart Hoardings
Smartband
Supply Chain Tracking
Evacuation Plan
### Concepts in Nutshell

#### Treehouse

<table>
<thead>
<tr>
<th>Concept 1</th>
<th>Concept 2</th>
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<tbody>
<tr>
<td>Volumetric Construction, Spatial Timber Assembly, Panelized Construction</td>
<td>Modular Construction, Flying Factories, Additive Methodologies - 3D printing, Smart Dynamic Casting</td>
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<td>43</td>
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<td>$8,680,952</td>
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#### Spotlight

<table>
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<td>$9,967,845</td>
<td>$9,501,900</td>
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<tr>
<td>$342.00</td>
<td>$326.00</td>
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</table>

*Local materials, Electric equipments, Portable materials on site, Integrated supply chain, AI and Robots to minimize wastage or rework, Electric self-erecting tower crane*

*Sensors for clash detection, BIM and AI for instant mitigation, BIM discipline integration, Smart Dynamic Casting, 3D printers, Built Robotics autonomous excavator*
Life Cycle Financial Manager
$550,000 less over the contract time
Life Cycle Costs

- **Treehouse CLT**
  - Construction: $8,700,000
  - M & O: $3,000,000
  - Replacement: $2,225,000
  - Risk Costs: $700,000
  - Financial Costs: $2,650,000

- **Tree House GLT**
  - Construction: $9,760,000
  - M & O: $3,100,000
  - Replacement: $2,300,000
  - Risk Costs: $1,200,000
  - Financial Costs: $2,980,000

- **Spotlight Concrete**
  - Construction: $9,970,000
  - M & O: $3,000,000
  - Replacement: $2,800,000
  - Risk Costs: $300,000
  - Financial Costs: $2,900,000

- **Spotlight Steel**
  - Construction: $9,500,000
  - M & O: $3,300,000
  - Replacement: $2,300,000
  - Risk Costs: $700,000
  - Financial Costs: $2,900,000
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<th>Criteria</th>
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<th>Treehouse GLT</th>
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<th>Spotlight Steel</th>
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</table>
Team Process

Initial Treehouse Concept

Inner Garden Concept

Kickoff 1/18-1/20
Peer Review 2/15
Crit 2/22
Winter Presentation 3/15
Absorption of Inner Gardens into Treehouse

L Shape Concept “Angel’s Wings”

Kickoff 1/18-1/20
Peer Review 2/15
Crit 2/22
Winter Presentation 3/15
Evolution of Treehouse

Team Process

Kickoff  Peer Review  Crit  Winter Presentation
1/18-1/20  2/15  2/22  3/15

Winter Presentation 3/15
Crit 2/22
Peer Review 2/15
Kickoff 1/18-1/20

Evolution of Treehouse

UCLA

164
Team Process

L Shape Concept “Angel’s Wings” becomes “Spotlight”

Kickoff 1/18-1/20
Peer Review 2/15
Crit 2/22
Winter Presentation 3/15
Team Process

Final Evolution of Treehouse

Kickoff: 1/18-1/20
Peer Review: 2/15

Final Evolution of Spotlight

Crit: 2/22
Winter Presentation: 3/15
Thank You!

MEP - Xiaoxi
Stanford - China

SE - Gabe
Stanford - US

CM - Aakanksha
Stanford - India

CM - Harry
Loughborough - UK

SE - Kostas
DTU - Greece

LCFM - Tim
Bauhaus - Germany

AR - Weronika
WAPW - Poland
Keep everyone in the loop