ANA SOFIA CARDONA
JOANNE MUÑIZ
NANYU ZHAO
SHUHUI QU

REINIER KOK
KOUROSH SALEHZADEH
FELIX BOLLWAHN
INTRODUCTION

METROPOLITAN AREA

UNIVERSITY OF PUERTO RICO
RIO PIEDRAS CAMPUS
INTRODUCTION

LOCAL HAZARDS:

HURRICANES
AUGUST - OCTOBER

EARTHQUAKES
LATEST (1918)- MAGNITUDE OF 7.5 IN RICHTER SCALE

TSUNAMIS

CLIMATE:

TYPE OF CLIMATE
HUMID - TROPICAL

TEMPERATURE
RANGES FROM 70 - 90 F (~ 20 - 30 C)

PRECIPITATION
RANGES FROM 2 -6 INCHES (~ 50 - 160 mm)

RELATIVE HUMIDITY
RANGES FROM 73% [MARCH] TO 78% [JUNE]

WIND SPEED
RANGES FROM 2 - 3 BEAUFORT (~ 2 - 5 m/s)

GENERAL DESCRIPTION:

EASTERNLY WINDS

TRADE WINDS

DAYLIGHT
12 HOURS [6AM - 6PM]

RAIN SEASON
APRIL - NOVEMBER
<table>
<thead>
<tr>
<th>Criteria</th>
<th>Emphasis</th>
<th>Palm Tree Concept Concrete</th>
<th>Palm Tree Concept Steel and Concrete</th>
<th>Hover Box Concept Steel and Concrete</th>
<th>Hover Box Concept Steel</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Team</td>
<td>Owner</td>
<td>Team</td>
<td>Owner</td>
</tr>
<tr>
<td>Construction costs</td>
<td>5.00%</td>
<td>8.57</td>
<td>6.5</td>
<td>6.00</td>
<td>8.5</td>
</tr>
<tr>
<td>Value for money</td>
<td>12.33%</td>
<td>8.14</td>
<td>8</td>
<td>7.00</td>
<td>9</td>
</tr>
<tr>
<td>Architectural aesthetics</td>
<td>11.67%</td>
<td>9</td>
<td>7.5</td>
<td>9.00</td>
<td>8</td>
</tr>
<tr>
<td>Addressing the required room program</td>
<td>4.67%</td>
<td>8</td>
<td>9</td>
<td>8.00</td>
<td>9</td>
</tr>
<tr>
<td>Innovation in design - Leapfrogging</td>
<td>14.00%</td>
<td>6.57</td>
<td>6.5</td>
<td>7.14</td>
<td>7</td>
</tr>
<tr>
<td>Integration of nature</td>
<td>7.67%</td>
<td>8</td>
<td>8.5</td>
<td>8.00</td>
<td>8.5</td>
</tr>
<tr>
<td>Creation of an open and collaborative space</td>
<td>16.67%</td>
<td>8.29</td>
<td>8.75</td>
<td>8.43</td>
<td>8.75</td>
</tr>
<tr>
<td>Usage of natural ventilation</td>
<td>10.00%</td>
<td>8.71</td>
<td>7.5</td>
<td>8.72</td>
<td>7.5</td>
</tr>
<tr>
<td>Provided safety for the occupants</td>
<td>5.67%</td>
<td>7.86</td>
<td>7</td>
<td>8.00</td>
<td>7.5</td>
</tr>
<tr>
<td>Resistance to natural hazards, especially earthquakes &amp; hurricanes</td>
<td>12.33%</td>
<td>8.29</td>
<td>6.75</td>
<td>8.57</td>
<td>8.75</td>
</tr>
<tr>
<td><strong>Sum weighted:</strong></td>
<td></td>
<td>8.11</td>
<td>7.61</td>
<td>7.99</td>
<td>8.23</td>
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</tbody>
</table>

**Result:**

<table>
<thead>
<tr>
<th></th>
<th>Team</th>
<th>Owner</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Palm Tree</strong></td>
<td>7.86</td>
<td>8.11</td>
</tr>
<tr>
<td><strong>Hover Box</strong></td>
<td>6.91</td>
<td>7.19</td>
</tr>
</tbody>
</table>
INTRODUCTION

CONCEPT DEVELOPMENT
INTRODUCTION

CONCEPT DEVELOPMENT
INTRODUCTION

CONCEPT DEVELOPMENT
COMFORT & SPACE
SOCIAL GATHERING
COMFORT & SPACE
THIRD FLOOR

- FACULTY OFFICE
- FACULTY LOUNGE
- ASSISTANT OFFICE
- SENIOR ADMINISTRATIVE OFFICE
- DEPARTMENT CHAIR OFFICE
- CONFERENCE ROOM
0% acceptability limit

90% acceptability limit

80% acceptability limit

Montly mean outdoor temperature (°C)

Operative temperature (°C)

San Juan

Amsterdam
## COMFORT REQUIREMENTS

<table>
<thead>
<tr>
<th></th>
<th>Mechanically conditioned</th>
<th>Naturally conditioned</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Class</strong></td>
<td>Class B</td>
<td>Class B</td>
</tr>
<tr>
<td><strong>Specifications</strong></td>
<td>24.5 to 27.5 °C</td>
<td>23 to 30 °C</td>
</tr>
<tr>
<td></td>
<td>76 to 81.5 °F</td>
<td>73.5 to 86 °F</td>
</tr>
<tr>
<td><strong>Thermal comfort</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Indoor Air Quality</strong></td>
<td>Excellent</td>
<td>Outdoor</td>
</tr>
<tr>
<td></td>
<td>40 &lt; RH &lt; 55%; CO₂ ≤ 800 ppm</td>
<td>CO₂ ≤ 800 ppm</td>
</tr>
<tr>
<td><strong>Daylighting quality</strong></td>
<td>Good</td>
<td>Good</td>
</tr>
<tr>
<td></td>
<td>DF ≥ 2.5%</td>
<td>DF ≥ 2.5%</td>
</tr>
</tbody>
</table>
• Minimum wind speed: 0,2 m/s

- Conditioned classrooms
- Humidity control
- Control thermal loads
- Hybrid Auditorium
• Microclimate desks
COMFORT & SPACE
THIRD FLOOR
COMFORT & SPACE

NO SHADING FINS

DF = 6.1%

DF = 6.6%
COMFORT & SPACE

OPEN SHADING FINS

DF = 6.1%

DF = 4.2%
COMFORT & SPACE

SEMI-OPEN SHADING FINS

DF = 6.1%

DF = 2.8%
COMFORT & SPACE

DF = 1.1%

DF = 1.8%

DF = 2.0%
• Thermal and moisture barrier
• Radiant cooling system
• Sprinkler system
• Concrete slabs
• Loads 25 W/m²
• Cooling power 40 W/m²
Annual energy consumption distribution of total 500 kWh

- Cooling machine consumption
- Ventilation energy consumption

94.6%

http://www.hellotokyo.jp/
# COMFORT & SPACE

## Design Loads

<table>
<thead>
<tr>
<th>Floor</th>
<th>Dead Load (PSF)</th>
<th>Live Load (PSF)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Roof</td>
<td>40</td>
<td>60</td>
</tr>
<tr>
<td>3</td>
<td>72</td>
<td>75</td>
</tr>
<tr>
<td>2</td>
<td>72</td>
<td>75</td>
</tr>
<tr>
<td>1</td>
<td>72</td>
<td>110</td>
</tr>
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</table>

<table>
<thead>
<tr>
<th>Wind</th>
<th>Seismic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wind Speed 170 mph</td>
<td>Risk III</td>
</tr>
<tr>
<td>Base Shear 170 kips</td>
<td>12% Building Weight</td>
</tr>
</tbody>
</table>

### Function Spaces

<table>
<thead>
<tr>
<th>Function Spaces</th>
<th>Live Load (PSF)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Office</td>
<td>50</td>
</tr>
<tr>
<td>Faculty Lounge</td>
<td>80</td>
</tr>
<tr>
<td>Auditorium (average)</td>
<td>100</td>
</tr>
<tr>
<td>Classroom &amp; Seminar</td>
<td>40</td>
</tr>
<tr>
<td>Labs</td>
<td>100</td>
</tr>
<tr>
<td>Server Room</td>
<td>125</td>
</tr>
<tr>
<td>Technical Support</td>
<td>100</td>
</tr>
<tr>
<td>Storage</td>
<td>250</td>
</tr>
<tr>
<td>Mechanical Room</td>
<td>100</td>
</tr>
<tr>
<td>Stair</td>
<td>100</td>
</tr>
<tr>
<td>Corridor</td>
<td>80 or 100</td>
</tr>
<tr>
<td>Roof</td>
<td>60</td>
</tr>
</tbody>
</table>
COMFORT & SPACE

FLOOR SANDWICH INTEGRATION

Major Beam Section: W24

Maximum Pipe Diameter: 21”
Maximum Height: 16 FT
Dropped Floor: 2 FT each
COMFORT & SPACE

CORE & STAIR
### Hurricane & Earthquake

<table>
<thead>
<tr>
<th>Probability of Occurrence</th>
<th>Very Low</th>
<th>Low</th>
<th>Medium</th>
<th>High</th>
<th>Very High</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>A-risks</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. Inflation in construction costs</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. Water price change</td>
<td></td>
<td></td>
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<tr>
<td>3. Vandalism in or outside the building</td>
<td></td>
<td></td>
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<tr>
<td>4. <strong>Hurricane during O&amp;M phase</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5. Earthquake during O&amp;M phase</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Probability of Occurrence</th>
<th>Very Low</th>
<th>Low</th>
<th>Medium</th>
<th>High</th>
<th>Very High</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>B-risks</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6. Refused permission</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7. Electricity price change</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8. Unexpected soil conditions</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>9. HVAC system performance</td>
<td></td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Probability of Occurrence</th>
<th>Very Low</th>
<th>Low</th>
<th>Medium</th>
<th>High</th>
<th>Very High</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>C-risks</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10. Refused permission</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>11. Electricity price change</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>12. Unexpected soil conditions</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>13. HVAC system performance</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
HURRICANE & EARTHQUAKE
RISK OF HURRICANE & EARTHQUAKE

Total Storms within 200 miles (1900-2011)

Hurricane Season

Earthquake (1973-2013)

Earthquake Risk
• Safety
  – CODE: IBC2006 ASCE

• Structure Component Meet TVD
  – 24% of total budget

• Integrate with A/C/M/L
HURRICANE & EARTHQUAKE

CANOPY DETAIL

- 176 MPH wind
- 3" venetian blind
- 13 kip/ft

95% of Heat
Radiant Barrier

venetian blind
Stripe Footing 2’
Retaining Wall (MAX)
11’
Load Path
HURRICANE & EARTHQUAKE
STRUCTURAL ANALYSIS RESULTS

Displacement < Length/360

- 22.6ft Beam
- 44ft Beam
- 8.5ft Cantilever

Bar chart showing percentages of displacement for different structures.
Maximum Interstory Drift Ratio < 0.02
HURRICANE & EARTHQUAKE
SYSTEM TRADE OFF
HURRICANE & EARTHQUAKE LOGISTIC & SITE

Loading/Unloading area
Building
Parking Establishment
Liebherr LTM 1095-5.1

- Total counterweight = 50,700 lbs
- Telescopic boom = 41 ft - 190 ft
- Operational weight = 132,000 lbs

Volvo EC140D

- Operating weight = 28370 - 33400 lb
Active energy savings
- Phase change materials
- Cooling ceiling with mixing ventilation
- Variable Air Volume ventilation
- Employ nearby workers
- Nearby construction materials

Passive energy savings
- Natural ventilation
- Insulation
- Exposed concrete slabs
- Overhang
- East-west orientation

Renewable energy
- Photovoltaic thermal - Night radiation cooling
- Photovoltaic
Energy balance (kWh/year)

- Current building stock: $78,500
- Building regulations: $30,800
- Palmtree mechanical: $3,000
- Palmtree hybrid: $0

Energy consumption (kWh/year)
- Energy production from PVT (kWh/year)
**Sustainability**

**Consumption**
- Cooling
- Air
- Equipment
- Light

**Production**
- Photovoltaic

**Energy in kWh**

<table>
<thead>
<tr>
<th>Energy in kWh</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
</tr>
<tr>
<td>60,000</td>
</tr>
<tr>
<td>120,000</td>
</tr>
<tr>
<td>180,000</td>
</tr>
<tr>
<td>240,000</td>
</tr>
</tbody>
</table>
• Electricity consumption 230,000 kWh

- North geometry: 46.2%
- South geometry: 41.3%
- Naturally conditioned geometry: 12.6%

Simulated with eQuest
SUSTAINABILITY

ACHIEVABLE LEED POINTS PER CATEGORY

[Chart showing achievable LEED points per category for each level: Certified, Silver, Gold, Platinum. Categories include Regional Priority, Innovation in Design, Indoor Environment Quality, Materials & Resources, Energy & Atmosphere, Water Efficiency, Sustainable Sites.]

80
SUSTAINABILITY

ROOF PLAN

Surface
Gutter

HYPERBOLIC PARABOLOID
SUSTAINABILITY

WATER

Water consumption of 250,000 gallons

- Radiant cooling ceiling
- Flushing toilet
- Watering plants
- Other

Diagram showing water management processes and consumption percentages.
SUSTAINABILITY

COOLING

Cooling distribution of 68,000 kWh

- Radiant cooling ceiling

- PVT – Night Radiation cooling
- Electricity – Cooling machine

Diagram showing the distribution of cooling with a pie chart showing 46% and 54%.
SUSTAINABILITY

SITE CONDITION - LOCAL COMPANIES

- Steel: 5mi
- Concrete: 6mi
- Construction equipment: 3mi
- Precasting concrete: 5mi
- Glazing company: 1mi
- Off-storage company: 9mi
- MEP company: 2mi
ESTIMATE AND TARGET VALUE - SUMMARY

<table>
<thead>
<tr>
<th>Description</th>
<th>Estimated Value</th>
<th>Target Value</th>
<th>Value Delta</th>
</tr>
</thead>
<tbody>
<tr>
<td>TOTAL</td>
<td>$8,117,564</td>
<td>$8,400,000</td>
<td>$282,436</td>
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<tr>
<td>A Substructure</td>
<td>$480,602</td>
<td>$865,291</td>
<td>$384,689</td>
</tr>
<tr>
<td>B Shell</td>
<td>$2,238,629</td>
<td>$2,005,911</td>
<td>$(232,718)</td>
</tr>
<tr>
<td>C Interiors</td>
<td>$643,335</td>
<td>$785,491</td>
<td>$142,157</td>
</tr>
<tr>
<td>D Services</td>
<td>$3,134,861</td>
<td>$2,362,728</td>
<td>$(772,133)</td>
</tr>
<tr>
<td>E Specialty Construction</td>
<td>$772,469</td>
<td>$853,376</td>
<td>$80,907</td>
</tr>
<tr>
<td>F Building Sitework</td>
<td>$253,930</td>
<td>$326,641</td>
<td>$72,711</td>
</tr>
<tr>
<td>G General Conditions</td>
<td>$593,737</td>
<td>$1,200,561</td>
<td>$606,824</td>
</tr>
</tbody>
</table>
SUSTAINABILITY

ACCUMULATED LIFE CYCLE COSTS

- O&M cost: $2,284,100 (12%)
- Construction cost: $2,709,000 (15%)
- Interest payment: $4,058,800 (22%)
- Replacement: $1,258,300 (7%)
- Risk surcharge: $1,258,300 (7%)
$952,766

- 18%

$808,383

Savings per year

Public sector comparator
Included canopy facade
Usage of the PVT system
Rainwater collection
Included extra income
ACCUMULATED CASH FLOW

SUSTAINABILITY

Break even after 18 years

<table>
<thead>
<tr>
<th>Year</th>
<th>Expenditures</th>
<th>Income</th>
<th>Cash flow cumulated</th>
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</thead>
<tbody>
<tr>
<td>1</td>
<td>-$9,000,000</td>
<td>-</td>
<td>-$9,000,000</td>
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<tr>
<td>2</td>
<td>-$7,000,000</td>
<td>-</td>
<td>-$6,000,000</td>
</tr>
<tr>
<td>3</td>
<td>-$5,000,000</td>
<td>-</td>
<td>-$1,000,000</td>
</tr>
<tr>
<td>4</td>
<td>-$3,000,000</td>
<td>-</td>
<td>$2,000,000</td>
</tr>
<tr>
<td>5</td>
<td>-$1,000,000</td>
<td>-</td>
<td>$3,000,000</td>
</tr>
</tbody>
</table>

2013
TEAM PROCESS

Establishing team rules

Communication Challenge

Decision-making Challenge

Kick-off  Crit  Cyber event  Fishbowl  Final
TEAM PROCESS

Visual decision making
Establishing Visual BIM-rules [Grid & software]

Model working

Integration Design & Technology

Step 1

Step 2

BIM COORDINATION

Clash control Navisworks
### Value for Money

<table>
<thead>
<tr>
<th>Environmental</th>
<th>Economical</th>
<th>Social</th>
</tr>
</thead>
<tbody>
<tr>
<td>• LEED Gold certification</td>
<td>• Energy savings of 60%</td>
<td>• Creation of open and collaborative space</td>
</tr>
<tr>
<td>• Low environmental impact</td>
<td>• External rent of auditoriums and classrooms</td>
<td>• Creation of the first educational net zero building in Puerto Rico as an icon</td>
</tr>
<tr>
<td>• Passive and active energy saving strategies</td>
<td>• Robots clean windows and PVT panels</td>
<td></td>
</tr>
</tbody>
</table>
“2+2+1+1+1 > 7”
Steven, Stanford

“With time NO becomes YES”
Kourosh, KTH

“Breathe in breathe out”
Joanne, UPR

“Discuss EVERYTHING”
Felix, Bauhaus

“Culture is more than nationality”
Ana Sofia, UPR

“Grab your hammers and break down that silo”
Reinier, DTU

“This team goes further”
Alan, Stanford