“No man is an island, entire of itself; every man is a...part of the main...”

- John Donne
Puerto Rico
University of Puerto Rico
Site constraints

- Earthquakes: seismically active area due to close fault
- Hurricanes: frequent storms during summer and fall

Source: http://www.nc-climate.ncsu.edu/climate/hurricanes/statistics
Climate conditions

- **Climatic Design Conditions**
  - 2% Cooling Design Temperature: 89.2°F
  - 99% Heating Design Temperature: 70.8°F
    - No Heating Required

- **Average Relative Humidity**: 76.5%

- **Yearly Rainfall**: 56.43 inches
  - Monthly Range: 1.95 inches to 6.35 inches
Perception of Climate
The Boomerang
## Concept Decision

<table>
<thead>
<tr>
<th></th>
<th>Average Weighting</th>
<th>Boomerang Steel</th>
<th>Boomerang Concrete</th>
<th>Floating Box Steel</th>
<th>Floating Box Concrete</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time targets</td>
<td>15,10 %</td>
<td>2,746</td>
<td>3,691</td>
<td>3,091</td>
<td>3,880</td>
</tr>
<tr>
<td>Cost targets</td>
<td>27,45 %</td>
<td>2,794</td>
<td>3,732</td>
<td>3,267</td>
<td>3,804</td>
</tr>
<tr>
<td>Quality targets</td>
<td>57,45 %</td>
<td>3,742</td>
<td>3,986</td>
<td>3,313</td>
<td>3,535</td>
</tr>
<tr>
<td>Total</td>
<td>100 %</td>
<td>3,307</td>
<td>3,879</td>
<td>3,288</td>
<td>3,732</td>
</tr>
</tbody>
</table>

Maximum score: 5
Target Value Design

Targets developed with our owners:

- Completion earlier
- Labs ready earlier
- Quick build up after hurricane

- Spatial requirements
- Social & educating building
- LEED + DGNB sustainability
- Energy performance >25% below baseline
- Integration into environment
- Integrated biomimicry concepts
- Structural performance in hurricanes
- Flexibility of the building

- < 880,000 $ annual rent
- Risk surcharge for hurricanes included
- Space efficiency and simplicity for o+m
# SWOT of Boomerang Concrete

<table>
<thead>
<tr>
<th>Internal origin</th>
<th>Helpful</th>
<th>Harmful</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Strengths</strong></td>
<td>Social building</td>
<td>Weaknesses</td>
</tr>
<tr>
<td></td>
<td>Integrated into environment</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Adapted to weather conditions</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Local production</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Low construction costs</td>
<td></td>
</tr>
<tr>
<td><strong>Opportunities</strong></td>
<td>Good opportunities to improve sustainability</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Natural ventilation</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Educating building (e.g. biomimicry and sustainability)</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>External origin</th>
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</tr>
</thead>
<tbody>
<tr>
<td><strong>Opportunities</strong></td>
<td>Good opportunities to improve sustainability</td>
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</tr>
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<td></td>
<td>Natural ventilation</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Educating building (e.g. biomimicry and sustainability)</td>
<td></td>
</tr>
<tr>
<td><strong>Threats</strong></td>
<td>Hurricanes and heavy rain endanger construction and operation</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Rather low sustainability over lifetime</td>
<td></td>
</tr>
</tbody>
</table>
POP Challenge

- **Product** – aspects of the building
- **Organization** – who is proactive/reactive?
- **Process** – team process

Façade example

- **façade concept**
  - design idea
  - architectural beauty
  - experience
  - material

- **loads, structural impacts**
- **constructability**
- **costs, profitability**
- **revision**

Evaluation of the façade and providing feedback
Biomimicry Challenge

social sustainability

biomimicry

ecological sustainability

economical sustainability

building design
Biomimicry Challenge

**biomimicry**

- atrium
- balconies
- café
- student offices

**social**

**ecological**

- natural ventilation
- dynamic shading / façade
- solar energy collection (PV panels)
- rainwater harvesting

**economical**

- net zero + cost advantages
- café and renting out rooms as second income source
Architectural Inspiration

- Comfortable space in tropical climate.
- Provides Natural illumination
- Maximizes Natural Ventilation
- Provides a sense of security and visual comfort.
Biomimicry Inspiration

- Tropical American plants with a deeply cleft calyx.
- They are common in Puerto Rico.
- Chosen for their ability to collect water in the central core and in between leaves; this provides a source of water for other organisms.
- In the case of the Bird of Paradise, its leaves move according to humidity levels and temperature.
Structural Ideas

- How do we prepare for Mother Nature?
- Use of developing technology
  - Shear Splices
  - Rocking Frames
  - Shear Walls
MEP Ideas

- Biomimicry: natural cooling and ventilation
- Adaptive comfort suitable for Puerto Rico
- Building management with some individual control
  - Enhanced social space
  - Resilient against future use and climate changes
Natural Ventilation Potential

PSYCHROMETRIC CHART
Adaptive Comfort

LEGEND
COMFORT
61% ■ COMFORTABLE
39% ■ NOT COMFORTABLE

MODEL: ADAPTIVE COMFORT ONLY
PLOT: COMFORT

All Hours ■ Selected Hours
1 a.m. through midnight

All Months ■ Selected Months
JAN through DEC

One Month JAN Next Month
One Day ■ Next Day

TEMPERATURE RANGE:
10 to 110° F ■ Fit to Data

Display Design Strategies

LOCATION:
San Juan Int’l Arpt, PR, PRI
Latitude/Longitude: 18.42° North, 66.09° West, Time Zone from Greenwich, 4
Data Source: TMY3 785260 WMO Station Number, Elevation 62 ft

DESIGN STRATEGIES: JANUARY through DECEMBER
1. Comfort (0 hrs)
2. Sun Shading of Windows (0 hrs)
3. High Thermal Mass (0 hrs)
4. High Thermal Mass Night Flush (0 hrs)
5. Direct Evaporative Cooling (0 hrs)
6. Two Stage Evaporative Cooling (0 hrs)
61.3% Adaptive Comfort Ventilation (5373 hrs)
7. Fan-Forced Ventilation Cooling (0 hrs)
8. Internal Heat Gain (0 hrs)
9. Passive Solar Direct Gain Low Mass (0 hrs)
10. Passive Solar Direct Gain High Mass (0 hrs)
12. Wind Protection of Outdoor Spaces (0 hrs)
13. Humidification Only (0 hrs)
14. Dehumidification Only (0 hrs)
15. Cooling, add Dehumidification if needed (0 hrs)
16. Heating, add Humidification if needed (0 hrs)

61.3% Comfortable Hours using Selected Strategies
(5373 out of 8760 hrs)
Site Plan
Structural Floorplan 1

<table>
<thead>
<tr>
<th>Columns</th>
<th>Member Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>Exterior</td>
<td>24” x 24”</td>
</tr>
<tr>
<td>Interior</td>
<td>14” x 14”</td>
</tr>
</tbody>
</table>

Island Team 05-11-2012
Supply Duct

Return Duct
Architectural Floorplan 2

- Emergency Stairs
- Large Classrooms
- Small Classrooms
- Tech. Office
- Restrooms
- Mechanical Room
- Instructional Labs
# Structural Floorplan 2

<table>
<thead>
<tr>
<th>Columns</th>
<th>Member Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>Exterior</td>
<td>24” x 24”</td>
</tr>
<tr>
<td>Interior</td>
<td>14” x 14”</td>
</tr>
<tr>
<td>Cantilever</td>
<td>20” x 20”</td>
</tr>
</tbody>
</table>

| Beams      | 18” x 22”     |
MEP Floorplan 2

Supply Duct
Return Duct
Architectural Floorplan 3

- Emergency Stairs
- Restrooms
- Mechanical Room
- Instructional Labs
- Seminar Rooms
- Faculty Offices
- Administration
Structural Floorplan 3

<table>
<thead>
<tr>
<th>Columns</th>
<th>Member</th>
<th>Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>Exterior</td>
<td>24” x 24”</td>
<td></td>
</tr>
<tr>
<td>Interior</td>
<td>14” x 14”</td>
<td></td>
</tr>
<tr>
<td>Cantilever</td>
<td>20” x 20”</td>
<td></td>
</tr>
<tr>
<td>Beams</td>
<td>18” x 22”</td>
<td></td>
</tr>
</tbody>
</table>

Island Team 05-11-2012
MEP Floorplan 3

Supply Duct
Return Duct
Section A-A
Section B-B
Evolution of the Foundations

Spread Footings

Eliminated due to overturning moment.
Evolution of the Foundations

- Accounts for the tension force
- Interferes with the underground water tank used for water recycling.

Eliminated due to water tank placement

Pile Footings
Evolution of the Foundations

- Shallow foundation
- Accommodates the water tank
- Time and cost is comparable to pile foundation

100’ by 100’ 30” thickness

Mat Foundation
Evolution of Roof

Post-Tensioned Waffle Slab
Depth: 20 inches

3'-0" Module
(30" x 30" Dome System)

Images Courtesy of Fundamentals of Building Construction Island Team 05-11-2012
Old and New Roof
Architectural Model 3D
Architectural Model 3D
Structural Model 3D
MEP Model 3D
Challenges

**Biomimicry**
- atrium
- balconies
- café
- student offices

**Ecological**
- natural ventilation
- dynamic shading / façade
- solar energy collection (PV panels)
- rainwater harvesting

**Economical**
- net zero + cost advantages
- café and renting out rooms as second income source
Floor Sandwich / Ventilation
Wind Availability

- Sea breezes from east across site
  - Naturally cooler than stagnant air
  - Westward side receives some wind exposure

- Average wind speed: 700 fpm
  - Typically varies between 150 and 1600 fpm

- Wind speed highest in afternoon when hottest
Wind Speeds

Wind Speeds (fpm)

Legend:

- Wind Speed (fpm)
  - 2% < 264
  - 17% 264 - 440
  - 46% 440 - 880
  - 33% 880 - 1760
  - 0% > 1760

Max 1,343.02
Min 150.50
Natural Ventilation Strategy

- Size for no more than 3F rise across room
  - 300 fpm in most spaces
  - Achievable most hours of year
- Maximum 700 fpm for ventilation in rooms
  - Achievable many hours of year
  - Less than 1 F rise
- Strategies:
  - Operable windows and grilles on both sides of room of at least 5% of floor area
  - Interior return fans to draw air inward
Review with Mentors

Third Floorplan

- Atrium
- 3rd Floor

- To block
- No sun

- Vents? Heat? Air?

- How to spread the room

- Passageway office to office?

- Need path to Admin.

- Early Sun Credits

- Wind

Island Team 05-11-2012
Natural Ventilation
Strategy to Achieve Net Zero

1. Baseline building according to IMC
2. Window shading and efficient fans
3. Setpoint to upper limit of ASHRAE standard
4. Improved insulation and windows
5. Photosensors for daylighting
6. Switch to adaptive comfort with natural ventilation
Energy Saving Strategies

Energy Use (kWh)

<table>
<thead>
<tr>
<th>Strategy</th>
<th>Energy Use (kWh)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Code Baseline</td>
<td>300,000</td>
</tr>
<tr>
<td>Efficient Equipment and Shading</td>
<td>250,000</td>
</tr>
<tr>
<td>Adaptive Comfort</td>
<td>150,000</td>
</tr>
<tr>
<td>Improved Envelope</td>
<td>100,000</td>
</tr>
<tr>
<td>Daylighting</td>
<td>50,000</td>
</tr>
<tr>
<td>Natural Ventilation</td>
<td>25,000</td>
</tr>
</tbody>
</table>
eQuest Results

- 146,610 kWh on-site energy per year
  - Design temperature of 83F (limit of acceptability with adaptive comfort standard)
  - 184,400 kWh at design temp. of 76F (ASHRAE)

- 44 tons maximum cooling load
  - Occurs on October 19, 4 pm
  - Reduced from 60 tons with change in setpoint

- 49% percent reduction from baseline
PV Panels

- Polycrystalline silicon PV panels
- Most common, less expensive
- Not tilted to be more resistant during hurricanes
- Energy gained: 194,293 kWh/year
- Energy needed: 184,840 kWh/year
- Investment costs: $ 92,600
Trade-off PV Panels

Profitable after 3 years

PV investment and following electricity bill savings  cumulated cash flows
Dynamic Façade
Façade Override
Enclosed Façade
Façade Material

- corten steel
  - high strength
  - weather resistance
  - strong enough to protect windows
  - nice appearance

## Strengths & Weaknesses Façade

<table>
<thead>
<tr>
<th></th>
<th>Strengths</th>
<th>Weaknesses</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Quantitative</strong></td>
<td>• Saves energy costs</td>
<td>• Construction costs</td>
</tr>
<tr>
<td></td>
<td>• Smaller HVAC system possible</td>
<td>• Operation costs</td>
</tr>
<tr>
<td></td>
<td>• Protects glass windows in hurricanes</td>
<td>• Maintenance and regular replacement costs for motors</td>
</tr>
<tr>
<td></td>
<td>• Lower cleaning costs for windows</td>
<td>• Hurricane risk buffer</td>
</tr>
<tr>
<td><strong>Qualitative</strong></td>
<td>• Aesthetical beauty</td>
<td>• Motors and sensors quite sensitive</td>
</tr>
<tr>
<td></td>
<td>• Perfect shading</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Advances natural ventilation</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Local / biomimicry solution</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Material perfect for humid and rainy climate</td>
<td></td>
</tr>
</tbody>
</table>
Façade Financing Possibility

- Winter Q
- Spring Q
- Delta
Trade-off Façade

Profitable after 5 years
Rainwater Harvesting

10,000 gallon tank fed by permeable PVC pipe
Rainwater Harvesting

- Can harvest 80,000 gallons/year
- Non-potable use: 73,800 gallons/year
- Conclusion: rainwater harvesting beneficial
Trade-off rainwater harvesting

- Rainwater gained: 80,000 gal/year
- Non-potable water needed: 73,800 gal/year
- Potable water needed in addition: 66,960 gal/year
- Investment costs: $4,150

Profitable after 7 years

Cumulated cash flows

Rainwater harvesting system investment and following water bill savings

Cumulated cash flows

Island Team 05-11-2012
Development Organization & Process

proactive
- water usage and supply
- water calculations and equipment
- sustainable lifecycle idea
- local experience
- placement of the tank

rainwater harvesting

revision

reactive
- structural solutions for the foundation
- costs constructability

evaluation of the rainwater harvesting system
Hand Calculations

Back of Envelope Calculation

- Used for initial and major changes in the product

What is a reasonable size to get the process to start with?

What sizes should the team expect to allow them to move forward with their processes?
Revit Structure 2010

- Integration with Architecture and MEP
- Used for clash detections
- Enables visual communication on the product

Do the columns line up with the walls?
BIM Validation checks the BIM for completion.

Why is the columns not touching the roof?

How does that impact the analysis?
ETABS/ADAPT

- Structural Analysis Modeling Program

- Used to analyze:
  - Gravity Loading
    - IBC 2009 Design Combination
    - Post tensioned Concrete Tendons
  - Lateral Loading

What does the software tell us?
Hand Calculation

Spot Checking

- Validates the process
- Ensures that the whole “Garbage In, Garbage Out” syndrome did not happen.

Does that make sense?

Did the software provide us with meaningful results?
Gravity Load Path

Gravity Load

Moment

Couple Force
ETABS Analysis

- ETABS Animation!
## ETABS Data

### Input Loading Data

<table>
<thead>
<tr>
<th>Load Type</th>
<th>Floor</th>
<th>Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dead Load</td>
<td>Typical Floor</td>
<td>120 psf</td>
</tr>
<tr>
<td></td>
<td>Roof</td>
<td>80psf</td>
</tr>
<tr>
<td>Live Load</td>
<td>Typical Floor</td>
<td>60 psf</td>
</tr>
<tr>
<td></td>
<td>Roof</td>
<td>30psf</td>
</tr>
<tr>
<td>Wind Load</td>
<td>Typical Floor</td>
<td>43 kips</td>
</tr>
<tr>
<td></td>
<td>Roof</td>
<td>25 kips</td>
</tr>
<tr>
<td>Seismic</td>
<td>Base Shear</td>
<td>765 kips</td>
</tr>
</tbody>
</table>

### Data Result

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximum Beam Deflection</td>
<td>1.27 in</td>
</tr>
<tr>
<td>Axial Force @ Column C31</td>
<td>254 kips</td>
</tr>
<tr>
<td>Shear Force @ Column C31</td>
<td>330 kips</td>
</tr>
</tbody>
</table>
ADAPT Analysis

Max Deflection: 1.18”

Tendon Height Diagram
File: Support Line 49_pt

Island Team 05-11-2012
ADAPT Analysis

Section of Tendon Placement

Unit:

- 1.18
- 1.10
- 1.01
- 0.93
- 0.84
- 0.76
- 0.67
- 0.59
- 0.50
- 0.42
- 0.34
- 0.25
- 0.17
- 0.08
- 0.00
- 0.09

Island Team 05-11-2012
Lateral Resistance

12” Shear Wall
# Lateral Resistance

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Site Condition</td>
<td>D</td>
</tr>
<tr>
<td>Ss</td>
<td>0.9</td>
</tr>
<tr>
<td>S1</td>
<td>0.31</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Floor</th>
<th>Applied Load</th>
</tr>
</thead>
<tbody>
<tr>
<td>Roof</td>
<td>192 k</td>
</tr>
<tr>
<td>3rd</td>
<td>383 k</td>
</tr>
<tr>
<td>2nd</td>
<td>192 k</td>
</tr>
<tr>
<td>Base</td>
<td>764 k</td>
</tr>
</tbody>
</table>
Lateral Load Path
Lateral Analysis Results

Dominate Period: 0.358s
Lateral Analysis Results

<table>
<thead>
<tr>
<th>Cd</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Max Elastic Defl.</td>
<td>0.32”</td>
</tr>
<tr>
<td>Code Amplified IDR</td>
<td>1.1%</td>
</tr>
<tr>
<td>Code Limit IDR</td>
<td>2%</td>
</tr>
</tbody>
</table>
Lateral Analysis Results

- ETABS Animation!
Shear Wall Design

SECTION-BB

Foundation 's Reinforcement are not shown

SECTION-AA

Vertical Bars
Transverse Bars

12"

Gauge
# Shear Wall design

<table>
<thead>
<tr>
<th>Type</th>
<th>Reinforcement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vertical: within 30” from the edge</td>
<td>#11 Bars @ 4”</td>
</tr>
<tr>
<td>Vertical: Others</td>
<td>#11 Bars @12”</td>
</tr>
<tr>
<td>Shear Reinforcement</td>
<td># 6 Bars @8”</td>
</tr>
</tbody>
</table>
Earthquake Recovery

Applied Technology Council ATC-13 (1985)

Result:
- Probability of MMI 7 : ~ 2.3%
- Damage State Level 4
- 10-80 Days for Repair
Calculating the risk surcharge for hurricanes and natural catastrophes:

- construction period
- operation period
### Risk Assessment Results

<table>
<thead>
<tr>
<th>Probability of Occurrence</th>
<th>Severity of Consequences</th>
</tr>
</thead>
<tbody>
<tr>
<td>• complaints</td>
<td>• material prices</td>
</tr>
<tr>
<td>• finance</td>
<td>• income</td>
</tr>
<tr>
<td>• owner bankruptcy</td>
<td>• interface</td>
</tr>
<tr>
<td>• bankruptcy</td>
<td>• inflation</td>
</tr>
<tr>
<td>• contract</td>
<td>• planning</td>
</tr>
<tr>
<td>• input</td>
<td>• demand</td>
</tr>
<tr>
<td>• vandalism</td>
<td>• resource prices</td>
</tr>
<tr>
<td>• maintenance</td>
<td>• performance change</td>
</tr>
<tr>
<td>• ground / soil</td>
<td>• technology</td>
</tr>
<tr>
<td>• technical construction</td>
<td>• management</td>
</tr>
<tr>
<td>• operation</td>
<td>• change of guidelines</td>
</tr>
<tr>
<td>• operation</td>
<td>• interest rate</td>
</tr>
<tr>
<td>• tendering</td>
<td>• weather conditions</td>
</tr>
<tr>
<td></td>
<td>• weather conditions</td>
</tr>
<tr>
<td></td>
<td>• during construction</td>
</tr>
<tr>
<td></td>
<td>• during operation</td>
</tr>
</tbody>
</table>

- **Risk surcharges:**
  - **construction period:** $250,000
  - **operation period:** $875,000
BIM Coordination
BIM Coordination

Modeling

- Revit Architecture
- Revit Structure
- Revit MEP

Remodel

Clash detection

Navisworks

Feedback

Island Team 05-11-2012
# BIM Coordination

## Clash detection 2012-04-12

<table>
<thead>
<tr>
<th>Clash</th>
<th>Status</th>
<th>Detected on</th>
<th>Comment/Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>Misplaced columns in facade</td>
<td>Resolved</td>
<td>2012-04-12</td>
<td>Correct placement in atrium</td>
</tr>
<tr>
<td></td>
<td>In progress/partly resolved</td>
<td>2012-04-15</td>
<td>Atrium columns still using Move architecture</td>
</tr>
<tr>
<td>Misplaced columns interior</td>
<td>Active</td>
<td>2012-04-12</td>
<td>Hide inside walls? Some clash with open space</td>
</tr>
<tr>
<td>Facee val to thin</td>
<td>Resolved</td>
<td>2012-04-12</td>
<td>Make facee thicker?</td>
</tr>
</tbody>
</table>
Site Logistics
Site Logistics
Site Logistics
Truck Route

One way traffic
Off Site Logistics

- Concrete: 4.6 mi (map)
- Precast concrete: 8.7 mi
- Glazing: 7.0 mi
- Hospital: 0.7 mi
- Equipment rental: 6.3 mi
- Off site storage: 6.1 mi
Equipment

- Excavator with high capacity
  - Weight: 72 500 lb

- Small excavator for sewer etc.
  - Weight: 7 800 lb
Equipment

- Two mobile cranes suitable for slopes
- Load: 2 500 - 120 000 lb
Equipment

- Sky lift for fitting of windows and shading
- Used for material laydown
Schedule

- Construction start: 9-14-2015
- Lab finished: 2-4-2016
- Building enclosed: 4-19-2016 (4 weeks early)
- Construction finished: 8-1-2016
Alternative Schedule

2016-02-04  Lab finished  2016-05-02  Lab finished
Constructability 4D
Construction innovations

- Tablets with 3D model of the building → better understanding of the building

- Over night material laydown → reduces construction time
Cost Estimate

Construction cost

- **Budget**: $7,650,000
- **Boomerang Winter Quarter**: $7,430,000
- **Boomerang Spring Quarter**: $7,560,000

Cost per SF

- **Reference building**: $250
- **Boomerang Spring Quarter**: $252
Cost Estimate
Life Cycle Costs

Life Cycle Costs (NPV)

- Construction costs: $4,707,646 (29%)
- Operation & Maintenance costs: $2,710,727 (17%)
- Replacement costs: $912,862 (6%)
- Risk surcharge: $521,703 (3%)
- Interest payments: $912,862 (6%)

Sensitivity analysis of LCC

Construction costs
Operation & Maintenance costs
Replacement costs
Risk surcharge
Interest payments

-10% basic NPV  5% 10%
LCC Comparisons

Necessary rent payments to cover LCC (base rate)

<table>
<thead>
<tr>
<th>Comparison</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Public Sector Comparator</td>
<td>$1.142.300</td>
</tr>
<tr>
<td>Public Private Partnership</td>
<td>$1.111.800</td>
</tr>
<tr>
<td>LCC 1 (second income)</td>
<td>$997.500</td>
</tr>
<tr>
<td>LCC 2 (PV panels -&gt; net zero)</td>
<td>$909.200</td>
</tr>
<tr>
<td>LCC 3 (rainwater harvesting)</td>
<td>$908.300</td>
</tr>
<tr>
<td>Financial Engineering (structured loans)</td>
<td>$870.000</td>
</tr>
</tbody>
</table>

Savings of 23%
Property Cash Flow

Break-even in year 11

<table>
<thead>
<tr>
<th>Year</th>
<th>Cash Flows</th>
<th>Cash Flows cumulated</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>-$10,000,000</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>-$8,000,000</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>-$6,000,000</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>-$4,000,000</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>-$2,000,000</td>
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</tr>
<tr>
<td>5</td>
<td>$0</td>
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</tr>
<tr>
<td>6</td>
<td>$2,000,000</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>$4,000,000</td>
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<td>8</td>
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<tr>
<td>9</td>
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<tr>
<td>10</td>
<td>$10,000,000</td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>$0</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>$2,000,000</td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>$4,000,000</td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>$6,000,000</td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>$8,000,000</td>
<td></td>
</tr>
<tr>
<td>16</td>
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</tr>
<tr>
<td>17</td>
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</tr>
<tr>
<td>18</td>
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</tr>
<tr>
<td>19</td>
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<td>24</td>
<td>$2,000,000</td>
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</tr>
<tr>
<td>25</td>
<td>$4,000,000</td>
<td></td>
</tr>
</tbody>
</table>
Real Cash Flows

Replacements during the summer holidays from year 16 to 20
Loan structures & financial ratios

Senior annuity loan
First junior annuity loan
Second junior annuity loan for replacements
DSCR
LLCR

Island Team 05-11-2012
Sustainability Approach

- 208 PV panels
- Water Harvesting 80,000 Gal./Yr.
- Balconies for social sustainability
- Re-Use of Excavated Terrain
- Dynamic Facade
# LEED Gold

<table>
<thead>
<tr>
<th>Category</th>
<th>Max. Points</th>
<th>Points given</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sustainable site</td>
<td>26</td>
<td>15</td>
</tr>
<tr>
<td>Water Efficiency</td>
<td>10</td>
<td>9</td>
</tr>
<tr>
<td>Energy and Atmosphere</td>
<td>35</td>
<td>35</td>
</tr>
<tr>
<td>Materials and Resources</td>
<td>14</td>
<td>4</td>
</tr>
<tr>
<td>Indoor Environmental Quality</td>
<td>15</td>
<td>14</td>
</tr>
<tr>
<td></td>
<td><strong>100</strong></td>
<td><strong>77</strong></td>
</tr>
</tbody>
</table>

- Certified 40 to 49 points
- Silver 50 to 59 points
- Gold 60 to 79 points
- Platinum 80 to 110
## DGNB Silver

<table>
<thead>
<tr>
<th>Evaluation Area</th>
<th>Criteria Group</th>
<th>Average Performance</th>
<th>Total Performance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Environmental Quality</td>
<td>Life Cycle Analysis</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Global and Local environmental Impact</td>
<td>87,5 %</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Ressource Consumption and Waste Generation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Economic Quality</td>
<td>Life Cycle Costs</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Economic Performance</td>
<td>70,0 %</td>
<td></td>
</tr>
<tr>
<td>Sociocultural and Functional Quality</td>
<td>Health, Comfort and User Friendliness</td>
<td></td>
<td>77,4 %</td>
</tr>
<tr>
<td></td>
<td>Functionality</td>
<td>74,8 %</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Aesthetic Quality</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Technical Quality</td>
<td>Technical Quality of Building Design and Systems</td>
<td>75,0 %</td>
<td></td>
</tr>
<tr>
<td>Process Quality</td>
<td>Quality of the Planning Process</td>
<td>82,4 %</td>
<td></td>
</tr>
<tr>
<td>Site Quality</td>
<td>Site Quality</td>
<td>(not counted)</td>
<td></td>
</tr>
</tbody>
</table>

Bronze > 50 %  Silver > 65 %  Gold > 80 %
Target Value Design

- Completion earlier
- Labs ready earlier
- Quick build up after hurricane

- < 880,000 $ annual rent
- Risk surcharge for hurricanes included
- Space efficiency and simplicity for o+m

- Spatial requirements
- Social & educating building
- LEED + DGNB sustainability
- Energy performance >25% below baseline
- Integration into environment
- Integrated biomimicry concepts
- Structural performance in hurricanes
- Flexibility of the building
### Team communication

<table>
<thead>
<tr>
<th>• Informal communication</th>
<th>• Smaller chats</th>
<th>• Team meetings</th>
<th>• Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Exchange of links and videos</td>
<td>• Sub-group meetings</td>
<td>• Sub-group meetings</td>
<td>• Forums in box for discussions</td>
</tr>
<tr>
<td>• “In-between” communication</td>
<td>• Back-up to GoToMeeting</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

---

![facebook](facebook.png)

![skype](skype.png)

![GoToMeeting](GotoMeeting.png)

![box](box.png)
Team Development

Winter quarter presentation

Fish bowl

Proactive

Reactive

Final presentation

Storming

Performing
Team Process Assessment Survey

Team Communication Pace

Week 9 | Week 10 | Week 11 | Week 12 | Week 13 | Week 14 | Week 15

0 | 0.5 | 1 | 1.5 | 2 | 2.5 | 3
Team Culture

Rob [MEP]

Wenhao [SE]

Chris [SE]

Maria [A]

Gustav [CM]

Sabrina [LCFM]
Team Culture
Thank you!

Humberto Cavallin
Mayra Jimenez
David Bendet
Willem Kymmell
Greg Luth
Nick Arenson
Erik Kneer
Greg Deierlein
Eduardo Miranda
Anirudh Rao
Florian Aalami (ADAPT)

Renate Fruchter
Derek Ouyang
Riam Firouz
Michael Seaman
Afaan Naqvi
Kyle Adams
John Nelson
Erik Kolderup
Peter Rumsey

Kjell Nilver
Fredrik Wincent (Veidekke)
Nima Assadi (Veidekke)
Stefan Söderberg (Veidekke)

Björn Wundsch
Matthias Ehrlich
Rubén (Palisade @Risk)
Steve Beeusaert (Palisade @Risk)
Jaime Weisberg (Palisade @Risk)