The creation of building excellence begins with an idea that is then pursued to its fullest potential. We at Genesis Design strive to exceed this potential through a sustainable, resilient, and integrative approach. Through these principles, we create for the future.
0.0 EXECUTIVE SUMMARY

Genesis Design set out to create a sustainable, resilient, and integrative project in order to meet and exceed the 2016 AEI Student Competition goals. We achieved the goals through an integrative project team that operated on the principles of mutual respect and responsibility; the result is the high-performance Boylston Street High Rise.

0.1 INTEGRATION

The integrated project delivery team structure functioned through increased collaboration and information exchange. We understand that only through the mutual sharing of responsibilities and information could the team design, build, and maintain a high-performance building with optimal efficiency. Our series of integrated systems is shown in the figures to the right.

0.2 SUSTAINABLE DESIGN

The Boylston Street High Rise is a high-performance facility that meets the project requirements of 50% ASHRAE 90 as well as several other sustainable features both calculated and unquantifiable attributes.

- An integrated dual façade containing vertical PV arrays, passive solar shading, and natural ventilation; reducing the total building energy by more than 54%.
- Combined geothermal and caisson system to reduce total HVAC load by 8.0%.
- Interactive Touch-Screens to educate the public on the facility features and sustainable practices.

0.3 RESILIENT DESIGN

The Design Team improved the resiliency of the structure as the prescribed 100 Year Wind Standard and Immediate Occupancy. The building will also be resilient to the unpredictable of forces of nature and time.

- A resilient envelope design of laminated glass for shatter protection.
- Braced-frame core for damping and immediate occupancy assurances.
- A critical power backup system for system operation.
- Flexible office and HVAC design for future layouts for tenant and city needs.

0.4 INTEGRATIVE DESIGN

Genesis Design holds complete integration of the facility systems within the building and city to the highest importance. The final design promotes connection to the internal systems, the surrounding community, and the people.

- Interactive plaza that ensures occupant comfort and safety as well as community interaction.
- The optimized dual façade with components involving every facet of the building operation.
- Construction techniques to mitigate negative impacts on the surrounding community.
# INTEGRATION SUBMITTAL

## PART 1: NARRATIVE

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.0 PROJECT INTRODUCTION</td>
<td>4</td>
</tr>
<tr>
<td>2.0 SITE ANALYSIS</td>
<td>4</td>
</tr>
<tr>
<td>3.0 TEAM GOALS</td>
<td>6</td>
</tr>
<tr>
<td>4.0 TEAM DYNAMIC</td>
<td>7</td>
</tr>
<tr>
<td>5.0 BIM PROCESS DESIGN</td>
<td>9</td>
</tr>
<tr>
<td>6.0 SUSTAINABILITY GOALS</td>
<td>9</td>
</tr>
<tr>
<td>7.0 RESILIENCY GOALS</td>
<td>12</td>
</tr>
<tr>
<td>8.0 INTEGRATION GOALS</td>
<td>14</td>
</tr>
<tr>
<td>9.0 LEED RATING</td>
<td>17</td>
</tr>
</tbody>
</table>

## PART 2: SUPPORTING DOCUMENTS

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>A. GENESIS DESIGN IPD PROCESS</td>
<td>19</td>
</tr>
<tr>
<td>B. BIM EXECUTION PLANNING</td>
<td>20</td>
</tr>
<tr>
<td>C. TEAM INTERACTION</td>
<td>21</td>
</tr>
<tr>
<td>D. PROGRAM COLLABORATION</td>
<td>22</td>
</tr>
<tr>
<td>E. SITE ANALYSIS</td>
<td>23</td>
</tr>
<tr>
<td>F. LEED POINTS</td>
<td>24</td>
</tr>
<tr>
<td>G. BUILDING RESILIENCY OVERVIEW</td>
<td>25</td>
</tr>
<tr>
<td>H. I-90 SOLUTIONS</td>
<td>26</td>
</tr>
<tr>
<td>I. BUILDING FACILITY MANAGEMENT</td>
<td>27</td>
</tr>
<tr>
<td>J. LESSONS LEARNED</td>
<td>28</td>
</tr>
</tbody>
</table>

## PART 3: DRAWINGS

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>I-01. PROJECT OVERVIEW DIAGRAM</td>
<td>29</td>
</tr>
<tr>
<td>I-02. MECH/ELEC SYSTEMS</td>
<td>30</td>
</tr>
<tr>
<td>I-03. ENERGY &amp; LIFECYCLE ANALYSIS</td>
<td>31</td>
</tr>
<tr>
<td>I-04. COST &amp; SCHEDULE</td>
<td>32</td>
</tr>
<tr>
<td>I-05. ARCHITECTURAL OPTIMIZATION</td>
<td>33</td>
</tr>
<tr>
<td>I-06. DOUBLE SKIN FAÇADE INTEGRATION</td>
<td>34</td>
</tr>
<tr>
<td>I-07. TYPICAL OPEN OFFICE FLOOR</td>
<td>35</td>
</tr>
<tr>
<td>I-08. LOBBY, RETAIL, FOOD HALL</td>
<td>36</td>
</tr>
<tr>
<td>I-09. SUBGRADE LEVELS</td>
<td>37</td>
</tr>
<tr>
<td>I-10. PLAZA DESIGN</td>
<td>38</td>
</tr>
</tbody>
</table>

## STRUCTURAL SUBMITTAL

### PART 1: NARRATIVE

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.0 EXECUTIVE SUMMARY</td>
<td>39</td>
</tr>
<tr>
<td>1.0 PROJECT INTRODUCTION</td>
<td>40</td>
</tr>
<tr>
<td>2.0 INTEGRATIVE APPROACH</td>
<td>41</td>
</tr>
<tr>
<td>3.0 BUILDING AND SITE</td>
<td>41</td>
</tr>
<tr>
<td>4.0 CODE ANALYSIS</td>
<td>41</td>
</tr>
<tr>
<td>5.0 GRAVITY SYSTEM DESIGN</td>
<td>42</td>
</tr>
<tr>
<td>6.0 LATERAL SYSTEM DESIGN</td>
<td>47</td>
</tr>
<tr>
<td>7.0 FOUNDATION SYSTEM DESIGN</td>
<td>51</td>
</tr>
<tr>
<td>8.0 PROGRESSIVE COLLAPSE</td>
<td>51</td>
</tr>
<tr>
<td>9.0 BUILDING ENCLOSURE DESIGN</td>
<td>52</td>
</tr>
</tbody>
</table>

### PART 2: SUPPORTING DOCUMENTS

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>A. HEATING AND COOLING LOADS</td>
<td>89</td>
</tr>
<tr>
<td>B. ENERGY &amp; WATER SUMMARY</td>
<td>90</td>
</tr>
<tr>
<td>C. DOUBLE SKIN FAÇADE ANALYSIS P1</td>
<td>91</td>
</tr>
<tr>
<td>D. DOUBLE SKIN FAÇADE ANALYSIS P2</td>
<td>92</td>
</tr>
</tbody>
</table>

# MECHANICAL SUBMITTAL

### PART 1: NARRATIVE

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.0 EXECUTIVE SUMMARY</td>
<td>74</td>
</tr>
<tr>
<td>1.0 PROJECT INTRODUCTION</td>
<td>75</td>
</tr>
<tr>
<td>2.0 INTEGRATIVE APPROACH</td>
<td>76</td>
</tr>
<tr>
<td>3.0 COMPUTER PROGRAMS</td>
<td>76</td>
</tr>
<tr>
<td>4.0 CODES AND STANDARDS</td>
<td>76</td>
</tr>
<tr>
<td>5.0 SITE ANALYSIS</td>
<td>77</td>
</tr>
<tr>
<td>6.0 DEMAND REDUCTION</td>
<td>78</td>
</tr>
<tr>
<td>7.0 RESOURCE REDUCTION</td>
<td>84</td>
</tr>
<tr>
<td>8.0 MECHANICAL DESIGN</td>
<td>85</td>
</tr>
<tr>
<td>9.0 LEED ANALYSIS</td>
<td>88</td>
</tr>
<tr>
<td>10.0 MEP STARTUP</td>
<td>88</td>
</tr>
<tr>
<td>11.0 CONCLUSION</td>
<td>88</td>
</tr>
</tbody>
</table>

### PART 2: SUPPORTING DOCUMENTS

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>A. HEATING AND COOLING LOADS</td>
<td>89</td>
</tr>
<tr>
<td>B. ENERGY &amp; WATER SUMMARY</td>
<td>90</td>
</tr>
<tr>
<td>C. DOUBLE SKIN FAÇADE ANALYSIS P1</td>
<td>91</td>
</tr>
<tr>
<td>D. DOUBLE SKIN FAÇADE ANALYSIS P2</td>
<td>92</td>
</tr>
</tbody>
</table>
# TABLE OF CONTENTS

E. NATURAL VENTILATION ........................................ 93
F. GEOTHERMAL CAISSON ANALYSIS .......................... 94
G. LIFECYCLE ANALYSIS ........................................ 95
H. MECHANICAL DECISION MATRIX .......................... 96
I. LEED ANALYSIS .................................................. 97
J. LIFE SAFETY AND RESILIENCY ANALYSIS ............... 98

**PART 3: DRAWINGS**
M-01. TYPICAL OFFICE FLOOR (AIRSIDE) .................. 99
M-02. LOBBY FLOOR PLAN (AIRSIDE) ....................... 100
M-03. RETAIL FLOOR PLAN (AIRSIDE) ..................... 101
M-04. VENTILATION & EXHAUST ............................. 102
M-05. MECH PENTHOUSE & ROOF LAYOUT ............... 103
M-06. HW & CW SCHEMATIC ................................ 104
M-07. RAINWATER COLLECTION ............................ 105
M-08. RISER DIAGRAMS ....................................... 106
M-09. AHU & CHILLER SCHEDULES ......................... 107
M-10. BUILDING MANAGEMENT SYSTEM ................. 108

**ELECTRICAL SUBMITTAL**
PART 1: NARRATIVE
0.0 EXECUTIVE SUMMARY ..................................... 109
1.0 PROJECT INTRODUCTION ................................ 110
2.0 INTEGRATIVE APPROACH .................................. 111
3.0 CODES & STANDARDS ..................................... 111
4.0 SITE ANALYSIS ............................................. 111
5.0 FAÇADE DESIGN ............................................ 112
6.0 POWER GENERATION ..................................... 115
7.0 POWER REDUCTION ........................................ 117
8.0 ELECTRICAL SYSTEM ..................................... 119
9.0 LIGHTING DESIGN .......................................... 121
10.0 CONCLUSION ............................................... 123

PART 2: SUPPORTING DOCUMENTS
A. ELECTRICAL DECISION MATRIX ......................... 124
B. SOLAR & SHADOW ANALYSIS .............................. 125
C. PHOTOVOLTAIC CALCS ..................................... 126
D. INTERIOR DAYLIGHTING .................................... 127
E. FIXTURE SCHEDULE .......................................... 128
F. FIXTURE CONTROLS NARRATIVE ....................... 129
G. LPD SUMMARY & CALCS .................................. 130
H. BUILDING ENERGY USAGE ................................ 131
I. SHORT CIRCUIT & VOLTAGE DROP CALCS ........... 132
J. REGENERATIVE ELEVATOR & ESCALATOR ............. 133

PART 3: DRAWINGS
E-01. ELECTRICAL RISER DIAGRAM ......................... 134
E-02. ELECTRICAL PANEL SCHEDULES ................. 135
E-03. PHOTOVOLTAIC DIAGRAMS ......................... 136
E-04. BUILDING FAÇADE DESIGN ......................... 137

E-05. BUILDING MANAGEMENT SYSTEM .................. 138
E-06. OFFICE COMPARISON & ZONES ..................... 139
E-07. OFFICE LIGHTING & POWER PLAN ............... 140
E-08. GREEN LEVEL & MEZZANINE ....................... 141
E-09. LEVEL 1 STREET ......................................... 142
E-10. LEVEL 2 & 3 ............................................... 143

**CONSTRUCTION SUBMITTAL**
PART 1: NARRATIVE
0.0 EXECUTIVE SUMMARY ..................................... 144
1.0 PROJECT INTRODUCTION ................................ 145
2.0 PROJECT DELIVERY ........................................ 145
3.0 COMPUTER PROGRAMS .................................... 146
4.0 ZONING & JURISDICTIONAL REQUIREMENTS .......... 146
5.0 SITE ANALYSIS ............................................. 147
6.0 3D & 4D COORDINATION ................................ 150
7.0 BUILDING SYSTEMS ....................................... 150
8.0 RESILIENCY .................................................. 153
9.0 SUSTAINABILITY ............................................ 155
10.0 PROJECT SCHEDULE ...................................... 156
11.0 COST CONTROL ............................................. 157
12.0 CONCLUSION ............................................... 158

PART 2: SUPPORTING DOCUMENTS
A. DECISION MATRIX ............................................. 159
B. BIM COORDINATION .......................................... 160
C. SSSP & EMERGENCY ......................................... 161
D. CRANE SELECTION ........................................... 162
E. MATERIAL TRACKING ........................................ 163
F. MAINTENANCE PLAN ........................................ 164
G. GENERAL CONDITIONS ..................................... 165
H. TOTAL BUDGET SUMMARY ............................... 166
I. LIFECYCLE SAVINGS & ADD ALTERNATES ............ 167
J. LEED ANALYSIS ............................................... 168

PART 3: DRAWINGS
C-01. BIMEX PLANNING ......................................... 169
C-02. SITE CONDITIONS ......................................... 170
C-03. SITE LOGISTICS ........................................... 171
C-04. PHASING DIAGRAMS .................................... 172
C-05. CPM SCHEDULE ........................................... 173
C-06. SCHEDULE & PREFABRICATION ..................... 174
C-07. MATRIX SCHEDULE ....................................... 175
C-08. EDUCATION ............................................... 176
C-09. EMBODIED ENERGY ...................................... 177
C-10. PROJECT COLLABORATION ......................... 178
1.0 PROJECT INTRODUCTION
The AEI Student Design Competition emphasizes the development and integration of innovative and original solutions to a design challenge. The 2016 design challenge is centered around a 17-story mixed use infill building located on Boylston Street in the Back Bay area of Boston, Massachusetts. The competition building will be referred to as the “Boylston Street High Rise. The dense urban surroundings consist of prominent buildings such as the Prudential Tower to the south and the Hynes Convention Center to the west (see Figure 1). The various parts of the project include a multi-level underground parking garage, large public lobbies, 3 floors of retail space, 14 floors of office space, connection to restaurant spaces, connection to a large public entry structure for the existing Prudential shopping center, and a multi-use street level plaza.

Figure 1 – Site & Surrounding Buildings

GENESIS DESIGN strived to address the following three challenges surrounding the Boylston Street High Rise:

1. Designing and constructing sustainably to promote a healthy city and environment.
2. Providing resiliency with respect to local environmental conditions and the adapting city.
3. Creating innovative systems that integrate within the building, the surrounding city, and the public.

By analyzing the goals of project stakeholders, we formed team goals that continuously drove design decisions. Then, through the use of Integrated Project Delivery (IPD) and Building Information Modeling (BIM), the team designed the integrated systems of the Boylston Street High Rise, shown below in Figure 2. For the full annotated version of this image (Please see Drawing I-01).

Figure 2 – Building Systems Summary

The primary changes feature an innovative dual-optimized façade which include photovoltaics, solar shading, and natural ventilation. Integrated systems also allowed Genesis Design to leverage multiple energy reduction technologies including but not limited to: geothermal caissons and an automated building management system. Lastly, fully covered security and an efficient operation came together in the forms of integrated electrical and mechanical redundancy, structural design for disaster situations, as well as lean construction techniques and long-term facility management plans. Each of these systems proved beneficial but not without their challenges such as system clashes, cost increases, and design feasibility. These challenges and associated compromises are addressed throughout the report.

2.0 SITE ANALYSIS
To successfully design and build the Boylston Street High Rise, Genesis Design performed a detailed site analysis to fully understand all site opportunities and
INTEGRATION NARRATIVE

Constraints. Investigations were performed on local environmental, subterranean, and city conditions. For detailed conclusions, refer to Site Analysis (Integration Supporting Document E). Main takeaway points include promising solar capture opportunities with photovoltaic technology, dual façade heat retention, and a closed-loop geothermal system inside of structural caissons in response to poor soil conditions. Weather analyses reveal the building’s design should prepare for hurricanes, earthquakes, snow storms, and floods resulting in power outages.

A subterranean analysis revealed the close proximity to the existing I-90 tunnel and the adjacent exhaust fan room; these must remain operational throughout the entire project. How these challenges were addressed in design and construction are available on Drawing C-02 of the Construction Report and section 5.7 of the Structural Report.

The Boston Redevelopment Authority will act as the main point of contact between Genesis Design and the Boston code department. The BRA describes zoning and local codes with respect to building height, occupancy type, setbacks, and other design criteria. Genesis Design regularly referred to the BRA when making decisions that could affect the building from a zoning perspective.

The use of this information proved to be an invaluable resource for the Boylston Street High Rise’s design. The agency helps plan future neighborhoods, identifies height and density limits, charts the course of sustainable development and resilient building construction, and provides insightful research to ensure that Boston retains its distinctive character. An example of codes referenced include: The required setback from adjacent buildings when introducing the dual façade.

2.1 SURROUNDING COMMUNITY

The Boylston Street High Rise is located in Boston’s Back Bay neighborhood, composed of both residential and commercial buildings with a full range of amenities. The site is situated north of the Prudential Tower and will occupy the last vacant spot in the Prudential Center office and retail complex. The building is situated directly between Hynes Convention Center to the west and Prudential Shopping Center to the east. Construction related deliveries to the site will be limited to Boylston Street at the north end of the site. Boylston Street is a three lane, one-way street running from west to east with one lane of parking on each side of the street. This posed a considerable challenge for compact site logistics as well as minimizing disruption to city functions. During construction, the parking lane closest to the site (now cab parking) will be blocked to allow for construction deliveries and pedestrian rerouting. It is important to note, however, that all lanes of traffic on Boylston Street and I-90 will remain open at all times, except for very minor planned lane closures. A small site necessitates that comprehensive site planning be completed by the construction team with the help of all design options. This ensures that the design goals come to fruition in a safe and efficient way. Please see the typical site logistics plan in Figure 3 below.

Figure 3- Site Logistics Plan Layout.

Another area of focus to minimize the impact on the surrounding community was to choose less invasive construction methods. For example, the use of caissons instead of driven piles minimizes sound pollution and surrounding foundation disruption that could be created by pile driving. See Sections 5.1 and 9.2 of the Construction Report for a detailed analysis of chosen construction methods and their impact on adjoining structures.

2.2 PROJECT STAKEHOLDERS

Early in the design process, Genesis design defined the project stakeholders and the influence they will have on the project. A construction project involves many
people of varying backgrounds and with many goals. It was decided that the stakeholders all had one common goal: to safely build an efficient and innovative building which has a positive effect on the surrounding community. The stakeholders for the Boylston Street High Rise include: the project developer, the city of Boston, future tenants, project architect, project engineers, construction team, neighboring businesses, and the general public. While each of these participants may have slightly different goals, it was important for Genesis Design to find commonalities within them, while still realizing the goals of the project team in order to complete a project which adds value to the area.

3.0 TEAM GOALS

Genesis Design acknowledges that the success of this project comes from the mutual respect and dedication of team members that together overcome the constraints unique to the Boylston Street High Rise. We are committed to excellence in innovation through engineering design, design execution, and life-time operation.

Additionally, we acknowledge the urban context and the significance of healthy city growth. The IPD design team strives to create only the most sustainable building systems that can withstand the test of time through integrated systems and connection to the surrounding community and environment. To do so, the team adopted three design drivers: Sustainability, Resiliency, and Integration.

3.1 SUSTAINABILITY GOALS

Sustainability Within Promotes Sustainability Throughout The team focused on interconnected systems that operate toward the same goal; the creation of a high performance building both in construction and extended lifespan. The team strived to create a healthy environment for the building occupants as well as the surrounding community.

- DESIGN ⇒ The team members from each discipline created a list of the most innovative and sustainable technologies available in their fields. The researched topics were compared to the systems of the other disciplines to determine the best combination. The basis of these options resided in the ability of each system to operate efficiently in connection with one another. See Section 4.2 for the Decision Matrix.

- CONSTRUCTION ⇒ The transition from conceptual design to reality brought forth many construction options for building sustainability. For instance, the “Just-in-Time” delivery method ensured an efficient work flow while the bulk of materials being delivered were produced locally using a maximized amount of Green materials, please see CSD E.

- LIFESPAN ⇒ The team design approach focused on building system efficiency throughout the lifespan of the building. Using the LEED and ASHRAE requirements, the team goal is to achieve LEED Platinum through cogeneration systems, water collection/reduction plans, and efficient systems (See completed LEED Analysis on ISDG).

3.2 RESILIENCY GOALS

Resiliency in Operation and Resiliency in Time The design ensures system operation during the harshest of conditions. Whether through the unpredictable forces of nature or mankind, the design will continue to provide system serviceability and occupant safety. The engineering finesse of the design allows for flexibility through each system to provide continued service through the lifespan of the building; capable of adapting to occupant and city needs.

- IMMEDIATE OCCUPANCY ⇒ Continued operation is crucial for tenant satisfaction which is achieved by creating a dependable series of building systems. The design utilizes the idea of redundancy and safety in structural planning, electrical power backup, and continued mechanical functions. The design has been tested for durability to ensure continued operation of the building’s critical systems (Please see Resiliency in ISDG).

- UNPREDICTABLE FORCES ⇒ The design team analyzed the harsh effects of the forces of nature and mankind. The structural core is designed to absorb the forces of severe windstorms and earthquakes while the specially engineered façade can withstand strong winds, driving rain, and destructive debris. We designed for the
INTEGRATION NARRATIVE

unpredictable to ensure occupant safety and building function ability. Please see SSD B & C of the Structural Report.

- **FLEXIBILITY** ⇔ The team focused on the building’s ability to adapt to changing needs. The raised access flooring, as well as the versatile mechanical systems, allow for easy system distribution changes based on tenant preferences. Please see Drawing I-07 for the detailed plans of the Flexible Office Layout.

3.3 INTEGRATION

A positive connection of systems, city, and surroundings.
The design team understands that this building does not stand alone, rather it is becoming an integral part of the existing community. It is important to connect these city fixtures to this facility in both direct and indirect services.

- **CITY** ⇔ The building is being introduced during a time when Boston is implementing a Green initiative. The city goal focuses on the creation of more sustainable attributes that promote healthy city growth and city living. The design builds upon these city goals by reducing energy intake, producing renewable energy, collecting/recycling rainwater, and providing public spaces (Please see ISD E).

- **PEOPLE** ⇔ A main design feature includes a sustainable and interactive plaza. Through the plaza design, we are creating a safe, healthy environment that provides opportunity for community interaction as well as education on sustainability for the general public. Additional design features include public-available retail space; providing accessible shopping for general needs. See Drawing I-10 for detailed Plaza Design.

- **ENVIRONMENT** ⇔ The team goal is to create an energy efficient high-rise building accompanied with a highly sustainable plaza. These goals are met through the dual façade, geothermal caissons, and solar arrays. These features successfully reduced the energy consumption and are capable of giving back to the city grid. The plaza features several sustainable designs including a wind tree and vertical green wall. Overall, the design reduces the energy intake while producing clean, renewable energy to provide for a healthy indoor and outdoor environment.

- **PROJECT DELIVERY** ⇔ Genesis Design will utilize an Integrated Project Delivery Method (IPD) to increase collaboration and communication. Using an IPD approach helps the owner and contractor build a less adversarial relationship, allowing for more cost and schedule savings. All parties are working towards the same goal due to the nature of the contractual relationships between the participants. It also allows for the construction team to have input in the design and help the owner and architect make decisions early on in the design process. This is a great way to foster communication between all members of the project team. See Figure 4 below for a visual representation of how the IPD method helps save costs by making design changes early.

![Figure 4 – MacLeamy Curve showing IPD Process Advantage.](image)

The IPD project team assists in finalizing the design to avoid changes late in the process. Curve 2 shows the drastic increase in cost when making changes to the design late in the process. Curve 1 then shows the rapid decrease in project control as the design and construction processes come to a close. Therefore, the earlier designs are finalized the more controlled and cost-effective the project can be; which is expressed by Curve 4 as the IPD Design Process.

4.0 TEAM DYNAMIC

As stated above, the team chose to utilize an IPD method. The IPD approach functions most effectively with increased collaboration between the options. This includes meetings with open communication, equal
opportunity in decision making, and the sharing of information. For more on IPD, see Section 6 of the Construction Report.

4.1 COLLABORATION
Team collaboration is vital to the success of any project; therefore, concise team meetings were held three times a week to allow team members to stay updated. A primary planning meeting was held every Monday to prepare for the upcoming week; documentation can be found in the BIM EX plan located on supporting Document B. During these meetings, tasks were prioritized and deadlines were established to keep the project progress on track.

These meetings also increased collaboration between disciplines through openly discussions to allow for outside perspective, general coordination issues, and potential clash detection. As decisions cannot be made by one discipline without affecting another, a Decision-Matrix was established. This allowed for each of the team members to rank their options and receive a quantitative representation of the choices. The decision process also included compromise between options as each decision has associated pros and cons. The primary example includes the mechanical benefits associated with the dual façade versus the substantial upfront cost. In the end, a lifecycle cost and energy analysis proved substantial enough to outweigh the direct costs.

4.2 DECISION-MAKING MATRIX
The main project values, as described in the previous section, provide the main criteria categories for the decision-making matrix. These categories are then broken down into detailed project goals. Figure 5 shows a typical layout of the decision matrix and the corresponding subcategories. Completed versions can be found on ISD C.

Various project options, such as renewable energy techniques, are placed in the left column. A weighted value from 1-5 is then assigned to each of the project goals based on their priority importance for the particular decision; shown in Figure 6.

Once the setup is complete, the criteria are ranked from 1-5 based on how well they meet the project goal. The weighted value is then multiplied by the rank to produce a score. Each of the criterion scores is summed to produce a final option score. The available options were then labeled with a Yes, Maybe, or No recommendation. This provided a quantitative illustration for each option that the team could use for decision justification. Nevertheless, the results from this process were not compulsory. This process was more of a checking system to ensure that the decisions being made had proper validation and cause. Further cost, energy, and constructability analyses were conducted in order to ensure feasibility before decisions were made.

4.3 COMMUNICATION TECHNOLOGY
Constant communication between all group members is key to any project. Genesis Design ensured constant communication throughout the design process in order to achieve an innovative, resilient, and integrated design. The app GroupMe, a multi-user text messaging service, was the primary means of communication outside of meetings. By using GroupMe a single message would inform all members of any changes. GroupMe allowed for arranging team meetings when members are across campus, traveling, or unable to access a computer.

Additional digital communication included the sharing of graphic designs and files. All files used for the design of the Boylston Street High Rise were stored on a central server and were also accessible via Google Drive. By keeping all files in a central location, we were able to easily use and exchange information gathered by other group members as well as having a location to combine.
INTEGRATION NARRATIVE

reports and presentations. The management and interoperability of these programs was also a constraint for project development as many programs are not fully compatible; therefore, an integrated BIM process was established to ensure a proper connection of information and programs. A brief example of this interoperability is shown below in Figure 6, and a full version is located on Supporting Document C.

5.0 BIM PROCESS DESIGN

The exchange of information is the cornerstone to any successful IPD project. Therefore, it was vital that the variety of software programs were able to be connected and shared. Although total compatibility is the goal, this is not feasible. There were many instances where interoperability caused significant delays. Supporting Document C shows a graphic on the relationship and compatibility between all software used in the design process.

Revit was the primary modeling software used by Genesis Design. It allowed the team to view all design decisions in a scaled 2D and 3D model and became the primary coordination between system designs.

In addition to being a powerful communication tool, the Revit models were also exported to NavisWorks so the construction team to check for system clashes and plan erection sequences. Many instances of mechanical and structural clashes were detected, necessitating a redesign of supply ducts. This ensured that the system components could be feasibly integrated. The benefit of this analysis is expressed both in the time and cost savings associated with on-site rework prevention.

6.0 SUSTAINABILITY GOALS

In Section 3.1, we laid out the team goals determined by the Sustainability design driver. In these next sections, we summarize the systems that accomplished those team goals which include:

- The Optimized Dual Façade – Increased thermal properties as well as supported natural ventilation, solar shading, shown in Figure 7.
- The Integrated Geothermal Caisson Foundation – Decreased energy loads for mechanical systems.
- The Sustainable Construction Plan – Reduced the total embodied construction energies associated with time of construction and materials used.
- The Total System Demand Reduction – Reduced the energy demands of the building while simultaneously producing renewable energy.

6.1 OPTIMIZED DUAL FAÇADE: ENERGY

The optimized double skin façade, or dual façade is a multidisciplinary integrated design that improves building sustainability. A detailed wall section for component visualization is shown in Figure 8. The sustainability aspects include energy reduction and production capabilities within the façade itself. The north and east facades, which differ from the dual façade, feature an efficient double pane curtain system with a U-value of 0.24. The U-value is measured by layering window components such as glazing, air gaps, Venetian blinds, and window glass materials. The
INTEGRATION NARRATIVE

previously mentioned dual façade design is utilized on the west and south facing exterior.

The west and south façades are subject to the most solar radiation. Therefore, solar shading in the form of horizontal blinds are placed between the interior and exterior curtain wall. These shading devices will control natural lighting into the office space, while decreasing solar, radiation, and convective heat gains negatively impacting the cooling mechanical load of the building.

Because these two façades also have the most exposure to direct daylight, several configurations using passive shading, daylight redirecting devices, and PV panels were analyzed in order to utilize this site condition. Genesis Design found that, in terms of maximizing sustainability, daylight is most useful as a supplementation of electric light, and secondly most useful as a means of generating electricity. Because of this, we designed to maximize natural daylighting as much as possible, and placed PV panels where they would not interfere with natural daylighting on the interior of the building.

The double skin façade design with its varied mechanical and solar functions is pictured below in

The PV panels were placed directly above the raised access floor and directly above the ceiling plenum at a dimension of approximately 30 inches. These PV arrays are depicted as blue slabs in Figure 8 and have been strategically placed where occupant view and natural lighting is less usable. The south and west façades are highly valuable in terms of PV potential; the introduction of the vertical array approximately triples the amount of PV generation that would be possible with only a roof-mounted system. Please see ESD-F for full PV energy generation calculations.

Though beneficial on an energy standpoint, the dual façade provided challenges for the construction process and structural design through increased dead loads, connections, installation, cost, and maintenance. For instance, the structural and construction team collectively designed a structural system to allow for both layers to be erected at once. This effectively reduced the erection time of the dual façade in half reducing the schedule and general condition costs.
6.2 GEOTHERMAL CAISSONS
The team originally assessed a geothermal system and spread footing integration but found the soil to be undesirable. Therefore, it was determined that displaced water within the earth was not a practical application. However, the combined approach between structural caissons and a closed loop geothermal system led to a more viable option. This strategy helped to combat the poor soil conditions and utilize the economical heat exchange between the concrete and the earth’s constant 50°F temperature below the frost line. See Figure 10 below.

This sustainable design allows the mechanical systems to absorb or reject heat into the earth depending on the temperature of the building and time of year. The system reduces the energy needed to maintain thermal comfort in the building by 8% without placing extremely large demands on the mechanical equipment. This system also had associated challenges especially for construction in regards to excavation, installation, cost, and quality control. Though no recorded instances of geothermal caisson failures have been recorded, it was still vital that the installation process be handled with quality assurances and that proper maintenance plans be in place to monitor the system. Please see Section 7.3 Geothermal Caissons of the Mechanical Report and Foundation Design and Progressive Collapse Analysis (SSD H) of the individual disciplines submittals for further detail on how the caissons aspects were integrated successfully.

6.3 TOTAL DEMAND REDUCTION
Genesis Design calculated demand reduction of the building’s energy usage to be of upmost importance in creating a sustainable and efficient building. The Boylston Street High Rise construction followed the ASHRAE 90.1-2007 Standard in cohesion with the existing architectural details provided in the competition package. The Boylston Street High Rise Baseline Building, with an energy demand of 125,138,558 kBTU/yr, was reduced to 57,651,716 kBTU/yr when compared to the design establishments of Genesis Design. The final design has produced an overall reduction of 54% to the ASHRAE baseline energy consumption. Integrated design strategies to reduce energy demand include envelope optimization, solar shading on each side of the facade, and low flow water equipment. See Section 6.0 Demand Reduction and 7.0 Resource Production of the Mechanical Report, and ESD-H for details on how the building’s baseline was reduced to 54%.

6.4 EMBODIED ENERGY
Embodied energy is the total energy input in acquiring, manufacturing, transporting, installing, and maintaining materials during a construction process. Different materials have associated levels of embodied energy, and it was the goal of the team to reduce the high-energy materials, the transportation distance, and the amount used. These were accomplished through the recycling and reduction of construction materials as well as the strategic selection of suppliers to the proximity of the site. The main materials analyzed were the most common materials in the building such as steel and concrete. Concrete proved to be the best option for embodied energy reduction as the material composition requires an exorbitant amount of energy. A summary of the embodied energy results for the building is shown below in Figure 11. In the end, we were able to reduce the total embodied energy by approximately 39.8%; see Drawing C-09 of the Construction Report for calculations.
7.0 RESILIENCY GOALS

In Section 3.2, we laid out the team goals determined by the Resiliency design driver. In these next sections, we describe the systems that accomplished those team goals which include:

- The Optimized Dual façade – Increased durability and safety during adverse conditions.
- The Emergency Power Plan – Increased redundancy for guaranteed continued performance for critical systems, shown in Figure X below.
- The Structural Resiliency Plan – Designed to withstand earthquakes as well as progressive collapse scenarios, shown below in Figure 12.
- The Total Building Security Measures – Designed for both occupant and data security.

Furthermore, the team decided to use glass with rounded edges as it decreases stress at the corner of the panels affectively reducing the chance of cracking at the corners due to in-plane loading when torsional and racking effects are applied. Lastly, an anchor film was implemented along the glass to firmly secure the panes within the mullions and increase the capacity of the lamination.

The construction team will then conduct a hurricane mockup test on the façade to test for water infiltration and pane sealing. The test will provide quality assurances as to the resiliency of driving. The check for proper installation will be a security check to ensure the installation meets the structural specifications for system resiliency.

To truly allow for an immediate occupancy level it is important for the glass to resist earthquake, wind, and thermal movements. All of the above methods allow for the façade to function in any type of environment as well as to allow occupants to return to work after a harsh storm. While these additional features come with a cost, the team assessed that it is justifiable due to the potential for significant data loss in a disaster scenario.

7.1 OPTIMIZED DUAL FAÇADE: SAFETY

At the beginning of the design process, it was determined that the building’s enclosure would be a key aspect to the overall resiliency of the structure. We determined that a laminated glass façade would need to be implemented to protect both building occupants and surrounding pedestrians.

Laminated glass is a multi-layered glass that when shattered holds the broken pieces to a laminated film. Two layers of ¼” glass are designed to resist the 97psf wind forces caused by the 100 year wind speeds specified by the design competition. The thicker pieces of glass also assist impacts due to ballast rocks during large wind storms. The team also chose to increase the mullion width to 3 inches to increase glass bite and its ability to handle higher wind pressures. The joints were also sealed with silicone, providing a wet curtain wall system. For more details on the structural aspects of the façade see SSDJ and S-10.

7.2 EMERGENCY POWER & START UP

In the case of a power outage, the Boylston Street High Rise will provide backup power to emergency and critical systems. This will serve a portion of the lighting on every floor, as well as emergency exit signs and the fire alarm system. Additionally, exhaust fans, fire pumps, and domestic water pumps are backed by the system.

There are two diesel generators for backup power, each redundantly capable of supporting all of the building’s critical loads. This forms a 2N generator configuration which will remain operational for 48 hours even if one of the generators fails. The startup of these generators is delayed by a few seconds which can consequently be enough time to lose server power. Loss of power to these critical elements may result in the
loss of data, which would be a detriment to the tenants. Therefore, one uninterruptible power supply was specified for every to provide backup power within a fraction of second, effectively maintaining continuous power for the critical servers. These UPS’s will provide enough time to start the diesel generators without interrupting power at all.

A double redundancy configuration was specified at the top of the power distribution system. This includes two separate utility connections and two separate transformers. The transformers have a concrete wall between them, so that they will not harm the other in the event of an explosive failure. All of this equipment is sized to the peak load demand of 2500 kVA to support the entire building, so that any equipment can be bypassed for maintenance or in the event of a failure. Although this additional level of redundancy has an additional cost associated with it, it’s necessary due to the potential loss of tenant information and data in the event of a power loss. The configuration is shown below in Figure 13.

![Double Redundancy Configuration](image)

**Figure 13: Double Redundancy Configuration**

The medium-voltage utility power connections are located in the sub-grade Green Mezzanine parking level. The location of this equipment makes it vulnerable to water damage in the event of a hurricane or flood. Therefore, the Genesis design team has implemented a “Bathtub” design. The floor and wall designs as well as the water-tight doors ensure protection in the event of excessive water infiltration.

The mechanical heating and cooling plants are located in the mechanical penthouse avoiding possible flood and water damage. Those heating and cooling plants are sized to run at full load capacity even if a large heating or cooling component requires maintenance shutdown. When in the process of finishing construction and phasing into starting up mechanical equipment, it is important to not restrict the use of air handling units which have not been outfitted with filters as well as limit the migration of construction contaminates into occupied spaces within the building. All air side components shall be constructed in accordance with SMACNA duct and NFPA Standards governing the installation of all HVAC system constructions. ASHRAE 62.1 defines HVAC system start-up by the testing or inspecting for cleanliness, functional operation and balancing of all HVAC systems. The Boylston High Rise’s owner shall be provided with a total mechanical system balancing report, as-built construction drawings and all design criteria assumed by the mechanical design team.

### 7.3 PROGRESSIVE COLLAPSE

Genesis Design decided that in order to truly provide resiliency to the structure and safety to the occupants and pedestrians, we would need to design for the possibility an accidental or intentional explosions. Progressive collapse consists of preventing the spread of local failure from one structural element to another that inevitably results in the failure of a portion or possibly the entire building. Through a schematic analysis it was determined that a more in depth analysis would need to be performed to provide a truly progressive collapse resistant structure. See Section 8.0 of the Structural Report for more details.

### 7.4 ELASTIC EARTHQUAKE DESIGN

In order to ensure resiliency during all types of natural disasters, the Genesis Design team chose to expand the requirement of immediate occupancy to include seismic events. In order to accomplish this, the team chose to design an elastic system to resist the full force experienced during an earthquake. Typically a structure is designed to withstand earthquake loads by allowing members to slightly deform without losing any strength which allows for the structure to experience minor damage without collapsing. By using elastic design, the Design Team was able to prevent deformations and damage to the structure during an earthquake event. Preventing damage to the structure met the immediate occupancy requirements set forth by the competition as well as ensured a sturdy and resilient structure. See Section 6.4 of the Structural Report for more details.
INTEGRATION NARRATIVE

7.5 TOTAL SECURITY MEASURES
Occupant safety as well as tenant security is of primary importance to the Genesis Design Team. Therefore, extensive measures were taken to ensure client peace of mind. Turnstiles are located at the main office entrance that requires swipe card access. These access cards will be unique, given to personnel working on the office levels 4-17, allowing for specified access to sensitive areas such as the server room and private offices. Security cameras will also be located throughout the building including the plaza and will be recorded for record keeping.

In the event of a fire, the Genesis Design team has equipped the high rise with several integrated protective measures. The raised access floor will be fitted with a VESDA (Very Early Smoke Detection Apparatus) in the event of a below-floor electrical fire; the ceiling plenum will also be equipped with smoke detection units. These two systems will connect to the fire alarm system which will in turn contact emergency services.

Once the alarms are triggered, a dual fire suppression system is activated. Unlike common water-based sprinkler systems, the Boylston Street High Rise will be protected by Nitrogen gas. The gas is released in a fire-suppressive cloud without damaging sensitive electrical equipment such as the office computers and server rooms. This will ensure safety while preventing costly damages.

Occupants will have emergency egress access via two stair wells. The stairwells are encased in a two-hour fire-rated wall system with a fire-rated door assembly for ensured stairwell isolation. An emergency evacuation plan will also be instituted during the entire construction process to ensure worker safety. The full plan is detailed on Supporting Document C of the Construction Report.

Each of these fire detection and fire suppression systems are linked to the Honeywell Monitoring Program: An integrated building management system which is described in full detail in the following section as well as Section 7.3 of the Lighting/Electrical Report. The consistent monitoring of these systems is critical as an unmaintained system or unnoticed faulty connection could cause loss of property or even lives.

8.0 INTEGRATION GOALS
In Section 3.2, we laid out the team goals determined by the Integration design driver. In these next sections, we describe the systems that accomplished those team goals. These systems include:

- The Optimized Dual Façade – Creation of a unique, yet energy efficient, building façade that encompasses each of the design options.
- The Flexible Office Plan Layout – Designed an efficient and flexible work space to promote occupant health and productivity as well as flexibility in present and future space demands.
- The Core System Connections – Planned to best service building needs and create an integrated and redundant system.
- The Sustainable Public Plaza – Created to provide a safe and healthy gathering space that promotes education and interaction.
- The Honeywell System Manager – Implemented to monitor all systems for performance/maintenance updates throughout the building lifecycle.

8.1 OPTIMIZED DOUBLE FAÇADE
From an integration standpoint, the dual façade represents a multi-disciplinary design that successfully meets both engineering and architectural goals. The dual façade is comprised of a prefabricated inner and outer layer structurally secured to the building superstructure. The design promotes efficient mechanical operations while both absorbs and reflects solar radiation. The complete description of challenges and functions can be found in each of the individual reports.

8.2 TYPICAL TENANT OFFICE FLOOR
We were challenged to create a flexible design that met the demands of current tenants as well as planned for future occupants. Such challenges included the need for occupant health and productivity, flexibility in layout, and flexibility in building systems. The following section describes our approach and how we met these challenges. A summary floor plan is shown on the following page in Figure 14.
According to Carrier United Technologies, the greatest change in offices has been the need for voice, data, and power connections for every worker’s workstation. IFMA (International Facility Management Association) reported that on average an office worker experiences a move or new office layout every 5-½ months resulting in a 44 percent move rate; often referred to as churn. The cost associated with a churn is one of the largest costs an owner or tenant may face mainly due to cabling and HVAC system moves. The advantage of our raised access flooring design is that cable and HVAC moves are greatly simplified and a system that reduces the amount of movement of these systems could help reduce total system life cycle cost.

The key design in meeting the flexibility challenge resides in the raised access floor (RAF) and lighting plans. The RAF is movable grid system that works in tandem with the mechanical system to promote flexibility in air distribution locations. The selection of the RAF provided immense benefits for control and comfort and is detailed on page 83 of the Mechanical Report in Section 6.3 Underfloor Air Distribution. However, the under floor air system also posed constructability and structural challenges. The RAF has an added cost per square foot associated with materials and installation as well as causes issues with sequencing work; whereas the structural design faced clash issues with both supply on the floor and return in the ceiling. Each set of challenges are addressed in the individual reports with the associated compromises and strategies to mitigate the clashes such as matrix scheduling the flow of work.

### 8.3 ROOF & MECHANICAL PENTHOUSE

As previously mentioned, the mechanical heating and cooling plants are located in the mechanical penthouse. The choice of location maximizes leasable space within the retail and garage space as well as prevents possible flood and water damage associated with subgrade mechanical rooms. Only 15% of the roof was to be occupied by mechanical equipment which is shown in Figure 15 below. The mechanical penthouse features chillers and boilers as well as air handling units for the lobby, office floors, retail, food court, and entrance areas.

Additional roof design features include a 415 kW photovoltaic array capable of producing approximately 5.89% of the total building electrical needs; see Electrical Supporting Document C for further details. Additional design implementations include a water collection system that will be collected in water storage tanks located in the subgrade parking levels. The water stored there will be used in the facility’s gray water systems such as the water closets, urinals, and plaza vegetation irrigation. A full write up on the gray water collection system is available on Section 7.2 of the Mechanical Report.
8.4 PUBLIC PLAZA

One of the primary goals for Boston’s Green initiative includes the introduction/renovation of public spaces. Therefore, it was one of Genesis Design’s primary goals to create a safe and inviting communal area that promotes sustainable practice and education. Shown below in Figure 16 is an overview of the plaza layout. See Drawing I-10 for full details of all the Plaza features described in this section.

![Figure 16 – Plaza Design Layout and Functions Overview](image)

The Plaza will feature an open public space protected by reinforced barriers disguised as planters and benches. The planters encapsulate seating nooks for 6 to 10 individuals thereby creating a wind refuge. Additional vegetation featured in the plaza takes on the form of mechanical vegetation; a way to bring technology and nature together in what is known as the Wind Turbine Tree. The plaza will feature one wind tree, shown below in Figure 17, which will provide 3.1 kW of clean, renewable energy to the plaza.

![Figure 17 - Wind Turbine Tree Featured in Public Plaza.](image)

This power is free to the public within the plaza. This will allow individuals to work or socialize while enjoying nature and the plaza amenities.

The next feature to utilize the wind energy is a CO₂ air filter created by Carbon Engineers. The design will absorb 20 pounds of CO₂ from Boylston Street daily and exhaust the filtered air into the plaza.

Any remaining wind energy produced will power the Plaza lights. The lights will serve several purposes including aesthetics, late-hour occupant safety, and pedestrian flow. A linear light design will be integrated within the Plaza landscape to create distinguishable pathways to the retail and office entrances. See Drawing E-09.

The plaza will also feature a vegetative green wall to provide a natural aesthetic as well as an iconic branding to the building. The weather and cardinal direction will be taken into consideration when designing the green wall to ensure year-round performance. The list of the pros and cons assessed in the decision are described in Drawing I-10.

Encapsulating all aspects of the project is three educational touch screens, shown below in Figure 18, located within the Plaza. The information details all sustainable facility and Plaza features. Individuals can select certain features and learn about the environmental and city benefits it provides.

![Figure 18 – Interactive Touch-Screen Kiosks](image)
The Plaza encapsulates each of the Genesis Design project goals as well as the future goals for the city. Each of the plaza amenities provides comfort, safety, and sustainability for the public and building occupants. All of these features are then contained on interactive kiosks that provide information on the innovative and sustainable Boylston Street High Rise and Plaza.

8.5 HONEYWELL SYSTEM MANAGER
Each of the above mentioned systems will be monitored electronically via the Honeywell Management System. The program will monitor and record system output to be compared against optimum performance data. The regular assessment of this data will assist in system maintenance to ensure systems are running at optimum performance. The full Honeywell System Manager is described further in Section 7.3 of the Electrical Report.

9.0 LEED RATING
The full assessment of the Boylston Street High Rise project resulted in a LEED Platinum score of 84 out of 110 possible points. A summary visual is shown below in Figure 19 and the overall assessment and is available on ISD F of the Supporting Documents.

Though the Boylston Street High Rise is a benchmark in high-performance design; its true sustainability potential could not fully be measured. The overall design and accompanying plaza contain features that could not be fully measured on a LEED scale. These features primarily include the intangible benefits of flexibility, resiliency, and education.

The Boylston Street High Rise is currently a LEED Platinum facility; the highest rank in sustainable design. However, the flexible and resilient design features ensure continued function even through changing city and tenant needs. This is invaluable in reducing the need to restructure and remodel which is an added expense of time and valuable materials.

The building also features interactive kiosks that educate the public on the immense benefits of sustainability. Those interested can learn more about the premise of LEED and how the Boylston Street High Rise met and exceeded these standards. The kiosks will also feature sustainable practices that can be conducted on an individual basis; further contributing to the LEED goal of designing, building, and living sustainably.

10.0 CONCLUSION
The AEI Student Design Competition set forth a challenge to create a high-performance building that exhibits strength in design, flexibility in performance, efficiency in operation, and promotion of the city. Genesis Design adopted these goals and made them the foundation to the following three design drivers: Sustainability, Resiliency, and Integration. Each of these goals were accomplished, but not without their share of design challenges and team compromises. Through these obstacles, the Genesis Design team grew in knowledge both personally and professionally.

10.1 GOALS SUMMARY
The project challenges span each of the team disciplines of Structural, Mechanical, Construction Management, Lighting/Electrical, and Architectural. Each discipline worked together to overcome these challenges by setting design goals; these goals ranged anywhere from energy reduction to architectural branding. A goal overview and the accompanying achievements are listed on the following page in Table 1.
### Table 1 – Project Goal Summary

<table>
<thead>
<tr>
<th>SYSTEM COMPONENT</th>
<th>PROJECT ACHIEVEMENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>OPTIMIZED DUAL FACADE</td>
<td>Reduced Mechanical Loads by 47%</td>
</tr>
<tr>
<td>GEOTHERMAL CAISSONS</td>
<td>Reduced Mechanical Loads by 8%</td>
</tr>
<tr>
<td>EMBODIED ENERGY</td>
<td>Reduction of 39.8%</td>
</tr>
<tr>
<td>SOLAR ARRAY</td>
<td>Produces 343,856 kWh</td>
</tr>
<tr>
<td>RAIN WATER COLLECTION</td>
<td>72.8% Runoff Reduction</td>
</tr>
<tr>
<td>ELEVATOR/ESCALATOR SAVER</td>
<td>Saves 158,414 kWh Annually</td>
</tr>
<tr>
<td>LIGHTING CONTROL</td>
<td>Demand Reduction of</td>
</tr>
<tr>
<td>WIND TURBINE TREE</td>
<td>Produces 3.1 kW for free public use</td>
</tr>
<tr>
<td>CO2 ABSORBER</td>
<td>Removes 20.2 lbs of CO2 Daily</td>
</tr>
<tr>
<td>STEEL BRACE FRAME</td>
<td>Reduction of Concrete and Schedule Duration</td>
</tr>
<tr>
<td>LAMINATED GLASS</td>
<td>Safety for Occupants and Pedestrians</td>
</tr>
<tr>
<td>OFFICE LAYOUT</td>
<td>Occupant Well Being and Layout Flexibility</td>
</tr>
<tr>
<td>RAISED ACCESS FLOOR</td>
<td>Reduce Mechanical Cost and Added Flexibility</td>
</tr>
<tr>
<td>BATH TUB DESIGN</td>
<td>Damage and Operation Assurance</td>
</tr>
<tr>
<td>STRUCTURAL COMPOSITION</td>
<td>100 Year Wind and Disaster Design</td>
</tr>
<tr>
<td>I-90 TRANSFER TRUSS</td>
<td>Structural Element to Construction over Tunnel</td>
</tr>
<tr>
<td>MATRIX SCHEDULE</td>
<td>Reduction of 12 Weeks</td>
</tr>
<tr>
<td>SYSTEM MANAGEMENT</td>
<td>Reduction of Cost and Time - Increase in Efficiency</td>
</tr>
<tr>
<td>PLAZA DESIGN</td>
<td>Public Comfort, Safety, and Education</td>
</tr>
<tr>
<td>CONSTRUCTION ADVERTISEMENT</td>
<td>Construction Impact Mitigation</td>
</tr>
<tr>
<td>SITE LOGISTICS PLANS</td>
<td>Reduce Natural Flow of City Operations</td>
</tr>
<tr>
<td>VERTICAL GREEN WALL</td>
<td>Added Branding, Environmental, and Public Benefits</td>
</tr>
</tbody>
</table>

### 10.2 PROJECT CHALLENGES

The Genesis Design team operated on the basis of integrative decisions. Each design aspect required a choice between multiple options. Though these decisions are addressed by the decision matrix, many required inter-disciplinary compromise. A few of the primary challenges and compromises include:

- **Increased cost versus the energy reduction and production of the optimized dual façade** – The team concluded the mechanical system and office layout flexibility supported by the RAF was immensely beneficial to tenants; so the construction team created the matrix schedule for installation management while the mechanical team resized the ducts to integrate with the structural system.

### 10.3 LESSONS LEARNED

Each step of the Boylston Street High Rise project offered a learning opportunity. Whether through the guise of proper team function or overcoming an engineering challenge; the team both together and individually was able to grow in knowledge and professional understanding. The primary lessons that apply to all projects both on a group and individual basis are listed on **ISD J**.

### 10.4 FINAL WORDS

We at Genesis Design believe that the Boylston Street High Rise is a testament to high-performance buildings and stands as a benchmark to the future vision of Boston. Through our integrated project team, we have created a sustainable and resilient facility that will continue to perform a valuable service to the tenants, occupants, and city of Boston.

The creation of building excellence begins with an idea - that is pursued to full potential. We at **Genesis Design** strive to exceed this potential through a **sustainable**, **resilient**, and **integrative** approach. Through these principles, we create for the future.
CREATING A TEAM DYNAMIC

2. Enthusiastic, communicative, and driven members created a unified team identity, Genesis Design, and consensus to collaborate their best work into a competitive project design.

PRELIMINARY SITE ANALYSIS

3. Opportunities and constraints of the site’s environmental factors were quickly, but carefully examined to leverage the best possible design response.

CREATING PROJECT GOALS & DRIVERS

4. The team adopted 3 design drivers of Sustainability, Resiliency, and Integration. Relating to each, more specific project goals were developed and constantly influenced the team’s design process.

SUPPORTING DOCUMENT A: GENESIS DESIGN IPD PROCESS

UNDERSTANDING THE PROJECT

1. The process began with fully understanding the 2016 AEI Student Competition program and guidelines. Knowledge on the building’s importance to and impact on all project stakeholders (building owner, occupants, and city of Boston) was established.

BIM-EXECUTION PLANNING

7. BIM execution planning enhances communication and organization through intelligent management of responsibilities, schedules, and information exchange. The BIM-Ex is a living document, changing to the team’s need and performance.

INNOVATIVE DESIGN CHARRETTE

5. Design charrettes were creative bursts of energy that built momentum to meet project goals. Innovative ideas and technologies were constantly researched and brought to attention for potential implementation. The team shared information and provided feedback as much as possible from the beginning.

steps are constantly interconnecting & repeating

8. The design process consists of conducting extensive research and code analysis, utilizing a variety of software programs, and reaching out to design professionals and manufacturers for information and advice.

DETAILS ANALYSIS, CALCULATIONS & SPECIFICATIONS

9. Through software analysis programs, calculations, and specifications, design decisions are determined successful or not with proof. Conveying our work’s process and results to be easily understood was imperative.

DISCUSSION & COLLABORATION

10. Communication and team dynamic are ultimately important as technical capability, therefore multiple weekly team meetings, group messaging, and shared workspaces helped information exchange and responsibility designation.

SYNTHESIS INTO FINAL DOCUMENTS

11. The synthesis of final design documentation took an enormous amount of coordination and strategy to best convey the total scope of project goals and continuous integrative project delivery accomplishment with acknowledgment of lessons learned.

with final deadline approaching
WHY BIM EXECUTION PLAN?

In order to successfully implement Building Information Modelling on this project, Genesis Design developed a BIM Execution Plan. This plan acted as a guiding force throughout the length of the project. It was a living document which aided in the communication between team members as well as allowed the team to choose aspects in which to implement BIM.

In order to work efficiently, we first established collaboration procedures. Meeting times and topics were created by the entire team (see Table 1); these meetings were then supplemented with additional meetings by the individual project teams (mech., elec., etc.). Additionally, a BIM project schedule was developed by the construction team which set goals for the duration of the project (see Table 2). These project deadlines included the broad, most important, deadlines which needed to be met in order to continue the project successfully. Table 3 illustrates which areas of the project Genesis Design felt BIM would be most useful. These BIM uses were then evaluated to determine which parties would be responsible for completing them.

In order to effectively communicate as a team, it was important to practice good file management. The team has a private central drive where all files can be stored and accessed by team members. Early on, it was subcategorized for an efficient management system. Google Drive was also utilized to communicate when access to a school computer was not possible.

The main means of communication was GroupMe, a messaging service where all members of the team can connect and ask questions very quickly. The rapid communication through cellular devices ensured quick responses for an optimized form of communication.

### Table 1: Team Meetings

<table>
<thead>
<tr>
<th>Meeting Type</th>
<th>Project Stage</th>
<th>Participants</th>
<th>Location</th>
<th>Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Progress Update</td>
<td>Project Duration</td>
<td>All Team Members</td>
<td>333 Sackett Building</td>
<td>M-F 3:30-5:30</td>
</tr>
<tr>
<td>Design Brainstorming</td>
<td>First Quarter</td>
<td>All Team Members</td>
<td>333 Sackett Building</td>
<td>M-F 3:30-5:30</td>
</tr>
<tr>
<td>Collaborative Work Time</td>
<td>Middle Quarters</td>
<td>All Team Members</td>
<td>333 Sackett Building</td>
<td>M-F 3:30-5:30</td>
</tr>
<tr>
<td>Project Completion</td>
<td>Final Quarter</td>
<td>All Team Members</td>
<td>333 Sackett Building</td>
<td>M-F 3:30-5:30</td>
</tr>
</tbody>
</table>

### Table 2: Project Deadlines

<table>
<thead>
<tr>
<th>Project Phase Milestone</th>
<th>Estimated Start Date</th>
<th>Estimated Completion Date</th>
<th>Project Stakeholders Involved</th>
</tr>
</thead>
<tbody>
<tr>
<td>Complete Design Charrette</td>
<td>9/7/2015</td>
<td>9/7/2015</td>
<td>All Team Members</td>
</tr>
<tr>
<td>Determine Structure</td>
<td>6/1/2015</td>
<td>6/1/2015</td>
<td>Structural Team</td>
</tr>
<tr>
<td>Develop Systems</td>
<td>6/1/2015</td>
<td>6/1/2015</td>
<td>Complete Electrical System</td>
</tr>
<tr>
<td>Complete Architecture</td>
<td>7/1/2015</td>
<td>7/1/2015</td>
<td>All Team Members</td>
</tr>
<tr>
<td>Complete Revit Model</td>
<td>8/1/2015</td>
<td>8/1/2015</td>
<td>All Team Members</td>
</tr>
<tr>
<td>Finalize Budget/Schedule</td>
<td>9/1/2015</td>
<td>9/1/2015</td>
<td>Construction Team</td>
</tr>
<tr>
<td>Final Draft for Revisions</td>
<td>10/1/2015</td>
<td>10/1/2015</td>
<td>All Team Members</td>
</tr>
<tr>
<td>Final Submission</td>
<td>11/1/2015</td>
<td>11/1/2015</td>
<td>All Team Members</td>
</tr>
</tbody>
</table>

### Table 3: BIM Goal Use Analysis

<table>
<thead>
<tr>
<th>BIM Use</th>
<th>Value to Project</th>
<th>Responsible Party</th>
<th>Value to Responsible Party</th>
<th>Capability Rating</th>
<th>Additional Resources/Competencies Required to Implement</th>
<th>Notes</th>
<th>Processed With Use</th>
</tr>
</thead>
<tbody>
<tr>
<td>Workforce Training</td>
<td>Low</td>
<td>Facility Manager/Owner</td>
<td>High</td>
<td>3</td>
<td>Training Required</td>
<td>Building Automation System (BAS)</td>
<td>No</td>
</tr>
<tr>
<td>Building Systems Analysis</td>
<td>High</td>
<td>Mech. Engineers</td>
<td>High</td>
<td>3</td>
<td>High</td>
<td>Good for systems design</td>
<td>Yes</td>
</tr>
<tr>
<td>Record Keeping</td>
<td>High</td>
<td>Facilities Manager/Ownder</td>
<td>High</td>
<td>3</td>
<td>High</td>
<td>Documents are organized and accessible</td>
<td>Yes</td>
</tr>
<tr>
<td>Cost Estimation</td>
<td>High</td>
<td>Construction Team</td>
<td>High</td>
<td>3</td>
<td>High</td>
<td>Communication is key</td>
<td>Yes</td>
</tr>
<tr>
<td>3D Modeling</td>
<td>High</td>
<td>Construction Team</td>
<td>High</td>
<td>3</td>
<td>High</td>
<td>Accurate model necessary to help build an accurate schedule</td>
<td>Yes</td>
</tr>
<tr>
<td>Engineering Analysis</td>
<td>High</td>
<td>Mech. Engineers</td>
<td>High</td>
<td>3</td>
<td>High</td>
<td>Training in end purchase of latest software may be necessary</td>
<td>Yes</td>
</tr>
<tr>
<td>GIS Analysis</td>
<td>High</td>
<td>Mech. Engineers</td>
<td>High</td>
<td>3</td>
<td>High</td>
<td>Helps with site design</td>
<td>Yes</td>
</tr>
<tr>
<td>GIS Coordination</td>
<td>High</td>
<td>All Engineers</td>
<td>High</td>
<td>3</td>
<td>High</td>
<td>Communication between departments is key</td>
<td>Yes</td>
</tr>
</tbody>
</table>

New Business

- Strategic initiatives outside of Blockchain
  - Look into similar buildings in Boston
  - Collaboration
  - GIS
  - Energy Usage
  - Emergency operation

Recent projects

- Development of site schedule for work
- Building envelope schedule for work
- Final design of work
- Project coordination
**DECISION MATRIX**

Genesi Design’s three design drivers (Sustainability, Resiliency, Integration) and project goals provide the main criteria categories. A weighted value of 1-5 is assigned to each of the detailed project goals for each system category, and then each specific option within the category is also assigned a rank of 1-5. After multiplication and summation, the total score provides quantitative representation for decision justification, especially in the case of dispute resolution. High total scores resulted in the pursuit of further research and calculation justification, not definitive implementation.

**TEAM PERSONALITY TYPES**

Genesi Design’s team members consist of different personality types and throughout the project design, communication grew stronger as we became accustomed to each other’s strengths in different areas. Myer’s Briggs Personality Test was treated as a fun team activity.

**Figures** — Image Property of NERIS Analytic Limited
REVIT
Revit is the main collaboration building design software specifically for BIM. A central model is made to incorporate architectural, MEP, structural, and construction design.

SAM
Developed by NREL, the System Advisor Model software calculates PV system production with equipment and shading losses, as well as financial analyses.

PRIMAVERA 6
Scheduling software for final schedule formation with direct links to Navisworks 4D scheduling.

EXCEL
Excel gathers and organizes info outputs into easily interpretable data and charts.

ADAPT
Finite element software used for RC slab design.

RAM
Software used to design gravity members.

ETABS
Design and Analysis software used for lateral sizing and modal analysis.

PROJECT
Scheduling software used for initial schedule creation and link to Navisworks 4D model.

SKETCHUP
Used to model custom objects such as the double skin façade and import as an object into Revit for systems coordination and rendering.

SKETCHUP
Used to model custom objects such as the double skin façade and import as an object into Revit for systems coordination and rendering.

PHOTOSHOP
Graphic/image creation and editing.

BLUEBEAM
Used for vast array of tools such as drawing coordination overlays, pdf markups/commentary, area take-offs, document compilation, etc.

REVIT MEP
Used to design duct and piping runs to investigate clash detection.

NAVISWORKS
Used for clash detection of system integration and construction simulation.

ECOTECT
Using an AutoCAD created site model (.dxf), Ecotect uses weather data files to calculate solar radiation and shadowing important to preliminary building site analysis.

DAYSIM
Used for interior daylighting, this software includes DA and UDI calculation tools.

AGI32
AGI32 was used for lighting calculations for larger, more complicated spaces that ElumTools cannot handle.

TRACE 700
Used to create an energy model for mechanical design analysis.

IES VE
Used as a supplementary energy modeling program to TRACE.

REVIT
Tool for design and documentation, links into Revit.
ABOVE THE URBAN CONTEXT

The Back Bay in Boston, MA is an important mixed-use commercial and expensive residential neighborhood. Located adjacent to the Charles River and Newbury Street high-end shopping, the Boylston Street High Rise is the last plot of land developed within the Prudential Center Complex. The complex includes three skyscrapers, and urban shopping mall. Other notable surrounding buildings are the Hynes Convention Center and Exeter/Fairfield residential apartment complexes.

Pedestrian/Traffic Analysis

Local traffic patterns are an important aspect to consider when thinking about traffic deliveries and road closures. Due to the fact that Boylston St. cannot be closed at any time during construction. By analyzing the traffic patterns surrounding the site the Design Team chose to have all deliveries to the site occur during the hours of 6-9am. During an initial investigation the Design Team considered the most efficient system to ferry pedestrians around the construction site. It was decided that taking away parking spots along Boylston St. and converting them into pedestrian walkways in front of the site.

SOLAR ANALYSIS

Initially the Design Team performed a solar radiation analysis. A solar analysis assisted the mechanical and electrical teams located the optimal location of roof solar panels. Using the solar radiation analysis the mechanical team was able to determine that the optimal location of a double skin façade would be on the south and west side of the structure due to the ability of the space between glass layers to heat up allowing natural air flow through the space. The radiation model showed that a large portion of the structure was shaded by the even larger prudential center tower.

WIND ANALYSIS

In order to assess the potential for wind turbines to be located on the Boylston High-rise site a simple wind analysis was performed. An initial analysis determined that roof top wind turbines would not be an efficient energy generation feature. In addition to roof top turbines it was concerns over wind speeds causing issues in the plaza area. A previous analysis performed by the Boston Redevelopment authority indicated that wind speeds in the plaza would be within reasonable levels upon completion of the new high rise structure. The design Team decided to utilize the wind present in the plaza by installing a “wind-tree” and converts the wind into usable power for the plaza lighting.

GEOTECHNICAL ANALYSIS

The Boylston site has many unique geotechnical features. The building sits on very poor soil requiring the Structural Design Team to design deep foundations which extend down to bed rock located 150’ below as well as allowing the Mechanical Design Team to install geothermal wells in each caisson. In addition to the poor soil an existing sheet pile wall surrounds the site holding back the water table from pushing on the foundation walls surrounding the parking garage. The low water table extends to the top of the an existing mat foundation which exists below the two parking garage levels. The structural team believes that the existing mat foundation can be used to support columns that only support the parking garage levels. Another important site implication is the effect of having I-90 running below the south-west corner of the building. I-90 prevented a column to extend to the foundation and required a transfer truss to be designed.
LEED ANALYSIS SUMMARY

INDOOR ENVIRONMENT QUALITY

- AIR QUALITY - 2
  
  Underfloor Air is provided by LEED documentation to have a ventilation effectiveness of greater than 1. The dual optimized façade will also provide opportunity for natural ventilation.

- LOW EMITTING MATERIALS - 4
  
  Materials selected for use during construction and throughout the building were chosen based on green building standards. Materials with low amounts of VOC’s are safe to use for the worker installing them, and they also contribute to a safer and cleaner working environment for future tenants.

SYSTEM CONTROLS - 4

The adjustable diffusers, building management, and automation systems will facilitate the delivery of ASHRAE Standard 55 ventilation values for annual thermal comfort. Greater than 50% of every typical tenant office interior zone is outfitted with personalized airflow settings per work station.

DIA LIGHT & VIEWS - 2

Simulations of spatial daylight anatomy, demonstrating 55%, 75%, and 90% achievement. Simulation of illuminance calculations of 300 = 3000 lux for 9 a.m. and 3 p.m.

MATERIALS & RESOURCES

- WASTE MANAGEMENT - 2
  
  The demolition of the existing site was comprised of mainly steel and reinforced concrete, this is shipped 20 miles to Dedham Recycling. This facility recycles used construction materials and converts it into usable products. The recycled concrete is converted to aggregate. Materials on site will be sorted and recycled before being disposed of in order to control waste to landfills.

- RECYCLED MATERIALS - 2
  
  The concrete and steel used is composed of recycled materials including silica fly ash in replacement of the Portland cement. Jarmak Wood will also provide the accented wood finishes for the office space using reclaimed wood from the northeast region of the U.S. The reuse and reduction of these materials effectively decreased the embodied energy by 39.8%.

- REGIONAL MATERIALS - 2
  
  The majority of materials will be provided within a 150 mile radius of the site. This includes the cement, concrete, steel, wood, and curtain wall system and dual optimized façade.

ENERGY & ATMOSPHERE

- OPTIMIZED ENERGY PERFORMANCE - 19
  
  Dual Optimized Façade (S&W) implemented on the south and west faces that reduce the mechanical load by >50% by restricting solar gains.

- ON-SITE RENEWABLE ENERGY - 7
  
  The design includes a solar array implemented on 50% of the west and south facades and a rooftop array. Additional renewable energy will include the 3.1 kW wind turbine tree located in the Plaza.

- ENHANCED COMMISSIONING - 2
  
  The building mechanical and electrical systems will be monitored for system performance. This will ensure that the designated outputs are being met with an assured optimal performance.

WATER EFFICIENCY

- WATER USE REDUCTION - 4
  
  Use of the rain water collection will reduce the overall usage of city water. This will be used in the bathroom fixtures which will include low-flow toilets and waterless urinals. The overall water collection will take place on both the roof and plaza space. The total rain water collection results in a 75% reduction in city water usage.

- WASTEWATER TECHNOLOGIES - 4
  
  The building will utilize high-efficiency dual flush toilets as well as waterless urinal technology for water use optimization.

SUSTAINABLE SITES

- DEVELOPMENT & COMMUNITY - 5
  
  This site is excellent from a community density standpoint. Within ¼ mile from the site are dozens of businesses and shops which future tenants and employees can utilize. Having a project close to businesses allows for reduced car usage, leading to lower emissions. Building the community from within is a good strategy to lower emissions and keep people involved in the local community.

- ALTERNATIVE TRANSPORTATION - 11
  
  LEED requires at least 10 basic services within 1/2 mile of the project site. This credit also requires a dense residential zone within 1/2 mile of the project site. The MBTA Back Bay train station is located 0.48 miles to the south east of the project site, within the LEED mandated 1/2 mile to qualify for the Alternative Transportation Access credits.

TOTAL POINTS: 84

SUPPORTING DOCUMENT F: LEED POINTS
PROGRESSIVE COLLAPSE
The Design Team chose to add progressive collapse as an additional scope of work in order to increase the building’s overall resilience against accidental and intentional explosions. Analysis determined that a more in-depth analysis would need to be determined due to inelastic results.

COLUMN MOVEMENT
Columns were moved on the north side of the structure in order to line up with the column line at the store front levels. Allowing to extend the length of the building eliminates transfer beams on the fourth floor level. Transfer beams reduce resiliency due to significant damage that is possible if a support column is removed. An efficient load path is very important when designing a resilient structure.

BRACED FRAME CORE
Changing of the building’s core to an eccentric and double story X-brace not only decreases the construction schedule but also increases the building’s resiliency through the introduction of dampers. Dampers assist with the reduction of accelerations experienced by occupants as well as reduce stresses experience by the façade system. Occupants feel discomfort when a building has excessive motion and accelerations. Therefore the Design Team determined that damping of the structure to 20% of critical provides a level of acceleration that is acceptable for occupant comfort.

GLASS SELECTION
In order to protect occupants from flying debris and high wind speeds was a key way to increase the overall resiliency of structure. In order to prevent shattering and falling of glass fragments due to flying baluster that can be picked up during large wind storms. Laminated tempered glass is the optimal glass for the exterior cladding of the structure due to its high strength and shatter resistance. Another benefit of a laminated façade is the ability to hold broken glass fragments in place increasing the safety of bystanders as well as clean up following a storm.

ELECTRICAL REDUNDANCY
In the main transformer vault, two 2500 kVA transformers form a 2n configuration, meaning each is independently capable of supporting the entire building. Since both connect to the main switchgear, it is possible to completely disconnect one transformer for servicing without interrupting the building power at all. This system also includes redundant medium-voltage utility connections (to NSTAR and National Grid) to provide sufficient power in the event of a power outage from one of the providers. Uninterruptible power supplies, which are on every floor, will provide immediate continuous power to critical server loads in the case of a power outage. These give an adequate amount of time for the two rooftop diesel generators to start, which will provide 48 hours of backup power.

MECHANICAL REDUNDANCY
All main HVAC equipment will follow the resiliency measure of n + 1 for system availability in the event of a major component failure. This includes cooling towers, air handling units and direct outdoor air supply systems. Each “n + 1” component of this system will cycle through into operation each month in prevention of the system becoming dormant too long.
### Site Conditions
Possibly the most complex aspect of this project has to do with the Massachusetts Turnpike running directly adjacent to the south-west corner of the building. It is imperative that the traffic on this road is never interrupted throughout the construction process. The north wall of the turnpike acts as the rear wall of the Boylston Street High Rise, however, it is not structural in nature. The building is essentially hung by two transfer trusses which transfer column loads around the turnpike and down to the caissons. Connected to the turnpike, and a part of the project building, is a two-story turnpike fan room (highlighted below in red). This room must be avoided during the controlled demolition of the existing parking garage. This room will be monitored throughout the duration of the project to ensure full capability of the highway exhaust system.

### Dealing with Interstate 90
As stated above, Interstate 90 runs along the south perimeter of this project. This forced the structural team to transfer column loads around the roadway. This was accomplished by using two transfer trusses on the fourth floor. These are highlighted in red in the image below. This effectively takes the column load from the columns in the south-west corner and transfers them to the columns which are leading to the deep foundations. From a construction standpoint, everything on the site except for the existing fan room will be selectively demolished. The image below highlights the transfer trusses in red, showing the overhang of interstate 90. Highlighted in blue is the braced frame.

### Cantilevered Truss Design
A cantilevered truss was chosen as the optimal solution to support the cantilevered floors. Another possible option would be a post-tensioned beam located above I-90. This option was ruled out due to its required size as well as its hindrance to the construction schedule due to the need to continually stress the tendons. The trusses were designed to function as separate elements for strength design. This means that in case of a disaster such as an explosion the structure wouldn’t collapse due to redundancy in the trusses. For serviceability, the trusses were designed as one unit in order to size for deflection in an optimal manner. Due to the truss’s effect on the structure as a whole it was decided that deflection of the truss should be limited as much as possible. Instead of the code allowable 2.25” deflection the Design Team limited the total deflection to 1.09”. It was decided that the optimal location for the truss would be the 4th floor. This location has the least impact on architecture as well as impact on the construction schedule. If the Truss would have been located on a higher floor the structure would have been hindered by the need to build the entire structure followed by the need to return and construct the missing bay.

### Deep Foundation Selection
The geotechnical report included with the project documents recommended a deep foundation system. One deep foundation system considered was driven piles; this had several negative qualities associated with it however. The geotechnical report suggests that driving piles would not be an acceptable foundation alternative due to the potential for disturbance of the subsurface clay. Another reason for discounting driven piles was the negative impact they would have on the surrounding buildings and roadways. Driving piles includes excessive vibrations in the surrounding area; this could have an effect on the subterranean interstate. The excessive vibrations could compromise the structural integrity of the highway and the exhaust fan room connected to it. Drilling caissons doesn’t have as negative an impact on these adjacent structures, so it was considered a more suitable option. Another reason for choosing caissons was the ability to incorporate geothermal heat recovery loops; an innovative way to integrate the mechanical team in a mostly structural and construction area of the project.
PREDICTIVE AND CORRECTIVE MAINTENANCE

One of the primary Genesis Design goals is the resiliency of the facility. The systems were designed to perform against the unpredictable forces of nature; however, the unreliant forces of time also cause damage to the performance of a system. The Genesis Construction team developed a Predictive and Corrective Maintenance Plan to best handle the inevitable wear and tear of system components. The predictive maintenance portion of the program is perhaps the most challenging due to the number of systems and their variety of components. Therefore, building management system was developed in order to track system performance. The monitoring of these values will alert the maintenance staff when a system reaches below an acceptable output level. The system will then require corrective maintenance to resolve the problem. This maintenance may include changing oil, changing filters, cleaning the system, or replacing a component. The monitoring of each system will create a pattern that the maintenance crew then regularly schedule to ensure minimal system interruption during prime working hours.

CORRECTIVE MAINTENANCE CURVE

The yellow curve shows the typical lifespan of system equipment. The component will begin working at 100% design capacity and progressively decrease due to natural wear and tear of system components. This is especially true for moving system components such as the inner workings of elevator equipment. The system continual to deteriorate until the equipment reaches the projected service life span and needs replaced. The replacement of equipment is often very costly for material and loss of productivity time due to system shutdown.

With the Predictive and Corrective Maintenance Plan the team can monitor these critical systems for signs of deterioration and plan schedule down-times for corrective maintenance. This corrective maintenance will then bring the system back to near 100% working condition.

CLASH CORRECTIONS

To the left is a clash between a mechanical supply duct run and structural steel floor framing. To rectify this, the ductwork was resized to slightly more rectangular rather than square in order to fit under the floor. Changing the cross sectional layout of the ductwork necessitates a recalculation of the fan size due to more turbulent air flow through a rectangular duct. By catching this in the design process rather than in the field during construction, the team was able to save time on the order of a few days fieldwork.

INTELLIGENT BUILDING MANAGEMENT SYSTEM

Genesis Design decided to adopt Honeywell’s Enterprise Buildings Integrator as the Boylston Street High Rise’s comprehensive, network-based solution for building automation and management. It has the ability to incorporate all the industries open standards mentioned above into a single-point of access for the building facility manager. This allows the building to be flexible for future planning in terms of system expansion and life-cycle savings.
The process of designing and construction a building provides immense opportunity to grow in both professionally and personally. The project tested individual knowledge and the ability to learn, but it also provided opportunity to learn and grow as a team. The Genesis Design Team realizes the immense importance of learning from these experiences to better equipped us for handling real-world challenges. These challenges that we faced and overcame are described below; summarizing the positives and negatives that we have noted for future reference.

**INDIVIDUAL LEVEL**
- Responsibility for Work
- Value of Time Management
- Acquiring/Applying Info.
- Working Toward Problem Solutions

**COLLABORATION/COMMUNICATION**
- Developing Team Structure
- Establishing Team Identity
- Mutual Respect/Responsibility
- Establishing Meet Times
- Value of Open Communication
- Necessity of Interoperability
- File Sharing Organization
- Communication through Technology
- Value of Work Proximity
- Value of Design Professional Consultations

**DESIGN PROCESS**
- Balancing Details and Efficiency
- Decision Making Pros and Cons
- Decision Analysis
- Process of Tradeoff Analyzation
- Execution of Designs While Maintaining Goals

A group based project tests an individuals ability to both work together and separate. Often times the work load is divided and a great deal of research and planning is required. This work must be completed accurately and within a timely fashion as the group is depending on your individual effort. This requires a great deal of responsibility and time management to identify the problem, collect data, and work toward a solution.

The first stage of developing Genesis Design involved coming together as individuals and establishing the primary goals for the team. This further developed into goals for the project which created our team identity and design drivers. The establishment of our identity was crucial in that it gave our team direction and motivation for the project; thereby reducing our role ambiguity in the team and the project.

Once the design process started, the team quickly realized the importance of information sharing. This includes both verbal and digital exchanges of information. Therefore, we created a communication system, central file location, and weekly meetings to stay in constant communication. The sharing of digital files then quickly lead to the challenge of information sharing between programs which lead to an in depth analysis into program interoperability. In the end we realized that only through a combination of mutual respect, responsibility, and communication would our team be able to function effectively with project success.

The scope of this student design process is very large. In the beginning of the design process, it was easy to find yourself designing to a extremely minute level of detail. Although Genesis Design has delivered a submission with a highly executed design, it was difficult to find a level of efficiency in order to complete the scope of the project within the time frame allotted. The solution to this situation was to find a middle ground that provided a highly integrated and developed design, yet did not hinder the progress of the design timeline. This required much discipline and coordination between all building design options.
WHOLE BUILDING DIAGRAM

1. Rain Water Collection
2. Optimized Dual Facade
3. Transfer Truss
4. Core Structure
5. Escalator/Elevator Energy Saver
6. Geothermal Caissons
7. Bathtub Design
8. Solar Array
9. Outdoor Green Space
10. RAF Air Distribution
11. Advanced Lighting Controls
12. Wind Turbine Tree
13. Interactive Kiosks
14. CO2 Absorber

- 72.8% Run-off Reduction
- Acts as thermal boundary
- Supports hanging columns over I-90
- 12 Week Schedule Reduction
- Saves 158,414 kWh annually
- Reduces total energy needs by 8%
- Allows for continual building operation
- 343,856 kWh Array
- 9,475 SF of outdoor terraces
- High efficiency of air distribution
- Reduced power consumption
- Produces 3.1 kW of energy for public
- Eliminates 20.2 lbs CO2 per day

DOUBLE SKIN FAÇADE DIAGRAM
LIFECYCLE COST ANALYSIS
While the importance of innovative design solutions to complex problems cannot be understated, they are nevertheless usually costly. Genesis Design made every effort to make decisions which made financial sense to the property owner. Higher up front costs for highly efficient systems leads to lower energy bills. In order to quantify these savings, the total building energy usage had to be calculated on a baseline building. In the Energy Use Cost Analysis table below, Genesis Design was able to reduce the energy cost per year by about 5.88 MM. This over 50% reduction was due mostly to the redesigned façade and mechanical systems. As shown, this is also where most of the additional cost figures come into play. As detailed in the Exterior Envelope Cost Comparison table below, the difference between a typical glazing system and the optimized dual skin façade with integrated photovoltaics is about $750/SF glazing area. This is significant, but as shown in the payback period graph, this expense can be paid off within the lifespan of the building.

Optimized Dual Façade Cost Analysis
While the double skin façade had numerous positive impacts on the mechanical loads for the building, it comes at a high initial cost. To calculate the construction cost of building this system, the exterior enclosure cost was first estimated per square foot of glazing area. The double skin portion was then estimated to be 2.5 times the cost of a typical system based on the recommendation of a façade manufacturer. This includes a uniform system with integrated photovoltaics. This number was then applied to 60% of the total exterior enclosure, the portion of the building which has the double skin façade. This cost will be paid back however, due to the mechanical savings that it will achieve.

Payback for HVAC & Double Skin Façade
In order to calculate payback period, an initial investment had to be calculated. The cost differential between the baseline building and the Genesis Design model was used as the investment total. The cash flow used to calculate payback is the savings generated by the efficient design. While the analysis made represents a linear payback model, a reality the payback would flatten after 10 or so years due to the replacement and regular maintenance of system components. This expected actual return is modeled by the green curve on the graph.

Mechanical Reduction Assessment
The graph to the right shows the mechanical building reductions from the initial baseline building analysis. The table shows the total energy reduction of 54% and reduction of water demands by 89%. This is accomplished through a rain water collection system on the roof and plaza levels. This water will be used in the restroom facilities as well as a secondary water source for the vertical green wall.
Genesis Design chose to make several modifications to the original rooftop design and photovoltaic layout:

- **Incorporate a large PV array on the south roof:** The original design placed generators on the South roof. Since this is one of the most optimal opportunities for solar panels, the generators were relocated to the East roof to make room for one of the building’s best-performing PV arrays.
- **Tilting the roof PVs:** Roof PVs are not tilted at 10° on the roof zones and 35° on the wall-mounted zones to produce more electricity than the original design.
- **Getting rid of shadows:** Since PV array production is dramatically affected by partial shadowing, the wind turbines on the original design would be detrimental to the system’s performance. Genesis design got rid of these turbines to optimize the performance of the upper roof PV array.

Genesis Design chose to make several modifications to the building framing layout:

- **Simplified Framing Layout:** The framing layout was simplified to make bays more regular and remove the exterior indentations that were on the original architectural layout. This decision led to a simplified construction process while allowing for additional interior space.
- **Space for Double Skin Facade:** By simplifying the layout and removing indentation out and into the building, the team was able to make room on the exterior for an uninterrupted double skin façade.

Genesis Design chose to make several modifications to the original column layout of the building:

- **Eliminate Transfer Girders:** The original design placed at coordinates that led to the column line having to shift at the retail level. This led to the creation of heavy transfer girders to transfer the load into an eccentric lower column.
- **Reduce Overall Building Weight:** By moving the column lines to line up from the top of the building down to the plaza, the transfer girders were eliminated reducing the overall weight of the structure by 26,000 lbs. from the original column layout.
- **Simplify Construction:** Since the columns lines extending directly from the top of the building to the plaza, a straightforward column erection sequence was established, reducing construction time and hence cost.

Genesis Design chose to make several modifications to the open office layout:

- **13 new private offices**
- **9 new conference Rooms**
- **178 new workstations**
- Larger breakroom
- More flexibility
- More support areas

There are many pros and cons associated with open office spaces. Cons include lack of privacy, sickness spread in close quarters, and the feeling of stress. However, Genesis Design combats the cons to attract tenants to the Boylston Street High Rise, and the chart on the right summarizes the design strategies used. In terms of electrical design, by creating opportunities to bring daylight into the interior space, higher occupant comfort and happiness is achieved while also reducing lighting and cooling loads.
DOUBLE SKIN FAÇADE INTEGRATION

This design and construction of a double skin façade is truly an integrative process due to the complex nature of the system. All project members need to have input in the design, from the mechanical load reduction to the daylighting characteristics. Structural connection details and the construction process including quality control planning also are critical to the design of a successful system.

COST BREAKDOWN

While the double skin façade had numerous positive impacts on the mechanical loads for the building, it comes at a high initial cost. To calculate the construction cost of building this system, the exterior enclosure cost was first estimated per square foot of glazing area. The double skin portion was then estimated to be 2.5 times the cost of a typical system based on the recommendation of a façade manufacturer. This includes a unitized system with integrated photovoltaics. This number was then applied to 40% of the total exterior enclosure, the portion of the building which has the double skin façade. This cost will be paid back however, due to the mechanical savings that it will achieve. See drawing 113 for a lifecycle analysis.

### Exterior Envelop Cost Comparison

<table>
<thead>
<tr>
<th></th>
<th>Unit Quantity</th>
<th>% Total</th>
<th>Cost/Unit</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Typical Curtainwall System</td>
<td>SF 52,194</td>
<td>60%</td>
<td>$499.85</td>
<td>$26,089,000.00</td>
</tr>
<tr>
<td>Double Skin System</td>
<td>SF 34,796</td>
<td>40%</td>
<td>$1,249.62</td>
<td>$43,482,000.00</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td></td>
<td></td>
<td><strong>$69,571,000.00</strong></td>
</tr>
</tbody>
</table>

### MAINTENANCE

Small access doors are to be placed every 40 feet across the façade. A cleaner is to enter the cavity to clean the inside of the windows while standing on the supportive grate below. The outside of the windows are to be cleaned using the standard harness and pulley system.

WAREMA’S LONWORKS automated control uses solar position tracking to position the cut off angle of slats to exclude direct solar radiation and make the best possible use of diffused daylight. As for the structure of the slats, a frit coating is applied to the perforated aluminum band. A second layer of 644 9000 white selective paint is applied. The selective coating only reflects visible light into the room, while ultraviolet and infrared raditions are absorbed by the slat and reflected as heat radiation within the double skin, not into the interior of the building. This reflects the design goal which is to keep heat out of the rooms. Please refer to the Mechanical Note in Section 7.1 for the natural ventilation and mechanical performance of the double skin façade. The horizontal blinds are used throughout the double skin on the Boylston Street high-rise’s south and west facades.

### STRUCTURAL CONSIDERATIONS

The façade is designed so that the structural action of the building, which is typically considered the primary load-bearing component of the envelope, is not affected by the mechanical components of the system. This was especially true when designing the façade of a building with a high vertical load. The facade supports only the glazed and non-glazed elements above it, and the mechanical components are designed to provide support for the façade while keeping the load below.”

### DOUBLE SKIN FAÇADE CONNECTION DETAIL

The façade is constructed using a unique connection system that minimizes the load on the structural elements. The connection details were designed to ensure that the mechanical components do not affect the structural integrity of the building. The connection system is designed to be highly resistant to external forces such as wind and seismic activity.

### SPANDREL WALL WITH INSULATION

Spandrel glass was used to aesthetically harmonize with the vision glass as well as hide raised floor, ceiling and floor construction from the exterior. On gray, overcast days, a greater visual disparity is created versus minimal contrast for other weather conditions. The ceramic frit of the spandrel glass does not affect U-value performance. The insulation behind the air space gives the wall construction a higher R-value. Collaboration and special care in calculating window-to-wall ratios were done with the Mechanical team to optimize the energy performance of the facades.

SUMMER

In summer months, the façade control scheme opens both the top and bottom louvers in order to ventilate the cavity. Heat gain between the plates along with solar velocity will create a natural buoyancy naturally causing the air to rise out of the cavity. The system essentially is set to cool itself off in order to avoid overheating. This set up assists in controlling the envelope load of the building.

Hybrid Natural Ventilation

During ideal outdoor air weather conditions, with a temperature range of 50 to 65 degrees Fahrenheit and a maximum relative humidity of 60%, the façade will open completely and condition the space using only outside air. The office area will be negligibly pressurized in order to draw the outside air through the window and across the floor plan. This control sequence allows supply fans and fans to the doors and (DCC) to be turned off completely. Vertical louver return fans are turned on to pressure the office space.

WINTER

During the winter months, the cavity is set to close itself completely. The solar heating devices are designed to absorb and capture heat, especially heating the space using solar gains. This captured radiation is then distributed evenly throughout the building and shown as Day. This control sequence significantly reduces envelope load during the winter months.

### DOUBLE SKIN FAÇADE INTEGRATION

Project: THE BOYLSTON STREET HIGH RISE

BOSTON, MA 02115

See Drawings: I-06

Date: 02 - 2016

Sheet: 17 FEB 2016

PAGE 34
SCOPE OF WORK

Before beginning the design of the Boylston Street High Rise, it was important to define the exact scope of work. It was decided that the office levels (floors 4-17) would be completely designed and fit out ready for tenant move-in. These floors were fully designed and estimated based on a typical floor plan which Genesis Design developed. This includes the design of a flexible office space capable of accommodating several different types of tenants. All potential tenants will benefit from the multiple layer redundancy built into the systems on which the building operates.

The food and retail area of the building (floors 1-3), were designed to a core and shell level. Mechanical and lighting/electrical rough-ins will be provided, however the space will be left to be fit-out at the discretion of the owner and retail tenants. This area was also estimated at a core and shell level, meaning finishes and fixtures were removed from the cost estimate.

Because of the compact nature of the matrix schedule, Genesis Design will be able to turn the retail area of the building over to the owner approximately 6 months before the building is finished. This was done in an effort to allow the owner to select tenants and finish these areas as they see fit. It is not expected that the retail areas will be finished before the completion of the projects upper floors, so partial building occupancy should not be required. Retail occupancy comes with inherent safety risks, as it would be hazardous to allow customers on the first floors of a building which is under construction. It is the goal of Genesis Design to finish upper floors as the retail areas of the building is complete, allowing for total building occupancy in late December, 2017.

Framing Plan for Retail Area

Exterior enclosure begins. Floors 1-3 turned over for tenant fit-out.
Genesis Design chose to light the two parking garage levels with LED luminaires in order to fall below 50% of the ASHRAE lighting power density baseline. The challenge of this large space was the shallow ceiling height of 8.5 feet; it was necessary to find highly efficient fixtures with as wide of an optical distribution as possible. The Evolve™ LED fixture by GE was specified:

- High efficiency of 121 lumens/watt (4,220 lumens, 35 watts)
- Wide, diffuse lens allows for a wide vertical distribution (blue) and a symmetrical horizontal distribution (red)
- Motion-sensing option allows for luminaires to dim to 50% when there is no occupancy.
- Between the two spaces, an average of only 44.3% of the ASHRAE LPD allowance was used.
- Lighting shall be controlled by occupancy sensors that automatically reduce lighting power of each luminaire by a 30% when there is no activity detected within a zone after 30 minutes. Lighting zones are seen above (none above 3,600 ft). There are no daylight zones.
THE BOYLSTON STREET PLAZA

The city of Boston issued a Green Initiative plan with the goal to create a healthier and more sustainable city. Part of this future vision is the implementation and improvement of public spaces. Therefore, at Genesis Design have created a public space that encompasses the city goals as well as our own goals of Sustainability, Resilience, and Integration. The final design includes several innovative features that provide privacy to the city, support to the environment, and comfort to the people. Below is a graphic summary of the plaza features and the intangible benefits that it provides to the city and its population.

The figure to the right shows the location of these features.

PLAZA SPACES: SEATING NOOKS

The plaza will feature several different spaces. The two primary spaces include the seating nooks/cafe and the walkways. The cafe and seating nooks promote a relaxing atmosphere designed for occupant leisure and socializing while the walkways are meant for flow of foot traffic to and from the Boylston Street High Flow amenities. The distinguishing difference between these two spaces is in the masonry patterns, subtly differentiating where to walk and where to lounge. The seating nooks are designed to provide occupant comfort and safety, see the figure to the right. The nooks are enclosed by reinforced concrete planters that provide protection from vehicular traffic. The planters also feature a sloping shape that provides a unique aesthetic look while protecting the occupant from the forces of the wind. Within the planters will be climate appropriate vegetation, most likely evergreen shrubbery, to provide both a visual break from the surrounding concrete landscape as well as provide added windbreakage.

The nooks will also be equipped with GDO receptacles which will be powered through the wind tree energy; see figure to the right. Occupants will be able to access this for free to power their electronic devices. Additionally supporting these electronic services will be a Wi-Fi station and light and nine combination providing both AC/US service and lighting safety.

Lastly, the nooks will be comprised of both Green concrete and reclaimed timber benches to further support the Boylston Street High Flow goal of sustainability. The wood products will be supplied by Jarmak Corporation while the Green concrete will be provided by Boston Sand and Gravel; see the Construction Document for further details.

Embedded within the central planter is a CO2 absorbing device. The premise behind the device is to absorb the equivalent amount of CO2 emitted by vehicles passing and parking in front of the building. The table to the right shows the summary calculations on how this will be accomplished. In summary, the device will absorb over 20 pounds of CO2 a day and will supply the clean air to the center of the Plaza.

INTERACTIVE TOUCH-SCREEN KIOSKS

We at Genesis Design strongly believe in our founding goals of Sustainability, Resilience, and Integration. We believe that these drivers promote a healthy city and natural environment. The Boylston Street High Flow stands as a benchmark to Green building and contains many innovative features and systems that often go unnoticed. Therefore, we have integrated three kiosks throughout the plaza space to educate the public on what the Boylston Street High Flow and accompanying flora are doing to create a better future for the city of Boston and its population.

Each kiosk will contain three options: To learn about the Building; to learn about the Shopping Center; or to learn about the city of Boston. The images to the right show the sequence of screens one may encounter in wanting to learn about the high flow features. The option to learn more about the shopping centers will include a map of the mall as well as any other advertisement options they wish to include. The third option will provide a layout of the city including the major landmarks and the many businesses and activities available. Lastly, the kiosks will make an initial debut during the construction activity to better mitigate the negative aspects associated with change within a city.

VERTICAL GREEN WALL

The plaza will also feature a vertical green on the front facade of the building. The integration of a green wall within the Boston climate proved particularly challenging. The initial goals for this feature were to create a sustainable plaza design that provided both flexibility and branding to the tenants of the building. The primary challenge in accomplishing these goals was finding the right vegetation to withstand the harsh climate and north-facing facade. Several case studies were conducted including the vegetative green wall at the Brighton Beach Library in Boston as well as the Japanese in Boston to determine if this feature would be feasible.

The resulting research revealed a possibility of evergreen vegetation or grass species capable of surviving cold climates and indirect sunlight. A sample visual of this vertical green wall is shown below.

There are immense benefits to a vertical green wall to not only the city, the building, and the people. The green wall is an iconic aesthetic that displays both prestige in sustainability as well as branding for the building. The visual benefits also promote occupant health and productivity, a study associated with the USGBC. The physical attributes also benefit building such as: Thermal Increase, Wind Barrier, Sound Absorber, and CO2 Absorber.

The main issues associated with the vertical green walls include the maintenance and watering requirements and the structural supports necessary to support the structure. The maintenance associated with the particular species utilized in the wall require minimal to no maintenance as is the characteristic of the species. Additionally, any watering that will be required will be supplemented by the water collection system. Lastly, the vertical wall will be freestanding, supported by the plaza slab and intermittently attached to the facade. The slab supports were taken into consideration when designing for the construction loads.

Graphic Design:

PLAZA DESIGN

GENESIS DESIGN

THE BOYLSTON STREET HIGH RISE

BOSTON, MA 02115

PLAN NO.: 1-10

PCD NO.: 02-2016

DATE: 17 FEB 2016

N/A

PAGES: 38

TEXT: 56

DRAWING TITLE: PLAZA DESIGN

DRAFT: 4
STRUCTURAL NARRATIVE

0.0 EXECUTIVE SUMMARY
Genesis Design’s structural team set out to design a resilient, sustainable, and integrative project in order to meet and exceed the requirements of immediate occupancy, improve building resiliency, and produce a more efficient structural design for the 2016 AEI Student Competition.

0.1 INTEGRATION
The structural team placed integration of the design process with all disciplines and integrated building system results as a high priority for the project. Using BIM technologies and workflow strategies the structural team was able to demonstrate all decisions as well as discuss the impact of each system on the structure and all team members.

0.2 GRAVITY SYSTEM DESIGN
A highly efficient and optimized gravity system was designed for the Boylston Street High Rise. The gravity system features:
- Open office floor plan
- Optimized member depths and placement for quick erection and schedule savings as well as sustainable design
- Cantilevered transfer truss located on the fourth floor supporting floors located above I-90.

0.3 LATERAL SYSTEM DESIGN
An efficient lateral system was designed to meet the increased above industry code “100” year MRI wind loads by the competition as well as to increase the resiliency of the structure. The lateral system features:
- A two bay eccentric (EBF) and concentric 2-story X-braced frame core consisting of 2 EBF and 4 CBF segments per floor helps reduce eliminate the need for a hat-truss, as well as, accelerate the construction schedule by 5 weeks saving 1.1 million dollars of shear wall option
- Perimeter moment frames assist in reducing overall building torsion, as well as, adding elements to assist with the progressive collapse resistance feature incorporated into our design
- Introduction of additional damping to the structure to reduce peak floor accelerations to allow for 24/7 occupation of the structure during any disaster situation and occupant comfort related to motion perception

0.4 FAÇADE SYSTEM DESIGN
To improve the resiliency as well as to meet the reduction of 50% ASHRAE requirements set by the competition the team designed an integrated façade system. The system features:
- A double skin façade on the south and west sides of the structure consisting of a 3’ with exterior photovoltaic panels and interior blinds.
- All facades consist of 3” mullions (have a larger bite), laminated glass panel (resists falling of shattered glass), increased water penetration limits (increased from 20% wind speed to 40%), round glass edges (helps prevent cracking glass corners due to large stress concentrations)

0.5 RESILIENT SYSTEM DESIGN
To maximize the building’s resiliency and ability to allow for immediate occupancy the structural team investigated:
- A progressive collapse scenario at the schematic level
- Removal of transfer beams and redundancy of transfer truss (only needed one truss but two were designed)
- Utilized a “100” year wind calculation to account for extreme wind events
1.0 PROJECT INTRODUCTION

The 2016 AEI Student Design Competition set forth the challenge to design a 17-story mixed-use building located in a dense urban setting within Boston, MA, which requires focus on three main areas:

1. Address all possible ideas for sustainable design and construction.
2. Provide resiliency with respect to local environmental conditions.
3. Consider integration with and impact on adjoining businesses, structures, and public ways.

Our highly collaborative, multidisciplinary design team, Genesis Design, created unified goals that continuously drove decisions from conceptualization of ideas to fruition of an innovative, high performance, integrated systems building that will be known as the Boylston Street High Rise (Fig. 1).

1.1 STRUCTURAL SCOPE

The 2016 AEI Student Design Competition included a thorough scope of work for engineering of the Boylston Street High Rise. The structural scope of work for the project is listed below:

- Innovative sustainable ideas
- Use innovative or original ideas to increase the performance of the structure
- Integrate with other disciplines to produce a high quality overall building system.
- Design a lateral system that resists a “100 year” wind speed given by ASCE7-05
- Design for immediate occupancy after severe environmental conditions, specifically in a hurricane situation

In order to provide additional benefits to the owner, the Design Team decided to add supplemental performance based requirements. These additions to the scope of work include:

+ Expanded harsh environmental conditions to include immediate occupancy following a disaster such as an earthquake
+ Investigate progressive collapse as a means to increase resiliency of the structure
+ Increase occupant comfort and resiliency of the façade by introducing damping into the structure reducing the possibility of glass breakage through reduced drift and accelerations.

The Structural Supporting Documents (SSD) (pg. 54 to pg. 63) provide assumptions, calculations, and resources to support the solutions. The Structural Drawings (pg. 64 to pg. 73) offer technical drawings and graphic visuals of the structural systems and their important details.

1.2 STRUCTURAL GOALS

Genesis Design developed a set of shared design drivers and team goals based off project requirements and project stakeholder objectives. The Sustainability driver’s goals are to create a high performance, energy efficient building through its full lifespan, while promoting a healthy environment for its occupants. The Resiliency driver’s goals are to ensure building operation and security during the harshest conditions, as well as provide flexibility for adapting to changing occupant needs. Lastly, the Integration driver’s goals are to successfully optimize integrated systems within the building through Integrated Project Delivery’s increased collaboration, and have the building become an integral, engaging part of the surrounding community. More
specific structural goals were developed, correlating to and enhancing the completion of team goals:

**SUSTAINABILITY**
A structure that reduces embodied carbon in addition to assisting other disciplines reduce energy usage and increase energy production.

**RESILIENCY**
Design a structure that performs well during a natural disaster (i.e. Hurricane) as well as has immediate occupancy following said disaster.

**INTEGRATION**
Design a structure that allows for the architecture to integrate with the surrounding city in addition to creating a structure where all disciplines are able to design the most efficient structure.

Throughout the Structural Narrative, black and bolded text will point out significantly important concepts and findings connecting to the particular team goals and design drivers easily noted.

### 2.0 INTEGRATIVE APPROACH

In contrast to the traditional method for project delivery of Design-Bid-Build, to move away from the reactionary design and adversarial checks and balances. Genesis Design chose to approach the project using Integrated Project Delivery (IPD) with Building Information Modeling (BIM). With IPD, all disciplines of the design team participate in decision making. Sharing information and providing feedback is done as much as possible from the very beginning. Genesis Design resolves disputes with respect and created a Decision Matrix to measure decisions against how well they achieve our team’s project goals. The integrative approach has taught us that the team dynamic is as important as technical capability in such projects. While IPD is undoubtedly a more demanding and intensive process, the final production could not have been achieved without this method.

### 3.0 SITE ANALYSIS

In order to better understand the building within its surroundings, the Design Team engaged in an in-depth analysis of the site. For more details on these findings see Section 2.0 of the Integration Report.

Important aspects of the site include the plaza entrance and mall entrance. The plaza was analyzed for construction loads. Beneath the 17 story main tower is a two story parking garage resting on an existing mat slab. Surrounding the parking garage are existing sheet pile walls placed during the Prudential Center construction, lowering the water table on the site. For water remediation on caissons, see Drawing C-02. The main bearing surface is a bedrock layer located 150’ below grade with poor soil conditions located near the surface.

Surrounding the structure are several low rise buildings with gravel roofs. These structures could pose a risk of flying debris during significant wind storms, such as hurricanes, and was considered during the design of the building’s exterior façade.

The structure will be physically connected to the existing mall through the parking garage in addition to several stairways. Interstate I-90 is located beneath the south-west side of the building footprint. Because of this, a significant portion of the structure will need to be cantilevered over the highway (See Fig. 2).

![Figure 2](image_url)

**Figure 2** – Rendered image showing building location in relation to Interstate I-90.

### 4.0 CODE ANALYSIS

The structural team investigated the applicable codes for the Boston Massachusetts area (ASCE 7-05 and ICB 2009). During this time an investigation into applying the newer ASCE7-10 to the project was considered. The Structural Team determined that ASCE7-05 (141 mph) had a higher base wind speed over ASCE7-10 (132 mph) when considering a 1,796 year mean reoccurrence interval for wind. To view the results of this analysis see
SSD C. An analysis of wind speeds for each code was performed to provide more resiliency to the structure. In order to analyze the effects of dampers on the structure a performance based technique was used.

5.0 GRAVITY SYSTEM DESIGN

The first system designed and analyzed was the gravity system. It was decided by the Design Team that a lightweight gravity system and an optimized load path were critical for the economic and efficient design of the gravity system. Each floor was optimized to meet competition and owner’s needs while also accommodating the needs of all disciplines. Particularly, as the office floors incorporated Underfloor Air Flow Distribution (UAFD). After designing for strength and serviceability, the framing design was considered for floor vibrations which ultimately governed the size of the members. Additionally, exterior column locations were modified in order to eliminate transfer beams and increase retail rentable space by 600 S.F.

5.1 SPECIFIC GRAVITY SYSTEM GOALS

The structural team began by laying out specific goals that the gravity system had to meet. The specific goals are:

1. Structural Impact:
   - Reduce Seismic Weight
2. Architectural Impact:
   - Maintain a high floor to ceiling height for occupant comfort
   - Maintain an open floor plan surrounding the core spaces
3. MEP Impact:
   - Reduce infill beam sizes throughout the floor plan as smaller “tap-off” service ducts may frequently cross their span
   - Maintain high floor to ceiling height
   - Maintain ample plenum space
4. Construction:
   - Organize layout for simple erection
   - Optimized members to reduce the number of unique pieces

5.2 GRAVITY LOADS

The gravity system was designed with the required loading conditions per ASCE7-05. The un-factored gravity loads for the typical floor designs were: Dead Load = 72psf and Live Load = 100psf. This decision incorporated increased resiliency for the owner of the structure by allowing for greater office flexibility. A detailed description of all loading conditions can be found on SSD B.

5.3 CHANGES TO ARCHITECTURAL LAYOUT

The Design Team made several changes to the architecture of the Boylston Street High Rise. These changes included removing some irregularities from the framing system, moving the front retail space curtain walls outwards in order to move the columns into the retail space (See Fig. 3). Moving the columns helped reduce thermal bridging from the proposed architectural design which original featured columns extending outside. By moving the columns indoors, the structural
team was able to remove cold-bridging at the retail levels. A discussion on why these decisions were made is provided below.

Simplification of the architectural floor plans were made to increase rentable space as well as allows the Structural Team to simplify beam layouts and column locations. This allowed for all columns to be located on the exterior of the structure and not interfere with any open office plans. Another change to the structure included bumping out the interior wall on the front façade of the retail space. Moving out this wall allowed for a 600 S.F. increase in rental space in addition to having the ability to brace these columns at every floor instead of having a 4 story unbraced length.

5.4 UNDERFLOOR AIR DISTRIBUTION

In collaboration with the Design Team, it was decided that an underfloor air distribution system would meet space requirements more efficiently. In order to accommodate raising the floor on each office level by 18”, the Design Team raised the building by 18” effectively offsetting each floor by 1”. This increases the building height by 18” which is within zoning limits and does not significantly change the overall architecture. An analysis of manufacturer’s specifications determined that cross bracing between risers were not required due to the low height of riser (less than 24” tall) and the low seismic region of Boston. The raised access floor allows for a decrease in the plenum space located below the structural steel to only include small return ducts (See Fig. 4a & b). For a discussion of the underfloor air distribution system see Section 6.3 of the Mechanical Narrative.

5.5 ALTERNATE GRAVITY SYSTEMS

The Structural Design Team began by investigating five alternate gravity systems. These systems included a flat plate concrete slab, two-way post tensioned slab, Diagrid gravity/lateral system, a composite steel system, and a non-composite steel system. The structural team reviewed each option for overall cost, impact on schedule, overall weight of system, and Boston’s construction force’s familiarity with the specific construction type being considered. The design matrix (See Fig. 5) was used for preliminary gravity decisions.

![Figure 5 – Gravity system decision matrix](image)

The Design Team decided that a concrete flat plate and post-tensioned slab systems would be the most expensive systems, over $5/sf more than the composite steel deck system; have the most impact on schedule, limitations to pouring in winter and longer construction duration. The concrete systems were the heaviest systems, approximately 100psf over a comparable steel system, as well as Boston’s unfamiliarity with high rise concrete construction.

![Figure 4a – Deck section showing integration of raised access floor system with MEP](image)

![Figure 4b – Plenum section](image)
Through analysis, the Structural Team verified that a steel framed structural system (selected by the above decision matrix) would be the most efficient system to use on the Boylston Street High Rise. One sustainable benefit of steel is a decrease in carbon pollution which is generally created during the curing of a large quantity of concrete. During the analysis, a non-composite slab was deemed to take up much plenum space and thus deemed inefficient (See Fig. 6). This lead the team to design a composite slab design. The Structural team analyzed multiple deck depths to determine the most economical decking size. It was determined that a 2” deck with 3-1/4” topping would be the most efficient system and save over 230,000 lbs. of steel over a composite system using 1” or 3” decks.

To meet the required 2-hour fire rating between floors per IBC section 6.01, it was determined that a 3-1/4” lightweight concrete topping on a 2” metal deck (5.25” thickness total) would work for the typical floor. The specific type of deck selected was a Vulcraft 2VLI19 or equivalent for all office and retail floors.

**Figure 6 – Comparison of steel depths for composite and non-composite sections**

The Structural Team enforced a minimum floor beam size of W12x40 in order to reduce vibration and connection issues. This size was chosen because it is common throughout the industry. Multiple layouts were parametrically analyzed using Ram structural System (RAM) to determine the layout that reduced the overall weight of steel the most, as well as to determine an optimized floor layout. Calculations to verify designs are given on SSD.D.  

### 5.6 FRAMING OPTIMIZATION

During the initial design of the gravity system; the Design Team set a maximum beam depth allowed for “tap-off” ducts to run underneath the infill beams. The gravity system took into consideration not to frame deep beams into shallow girders; this decreases labor costs as well as possible stresses due to fit up issues during construction. Floor beams were optimized to decrease the total number of beam types on the system, this allows for ease of erection and fabrication time due to repetition. Finally, the framing was optimized using common industry standards listed in the July 2006 edition of Steelwise, a periodical released by the AISC. Recommendations utilized are:

1. No camber was specified less than ¼” and always in ¼” increments
2. The camber of beams less than 25’ in span, or with webs less than ¼” thick was avoided as they tend to incur damage from local stresses generated by the cambering process
3. No camber was specified for spandrel members and girders to avoid complications in the connection of the cladding system and infill beams respectively.

The final optimized framing layout for the typical office floor and Retail level 2 are given in Drawings S-04 & S-05.

**Figure 7 – Typical Office Floor Framing Layout with blowup of typical bay**

In addition to camber considerations, the structural team was worried about floor vibration caused by walking. Due to the extreme length of the bays between gridline F.3 and D.3, the Structural Team used AISC Design Guide 11 to perform an analysis of the long bays located on the north side of the building footprint (See SSD.D for analysis). This analysis determined that the required beam needed for strength and deflection (W24x62) was inadequate to deal with vibrations issues. To amend this issue and keep the same structural depth, the beam was
enlarged to a W24x94 (a 50% increase in weight) on the typical 60 foot bay. Other bays, with smaller spans, met vibration criteria under their designed member sizes. The floor framing plan with an exploded bay is shown in Fig. 7.

### 5.7 CANTILEVERED DESIGN

An important aspect of the gravity system design was the structure’s inability to carry gravity loads on the south-west side of the structure to the foundation due to the building overhanging Interstate 90 (See Fig. 8).

![Figure 8 – Truss overhanging Interstate 90](image)

Two options were considered to support the cantilevered portion of the system. The first option considered was a post-tensioned beam system located over the turnpike tunnel roof. After team coordination and studies, the post-tensioned beam was decided not to be a viable solution due to the lack of adequate space for a backspan, in addition to a limitation on the depth of the beam permitted. To make a viable beam to hold the column, considering only strength, a six foot deep by ten foot wide beam would have been needed. Another implication of using a post-tensioned beam was the need for staged stressing, this process would need to be done every three floors causing a delay in the construction schedule. The second option, a cantilevered truss system located between the 4th and 5th floors was studied to support the building’s top floors above Interstate I-90. This system proved to be the most economical solution while causing the least amount of delays and complications to the construction without interfering with the architectural layout of the retail spaces. Details on the SAP 2000 analysis are provided in SSD F. Multiple configurations were considered for the truss on Level 4. The first step in the design process was determining whether a one-directional or two-directional truss would be required. Each configuration was considered for the worst case direction (the one having the longest span). The truss was initially designed for strength while keeping deflection limits in mind. The various configuration included tension and compression diagonal truss members and combinations of “M” and “W” shaped trusses over two bays.

The team selected a “W” truss in the overhanging bay along with a diagonal web member for the back span bay as this configuration had the least deflection as well as the lowest overall weight. The truss configuration can been seen in Fig. 9 showing the percentage of capacity used per member for one direction. The “C” and “T” symbolize compression and tension members respectively. A one-directional was not able to economically meet deflection criteria (L/240 = 2.15in). A second truss was added in the other direction to meet deflection criteria and add strength redundancy and resiliency to the cantilever system. Since initial the truss was design using the worst case, the double truss met better performance capacities. The actual deflection of both directions acting together is 1.14in over a distance of 43 feet in both directions which is below the limit of

![Figure 9 – Truss Configurations showing symmetric](image)
2.0 in. To see erection details of the cantilevered truss see Section 5.3 of the Construction Management Report.

5.8 GRAVITY COLUMN DESIGN

The perimeter gravity columns were optimized to achieve an efficient 75-90% Demand/Capacity ratio. The column design was performed using RAM Structural and checked by hand. In coordination with the Construction Management team, it was decided to splice the columns every two stories (every 28’) as done in popular steel construction practice. Splicing every two floors facilitates the coordination of the lift sequences and speed up the schedule duration of a typical floor. The typical splicing length also allows for all columns to fit on a standard truck bed for transportation to the site.

Typical Column sizes ranged from W14x61 at the upper roof level to W14x550 at the lobby level. The top level columns support the mechanical floors as well as the rooftops which are covered in photovoltaic panels which were designed as a high live load of 50psf. Smaller section depths were possible at the mechanical levels; however, with the switch to a smaller cross section comes a more expensive splice connection. Working with the Construction Team, it was determined that the savings of moving to a smaller more efficient column size would outweigh the savings achieved by using a smaller section.

The columns were placed so that they went uninterrupted from the mechanical floor down to the retail level eliminating transfer girders located above the retail level (See Figure 3). This eliminated the use of transfer girders that were initially used as shown in the retail level façade in the original architectural model. The location of the columns also allow for a more streamlined construction and reduced the likelihood of unbalanced column loading throughout the structure. Shifting of the columns reduced the overall structural weight by approximately 13 tons.

5.9 CONNECTION DESIGN

Using AISC 360-10 connection requirements and working with the Construction management Team, it was determined that a shear tab would be the most optimal gravity connection type. It allows for a quick erection time and pre-fabrication in turn reducing cost and simplifies constructability due to the familiarity of erectors with this connection type.

To further reduce cost, it was decided to use an extended shear tabs to avoid coping the top part of the beams framing into the girders. The typical extended shear tab design was a 3/8in plate welded onto the girder with a 3/8in minimum weld along the length of the plate on both sides, resulting in 12in on each side. The beam is bolted onto the connection by 4-3/4in diameter A325N bolts. The decision to bolt the beam was made to prevent bolt sharing across the girder. The connection has the capacity to carry a 62kip load in a typical 60 foot bay. Fig. 10 shows a detail of the extended shear tab connection. Detailed connection locations and calculations are given in SSD F.

5.10 PARKING GARAGE DESIGN

The Structural Team started the parking garage design by developing goals for the space. These goals included keeping as large of a floor to ceiling height as possible by minimizing slab thickness and deflections.

Several options were considered, including using epoxy coated rebar as opposed to standard steel rebar, as well as post-tensioned slabs. The post-tensioned system was ruled out due to the high cost of the system and the longer duration of construction. It was ultimately decided that a mildly reinforced slab with epoxy coated rebar would be sufficient to preserve the necessary architectural height requirements while providing a durable solution. The parking garage slab was designed
as a 12” thick slab made of 5,000psi concrete. The slab contains a bottom mat of #5’s at 12” o.c. in both directions. The top bar was limited to #5 bars for simplicity of construction. A 40” square column, which was axial controlled, containing 28#11 bars represents the cross section for the worst case gravity load (See SSD E for column hand calculations). A detailed floor plan design can be found in Drawing S-06.

Through analysis, it was determined that no changes were necessary to any of the retaining walls indicating that the design team could save money by keeping the existing retaining walls due to no change in the applied hydrostatic, soil, and gravity forces applied to the retaining walls.

5.11 GRAVITY SYSTEM SUMMARY

The structural gravity system was optimized to meet and exceed the following goals set at the beginning of the section:

- Low seismic weight-decking slab only weights 42psf
- High floor to ceiling height
- Allowed for open floor plan
- Limited beam depth to all for “tap-off” ducts-infill beams no deeper than 24”
- Simple erection-limited infill beams to 6 types
- Economical transfer of cantilevered floor-truss located on 4th floor
- Assisted Construction Management Team limit number of clashes with mechanical system

6.0 LATERAL SYSTEM DESIGN

Simultaneously with the design of the gravity system, an investigation into lateral systems and an analysis and design of the optimal lateral system took place. An optimized lateral system includes a highly efficient, redundant, and low cost system while accommodating all disciplines.

As a result, a lateral system including a braced frame core system consisting of double story X-braces in the North-South direction, with single story diagonal and eccentric braced frames in the East-West directions. The East-West direction is also complimented with moment frames on both faces of the building to aid with resiliency and torsional effects.

6.1 LATERAL SYSTEM GOALS

To design the lateral system, lateral goals were developed. These included:

1. Structural
   - No structural damage and immediate occupancy post major disaster which includes hurricanes and earthquakes
2. Architectural
   - Accommodate all existing core openings (elevator shafts, stair openings, and mechanical penetrations)
   - Do not impede interior layout (doors, windows, exteriors façade)
   - Maintain floor to ceiling height
3. Mechanical & Lighting/Electrical
   - Design to allow ease of access and effective equipment layout vertically through the access openings near the stairs.
4. Construction Management
   - Coordinate safe and efficient construction of the lateral systems in regards to the chosen Gravity System.
6.2 ALTERNATE LATERAL SYSTEMS

The structural team conducted a three stage process in order to determine viable options for lateral systems. The first being an empirical evaluation of systems to be considered, the second being a reexamination of our goals & preliminary analysis, and the third being additional modifications & final optimizations for the lateral options to increase resiliency.

1. Empirical Evaluation:
The Structural Team considered what system would be most appropriate for the architectural layout of the building, as well as, suitable to accommodate the needs of other disciplines. Since the architectural layout offered a centralized building core to optimize rentable office space, a collaborative decision was made to maintain this core location.

2. Reexamination of our Goals & Preliminary Analysis:
As the building core was maintained, this offered us a Shear wall core or braced frame core as options. An additional system, was analyzed (diagrid system).

Diagrid structures incorporate the lateral and gravity systems into one allowing for an overall decrease in the weight of the structure. After schematically analyzing a diagrid system it was determined that any material savings would be outweighed by the cost of the complicated connections.

A cost comparison was run between the shear wall core option and the braced frame core option taking into account the time saved in construction due to the faster erection of steel. Table 1 shows the difference in cost and the time saved by choosing a braced frame core.

Table 1 – Cost and Schedule Comparison of Lateral Options

<table>
<thead>
<tr>
<th>Lateral Option</th>
<th>Cost</th>
<th>Schedule Duration</th>
<th>Final Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Braced Frame Core</td>
<td>$3,595,000.00</td>
<td>3 weeks</td>
<td>$150,000.00</td>
</tr>
<tr>
<td>Shear Wall Core</td>
<td>$2,336,000.00</td>
<td>8 weeks</td>
<td>–</td>
</tr>
</tbody>
</table>

3. Additional Modifications & Optimization:
After deciding that the braced frame core would be more cost effective, the team looked into the addition of elements to make the structure perform better, and increase occupant comfort and building resiliency. The primary addition was the addition of moment frames in the weak direction of the structure (See Fig. 12 for a lateral interaction image). The introduction of braced frames into the core was less favorable in the E-W direction due to the presence of openings and doors.

Table 2 – Effects of Various Lateral Systems on Various Disciplines

<table>
<thead>
<tr>
<th>System</th>
<th>Construction Management</th>
<th>Lighting/Electrical</th>
<th>Mechanical</th>
<th>Structural</th>
<th>Architectural</th>
</tr>
</thead>
<tbody>
<tr>
<td>Braced Frame Core</td>
<td>-Higher Initial Cost</td>
<td>-Allows for Simple Utilities Cordination</td>
<td>-Allows Penetrations Through Core</td>
<td>-Increases Core's Depth-to-Height Ratio</td>
<td>-Does Not Hinder Core Openings</td>
</tr>
<tr>
<td></td>
<td>-Shorter Erection Time</td>
<td></td>
<td>-Limits Plenum Space Around core</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>-Simultaneous Erection</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>-No Need For Concrete Contractor</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Shear Wall Core</td>
<td>-Longer Duration</td>
<td>-</td>
<td>-Rigid Structure Takes Load Efficiently</td>
<td>-Does Not Allow For Damping</td>
<td>-Limits Flexibility of Core</td>
</tr>
<tr>
<td></td>
<td>-Need For Special Erection Equipment</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Additionally, the mid-rise nature of the building led us to the decision that no extreme lateral systems were necessary, even considering the dangers of hurricanes. The choice of a less complicated lateral systems allowed for a more efficient system.
Additionally, the use of damping to reduce accelerations due to wind or seismic was investigated for the structure.

Our Decision:
Following the extensive analysis of all considered framing systems and additional options. It was chosen that a damped braced frame core with exterior moment frames would be chosen as lateral system for our building. See Table 2 for the effects on other disciplines by changing the lateral system to a brace frame core.

6.3 BRACED FRAME CORE

Using the braced frame core, the structural team was able to expand the width of the core from just the elevator shaft to encompass the entire “Building core” spaces (See Fig. 11). This decreases the width to height ratio of the core and eliminates the need for a hat truss for drift control. A braced frame core further allows for the structure to be damped easily through dampers located in the additional bay of the core. For information on damping of the structure see Section 6.5 of the narrative.

The proposed design was analyzed assuming a rigid diaphragm and resulted with typical bracing sizes ranging from W14x90 to W14x211 and columns ranging from W14x120 to W36x652. These member sizes are controlled by drift. The lateral system is topped by moment frames in the mechanical penthouse area which transfers to the braced frame core and finally transitions into concrete shear walls and moment frames at the base of the building (See Fig. 13 for a core elevation).

Multiple braced frame layouts were considered for the strong direction. Through analysis it was determined that double story x-shapes reduced deflections and transferred forces the best. The structural team wanted to reduce the overall drift of the structure as a way to increase the resiliency of the façade system. In the end the structure was designed to the L/300 deflection limit, at the “100 year wind speed”. The “100” year wind speed was used as a recommendation of a nationally recognized structural engineering firm’s upcoming document discussing a proposed rating and assessment system for determining the deflection levels for varying levels of building quality.

By switching to the steel core system the structural cost was increased by 153% of a comparable concrete shear wall system, and the schedule time was reduced by 5 weeks. The increase cost was mostly offset by the reduction in schedule duration (and the corresponding savings in general conditions) only costing $150,000 more. This increase in cost does not take into account the revenue generated from opening the office spaces 5 weeks early. More information on cost savings of the new brace frame core can be found in the Construction Management report in Drawing C-02.

6.4 ELASTIC EARTHQUAKE DESIGN

To expand upon the idea of immediate occupancy the Design Team chose to design an elastic system to resist the full earthquake forces. Typically a structure is designed to withstand forces due to earthquake loads by allowing members to slightly deform without losing any strength. This method allows for the structure to experience damage without collapsing. By using elastic design the design team was able to prevent deformations and damage to the structure during an earthquake event. Preventing damage to the structure met the immediate occupancy requirements set forth by the competition.
The Structural Design team used an R value of 1 as compared to the typical value of 3 to determine the true forces on the structure. Through analysis it was determined that seismic values using an R equal to one did not control over lateral forces due to the “100” year wind speeds specified by the design competition.

6.5 DAMPING ANALYSIS

The Structural Team researched damping to determine its viability on this project to improve the overall performance of the structure. It was found that for wind applications, damping ratios of 1-2% are typically used in the United State for steel and concrete buildings at serviceability levels (ASCE 7-10), and 1-1.5% per ISO 1997. Damping is an appropriate addition to the structure because it allows for the immediate occupancy of the structure not only after but also during a major natural disaster. Damping reduces the acceleration of the floors which helps improve the resiliency of the façade system as well as increase occupant comfort.

Design of the damping began with determining the optimal location for the damping. The dampers were placed in the vacant bay of the core of the building in the East-West direction. It was determined that the location that provided the most effect on the structure would be near the top of the building. The Structural Team performed a schematic analysis of the required critical damping needed to limit the peak floor acceleration of the structure to an acceptable level.

Due to a lack of wind tunnel test results to perform a time history/response spectrum analysis, the team determined that the most appropriate way to determine the effect of loads on the structure was to perform a seismic response spectrum analysis and determine the effects that damping had to limit the accelerations on the 17th floor. According to the article “Wind-Induced Motion of Tall Buildings: Designing for Occupant Comfort” by Melissa Burton a building’s peak floor acceleration should not exceed 3% of gravity due to a “10” year wind speed. In order to reach this acceleration goal it was determined that the structure will need to be damped to 20% critical in order to reduce 40% of the 17th floor’s acceleration.

6.6 LATERAL CONNECTION DESIGN

Typical braced frame connections were designed to not allow moments within the connections (see Fig. 14). These connections will allow for quick, safe, and economical erection of the core. For the exterior moment frames, a welded flange plate connection will be used. This connection type will be used because of its common use in seismic regions and helps with continuity for progressive collapse.

6.7 LATERAL DESIGN SUMMARY

Through an integrative process with other disciplines and structural analysis, it was determined that the most effective lateral system to resist the higher wind speeds and elastic earthquake loads (See Fig. 15) specified by the design competition would be a braced frame core with exterior moment frames that transition into concrete shear walls and moment frames at the parking garage level. The braced frame core costs slightly more than a comparable shear wall concrete core, but the true savings come in the accelerated schedule allowed by the steel erection process. The ability to introduce damping into the structure allows for resiliency in occupant comfort as well as façade acceleration and movements.
7.0 FOUNDATION DESIGN

Through discussion with the MEP and CM teams, it was determined that a combination of a geo-thermal system and a foundation system would be benefit all parties. Because of the poor soil conditions found on the site, it was determined that the best solution would be caissons. This type of foundation bears on the bedrock located 150 ft. below the surface. A caisson allows for the geothermal tubing to extend into the earth within the rebar cage. It was determined that a 7’ diameter caisson will be needed for the worst case location (under the transfer truss). Calculations for the caisson can be found in the SSD H. All caissons require two 3/4” tubing loops running the length of the caisson which does not reduce any strength. Caissons will be dug and constructed to support each of the 26 columns that extend the total height of the building (See Fig 16 for an overview of the caisson design). For water remediation of the caisson construction see Drawing C-02 of the Construction Management report.

8.0 PROGRESSIVE COLLAPSE

The Design Team determined that in order to maximize resiliency of the structure, the building would need to be designed to prevent progressive collapse caused by many various disasters. By designing with progressive collapse in mind, the building can maintain its stability after the destruction of a beam or column due to an accidental or intentional explosion.

While the time to perform a true progressive collapse analysis was outside of the scope of work, it was decided that performing an approximate analysis on an exterior column would be a schematic representation of the added impact of designing the structure for progressive collapse.

Through the removal of an exterior column, it was determined by using an approximate cable analysis, that the members experiencing the removal of a support
column result in a non-elastic result, due to excessive deflection experienced by the beams (over 3’ deflection). Through research the Structural Team recommends multiple methods to reduce the impact of progressive collapse.

One recommendation is to increase the number of moment frames located around the perimeter of the structure (moment frame connections have greater capacities over the comparable gravity connections).

Another option to reduce the size of wide flange members needed to meet the required capacities is to introduce post-tensioned tendons into the slab above the problematic areas (Tendons are shown in red) (See Fig. 17), because of the tendons high yield strength the member sizes could be reduced significantly in addition to stiffening up the bay. It was also decided to place tendons on the perimeter column line above the exterior beam where the deflection would be the greatest.

9.0 BUILDING ENCLOSURE

9.1 FAÇADE CONSIDERATIONS

The building’s enclosure is a key aspect to the overall resiliency of the structure. The Design Team determined that to best protect the occupants of the building as well as those around the building a laminated glass façade would need to be used in order to provide protection against wind driven debris or blasts.

Laminated glass is a multi-layered system that when the glass shatters the broken pieces remain attached to the lamination. The design team also decided that increasing the mullion widths to 3” increases the “glass bite” significantly (see Fig. 18). By increasing the mullion width the façade system is better able to handle higher wind forces as well as large impacts. It was also determined that a wet glazing system with a backer rod provides better results over a dry glazing system.

During the specifying of the façade system, the Design Team would request a curtain wall system that requires an increased water penetration level over a typically specified system. On most projects a façade would be specified to 20% of design wind pressures, but for the Boylston Street High Rise a water penetration level of 40% design pressures is recommended. This will be tested using the ASTM standard E331-00. The testing would be performed by a local testing service. Thompson Lichtner Testing & Consulting is a possible firm.

The Design Team also specified a glass with rounded edges. Rounded edged glass is commonly used in seismic and heavy loading situations, as it decreases extreme stresses at the corner preventing diagonal cracks occurring under extreme racking conditions.

9.2 DOUBLE SKIN FAÇADE DESIGN

In the process of designing the double skin façade, the structural team implemented all resilient features mentioned in section 9.1 (Façade Considerations) (See Figure 18 – Location of increase bite location)
The Structural Team had to design for an increased façade loading, design a connection that supports the outer layer of the façade as well grating which is located between the two layers. The grating allows for maintenance workers to access the space for cleaning and repair of the PV electrical systems. The structural team integrated with the Electrical and Lighting Team by selecting a mullion system that allows for PV wires to be run through the exterior mullion system and into the building. See Fig. 20 for a typical double skin façade connection detail.

**10.0 Conclusion**

The Structural Team designed an efficient system that address building resiliency, immediate occupancy following a natural disaster, and integration with all mechanical and electrical systems while reducing the overall cost and schedule duration of the structure (See Table 3 for a brief overview). The Structural Team designed:

- An optimized gravity system that included:
  - A gravity design which reduced 26,000 lbs. of steel
  - A layout which eliminated a number of transfer beams located on the fourth floor
  - A regular bay system which allows for quick erection times.

- A mildly reinforced parking structure that maximizes floor-to-floor heights
- A transfer truss system to support the cantilevered section of the southwest portion of the structure
- A foundation system that combines caissons and a geothermal system
- A lateral system which allows for occupant comfort and safety during and after a significant natural disaster which includes:
  - Two eccentric braced frame in the East-West direction per story
  - Four double story X-braced core in the North-South direction per two stories
  - A braced frame core system which has a higher depth to width ratio than originally proposed
  - A core system which decreased the construction schedule by 5 weeks
  - Damping to bring the structure to 20% of critical damping
- Multiple forms of resiliency:
  - Schematic progressive collapse analysis which resulted in a non-elastic result
  - Redundancy in the truss system due to the need for only one truss but two being designed
  - Removal of transfer trusses located at the store front façade on the fourth floor
  - Elastic earthquake analysis and design
  - Epoxy coated rebar in parking garage structure protects rebar from corrosion due to salts
  - “100” year MRI wind drift allowance
- An efficient and resilient façade design that includes:
  - Glass panels that have rounded edges reducing stress concentration during racking
  - An outer laminated glass panel layer which prevents shattering and falling of glass during an impact due to flying debris
  - 3” mullions to increase glass bite

**Table 3 – Summary of goals and design results**

<table>
<thead>
<tr>
<th>Integrated Project Ideals</th>
<th>Responsibilities/Goals</th>
<th>Design Results</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Resiliency</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Immediate Occupancy</td>
<td>Façade designed for impacts</td>
<td></td>
</tr>
<tr>
<td>Following a Disaster</td>
<td>Elastic Earthquake Design</td>
<td></td>
</tr>
<tr>
<td>Design For “100” Year Wind Forces</td>
<td>Damping of Structure</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Epoxy Coated Rebar</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Progressive Collapse Analysis</td>
<td></td>
</tr>
<tr>
<td><strong>Sustainability</strong></td>
<td>Double Skin Façade Connection Design</td>
<td></td>
</tr>
<tr>
<td>50% ASHRAE 90.1 Limits</td>
<td>Geothermal Caissons Design</td>
<td></td>
</tr>
<tr>
<td><strong>Integration</strong></td>
<td>Create a Highly Collaborative Project</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Design of Brace Frame Core</td>
<td></td>
</tr>
</tbody>
</table>
LESSONS LEARNED

Throughout the course of designing the Boylston High-rise, the structural team learned many things. These lessons learned have provided vital help throughout the course of the design process. The structural team is confident that these lessons learned will continue to aid them in their current and future professional success. Outlined below are some of these key lessons:

1. Begin by locating columns in an efficient location for the typical column in addition to the parking garage structure:
   A. It is important to layout the columns at the beginning of the project with the typical floor plan in addition to the parking garage below. An efficient and well thought out column layout is the key to an lightweight structural system that meets the needs of all occupants as well as benefits the other disciplines working on the project. An efficient column layout also helps improve and simplify the load path for not only the gravity system but the lateral system as well.

2. Effective communication is the key to an integrated project:
   A. Communication between all disciplines is one of the most important aspects of any design project. Communication of all team members desires and needs for the project allow for the structural team to accommodate the needs of all members without having to redesign aspects of the structure.

3. Industry Professionals are an invaluable resource:
   A. Throughout the design process the structural team learned that industry professionals have a wealth of knowledge of technical aspects of various analysis programs, and information on new and innovative technologies that are not typically taught in undergrad level classes. The structural team learned that every expert is knowledgeable in a specific area of the structural industry.

4. BIM tools and technology are essential for a complete and holistic project:
   A. Interdisciplinary work requires an efficient and effective form of graphic communication. Early implementation of BIM tools such as Revit were an effective way of displaying information between team members as well as between several programs, these programs include NavisWorks as well as BIM connected programs like SAP2000, ETABS, and RAM Structural Systems.

APPLICABLE CODES & STANDARDS

Codes and Standards:

BIM and Structural Analysis/Design Software:
One of the first steps of the structural design process is determining all applicable lateral loads on the structure. It is important to analyze wind vs. seismic forces and determine the controlling load case. An Equivalent Lateral Force analysis was performed per §12.8 of ASCE7-05. Values were determined from Massachusetts building code. A diagram showing the maximum applied story shear due to a seismic event is located to the right.

**Assumptions:**
- Lateral system to calculate period: Eccentrically Braced Frame
- Same in both directions due to no change in “Lateral System”
WIND LOADING ANALYSIS

The Structural Team began by analyzing the most applicable code for the Boston area. In order to provide the most resilient structure the design team determined that when converting the '05 wind speed into a “100” year, 1697 MRI wind speed the ‘05 wind speed became greater than the 7-10 equivalent. The Building is located in an exposure B area due to its distance from the shore and bay areas in Boston. All applicable wind pressures are broken down to the right.

### Table C.2 ASCE 7-05 Input Parameters

<table>
<thead>
<tr>
<th>Code</th>
<th>Wind Speed</th>
<th>Adjustment Factor</th>
<th>Final Wind Speed</th>
</tr>
</thead>
<tbody>
<tr>
<td>7-05</td>
<td>105</td>
<td>1.35</td>
<td>142</td>
</tr>
<tr>
<td>7-10</td>
<td>139</td>
<td>1</td>
<td>139</td>
</tr>
</tbody>
</table>

Adjustment Factor for 05:0.36+(0.1)Ln((12)(1697))

### Table C.3 Wind pressures calculated per ASCE 7095

<table>
<thead>
<tr>
<th>Location</th>
<th>z (ft)</th>
<th>qz or qh (psf)</th>
<th>Cp</th>
<th>qzGC_p (psf)</th>
<th>GC</th>
<th>qzGC_p(+GCp)</th>
<th>qzGC_p(-GCp)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Windward</td>
<td>0</td>
<td>25.0</td>
<td>0.8</td>
<td>21.0</td>
<td>0.18</td>
<td>9.2</td>
<td>11.8</td>
</tr>
<tr>
<td></td>
<td>16.5</td>
<td>25.9</td>
<td>0.8</td>
<td>21.7</td>
<td>0.18</td>
<td>9.2</td>
<td>12.5</td>
</tr>
<tr>
<td></td>
<td>33</td>
<td>31.6</td>
<td>0.8</td>
<td>26.5</td>
<td>0.18</td>
<td>9.2</td>
<td>17.3</td>
</tr>
<tr>
<td></td>
<td>49.625</td>
<td>35.5</td>
<td>0.8</td>
<td>29.8</td>
<td>0.18</td>
<td>9.2</td>
<td>20.6</td>
</tr>
<tr>
<td></td>
<td>66.125</td>
<td>38.5</td>
<td>0.8</td>
<td>32.3</td>
<td>0.18</td>
<td>9.2</td>
<td>23.1</td>
</tr>
<tr>
<td></td>
<td>80.125</td>
<td>40.7</td>
<td>0.8</td>
<td>34.2</td>
<td>0.18</td>
<td>9.2</td>
<td>25.0</td>
</tr>
<tr>
<td></td>
<td>94.125</td>
<td>42.6</td>
<td>0.8</td>
<td>35.8</td>
<td>0.18</td>
<td>9.2</td>
<td>26.6</td>
</tr>
<tr>
<td></td>
<td>108.125</td>
<td>44.3</td>
<td>0.8</td>
<td>37.2</td>
<td>0.18</td>
<td>9.2</td>
<td>28.0</td>
</tr>
<tr>
<td></td>
<td>122.125</td>
<td>45.9</td>
<td>0.8</td>
<td>38.5</td>
<td>0.18</td>
<td>9.2</td>
<td>29.3</td>
</tr>
<tr>
<td></td>
<td>136.125</td>
<td>47.4</td>
<td>0.8</td>
<td>39.7</td>
<td>0.18</td>
<td>9.2</td>
<td>30.5</td>
</tr>
<tr>
<td></td>
<td>150.125</td>
<td>48.7</td>
<td>0.8</td>
<td>40.9</td>
<td>0.18</td>
<td>9.2</td>
<td>31.7</td>
</tr>
<tr>
<td></td>
<td>164.125</td>
<td>50.0</td>
<td>0.8</td>
<td>41.9</td>
<td>0.18</td>
<td>9.2</td>
<td>32.7</td>
</tr>
<tr>
<td></td>
<td>178.125</td>
<td>51.1</td>
<td>0.8</td>
<td>42.9</td>
<td>0.18</td>
<td>9.2</td>
<td>33.7</td>
</tr>
<tr>
<td></td>
<td>192.125</td>
<td>52.3</td>
<td>0.8</td>
<td>43.9</td>
<td>0.18</td>
<td>9.2</td>
<td>34.6</td>
</tr>
<tr>
<td></td>
<td>206.125</td>
<td>53.3</td>
<td>0.8</td>
<td>44.7</td>
<td>0.18</td>
<td>9.2</td>
<td>35.5</td>
</tr>
<tr>
<td></td>
<td>220.125</td>
<td>54.3</td>
<td>0.8</td>
<td>45.6</td>
<td>0.18</td>
<td>9.2</td>
<td>36.4</td>
</tr>
<tr>
<td></td>
<td>234.125</td>
<td>55.3</td>
<td>0.8</td>
<td>46.4</td>
<td>0.18</td>
<td>9.2</td>
<td>37.2</td>
</tr>
<tr>
<td></td>
<td>250.708</td>
<td>56.4</td>
<td>0.8</td>
<td>47.3</td>
<td>0.18</td>
<td>9.2</td>
<td>38.1</td>
</tr>
<tr>
<td>Leeward</td>
<td>250.708</td>
<td>56.4</td>
<td>-0.5</td>
<td>-29.6</td>
<td>0.18</td>
<td>9.2</td>
<td>-38.8</td>
</tr>
<tr>
<td></td>
<td>250.708</td>
<td>56.4</td>
<td>-0.7</td>
<td>-41.4</td>
<td>0.18</td>
<td>9.2</td>
<td>-50.6</td>
</tr>
<tr>
<td>Side</td>
<td>251.708</td>
<td>56.4</td>
<td>1.5</td>
<td></td>
<td></td>
<td>84.7</td>
<td></td>
</tr>
<tr>
<td>Parapet (WW)</td>
<td>251.708</td>
<td>56.4</td>
<td>-1</td>
<td></td>
<td></td>
<td>-56.4</td>
<td></td>
</tr>
<tr>
<td>Parapet (LW)</td>
<td>250.708</td>
<td>56.4</td>
<td>-1.04</td>
<td>-61.5</td>
<td>0.18</td>
<td>9.2</td>
<td>-70.7</td>
</tr>
<tr>
<td>Roof (h/2-h)</td>
<td>250.708</td>
<td>56.4</td>
<td>-0.7</td>
<td>-41.4</td>
<td>0.18</td>
<td>9.2</td>
<td>-50.6</td>
</tr>
</tbody>
</table>

Figure 2. Wind Loading in North-South Direction

Figure 3. Wind Loading in East-West Direction
Gravity System Discussion

- Regular beam layout allows for easy erection
- Regular beam sizes allow for simple erection
- Changes from architectural plan allowed for simplification of framing plan
- South side columns were shifted to line up with columns located in core (1)
- North side columns were shifted to eliminate transfer girders (2)

Decking Design:
- Composite Deck with Lightweight Concrete Topping (2" Deck with 3.25" Concrete Topping)
- 19 Gauge Decking
- 2-hr Fire Rating between Floors
- '11' Un-shored Construction Clear Span
- At 10' Beam Spacing Decking has a capacity of 156 psf “Superimposed Live Load” Capacity

**Floor Vibration Analysis**

**Beam Properties:** W24x4

Area=27.7 in²
Ixx=2700 in⁴
Depth=24.3 in

**Deck Properties:**
- wₓ = 110 psf
- fᵧ = 3000 psi

**Girder Properties:** W24x48

Area=20.1 in²
Ixx=1830 in⁴
Depth=23.7 in

**Beam Mode Properties:**
- Effective Slab Width: 10h=120 in
  - min of (0.41)(58.33)(12 in)(10 ft) = 0.41(58.33)(12 in) = 0.41(207.2) = 84.5 in
- Beam Mode Fundamental Frequency: fj = 0.18(g/Δl) = 0.18(3845)(20.7/2+2) = 152 Hz

**Composite Beam Validation:** RAM Steel Beam Output: W21x44, φM₁=537.11 ft·kips, bₓ=120 in

- bₓ= min span/8 = (43.5 ft)(12 in/ft)/8 = 65.25 in
- 1/2 clear = (1/2)(10 ft)(12 in/ft) = 60 in
- bₓ= (2)(60)=120 in

**Locate Plastic Neutral Axis:**

- Vₓ max = 0.85Δf, bₓ= 0.85(3)(120)(3.25) = 995 kips
- Vᵧ max = FₓAₓ(50)(13) = 650 kips → Case 1
- Vₓ max = 650>0.85Δf, bₓ>0.85(3)(120)*a = 2.124 in

**Composite Beam Check:**

- Vₓ max = φVₓ max/d + τbₓ/a = (0.9)(650)(20.7/2+2)/2 = 156 in
- $\phi M_4 = 550.29$ ft·kips
Column Design

Upon Completion of the gravity framing the Structural Design Team began laying out the gravity column system. The columns were limited to W14’s and were designed in RAM Structural systems. The Structural Team decided to try and eliminate large unbraced length throughout the building. In order to do this the team moved columns to be slightly out of line with the main column grid. This allowed for the removal of the large sloped columns located at the entrance of the structure. The structural team designed by hand the worst case gravity concrete column located below a column supporting the cantilevered floor.

Concrete Column Design

For worst case loading located below transfer Truss

Loads: \[ P_d = 3809 \text{ kips} \]
\[ P_l = 1354 \text{ kips} \]
\[ M_1 = 30 \text{ Kip-ft} \]
\[ L = 10' \]

Slenderness Check
\[ \frac{k_{lu}}{r} = 0.83 \times 10 \times 12 / (0.3 \times 40) = 8.3 \]

34 - 12(M_1/M_2) = 12(30/30) = 22 > 8.3 \iff The column is not slender

\[ P_u = 1.2(P_d) + 1.6(P_l) = 6737.2 \text{ kips} \]

\[ \phi P_n = \phi r(0.85f'_c(a_g - a_{st}) + a_{st}(f_y)) \]
\[ = 0.65(0.8)(0.85(8)((40)(40)-43.68) + 43.68(60)) = 6865.964 \text{ Kips} \]

\[ P_u / \phi P_n = 6737.2 / 6865.964 = 0.981249 \]

Moment is negligible due to size of column and “D” dimension

Column Design Assumption

- Column sections were limited to only W14’s for gravity system
- Columns range from W14x61 to W14x550
- Columns are spliced every 2 floors to allow for ease of transportation (28’ per column)
- Columns were optimized to achieve a demand-to-capacity ratio between 75-90% where possible
- RAM Structural System shows column capacity ratios in various colors as shown below

Figure 4. RAM Model showing interaction ratios

Stirrup Spacing Determination:

\[ \min \frac{16d_s}{16}(11/16) = 11'' \]
\[ \frac{48d_s}{48}(1/2) = 24'' \]

Use 11" O.C.

40"x40" RC Column Section
\[ A_g = 1600 \text{in}^2 \]
\[ A_s = 43.68 \text{in}^2 \]
\[ p = 2.73\% < 4\% \]
\[ \text{Cover} = 2" \]
TRUSS MODELING AND RESULTS

The design of a truss support for the two retail floors consisted by an empirical selection of the lightest weight configuration with the least amount of sections. The truss was modeled using SAP2000 with pins supports at the bottom two column locations and a pin at the far most top column connection to provide a more realistic model. A deck with concrete to brace the top flanges of the beams as appropriate. Strength-wise a single truss is able to meet load requirements; but, it does not meet deflection requirements. A second truss was added to meet deflection criteria and provide added resiliency.

The allowable deflection was calculated to be by the allowable live load deflection: L (Length of bay) / 240 = 43ft*12ft/in / 240 = 2.15 inches.

The deflection output from using a two two-bay trusses from the Load Case 1.2D +1.6L is: -0.095 feet = 1.14 inches at end corner (Shown with cross in Fig. 6).

EXTENDED SHEAR TAB CALCULATIONS

The following calculations show the design of an extended shear tab as described in the narrative and shown in the drawings.

### Beam: W24x84 A992 Steel

<table>
<thead>
<tr>
<th>Assumptions:</th>
<th>Bolt Spacing = 3 in</th>
<th>Horizontal Edge Distance = 1.5 in</th>
<th>Stand Bolt Holes</th>
<th>(A36 Plate)</th>
</tr>
</thead>
<tbody>
<tr>
<td>D=24.1 in</td>
<td>b=9.02 in</td>
<td>t=0.770 in</td>
<td>w=0.44 in</td>
<td>Vc=62 kips</td>
</tr>
<tr>
<td>Eccentricity:</td>
<td>e=(8.67/2) + (0.415/2) + 1.5 + 3/2 = 7.6275 in</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bolt Shear:</td>
<td>22.5 kips*(3.4)</td>
<td>76.5 kips</td>
<td>&gt;62 kips</td>
<td></td>
</tr>
<tr>
<td>Bolt Bearing and Tear out on Beam:</td>
<td></td>
<td>(Bolt Spacing = 3 in)</td>
<td>Horizontal Edge Distance = 1.5 in</td>
<td></td>
</tr>
<tr>
<td>Interior:</td>
<td>Table 7-4<em>Fy=478.9 kips/in</em>(0.44 in)=38.63 kips</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Edge:</td>
<td>Table 7-5<em>Fy=49.4 kips/in</em>(0.44 in)=21.74 kips</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>φRn=38.6*(21.7)=727 kips</td>
<td>&gt;62 kips</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bolt Bearing and Tear out on Plate:</td>
<td></td>
<td>(Bolt Spacing = 3 in)</td>
<td>Horizontal Edge Distance = 1.5 in</td>
<td></td>
</tr>
<tr>
<td>Interior:</td>
<td>Table 7-4<em>Fy=378.2 kips/in</em>(0.375 in)=29.36 kips</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Edge:</td>
<td>Table 7-5<em>Fy=344 kips/in</em>(0.375 in)=16.5 kips</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>φRn=629.4*(16.5)=209.4 kips</td>
<td>&gt;62 kips</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maximum Plate Thickness:</td>
<td></td>
<td>(Bolt Spacing = 3 in)</td>
<td>Horizontal Edge Distance = 1.5 in</td>
<td></td>
</tr>
<tr>
<td>db=2/1=1/16=0.4375 &gt; 3/8&quot; : no need to check plate thickness limit</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lw=22.4=1.5→Edge distance of 1.5&quot; is ok</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Beam Shear Yielding:</td>
<td>h=24.1 in</td>
<td>φRn=(0.6)*fy=318.12 kips=62 kips</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Beam Shear Rupture: A0= [h_b=3]/[3/4+1/6+1/16]+*[n]* = 21.4-3/[3/4+1/16+1/16] = 0.44 = 8.261 in²

### φRn=0.6*A0

### Plate Shear Yielding: φRn=0.6*A0 = (0.75)(0.6)(65)(8.261)=241.6 kips>62 kips

### Plate Shear Rupture: φRn=15*[4(3/4+1/16+1/16)]*c=4.3125 in²

### Plate Block Shear: Assume hA=1.5" and tA=1.25"

### Table 9.3a → 46.2 k/in

### Flecture-Shear Interaction:

### Plate Buckling:

### Plate Yielding Controls over Plate Buckling

### Typical Gravity Connection Details

**Figure 5. Truss bays with Interaction ratios for demand capacity**

**Figure 6. Deformed shape of west side truss**

**Figure 7. SAP2000 model of truss**
Exterior Moment Frames: The exterior moment frames were located to resist torsion in the weak direction of the structure. They are also located to prevent progressive collapse in the most critical locations of the structure. The moment frames add extra capacity into the weak direction of the brace frame.

Strong Axis X-Bracing: Double story X-Bracing was placed at four locations along the short axis of the core. Double story x-bracing was selected due to the increased stiffness over other comparable options (v-shaped, A shaped, and single story x-shaped). These braces can be integrated into walls on the exterior of the core next to the elevator shafts.

Eccentric Brace Frame: An eccentric braced frame was located along the long axis of the core. The frame occupies two of the three bays that make up the building “core”. By not occupying the third bay the Structural Team allowed for an introduction of damping into the structure. The eccentric braces extend into the bay to approximately the same location as the concrete core. The braces were designed to not interfere with any architectural penetrations currently located in the core.

Parking Garage Levels: At the parking garage levels all lateral elements are converted into concrete moment frames. Moment frames are the best option for the core due to the fact that they do not interfere with any layout issues within the parking garage layer, as well as a clean method of delivery for all loads into the caisson foundation.

<table>
<thead>
<tr>
<th>Element</th>
<th>% of lateral in X-direction</th>
<th>% of lateral in Y-direction</th>
</tr>
</thead>
<tbody>
<tr>
<td>X-braces</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Chevron + Eccentric Brace</td>
<td>47.9</td>
<td>-</td>
</tr>
<tr>
<td>2-bay Moment Frame</td>
<td>2</td>
<td>-</td>
</tr>
<tr>
<td>3-bay Moment Frame</td>
<td>2.2</td>
<td>-</td>
</tr>
</tbody>
</table>

Figure 8. Typical Office Floor Plan showing location of Lateral Elements

Figure 9. Typical Office Floor Plan showing location of Lateral Elements
CAISSON FOUNDATION ANALYSIS

Maximum Column Load: 5163 kips
Bearing Conditions:
- Skin Friction = 14.4 ksf
- Bearing on Bedrock: 100 ksf

*The above bearing pressure occurs at 5' below the top of bedrock therefore the caisson will have skin friction for 5' = (2)(n)(r)(14.4)+(100)(n)(r)^2

R = 3.39' round - 7' Diameter for constructability reasons

Concrete and Reinforcement Check:

Minimum reinforcement was introduced into the caisson. The minimum requirement is 1% of concrete cross sectional area: 0.01*(π*(84/2)^2) = 55.42 in² - Use 56 in²
This corresponds to 36 #11 bars equally spaced with minimum shear reinforcement to hold the rebar together.

PROGRESSIVE COLLAPSE ANALYSIS

Discussion of worst case Axial Force:
1. Determination of initial length
2. Calculations of end reactions
3. Determination of "Moments" on cable
4. %Sag determined as function of moment/max moment
5. Finding sag length to give member same length as initial assumption
6. Calculation of constant horizontal reaction
7. Determination of maximum axial force

Figure 10. Geothermal Caisson showing water flow direction, along with bearing and frictional forces

Figure 11. Geothermal Caissons location in relation to mat foundation (in red)

Figure 12. Shear diagram after removal of column at midspan
Buildings Enclosure Information

Double skin Unitized curtain wall system consisting of Insulated Glass Unit System inner layer and a Laminated Glass System outer layer. The outer layer protects the inner layer by dissipating energy and forces throughout the mullions and into the buildings framing systems. This allows the inner layer to be utilized fully for energy saving purposes.

This system will be tested through a mockup to assure that it withstands all expected wind loss without allowing water penetration and performing otherwise as expected. This will be done as required per ASTM requirements.

Glass to Mullion Connection
- Clearance between glass edge and aluminum framing to allow movement cause by inter-story drift in accordance with manufacturer
- Extension of film over edge of surrounding frame to hold fragments in place and prevent the pane from falling out
- Wet glazing (silicone seal over back-up rod). This improves resistance to water penetration

Mullion Sizing
Stiffer structural systems to reduce inter-story drift
3” Mullion - Increase the glass bite and allows the system to withstand higher wind loads.

C&C Forces Calculations:
P=56.4(1.55)-56.4(.18)≈97psf
This led to two ¼” laminations being selected

Solar PV Panels
30” on each floor capturing exterior light to supply the building. The cables from the panels will be integrated within the mullions to avoid the risk of their damage and improve aesthetics.

Rounded Corners
Rounded corners avoids point of stress concentration at corner-edge regions. The corners will have a rounding of radius of 0.5in. Rounded corners in glass panels are 50-90% more resistant against cracking and fallout (Dr. Memari, 2006).

Insulated Glass Unit System
System to help insulation of curtain wall.
#1 ¼” Clear Glass Fully Tempered
#2 1/2” Argon Space
#3 ¼” Clear Glass Fully Tempered

Laminated (Safety) Glass System
Multi-layered glass system where the broken shards remain attached to film that is located between layers.
#1 ¼” Clear Glass Fully Tempered
#2 0.060” PVB Interlayer
#3 ¼” Clear Glass Fully Tempered

Connection Detail
Section showing inner and outer façade layers attachment location and type in regards to structure. Both systems will be window walls, meaning that they sit on the structure as opposed to being attached through an outward extension. The outer layer sits on a C-angle that is welded onto the slabs perimeter angle

Figure 13. Double Skin façade components
References

Double Skin Façade:
Structural Performance of Double-Skin Façade Systems Subjected to Blast Pressures (Tuan Ngo; Chao Ding; Raymond Lumantarna; Abdallah Ghazlan; and Marc Zobec)
Curtain walls toughen up (Mark robins)

ASTM:
E331-00 Test Method for Water Penetration of Exterior Windows, Skylights, Doors, and Curtain Walls by Uniform Static Air Pressure Difference
E283-04 Test Method for Determining Rate of Air Leakage Through Exterior Windows, Curtain Walls, and Doors Under Specified Pressure Differences Across the Specimen
E330-02 Test Method for Structural Performance of Exterior Windows, Skylights, Doors, and Curtain Walls by Uniform Static Air Pressure Difference
E1105-00 Test Method for Field Determination of water penetration of Installed Exterior windows, Skylights, Doors, and curtain walls by Uniform or Cyclic Static Air Pressure Difference

Damping:
Wind-Induced Motion of Tall Buildings: Designing for Occupant Comfort (Melissa Burton)
Progressive Collapse:
UFC 4-023-03: Design of Building To Resist Progressive Collapse (James C. Dalton, July 2009)

Codes:
ACI 318-11 (American Concrete Institute, 2011)
ASCE7-05/10 (American Society of Civil Engineers)
ISO (International Standards Organization, 1997)

Other:
Steelwise: Specifying Camber (Erika Winters Downey, July 2006)
Principles of Foundation Engineering, 8th Edition (Braja M. Das, 2016)
BOYLSTON ST. HIGH RISE

BOSTON, MASSACHUSETTS

AEI TEAM 2-2016

STRUCTURAL ENGINEERING-BUILDING OVERVIEW

FOUNDATION: THE BOYLSTON STREET HIGH RISE IS BUILT ON 26 GEOTHERMAL CAISSONS. COLUMNS THAT DO NOT RUN THE HEIGHT OF THE BUILDING (I.E. THE PARKING GARAGE LEVELS) BEAR ON AN EXISTING MAT SLAB.

GRAVITY SYSTEM: THE GRAVITY SYSTEM CONSISTS OF A COMPOSITE STEEL SYSTEM CONSISTING OF A 2VL19 DECK WITH A 3 1/4" CONCRETE Topping. THE SYSTEM IS LIGHTWEIGHT AND ALLOWS FOR AN OPEN OFFICE FLOOR PLAN. THE OFFICE LEVELS ARE SUPPORTED BY A STORY HIGH CANTILEVERED TRUSS SYSTEM LOCATED ON THE FOURTH FLOOR OF THE BUILDING.

LATERAL SYSTEM: THE LATERAL SYSTEM WAS DESIGNED TO SUPPORT A "100" YEAR WIND FORCE, AND CONSISTS OF AN ECCENTRIC AND DOUBLE STORY X BRACED FRAME CORE. THE SYSTEM ALSO CONTAINS EXTERIOR MOMENT FRAMES WHICH HELPS PREVENT TORSION OF THE STRUCTURE IN ADDITION TO HAVING CONNECTIONS THAT HELP A PROGRESSIVE COLLAPSE SCENARIO.

FAÇADE DESIGN: THE FAÇADE CONSISTS OF A STANDARD CURTAIN WALL AS WELL AS A DOUBLE SKIN FAÇADE SYSTEM. BOTH FAÇADE SYSTEMS CONTAIN AN OUTER LAMINATED GLASS LAYER TO RESIS IMPACTS FROM FLYING DEBRIS. THE FAÇADE ALSO SPECS ROUNDED GLASS EDGES TO REDUCE THE EFFECTS OF CRACKING DUE TO LARGE IN PLANE DRIFTS. THE DESIGN TEAM ALSO SPECD A 3" MULLION IN ORDER TO INCREASE THE OVERALL BITE OF THE GLAZING SYSTEM. A WET GLAZING SYSTEM IS USED DUE TO THE BETTER RESULTS. THE DESIGN TEAM ALSO SPECD A HIGHER LEVEL OF WATER PRESSURE STANDARDS. THIS IS DUE TO THE FACT THAT WATER PENETRATION IS THE NUMBER ONE CAUSE OF FAÇADE FAILURE.

IMAGES (CLOCKWISE FROM TOP-LEFT):
1.) ETABS MODEL SHOWING INTERACTION/CAPACITY OF LATERAL SYSTEM ELEMENTS
2.) VIEW OF CANTILEVERED TRUSS OVERHANGING I-90
3.) RENDER OF OVER ALL STRUCTURE SHOWING SIMPLIFIED FRONT COLUMN LOCATIONS
4.) RENDERING OF OFFICE SPACE SHOWING OPEN OFFICE FLOOR PLAN
5.) RENDER OF DOUBLE SKIN FAÇADE SYSTEM SHOWING PV-PANELS AND INTERIOR BLINDS. AS WELL AS A GRATE FOR MAINTANCE
6.) RENDER SHOWING ALL CHANGES TO ARCHITECTURE OF THE STRUCTURE
WORK FLOW DIAGRAM

SOFTWARE UTILIZATION

REVIT: Revit was used as the primary 3D modeling software. Complete structural drawings were created using Revit as well as to find any clashes with other systems.

ROAM STRUCTURAL SYSTEM: Analysis and design of gravity system. Un-able to link to Revit 2016.

ETABS: Primary lateral design software also used to perform modal and damping analysis. Un-able to link to Revit 2016.

SAP2000: Used to perform schematic bracing configuration analysis

ADAPT BUILD: Finite slab analysis program used to design the parking garage and first floor levels.

HAND CALCULATIONS: Hand calculations were used to perform simple designs in addition to preliminary design calculations

SP COLUMN: Concrete column design program used for sizing of worst case gravity column

EXCEL: Excel was used to perform lateral force calculations using a student made spreadsheet

RISA 2D: A basic program used to quickly generate shear and moment diagrams
4D STRUCTURAL SYSTEM ERECTION MODEL IMAGES


MECHANICAL, ELECTRICAL, AND PLUMBING CORODINATION

THE DESIGN TEAM DETERMINED THAT THE MOST EFFICIENT MECHANICAL SYSTEM FOR THE TYPICAL OFFICE SPACE INCLUDED AN UNDERFLOOR AIR DISTRIBUTION SYSTEM. AN UNDERFLOOR AIR DISTRIBUTION SYSTEM MOVES HALF OF THE MECHANICAL DUCT WORK ABOVE THE FLOOR SLAB AND BELOW THE RAISED FLOOR SYSTEM. THIS SYSTEM REQUIRES ONLY SMALL "TAP OFF" DUCTS BELOW THE BEAM SYSTEM. IN ADDITION TO THE DECREASE IN OVERALL DUCT SIZES, SPACE CAN BE SAVED BY RUNNING THE ELECTRICAL SYSTEM IN CONDUIT THROUGH THE RAISED FLOOR SYSTEM. THE RAISED SYSTEM ALLLOWS FOR MORE FREEDOM IN STEEL MEMBER SIZES, WHICH WAS NEEDED DUE TO THE LONG SPANS CREATED BY THE OPEN FLOOR PLAN.

BOYLSTON STREET SITE CONTEXT

THE NEW HIGH RISE TOWER IS LOCATED ON BOYLSTON STREET IN THE BACK BAY DISTRICT OF BOSTON. THE SITE IS LOCATED ON POUR SOIL CONDITIONS RESULTING IN THE NEED TO DESIGN DEEP FOUNDATIONS TO SUPPORT THE 17 STORY OFFICE TOWER. THE NEW STRUCTURE IS BUILT OVER AN EXISTING PARKING STRUCTURE, WHILE THE ORIGINAL PARKING STRUCTURE WILL BE DEMOLISHED THE MAT SLAB WILL BE REUSED TO SUPPORT THE STRUCTURE UP TO FLOOR 1. THE STRUCTURAL TEAM ATTEMPTED TO KEEP THE IMPRESSIVE FRONT FAÇADE AS APPEALING AS POSSIBLE WHILE SIMPLIFYING THE STRUCTURE AND ELIMINATING TRANSFER BEAMS. THE SITE IS SURROUNDED BY EXISTING SHEET PILES WHICH HOLDS BACK THE WATER TABLE FROM PUSHING ON THE RETAINING WALLS AT THE PARKING GARAGE LEVELS.

EFFECTS OF LATERAL SYSTEM CHANGE ON ALL DISCIPLINES

WHEN THE DESIGN TEAM DISCUSSED CHANGING THE LATERAL SYSTEM THE STRUCTURAL TEAM ANALYZED THE EFFECTS OF MAKING THE CHANGE ON EACH DISCIPLINE. THROUGH DISCUSSIONS WITH EACH DISCIPLINE THE STRUCTURAL TEAM CREATED A PROS AND CONS CHART, AS SEEN ABOVE. THROUGH THE TABLE THE STRUCTURAL TEAM DETERMINED THAT SWITCHING TO THE BRACED FRAME CORE WAS AN OVERALL BENEFIT TO THE STRUCTURE.
Typical Office Floor Plan

TYPICAL FLOOR NOTES:
1. FLOOR TO FLOOR HEIGHTS IS 14'-0"
2. THE BUILDING IS 21 STORIES TALL WITH 17 OCCUPIABLE FLOORS AND 2 BELOW GRADE PARKING GARAGES
3. LIGHT WEIGHT CONCRETE (F'c=4,000psi @28 DAYS)
4. 2" 19 GAGE GALVANIZED COMPOSITE FLOOR DECK (VULCRAFT OR APPROVED EQUIVALENT)
5. TYPICAL SLAB THICKNESS= 5.25"
6. ALL STEEL= ASTM A992 GRADE 50
7. SHEAR STUDS: 3/4" DIA., 4" LONG
8. DECK DIRECTION ALWAYS PERPENDICULAR TO INFILL BEAMS
RETAIL FLOOR NOTES:
1. FLOOR TO FLOOR HEIGHT IS 16'-0"
2. THE BUILDING IS 21 STORIES TALL WITH 17 OCCUPIABLE FLOORS AND 2 BELOW GRADE PARKING GARAGES
3. LIGHT WEIGHT CONCRETE (F'c=4,000psi @28 DAYS)
4. 2" 19 GAGE GALVANIZED COMPOSITE FLOOR DECK
OR APPROVED EQUIVALENT
5. TYPICAL SLAB THICKNESS: 5.25" 6. ALL STEEL= ASTM A992 GRADE 50
7. SHEAR STUDS: 3/4" DIA., 4" LONG
8. DECK DIRECTION ALWAYS PERPENDICULAR TO INFILL BEAMS

SCALE: 3/32" = 1'-0"
REINFORCED CONCRETE FLOOR NOTES:
1. FLOOR TO FLOOR HEIGHT IS 9'-6"
2. THE BUILDING IS 21 STORIES TALL WITH 17 OCCUPENABLE FLOORS AND 2 BELOW GRADE PARKING GARAGES
3. SLABS ARE MADE OF 5,000PSI CONCRETE AT 28 DAYS
4. TYPICAL SLAB THICKNESS FOR PARKING GARAGE=12"
5. TYPICAL SLAB THICKNESS FOR ENTRY LEVEL=16"
6. ALL REINFORCING STEEL=ASTM A615 GRADE 60 EPOXY COATED REBAR

A BOTTOM MAT OF #5@12" O.C. IN BOTH DIRECTIONS WITH A LAP LENGTH OF 3'

3D VIEW OF PARKING GARAGE
SLAB REINFORCEMENT PLACEMENT DETAIL
NOTES:
1. ALL PLATES, ANGLES, CHANNELS USE A36 STEEL
2. ALL W-SHAPES USE A992 STEEL
3. ALL WELDS USE E70XX WELD STRENGTH
4. ALL BOLT GROUPS USE 3/4" DIA. A325-N BOLTS

1A TYPICAL SHEAR TAB CONNECTION
2A BRACED FRAME CONNECTION
3A MOMENT FRAME CONNECTION

NOTES:
1. ALL PLATES, ANGLES, CHANNELS USE A36 STEEL
2. ALL W-SHAPES USE A992 STEEL
3. ALL WELDS USE E70XX WELD STRENGTH
4. ALL BOLT GROUPS USE 3/4" DIA. A325-N BOLTS
UNITIZED FACADE SYSTEM
ALLOWS FOR QUICK AND EFFICIENT ERECTION AND INSTALLATION

VERTICAL MULLIONS SPACED EVERY 5 FEET

EXTERIOR FACADE TO C-ANGLE CONNECTION

INSULATED GLASS UNIT (IGU) SYSTEM
1 & 3 - 1/4" CLEAR GLASS
2 - 1/2" ARGON SPACE

LAMINATED GLASS SYSTEM
1 & 3 - 1/4" CLEAR GLASS
2 - 0.006" PVB INTERLAYER

ALUMINUM MULLIONS, 3" WIDTH
INCREASES GLASS BITE
INCREASING WIND PRESSURE CAPACITY

ROUNDED CORNERS, REDUCE STRESS CONCENTRATION AT CORNERS

ALUMINUM GRADE TO ALLOW MAINTENANCE OF INNER DOUBLE SKIN FACADE SPACE

FACADE TO FLOOR CONNECTION, WINDOW WALL SYSTEM

YKK SECTION OF FACADE CONNECTION TO SLAB

YKK SECTION OF VERTICAL MULLION
0.0 **EXECUTIVE SUMMARY**
The Genesis Design mechanical team set out to design a building that followed the team ideal of resiliency, sustainability, and integration in order to exceed the design requirements of the AEI Student Competition. The following Mechanical Narrative includes the completed project scope and team driven goals, as well as design decisions, and design summaries. In addition to the design narrative, a section of supporting documents and system drawings detailing hand calculations and system specifications are included within this document.

0.1 **PROJECT GOALS**
The Mechanical Design Team established a list of goals and requirements to achieve in the system design. These include:
- Achieve a minimum 50% reduction of the baseline established by ASHRAE 90.1-2007.
- Significantly reduce the water consumption of the building.
- Achieve near-zero storm water runoff from site.
- Design each system to cohesively integrate with each building discipline involved in the development of the Boylston Street High Rise.

In order to accomplish these goals, the following major systems were implemented into the mechanical system design.

0.2 **DOUBLE SKIN FACADE**
The Genesis Design Double Skin Façade was designed for the south and west facades of the building. This façade design acts as a thermal barrier in heating mode and allows for natural ventilation during optimal degree days; in turn reducing the solar heat gain into the building with significantly reduces the cooling dominated mechanical load.

Energy Savings: 37%

0.3 **GEOTHERMAL CAISONS**
26 vertical geothermal caissons plunge 137 feet into the earth as a method of heat expulsion or recovery depending on the season. This system is a closed loop combined with hybrid ground source heat pumps system featuring two u-tube loops per geothermal caisson.

Energy Savings: 8.0%

0.4 **OFFICE DESIGN**
- Dedicated outdoor air and four air handling units provide conditioning for the latent, sensible and ventilation loads serving 14 stories.
- Under floor air distribution (UFAD) creates a personalized ventilation system at each workstation.

0.5 **DOUBLE SKIN FACADE**
- Hybrid ground source heat pumps provide sensible and latent space heating and cooling.
- Dedicated outdoor air system (DOAS) provides ventilation required to each leasable area.
- Vestibules added to entries to assist with stack effect pressure mitigation.

0.6 **RAINWATER COLLECTION SYSTEM**
A rainwater collection system was implemented onto the roof and plaza to capture all runoff storm water and reuse it as grey water throughout the building.

Grey Water Reduction: 72.8%

Overall ASHRAE Baseline Reduction: 54%
MECHANICAL NARRATIVE

1.0 PROJECT INTRODUCTION
The Architectural Engineering Institute Student Design Competition emphasizes the development and integration of innovative and original solutions encapsulated into a design challenge. The 2016 design challenge is centered around a 17-story mixed-use infill building located on Boylston Street in the Back Bay area of Boston, Massachusetts. Throughout the entirety of this narrative, the building presented will be referred to as the “Boylston Street High Rise”. The dense urban surroundings consist of prominent buildings including the Prudential Tower to the south and the Hynes Convention Center to the west; see Figure 1 below. Various entities of the project include a multi-level underground parking garage, large public lobbies, three floors of leasable retail spaces, fourteen floors of typical office space, street connection to a restaurant/food court area a large public entry structure leading into the existing Prudential shopping center, and multi-use street-level plaza.

![Figure 1 – Prudential Center Complex & Surroundings](image)

1.1 MECHANICAL SCOPE
The main focus within Genesis Design is to ensure the integration between every facet of the architectural, structural and electrical detail is meshed with the mechanical systems into one cohesive enclosure, while developing detailed mechanical systems implemented into the Boylston High Rise. The scope of this Mechanical Design Narrative encompasses a thorough analysis of all HVAC systems seamlessly intertwined within our seventeen-story structure. The mechanical design submittals following this narrative shall include a complete description of mechanical systems that will serve the entire building. In addition to the AEI Student Design Competition expectations, Genesis Design has developed descriptive plans of main mechanical spaces (e.g. the mechanical mezzanine and mechanical penthouse), supporting documents of a Photovoltaic Integrated Double Skin Façade, rainwater collection system and the closed loop geothermal caisson construction to illustrate the mechanical coordination and feasibility solutions within the Boylston High Rise. While completing the project design each focal point including HVAC, plumbing, fire suppression, and all renewable energy systems were carefully placed within the Boylston Street High Rise in order to maximize the ease of maintenance, serve the building in the most efficient way possible, and accommodate the area for all structural and MEP disciplines.

Completing the design of a project such as the Boylston High Rise requires an integrated, multidisciplinary team. As stated previously, Genesis Design recognizes the scope of the AEI Student Design Competition requirements does not fully suggest all major goals that Genesis Design has set for themselves as a collaborative interdisciplinary team. Genesis Design’s mechanical team has prepared the following design summary to address the complete scope of the Boylston Street High Rise.

1.2 MECHANICAL GOALS
Genesis Design has developed a set of shared design drivers and team goals based on project requirements and project stakeholder objectives. The Sustainability driver’s goals are to create a high performance, energy efficient building through its full lifespan, while promoting a healthy environment for its occupants. The Resiliency driver’s goals are to ensure building operation and security during the harshest conditions, as well as provide flexibility for adapting to changing occupant needs. Finally, the Integration driver’s goals are to successfully optimize integrated systems within the building through IPD’s increased collaboration resulting in the building becoming an integral, engaging part of the surrounding city community. More specific mechanical goals were developed, correlating to and enhancing the completion of team goals:
2.0 INTEGRATIVE APPROACH
The traditional method for project delivery in the industry is Design-Bid-Build. The linear travel of information from architect to engineers to general contractor is one of purely reactionary design and adversarial checks and balances. In contrast, Genesis Design has chosen to approach the project using an Integrated Project Delivery (IPD) process with Building Information Modeling (BIM). With IPD, all disciplines of the design team participate in the decision-making. Sharing information and providing feedback is prioritized from the project outset. BIM enhances communication through intelligent management of digital representations. The compilation of all analyses, calculations and specifications manifest into a 4D model that aligns construction planning with performance. The process limits costly design changes, increases work efficiency and creates trust within the team. It is also inevitable that any high performing team is likely to have disagreements. Genesis Design resolves disputes with respect and has created a Decision Matrix to measure decisions against how well they achieve our team’s project goals and objectives. Please refer to the Mechanical Decision Matrix (Mechanical Supporting Document H) for major electrical design decisions. The integrative approach has taught Genesis Design that the team dynamic is ultimately as important a project input as technical capability. While the IPD process is undoubtedly a more demanding and intensive process, the final production of a higher quality, much more innovative building is a truly rewarding experience.

3.0 COMPUTER PROGRAMS
Learning and maximizing the capability of software is an essential component of the Building Information Modeling approach. Proof of collaboration is key throughout this design process. This collaboration is depicted through computer software modeling and analysis methods. Each software platform employed to obtain numerical outputs utilizes BIM software that fully integrates each aspect of the project into one package. In order to create these previously-stated connections, the Mechanical Design team has implemented the following software platforms into the design of the Boylston High Rise:

AUTOCAD: 2D computer drafting to create drawing details and 3D modeling for exporting into other compatible programs.

REVIT: Realistic Building Information Modeling of spaces used as an Integration Clash Detection tool as well as collaborative platform to guide the design decision making process.

Trace700: Comprehensive building load analysis modeling software. Fully utilized to calculate HVAC cooling and heating loads, implement equipment schedules and assign sizes to all mechanical equipment which account for thermal comfort and ventilation requirements serving the Boylston Street High Rise.

Microsoft Excel: Tabular bookkeeping spreadsheet calculating geothermal caisson and DSF performance.

4.0 CODES AND STANDARDS
Genesis Design has created all entities of the mechanical design in accordance with a variety of codes that comply with local and national jurisdiction to ensure a safe, comfortable and resilient building delivered to both client and occupant. The specific standards include:

Hvac
  + ASHRAE 62.1: ANSI/ASHRAE Standard 62.1 is the recognized standard for ventilation system
design and acceptable IAQ for high-rise buildings.

+ **ASHRAE 55**: Standard 55 specifies conditions for acceptable thermal environments and is intended for use in design, operation, and commissioning of buildings and other occupied spaces.

+ **ASHRAE 90.1, v2010; Energy-Efficient Design of High-Rise Buildings**: Effective in Boston since July 2014. The competition specifies that the project’s energy goal be limited to a value of a 50% reduction of the baseline established by ASHRAE 90.1, v2007, but Genesis Design as a team goes beyond by following the more stringent amendments in the newer addition.

+ **2014 Massachusetts Building Code**.

+ **2014 Massachusetts Mechanical Code** which follows the **International Mechanical Code 2009**.

**Fire Protection**:

+ **NFPA 54**: National Fuel Gas Code.

+ **2014 Massachusetts Fuel Gas Code**.

**Plumbing**:

+ **2014 Massachusetts Plumbing Code**.

5.0 **SITE ANALYSIS**

The Boylston Street High Rise fills the last vacant lot of the 23-acre Prudential Center complex in the heart of Boston’s Bay Back neighborhood. Owned by Boston Properties, a Real Estate Investment Trust, the complex includes three skyscrapers to the building’s south: Prudential Tower (749’), 111 Huntington Avenue (549’), and 101 Huntington Avenue (336’), as well as the vast Prudential Shops urban mall center at the Prudential Tower’s base. As part of the project, an entrance structure adjacent to the new street-level plaza serves as a “front door” and connects the Boylston Street High Rise’s second level retail to the rest of the mall. Also sharing the plaza, the Hynes Convention Center is located immediately to the building’s west, while the Exeter and Fairfield residential apartment complexes are to its east; see **Figure 1**.

To successfully design and build the Boylston Street High Rise, the Genesis Design mechanical team has performed a detailed site analysis to fully understand the accompanying opportunities and constraints within ASHRAE climate zone 5A. Investigations were done on local environmental, subterranean and city conditions.

For detailed conclusions, refer to **Site Analysis (Integration Supporting Document B)**. While it is important to recognize that climate zone 5A is primarily a heating season climate for a typical building construction, the internal heat loads associated with the high number of computers, centralized elevators and data server rooms provide a significant heat load to the adjacent spaces and mechanical system serving the Boylston Street High Rise. As a result the building primarily requires mechanical cooling throughout the course of the year. The mechanical design team effectively provided dedicated solutions to decrease the solar heat gain into the building so that the cooling load was minimized regardless of the time of year.

To summarize the findings of site climate and solar conditions, the analysis reveals promising opportunities for natural ventilation while providing a significant amount of daylight casting into the plan south and west sides of the Boylston High Rise without the significant effects of solar heat gain negatively impacting the HVAC cooling load. This lends sufficient justification for the implementation of a Double Skin Façade. See **Solar & Shadow Analysis (Electrical Supporting Document B)** for calculations and charts, in addition to **Figure 2** below for solar effects on the structure.

**Figure 2** – Severity of Solar Blockage from Surrounding Buildings.

A subterranean analysis also reveals the building’s close proximity to the recently constructed I-90 tunnel and adjacent exhaust fan room. Challenges addressed in detail in Section 2.0 of the Integration Narrative describe the approach taken to ensure continued operation of the tunnel and fan room, as well as the construction and structural challenges associated with excavation and building around the existing structures. After reviewing the site-specific geotechnical report, it was determined that the poor soil conditions guided the
Structural Design team to a caisson foundation; see Foundation Design Analysis (Structural Support Document H).

To complement the building’s integrated design, the Mechanical Design Team has integrated a closed loop geothermal heat pump system, featuring two geothermal u-tube loops placed in the center of each structural caisson.

6.0 DEMAND REDUCTION
To ensure the most sustainable design possible, a large variety of energy generation technologies have been considered when designing the Boylston Street High Rise. Some technologies were dismissed because they were found to be ineffective based on the site and climatic conditions. An outline of all considered mechanical systems can be found on the Mechanical Decision Matrix (Mechanical Supporting Document H).

Every building requires energy and material resources to achieve thermal comfort, a healthy indoor air quality, and to meet the electricity demands of its occupants. The Mechanical Design Team has investigated minimizing the HVAC systems demand as an initial energy reduction strategy. This strategy brought to light many ways to reduce the amount of primary energy the Boylston High Rise will be using over the lifetime of the building, in addition to reducing the peak electrical demand when the HVAC envelope loads are at their highest.

The Boylston Street High Rise construction followed the ASHRAE 90.1, v2007 Standard while incorporating existing architectural details delivered from the baseline building’s architect, FX Fowle. The Boylston Street High Rise baseline building’s original energy demand of 48.3 BTU/hr-ft² was reduced by Genesis Design to 14.3 BTU/hr-ft². The Boylston Street High Rise’s mechanical system consumption in energy was reduced by 53% in comparison to the baseline building. A summary chart featuring these and additional values can be found in Table 1 below. These reductions have been harnessed by optimizing not only the mechanical system, but also the envelope of the building enhancing a thermally efficient façade and roof assembly while creating an appealing architectural aesthetic.

### Table 1: Baseline Building Statistics

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy EUI</td>
<td>48.3 BTU/hr-ft²</td>
</tr>
<tr>
<td>Grey Water</td>
<td>3,360,000 gallons/yr</td>
</tr>
</tbody>
</table>

6.1 FAÇADE DESIGN
The baseline building is assumed to consist of an ASHRAE Standard 90.1, v2007 construction curtain wall envelope for a building in climate zone 5A. The existing baseline building provided by FX Fowle is shown in the architectural Revit model to be 76% window area when considering floors two through 17. There are certain factors that drove the design techniques when developing the designs of Boylston’s complete aesthetic because it was clear to the members of Genesis Design that the architect and owner were attracted to the aesthetic that a large glass façade presented. Therefore, the overarching design driver set by the mechanical design team has been preserving the theme of the façade established by the architect, FX Fowle and having it be a recognizable rendition; as well as optimizing the thermal capacity of the construction without hindering occupant views or restricting daylight into the space. Following these ideals, the double skin façade was implemented on the south and west faces of the Boylston Street High Rise. The Double Skin Façade Analysis P1 & P2 (Mechanical Supporting Document C & D) describes its efforts in overall building energy reduction. Section 6.1.2 below outlines the design of the north and east façades.

![Figure 3 – Double Skin Façade View into Typical Office](image-url)
6.1.1 DOUBLE SKIN FAÇADE DESIGN

In reference to the solar study and applicable site information, please see Double Skin Façade Integration (Integration Drawing I-06), Building Façade Design (Electrical Drawing E-04), and Double Skin Façade Analysis P1 & P2 (Mechanical Supporting Document C & D) to fully understand the integration of the Double Skin Façade with each discipline.

The Genesis Design Team has developed a project specific double skin façade to reduce solar heat gain into the south and west façade implemented only on floors five through 17, more commonly known as the typical office floors. As shown in Figure 4 above, the west and south sides of the building receive the most solar gains throughout the course of the day; this measure is based on the sun path and the severity of solar blockage from surrounding buildings. In determining the best way to utilize this natural daylight, Genesis Design has considered several configurations using passive shading, daylight redirecting devices, and photovoltaic panels. In terms of maximizing sustainability features of the Boston climate, it is clear that daylight is primarily most useful as a supplementation of electric light, and secondly most useful as a means of generating electricity. As a direct result of this consideration, our team has designed a façade to redirect daylight into the area as much as possible for lighting purposes, and implemented photovoltaic panels on the bottom of each cavity where natural light will not have a large impact on the interior floorplan (see Figure 5). The photovoltaics will generate electricity to feed back into the Boylston Street High Rise electrical grid, in order to minimize the total electrical demand for this site and further reduce the building’s annual energy usage.

The completed optimized dual façade features daylight louvers that double as thermal horizontal blinds. The blinds are placed near the outer skin of the three foot façade and work by reflecting direct daylight to the ceiling which simultaneously restricts these harsh direct solar rays and converts them into diffuse daylight to illuminate the office space. See 6.2 Daylight & Occupancy Sensors (Electrical Narrative) for a detailed analysis of the reduction in demand for interior electrical lighting.

Shown in Figure 5, the combination louvre and horizontal blind system is integrated within a smart control system tracing the sun and tilting the panels when it is near the horizon to avoid glare issues. Most importantly, the horizontal blind system does not sacrifice the occupants’ views of outdoor environment but rather delivers a similar thermal effect when handling direct solar heat gains through the façade. As mentioned previously, the Boylston Street High Rise’s mechanical load is mostly

Figure 4 – Cumulative Annual Incident Solar Radiation.

Figure 5 – Double Skin Façade Diagram.

1. Solar radiation hits the exterior skin. 2. Horizontal blinds absorb solar radiation facilitating convective heat currents within air gap. 3. Horizontal blind operability also eliminates direct solar glare while advancing daylighting. 4. Horizontal blinds maintain views from interior to exterior.
MECHANICAL NARRATIVE

dominated by cooling mode. The solar gains that would typically help reduce the heating load in the winter months, will not benefit the energy demand in this application. See Double Skin Façade Analysis P1 (Mechanical Supporting Document C) for the cooling reduction load analysis based on solar gain.

The total amount of energy, in the form of heat, that enters through a typical window glazing will significantly elevate the mechanical equipment’s peak cooling load and total load at the end of each operating day; quantified as \( Q_{\text{Total}} \). Equation 1 below outlines the effects a façade encounters throughout its lifetime. As mentioned previously, the west and south façades on the Boylston High Rise receive the most direct solar radiation; therefore, implementation of a façade that minimizes the total amount of solar heat that will impact the interior space is key to optimizing the performance of the Boylston Street High Rise when operating in cooling mode.

**Equation 1:**

\[
Q_{\text{Total}} = Q_{\text{Solar}} + Q_{\text{Radiation}} + Q_{\text{Convection}}
\]

+ \( Q_{\text{Total}} \) is the total heat entering the indoor space through glazing.
+ \( Q_{\text{Solar}} \) is the solar heat entering the indoor space through glazing.
+ \( Q_{\text{Radiation}} \) is the heat entering the indoor space by thermal radiation through the glazing internal surface.
+ \( Q_{\text{Convection}} \) is the heat entering the indoor space by thermal convection through the glazing internal surface.

Mechanically speaking, the implementation of horizontal blinds in a typical building application creates a barrier to instantaneous solar heat gain into the interior of the building. These instantaneous gains in the form of convective gains. When solar rays intrude into the interior of the building and strike a horizontal blind hung on the inside of the window eave, the heat gain is still introducing itself to the space, this time-lag associated with heat transfer translating itself from the blind holding the heat, in its thermal mass, to the space absorbing the load; this is characterized as a conductive gain. When the space absorbs this conducted heat load, it will be returned to the air handling unit within fifteen minutes of it being released from the blind itself and will contribute to a large delta T between supply air temperature and return air temperature, decreasing efficiency. With this consideration as a driving factor, the Boylston Street High Rise features the application of horizontal blinds that follow the design shown in Figure 6 below, and are placed outside of the building construction within the double skin façade; virtually eliminating that described conductive heat transfer intruding into that façade.

Although there are many applications of a double skin façade that have been utilized throughout the world, Genesis Design has created the opportunity to capture the benefits of natural ventilation by splitting the double skin façade cavity into segments that only span the floor to ceiling height length. As you can see in Figure 6 below, the exterior mechanical grilles allow wind to flow into the cavity and follow a path into the interior façade pane which feature 28.5 square feet of operable double hung windows per pane which exceeds the opening area in reference to 25% of the zonal office square footage. The exterior mechanical dampers are aligned with the height of the interior raised access floor for ventilation purposes, and to complete the fluid architectural aesthetic Genesis Design strived to achieve. See Figure 6 below for Dual Façade component view.

Figure 6 – DSF Exploded Component View.
MECHANICAL NARRATIVE

The double skin façade requires complex controls in order to perform, in the manner it is expected, to reduce energy costs. The controls will operate to provide functions in three different modes throughout the year depending on the Boston weather conditions. These façade controls will be combined with the lighting controls referenced on Controls Narrative (Electrical Supporting Document F) and managed by the BMS system, Building Management System (Electrical Integration Drawing E-05).

During the winter, the façade will act as a thermal barrier between the outdoor and indoor air. Controls that tie into the functions of the horizontal blinds will become another entity of the Boylston Street High Rise building management system. Each cavity damper of the façade will close, sealing itself off from cold outside air. The three foot air gap between the two curtain walls will begin to heat through solar collection and the horizontal blinds between the walls will act as a thermal storage mass, to effectively aid in the heating process. It is important to recognize that one of the main issues with Double Skin Façade construction is that the peak cavity air temperature can negatively affect the interior environment of the building. It is calculated that during the heating season, the cavity can reach a maximum temperature of 27˚F with temperatures averaging around 18˚F. Although there is not a concern for overheating during the heating season temperature sensors connected to the building’s automated system will be placed in the cavity, and control schematics will instruct the louvres at the bottom of each façade component to open when the cavity temperature exceeds 70˚F, allowing natural buoyancy to drive the heated air upward and out of the cavity. The buoyance-driven air flow rate through each single story cavity is about 1,802 cfm and will not require mechanically-driven ventilation. Figure 7 below illustrates the process of heat collection within the closed cavity of the façade during the winter months.

The summer mode follows a control scheme similar to that in winter, however instead of collecting solar heat with the façade, natural buoyancy and wind velocity will propel the hot air out of the top damper to the outdoor environment at about 12,500 cubic feet per minute.

Though this system will not eliminate the total conductive heat gain in the summer, the double skin has been proven to significantly reduce the building envelope load by at least 44% compared to a non-shaded curtain wall. Figure 8 below illustrates the process of heat escaping through the open cavity of the façade during summer months, which is calculated to reach temperature peaks of 111˚F. See Double Skin Façade Analysis P2 (Mechanical Supporting Document D) for buoyancy-driven air flow and cavity temperature calculations.

During absolutely ideal outside weather conditions, most frequently occurring during spring and fall, the double skin façade will open and allow outdoor air to propagate into the office spaces through operable windows. The optimal days for natural ventilation include conditions where outside air temperatures lie between 50 and 65
degrees Fahrenheit and below 65% relative humidity. When the controls are activated by these conditions, each of the typical office spaces will become slightly negatively pressurized, consequently directing the outdoor air from the façade which will draft into the building, essentially allowing the direct outside air and supply air ventilation to cease, while still providing the space with natural ventilation and thermal comfort. Figure 9 below illustrates the process of the natural ventilation mode during the mid-season months. This system will reduce ventilation and condition loads by 13.4% on average annually, provided that return fans will be engaged, exhausting the room air to create the sweep of outside air into the building.

Through the implementation of the optimized dual façade, reductions in energy demand have been met with the assistance of the horizontal blind shading system capturing the solar heat gains from intruding into the building. The creation of a large air barrier employed in the façade, greatly reduces thermal exchange between the indoor and outdoor climate. As stated above, when the façade cavity is sealed in the heating season, the difference in temperature between the average outdoor air and peak cavity temperature can reach 52°F.

The Genesis Design Double Skin Façade has reduced the ASHRAE baseline building mechanical load by 45%. See Double Skin Façade Analysis P1 (Mechanical Supporting Document C) for the results of the completed study featuring the performance of the Double Skin Façade which has fallen within the range of the manufacturer’s published performance data.

### 6.1.2 NORTH AND EAST FAÇADE

The east and north façades receive significantly less solar radiation due to adjacent building blockage and the sun’s angular path. In order to optimize the final two façades, Genesis Design has selected a curtain wall construction consisting of clear / VNE1-63 Vision Glass and a spandrel component made up of two types of glass, clear / VNE1-63 and V903 with an insulation backing panel. The summer u-value of the Vision Glass is 0.20, and winter u-value is 0.24. These thermal properties correspond to the climate zone 5A, ASHRAE 90.1, v2010 fenestration assembly max u-value of 0.35 and below (for nonmetal framing with 40% vertical glazing or less outlined on Table 5.5-S). The percentages of glass and window construction pertaining to the east and north façades for the baseline building and new construction are outlined in Table 2a, Table 2b, and Table 2c below. These values are calculated from the architectural Revit model provided by Fx Fowle. See Building Façade Design (Electrical Drawing E-04) for glass type specifications and performance.

#### Table 2a: North and East Façade Baseline Building

<table>
<thead>
<tr>
<th></th>
<th>% glass:</th>
<th>% wall:</th>
</tr>
</thead>
<tbody>
<tr>
<td>North Façade</td>
<td>96</td>
<td>4</td>
</tr>
<tr>
<td>East Façade</td>
<td>71</td>
<td>29</td>
</tr>
</tbody>
</table>

#### Table 2b: North and East Façade New Construction

<table>
<thead>
<tr>
<th></th>
<th>% glass:</th>
<th>% wall:</th>
</tr>
</thead>
<tbody>
<tr>
<td>North Façade</td>
<td>33</td>
<td>67</td>
</tr>
<tr>
<td>East Façade</td>
<td>40</td>
<td>60</td>
</tr>
</tbody>
</table>

#### Table 2c: North and East Façade Glass Reduction

<table>
<thead>
<tr>
<th></th>
<th>% glass:</th>
<th>% wall:</th>
</tr>
</thead>
<tbody>
<tr>
<td>North Façade</td>
<td>-63</td>
<td>+63</td>
</tr>
<tr>
<td>East Façade</td>
<td>-31</td>
<td>+31</td>
</tr>
</tbody>
</table>

### 6.2 ROOF DESIGN

Two levels within the roof construction includes the mechanical mezzanine and the mechanical penthouse which occupy a large area of the exposed roof. Although thermal resistance of the roof controls a large portion of the amount of heat transfer between the indoor and outdoor environment, a large majority of the conditioned spaces are not exposed to the roof area. Boston, Massachusetts is situated in climate zone 5A. ASHRAE Standard 90.1, v2007 outlines a minimum roof R-value of R-20. By following ASHRAE Standard 90.1, v2010 recommends a minimum R-30 construction. To increase
the roof’s construction to R-30 energy reduction cost savings will only be 1% resulting in $3,518 annually. This clearly would not be beneficial to the payback period of the design based on very high first costs of construction and materials.

6.3 UNDERFLOOR AIR DISTRIBUTION

The mechanical design team investigated different alternatives of air delivery to introduce supply air into each of the typical office floors. The goal when selecting an air distribution system for the office area has been to produce a flexible and adaptable design with underfloor air distribution. See 8.2.2 Resiliency for Typical Tenant Office (Mechanical Narrative) for system flexibility features.

The second feature of underfloor air distribution is that the same principle of warm air rising from hot electrical gear could be applied to warm air around occupants. Traditional overhead systems are designed specifically to mix the air in the space and prevent stratification in the room. The client would not be as satisfied with the traditional system without implementing an increasingly complex overhead system in order to deliver specific thermal comfort and personal ventilation to each individual occupant within the space. In addition, overhead systems require more fan energy to overcome static losses of generating the mixing patterns required within the space which would negatively impact the budget of the building.

By implementing this underfloor system, air will be supplied at low pressure and the energy for space conditioning will be reduced by 9%. The ventilation air can be provided in the zone where it is needed most, with pollutants being moved gently toward the ceiling return, improving indoor air quality. On each of the office floors, adjustable diffusers will be placed one per workstation and will discharge air to small areas in the space shown in Figure 10. These diffusers will be adjustable by the occupant and can result in an improvement in personal thermal comfort. This results in a system that can be more energy efficient, comfortable while at the same time provide better ventilation.

Figure 10 – Titus UFAD Adjustable Round Diffuser.

With the implementation of underfloor air distribution, the supply air temperature delivered to each of the occupants has increased from 55°F to 62°F because the air is being supplied directly to the occupants work spaces at lower velocities. This reduces the load placed on the direct outdoor air system handling ventilation as well as latent loads. With resiliency driving Genesis’s Design principles, this type of system provides the occupant with a very modifiable HVAC system, as previously explained. Workstation diffuser layouts are very malleable with underfloor air distribution because of the ease of interchangeable floor panels for diffusers. Each workstation will be customized to the tenant’s layout and will receive one diffuser per workstation that will be controlled manually by the occupant. This will allow the diffuser to be opened from a range of 0% to 100%, adjusting the amount of airflow on them instantaneously and over a longer period of time.

The space between the access floor and the structural floor is the floor plenum. Using this sixteen-inch tall space as an air distribution plenum requires special considerations which include assuring floor panel seams are constructed with a tight seal to prevent air leakage from the plenum into the office space. Figure 11 below illustrates the construction of the office interior.
7.0 RESOURCE PRODUCTION

The Mechanical Design team’s second strategy to meet the 50% reduction requirement of the ASHRAE 90.1, v2007 baseline building is to investigate resource production.

7.1 PHOTOVOLTAIC ELECTRICITY

Genesis Design has created a solution to utilize vertically-oriented PV panels, as seen in Figure 12. At two rows per floor, the array will span from the eighth floor level to the roof. This design allows for 21 rows of PV panels, totaling 756 (wattage) panels on the south façade and 462 on the west, effectively reducing the building’s total annual energy by 6.11%. Although it is known that vertical PV panels produce around 65% of energy produced by 35° fixed-tilt (optimal for Boston) panels, this orientation allows more than one thousand panels to exist without obstructing usable daylighting. See 5.0 Façade Design (Electrical Narrative) for further related photovoltaic panel design information.

7.2 RAINWATER COLLECTION

In order to supplement grey water demand, a rainwater collection system has been designed to capture and store water for future use. Water will be collected from both the plaza and rooftop and will drain into a storage tank located on the Green Level Floor Plan. See Rainwater Collection (Mechanical Drawing M-07) for calculations and charts. The collected water will be used to supply water closets with greywater, thereby reducing the dependence from the Boston water treatment plant by 72.8% on average per year. Not only will this reduce the water demand, but will also result in zero excess runoff to neighboring locations as well as mitigate the impact of the Boylston High Rise on adjacent structures, transportation areas and the public plaza. The rain water basin and associated mechanical equipment will be stored in room GL 15.

7.3 GEOTHERMAL CAISSONS

Geothermal systems utilize a series of pipes that run underground and dissipate or collect heat from the earth depending on the time of year. Boston has notoriously poor soil qualities, which would make geothermal systems undesirable in a location similar to this site under normal conditions. However, the Mechanical Design team has found it would be beneficial to integrate the geothermal piping into the foundation’s caissons, essentially providing the same desired heat extraction properties, without having to deal with unstable soil conditions. See Foundation Design and Progressive Collapse Analysis (Structural Supporting Document H) for further related structural bearing caisson information. These geothermal wells are coupled with hybrid heat pumps in the retail spaces of the building, in order to deal with the sensible and latent loads associated with each retail demographic. Because the geothermal heat exchange process will not supply enough cooling for the designated space load, a future connection to cooling tower system supply the retail area’s unsatisfied space and support occupant load not met by the geothermal system if they exceed the base load predicted for that space. This type of system allows individual control and metering of the retail spaces, so tenants can control their thermal comfort and be charged solely based on their energy usage. The geothermal ground source heat pump selection reduced energy consumption by 10.09 million kBTU/year, resulting in a 8% load reduction on the
MECHANICAL NARRATIVE

ASHRAE 90.1, v2007 baseline building. Figure 13 below illustrates the cohesion of the closed loop system within the caissons in order to create a solid structural platform for the Boylston Street High Rise.

Figure 13 – Geothermal Caissons Diagram

7.4 WIND

Boston, Massachusetts is a location with relatively high average wind velocities. Wind harvesting in cities is very complicated and notoriously known not to be cost effective. However, Genesis Design has designed an application for wind turbines to be constructed in the form of trees located at the plaza entrance, see Figure 14. The turbine trees have been designed to power outdoor receptacles and phone charging stations during the warmer seasons. In the colder seasons, when the plaza is not utilized, the power produced will flow back into the building’s grid. The wind-driven trees will remind occupants of the owner’s goals to be innovative and provide a reminder of the building’s efficient characteristics. A wind-driven tree was selected with the intention of getting the public involved with this energy-efficient building, to positively brand the Boylston High Rise and produce useful energy with the goal of decreasing the load on the electrical grid.

Figure 14 – Wind-driven Turbine Trees on Public Plaza.

Embedded within the central planter is a CO2 absorbing device. The premise behind the device is to absorb the equivalent amount of CO2 emitted by vehicles passing and parking in front of the building. Public Plaza (Integration Drawing I-10) summarizes calculations on how this will be accomplished. In summary, the device will absorb over 20 pounds of CO2 a day and will supply the clean air to the center of the public plaza.

8.0 MECHANICAL DESIGN

To ensure the most sustainable design possible, a large variety of mechanical systems implemented throughout the Boylston High Rise have been considered for each space. A number have been dismissed since they were deemed ineffective for a certain type of space. A detailed outline of the HVAC systems that have been considered, and ensuing decision process is in the Mechanical Decision Matrix (Supporting Document H).

8.1 LOBBY AND RETAIL

The first three stories of the Boylston Street High Rise consist of retail space for vendors, and a large lobby and atrium area for the offices above. Many different high-end retail companies will occupy and showcase a wide array of products, driving the decision of the mechanical design team to select a system that is individualized per space. Each retail space can be easily metered which allows the property owner to charge per tenant for utility usage. Mechanical closets in each of the retail areas will be used for hybrid ground source heat pumps (GSHP) which will be selected and sized for the specific retail occupant. An outdoor air duct connection will be provided to the top of each GSHP. The Boylston High Rise retail spaces are predicted to operate between the hours of 10am to 9pm (Monday through Saturday) and 11am to 8pm on Sunday, based on the existing operating hours of The Shops at Prudential Center. During unoccupied hours, the controls will follow a schedule that will supply only the amount of outdoor air necessary based on the square footage; reducing the volume supplied for the occupants.

The geothermal caissons reject and extract 10,094,137 kBTU/year of energy into the earth through a system of 52 vertical runs that intrude 150 feet into the earth. The natural heat exchange process will be evenly distributed to the retail spaces via water source heat pump connections and supplementary cooling will be provided
by a central chiller with heating via a dedicated natural gas fired boiler. Provided direct outdoor air system connections will supplement this system in order to meet ventilations loads. The closed loop geothermal system is being utilized in the retail area because future tenants will find the utility savings appealing and because this area is predicted to have the longest operating hours, resulting in the system having a greater impact on reducing the buildings EUI.

Boylston’s geothermal exchange consists of a reversible vapor compression cycle that is coupled with a heat exchanger in the form of bore holes in the ground utilizing a water-to-air heat pump. The water-to-air configuration circulates a water and antifreeze solution through a liquid-to-refrigerant heat exchanger and a series of buried thermoplastic piping. The vertical wells that are enclosed in the structural caissons consist of two small (3/4 in) diameter, high-density polyethylene tubes in a vertical borehole filled with grout.

The stack effect for both winter and summer must also be considered for these spaces. The Mechanical Design team has assigned two new rotating doors, one per each entrance doorway, to keep the space appropriately pressurized and reduce the number of air changes from the indoor to outdoor environments. The main fire escape stairwells that run up the building are to be positively pressurized as well, to reduce stack effect to a manageable pressure difference. Perimeter heating in the lobby will be required in order to compensate for the cold air infiltration into the building through operable doors in the winter months. A special consideration to point out is the implementation of an air locked vestibule leading into the lobby to decrease the volume of unconditioned air infiltration that penetrates the building from the outdoor environment.

### 8.1.1 PLUMBING DESIGN

Although the retail and lobby area is not fully developed in the project description, it is a requirement by the International Building Code for this type of public area to have a restroom on the floorplan upon project completion. The planned main plumbing design element of the lobby space is proposed to provide sanitary connections suitable for each retail space. Table 2902.1 of Chapter 29, outlines the number of minimum plumbing facilities for certain space classifications. Number 6, Occupancy M requires one water closet per each set of 500 male and female combinations.

### 8.1.2 RESILIENCE & LIFE SAFETY

Endurance and operation during a natural disaster were the design foci when selecting mechanical systems for the lobby and retail space. Controlling and accounting for 12 elevators, and the heat gain dissipated into the space, is integral to ensuring the safety of the occupants. KONE MonoSpace elevators have a motor size of 15 horsepower in comparison to a typical 40hp existing hydraulic elevator. These elevators are estimated to have a load percentage of 75%, while continuously operating approximately 30% of time. The required volume of air to keep the space temperature at 85°F is approximately 3,200 cfm removing a 103,100 BTUH heat load from the top landing of the elevator hoist way. See section 6.0 Power Reduction (Electrical Narrative) for elevator power supply connections and resiliency measures.

### 8.2 TYPICAL TENANT OFFICE

Starting with the fourth floor, the office spaces occupy 14 of the 17 stories within the Boylston High Rise. Genesis Design has taken this into consideration and made it a major focus point for an energy efficient space. After analyzing neighboring high-rise office buildings along Boylston Street, which showcased many of the same amenities with the same caliber owner, they clearly illustrated that the mechanical design implemented into the office spaces would have to be flexible and resilient enough to suit one tenant per floor while allowing for a customized layout of office spaces on each respective floor operating on a typical 7am to 6pm work week schedule. As stated in section 6.3 Underfloor Air Distribution (Mechanical Narrative), the air supplying the space will be directed into a 16 inch high raised access floor that is a space-zoned pressurized plenum served from the mechanical penthouse level, housing the air handling units for all of the addressed spaces. See Mechanical Penthouse and Roof Layout (Mechanical Drawing M-05) for all air handling unit placement and coordination within the mechanical penthouse and mechanical mezzanine.
MECHANICAL NARRATIVE

On the north and east façade edges, perimeter heating will be implemented into the typical office floors in order for the infiltration effects of the curtain wall façade not to directly impact the thermal comfort of the occupant situated closest to the window. Demand Control Ventilation (DVC) will be implemented in the private offices and a 50-hour work week is coordinated into the HVAC controls schedule.

8.2.1 PLUMBING DESIGN
Low-flow water fixtures within the restrooms include sink faucets and toilets that release a lower volume of water per minute, thereby conserving water while using a high-pressure technique to provide the user with the same facility experience. The baseline building experienced a 1.6 gallon per flush capacity, which has been reduced to a 0.65 gallon flush capacity. This feature reduces toilet fixture water usage by 60%. Traditional faucets use approximately 2.5 gallons of water per minute and water usage can be reduced by 60% with a 1.5 gallons per minute fixture. Connections will be provided for breakroom sink and other utility customizations.

8.2.2 RESILIENCY & LIFE SAFETY
According to Carrier United Technologies, the greatest change in office enhancements has been the essential need for voice, data and power connections provided to every worker’s workstation. IFMA (International Facility Management Association) reported that on average an office worker experiences new office layout every 5.5 months resulting in a 44% move rate; often referred to as churn. The cost associated with a churn is one of the largest costs an owner or tenant may face. The advantage of access flooring is that cable and HVAC moves are greatly simplified and a system that reduces the number of moves of these systems could help reduce total system life cycle cost. The 16 in. tall plenum will be fire rated according to manufacturer’s recommendations upon installation.

8.3 PARKING GARAGE
Because of provisions concerning air changes per hour to expel car exhaust in an underground parking garage, an exhaust shaft will remain on the west-facing edge of the garage and will bring in outside air through side wall louvres on the east-facing edge. See Figure 15 below for both exhaust and intake shaft locations within the Green Mezzanine level.

Figure 15 – Parking Garage Exhaust Placement

When considering the design of buildings with attached parking garages, ASHRAE 62.1 outlines that one of the most important considerations is to limit the entry of vehicular exhaust into occupied spaces of the building by maintaining a slightly negative garage pressurization in reference to the indoor environment.

Outlined in Table 6-4 in ASHRAE 62.1, 2007 shows the required exhaust rate of 0.75 cfm/ft² for parking garages that are enclosed by two or more walls and less than 50% open to the outside. Section 501.2.1 of the 2009 International Mechanical Code outlines the location of exhaust outlets and is used to guide the design of the Boylston Street High Rise. This code also requires the exhaust fan to be capable of 1.5 cfm/ ft², although from an energy standpoint, the exhaust fan is modeled to run at the capacity for 0.75 cfm/ ft². The underground parking has a combined accessible area of approximately 67,700 square feet. NFPA requires a minimum of six air changes per hour within the parking structure.

8.3.1 PLUMBING DESIGN
Domestic and sanitary water main lines serve the building along the west edge of the Boylston High Rise within the Utility Pathway, GL 13.

8.3.2 RESILIENCY & LIFE SAFETY
The bathtub design refers to rooms on the bottom two levels of the building (Green Level and Green Mezzanine) which may be subject to water infiltration in the event of a severe storm or flooding. Mechanical equipment housed within these rooms on the floors which are susceptible to water damage will be protected from the

AEI TEAM 02-2016 MECHANICAL SUBMITTAL PAGE 87
8.4 KITCHEN AND FOOD COURT

The scope outlined in the client’s needs for this phase of the project includes a basic design for the ventilation of a food court area. This area will be served by a variable air volume system with a kitchen make-up air unit pad space configured within the mechanical room to serve up to 80% of the total required air volume required within the space. The exhaust shaft for the hood exhaust will remain as is for future fit out. Both the kitchen and food court area will have separate supply outdoor air units. The next phase of the project is planned to be kitchen space completion. When completing this design, transfer air between the food court and kitchen spaces shall follow the design recommendation of below 50 feet per minute in order to ensure the food stays hot until served to patrons. The kitchen area shall be a more negatively pressurized space in comparison to the food court, which was designed as a public area with dining stations rather than a restaurant, adjusting to the broad project description. All design guidelines are in reference to ASHRAE Applications, Chapter 31 and ASHRAE Fundamentals, Chapter 30.

8.4.1 PLUMBING DESIGN

Future connections will be provided for planned sink and self-cleaning exhaust hood, domestic water and dishwasher, food grinder and sanitary water to be furnished upon kitchen fit out completion.

8.4.2 RESILIENCY & LIFE SAFETY

The food court entrance area is a three-story open concept. Smoke is exhausted through the fourth floor onto the Food Hall entrance roof. The fire safety smoke exhaust fan is sized to be at 158,800 cubic feet per minute designed to keep the smoke at least 10 feet above the highest occupied surface for 1200 second (20 minute) analysis at 50 feet. The smoke control systems follows Section 513 of the 2009 International Mechanical Code.

9.0 MEP STARTUP

When in the process of finishing construction and phasing into the starting up mechanical equipment, it is important not to restrict the use of air handling units which have not been outfitted with filters, while limiting the migration of construction contaminates into occupied spaces within the building. ASHRAE 62.1 defines HVAC system start-up by the testing or inspecting for cleanliness, functional operation and balancing of all HVAC systems. The owner shall be provided with a mechanical system balancing report, as-built construction drawings and all design criteria assumed by the mechanical design team.

10.0 LEED RATING

Genesis Design’s Boylston Street High Rise is fit to receive 84 points which will gain the title of a LEED Platinum rated design. For a detailed point breakdown specifically contributed to by the mechanical design team, see LEED Analysis (Mechanical Supporting Document I).

11.0 CONCLUSION

In conclusion, the main focus within Genesis Design was to ensure the integration between every facet of the architectural, structural and electrical detail is meshed with the mechanical systems into one cohesive enclosure, while developing detailed mechanical systems implemented into the Boylston High Rise. With the assistance and expertise of each project discipline, the mechanical design team developed descriptive analyses of main mechanical spaces (e.g. the mechanical mezzanine and mechanical penthouse), Photovoltaic Integrated Double Skin Façade, rainwater collection system and the closed loop geothermal caisson construction which illustrated the mechanical coordination and feasibility solutions within the Boylston Street High Rise. The competition of this design project showcased the performance of the outlined building optimizing solutions and resulted in an overall building reduction of 54% in reference to ASHRAE Standard 90.1, v2007.
ASHRAE 90.1, V2007 BASELINE REDUCTION

Mechanical team’s specific goals are to reduce the ASHRAE Baseline building by a minimum of 50% in energy consumption.

ASHRAE 90.1, V2007 BASELINE

ENERGY CONSUMPTION SUMMARY
By ACADEMIC

<table>
<thead>
<tr>
<th>Energy Type</th>
<th>Elect</th>
<th>Gas</th>
<th>Water</th>
<th>% of Total</th>
<th>Total Building Energy</th>
<th>Total Source Energy</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>kWh</td>
<td>MWh</td>
<td>(100)</td>
<td></td>
<td>(Mbtu/yr)</td>
<td>(Mbtu/yr)</td>
</tr>
<tr>
<td>ASHRAE BASELINE</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Primary heating</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Energy Cooling</td>
<td>51.6%</td>
<td>20,306,060</td>
<td>23,577,107</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other HVAC Accessories</td>
<td>1.7%</td>
<td>733,020</td>
<td>2,158,213</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Heating Subcool</td>
<td>13.3%</td>
<td>23,131,280</td>
<td>27,778,036</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Primary cooling</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cooling Compressor</td>
<td>4.6%</td>
<td>1,975,205</td>
<td>5,368,205</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Free Cooling Fans</td>
<td>4.4%</td>
<td>1,896,702</td>
<td>5,058,904</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Condenser or Heat Pump</td>
<td>0.6%</td>
<td>251,852</td>
<td>755,915</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other HVAC Accessories</td>
<td>0.6%</td>
<td>16,686</td>
<td>58,686</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cooling Subcool</td>
<td>9.8%</td>
<td>4,138,745</td>
<td>12,428,475</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Auxiliary</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Supply Fans</td>
<td>0.4%</td>
<td>3,627,119</td>
<td>10,802,445</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pumps</td>
<td>0.6%</td>
<td>250,615</td>
<td>701,815</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stand alone Bose 1.5MWh</td>
<td>0.0%</td>
<td>0</td>
<td>0</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Aux Subcool</td>
<td>0.9%</td>
<td>3,027,732</td>
<td>11,634,260</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lighting</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lighting</td>
<td>17.9%</td>
<td>2,198,450</td>
<td>31,359,866</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Receptacle</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nonreceptacle</td>
<td>10.5%</td>
<td>4,891,003</td>
<td>23,451,917</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cogeneration</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cogeneration</td>
<td>0.0%</td>
<td>0</td>
<td>0</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>100.0%</td>
<td>43,421,565</td>
<td>88,653,317</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

BASELINE REDUCTION STRATEGIES

DEMAND REDUCTION AND RESOURCE PRODUCTION WERE THE TWO MAIN FOCUSES THE MECHANICAL DESIGN TEAM USED IN ORDER TO ACHIEVE A 50% REDUCTION OF THE ASHRAE BASELINE. DEMAND REDUCTION STRATEGIES INCLUDE FACADE IMPROVEMENTS, ELECTRIC LOAD REDUCTION, A HYBRID NATURAL VENTILATION SCHEME, AND EFFICIENT SYSTEM SELECTION. RESOURCE PRODUCTION STRATEGIES INCLUDE PHOTOVOLTAIC ELECTRICITY, HEAT EXTRACTION AND REJECTION VIA GEOTHERMAL CAISSONS, AND SLIGHT WIND PRODUCTION. THROUGH THESE DESIGN STRATEGIES, THE MECHANICAL DESIGN TEAM ACHIEVED AN OVERALL ASHRAE BASELINE BUILDING REDUCTION OF 53%.

GENESIS DESIGN

ENERGY CONSUMPTION SUMMARY
By ACADEMIC

<table>
<thead>
<tr>
<th>Energy Type</th>
<th>Elect</th>
<th>Gas</th>
<th>Water</th>
<th>% of Total</th>
<th>Total Building Energy</th>
<th>Total Source Energy</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>kWh</td>
<td>MWh</td>
<td>(100)</td>
<td></td>
<td>(Mbtu/yr)</td>
<td>(Mbtu/yr)</td>
</tr>
<tr>
<td>MECHANICAL DESIGN</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Primary heating</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Energy Cooling</td>
<td>11.0%</td>
<td>1,474,420</td>
<td>4,065,200</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other HVAC Accessories</td>
<td>0.5%</td>
<td>537,430</td>
<td>320,938</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Heating Subcool</td>
<td>12.7%</td>
<td>1,091,850</td>
<td>2,318,800</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Primary cooling</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cooling Compressor</td>
<td>11.0%</td>
<td>1,528,030</td>
<td>4,614,176</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Free Cooling Fans</td>
<td>2.1%</td>
<td>356,317</td>
<td>864,774</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Condenser or Heat Pump</td>
<td>1.8%</td>
<td>40,025</td>
<td>144,894</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other HVAC Accessories</td>
<td>0.3%</td>
<td>76,356</td>
<td>100,589</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cooling Subcool</td>
<td>13.6%</td>
<td>1,923,330</td>
<td>4,773,908</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Auxiliary</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Supply Fans</td>
<td>0.1%</td>
<td>882,400</td>
<td>2,552,822</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pumps</td>
<td>0.5%</td>
<td>36,089</td>
<td>115,779</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stand alone Bose 1.5MWh</td>
<td>0.0%</td>
<td>0</td>
<td>0</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Aux Subcool</td>
<td>0.4%</td>
<td>801,049</td>
<td>2,673,841</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lighting</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lighting</td>
<td>33.6%</td>
<td>1,014,782</td>
<td>16,861,842</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Receptacle</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nonreceptacle</td>
<td>27.0%</td>
<td>9,325,459</td>
<td>11,773,308</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cogeneration</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cogeneration</td>
<td>0.0%</td>
<td>0</td>
<td>0</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>100.0%</td>
<td>4,043,540</td>
<td>8,810,935</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Monthly HVAC Energy
REDUCE ENERGY AND WATER USE

Mechanical Team's specific goals are to reduce the ASHRAE 90.1 V2007 Baseline by a minimum of 50% and achieve zero storm water runoff from the site.

<table>
<thead>
<tr>
<th></th>
<th>BASELINE BUILDING</th>
<th>DESIGN</th>
<th>PERCENT REDUCTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>ENERGY (kBTU/yr)</td>
<td>125,138,558</td>
<td>57,651,716</td>
<td>54%</td>
</tr>
<tr>
<td>GREY WATER DEMAND (Gal/yr)</td>
<td>3,360,000</td>
<td>371,342</td>
<td>89%</td>
</tr>
</tbody>
</table>

***GREY WATER DEMAND REDUCTION INCLUDES NEW WATER CLOSET SELECTION, AND COLLECTION AND STORAGE OF ALL STORM WATER OVER THE COURSE OF A YEAR TO ACHIEVE ZERO RUNOFF FROM THE SITE.

SYSTEM SCHEMATIC:

THE DIAGRAM TO THE LEFT REPRESENTS A SIMPLISTIC SCHEMATIC OF THE IMPLEMENTED SYSTEMS. HEAT IS EXCHANGED TO THE HOT WATER LOOP THROUGH THE USE OF A GAS FIRED BOILER. THIS LOOP CONNECTS TO THE HOT WATER COILS OF EACH AHU IN THE BUILDING. HEAT IS EXTRACTED FROM THE CHILLED WATER LOOP THROUGH THE USE OF A CENTRIFUGAL CHILLER. THIS LOOP CONNECTS TO THE CHILLED WATER COILS OF EACH AHU IN THE BUILDING. A GROUND SOURCE HEAT PUMP SYSTEM HAS BEEN DESIGNED TO CONDITION ALL RETAIL SPACES. HEAT IS TO BE EXTRACTED AND REJECTED FROM THIS SYSTEM THROUGH THE USE OF GEOTHERMAL CAISSONS.
SOUTH AND WEST FAÇADE OPTIMIZATION

MECHANICAL TEAM’S SPECIFIC GOALS ARE TO REDUCE THE AMOUNT OF SOLAR HEAT, RADIATION, AND CONVECTIVE HEAT GAIN WITHOUT HINDERING NATURAL VENTILATION ON THE SOUTH AND WEST FACADES. THERE ARE MANY CONSIDERATIONS WHEN IMPLEMENTING A DOUBLE SKIN FAÇADE CONSTRUCTION INCLUDING THE TOTAL SAVINGS OF MECHANICAL ENERGY, OVERHEATING PREVENTION, AND CONTROLS. PAGE 1 OF THIS DOCUMENT SUMMARIZES THE RESULTS OF GENESIS DESIGN’S DOUBLE SKIN FAÇADE THERMAL PERFORMANCE IN COMPARISON TO WAREMA’S MANUFACTURED EXTERNAL VENETIAN BLIND TECHNICAL PERFORMANCE PUBLISHED DATA.

BUILDING ENVELOPE REDUCTION RESULTS FROM TRACE 700 SIMULATION

<table>
<thead>
<tr>
<th>WALL</th>
<th>WINDOW</th>
<th>TOTAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>SOUTH FAÇADE</td>
<td>159</td>
<td>34126</td>
</tr>
<tr>
<td>WEST FAÇADE</td>
<td>166</td>
<td>24356</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>WALL</th>
<th>WINDOW</th>
<th>TOTAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>SOUTH FAÇADE</td>
<td>123</td>
<td>48681</td>
</tr>
<tr>
<td>WEST FAÇADE</td>
<td>0</td>
<td>50434</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>WALL</th>
<th>WINDOW</th>
<th>TOTAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>SOUTH FAÇADE</td>
<td>-1313</td>
<td>0</td>
</tr>
<tr>
<td>WEST FAÇADE</td>
<td>-1009</td>
<td>0</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>WALL</th>
<th>WINDOW</th>
<th>TOTAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>SOUTH FAÇADE</td>
<td>-401</td>
<td>0</td>
</tr>
<tr>
<td>WEST FAÇADE</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

IN CONCLUSION, GENESIS DESIGN HAS COMPLETED THE ENERGY PERFORMANCE STUDY BECAUSE THE SIMULATED PERFORMANCE RESULTS AVERAGE TO A 44% SOLAR HEAT GAIN REDUCTION IN RELATION TO THE FX FOWLE BASELINE BUILDING.

THE RESULTS CONCLUDE THAT THE SOUTH FACING DOUBLE SKIN FAÇADE HAS REDUCED THE COOLING PEAK LOAD ON THE COIL BY 62% IN THE COOLING SEASON AND BY 37% IN THE HEATING SEASON. THE WEST FACING DOUBLE SKIN FAÇADE CONSTRUCTION HAS REDUCED THE COOLING PEAK LOAD BY 45% IN THE COOLING SEASON AND BY 33% IN THE HEATING SEASON.

WAREMA EXTERNAL VENETIAN BLIND TECHNICAL DATA

Function
Sticks with a selective coating only reflect the visible light into the room. The ultraviolet and infrared radiations are absorbed by the slat and reflected as heat radiation. These long-wave rays are not reflected into the interior.

Comparative Test
When comparing the physical radiation characteristics of external Venetian blinds in white aluminum color with external Venetian blinds with selective coating, the result is that the selective coating guides about 30% more daylight and about 50% less heat into the building.
SOUTH AND WEST FAÇADE OPTIMIZATION

MECHANICAL TEAM’S SPECIFIC GOALS ARE TO REDUCE THE AMOUNT OF SOLAR HEAT, RADIATION, AND CONVECTIVE HEAT GAIN WITHOUT HINDERING NATURAL VENTILATION ON THE SOUTH AND WEST FACADES. THERE ARE MANY CONSIDERATIONS WHEN IMPLEMENTING A DOUBLE SKIN FAÇADE CONSTRUCTION INCLUDING THE TOTAL SAVINGS OF MECHANICAL ENERGY, OVERHEATING PREVENTION, AND CONTROLS. PAGE 2 OF THIS DOCUMENT SUMMARIZES THE FINDINGS FROM A CALCULATION BASED METHOD PUBLISHED TO COMBINE THE RESULTS OF THE GENESIS DESIGN ENVELOPE LOAD AND COMPUTATIONAL FLUID DYNAMICS.

EQUATION 1: BOUYANCY-DRIVEN AIR FLOW RATE THROUGH SINGLE STORY CAVITY
\[ V = \left(-6.2 \times \left(h/d\right)+647.5\right) \times \text{Opening} \times \sqrt{D_{\text{Average}}} \]  
SI: 3062 m³/hr
IP: 1802 cfm

EQUATION 2: PEAK CAVITY AIR TEMPERATURE
\[ T_{\text{PeakCavityAir}} = 2.43 \times (T_{\text{AverageCavityAir}})^{0.78} \]  
SI: 44°C
IP: 111°F

EQUATION 3: AVERAGE CAVITY AIR TEMPERATURE
\[ T_{\text{AverageCavityAir}} = 1.05 \times T_{\text{ZoneAir}} - 2.97 \]  
SI: 41°C
IP: 105°F

EQUATION 4: PEAK CAVITY AIR TEMPERATURE
\[ T_{\text{PeakCavityAir}} = 2.43 \times (T_{\text{AverageCavityAir}})^{0.78} \]  
SI: 44°C
IP: 111°F

EQUATION 5: TEMPERATURE DIFFERENCE (PEAK CAVITY - OUTDOOR AIR TEMPERATURE)
\[ \Delta T_{\text{Real}} = 1.87 \times (T_{\text{PeakCavityAir}} - T_{\text{AverageCavityAir}}) \]  
SI: 15°C
IP: 50°F

EQUATION 6: TEMPERATURE DIFFERENCE (PEAK CAVITY - OUTDOOR AIR TEMPERATURE)
\[ \Delta T_{\text{Real}} = 1.87 \times (T_{\text{PeakCavityAir}} - T_{\text{AverageCavityAir}}) \]  
SI: 11°C
IP: 52°F

EQUATION 7: CAVITY PRESSURE
\[ \Delta P_{\text{Real}} = 28.44 \times \Delta T_{\text{real}} + 1.15 \]  
SI: 0 PASCALS

COOLING 0.4%

CUMULATIVE ANNUAL SOLAR RADIATION ON THE BOYLSTON FAÇADE SURFACE

HEATING 99.6%

WHEN THE FAÇADE CAVITY IS SEALED, THE DIFFERENCE IN TEMPERATURE BETWEEN THE AVERAGE OUTDOOR AIR AND PEAK CAVITY TEMPERATURE CAN REACH 52°F. THE DIFFERENCE IN TEMPERATURE CREATES AN EXCELLENT THERMAL BARRIER.

IF OPEN CAVITY REACHES T_{\text{MAX}} = 111°F, WIND AND NATURAL BOUYANCY DRIVE THE HOT AIR UPWARDS AND OUT AT 2132 CUBIC FEET PER MINUTE.

CALCULATIONS BASED ON PUBLISHED LITERATURE, “ENERGY SIMULATION OF A DOUBLE SKIN FAÇADE: A PROCESS USING CFD AND ENERGYPLUS” ALEXANDRA PAPPAS AND ZHIQIANG ZHAI.
SUPPORTING DOCUMENT E: NATURAL VENTILATION

CALCULATION PROCEDURE FOR DETERMINING NATURAL VENTILATION RATES

SUPPORTING DOCUMENT E SUMMARIZES THE WIND SPEED INTO THE DOUBLE SKIN FAÇADE AND THE EFFECT OF THE BUILDING'S INDOOR AIR QUALITY BASED ON BOSTON'S AIR HEALTH. THE FOLLOWING RESULTS SHOW THAT 41 CFM OF OUTDOOR AIR FLOW WILL BE ENTERING THE BUILDING ON AN AVERAGE WIND SPEED DAY. THE designing COMPONENTS VENTILATION AND WIND FANING THE BUILDING'S CORE WILL CREATE THE NEGATIVE SUCTION TO PULL OUTDOOR AIR THROUGH THE FAÇADE AND SATISFY THE 3 AIR CHANGES PER HOUR REQUIREMENT FOR VENTILATION. THE AIR TRAVELING THROUGH THE RETURN AIR SYSTEM WILL BE ONE HUNDRED PERCENT EXHAUSTED.

STEP 1: WIND, BUILDING, AND TERRAIN DATA

<table>
<thead>
<tr>
<th>VARIABLE</th>
<th>VALUE</th>
<th>DEFINITION</th>
</tr>
</thead>
<tbody>
<tr>
<td>h</td>
<td>14</td>
<td>MAST HEIGHT IN THE REFERENCE TERRAIN [FT]</td>
</tr>
<tr>
<td>Vrh</td>
<td>12</td>
<td>WIND SPEED IN THE REFERENCE TERRAIN AT HEIGHT [MPH]</td>
</tr>
<tr>
<td>ar</td>
<td>0.47</td>
<td>TERRAIN CONSTANTS OF THE REFERENCE TERRAIN (TABLE 1-1)</td>
</tr>
<tr>
<td>br</td>
<td>0.35</td>
<td>TERRAIN CONSTANTS OF THE BUILDING TERRAIN (TABLE 1-1)</td>
</tr>
<tr>
<td>ab</td>
<td>0.47</td>
<td>TERRAIN CONSTANTS OF THE REFERENCE TERRAIN (TABLE 1-1)</td>
</tr>
<tr>
<td>bb</td>
<td>0.35</td>
<td>TERRAIN CONSTANTS OF THE BUILDING TERRAIN (TABLE 1-1)</td>
</tr>
</tbody>
</table>

STEP 2: DETERMINATION OF REFERENCE VELOCITY

\[ V_{ref} = V_{bH} = \left(\frac{33}{h}\right)^{br} + \frac{H}{33^{bb}} + \frac{ab}{ar} \cdot V_{rh} \]

<table>
<thead>
<tr>
<th>VARIABLE</th>
<th>VALUE</th>
<th>DEFINITION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ai</td>
<td>7.125</td>
<td>AREA OF THE ITH WINDOW</td>
</tr>
<tr>
<td>XL</td>
<td>0.75</td>
<td>THE HORIZONTAL LOCATION OF EACH WINDOW ON THE WALL</td>
</tr>
<tr>
<td>XLH</td>
<td>0.75</td>
<td>THE VERTICAL LOCATION OF EACH WINDOW ON THE WALL</td>
</tr>
<tr>
<td>Ai</td>
<td>7.125</td>
<td>AREA OF THE ITH WINDOW</td>
</tr>
<tr>
<td>XL</td>
<td>0.75</td>
<td>THE HORIZONTAL LOCATION OF EACH WINDOW ON THE WALL</td>
</tr>
<tr>
<td>XLH</td>
<td>0.75</td>
<td>THE VERTICAL LOCATION OF EACH WINDOW ON THE WALL</td>
</tr>
</tbody>
</table>

STEP 3: DETERMINE Cp FOR EACH WINDOW ON HIGHRISE BUILDING

<table>
<thead>
<tr>
<th>VARIABLE</th>
<th>VALUE</th>
<th>DEFINITION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cp</td>
<td>1.64</td>
<td>PRESSURE COEFFICIENT</td>
</tr>
<tr>
<td>Ar</td>
<td>0.44</td>
<td>( \theta = \frac{A_r \cdot 3.1415}{210} ) (WIND ANGLE IN RADIANS)</td>
</tr>
<tr>
<td>Xr</td>
<td>0.5</td>
<td>( W = XL - 0.51/0.5 )</td>
</tr>
<tr>
<td>AS</td>
<td>25</td>
<td>ANGLE BETWEEN THE WIND DIRECTION AND THE OUTWARD NORMAL OF THE WALL UNDER CONSTRUCTION</td>
</tr>
<tr>
<td>S</td>
<td>1</td>
<td>THE RATIO OF THE WIDTH OF THE WALL UNDER CONSIDERATION TO THE WIDTH OF THE ADJACENT WALL</td>
</tr>
</tbody>
</table>

STEP 4: VENTILATION THROUGH MULTIPLE INLETS AND OUTLETS

<table>
<thead>
<tr>
<th>VARIABLE</th>
<th>VALUE</th>
<th>DEFINITION</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \Delta Q_i )</td>
<td>0.31</td>
<td>FLOW THROUGH THE ITH APERTURE (CFM)</td>
</tr>
<tr>
<td>Cdi</td>
<td>0.62</td>
<td>DISCHARGE COEFFICIENT FOR THE ITH APERTURE (0.62 RECOMMENDED VALUE)</td>
</tr>
<tr>
<td>Cpl</td>
<td>1.64</td>
<td>PRESSURE COEFFICIENT FOR THE ITH APERTURE</td>
</tr>
<tr>
<td>Cpl</td>
<td>-0.5</td>
<td>INTERNAL PRESSURE COEFFICIENT</td>
</tr>
<tr>
<td>Ae</td>
<td>28.5</td>
<td>SUM OF ALL WINDOW AREAS (FT)</td>
</tr>
</tbody>
</table>

STEP 5: APERTURE FLOW RATE CORRECTION

\[ Q_i = \frac{C_{PQ}}{1 + C_{Q}} \]

<table>
<thead>
<tr>
<th>VARIABLE</th>
<th>VALUE</th>
<th>DEFINITION</th>
</tr>
</thead>
<tbody>
<tr>
<td>C0</td>
<td>0.068</td>
<td>( C_0 )</td>
</tr>
<tr>
<td>C1</td>
<td>-0.839</td>
<td>( C_1 )</td>
</tr>
<tr>
<td>C2</td>
<td>1.733</td>
<td>( C_2 )</td>
</tr>
<tr>
<td>C3</td>
<td>-1.556</td>
<td>( C_3 )</td>
</tr>
<tr>
<td>C4</td>
<td>-0.922</td>
<td>( C_4 )</td>
</tr>
<tr>
<td>C5</td>
<td>0.344</td>
<td>( C_5 )</td>
</tr>
<tr>
<td>C6</td>
<td>-0.801</td>
<td>( C_6 )</td>
</tr>
<tr>
<td>C7</td>
<td>1.118</td>
<td>( C_7 )</td>
</tr>
<tr>
<td>C8</td>
<td>-0.961</td>
<td>( C_8 )</td>
</tr>
<tr>
<td>C9</td>
<td>0.691</td>
<td>( C_9 )</td>
</tr>
<tr>
<td>C10</td>
<td>0.399</td>
<td>( C_{10} )</td>
</tr>
<tr>
<td>C11</td>
<td>0.046</td>
<td>( C_{11} )</td>
</tr>
</tbody>
</table>

STEP 6: SCREENING AND WINDOW TYPE CORRECTION

Correct air flow rate by multiplying value by 0.65 for double skin construction

41.3 CFM

STEP 7: AIR CHANGES PER HOUR CALCULATION

<table>
<thead>
<tr>
<th>VARIABLE</th>
<th>VALUE</th>
<th>DEFINITION</th>
</tr>
</thead>
<tbody>
<tr>
<td>ACH</td>
<td>0.97</td>
<td>ACH = ( \frac{Q}{Z \cdot VOLUME} )</td>
</tr>
</tbody>
</table>

STEP 8: SURROUNDING FLOW EFFECTS CALCULATION

<table>
<thead>
<tr>
<th>VARIABLE</th>
<th>VALUE</th>
<th>DEFINITION</th>
</tr>
</thead>
<tbody>
<tr>
<td>SCF</td>
<td>1</td>
<td>SHIELDING CLASS FACTOR</td>
</tr>
<tr>
<td>ACH1</td>
<td>0.97</td>
<td>ACH WITH SCF ACCOUNTED</td>
</tr>
<tr>
<td>ACH &lt; 3</td>
<td>3</td>
<td>IF ACH IS LESS THAN 3 USE ACH = 3</td>
</tr>
</tbody>
</table>
SUPPORTING DOCUMENT F: GEOTHERMAL CAISSON ANALYSIS

STRUCTURAL CAISSONS COUPLED WITH A CLOSED LOOP GEOTHERMAL HEAT PUMP SYSTEM

Mechanical Team’s specific goals are to reject and extract heat from the earth through a geothermal loop tied into the building’s structural caissons.

GROUND SOURCE HEAT PUMP RESULTS FROM TRACE700 SIMULATION

<table>
<thead>
<tr>
<th>Geothermal Input Comparison</th>
<th>TRACE 700 TEMPLATE DATA</th>
<th>MECHANICAL TEAM DESIGN DATA</th>
<th>Energy Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Borehole field design flow rate (GPM)</td>
<td>153.58</td>
<td>150</td>
<td>≈1</td>
</tr>
<tr>
<td># of boreholes</td>
<td>64</td>
<td>52</td>
<td>Refer to Total lineal feet</td>
</tr>
<tr>
<td>Borehole length</td>
<td>250</td>
<td>150</td>
<td></td>
</tr>
<tr>
<td>Borehole radius</td>
<td>2.25</td>
<td>2.25</td>
<td>1</td>
</tr>
<tr>
<td>Pipe thermal conductivity</td>
<td>0.22491</td>
<td>0.22491</td>
<td>1</td>
</tr>
<tr>
<td>Pipe out diameter</td>
<td>1.05</td>
<td>1.05</td>
<td>1</td>
</tr>
<tr>
<td>U-tube distance</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Pipe wall thickness</td>
<td>0.09567</td>
<td>0.09567</td>
<td>1</td>
</tr>
<tr>
<td>Ground thermal conductivity</td>
<td>0.43016</td>
<td>0.42</td>
<td>≈1</td>
</tr>
<tr>
<td>Ground density x specific heat</td>
<td>120.64</td>
<td>115</td>
<td>≈1</td>
</tr>
<tr>
<td>Far field ground temperature</td>
<td>50</td>
<td>50</td>
<td>1</td>
</tr>
</tbody>
</table>

TOTAL LINEAL FEET OF PIPE (# of holes * borehole length) | 16000 | 7800 | 0.4875

TOTAL LOAD REJECTED AND EXTRACTED FROM EARTH

TRACE MODEL OUTPUT = 20,705,922 KBTU/yr

BASED ON LINEAL FEET OF PIPING, GENESIS DESIGN-derived an adjustment factor to acquire a more accurate value for energy savings.

REDUCTION ENERGY FACTOR = 0.4875

SYSTEM ENERGY SAVINGS = 20,705,922 * 0.4875

SYSTEM ENERGY SAVINGS = 10,094,137 KBTU/yr

PERCENTAGE OF BASELINE = 8.0% ENERGY REDUCTION

WHY WE DESIGNED THIS WAY?

In a normal geothermal design application, the mechanical design team would have used ground loop design software (GLD), or Gaia Geothermal to model our system and import it as an .idf file into Trace for analysis. Unfortunately, these two software packages are not available without a large cost associated with obtaining the product.

As a result, Genesis design utilized the sample template provided to users and interpolated the analysis to produce acceptable results for our application. The project specific heat transfer rates and conductivity factors were very similar to the templates values, but the main difference between the Trace provided template and our design was area of influence for the loop due to number of boreholes and borehole length. When approaching the challenge, it was clear that our system has less area of influence, therefore we engineered a modest reduction factor based on lineal feet of pipe and applied it to the load reduction. This resulted in a reasonable output from Trace for the system to estimate our system savings.
LIFECYCLE COST ANALYSIS

While the importance of innovative design solutions to complex problems cannot be understated, they are nevertheless usually costly. Genesis Design made every effort to make decisions which made financial sense to the property owner. Higher up front costs for highly efficient systems leads to lower energy bills. In order to quantify these savings, the total building energy usage had to be calculated against a baseline building. In the Energy Use Cost Analysis table below, Genesis Design was able to reduce the energy cost per year by about $3.88 MM. This over 50% reduction was due mostly to the redesigned façade and mechanical systems. As no surprise, this is also where most of the additional cost figures come into play. As detailed in the Exterior Envelope Cost Comparison table below, the difference between a typical glazing system and the optimized dual skin façade with integrated photovoltaics is about $750/5F glazing area. This is significant, but as shown in the payback period graph, this expense can be paid off within the lifespan of the building.

<table>
<thead>
<tr>
<th>Energy Usage Cost Analysis</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
</tr>
<tr>
<td>Baseline</td>
</tr>
<tr>
<td>Energy Consumed (kWh/yr)</td>
</tr>
<tr>
<td>Cost of Energy ($/kWh)</td>
</tr>
<tr>
<td>Cost per year ($/yr)</td>
</tr>
<tr>
<td>Yearly Savings</td>
</tr>
<tr>
<td>Boylston Street High Rise</td>
</tr>
<tr>
<td>Energy Consumed (kWh/yr)</td>
</tr>
<tr>
<td>Cost of Energy ($/kWh)</td>
</tr>
<tr>
<td>Cost per year ($/yr)</td>
</tr>
<tr>
<td>Yearly Savings</td>
</tr>
</tbody>
</table>

OPTIMIZED DUAL FAÇADE COST ANALYSIS

While the double skin façade had numerous positive impacts on the mechanical loads for the building, it comes at a high initial cost. To calculate the construction cost of building this system, the exterior enclosure cost was first estimated per square foot of glazing area. The double skin portion was then estimated to be 2.5 times the cost of a typical system based on the recommendation of a façade manufacturer. This includes a unitized system with integrated photovoltaics. This number was then applied to 40% of the total exterior enclosure, the portion of the building which has the double skin façade. This cost will be paid back however, due to the mechanical savings that it will achieve.

<table>
<thead>
<tr>
<th>Exterior Envelope Cost Comparison</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unit</td>
</tr>
<tr>
<td>Typical Curtainwall System</td>
</tr>
<tr>
<td>Double Skin System</td>
</tr>
<tr>
<td>Boylston Street High Rise Total</td>
</tr>
</tbody>
</table>

In order to calculate payback period, an initial investment had to first be calculated. The cost differential between the baseline building and the Genesis Design model was used as the investment total. The cash flow used to calculate payback is the savings generated by the efficient design. While the analysis represents a linear payback model, in reality the payback would flatten after 10 or so years due to the replacement and regular maintenance of system components. This expected actual return is modeled by the green curve on the graph.
### System Efficiency

<table>
<thead>
<tr>
<th>System Efficiency</th>
<th>Reasons for Decision</th>
<th>Explanation of Decisions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Occupancy Controls</td>
<td>Energy reduction</td>
<td>Occupancy controls monitor the usage of spaces by occupants, further reducing the HVAC load based on the implemented schedule of the building.</td>
</tr>
<tr>
<td>Demand Control Ventilation</td>
<td>Energy reduction</td>
<td>Demand control ventilation (DCV) is an integral part of Bulyon’s ventilation design in the typical office floors. It adjusts outside ventilation air based on the number of occupants and the ventilation demands that the occupants of each floor space. This system will feed back to the building management system additionally providing data to determine the need to override system sequencing for thermal mass flushing before the 11:00pm local time.</td>
</tr>
<tr>
<td>Condenser Recovery</td>
<td>Cooling demand</td>
<td>In a pressurized condenser recovery system, the pressurized condensate is generally used as boiler make-up water. Bulyon is generally known to be a heating dominated climate, yet the server loads within the building requires a state of constant cooling.</td>
</tr>
<tr>
<td>Building Management System</td>
<td>System cohesion</td>
<td>The BMS is a system that is implemented to monitor all systems for performance/maintenance updates including double skin façade, lighting, geothermal loop, all space, retail for meeting purposes, etc.</td>
</tr>
<tr>
<td>Variable Frequency Drives</td>
<td>Building usage</td>
<td>The chillers will operate on an n+1 configuration and cycle use every month, reducing the need for variable frequency drives.</td>
</tr>
</tbody>
</table>

### System Categories

<table>
<thead>
<tr>
<th>System Category</th>
<th>Reasons for Decision</th>
<th>Explanation of Decisions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Architectural Façade</td>
<td>Site conditions/ integration</td>
<td>Solar thermal gains combined the need of structural caissons and better soil conditions for a closed loop system acting as a heat exchanger for the retail spaces.</td>
</tr>
<tr>
<td>Mechanical System</td>
<td>System performance/maintenance updates</td>
<td>When implemented, a solar chimney is an essential addition to a high rise building with ample space for a vertical shaft. Although it improves natural ventilation by converting air heated by passive solar energy collected in central solar collectors, adding a thermal chimney can cause large circulation issues through the core. Also, the two levels of mechanical areas placed on top of the Bulyon vertical high-flow limits use a large solar collection area (ex: roof).</td>
</tr>
<tr>
<td>Wind</td>
<td>Façade integration</td>
<td>Building management system and ventilation demand that the occupants of each floor and space. This system will feed back to the building management system additionally providing data to determine the need to override system sequencing for thermal mass flushing before the 11:00pm local time.</td>
</tr>
<tr>
<td>Solar Electric</td>
<td>Façade integration</td>
<td>Boston, MA weather and ASHRAE Fundamentals provides the opportunity to operate in natural ventilation mode 80% of working hours on floor 5 through.</td>
</tr>
<tr>
<td>Biomass</td>
<td>Façade integration</td>
<td>Boston, MA weather and ASHRAE Fundamentals provides the opportunity to operate in natural ventilation mode 80% of working hours on floor 5 through.</td>
</tr>
</tbody>
</table>

### Architectural Façade

<table>
<thead>
<tr>
<th>Architectural Façade</th>
<th>Reasons for Decision</th>
<th>Explanation of Decisions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thermal chimney</td>
<td>Site conditions/ integration</td>
<td>Solar thermal gains combined the need of structural caissons and better soil conditions for a closed loop system acting as a heat exchanger for the retail spaces.</td>
</tr>
<tr>
<td>Double skin façade</td>
<td>Site conditions/ integration</td>
<td>Solar thermal gains combined the need of structural caissons and better soil conditions for a closed loop system acting as a heat exchanger for the retail spaces.</td>
</tr>
<tr>
<td>Vertical photovoltaics</td>
<td>Façade integration</td>
<td>Vertical PV’s have less electrical output than tilted and tracking PV’s. However, they are ideal for the building’s South and West facades because they do not block any usable work plane height daylight protruding through the façade. These can be implemented continuously across the façade at the floor and structure height.</td>
</tr>
<tr>
<td>Tracking photovoltaics</td>
<td>Façade integration</td>
<td>Vertical PV’s have less electrical output than tilted and tracking PV’s. However, they are ideal for the building’s South and West facades because they do not block any usable work plane height daylight protruding through the façade. These can be implemented continuously across the façade at the floor and structure height.</td>
</tr>
<tr>
<td>Occupancy controls</td>
<td>Energy reduction</td>
<td>Demand control ventilation (DCV) is an integral part of Bulyon’s ventilation design in the typical office floors. It adjusts outside ventilation air based on the number of occupants and the ventilation demands that the occupants of each floor and space. This system will feed back to the building management system additionally providing data to determine the need to override system sequencing for thermal mass flushing before the 11:00pm local time.</td>
</tr>
<tr>
<td>Condenser recovery</td>
<td>Cooling demand</td>
<td>In a pressurized condenser recovery system, the pressurized condensate is generally used as boiler make-up water. Bulyon is generally known to be a heating dominated climate, yet the server loads within the building requires a state of constant cooling.</td>
</tr>
<tr>
<td>Building management system</td>
<td>System cohesion</td>
<td>The BMS is a system that is implemented to monitor all systems for performance/maintenance updates including double skin façade, lighting, geothermal loop, all space, retail for meeting purposes, etc.</td>
</tr>
<tr>
<td>Variable frequency drives</td>
<td>Building usage</td>
<td>The chillers will operate on an n+1 configuration and cycle use every month, reducing the need for variable frequency drives.</td>
</tr>
</tbody>
</table>
**LEED SPECIALTY AREAS**

The table below shows the LEED categories analyzed for the Boylston Street High Rise. It is not all inclusive, but rather it shows significant areas of interest. These are the areas where the majority of our points came from and they are the most interesting and exciting categories.

<table>
<thead>
<tr>
<th>LEED 2009 for New Construction and Major Renovations</th>
<th>Materials and Resources, Continued</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Sustainable Sites</strong></td>
<td><strong>Indoor Environmental Quality</strong></td>
</tr>
<tr>
<td>Possible Points: 26</td>
<td>Possible Points: 15</td>
</tr>
<tr>
<td><strong>11</strong> Water Efficiency</td>
<td><strong>Materials and Resources, Continued</strong></td>
</tr>
<tr>
<td>Possible Points: 10</td>
<td></td>
</tr>
<tr>
<td><strong>15</strong> Energy and Atmosphere</td>
<td><strong>Materials and Resources, Continued</strong></td>
</tr>
<tr>
<td>Possible Points: 35</td>
<td></td>
</tr>
<tr>
<td><strong>4</strong> Materials and Resources</td>
<td><strong>Innovation and Design Process</strong></td>
</tr>
<tr>
<td>Possible Points: 14</td>
<td>Possible Points: 6</td>
</tr>
<tr>
<td><strong>8</strong> Regional Priority Credits</td>
<td><strong>Regional Priority Credits</strong></td>
</tr>
<tr>
<td>Possible Points: 4</td>
<td>Possible Points: 4</td>
</tr>
</tbody>
</table>

**Storm water is collected in a tank located on the Green Mezzanine Level completely mitigating runoff water from the building providing non-potable water for interior spaces.**

**Double Skin Façade implemented on the south and west faces that reduce the mechanical load by >50% by restricting solar gains.**

**Photovoltaic panels implemented on 50% on the west and south facades.**

**Underfloor Air Distribution is implied by LEED documentation to have a ventilation effectiveness of greater than 1.**

**>50% of every typical tenant office interior zone is outfitted with personalized airflow settings per work station.**

**The adjustable diffusers in cohesion with building management and automation systems will facilitate the delivery of ASHRAE Standard 55 ventilation values for annual thermal comfort.**
FIRE SUPPRESSION SYSTEMS

ENDURANCE AND OPERATION FOR 48 HOURS AFTER A POWER OUTAGE WAS THE DESIGN FOCUS WHEN SELECTING MECHANICAL SYSTEMS FOR THE BOYLSTON HIGH RISE. THE FOLLOWING SYSTEMS MUST THREE DIFFERENT FIRE PUMPS SERVE DIFFERENT ZONES OF BOYLSTON TO REACH EACH FLOOR AS EFFICIENTLY AS POSSIBLE AND MINIMIZE THE REDUCTION IN PRESSURE THROUGH THE SYSTEM.

LOBBY & RETAIL
CONTROLLING AND ACCOUNTING FOR 12 ELEVATORS AND THE HEAT GAIN DISSIPATED INTO THE SPACE IS IMPORTANT TO THE SAFETY OF THE OCCUPANTS.

SOLUTION
KONE MONOSPACE HAS A MOTOR SIZE OF 15 HORSEPOWER (AS OPPOSED TO A TYPICAL 40HP EXISTING HYDRAULIC ELEVATOR).

ELEVATOR OPERATION
THESE ELEVATORS ARE ESTIMATED TO HAVE A LOAD PERCENTAGE OF 75%, CONTINUOUSLY OPERATING ABOUT 30% OF TIME. THE REQUIRED VOLUME OF AIR TO KEEP THE SPACE TEMPERATURE DOWN TO 85°F IS APPROXIMATELY 3,200 CFM REMOVING A 103,100 BTUH HEAT LOAD FROM THE TOP LANDING OF THE ELEVATOR HOIST WAY AND EXHAUST IT WITH A FAN LOCATED ON THE ROOF DIRECTLY ABOVE THE ELEVATOR SHAFT.

PARKING GARAGE
THE BATHTUB DESIGN REFERS TO ROOMS ON THE BOTTOM TWO LEVELS OF THE BUILDING (GREEN LEVEL AND GREEN MEZZANINE) WHICH MAY BE SUBJECT TO WATER INFILTRATION IN THE EVENT OF A SEVERE STORM OR FLOODING.

SOLUTION
MECHANICAL EQUIPMENT HOUSED WITHIN THESE ROOMS ON THE FLOORS WHICH ARE SUSCEPTIBLE TO WATER DAMAGE WILL BE PROTECTED FROM THE DAMAGING EFFECTS OF WATER ON ELECTRICAL COMPONENTS. THE EXISTING MECHANICAL ROOM ALONG THE EAST WALL AND MECHANICAL ROOM GL 07 ARE PROTECTED FEATURING DOORS WHICH ARE RAISED OFF THE FLOOR AND HAVE A SEALING CONSTRUCTION SIMILAR TO THOSE INSIDE A SHIP. THESE DOORS CAN STOP WATER FROM INFILTRATING THE ROOMS AND CAUSING DAMAGE TO ELECTRICAL AND MECHANICAL EQUIPMENT.

FOOD COURT
THE FOOD COURT ENTRANCE AREA IS A 3-STORY OPEN CONCEPT. SMOKE IS EXHAUSTED THROUGH THE FOURTH FLOOR ONTO THE FOOD HALL ENTRANCE ROOF.

SOLUTION
THE SMOKE EXHAUST FAN IS SIZED TO BE AT 158,800 CUBIC FEET PER MINUTE KEEP THE SMOKE AT LEAST 10 FEET ABOVE THE HIGHEST OCCUPIED SURFACE FOR 1200 SECOND (20 MINUTE) ANALYSIS AT 50 FEET. THE SMOKE CONTROL SYSTEMS OUTLINED IN THE BOYLSTON STREET HIGH RISE FOLLOW SECTION 513 OF THE 2009 INTERNATIONAL

STAIRWELL PRESSURIZATION
DURING THE EVENT OF A FIRE EMERGENCY, IT WILL BE ESSENTIAL TO EVACUATE OCCUPANTS THROUGH THE STAIRWELLS BECAUSE ALL ELEVATORS WILL BE OUT OF ORDER FROM THE 17TH STORY AND BELOW. THE STAIRWELL WILL BECOME AN AREA OF REFUGE AND SHELTER AND AIR WILL BE PROVIDED WITHIN THE SPACE TO POSITIVELY PRESSURIZE IT, ALLOWING NO SMOKE TO INVADE THE SPACE WHEN THE DOORS WERE OPENED. A DUCT CHASE SHOWN IN THE DIAGRAM TO THE LEFT WILL RUN THE ENTIRE HEIGHT OF THE BUILDING AND WHEN THERE IS A FIRE WITHIN THE BUILDING, EVERY THIRD FLOORS DAMPER THAT WILL OPEN, PROVIDING THE STAIRWELL WITH A POSITIVE PRESSURE DIFFERENTIAL OF 0.15 IN WG CONTAINING THE SMOKE WITHIN THE OFFICE FLOOR SPACE.
OPEN OFFICE INTERIOR FLEXIBILITY

1. Double skin façade with operable horizontal blinds
2. Column design around the floor’s perimeter for flexibility
3. Dropped ACT ceiling
4. General ambient down-lighting with easily changeable layouts
5. Raised access floor
6. Flexible electrical conduit and mechanical duct layout

TYP. OFFICE FLOOR SUPPLY LAYOUT

TYP. OFFICE CEILING RETURN LAYOUT
FOOD COURT AND OFFICE LOBBY

The lobby load is heavily influenced by infiltration and envelope loads. AHU-5 is ducted to both of these spaces in order to condition, ventilate, and pressurize the lobby against stack effect. The round ductwork has an aesthetic appeal to anyone entering, but are hidden up high and out of sight to maintain the visually appealing grand entrance of the building.
THIS HYBRID SYSTEMS IS USING A COMBINATION OF A GROUND-SOURCE RESOURCE WITH OUTDOOR AIR COOLING TOWER. HYBRID APPROACHES ARE PARTICULARLY EFFECTIVE WHERE COOLING NEEDS ARE SIGNIFICANTLY LARGER THAN HEATING NEEDS SUCH AS THE RETAIL SPACES WHERE THEY ARE NOT IN THE SCOPE OF THIS PROJECT PHASE. 26, 137 FT DEEP VERTICAL WELLS ARE BEING DRILLED FOR THE STRUCTURAL CAISSONS. WATER IS DRAWN FROM THE BOTTOM OF THE STANDING COLUMN AND RETURNED TO THE TOP OF THE U-TUBE.

ACCORDING TO DOE IN 2012, DURING PERIODS OF PEAK HEATING AND COOLING, THE SYSTEM CAN BLEED A PORTION OF THE RETURN WATER RATHER THAN REINJECTING IT ALL, CAUSING WATER INFLOW TO THE COLUMN FROM THE SURROUNDING AQUIFER. THE BLEED CYCLE COOLS THE COLUMN DURING HEAT REJECTION, HEATS IT DURING HEAT EXTRACTION.

TOTAL LOAD REJECTED AND EXTRACTED FROM EARTH MODELS (EXCEPT AS PER EIA REPORT): BASED ON LINING PUMP OF HYBRID, GENESIS DESIGN DERIVED AN ADJUSTMENT FACTOR TO ACQUIRE A MORE ECONOMIC VALUE FOR ENERGY SAVINGS.

RECIPIENT ENERGY SAVINGS = 0.4875

SYSTEM ENERGY SAVINGS = 8.0%

PERCENTAGE OF ANNUAL = 9.0% ENERGY REDUCTION

PROPOSED HEAT PUMP CLOSET LAYOUT

HYBRID GROUND SOURCE HEAT PUMP SCHEMATIC
### Ventilation Calculations

#### VENTILATION CALCULATIONS

<table>
<thead>
<tr>
<th>Room Type</th>
<th>Area (sq. ft)</th>
<th>Units</th>
<th>Area Exhaust Rate (CFM/sq ft)</th>
<th>Unit Exhaust Rate (CFM/unit)</th>
<th>Total CFM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Office</td>
<td>100</td>
<td>0.5</td>
<td>50</td>
<td>50</td>
<td>50</td>
</tr>
<tr>
<td>Restroom</td>
<td>150</td>
<td>1</td>
<td>0</td>
<td>50</td>
<td>50</td>
</tr>
<tr>
<td>Storage</td>
<td>120</td>
<td>0.5</td>
<td>60</td>
<td>60</td>
<td>60</td>
</tr>
<tr>
<td>Elevation</td>
<td>100</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

### Exhaust Calculations

#### VENTILATION EQUATIONS (ASHRAE 62.1 V2007)

\[ V_{bz} = (R_p \cdot P_z) + (R_a \cdot A_z) \]

\[ V_{oz} = \frac{V_{bz}}{Ezn} \]

Total = \[ \sum V_{oz} \]

### Exhaus Calculations

#### Exhaust Calculations

<table>
<thead>
<tr>
<th>Room Type</th>
<th>Area (sq. ft)</th>
<th>Units</th>
<th>Area Exhaust Rate (CFM/sq ft)</th>
<th>Unit Exhaust Rate (CFM/unit)</th>
<th>Total CFM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Restroom</td>
<td>150</td>
<td>1</td>
<td>0</td>
<td>50</td>
<td>50</td>
</tr>
<tr>
<td>Storage</td>
<td>120</td>
<td>0.5</td>
<td>60</td>
<td>60</td>
<td>60</td>
</tr>
<tr>
<td>Elevation</td>
<td>100</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

### Total CFM

- Total CFM = 500 total CFM for Office Type
- Total CFM = 1820 total CFM for Restroom Type
FIGURE 1 - HW SCHEMATIC

FIGURE 2 - CHW SCHEMATIC
RAINWATER COLLECTION SYSTEM

The Mechanical Design Team implemented a rainwater collection system in order to capture all storm water that gathers on the roof and plaza producing zero runoff from the site. The tank (290,000 gallons) was sized based on the record single day rainfall of 7.96 inches in Boston, Massachusetts.

### Assumptions:
- 3 flushes/day-person
- Design Selection = Niagara Conservation Stealth® Dual Flush

### Rainwater Collection System

<table>
<thead>
<tr>
<th>Roof Area (sq. Ft)</th>
<th>Plaze Walkway Area (sq. Ft)</th>
<th>Single Day Rainfall Record (Inches)</th>
<th>Average Rainfall (Feet/Year)</th>
<th>Rainfall Collection per Year (Gal)</th>
<th>Water Closet Grey Water Percent Demand Reduction</th>
<th>Tank Size (Gal)</th>
</tr>
</thead>
<tbody>
<tr>
<td>23635</td>
<td>12793</td>
<td>7.96</td>
<td>3.6467</td>
<td>993658.07</td>
<td>72.80%</td>
<td>289967</td>
</tr>
</tbody>
</table>

### Water Closet Grey Water

<table>
<thead>
<tr>
<th>Office System</th>
<th>People</th>
<th>Work days/week</th>
<th>Flushes per person per day</th>
<th>Gal/flush</th>
<th>Water Use per Floor (Gal/Year)</th>
<th>Number of Floors</th>
<th>Total Office Grey Water Use (Gal/Year)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline</td>
<td>200</td>
<td>250</td>
<td>3</td>
<td>1.6</td>
<td>24000</td>
<td>14</td>
<td>3360000</td>
</tr>
<tr>
<td>Design</td>
<td>200</td>
<td>250</td>
<td>3</td>
<td>0.65</td>
<td>97500</td>
<td>14</td>
<td>1365000</td>
</tr>
</tbody>
</table>
DRAWING NOTES:

1. EACH PENTHOUSE AHU IS TO SERVE ONE QUADRANT OF THE OFFICE FLOOR PLAN ON FLOORS 4-17.
2. A SEPARATE DOAS IS TO BE TIED INTO THE GROUND SOURCE HEAT PUMPS FOR VENTILATION PURPOSES.
3. RAINWATER COLLECTION TANK IS TO ACT AS SUPPLEMENTAL WATER SOURCE FOR THE GREEN WALL SPRINKLERS ONLY IN EXTREME DROUGHT CIRCUMSTANCES.
4. DOMESTIC WATER LINES ARE TO BE USED FOR WATER CLOSET GREY WATER ONLY WHEN RAINWATER STORAGE TANK DOES NOT HAVE CAPACITY TO SUPPLY.
### AIR HANDLING UNIT SCHEDULE

<table>
<thead>
<tr>
<th>AHU NAME</th>
<th>ZONE SERVED</th>
<th>OA DB (F)</th>
<th>OA WB (F)</th>
<th>COIL LAT (F)</th>
<th>COIL AIRFLOW (CFM)</th>
<th>COIL SENSIBLE (BTU/HR)</th>
<th>COIL LATENT (BTU/HR)</th>
</tr>
</thead>
<tbody>
<tr>
<td>AHU - 1</td>
<td>S OFFICE</td>
<td>91</td>
<td>73</td>
<td>55</td>
<td>27050</td>
<td>744560</td>
<td>166530</td>
</tr>
<tr>
<td>AHU - 2</td>
<td>W OFFICE</td>
<td>91</td>
<td>73</td>
<td>55</td>
<td>27050</td>
<td>744560</td>
<td>166530</td>
</tr>
<tr>
<td>AHU - 3</td>
<td>E OFFICE</td>
<td>91</td>
<td>73</td>
<td>55</td>
<td>27020</td>
<td>744550</td>
<td>166520</td>
</tr>
<tr>
<td>AHU - 4</td>
<td>N OFFICE</td>
<td>91</td>
<td>73</td>
<td>55</td>
<td>27020</td>
<td>744550</td>
<td>166520</td>
</tr>
<tr>
<td>AHU - 5</td>
<td>LOBBY/FOOD</td>
<td>91</td>
<td>73</td>
<td>55</td>
<td>42478</td>
<td>917600</td>
<td>400067</td>
</tr>
<tr>
<td>DOAS - 1</td>
<td>OFFICE S &amp; W</td>
<td>91</td>
<td>73</td>
<td>55</td>
<td>54100</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>DOAS - 2</td>
<td>OFFICE N &amp; E</td>
<td>91</td>
<td>-</td>
<td>-</td>
<td>54040</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>DOAS - 3</td>
<td>RETAIL</td>
<td>91</td>
<td>73</td>
<td>-</td>
<td>11342</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>GSHP</td>
<td>RETAIL</td>
<td>91</td>
<td>73</td>
<td>47</td>
<td>-</td>
<td>775488</td>
<td>488596</td>
</tr>
</tbody>
</table>

### CHILLER SCHEDULE

<table>
<thead>
<tr>
<th>CHILLER NAME</th>
<th>ZONE SERVED</th>
<th>LAT (F)</th>
<th>SENSIBLE (BTU/HR)</th>
<th>LATENT (BTU/HR)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CHILLER - 1</td>
<td>OFFICE</td>
<td>55</td>
<td>992750</td>
<td>222040</td>
</tr>
<tr>
<td>CHILLER - 2</td>
<td>OFFICE</td>
<td>55</td>
<td>992750</td>
<td>222040</td>
</tr>
<tr>
<td>CHILLER - 3</td>
<td>OFFICE</td>
<td>55</td>
<td>992750</td>
<td>222040</td>
</tr>
<tr>
<td>CHILLER - 4</td>
<td>RETAIL/LOBBY</td>
<td>47</td>
<td>775488</td>
<td>488596</td>
</tr>
</tbody>
</table>
INTELLIGENT BUILDING MANAGEMENT SYSTEM

Genesis Design understands that the key to a truly integrative, sustainable design and the future of the building industry is implementation of an intelligent building management system that consolidates all aspects of a building’s control into one, simplified platform. The advantages include:

- Improved building performance through maximum energy efficiency
- More informed decision-making for facility manager and owner
- Automated monitoring & controlling through a single, manageable platform
- Lower lifecycle costs & improved return on investment
- Greater document control & appeal for tenants
- Direct day lighting
- Absorbed solar radiation
- Diffused day lighting
- Maintained views
- Operable windows

UNDERSTANDING THE MARKET’S LEADING STANDARDS

1. **BACnet**
   - A building automatic and control networking protocol developed by ASHRAE, typically used for HVAC, lighting, access, and fire detection controls. Organized into “objects” of analog/binary input/output representing the device itself and reports of data/current state of properties its measuring. BACnet IP over wireless is what the industry is looking at in terms of newest technology.

2. **LonWorks**
   - “Local Operating Networks” is a control networking protocol created by Echelon Corporation for devices over media such as twisted pairs, powerlines, fiber optics. LONWORKS is restricted to using LONTALK proprietary communication protocol.

3. **OPC Foundation**
   - OPC is a client-server technology. One application acts as the server providing data, and the other acts as a client using data. It’s a widely accepted industrial communication standard that enables the exchange of data between multivendor devices and controls applications without any proprietary restrictions.

4. **Modbus**
   - Modbus is a serial communication protocol developed by Modicon and uses programmable logic controllers (PLCs). Information is transmitted over serial lines between electronic devices.

**Honeywell**

Genesis Design decided to adopt Honeywell’s Enterprise Buildings Integrator as the Boylston Street High Rise’s comprehensive, network-based solution for building automation and management. It has the ability to incorporate all the industries open standards mentioned above into a single point of access for the building facility manager. This allows the building to be flexible for future planning in terms of system expansion and lifecycle savings.

**BUILDING MANAGEMENT SYSTEM**

- **1. VAV CONTROLLERS**
- **2. THERMOSTATS IN RETAIL SPACES**
- **3. PRESSURE SENSORS (1 OUTSIDE, 1 INSIDE/FLOOR)**
- **4. AIRFLOW SENSORS IN EVERY MAIN BRANCH OF DUCT RUN**
- **5. REGENERATIVE ELEVATOR AND ESCALATOR CONTROLLER**
- **6. PRESSURE SENSOR IN STAIRWELL**
- **7. WATER PRESSURE/TEMPERATURE SENSORS IN BOILER AND COOLING TOWERS**
- **8. UPS MONITORING**
- **9. SERVICE AND MAINTENANCE**

**ENERGY MANAGEMENT SYSTEM**

- **1. ENERGY & POWER METERING PER TENANT**
- **2. GEOTHERMAL TEMPERATURE AND PRESSURE CONTROLS (HEAT EXCHANGER) TO SEE SAVINGS**
- **3. TEMPERATURE AND HUMIDITY SENSORS IN DOUBLE SKIN FAÇADE TO SEE SAVINGS**
- **4. HORIZONTAL BLINDS TILT CONTROL**
- **5. LIGHTING FIXTURES & CONTROLS & OCCUPANCY SENSORS**
- **6. DEMAND CONTROL VENTILATION CONNECTED TO LIGHTING OCCUPANCY CONTROLS**

**LIFE SAFETY SERVER**

- **1. HVAC EQUIPMENT CONTROL TO CONTAIN SMOKE & CREATE SAFE HAVENS**
- **2. FIRE DOOR RELEASE**
- **3. SPRINKLER SUPERVISORY STATUS OF SUPPRESSION SYSTEMS, VALUES, AND FIRE HYDRANTS**
- **4. FIRE DETECTION & ALARM SYSTEM**
- **5. EGRESS LIGHTING CONTROLS**
- **6. ADVANCED DISTRIBUTED DIGITAL AUDIOMEDIA COMMUNICATION SYSTEM FOR ORDERLY/ZONED EVACUATION**

**SECURITY SERVER**

- **1. IP VIDEO CAMERAS SURVEILLANCE & CLOSED CIRCUIT TELEVISION**
- **2. ACCESS CONTROL FOR DOORS AND READERS**
- **3. INTRUDER PANELS & REPORTING**
- **4. PUBLIC ADDRESS AND VOICE ANNOUNCEMENT (PA/VA)**
- **5. PERIMETER PROTECTION**
- **6. LINKS TO EXTERNAL AUTHORITIES**
- **7. VOICE AND DATA COMMUNICATIONS**
- **8. STRUCTURED CABLE AND CABLE MANAGEMENT**

---

**Direct Daylight**

**Absorbed solar radiation**

**Diffused Daylight**

**Maintained views**

**Operable windows**

**LAN**

**WAN**

**Browser stations with single access point interface for Building Facilities Manager**

---

**DIAGRAM 1**

- **Wiring diagram for WAREMA Climatronic**
- **Operable Windows**
- **Diffused Daylight**
- **Maintained views**
- **Operable Windows**

---

**DOUBLE SKIN FAÇADE CONTROLS**

Forecasting: Use of exclusive algorithms incorporating weather patterns, historical usage, and real-time updates to continually hone natural/hybrid ventilation operation in connection with horizontal blind tilt controls. Upon sensing acceptable conditions of outdoor humidity and outdoor temperature from the nearest weather station, the BAS issues a signal to activate.
0.0 EXECUTIVE SUMMARY
Genesis Design’s electrical team set out to design a resilient, sustainable, and integrative design. When considering different building systems, energy efficiency was held to a very high importance in order to reduce the building’s carbon footprint. Highly efficient lighting and daylight harvesting systems were implemented to reduce energy usage. A photovoltaic array further reduces energy use by supplementing electricity for the building. Redundancy and emergency backup techniques were applied to the electrical design to ensure a dependable facility for building tenants.

0.1 INTEGRATION
Genesis Design chose to approach the project using Integrated Project Delivery (IPD) with Building Information Modeling (BIM). With IPD, all disciplines of the design team participate in decision making. The integrative approach has taught us that the team dynamic is ultimately as important as technical capability. See electrical narrative section 2.

0.2 ENERGY PRODUCTION
Incorporating power generation technologies in a dense city creates an influence on the building’s occupants and the surrounding community to do the same. Genesis Design’s electrical team produced a 1,600-panel, 414 kW photovoltaic system. Consisting of two façade-integrated zones and four roof zones, the system has an annual production of over 342 MWh. This effectively cancels 53.5% of the building’s annual receptacle loads, or 5.89% of the building’s overall energy usage. See electrical narrative section 6.

0.3 ENERGY REDUCTION
In electrical and lighting design, energy consumption can be reduced in a multitude of ways. Through electric lighting design and passive daylighting, Genesis Design reduced lighting consumption by 67.3% from ASHRAE’s lighting power density requirements. Nine regenerative elevators effectively cut their consumption 75.3%. Virtual thin-client desktop workstations were used in office spaces to cut receptacle consumption by 21.5%. See electrical narrative section 7.

0.4 ELECTRICAL SYSTEM RESILIENCY
The emergency electrical system will support essential systems for 48 on diesel generator power. Combined with UPS’s, this backup also provides power for critical servers so that tenants’ work data will never be compromised by a power outage. A double-redundancy configuration exists in the main electrical spaces with two utility connections and generators, each capable of supporting the entire building if one was to fail or need service. See electrical narrative section 8.

0.5 LIGHTING DESIGN
Genesis Design strived to achieve a 67.3% reduction in lighting energy consumption while producing functional and attractive environments at the same time. Energy-efficient LED lighting was implemented in most spaces to get the most out of the energy used. Daylight dimming systems, along with a façade-integrated aluminum blinds system to prevent direct daylight penetration, allow 14 office floors to be a highly functional work environment. See electrical narrative section 9.
1.0 PROJECT INTRODUCTION
The 2016 AEI Student Design Competition set forth the challenge to design a 17-story mixed-use building located in a dense urban setting within Boston, Massachusetts, which requires focus on three main areas:
1. Address all possible ideas for sustainable design and construction.
2. Provide resiliency with respect to local environmental conditions.
3. Consider integration with and impact on adjoining businesses, structures, and public ways.

Our highly collaborative, multidisciplinary design team, Genesis Design, created unified goals that continuously drove decisions from conceptualization of ideas to fruition of an innovative, high performance, integrated systems building that will be known as the Boylston Street High Rise.

1.1 ELECTRICAL SCOPE
The electrical scope of work set forth by the competition includes:
1. Building Power Distribution
2. Lighting Design
3. Fire Alarm Infrastructure
4. Data/Security Infrastructure

Additional electrical scope of work Genesis Design pursued to enhance final design includes:
+ Power Generation
+ Power Reduction
+ Daylight Design
+ Integrated Building Management System

The Electrical Narrative serves to provide comprehensive descriptions of all electrical system solutions as well as the rationale for their selection. The Electrical Supporting Documents provide assumptions, calculations, and resources to support the solutions. The Electrical Drawings offer technical drawings and graphic visuals of the electrical systems and their important details.

1.2 ELECTRICAL GOALS
Genesis Design developed a set of shared design drivers and team goals based off project requirements and project stakeholder objectives. The Sustainability driver’s goals are to create a high performance, energy efficient building through its full lifespan, while promoting a healthy environment for its occupants. The Resiliency driver’s goals are to ensure building operation and security during the harshest conditions, as well as provide flexibility for adapting to changing occupant needs. Lastly, the Integration driver’s goals are to successfully optimize integrated systems within the building through IPD’s increased collaboration and have the building become an integral, engaging part of the surrounding city community. More specific electrical goals were developed, correlating to and enhancing the completion of team goals:

SUSTAINABILITY
Invest in technologies that reduce power usage and generate electricity on site. Use daylight to promote a happy, healthy work environment.

RESILIENCY
Deliver reliable, quick transitioning power through additional degrees of redundancy and protection for all critical IT/data and life safety loads. Address spectrum of security measures. Provide flexible lighting and equipment load for changing occupant needs.

INTEGRATION
Create an advanced, connected building management system to manage energy demand and improve functionality. Optimize penthouse, façade, office, etc. design through IPD.

Throughout the Electrical Narrative, black and bolded text will make significantly important concepts and findings connecting to the particular team goals and design drivers easily noted.
2.0 INTEGRATIVE APPROACH
The traditional method for project delivery in the industry is Design-Bid-Build. The linear travel of information from architect to engineers to general contractor is one of purely reactionary design and adversarial checks and balances. In contrast, Genesis Design chose to approach the project using Integrated Project Delivery (IPD) with Building Information Modeling (BIM). With IPD, all disciplines of the design team participate in decision making. Sharing information and providing feedback is done as much as possible from the very beginning. BIM enhances communication through intelligent management of digital representations. The compilation of all analyses, calculations, and specifications manifest into a 4D model that aligns construction planning with performance. The process limits costly design changes, increases work efficiency, and creates trust within the team.

![Diagram of Project Progress]

Figure 2 – IPD Process Advantage
① Ability to control cost and function ② Cost of design changes ③ Traditional design process ④ IPD Design Process

It is also inevitable that any high performing team is bound to have disagreements. Genesis Design resolves disputes with respect and created a Decision Matrix to measure decisions against how well they achieve our team’s project goals. Please refer to the Electrical Decision Matrix (Electrical Supporting Document A) for major electrical design decisions. The integrative approach has taught us that the team dynamic is ultimately as important as technical capability. While IPD is undoubtedly a more demanding and intensive process, the final production of a higher quality, much more innovative building is a truly rewarding experience.

3.0 CODES & STANDARDS
Genesis Design took special care to examine and adhere to all applicable building codes, local amendments, and standards because of their importance to safety, health, resiliency, and energy efficiency:

1. **ASHRAE 90.1-2010**: Effective in Boston since July 2014. The competition specifies that the project’s energy goal be limited to a value of 50% of the baseline established by ASHRAE Standard 90.1 v2007, but Genesis Design’s electrical team goes beyond by following the more stringent amendments in the newer addition.

2. **IESNA**: The 10th addition of the Illuminating Engineering Society of North America’s Lighting Handbook was used to reference lighting technologies, suggested applications, and illuminance recommendations.

3. **IBC 2009**: The 8th edition of the International Building Code with Massachusetts amendments was used for provisions on fire protection systems, means of egress, and electrical systems.

4. **NFPA 70/NEC 2014**: The 2014 National Electrical Code with Massachusetts amendments was the benchmark for safe electrical design and installation.

4.0 SITE ANALYSIS
The Boylston Street High Rise replaces the last vacant lot of the 23-acre Prudential Center Complex in the heart of Boston’s Bay Back neighborhood. Owned by Boston Properties, a real estate investment trust, the complex includes three skyscrapers to the building’s south: Prudential Tower, 111 Huntington Avenue, and 101 Huntington Avenue, as well as the vast Prudential Shops urban mall center at the Prudential Tower’s base. As part of the project, an entrance structure adjacent to the new street level plaza serves as a “front door” and connects the Boylston Street High Rise’s second level retail to the rest of the mall. Also sharing the plaza, the Hynes Convention Center is located immediately to the building’s west, while the Exeter and Fairfield residential apartment complexes are to its east (see Figure 3).

As part of the initial IPD design process, Genesis Design’s
The electrical team conducted a detailed solar and shadow analysis on the site and shared their findings to make important preliminary decisions on the building’s energy design.

4.1 SOLAR ANALYSIS TAKEAWAYS

Ecotect is an environmental analysis tool used to simulate building performance for the earlier stages of conceptual design. After importing an AutoCAD 3D model of all potentially shadowing structures, Genesis Design used Ecotect to output an annual solar radiation analysis according to Project North orientation 19 degrees west of True North and Boston weather data file. See the Solar & Shadow Analysis (Electrical Supporting Document B) for calculations and charts. The analysis data showed substantially higher cumulative annual incident solar radiation measured in W/m² falling on the South and West facades in comparison to the North and East facades. See Figure 4, and be aware that yellow on the scale represents the highest incident solar radiation.

High solar radiation resulting in high solar heat gain was recognized by the mechanical team as design potential for implementing an innovative double skin façade for passive design and energy efficiency strategies. After conducting further annual shading, overshadowing, and direct sunlight hour analysis with Ecotect (see Figure 5), the electrical team decided building integrated solar photovoltaic technology as a renewable energy source should be pursued on the building’s roof, south and west facades. Unfortunately, additional analysis showed the public plaza to be in shadow majority of year and the surrounding rooftops of the Prudential Center complex as impracticable for offsite solar panel implementation. As a next step in the design process, in order to determine the full feasibility and output of solar PV arrays on the roof, south and west facade, detailed shading diagrams were created on Photovoltaic Diagrams (Electrical Drawing E-03, Page 136). Genesis Design used these diagrams in combination with System Advisor Model (SAM) software to calculate the power production losses in the building’s six zones of photovoltaic panels. SAM was developed by the National Renewable Energy Laboratory (NREL). In conclusion, on the south façade, surrounding building shading causes an energy production loss of 26%, which was the largest and most significant loss of all six PV panel zones. Exact details about the photovoltaic system will be covered in Sections 5.0 – 5.2, as well as Photovoltaic Calculations (Electrical Supporting Document, Page 126) which includes panel specification, production, and cost/payback data for the system.

5.0 FAÇADE DESIGN

Redesigning the façade for better performance was Genesis Design’s most integrative intensive task and had the highest impact on the Boylston Street High Rise’s energy profile. Many façade system options were considered and researched for implementation among team’s disciplines. The details of thesis decisions are fully...
covered in each disciplines Decision Matrix Supporting Documentation and Team Interaction (Integration Supporting Document, Page 21). Visual connection to the outdoor environment, daylight quality, advanced controls technology, and aesthetics were large discussion contributions made by the electrical team to influence the façade’s final design. Refer to Building Façade Design (Electrical Drawing E-04, Page 137) for glass type specifications for the double skin exterior and interior skins, as well as the north and east façade’s vision and spandrel glass/wall composition.

5.1 OPTIMIZING USEFUL DAYLIGHT

“Daylight harvesting” refers to the use of sunlight and skylight to provide functional interior illuminance at comfortable and appropriate levels. As part of Genesis Design’s Sustainability goals, daylighting’s high placed value was conveyed by the electrical team to all discipline team members. The many benefits of daylighting will be elaborated throughout the report. Firstly, daylighting has a proven positive impact on occupant well-being, productivity, and overall sense of satisfaction. These benefits contribute to making the Boylston Street High Rise a large market presence as a Class A office building for premier tenants. Fortunately, the core’s designation to the building’s center makes daylighting potentially available on the four façade sides of all 14 open office floors. DAYSIM is a daylighting analysis software used by the electrical team to measure popular daylight metrics such as Daylight Anatomy (DA) and Useful Daylight Index (UDI) for the interior building floor plan.

Figure 6 – DAYSIM Simulations of DA & UDI on 17th Floor

Daylight outside of 150 to 3000 lux (UDI) is either insufficient or overwhelming which results in visual and thermal discomfort. In our final façade system design, the 17th office floor (the highest occupied floor) yielded a DA of 99.77% for 150 lux (see Figure 6) and 86.73% for 300 lux for the work day hours of 8:00 AM to 6:00 PM. The 5th floor office yielded a Daylight Autonomy of 90.40% for 150 lux and 61.42% for 300 lux. Interior Daylighting (Electrical Supporting Document D, Page 127) contains comparisons to the building’s original façade design as well as Genesis Design’s varying horizontal shading device spacing to show design improvement and decision making justification.

5.2 SOLAR SHADING SYSTEMS

The challenge between maximizing useful daylighting and addressing issues of unwanted direct daylight penetration aka glare was constantly under evaluation by the electrical team during the process of deciding a solar shading system. In the original façade design, glazed curtain walls of double paned glass and spandrel from floor-to-floor height on all four sides did not appear to use any obvious shading methods. Calculations reveal 76% window area when considering Level 2 through 17. Without a shading device, the sun’s rays penetrating the interior will cause constantly fluctuation of visual and thermal discomfort in workspaces which decreases the productivity of workers and general pleasantness of the space. Traditionally, designers turn to implementation of fabric roller shades encompassing all windows. The disadvantages of the fabric shades are significantly increased reliance on the building’s electric lighting for more hours in the day and blocked or obstructed views to the outdoors. However, Genesis Design decided to pursue a more innovative solution. Glare was originally an issue for the south and west sides of the building which receive the largest amount of solar radiation. In response to the team’s final decision of implementing a double skin, numerous appropriate devices that complement the double skin were then pursued, including:

1. Integrated Concentrating Solar Facades (top image)
2. Colt International’s Shadovoltaics® (bottom image)
3. Onyx’s Solar Building Integrated PVs
4. SageGlass (Dynamic Electrochromatic Glass)
5. Fritted Glass/Mesh Sunscreen

See the Electrical Decision Matrix (Electrical Supporting Document A, Page 126) for full descriptions of the decisions made on the aforementioned options.
according to the team’s design goals. The final choice Genesis Design arrived at was to design a solar tracking, horizontal aluminum blinds system within the air gap of the double skin façade. The width of each curved, perforated aluminum slat is 12” and evenly spaced 9” vertically apart. Instead of blocking usable daylight, the horizontal blind system diffuses the sun’s direct daylight, therefore eliminating discomfort glare into the occupant’s workstation. The horizontal blinds reflect visible light (not IR or UV light) up to the ceiling and further into the room.

In addition, horizontal blinds are a complementary system to the function of the double skin by absorbing solar radiation. The naturally occurring convective heat currents then rise up within the air gap, facilitating natural ventilation without significant effects of solar heat gain negatively impacting the interior’s HVAC cooling load.

Looking at both a mechanical and electrical perspective, the horizontal blinds become the obvious choice of best solution (see Figure 7). The double skin façade with horizontal blinds was implemented on the south and west facades of the Boylston Street High Rise. The Double Skin Façade Analysis P1 & P2 (Mechanical Supporting Document C & D, Pages 91 & 92) describes its efforts in overall building energy reduction.

Genesis Design specified WAREMA as the horizontal blind system’s manufacturer, but the design team is well aware of the fact that international products add a layer of extra cost and coordination that is likely to be value-engineered. For the purposes of the competition, Genesis Design utilized the readily available, high quality data WAREMA provided for the product’s specification and analysis. The electrical design team is confident a similar product exists or is at least customizable in the United States.

Much like traditional venetian blinds, Genesis Design’s larger width horizontal blinds were made to have the ability to tilt in response to the sun’s path. During majority of the day’s hours, they will sit horizontally as to maintain outdoor views. When the sun falls below an altitude of 35.47° with respect to the normal direction of the façade, the system will automatically tilt the blinds 46.4° toward the exterior. This setting is used to avoid the deeper angles of low-altitude daylight penetration. This is a crucial detail, especially for the west façade which will face the setting sun almost every day of the year. Refer to Building Façade Design (Electrical Drawing E-04, Page 137) for full product (paint properties, solar transmittance) and tilt program details.

However, the described annual tilt program is catered to days with moderately clear skies. To account for cloudy days where tilt is not necessary, the horizontal blind system is fully integrated with a climate control program connected to incoming data from a local weather station. The same climate control program is used for the operable
window controls/automation of the double skin façade. For example, on a heavily overcast day, the station will detect a general illuminance of less than 10,000 lux. This measurement will keep the blinds horizontal to maximize daylight harvesting. Those particular weather condition will not cause occupant discomfort from direct daylight, and tilting the blinds becomes unnecessary. The control system also includes a wall switch control so that an occupant or building facility manager can manually override the tilt program in zones. The horizontal blinds can be dismantled from the carrier system easily for cleaning and maintenance. More information and diagrams pertaining to climate control program connected to a local weather station, refer to Building Management System (Electrical Drawing E-05, Page 138).

As for the east façade, WAREMA Dual Bracket Roller Blinds provide the option of two roller curtains. The motor system options are manually controlled from a wall switch. The first fabric layer is sheer and maintains views while diffusing direct daylight (not as well as the horizontal blinds). The second layer is a black out option for video conferencing or total privacy. It is made of 100% polyester (PVC-free) and polyurethane finish. Manual roller blinds are used for conference and video conferencing rooms.

Figure 9 – Spandrel with Insulation Wall Composition

5.3 NORTH & EAST STRATEGY
The north and east façades receive significantly less solar radiation due to the sun’s path. In order to optimize the other two façades, Genesis Design created a wall composition with thermal properties corresponding to climate zone 5A in reference to ASHRAE 90.1-2010 Table 5.5-5. Fenestration assemblies can have a U-value no higher than 0.35 for nonmetal framing with 40% vertical glazing or less. Overall, the Boylston Street High Rise’s complete, cohesive aesthetic played an equal part in its design.

6.0 POWER GENERATION
While on-site power generation is important for reducing the building’s carbon emissions, its value reaches far beyond that. Having such technologies will positively affect the building’s image as an environmentally-conscious urban icon, inspire its user’s sustainability education, and increase its financial worth. Publicly incorporating power generation technologies in a dense city creates an influence on the building’s occupants and the surrounding community to do the same. A large variety of energy generation technologies were considered in designing the Boylston Street High Rise. Some were dismissed as ineffective for this particular site’s conditions. A detailed outline of the energy systems considered can also be found in the Electrical Decision Matrix (Electrical Supporting Document A, Page 124). As a whole, the photovoltaic system includes 1,600 panels with some integrated with the façade and some on the building’s roof. The system generates approximately 342 MWH per year which is enough to supplement 73.65% of the building’s annual receptacle loads or 6.10% of the building’s total energy demand. The system is estimated to pay itself back in 9.2 years with incentives factored in. Six inverters (one for each PV zone) feed electrical energy directly into the building’s main distribution system. Any PV energy that is not used by the building loads can be sold back to the public grid for a net metering profit.

6.1 FAÇADE-INTEGRATED PV
As demonstrated in the Ecotect calculation in Figure 2, the building’s south and west double skin façades capture the most solar radiation. Due to this, these façade surfaces hold the largest opportunity for photovoltaic energy generation. However, these areas are also just as crucial in providing daylighting into the office spaces. Since daylighting reduces the energy required by the electrical lighting system, the electrical team concluded that PV implementation should avoid the
blocking of any useful daylight, as that would be contradictory. PVs cover the dropped ceiling and raised access floor details.

Figure 10 – PVs Covering Dropped Ceiling and RAF Details

A variety of geometries were considered for this design. Single-axis tracking PV panels (Colt Shadovoltaics) within the double skin were omitted because the tilting carrier system would make it very difficult to avoid shadowing on the panels from mullions and other panels. This particular type of technology would need to be imported from Europe which would increase the system cost too heavily. Fixed-tilt PV panels were also omitted. This configuration would require the panels to extend out beyond the original façade in an accordion style which would significantly shade parts of the interior, compromising daylight harvesting. Fixed-tilt PV panels did not settle with Genesis Design aesthetically or functionally with the double skin façades. To avoid these compromises, we arrived at a solution that would keep the façade PV panel placement out of the way of useful daylighting and allow the double skin façade to fully function. Our solution utilizes vertically-oriented PV panels, as seen in Figure 11. At two rows per floor, the array will range from the eighth floor level up to the roof. Arrays below the eight floor were shadowed too often but are made of replica spandrel glass to give the appearance of continuous, uniform façade. This makes room for 20 rows of PV panels, totaling 720 panels on the South façade and 440 on the West. Each of these 72-cell monocristalline panels have an efficiency of 19.45% and produce 238W when in direct sunlight. Although it is fact that vertical PV panels produce around 65% of what 35° fixed-tilt (optimal tilt for Boston) panels do, this orientation allows over a thousand panels to exist without obstructing usable daylighting.

Figure 11 – South-West Corner Façade System Render

On each floor, the lower panels start at floor level and extend up 32” above it. The upper panels are placed at the ceiling plenum level. Placement in these two elevations ensures that the panels do not obstruct “useful” daylight. Genesis Design had to carefully consider the compromises imposed by this design to determine whether or not the façade-integrated PVs would be cost effective. The shading from neighboring buildings, as previously discussed cuts photovoltaic production by 26% on the South façade and 2% on the West façade. This is on top of the 35% reduction caused by the vertical orientation (as opposed to optimally-tilted 35° panels). With Boston electricity rates and federal and state incentives considered, it was found that the South façade PVs will pay themselves back in 11.9 years, 8.8 years for the West façade. Although this payback is not as quick as the rooftop PV zones, it is still productive enough to justify a system with a life expectancy of at least 25 years.

6.2 ROOFTOP & PENTHOUSE PV

On the building’s roof and penthouse, PV panels can be tilted more freely since they do not compromise daylight harvesting. This region is also higher in elevation, which reduces the amount of shading by other buildings. These panels are wider than the façade-integrated panels; with an efficiency of 19.32% each has 96 cells and produces 315W in direct daylight. Shading diagrams for the four roof zones of PV panels is found in Photovoltaic Diagrams.
These arrays, totaling 440 panels, have an average payback period of about 6.1 years. The rooftop and penthouse region is undoubtedly the best area on the building’s surface for PV power production per unit area. As stated earlier, the optimal tilt angle for South-facing PV panels at Boston’s latitude is 35°. It is important to also consider self-shading of panels. On horizontal surfaces, more space is required for larger tilt angles in order to avoid panel self-shading. For example, the South region of the roof (at penthouse level) has about 37 feet of space in front of it, which would fit 2 rows of panels tilted at 35°. With a 10° tilt, the same space would instead fit 4 rows, doubling the size of the array but reducing each panel’s production by about 7%. This 10° tilt was specified for both the south roof and the penthouse roof. At the small cost of 7% production, this specification allowed twice as any panels in these areas, increasing the size of the building’s overall PV system by 10.4%. These space calculations accounted for a 5’ setback for maintenance on the roof surfaces. The penthouse is about 48 feet tall, creating space on its West and South exterior walls for two more PV arrays. Since the sun in Boston will not exceed an altitude of 71°, it is more manageable to achieve the optimal 35° tilt on these vertical surfaces. Four rows of 35° panels were specified for the penthouse south and west walls, effectively adding 128 more panels to the overall PV system.

7.0 POWER REDUCTION

7.1 REGENERATIVE ELEVATORS & ESCALATORS

The configuration of elevator banks in the Boylston Street High Rise is largely a function of its height. One bank, made up of 8 elevators, at the building core is enough to serve the 14 office floors with reasonable wait time, load factors, and total trip time for busy high-end financial service and office occupation. One freight elevator is also employed to move goods and equipment throughout the building. The initial identification card swipe at the security turnstiles on the second floor office entrance lobby with paired with an elevator destination control system. An algorithm is used to group office workers going to the same or adjacent floors from their identification cards, therefore saving an extensive amount of electricity use per year. A display panel adjacent to each elevator will indicate which floors it will be only be traveling to. The system uses the building’s LAN to monitor and relay performance, as well as connect to the BMS through an OPC server.

The Boylston Street High Rise utilizes machine room-less elevators where the engine, governor, and controller mechanism are housed within the hoist way itself. This decision saved construction costs and space requirements of a typical machine room. The flat, polyurethane-coated steel belt, which is significantly thinner than steel cables, permits a smaller, flatter
sheave mechanism. Additionally, through the emergency service corridor on Level 1, the elevator service vestibule is adjacent to the bank where elevator keys are located for firefighters in the case of an emergency. The elevators specified utilize a regenerative drive system. When an elevator cab is descending with weight (or ascending while empty), it will generate AC electrical energy to return to the building's power distribution. **Regenerative elevators will offset the total energy drawn by the elevators, effectively reducing the annual electricity bill by 2.83%.**

In a similar technology, the Boylston Street High Rise utilizes a regenerative solution for the downward traveling escalators that will be extensively used throughout the day in the new Prudential Entrance and food hall lobby. Brake resistors that normally generate wasted heat are replaced by regenerative drives that capture the energy and fed it back to the building’s power grid. On the other side, both escalators in the office lobby entrance with peak and nonpeak usage intervals will use a reduced stand-by speed when not in use to save energy consumption. A pressure sensitive piezo contact mat under the escalator detects approaching passengers and powers the escalator gradually back to full speed. See the Regenerative Elevator & Escalator (Electrical Supporting Document I, Page 133) for specifications and calculations.

### 7.2 DAYLIGHT & OCCUPANCY SENSORS

Genesis Design’s electrical team did an in depth analysis of all code requirements set out by ASHRAE 90.1-2010 for types of lighting and occupancy controls needed for various space types. Refer to the Fixture Controls Narrative (Electrical Supporting Document F, Page 129) for full descriptions. **Genesis Design prioritized the integrated design strategy of interior daylight harvesting to reduce the need for electric lighting. The final system design saved a substantial 13.27% in electricity usage and amounted to $92,257 in savings per year.** In today’s building industry, the efficiency of equipment is improving, but proliferation of auxiliary equipment and receptacles loads is increasing overall energy consumption. A desktop computer and monitor draws approximately 120 W of power even when idle and multiplied by the number of work stations in a high end financial firm, the energy usage skyrockets. By using smart power strips with built in occupancy sensors to go into power sleep mode after a specified period of time of inactivity, even more energy can be saved.

![Daylight Control Zones](image1)

**Figure 14 – Daylight Control Zones**

### 7.3 INTEGRATED BMS

Genesis Design understands that the key to a truly integrative, sustainable design and the future of the building industry is implementation of an intelligent building management system that consolidates all aspects of a building’s control into one, simplified platform. The advantages include:

1. Optimizing building performance through maximized energy efficiency
2. Automated monitoring and control through a single, manageable platform
3. Strategic control of building occupant safety and reduced risk
4. More informed decision making for facility manager and owner
5. Lower lifecycle costs and improved return on investment

Genesis Design decided to adopt Honeywell’s Enterprise Buildings Integrator as the Boylston Street High Rise’s
ELECTRICAL NARRATIVE

comprehensive, network-based solution for building automation and management. It has the ability to incorporate all the industries open standards (BACnet, LonWORKS, OPC, and Modbus) into a single-point of access for the building facility manager. This allows the building to be flexible for future planning in terms of system expansion and life-cycle savings. See Building Management System (Electrical Drawing E05, Page 138) for details of all devices on the BMS.

7.4 THIN CLIENT COMPUTERS

<table>
<thead>
<tr>
<th></th>
<th>Traditional Computers</th>
<th>Virtual Computers</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Computers/Floor</strong></td>
<td>189 machines</td>
<td>9 machines</td>
</tr>
<tr>
<td><strong>Average Consumption/Computer</strong></td>
<td>120 W</td>
<td>120 W</td>
</tr>
<tr>
<td><strong>Hours/Year Operating</strong></td>
<td>2160 hours</td>
<td>2160 hours</td>
</tr>
<tr>
<td><strong>Energy Consumption</strong></td>
<td>48,989 kWh</td>
<td>36,677 kWh/floor</td>
</tr>
</tbody>
</table>

Figure 15 – Thin Client Energy Savings for One Floor

With 14 stories of office space and 189 computers per story, the vast majority of the building's receptacle power is consumed by computers. Considering this, Genesis Design chose to implement virtual computing in these spaces. Virtual computer systems utilize large central servers with CPU cores which can be utilized by multiple workstations at the same time. These “thin client” workstations do not have local processors or disk storage like a traditional desktop computers. Instead, they consist of only an interface for the user to access the central servers. Using a sizing guide created by VMware, it was determined that 12 workstations can be implemented per server. This configuration averages 89.8 Watts per workstation, which includes the twelfth portion of the server plus the thin client consumption. Since traditional desktop computers consume about 120 Watts each, the virtual computer option saves each office floor 25.13% of the baseline computer energy consumption. Figure 15 above demonstrates the energy savings for a typical office floor. These savings are also represented in Building Energy Usage (Electrical Supporting Document H, Page 131).

8.0 ELECTRICAL SYSTEM

The bathtub design refers to rooms on the bottom two levels of the building (Green Level and Green Mezzanine) which may be subject to water infiltration in the event of a severe storm or flooding. Mechanical equipment housed within these rooms on the floors which are susceptible to water damage will be protected from the damaging effects of water on electrical components. The existing mechanical room along the east wall and mechanical room GL07 are protected featuring doors which are raised off the floor and have a sealing construction similar to those inside a ship. These doors can stop water from infiltrating the rooms and causing damage to electrical and mechanical equipment.

8.1 POWER DISTRIBUTION

Utility power for the Boylston Street High Rise is supplied by both NSTAR and National Grid. It is connected via underground conductors which enter at the Green Mezzanine level of the building’s Northwest corner. Two medium voltage splice rooms (GM16 and GM09) are located at this level. From GM16, a concrete-encased electric line extends up to the third floor, opening to the transformer vault 0310. Here, 13.3 kV AC power is supplied and stepped down to 480/277V with parallel 2500 kVA transformers. The building’s main electric
room 0312 sits adjacent to the transformer vault on the West side of the 3rd floor. A detailed layout of these main electrical spaces can be found in Electrical Drawing E-1, along with a riser diagram. The main switchgear in room 0312 splits the 480V conductors in three different directions. Two are equipment panels; MDP-1 is in 0312 and feeds the lower building equipment, including the lower air handling units (0113), all lower elevators, and the turnpike and garage exhaust fans. The other equipment panel, MDP-2, is located in the building’s penthouse and serves the 9 high rise elevators, as well as the penthouse AHU’s and chiller. This panel also serves the four automatic transfer switches, which will be discussed in the following Emergency Power section. The 6 inverters for the building’s photovoltaic arrays, which are located in the penthouse, feed 480V AC power into panel DP-PV. This panel is connected to MDP-2 so that all energy produced by the photovoltaic array will feed directly into the main power distribution. The electrical team saw this as the best decision, since it ensures that all PV energy will either be used by the building or sold back to the utility grid, and nothing is wasted. It also eliminates the need for battery storage and additional conductors. The third set of conductors from the main switchgear connects to the Square D main busway by Schneider Electric. This busway stretches from the 1st floor to the penthouse along the building’s central core. It feeds the lighting panel for each floor, which branch to feed transformers for each floor’s 208/120V receptacle panels.

8.2 EMERGENCY SYSTEM

There are four automatic transfer switches in the building’s penthouse. The largest and most important one, ATS-EM, is designated for the emergency power system. This switch feeds a special busway which connects to an emergency panel on every floor. These panels will serve a portion of the lighting on every floor, as well as emergency exit signs and the fire alarm system. Additionally, exhaust fans, fire pumps, and domestic water pumps are backed by emergency power. One of the penthouse air handling units is included at partial load (only fan loads) in order to provide ventilation for the building’s server rooms, which are covered by the other three switches. Due to the financial nature of the tenants’ jobs, a full power outage in the Boylston Street High Rise would be detrimental to their work. For this reason, the three other transfer switches serve the critical load panels on each floor. At 208/120V, the critical backup system allows for 10% of receptacles on each floor to be designated to critical power. These will primarily serve the telecommunication server rooms, combined with uninterruptible power supplies to ensure that the main computer servers never lose power. With their main servers backed to generator power, the financial firms will not have to worry about their work being lost due to any type of power outage.

In the event of a power outage, uninterruptible power supplies will be the first responders to sustain the electricity demand. Because of the large range of sizes available for UPS’s, Genesis Design chose to have them on every floor rather than one large one. In this configuration, a UPS failure will compromise a single floor rather than the whole building, making for a more resilient design. The UPS’s will give an adequate amount of time to get the two rooftop Cummins diesel generators started. These generators are sized to support the continuous emergency and critical loads, with enough fuel to do so for 48 hours. Electrical Drawing E-02 gives further insight on the generators system.

8.3 VOLTAGE DROP & SHORT CIRCUIT

According to ASHRAE 90.1-2010, feeders and branch circuit conductors shall be sized for a maximum voltage drop of 2% and 3% respectively at design load. Achieving those percentages is crucial to having an effective voltage level for building equipment to perform correctly. Short Circuit and Voltage Drop (Electrical Supporting Document I, Page 132) outline voltage drop calculations for the building’s major panels, which all fall under 2%. The document also includes a short circuit analysis. This analysis is an important item in selective coordination for the electrical system, which ensures that a short circuit won’t affect the continuity of upstream equipment.

9.0 LIGHTING DESIGN

The United States Energy Information Administration shows that lighting loads account for approximately 35-
ELECTRICAL NARRATIVE

40% of all electricity consumption in a typical office building. In accordance with the electrical team’s Sustainability project goals, it is imperative that the Genesis Design electrical team look into lighting systems that are efficient and controls systems that manage lighting well to pay large dividends.

9.1 TYPICAL TENANT OFFICE

Figure 17 – Original vs. Genesis Design Office Floor

There are many pros and cons associated with open office spaces. Cons include lack of privacy, sickness spread in close quarters, and the feeling of stress. However, Genesis Design combats the cons to attract tenants to the Boylston Street High Rise. In terms of electrical design, by creating opportunities to bring daylight into the interior space, higher occupant comfort and happiness is achieved while also reducing lighting and cooling loads. Genesis Design’s suggested office strategy is to place private offices around the core to allow for the workstations to receive the most useful daylight (reducing electrical lighting energy used), and while private office users are out of the room, the most electric light also can be saved. The office lighting is comprised of low general ambient downlights and workstation task lights. Several daylight zones were implemented. Cooper Lighting’s Neoray recessed linear LED downlight was chosen for flexibility for installation and compatibility with FifthLight DALI system that combines daylight sensing, occupancy detection, and temperature measure to the BMS. Refer to Office Comparison & Zones (Electrical Drawing E06, Page 139) and Office Lighting & Power (Electrical Drawing E07, Page 140) for details on the open office lighting design. Genesis Design’s open office lighting uses only 47% of the LPD allowance given by ASHRAE 90.1-2010.

9.2 PUBLIC PLAZA

The Boylston Street’s public plaza provides the greatest opportunity for public outreach as Boston has been working to increase and improve their public spaces through the Green Initiative Plan. From an electrical standpoint, the final design includes several innovative features from implementing a wind tree turbine, interactive touch screen kiosks, environment responsive landscape/seating design, smart streetlight poles combined with small cell technology and other unique, code compliant exterior lighting. For all of the integrative parts of the plaza design, reference Plaza Drawing (Integration Drawing, Page 38).

Figure 18 – Render of Office Space Lighting

Figure 19 – Ecotect Annual Solar Radiation and Site Wind Rose

After the initial solar and wind analysis, it was found that the plaza would be in shade for majority of the year and have strong winds coming from the west. NewWind is a power generation system comprised of 37 Aeroleafs® (micro-turbines where electrical current is generated by a magnetic assembly rotated by a blade over stator) in a tree shape. Activated by even slight air circulation, up to an estimated 75 kWh can be generated per day. The wind tree turbines power the GFCI receptacles within the public outdoor seating that occupants will have free
access to for powering their electronic devices. Additionally supporting the electronic devices, the electrical team researched and suggest that the Boylston Street High Rise be the first in Boston to start implementing smart streetlight poles. Los Angeles was the world’s first city to deploy Philips’ SmartPole with fully built in 4G LTE wireless technology from Ericsson. One of the latest Internet of Things (IoT) innovations, SmartPole provides double benefit to citizens: high quality, energy efficient LED public lighting and improved network performance in the dense urban area. Cellular traffic is expected to grow 9 times by 2020, according to Ericsson’s Mobility Report, and current telecom infrastructures will struggle to respond to this demand. Space in the SmartPole can be rented to mobile operators. Three touch-screen kiosks were specified to fully educate the public in all the innovative features and systems that make the Boylston Street High Rise a benchmark to sustainable building design. The programmed screens also provide options to learn about the all the plaza’s features, the Prudential Center Complex, and the city of Boston’s major landmarks, surrounding businesses, and activities available. The kiosks will also make an initial debut during construction to better mitigate the negative aspects associated with site’s noisy activity and pedestrian pathway changes.

Lastly, to make the plaza as useful and attractive to the public throughout the year despite the less ideal climatic conditions, the landscape and seating are designed as “nooks” for safety and comfort through enclosures made from reinforced concrete planters, bollards, and evergreen shrubbery to break wind patterns and provide protection from vehicular traffic. The plaza’s lighting design complement the masonry patterns that subliminally suggest areas to walk versus lounge. The lighting is controlled via timeclock programming to turn on when sufficient daylight is no longer available and turn off between the hours of midnight and 6:00 AM. The plaza falls under the definition of Exterior Lighting Zone 4 for high activity commercial districts in a major metropolitan area, and **Genesis Design’s plaza efficient lighting power is well below the 50% ASHRAE baseline at 27%**.

### 9.3 OFFICE LOBBY

![Figure 20 – Public Plaza Nighttime Render & Kiosk](image)

![Figure 21 – Original (left) vs. Genesis Design Office Lobby (right)](image)

The office lobby is a unique space in the Boylston Street High Rise. Taking advantage of the architecture in place, the decision to replace the wall materials with a Massachusetts premium reclaimed wood company’s panels, Jarmak Corporation, led to a more intimate feeling space. The original dropped ceiling was a bland perforated metal and was replaced with a more dynamic geometric pattern still using perforated metal hung with aircraft cables. At the edges of the triangles, linear LEDs will uplight the ceiling and light will spill outwards giving the ceiling a floating appear. Recessed linear wall washing on the sides will provide vertical illuminance and highlight the texture of the reclaimed wood. Linear LEDs will be embedded in the staircase and escalators for pathway lighting.

### 9.4 RETAIL SPACES

Genesis Design’s strategy for lighting design in retail spaces was to provide specific general and perimeter lighting fixtures. Establishment of a uniform base illuminance level of around 300-500 lux and separate zones for circulation areas can easily result in energy use reduction. When staff members need to perform daily tasks such as cleaning and restocking, general lighting can be turned on at a dimmed level while merchandise lighting is minimalized. Perimeter lighting is the wall-washing of vertical boundary surfaces and makes spaces feel larger. Overall, the combination helps create a sense
of well-being and visual comfort in the customer which results in longer visits to the store. **Genesis Design’s integrated design decision was to go as far as to provide core and shell construction with MEP rough-ins for all rentable retail space.** The electrical team calculated the highest potential lighting power allowance and sized the floor panels to meet those loads. The core and shell construction of retail spaces will be finished 6 months early, allowing the renting store to hire a third party to finish the space before the Boylston Street High Rise’s turnover date.

### 9.5 PARKING GARAGE

With an ASHRAE baseline lighting power density of only 0.19 Watts per square foot, achieving a parking garage lighting design under 50% of this requirement called for highly efficient fixtures. Another challenge was the shallow 8.5-foot ceiling height, which limits spacing. As a solution, Genesis Design specified Evolve™ LED fixtures by GE. At only 35 watts, each fixture has an output of 4,220 lumens. The wide, diffuse optic allows for 20’ spacing despite the low ceiling. With 82 and 95 fixtures in the Green and Green Mezzanine levels respectively, **both spaces achieved less than 45% of the baseline power density.** See **Electrical Drawing E-08** for more details.

### 11.0 CONCLUSION

The Genesis Design electrical team strived to create highly functional and pleasant spaces while holding energy efficiency to a very high importance in all elements of design. The team collaborated with the other Genesis Design disciplines using Integrated Project Delivery (IPD) with Building Information Modeling (BIM). In lighting and passive daylight design, a 67.3% reduction in energy consumption was achieved through highly efficient LED lighting. Further energy reduction was accomplished through regenerative elevators and escalators as well as a virtual computing system for the 14 office stories. Building-automated daylight blinds work with the double skin façade design to assist natural convection and avoid glare and daylight penetration issues in the workspaces. The 414 kW photovoltaic system has an annual production of over 342 MWh, which significantly offsets the building’s daily energy consumption. The electrical redundancy configuration and 48-hour emergency backup system ensure a resilient structure to protect life-critical systems as well as tenants’ work data.
## ELECTRICAL DECISION MATRIX

Genesis Design’s three design drivers (Sustainability, Resiliency, Integration) and project goals provide the main criteria categories. A weighted value of 1-5 is assigned to each of the detailed project goals for each system category, and then each specific option within the category is also assigned a rank of 1-5. After multiplication and summation, the total score provides quantitative representation for decision justification, especially in the case of dispute resolution. High total scores resulted in the pursuit of further research and calculation justification.

### GENESIS DESIGN DRIVERS

<table>
<thead>
<tr>
<th>SYSTEM CATEGORY</th>
<th>SPECIFIC OPTIONS WITHIN SYSTEM CATEGORY</th>
<th>ENERGY PREDICTION</th>
<th>SUSTAINABILITY</th>
<th>RESILIENCY</th>
<th>INTEGRATION</th>
<th>WEIGHT</th>
</tr>
</thead>
<tbody>
<tr>
<td>ELECTRICAL</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Energy</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Solar, PV</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wind</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fuel Cell</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hydroelectric</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>DC/AC Inverters</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Biomas</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ReGen Elevator</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Electric Elevator</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Green Escalator</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>WEIGHT</td>
<td></td>
<td>1 5 1 1 3 5</td>
<td>1 4 1 2 3</td>
<td>5 4 5 5 5</td>
<td>135</td>
<td>MAYBE</td>
</tr>
<tr>
<td>Building</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Integrated PVs</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Horizontal TVs</td>
<td></td>
<td>2 3 1 2 2</td>
<td>1 3 1 1 2</td>
<td>3 3 4 1 2</td>
<td>94</td>
<td>MAYBE</td>
</tr>
<tr>
<td>HVAC</td>
<td></td>
<td>2 3 2 1 1</td>
<td>1 2 1 2 2</td>
<td>3 3 3 1 2</td>
<td>74</td>
<td>NO</td>
</tr>
<tr>
<td>Vertical PVs</td>
<td></td>
<td>2 3 1 4 2</td>
<td>1 2 1 2 2</td>
<td>3 3 3 1 2</td>
<td>175</td>
<td>YES</td>
</tr>
<tr>
<td>Tracking PVs</td>
<td></td>
<td>2 3 4 1 2</td>
<td>1 2 1 2 2</td>
<td>3 3 3 1 2</td>
<td>137</td>
<td>MAYBE</td>
</tr>
<tr>
<td>Fixed Tilt PVs</td>
<td></td>
<td>2 3 4 1 3</td>
<td>1 2 1 2 2</td>
<td>3 3 3 1 2</td>
<td>139</td>
<td>MAYBE</td>
</tr>
<tr>
<td>WEIGHT</td>
<td></td>
<td>1 5 1 3 1 2</td>
<td>1 3 1 1 2</td>
<td>3 3 4 1 2</td>
<td>135</td>
<td>MAYBE</td>
</tr>
<tr>
<td>DAYLIGHT SHADING</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Horizontal Louvers</td>
<td></td>
<td>5 2 5 4 5</td>
<td>1 4 3 3 4</td>
<td>5 3 3 4 3</td>
<td>175</td>
<td>YES</td>
</tr>
<tr>
<td>Light Shelves</td>
<td></td>
<td>2 3 4 1 4</td>
<td>1 2 1 2 2</td>
<td>3 3 3 1 2</td>
<td>126</td>
<td>MAYBE</td>
</tr>
<tr>
<td>Mesh Screen</td>
<td></td>
<td>4 1 3 3 3</td>
<td>1 2 1 2 2</td>
<td>3 3 3 1 2</td>
<td>159</td>
<td>MAYBE</td>
</tr>
<tr>
<td>Sensor Roller Shades</td>
<td></td>
<td>2 3 1 3 3</td>
<td>1 2 1 2 2</td>
<td>3 3 3 1 2</td>
<td>129</td>
<td>MAYBE</td>
</tr>
<tr>
<td>Electrophotometric</td>
<td></td>
<td>3 1 4 3 3</td>
<td>1 2 1 2 2</td>
<td>3 3 3 1 2</td>
<td>117</td>
<td>MAYBE</td>
</tr>
<tr>
<td>WEIGHT</td>
<td></td>
<td>1 5 1 3 1 2</td>
<td>1 3 1 1 2</td>
<td>3 3 4 1 2</td>
<td>135</td>
<td>MAYBE</td>
</tr>
<tr>
<td>ELECTRICAL LIGHTING</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>LED Dali Lighting</td>
<td></td>
<td>5 1 3 2 4</td>
<td>1 5 2 1 1</td>
<td>5 4 2 4 3</td>
<td>163</td>
<td>YES</td>
</tr>
<tr>
<td>DE Power Lighting</td>
<td></td>
<td>4 1 3 3 4</td>
<td>1 2 1 2 2</td>
<td>3 3 3 1 2</td>
<td>116</td>
<td>MAYBE</td>
</tr>
<tr>
<td>POE Lighting</td>
<td></td>
<td>4 1 3 3 4</td>
<td>1 2 1 2 2</td>
<td>3 3 3 1 2</td>
<td>136</td>
<td>MAYBE</td>
</tr>
<tr>
<td>AMBIENT/TASK MODEL</td>
<td></td>
<td>4 1 4 3 4</td>
<td>1 5 3 1 1</td>
<td>5 4 3 4 3</td>
<td>170</td>
<td>YES</td>
</tr>
</tbody>
</table>

### System Category | Reasons for Decision | Explanation of Decisions

#### Electrical Energy
- **Site location, return on investment, practicality**
  - Through the preliminary Ecotect analysis, the Electrical team distinguished the potential for solar power as a renewable energy source. The roof, south, and west facades were the most promising for implementation. Wind energy is used in the public plaza in a small scale with the specification of the "wind tree turbine." Hydrogen fuel cells were considered for their powerful renewable energy source, but the cost or storage, transport, and system in general as well as plausibility for sole application of the Boylston Street High Rise made it impractical. Hydroelectricity was considered for the site’s proximity to the Charles River. Biomass was also suggested in conjunction with the city’s sewer utilities. However, the practicality, construction, maintenance, and cost outweighed the two systems’ advantages. Use of piezoelectricity technology did not achieve enough energy return to meet lifecycle cost goals. Lastly, regenerative elevator and green escalators were both specified for their heavy return on energy savings.

#### Building Integrated Photovoltaics
- **Least amount of daylight obstruction, expense, difficulty for integration**
  - Genesis Design’s electrical team wanted to utilize photovoltaics on the Boylston Street High Rise and looked into many innovative techniques. Firstly, Colt’s Shadowovoltaics’ system would act as a diffusion horizontal louvers within the double skin, but the issues with nullion shadowing and tracking mechanisms made the solution extremely complicated to the point of discard. Price quotes from Colt were also expensive. A second innovative solution was implementing ICSF, which are glass prisms concentrating solar rays onto a PV cell. The system array also diffuses direct glare. However, the cost and risk of unknown problems with the new emerging technology lead Genesis Design to suggest potential implementation on the south façade in break/dining areas windows. Although tracking PVs generally produce the most power, they present problems for our facades and roof. The range of tilt angles make it very difficult to avoid shadowing on the façade from mullions and other panels. On the façade, tilting PVs will block useful daylight which could be used better to supplement lighting. Vertical PVs have less electricity production than tilted and tracking PVs. However, they are ideal for the building’s South and West facades because they do not block any utilizable daylight for lighting. These can be implemented continuously across the façade at the floor and structure height.

#### Daylight Shading
- **Façade Integration, maintaining views, eliminated unwanted solar glare**
  - A variety of solar glare and shading techniques were considered. Horizontal louvers in the double skin won in comparison through multiple functions of absorbing heat for natural convention, maintaining views to the outdoors, and eliminating glare through an automatic control mechanism to tilt the shades at appropriate times. Light shelves did not block unwanted glare throughout the year. A mesh screen did not help function of the double skin. Electrophotometric was impractical for cost. Photo-sensor programmed roller shades were deemed the best solution for the east façade. These can be implemented continuously across the façade at the floor and structure height.

#### Electrical Lighting
- **Energy efficiency, controls implementation, flexibility**
  - DC powered and POE system are ways in which some commercial facilities believe they can save energy on lighting. Low voltage gives less options for manufacturers, and therefore less flexibility in the future. With POE, the additional amount of patch panels space in the data closet and amount of cat 5 cables that can hold maximum 60W of fixtures was concerning in terms of utilization and cost. Overall, LED lighting with smart DALI controls made the most sense for tenant control, turnover, and energy efficiency savings.
PRUDENTIAL CENTER COMPLEX

The Prudential Center Complex contains three skyscrapers. The Prudential Tower is 749’ tall and the second tallest building in Boston. Also, 111 Huntington Avenue is 549’ tall and the ninth tallest building. Lastly, 101 Huntington Avenue is 336’ tall. Other than those three skyscrapers, the other surrounding buildings do not significantly affect the solar radiation falling on the Boylston Street High Rise. The Boylston Street High Rise’s north façade faces 19 degrees west of true North.

ECOTECT SHADOW ANALYSIS

Ecotect’s shadow analysis can be run on any day of the year. During the summer, there is minimal Prudential Tower shadowing on the south façade’s bottom left corner from 11:15 AM – 12:15 PM. During the spring and fall, the Prudential Tower shades the whole building brief around 11:30 AM, and the south façade from 10:30 AM – 12:15 PM. In the winter, the Prudential Tower shades the whole building at 11:15 PM, and the south façade from 10:00 AM to 12:30 PM. These shadowing patterns impacted the solar photovoltaic and daylight control zones.

ECOTECT FACADE SOLAR ANALYSIS

The North façade receives the largest amount of diffuse and the least amount of direct solar radiation, therefore open office workstations are going to be concentrate along it. The West and South façade are concerning due to the large amount of heat gain, therefore implementing a double skin façade was decided. Lastly, the East façade will only receive direct daylight in the morning, making it an ideal location for non-daylight essential rooms.

ECOTECT PLAZA SOLAR ANALYSIS

Unfortunately, the plaza being located directly in front of the north façade of the building means it will be in shadow for 75% of the year. Paired with the wind traveling in from the west, Genesis Design took the time to come up with designs that would make the plaza user friendly despite the less than ideal environmental and temperature conditions.

**Chart 1 – Double Skin Façade Diagram**

<table>
<thead>
<tr>
<th></th>
<th>PLAZA</th>
<th>NORTH</th>
<th>SOUTH</th>
<th>EAST</th>
<th>WEST</th>
</tr>
</thead>
<tbody>
<tr>
<td>ANNUAL TOTAL RADIATION (WH/M²)</td>
<td>1.85e+06</td>
<td>1.42e+06</td>
<td>2.27e+06</td>
<td>1.37e+06</td>
<td>2.56e+06</td>
</tr>
<tr>
<td>ANNUAL TOTAL DIRECT RADIATION (WH/M²)</td>
<td>7.99e+05</td>
<td>1.22e+05</td>
<td>1.21e+06</td>
<td>3.02e+05</td>
<td>1.29e+06</td>
</tr>
<tr>
<td>ANNUAL TOTAL DIFFUSE RADIATION (WH/M²)</td>
<td>1.05e+06</td>
<td>1.29e+06</td>
<td>1.06e+06</td>
<td>1.07e+06</td>
<td>1.27e+06</td>
</tr>
<tr>
<td>ANNUAL TOTAL SUNLIGHT HOURS (HRS)</td>
<td>1052</td>
<td>764</td>
<td>2010</td>
<td>723</td>
<td>2363</td>
</tr>
</tbody>
</table>

*PERCENTAGE SHADING

75% 82% 54% 81% 45%
6 ZONES OF PHOTOVOLTAIC PANELS
Refer to Electrical Drawing E-03 for larger versions of the altitude/azimuth shading graphs.

West PH Wall
56 Panels

South PH Wall
72 Panels

PH Roof
184 Panels

South Façade
756 Panels

West Façade
462 Panels

South Roof
128 Panels

PH Roof Production (KWH)

South Façade
West Façade
South Roof
PH Roof
PH S Wall
PH W Wall
TOTAL

JANUARY 6,629 4,890 1,523 2,347 964 685 17,048
FEBRUARY 8,416 5,946 2,147 3,715 1,679 986 22,889
MARCH 12,958 7,269 3,797 5,505 2,298 1,236 32,113
APRIL 10,853 7,629 4,548 6,798 2,515 1,505 33,947
MAY 10,299 8,046 5,036 8,257 2,953 1,090 35,883
JUNE 9,646 8,134 5,605 8,271 2,808 1,763 36,227
JULY 10,309 8,105 5,857 8,618 3,031 1,751 37,673
AUGUST 11,606 8,495 5,138 7,774 2,834 1,706 37,602
SEPTEMBER 12,526 7,121 3,640 5,583 2,260 1,280 32,450
OCTOBER 8,793 6,592 2,282 4,311 1,915 1,045 24,331
NOVEMBER 5,751 4,271 1,440 2,223 873 611 15,106
DECEMBER 5,812 4,124 1,294 1,707 768 545 14,314

ANNUAL TOTAL 133,597 80,622 45,178 65,169 24,719 14,871 $42,157
COST $419,775 $255,505 $58,807 $142,034 $45,078 $43,228 $1,010,216
PAYBACK (YEARS) 11.9 8.8 6.3 5.8 5.2 7.8 9.2

Photovoltaic Energy Production by Zone (KWH)
The 17th and 5th floor office spaces were analyzed using 3D models, each with a single levitating office story. To ensure an accurate daylighting analysis, these models also included the geometry of the local surrounding buildings. A combination of AutoCAD, Sketchup and DAYSIM was used to achieve this.

**DAYLIGHT AUTONOMY STUDY**

Daylight Autonomy (DA) is a metric representing the percentage of occupied hours that a particular point exceeds a set illuminance value. In Electrical Supporting Document H these values were used to calculate energy savings from daylight harvesting. Useful Daylight Illuminance (UDI) is a similar metric which utilizes a range of illuminance values rather than a single threshold. The calculations were taken from a work plane 30” above the finished floor. Area calculations exclude the area of the building’s core. The lighting energy analysis in Electrical Supporting Document H includes a factor representing the percentage of each floor’s area to which Daylight Autonomy applies. For office floors 5-17, this percentage is 90.87%.

**DAYLIGHT BLINDS SYSTEM**

- 12” wide aluminum blinds vertically spaced at 9” hung inside the double skin assembly on the building’s South and West.
- Protection against direct daylight on the work plane to prevent visual glare and thermal discomfort.
- Automatic tilt adjustment via the BAS to protect against low-altitude sunlight.
- See Drawing E-04 for specific dimensions and tilt details.

**BLINDS CASE STUDY**

The 17th story office space was analyzed with zero ambient reflections to visualize direct daylight penetration. Both of these images are from 12:30 PM on November 15th with a clear sky:

Without blinds:
S & W direct daylight penetration

With blinds:
Work plane is shaded from direct daylight
<table>
<thead>
<tr>
<th>Type</th>
<th>Room</th>
<th>Product/Manufacturer</th>
<th>Description</th>
<th>Lamp</th>
<th>Dimming</th>
<th>Input Watts</th>
<th>Image</th>
<th>Additional Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>parking garage</td>
<td>GE Lighting: ECB-B-OA5D-S50-4-A-WHITE-DD1</td>
<td>Canopy light with drop lens, motion sensor, 5000K</td>
<td>LED</td>
<td>Dimming with Junction Box</td>
<td>35 W</td>
<td></td>
<td>area lighting</td>
</tr>
<tr>
<td>B</td>
<td>retail/utility</td>
<td>Indy Lighting: 5252-LF-3200-40-U-WH3-S</td>
<td>2'x2' recessed troffer, 4000K</td>
<td>LED</td>
<td>Step Dimming (33/66/100%)</td>
<td>36 W</td>
<td></td>
<td>general illumination</td>
</tr>
<tr>
<td>C</td>
<td>retail</td>
<td>Juno Lighting: 726LED-4K-WH-DIM</td>
<td>Wall wash/flood light line voltage track mounted, 4000K</td>
<td>LED</td>
<td>Dimming driver</td>
<td>35 W</td>
<td></td>
<td>perimeter lighting</td>
</tr>
<tr>
<td>D</td>
<td>plaza</td>
<td>Philips + Ericsson: Smartpole</td>
<td>Integrated 4G LTE wireless small cell technology with outdoor area/roadway lighting fixture</td>
<td>LED</td>
<td>n/a</td>
<td>88 W</td>
<td></td>
<td></td>
</tr>
<tr>
<td>E1</td>
<td>plaza</td>
<td>LED Linear: VarioLED OCEANOS 316/L-W840/510-IP68</td>
<td>1.25” In-ground linear LED in stainless steel mounting frame</td>
<td>LED</td>
<td>0-10V dimming</td>
<td>9.6 W/m</td>
<td></td>
<td>IP68 housing for permanent submersed installation, one-sided 5 m oilflex cable</td>
</tr>
<tr>
<td>E2</td>
<td>plaza</td>
<td>LED Linear: VarioLED OCEANOS 316/L-W840/1010-IP68</td>
<td>1.25” In-ground linear LED in stainless steel mounting frame</td>
<td>LED</td>
<td>0-10V dimming</td>
<td>9.6 W/m</td>
<td></td>
<td>IP68 housing for permanent submersed installation, one-sided 5 m oilflex cable</td>
</tr>
<tr>
<td>F</td>
<td>plaza</td>
<td>RAB Lighting: HBLED316A</td>
<td>Bulletshaped floodlight with reflector, NEMA 5Hx5V</td>
<td>LED</td>
<td>0-10V dimming</td>
<td>26 W</td>
<td></td>
<td>UL listed, wet location</td>
</tr>
<tr>
<td>G</td>
<td>open/private office</td>
<td>Conflux: YLCT</td>
<td>Adjustable task light, PIR occupancy sensor, freestanding base with powermat, 4000K</td>
<td>LED</td>
<td>Continuous dim to 10% maximum</td>
<td>9 W</td>
<td></td>
<td></td>
</tr>
<tr>
<td>H</td>
<td>open office</td>
<td>Cooper Lighting: 5233DR2-LS5-FTG-4-25LT-SI-EM</td>
<td>2”x4” recessed linear downlight with diffused lens</td>
<td>LED</td>
<td>Communicates with FifthLight DALI</td>
<td>9.25W/lf</td>
<td></td>
<td>*Maximum 64 devices on each DAU Bus</td>
</tr>
<tr>
<td>H1</td>
<td>open office</td>
<td>Cooper Lighting: FLY-MTS12-DAU</td>
<td>Combined daylight sensing, occupancy detection, temp measurement</td>
<td>n/a</td>
<td>FifthLight Multisensor</td>
<td>n/a</td>
<td></td>
<td>Measures 1,200 sq ft for daylighting and occupancy zones</td>
</tr>
<tr>
<td>I</td>
<td>corridor/elevator</td>
<td>Element Lighting: EASY-UH83540AN</td>
<td>4” LED downlight, adjustable 40 degrees, 3500K</td>
<td>LED</td>
<td>dimming driver, emergency mode</td>
<td>18W</td>
<td></td>
<td>Emergency housing with integrated battery back up</td>
</tr>
<tr>
<td>J</td>
<td>private office</td>
<td>Peerless Lighting BM82H_LH40/60_55H_U4_1P835</td>
<td>Direct/Indirect linear pendant</td>
<td>LED</td>
<td>dimming driver and occupancy sensor</td>
<td>44W</td>
<td></td>
<td></td>
</tr>
<tr>
<td>K</td>
<td>bathroom/utility</td>
<td>Indy Lighting: SD4BBD-12-27-2</td>
<td>4” downlight</td>
<td>LED</td>
<td>0-10V dimming</td>
<td>26 W</td>
<td></td>
<td></td>
</tr>
<tr>
<td>L</td>
<td>reception</td>
<td>Delray Lighting: KLP31-2-W-W30-D1</td>
<td>Decorative pendant</td>
<td>LED</td>
<td>0-10V dimmer</td>
<td>37W</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
### Type of Control

**Space Control**: Readily accessible local switch device to independently control the general lighting within the space.

**Programmable Timeclock**: Scheduled time-of-day operated control that turns lights off at specified times when typically unoccupied.

**Occupancy**: Turns ON lights automatically upon detection of motion. Turns lights OFF automatically after period of time area is vacated.

**Vacancy**: Turn ON lights manually. Turns lights OFF automatically after period of time area is vacated.

**Passive Infrared**: Detects motion from heat-emitting source within its field of view. Sensors have line of sight segmented lenses, and in order to see motion, a person must cross between two segments better for small enclosed spaces without partitions to block motion detection.

**Ultrasound**: Sensors produce low intensity, inaudible sound and detects changes in sound waves caused by small motions. They are volumetric in nature and are better for oddly shaped rooms.

**Manual Full On**: Manual full ON by local switch.

**Manual Partial On**: Manual partial ON by local switch to no more than 50% power.

**Automatic Full On**: Automatic full ON.

**Automatic Partial On**: Automatic partial ON no more than 50% power.

**Automatic Full Off**: Automatic full OFF after vacancy of 30 minutes or less. Also meets timeclock requirements.

**Automatic Partial Off**: Automatic reduction of lighting power to at least 50% after vacancy of 30 minutes or less. Only applicable to stairwells.

**Multi-level Lighting Control**: Controlled lighting shall have at least one control step between 30% and 70% for full lighting power in addition to all off.

**Multi-level Daylighting Control**: Photosensor to reduce lighting in response to available daylight. At least two levels between on and off (one between 50% and 70%, and another no greater than 35% of full power). Applies to side-light spaces greater than 250 square feet.

**Receptacle Control**: Automatically turns OFF at least 50% of receptacles in the space.

### Sensor Type

**Location Type**

<table>
<thead>
<tr>
<th>Sensor Type</th>
<th>Description</th>
<th>Code</th>
</tr>
</thead>
<tbody>
<tr>
<td>Space Type</td>
<td>Manual Full On</td>
<td>9.4.1</td>
</tr>
<tr>
<td></td>
<td>Manual Partial On</td>
<td>9.4.1</td>
</tr>
<tr>
<td></td>
<td>Automatic Full On</td>
<td>9.4.1</td>
</tr>
<tr>
<td></td>
<td>Automatic Partial On</td>
<td>9.4.1</td>
</tr>
<tr>
<td></td>
<td>Automatic Full Off</td>
<td>9.4.1</td>
</tr>
<tr>
<td></td>
<td>Automatic Partial Off</td>
<td>9.4.1</td>
</tr>
<tr>
<td></td>
<td>Multi-level Lighting Control</td>
<td>9.4.1</td>
</tr>
<tr>
<td></td>
<td>Multi-level Daylighting Control</td>
<td>9.4.1</td>
</tr>
<tr>
<td></td>
<td>Receptacle Control</td>
<td>8.4.2</td>
</tr>
</tbody>
</table>

### Additional Notes

**Space Type**

<table>
<thead>
<tr>
<th>Space Type</th>
<th>Code</th>
</tr>
</thead>
<tbody>
<tr>
<td>Parking Garage</td>
<td>9.4.1</td>
</tr>
<tr>
<td>Office Lobby</td>
<td>9.4.1</td>
</tr>
<tr>
<td>Elevator Lobby</td>
<td>9.4.1</td>
</tr>
<tr>
<td>Food Hall</td>
<td>9.4.1</td>
</tr>
<tr>
<td>Outdoor Terrace</td>
<td>9.4.1</td>
</tr>
<tr>
<td>Hallway</td>
<td>9.4.1</td>
</tr>
<tr>
<td>Service Vestibule</td>
<td>9.4.1</td>
</tr>
<tr>
<td>Utility/Control Room</td>
<td>9.4.1</td>
</tr>
<tr>
<td>Plaza</td>
<td>9.4.1</td>
</tr>
<tr>
<td>Prudential Entry/Arcade</td>
<td>9.4.1</td>
</tr>
<tr>
<td>Open Office</td>
<td>9.4.1</td>
</tr>
<tr>
<td>Private Office (&lt;250 ft²)</td>
<td>9.4.1</td>
</tr>
<tr>
<td>Conference Room</td>
<td>9.4.1</td>
</tr>
<tr>
<td>Video Conference Room</td>
<td>9.4.1</td>
</tr>
<tr>
<td>Break/Dining</td>
<td>9.4.1</td>
</tr>
<tr>
<td>Bathroom</td>
<td>9.4.1</td>
</tr>
<tr>
<td>Storage/Closets</td>
<td>9.4.1</td>
</tr>
<tr>
<td>Utility/Control Room</td>
<td>9.4.1</td>
</tr>
<tr>
<td>Service Vestibule</td>
<td>9.4.1</td>
</tr>
<tr>
<td>Egress/Service Corridor</td>
<td>9.4.1</td>
</tr>
<tr>
<td>Stairway</td>
<td>9.4.1</td>
</tr>
<tr>
<td>Hallway</td>
<td>9.4.1</td>
</tr>
</tbody>
</table>

**Ultrasonic Occupancy Sensor**: Reduces lighting power by 30% when no activity is detected for 30 minutes. Lighting zones are no larger than 3,600 ft². No daylight zones.

**PIR Occupancy Sensor**: Reduces lighting power by 30% when no activity is detected for 30 minutes. Lighting zones are no larger than 3,600 ft². No daylight zones.
### Lighting Power Density (LPD)

<table>
<thead>
<tr>
<th>Floor</th>
<th>Space Type</th>
<th>Total Area (ft²)</th>
<th>LPD Allowance (W/ft²)</th>
<th>Total LPD Allowance (W)</th>
<th>% of Baseline</th>
<th>Extra Controls LPD (W)</th>
<th>% of Baseline</th>
<th>Total LPD (W)</th>
<th>% of Baseline</th>
</tr>
</thead>
<tbody>
<tr>
<td>Green Level</td>
<td>Elevator Control Room (M/E Room)</td>
<td>148</td>
<td>0.55</td>
<td>81.9</td>
<td>100</td>
<td>0</td>
<td>0</td>
<td>81.9</td>
<td>100</td>
</tr>
<tr>
<td></td>
<td>Turnpike Fan Room (M/E Room)</td>
<td>207.5</td>
<td>0.95</td>
<td>198.7</td>
<td>100</td>
<td>0</td>
<td>0</td>
<td>198.7</td>
<td>100</td>
</tr>
<tr>
<td></td>
<td>M/E Spike Room (M/E Room)</td>
<td>278</td>
<td>0.55</td>
<td>152.9</td>
<td>100</td>
<td>0</td>
<td>0</td>
<td>152.9</td>
<td>100</td>
</tr>
<tr>
<td></td>
<td>Electrical Room</td>
<td>301</td>
<td>0.55</td>
<td>165.6</td>
<td>100</td>
<td>0</td>
<td>0</td>
<td>165.6</td>
<td>100</td>
</tr>
<tr>
<td></td>
<td>Storage</td>
<td>844</td>
<td>0.43</td>
<td>364.1</td>
<td>100</td>
<td>0</td>
<td>0</td>
<td>364.1</td>
<td>100</td>
</tr>
<tr>
<td></td>
<td>Service Vestibule (Transaction)</td>
<td>160</td>
<td>0.55</td>
<td>87.9</td>
<td>100</td>
<td>0</td>
<td>0</td>
<td>87.9</td>
<td>100</td>
</tr>
<tr>
<td></td>
<td>Elevator Pit</td>
<td>467</td>
<td>n/a</td>
<td>n/a</td>
<td>100</td>
<td>0</td>
<td>0</td>
<td>n/a</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Elevator Lobby</td>
<td>216</td>
<td>0.64</td>
<td>138.3</td>
<td>100</td>
<td>0</td>
<td>0</td>
<td>138.3</td>
<td>100</td>
</tr>
<tr>
<td></td>
<td>Stairway</td>
<td>233</td>
<td>0.64</td>
<td>150.0</td>
<td>100</td>
<td>0</td>
<td>0</td>
<td>150.0</td>
<td>100</td>
</tr>
<tr>
<td></td>
<td>Food Hall Entry</td>
<td>739</td>
<td>0.9</td>
<td>665.1</td>
<td>100</td>
<td>0</td>
<td>0</td>
<td>665.1</td>
<td>100</td>
</tr>
<tr>
<td></td>
<td>Service Corridor</td>
<td>2,025</td>
<td>0.66</td>
<td>1,344</td>
<td>100</td>
<td>0</td>
<td>0</td>
<td>1,344</td>
<td>100</td>
</tr>
<tr>
<td></td>
<td>Max Egress Passage</td>
<td>498</td>
<td>0.66</td>
<td>328.2</td>
<td>100</td>
<td>0</td>
<td>0</td>
<td>328.2</td>
<td>100</td>
</tr>
<tr>
<td></td>
<td>Elevator Pit</td>
<td>336</td>
<td>n/a</td>
<td>n/a</td>
<td>100</td>
<td>0</td>
<td>0</td>
<td>n/a</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Stairway</td>
<td>293</td>
<td>0.64</td>
<td>187.6</td>
<td>100</td>
<td>0</td>
<td>0</td>
<td>187.6</td>
<td>100</td>
</tr>
<tr>
<td></td>
<td>Hodding/Hunging</td>
<td>184</td>
<td>0.58</td>
<td>107.6</td>
<td>100</td>
<td>0</td>
<td>0</td>
<td>107.6</td>
<td>100</td>
</tr>
<tr>
<td></td>
<td>Bicycle Rack</td>
<td>403</td>
<td>0.58</td>
<td>234.8</td>
<td>100</td>
<td>0</td>
<td>0</td>
<td>234.8</td>
<td>100</td>
</tr>
<tr>
<td></td>
<td>Storage</td>
<td>38</td>
<td>0.64</td>
<td>24.3</td>
<td>100</td>
<td>0</td>
<td>0</td>
<td>24.3</td>
<td>100</td>
</tr>
<tr>
<td></td>
<td>Service Vestibule (Transaction)</td>
<td>180</td>
<td>0.66</td>
<td>118.8</td>
<td>100</td>
<td>0</td>
<td>0</td>
<td>118.8</td>
<td>100</td>
</tr>
<tr>
<td></td>
<td>Office</td>
<td>36</td>
<td>0.55</td>
<td>19.8</td>
<td>100</td>
<td>0</td>
<td>0</td>
<td>19.8</td>
<td>100</td>
</tr>
<tr>
<td></td>
<td>Elevator Key Closet</td>
<td>12</td>
<td>0.95</td>
<td>11.4</td>
<td>100</td>
<td>0</td>
<td>0</td>
<td>11.4</td>
<td>100</td>
</tr>
<tr>
<td></td>
<td>Janitor's Closet</td>
<td>29</td>
<td>0.63</td>
<td>18.3</td>
<td>100</td>
<td>0</td>
<td>0</td>
<td>18.3</td>
<td>100</td>
</tr>
<tr>
<td></td>
<td>Men's Staff Room</td>
<td>93</td>
<td>0.75</td>
<td>70.4</td>
<td>100</td>
<td>0</td>
<td>0</td>
<td>70.4</td>
<td>100</td>
</tr>
<tr>
<td></td>
<td>Dining Office</td>
<td>151</td>
<td>0.11</td>
<td>16.6</td>
<td>100</td>
<td>0</td>
<td>0</td>
<td>16.6</td>
<td>100</td>
</tr>
<tr>
<td></td>
<td>Security Office</td>
<td>57</td>
<td>0.63</td>
<td>36.5</td>
<td>100</td>
<td>0</td>
<td>0</td>
<td>36.5</td>
<td>100</td>
</tr>
<tr>
<td></td>
<td>Mail Room</td>
<td>67</td>
<td>1.11</td>
<td>73.4</td>
<td>100</td>
<td>0</td>
<td>0</td>
<td>73.4</td>
<td>100</td>
</tr>
<tr>
<td></td>
<td>Data</td>
<td>20</td>
<td>0.95</td>
<td>19.0</td>
<td>100</td>
<td>0</td>
<td>0</td>
<td>19.0</td>
<td>100</td>
</tr>
<tr>
<td></td>
<td>Electrical Room</td>
<td>48</td>
<td>0.95</td>
<td>45.6</td>
<td>100</td>
<td>0</td>
<td>0</td>
<td>45.6</td>
<td>100</td>
</tr>
<tr>
<td></td>
<td>PFC Room</td>
<td>141</td>
<td>0.95</td>
<td>134.4</td>
<td>100</td>
<td>0</td>
<td>0</td>
<td>134.4</td>
<td>100</td>
</tr>
<tr>
<td></td>
<td>Garage Store</td>
<td>57</td>
<td>0.55</td>
<td>31.8</td>
<td>100</td>
<td>0</td>
<td>0</td>
<td>31.8</td>
<td>100</td>
</tr>
</tbody>
</table>

### Areas of Focus: LPD Calculations

#### Office Lobby

In reference to Table 9.6.2 Control Factors Used in Calculating Additional Interior Lighting Power of ASHRAE 90.1-2010:

- **Total Office** = (130 + (2,598 sf)*(0.11 LPD)) = 2988 W
- **Total Private Office** = (170 + (2,598 sf)*(0.11 LPD)) = 2404 W
- **Total Break/Dining Area** = (85 + (1,770 sf)*(0.11 LPD)) = 504 W

#### Retail (General lighting see chart.)

In reference to Table 9.6.2(b) of ASHRAE 90.1-2010:

- **Additional Interior Lighting Power Allowance** = 1000 W + (Retail Area 1 x 0.6 W/sf) + (Retail Area 2 x 1.4 W/sf) + (Retail Area 3 x 1.4 W/sf) + (Retail Area 4 x 2.5 W/sf)
- **Retail Area 1 = for products not listed elsewhere**
- **Retail Area 2 = sale of vehicles, sporting goods, small electronics**
- **Retail Area 3 = sale of furniture, clothing, cosmetics, artwork**
- **Retail Area 4 = sale of jewelry, crystal, china**

### Plaza

In reference to Table 9.4.3(a), the Boylston Street High Rise falls under Lighting Zone 4: high activity commercial districts in a major metropolitan areas as designated by the local jurisdiction.

- **Base Site Allowance** = 1300W

#### Tradable Surfaces

- **Plaza area of 18,468 sf**(0.02 W/sf) + (Landscape area of 1,868 sf)**0.05 W/sf**(Main entries door width of 27 ft)**20 W/sf**(Other door widths of 3 ft)**30 W/sf**(Entry canopy area of 2345 sf)**0.4 W/sf**= 4,921 W

- **Nontradable Surfaces** = 0, no façade lighting

### Prudential Entry

- **Mail Concours = (1,900 sf)*(1.10 W/sf) = 4,050 W**
- **Atrium = (First 40 ft in height)**(0.03 ft per ft height)**(2,700 sf)**(Height above 40 feet of 15 ft)**0.02 ft per ft height)**= 4,050 W

In reference to Table 9.6.2 Control Factors Used in Calculating Additional Interior Lighting Power of ASHRAE 90.1-2010:

- **Control Factors for Additional LPD** = (4,050 sf)*(1.0 + 0.1) = 4,455W

#### Parking Garage (See chart.)
At 5,811 MWh/year, this overall design uses 58.71% less energy than the baseline design.

- The photovoltaic system supplements 5.89% of the building’s annual energy.

### Lighting & Daylighting Energy

- **Baseline**:
  - Electrical: 4,324.8 kWh/year
  - Gas: 1,641.4 kWh/year

- **Genius Design**:
  - Electrical: 4,067.5 kWh/year
  - Gas: 1,518.7 kWh/year

### Electrical Submittal

- **Baseline**:
  - Photovoltaics: 2,737 kWh/year
  - Lighting: 2,261 kWh/year

- **Genius Design**:
  - Photovoltaics: 2,737 kWh/year
  - Lighting: 2,261 kWh/year

### HVAC Energy

- **Baseline**:
  - Consumption: 1,022 kWh/year

- **Genius Design**:
  - Consumption: 871 kWh/year

### Receptacle Energy

- **Baseline**:
  - Electrical: 2,737 kWh/year

- **Genius Design**:
  - Electrical: 2,737 kWh/year

### Elevator Energy

- **Baseline**:
  - Electrical: 2,737 kWh/year

- **Genius Design**:
  - Electrical: 2,737 kWh/year

### Support Notes

- Photovoltaic energy production was proportionally subtracted from each site except HVAC Gas to accurately distribute the energy savings.

- Other continuous equipment considers receptacle loads for continuously-running appliances such as refrigerators. Computers were calculated to be in use for 20 hours per day and in sleep mode for 2 hours per day. Refrigerators were assumed to be running 10% of all hours.

- A multiplier for intermittent use equipment is used to account for loads which are not continuous, such as microwave ovens.
• Feeder conductors were sized to ensure that there is no voltage drop above 2%, as required by code.
• NEC Table 310.15(B)(16) was used to size conductors.
• Heat restrictions concerning multiple conductors within the same conduit are considered in voltage drop calculations as referenced in NEC Table 310.15(B)(3)(a).
• All building induction motors were considered in short circuit calculations.

**VOLTAGE DROP CALCULATIONS**

<table>
<thead>
<tr>
<th>Feeder</th>
<th>Primary Voltage</th>
<th>Length of Feeder (ft)</th>
<th>Connected Load (kA)</th>
<th>Conductor Type</th>
<th>Conductor Resistance (ohm/kft)</th>
<th>Voltage Drop</th>
<th>Drop ≤20%?</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Main Switchgear</td>
<td>480</td>
<td>45</td>
<td>431.1</td>
<td>2 x 240 kcmil</td>
<td>2.15`` Steel</td>
<td>0.061</td>
<td>0.14%</td>
<td>Yes</td>
</tr>
<tr>
<td>MDP-1</td>
<td>480</td>
<td>30</td>
<td>298.3</td>
<td>2 x 250 kcmil</td>
<td>2.15`` Steel</td>
<td>0.089</td>
<td>0.10%</td>
<td>Yes</td>
</tr>
<tr>
<td>MDP-2</td>
<td>480</td>
<td>318</td>
<td>139.2</td>
<td>8 x 250 kcmil</td>
<td>2 x 2.5`` Steel</td>
<td>0.071</td>
<td>0.09%</td>
<td>Yes</td>
</tr>
<tr>
<td>Main Bus Duct</td>
<td>480</td>
<td>78</td>
<td>342.9</td>
<td>5 x 500 kcmil</td>
<td>2 x 2.5`` Steel</td>
<td>0.071</td>
<td>0.23%</td>
<td>Yes</td>
</tr>
<tr>
<td>DP-AHU1</td>
<td>480</td>
<td>172</td>
<td>262.0</td>
<td>300 kcmil</td>
<td>1.25`` Steel</td>
<td>0.099</td>
<td>0.54%</td>
<td>Yes</td>
</tr>
<tr>
<td>DP-AHU2</td>
<td>480</td>
<td>37</td>
<td>263.0</td>
<td>2 x 300 kcmil</td>
<td>2.0`` Steel</td>
<td>0.099</td>
<td>0.52%</td>
<td>Yes</td>
</tr>
<tr>
<td>DP-ELV1</td>
<td>480</td>
<td>163</td>
<td>292.0</td>
<td>300 kcmil</td>
<td>1.25`` Steel</td>
<td>0.089</td>
<td>0.51%</td>
<td>Yes</td>
</tr>
<tr>
<td>DP-ELV2</td>
<td>480</td>
<td>24</td>
<td>223.3</td>
<td>2 x 4/0</td>
<td>2.5`` Steel</td>
<td>0.127</td>
<td>0.08%</td>
<td>Yes</td>
</tr>
<tr>
<td>DP-CIR</td>
<td>480</td>
<td>31</td>
<td>231.3</td>
<td>2 x 250 kcmil</td>
<td>2.0`` Steel</td>
<td>0.132</td>
<td>0.16%</td>
<td>Yes</td>
</tr>
<tr>
<td>ATS-EM (from MDP)</td>
<td>480</td>
<td>23</td>
<td>148.0</td>
<td>2 x 500 kcmil</td>
<td>2.0`` Steel</td>
<td>0.071</td>
<td>0.07%</td>
<td>Yes</td>
</tr>
<tr>
<td>ATS-EM (from Generators)</td>
<td>480</td>
<td>158</td>
<td>340.0</td>
<td>2 x 500 kcmil</td>
<td>2.15`` Steel</td>
<td>0.071</td>
<td>0.47%</td>
<td>Yes</td>
</tr>
<tr>
<td>ATS-CR1 (from MDP)</td>
<td>480</td>
<td>23</td>
<td>15.1</td>
<td>#14 AWG</td>
<td>0.1`` Steel</td>
<td>4.876</td>
<td>0.20%</td>
<td>Yes</td>
</tr>
<tr>
<td>ATS-CR1 (from Generators)</td>
<td>480</td>
<td>158</td>
<td>15.1</td>
<td>#14 AWG</td>
<td>0.1`` Steel</td>
<td>4.876</td>
<td>0.16%</td>
<td>Yes</td>
</tr>
<tr>
<td>ATS-CR2 (from MDP)</td>
<td>480</td>
<td>24</td>
<td>24.5</td>
<td>#12 AWG</td>
<td>0.1`` Steel</td>
<td>3.158</td>
<td>1.16%</td>
<td>Yes</td>
</tr>
<tr>
<td>ATS-CR2 (from Generators)</td>
<td>480</td>
<td>157</td>
<td>24.5</td>
<td>#12 AWG</td>
<td>0.1`` Steel</td>
<td>3.158</td>
<td>1.16%</td>
<td>Yes</td>
</tr>
</tbody>
</table>

**SHORT CIRCUIT SINGLE LINE REFERENCE**

**SHORT CIRCUIT CALCULATIONS**

<table>
<thead>
<tr>
<th>Reference Point</th>
<th>Name</th>
<th>&quot;XKMF SC Current&quot; (A)</th>
<th>&quot;S&quot; Factor</th>
<th>&quot;M&quot; Multiplier</th>
<th>M-Adjusted SC Current (A)</th>
<th>Total Motors Contribution (A)</th>
<th>Motor Multiplier</th>
<th>Motors SC Contribution (A)</th>
<th>Total SC Current @ Reference Point (A)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Main Switchgear</td>
<td>108,080</td>
<td>0.061</td>
<td>0.943</td>
<td>101,879</td>
<td>1,517</td>
<td>4</td>
<td>6,068</td>
<td>107,047</td>
</tr>
<tr>
<td>B</td>
<td>Main Bus Duct</td>
<td>101,879</td>
<td>0.258</td>
<td>0.795</td>
<td>80,953</td>
<td>1,517</td>
<td>4</td>
<td>6,068</td>
<td>87,021</td>
</tr>
<tr>
<td>C</td>
<td>MDP-1</td>
<td>101,879</td>
<td>0.300</td>
<td>0.781</td>
<td>79,602</td>
<td>1,517</td>
<td>4</td>
<td>6,068</td>
<td>85,670</td>
</tr>
<tr>
<td>D</td>
<td>MDP-2</td>
<td>101,879</td>
<td>0.635</td>
<td>0.650</td>
<td>61,422</td>
<td>1,517</td>
<td>4</td>
<td>6,068</td>
<td>67,480</td>
</tr>
<tr>
<td>E</td>
<td>DP-AHU1</td>
<td>79,602</td>
<td>2.813</td>
<td>0.262</td>
<td>20,878</td>
<td>1,517</td>
<td>4</td>
<td>6,068</td>
<td>26,946</td>
</tr>
<tr>
<td>F</td>
<td>DP-ELV1</td>
<td>79,602</td>
<td>2.576</td>
<td>0.298</td>
<td>23,578</td>
<td>1,517</td>
<td>4</td>
<td>6,068</td>
<td>29,646</td>
</tr>
<tr>
<td>G</td>
<td>DP-AHU2</td>
<td>79,602</td>
<td>4.056</td>
<td>0.171</td>
<td>13,395</td>
<td>1,517</td>
<td>4</td>
<td>6,068</td>
<td>19,661</td>
</tr>
<tr>
<td>H</td>
<td>DP-ELV2</td>
<td>61,422</td>
<td>0.226</td>
<td>0.816</td>
<td>50,117</td>
<td>1,517</td>
<td>4</td>
<td>6,068</td>
<td>56,185</td>
</tr>
<tr>
<td>I</td>
<td>DP-CIR</td>
<td>61,422</td>
<td>0.176</td>
<td>0.850</td>
<td>52,214</td>
<td>1,517</td>
<td>4</td>
<td>6,068</td>
<td>58,282</td>
</tr>
<tr>
<td>J</td>
<td>EMERG/CRIT</td>
<td>61,422</td>
<td>0.043</td>
<td>0.745</td>
<td>45,739</td>
<td>1,517</td>
<td>4</td>
<td>6,068</td>
<td>51,807</td>
</tr>
</tbody>
</table>

**F- AND M- FACTOR FORMULAS**

From "Short Circuit Current Calculations," ©2005 Cooper Bussman
REGENERATIVE ELEVATOR & ESCALATOR

KONE elevator’s EcoDisk is a permanent-magnet, gearless regenerative motor that uses less energy and paired with destination control technology, a substantial amount of energy savings is made over time. The machine room-less elevator technology eliminates the need for an entire machine room by attaching the hoisting machine to the guide rail, and placing all control and logic components within the confines of the hoistway.

Estimated Elevator Calculation Factors

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>Elevator Capacity</td>
<td>3500 lbs</td>
</tr>
<tr>
<td>Rated Speed</td>
<td>200 fpm</td>
</tr>
<tr>
<td>Total Building Height</td>
<td>270 ft</td>
</tr>
<tr>
<td>Total Floors Served</td>
<td>14 floors</td>
</tr>
<tr>
<td>Total Elevators Using Regen</td>
<td>9 regen elevators</td>
</tr>
<tr>
<td>Estimated Runs/Day and Runs/Year</td>
<td>675 and 176,175 runs</td>
</tr>
<tr>
<td>Cost per Kilowatt-Hour</td>
<td>$0.1426</td>
</tr>
<tr>
<td>Total Operating Days/Year</td>
<td>260 days</td>
</tr>
<tr>
<td>Idle Hours/Day</td>
<td>16.8 hours</td>
</tr>
<tr>
<td>Average Full Speed Run</td>
<td>27.5 seconds</td>
</tr>
</tbody>
</table>

Annual Savings between Generic and Specified Elevator

<table>
<thead>
<tr>
<th>Description</th>
<th>kWh</th>
<th>USD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Machine Room Cooling</td>
<td>48,767</td>
<td>$6,954</td>
</tr>
<tr>
<td>Elevator</td>
<td>160,015</td>
<td>$22,818</td>
</tr>
<tr>
<td>Total Energy Consumption (including lighting &amp; exhaust fan)</td>
<td>210,778</td>
<td>$30,015</td>
</tr>
</tbody>
</table>

REGENERATIVE ELEVATOR SAVINGS

With the help of Thyssen Krupp’s Elevator Energy Savings Tool, Genesis Design estimated calculation factors and calculated the annual energy savings:

ANNUAL ENERGY SAVINGS: 158,414 kWh & $22,590 aka 10.24 Metric Tons of CO2 Reduction

GREEN ESCALATOR SUMMARY

1. LUBRICATION-FREE STEP CHAIN
   Permanent greased and seal chain links do not require extra oil lubrication resulting in savings and reduced fire risk

2. REGENERATIVE SOLUTION
   During downward runs when passenger-loaded, inverter installed

3. EFFICIENT OPERATION
   Stand-by speed or stop & go result in additional energy savings

4. LED LIGHTING

Figure 1 – (Provided by KONE) EcoDisk Elevator Regenerative Motor

Figure 2 – (Provided by KONE) Conventional vs. Destination Control Elevator Panel

Figure 3 – (Provided by KONE) Green Escalator Components
BUILDING POWER DISTRIBUTION

Genesis Design sized the building’s electrical system to maximize resiliency and versatility for future retrofits.

- Two 2500 kVA main transformers create a redundant 2n configuration so that one can be serviced without interrupting the building’s power.
- Two 250 kVA generators create a redundant 2n configuration to maximize the resiliency for emergency and critical power systems.
- Three critical power bus ducts supply power for 10% of receptacles in occupied spaces. These are located in telecommunications rooms to protect servers.
- Individual UPS systems for each floor to back up tenants’ critical servers in the case of a power failure, giving time for the generators to start.
- Power generation equipment returns energy to the building’s distribution so that battery storage systems are unnecessary; unused energy will be sold back to the grid with net metering.

**EMERGENCY BUS DUCT**

- An emergency bus duct backs the building’s emergency lighting, critical chiller and AHU’s, exhaust fans, pumps, and fire protection equipment to generate power.
- Three critical power bus ducts supply power for 10% of receptacles in occupied spaces. These are located in telecommunications rooms to protect servers.
- Individual UPS systems for each floor to back up tenants’ critical servers in the case of a power failure, giving time for the generators to start.
- Power generation equipment returns energy to the building’s distribution so that battery storage systems are unnecessary; unused energy will be sold back to the grid with net metering.

**PANEL SCHEDULE**

<table>
<thead>
<tr>
<th>Location</th>
<th>Panel Schedule Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>Location: Penthouse ML05</td>
<td>DP-AHU1</td>
</tr>
<tr>
<td>Location: Penthouse ML05</td>
<td>DP-AHU2</td>
</tr>
<tr>
<td>Location: Penthouse ML05</td>
<td>DP-CHIL</td>
</tr>
<tr>
<td>Location: Penthouse ML05</td>
<td>DP-ELV1</td>
</tr>
<tr>
<td>Location: Penthouse ML05</td>
<td>DP-ELV2</td>
</tr>
</tbody>
</table>

**GENERATORS INFORMATION**

- Two 2500 kVA main transformers create a redundant 2n configuration so that one can be serviced without interrupting the building’s power.
- Two 250 kVA generators create a redundant 2n configuration to maximize the resiliency for emergency and critical power systems.
- Three critical power bus ducts supply power for 10% of receptacles in occupied spaces. These are located in telecommunications rooms to protect servers.
- Individual UPS systems for each floor to back up tenants’ critical servers in the case of a power failure, giving time for the generators to start.
- Power generation equipment returns energy to the building’s distribution so that battery storage systems are unnecessary; unused energy will be sold back to the grid with net metering.
Genesis Design chose to make several modifications to the original rooftop design and photovoltaic layout:

- Incorporate a large PV array on the south roof: the original design placed generators on the South roof. Since this is one of the most optimal opportunities for solar panels, the generators were relocated to the East roof to make room for one of the building’s best-performing PV arrays.
- Tilting the roof PVs: roof PVs are not tilted at 10° in the roof zones and 35° on the wall-mounted zones to produce more electricity than the original design.
- Getting rid of shadows: Since panel production is dramatically compromised by partial shadowing, the wind turbines on the original design would create shadows that would be detrimental to the system’s performance. Genesis design got rid of these turbines to optimize the performance of the upper roof PV array.

**MODULE SCHEDULE**

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>south</td>
<td>1</td>
<td>south</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>south</td>
<td>2</td>
<td>south</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>south</td>
<td>3</td>
<td>south</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>south</td>
<td>4</td>
<td>south</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>
<td>4</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>south</td>
<td>5</td>
<td>south</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
</tr>
</tbody>
</table>

**INVERTER SCHEDULE**

<table>
<thead>
<tr>
<th>Inverter</th>
<th>DC Voltage</th>
<th>DC Current</th>
<th>Wattage</th>
<th>Inverter Type</th>
<th>Inverter Eff.</th>
<th>Inverter Voltage</th>
<th>Shading</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>500</td>
<td>1000</td>
<td>1000</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>500</td>
<td>1000</td>
<td>1000</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>3</td>
<td>500</td>
<td>1000</td>
<td>1000</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>4</td>
<td>500</td>
<td>1000</td>
<td>1000</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>4</td>
</tr>
</tbody>
</table>

**SHADING DIAGRAMS**

To accurately predict the photovoltaic energy production losses associated with shading from surrounding buildings, six shading diagrams were created, one for each PV zone. The projected shapes were created by plotting the altitude and azimuth angles of other buildings’ roof corners with respect to the centroid point of each PV zone. From this, hourly shading data for each month was used for the shading input in the System Advisor Model. Using this method, Genesis Design was able to accurately predict the PV energy production with shading considered.

**ORIGINAL vs. GENESIS DESIGN ROOFTOP PV**

- Incorporate a large PV array on the south roof: the original design placed generators on the South roof. Since this is one of the most optimal opportunities for solar panels, the generators were relocated to the East roof to make room for one of the building’s best-performing PV arrays.
- Tilting the roof PVs: roof PVs are not tilted at 10° in the roof zones and 35° on the wall-mounted zones to produce more electricity than the original design.
- Getting rid of shadows: Since panel production is dramatically compromised by partial shadowing, the wind turbines on the original design would create shadows that would be detrimental to the system’s performance. Genesis design got rid of these turbines to optimize the performance of the upper roof PV array.
DAYLIGHT BLINDS DETAIL

TILT PROGRAM FOR DAYLIGHT BLINDS

Genesis Design’s goal in the office spaces was to maximize daylight harvesting, and effectively supplement as much of the electric lighting as possible. However, it is also important for thermal and visual comfort to prevent direct daylight penetration on the work planes. The solution reached was a system of 12" aluminum blinds, vertically spaced at 9" apart, integrated into the South and West double skin façades. In order to block direct daylight at any solar position, the blinds follow a program which will automatically switch between tilt two positions: horizontal and tilted toward the outside. On a clear day, when the sun’s azimuth is directly normal to the façade, the blinds will tilt at any altitude angle below 35.47°. This threshold angle becomes smaller as the sun moves away from the façade’s normal, as seen in the black curves below. Based on this geometrical algorithm, we were able to generate an annual solar position graph with four different tilt settings for the blinds system.

CLEAR DAY TILT PROGRAM

HORIZONTAL BLINDS SPECIFICATION

WAREMA’s Chromatics automated control device uses solar position tracking to position the cut of angle of slats to eliminate direct solar radiation and make the best possible use of diffused daylight. As for the structure of the slats, first a black coating is applied to the perforated aluminum band. A second layer of RAL 9003 white selectives are applied. The selectivity coating only reflects visible light into the room, while absorbed and infrared radiation are absorbed by the blade and reflected as heat radiation within the double skin, not into the interior. The blinds ensure good connection which is the drawing of heated air through the chimney effect. Please refer to the Mechanical Narrative, Section 7.1 for the natural ventilation and mechanical performance of the double skin façade. The horizontal blinds are used throughout the double skin on the Boylston Street High Rise’s south and west facades.

MANUAL ROLLER BLINDS SPECIFICATIONS

WAREMA’s Dual Bracket Roller Blinds provide the option of two roller curtains in one unit. The motor system options are manually controlled from the wall switch. The first fabric layer is sheer that maintains views while diffusing direct daylight. It is made of PTFE/PVC on polyester and 25% polyester. The second fabric layer is a black out option for video conferencing or total privacy. It is made of 100% polyester (PVC-free) and polyurethane finish. Manual roller blinds are used for conference and video conferencing rooms.

DOUBLE SKIN PERFORMANCE

Spandrel glass was used to aesthetically harmonize with the vision glass as well as hide raised axis floor and ceiling construction from the exterior. On gray, overcast days, a greater visual disparity is created versus minimized contrast for other weather conditions. The ceramic frit of the spandrel glass does not affect U-value performance. The insulation behind the air space gives the wall construction a higher R-value. Collaboration and special care in calculating window to wall ratios were done with the Mechanical team to optimize the energy performance of the façades.

GLASS TYPES SPECIFICATIONS

Double Skin: South & West Façade

<table>
<thead>
<tr>
<th>Exterior Skin Glass</th>
<th>Interior Skin Glass</th>
</tr>
</thead>
<tbody>
<tr>
<td>VNE1-63</td>
<td>VNE1-63</td>
</tr>
</tbody>
</table>

Curtain Wall: North & East Façade

<table>
<thead>
<tr>
<th>Vision Glass</th>
<th>Spandrel Glass</th>
</tr>
</thead>
<tbody>
<tr>
<td>VGC1-70</td>
<td>VGC1-70 &amp; VGC1-80</td>
</tr>
</tbody>
</table>

HORIZONTAL BLINDS CONTROLS

Horizontal blinds were Genesis Design’s most appropriate choice as a daylight shading technique. In summary, WAREMA’s LUMINWORKS automated controls lift the white painted, perforated aluminum blinds to diffuse direct daylight glare. The blinds also facilitate the convective heat currents which are important to the mechanical functions of the double skin façade. Appropriate decisions of glazing and wall material make the facade innovative and high performing.

DAYLIGHT BLINDS DETAIL

12" Blinds, 9" Vertical Spacing

Tilted at 46.4°

SOUTH-WEST CORNER

RENDERED VIEW OF SOUTH-WEST CORNER

TILTED SETTING For lower sun-attitudes

HORIZONTAL SETTING For higher sun-attitudes

CLEAR DAY TILT PROGRAM

1: All Blinds Horizontal
2: South Façade Blinds Tilted
3: West Façade Blinds Tilted
4: All Blinds Tilted

SPANDREL WALL WITH INSULATION

Insulation
Airspace (1’ Min.)
Spandrel Glass
Vision Glass

THE BOYLSTON STREET
HIGH RISE
BOSTON, MA 02115

BUILDING FAÇADE DESIGN

THE BOYLSTON STREET
HIGH RISE
BOSTON, MA 02115

BUILDING FAÇADE DESIGN

THE BOYLSTON STREET
HIGH RISE
BOSTON, MA 02115

BUILDING FAÇADE DESIGN

THE BOYLSTON STREET
HIGH RISE
BOSTON, MA 02115

BUILDING FAÇADE DESIGN

THE BOYLSTON STREET
HIGH RISE
BOSTON, MA 02115

BUILDING FAÇADE DESIGN

THE BOYLSTON STREET
HIGH RISE
BOSTON, MA 02115

BUILDING FAÇADE DESIGN

THE BOYLSTON STREET
HIGH RISE
BOSTON, MA 02115

BUILDING FAÇADE DESIGN

THE BOYLSTON STREET
HIGH RISE
BOSTON, MA 02115

BUILDING FAÇADE DESIGN

THE BOYLSTON STREET
HIGH RISE
BOSTON, MA 02115

BUILDING FAÇADE DESIGN

THE BOYLSTON STREET
HIGH RISE
BOSTON, MA 02115

BUILDING FAÇADE DESIGN

THE BOYLSTON STREET
HIGH RISE
BOSTON, MA 02115

BUILDING FAÇADE DESIGN

THE BOYLSTON STREET
HIGH RISE
BOSTON, MA 02115

BUILDING FAÇADE DESIGN

THE BOYLSTON STREET
HIGH RISE
BOSTON, MA 02115

BUILDING FAÇADE DESIGN

THE BOYLSTON STREET
HIGH RISE
BOSTON, MA 02115

BUILDING FAÇADE DESIGN

THE BOYLSTON STREET
HIGH RISE
BOSTON, MA 02115

BUILDING FAÇADE DESIGN

THE BOYLSTON STREET
HIGH RISE
BOSTON, MA 02115

BUILDING FAÇADE DESIGN

THE BOYLSTON STREET
HIGH RISE
BOSTON, MA 02115

BUILDING FAÇADE DESIGN

THE BOYLSTON STREET
HIGH RISE
BOSTON, MA 02115

BUILDING FAÇADE DESIGN

THE BOYLSTON STREET
HIGH RISE
BOSTON, MA 02115

BUILDING FAÇADE DESIGN

THE BOYLSTON STREET
HIGH RISE
BOSTON, MA 02115

BUILDING FAÇADE DESIGN

THE BOYLSTON STREET
HIGH RISE
BOSTON, MA 02115

BUILDING FAÇADE DESIGN

THE BOYLSTON STREET
HIGH RISE
BOSTON, MA 02115

BUILDING FAÇADE DESIGN

THE BOYLSTON STREET
HIGH RISE
BOSTON, MA 02115

BUILDING FAÇADE DESIGN

THE BOYLSTON STREET
HIGH RISE
BOSTON, MA 02115

BUILDING FAÇADE DESIGN

THE BOYLSTON STREET
HIGH RISE
BOSTON, MA 02115

BUILDING FAÇADE DESIGN
INTELLIGENT BUILDING MANAGEMENT SYSTEM

Genesis Design understands that the key to a truly integrative, sustainable design and the future of the building industry is implementation of an intelligent building management system that consolidates all aspects of a building’s control into one, simplified platform. The advantages include:

- Optimized building performance through maximized energy efficiency
- Automation monitoring & control through a single, manageable platform
- Strategic control of building occupancy safety & reduced risk
- More informed decision making for facility manager & owner
- Lower lifecycle costs & improved return on investment
- Greater occupant comfort & appeal for tenants

UNDERSTANDING THE MARKET’S LEADING STANDARDS

1. **BACnet**
   A building automatic and control networking protocol developed by ASHRAE, typically used for HVAC, lighting, access, and fire detection controls. Organized into “objects” of analog/binary input/output representing the device itself and reports of data/current state of properties. Its measuring BACnet IP over wireless is what the industry is looking at in terms of newest technology.

   "Local Operating Network” is a control-networking protocol created by Echelon Corporation for devices over media such as twisted pairs, powerlines, fiber optics. LonWorks is restricted to using LON’S LONTALK proprietary communication protocol.

   OPC is a client-server technology. One application acts as the server providing data, and the other acts as a client using data. It’s a widely accepted industrial communication standard that enables the exchange of data between multivendor devices and controls applications without any proprietary restrictions.

   Modbus is a serial communication protocol developed by Modicon and uses programmable logic controllers (PLCs). Information is transmitted over serial lines between electronic devices.

**Honeywell**

Genesis Design decided to adopt Honeywell’s Enterprise Buildings Integrator as the Boylston Street High Rise’s comprehensive, network-based solution for building automation and management. It has the ability to incorporate all the industries open standards mentioned above into a single point of access for the building facility manager. This allows the building to be flexible for future planning in terms of system expansion and life cycle savings.

**DOUBLE SKIN FAÇADE CONTROLS**

Forecasting: Use of exclusive algorithms incorporating weather patterns, historical usage, and real-time updates to continually hone natural/hybrid ventilation operation in connection with horizontal blind tilt controls. Upon sensing acceptable conditions of outdoor humidity and outdoor temperature from the nearest weather station, the WAREMA Climatronic’s sends a signal to activate the operable windows.

**LAN**

1. VAV controllers
2. Thermostats in retail spaces
3. Pressure sensors (1 outside, 1 inside/floor)
4. Airflow sensors in every main branch of duct run
5. Regenerative elevator and escalator controller
6. Pressure sensor in stairwell
7. Water pressure/temperature sensors in boiler and cooling towers
8. UPS monitoring
9. Service and maintenance

**WAN**

1. Energy & power metering per tenant
2. Geothermal temperature and pressure controls (heat exchanger) to see savings
3. Temperature and humidity sensors in double skin façade to see savings
4. Horizontal blinds tilt control
5. Lighting fixtures & controls & occupancy sensors
6. Demand control ventilation connected to lighting occupancy controls

**BUILDING MANAGER SERVER**

1. HVAC equipment control to contain smoke & create safe havens
2. Fire door release
3. Sprinkler supervisory status of suppression systems, values, and fire hydrants
4. Fire detection & alarm system
5. Egress lighting controls
6. Advanced distributed digital audio communication system for orderly/zoned evacuation

**ENERGY MANAGER SERVER**

1. IP video cameras surveillance & closed circuit television
2. Access control for doors and readers
3. Intruder panels & reporting
4. Public address and voice announcement (PA/VA)
5. Perimeter protection
6. Links to external authorities
7. Voice and data communications
8. Structured cabling and cable management

**SECURITY SERVER**

**LIFE SAFETY SERVER**

**PROJECT:**

**THE BOYLSTON STREET**

**HIGH RISE**

**BOSTON, MA 02115**

**DRAWING TITLE:**

**BUILDING MANAGEMENT SYSTEM**

**DRAWING NO.:** E-05

**SCALE:** N/A

**DATE:** 17 FEB 2016

**PROJECT MANAGER:**

**BUILDING MANAGEMENT SYSTEM:**

**BUILDING MANAGER**

**LIFE SAFETY MANAGER**

**ENERGY MANAGER**

**SECURITY MANAGER**

**PROJECT:**

**THE BOYLSTON STREET**

**HIGH RISE**

**BOSTON, MA 02115**

**DRAWING TITLE:**

**BUILDING MANAGEMENT SYSTEM**

**DRAWING NO.:** E-05

**SCALE:** N/A

**DATE:** 17 FEB 2016

**PROJECT MANAGER:**

**BUILDING MANAGEMENT SYSTEM:**

**BUILDING MANAGER**

**LIFE SAFETY MANAGER**

**ENERGY MANAGER**

**SECURITY MANAGER**
ACHIEVING A BETTER OPEN OFFICE DESIGN

There are many pros and cons associated with open office spaces. Cons include lack of privacy, sickness spread in close quarters, and the feeling of stress. However, Genesis Design combats the cons to attract tenants to the Boylston Street High Rise, and the chart on the right summarizes the design strategies used. In terms of electrical design, by creating opportunities to bring daylight into the interior space, higher occupant comfort and happiness is achieved while also reducing lighting and cooling loads.

OPEN OFFICE CONTROL ZONES SYSTEM

SCALE: 3/64 = 1’ – 0"

Daylight harvesting is an energy management technique to reduce general ambient overhead electrical lighting by utilizing natural daylight present in the space. Dimming or switching off lights when the sufficient lighting level of 150 lux is present reduces the energy consumption. The horizontal blinds work in tandem with the daylight harvesting system. When direct daylight is entering the space, the controls system will tilt the blinds to diffuse the glare. At all other times, the horizontal blinds will be flat to bounce light further into the space and maintain views to the exterior.

OPEN OFFICE INTERIOR FLEXIBILITY

GENESIS DESIGN’s open office primary and secondary side lighted areas. By code, the primary sidelighted area require automatic multilevel photocontrols including continuous dimming devices. The sidelighted width is the width of the window plus 2 feet on both sides. The sidelighted depth is one window head height (floor to top of glazing). Genesis Design decreased the window to wall ratio of the original design without compromising the energy savings attributed to daylight harvesting. Excessive glazing without proper shading techniques results in uncomfortably high illuminance levels and glare throughout the zones.

Daylight, Lighting, Views

- Good air circulation
- Good views to the exterior
- Dimming or switching off lights when the sufficient lighting level of 150 lux is present reduces the energy consumption. The horizontal blinds work in tandem with the daylight harvesting system. When direct daylight is entering the space, the controls system will tilt the blinds to diffuse the glare. At all other times, the horizontal blinds will be flat to bounce light further into the space and maintain views to the exterior.

OPEN OFFICE INTERIOR FLEXIBILITY

GENESIS DESIGN's suggested office strategy is to place private offices around the core to allow for workstations to receive the most useful daylight (reducing electrical lighting energy used), and while private office users are out of the room, the most electric light also can be saved.

Daylight harvesting is an energy management technique to reduce general ambient overhead electrical lighting by utilizing natural daylight present in the space. Dimming or switching off lights when the sufficient lighting level of 150 lux is present reduces the energy consumption. The horizontal blinds work in tandem with the daylight harvesting system. When direct daylight is entering the space, the controls system will tilt the blinds to diffuse the glare. At all other times, the horizontal blinds will be flat to bounce light further into the space and maintain views to the exterior.

OPEN OFFICE INTERIOR FLEXIBILITY

GENESIS DESIGN's suggested office strategy is to place private offices around the core to allow for workstations to receive the most useful daylight (reducing electrical lighting energy used), and while private office users are out of the room, the most electric light also can be saved.

Daylight harvesting is an energy management technique to reduce general ambient overhead electrical lighting by utilizing natural daylight present in the space. Dimming or switching off lights when the sufficient lighting level of 150 lux is present reduces the energy consumption. The horizontal blinds work in tandem with the daylight harvesting system. When direct daylight is entering the space, the controls system will tilt the blinds to diffuse the glare. At all other times, the horizontal blinds will be flat to bounce light further into the space and maintain views to the exterior.

Daylight harvesting is an energy management technique to reduce general ambient overhead electrical lighting by utilizing natural daylight present in the space. Dimming or switching off lights when the sufficient lighting level of 150 lux is present reduces the energy consumption. The horizontal blinds work in tandem with the daylight harvesting system. When direct daylight is entering the space, the controls system will tilt the blinds to diffuse the glare. At all other times, the horizontal blinds will be flat to bounce light further into the space and maintain views to the exterior.

Daylight harvesting is an energy management technique to reduce general ambient overhead electrical lighting by utilizing natural daylight present in the space. Dimming or switching off lights when the sufficient lighting level of 150 lux is present reduces the energy consumption. The horizontal blinds work in tandem with the daylight harvesting system. When direct daylight is entering the space, the controls system will tilt the blinds to diffuse the glare. At all other times, the horizontal blinds will be flat to bounce light further into the space and maintain views to the exterior.

Daylight harvesting is an energy management technique to reduce general ambient overhead electrical lighting by utilizing natural daylight present in the space. Dimming or switching off lights when the sufficient lighting level of 150 lux is present reduces the energy consumption. The horizontal blinds work in tandem with the daylight harvesting system. When direct daylight is entering the space, the controls system will tilt the blinds to diffuse the glare. At all other times, the horizontal blinds will be flat to bounce light further into the space and maintain views to the exterior.

Daylight harvesting is an energy management technique to reduce general ambient overhead electrical lighting by utilizing natural daylight present in the space. Dimming or switching off lights when the sufficient lighting level of 150 lux is present reduces the energy consumption. The horizontal blinds work in tandem with the daylight harvesting system. When direct daylight is entering the space, the controls system will tilt the blinds to diffuse the glare. At all other times, the horizontal blinds will be flat to bounce light further into the space and maintain views to the exterior.
SUGGESTED OFFICE LIGHTING LAYOUT
SCALE: 1/16 = 1" – 0"

SUGGESTED OFFICE POWER LAYOUT
SCALE: 1/16 = 1" – 0"

OPEN OFFICE RENDER
• Genesis Design’s open office lighting design used only 47% of the LPD allowance given by ASHRAE 90.1-2010
Genesis Design chose to light the two parking garage levels with LED luminaires in order to fall below 50% of the ASHRAE lighting power density baseline. The challenge of this large space was the shallow ceiling height of 8.5 feet; it was necessary to find highly efficient fixtures with as wide of an optical distribution as possible. The Evolve™ LED fixture by GE was specified:

- High efficiency of 121 lumens/watt (4,220 lumens, 35 watts)
- Wide, diffuse lens allows for a wide vertical distribution (blue) and a symmetrical horizontal distribution (red)
- Between the two spaces, an average of only 44.3% of the ASHRAE LPD allowance was used.
- Lighting shall be controlled by occupancy sensors that automatically reduce lighting power of each luminaire by a 30% when there is no activity detected within a zone after 30 minutes. There is no daylighting available in the parking garage levels.
LEVEL 2 FLOOR PLAN
SCALE: 1/16" = 1'-0"

OFFICE LOBBY SUGGESTION

LEVEL 3 FLOOR PLAN
SCALE: 1/16" = 1'-0"

MAIN ELECTRICAL ROOM LAYOUT

RETAIL LIGHTING DESIGN STRATEGY
- Provide a general lighting scheme suggestion
- Uniform base level of lighting with dimming
- Dimmed level for cleaning and repositioning (green energy, maintains lighting off completely)
- Perimeter lighting makes space feel larger, create a sense of well-being, and visual comfort therefore customers stay longer in a store.

GENERAL ILLUMINATION 2x2 TROFFER

PERIMETER LIGHTING FLOOD LIGHT

GENESIS DESIGN
E-10
0.0 EXECUTIVE SUMMARY

The future vision of Boston includes an increased number of high quality public spaces, reduced energy consumption, and renewable energy production. It’s critical that the Boylston Street High Rise provides the necessary attributes to perform not only a dependable service for the building tenants, but also for the surrounding city and environment. In order to meet these standards, the project goals of SUSTAINABILITY, RESILIENCY, and INTEGRATION must be achieved during the early stages of design and maintained throughout construction and building occupancy. These challenges are managed through the use of a highly collaborative project team that operates through the guiding principles of trust, dedication, and mutual respect.

0.1 DESIGN MANAGEMENT

The project was planned and executed using an Integrated Project Delivery (IPD) Method to ensure proper team collaboration. The team was structured to most effectively deliver the project while maintaining project goals. A list of how this was accomplished is shown below and is detailed in Construction Supporting Document A (CSD-A).

- Regularly Scheduled Team Meetings
- Weighted Decision Matrix for System Selection
- File Management Analysis and Setup
- Upfront System Comparisons for Decision Process

0.2 SUSTAINABILITY IN CONSTRUCTION

A primary goal for each option required sustainable system design and operation. From a construction standpoint, the detailed planning and control of material selection, delivery, and installation became a critical area for sustainability. These are detailed in Section 9.0 and include:

- IPD Structure to Reduce Waste in Rework
- Reused, Reduced, and Recycled Material Analyses
- Embodied Energy Reduction Techniques
- Advanced Material Tracking for Schedule Support
- Educational Community Outreach

0.3 RESILIENCY IN CONSTRUCTION

The building design ensures structural integrity and engineered system function during harsh conditions. The Boylston Street High Rise is built for safety with a series of highly durable and redundant response systems. The construction team created several plans to ensure occupant and worker safety as well as plans that assist in the continued operation and maintenance of these systems throughout the building lifespan; shown below and detailed in Section 8.0, CSD-F, and Drawing C-09.

- Emergency Evacuation Plans for Disaster Scenarios
- System Testing for Quality Control Assurances
- Prefabricated Items for Improved Worker Safety
- System Maintenance Plans for Lifecycle Operation

0.4 INTEGRATION DURING CONSTRUCTION

The condensed construction site posed several constructability challenges. The construction team carefully planned the site logistics to ensure a seamless integration into the existing city while optimizing construction time. See list below and Section 5.2 and Drawings C-03 and C-04 for plans and challenge solutions.

- Detailed Site Analysis and Planning
- Maintaining Boylston Street and I-90 Operation
- Planned Work Around I-90 and Fan Room
- Surrounding Building Impact Analyses
- Negative Impact Mitigation Plans

0.5 PROJECT SCHEDULE & BUDGET

The construction team implemented several techniques in order to provide a high-performance facility within a reasonable time and budget. This was accomplished through first creating a scope of work for each of the three areas: Garage, Retail, and Office; then creating an appropriate cost and schedule plan for each. These techniques are listed below and are further detailed on CSD-E and C-06.

- Prefabrication and Matrix Scheduling
- Just in Time Deliveries and Material Tracking
- Detailed System Cost and Schedule Comparisons
- Lifecycle and Payback Period Cost Analyses

The final project is estimated at a cost of $301,783,000 at a construction time of 18 months.
1.0 PROJECT INTRODUCTION
The 2016 AEI Student Design Competition set forth the challenge to design a 493,000 SF, 17-story mixed-use office building located on Boylston Street in Back Bay Boston, MA. The challenge requires focus on the design, construction, and life-long building performance. These design criteria are further defined through the team design drivers of SUSTAINABILITY, RESILIENCY, and INTEGRATION; each provided the foundation for the construction process.

1.1 CONSTRUCTION DESIGN DRIVERS
The goals of the construction team are to create a high-performance building that is both resilient in operation and resilient in time. Quality assurances will be provided while maintaining the project budget and schedule, as well as the health of the public and surrounding environment.

SUSTAINABILITY
The construction team focused on innovative ways to plan, green materials to utilize, efficient ways to build, and useful programs to maintain operation throughout the life span of the building.

RESILIENCY
The construction techniques ensure quality control in facility performance in even the harshest of conditions. Added emergency procedures assure occupant and worker safety and continued system performance.

INTEGRATION
Construction planning focuses on maintaining the function ability of city life, ensuring public health and safety, and conserving adjacent structures.

These areas of focus will be implemented into each construction service. These services include: a detailed assessment of the project schedule, cost/payback, and resource management; an extensive site analysis; and an operation and maintenance plan for life-long system assistance.

2.0 PROJECT DELIVERY
The construction management team will utilize an Integrated Project Delivery Method (IPD) to increase collaboration and communication. Using an IPD approach helps the owner and contractor build a less adversarial relationship as well as allows for more cost and schedule savings because all parties are working towards the same goal. It also allows the construction team to have early input in the design by assisting the owner and architect in feasibility assessments. This has been proven to save money on construction projects in the past, and it is a great way to foster communication between all engineering, architecture, and construction teams working on the project. Figure 1 below is a visual representation of how the IPD method helps save costs by making early design changes.

2.1 CO-LOCATION
Genesis Design utilizes co-location to increase collaboration between the design and construction teams. Co-location means that design and construction teams will share an office space. A layout of the co-location office is shown below in Figure 2.

With the limited site space, the office will be located at 39 Newbury Street, a ten minute walk from the site. The cost associated with this setup is included in the general conditions costs on CSD-G. Personnel in the co-location office will include:
Owner representatives, construction managers, architects, engineers, and subcontractors. By using a co-location office, the project management team will have all trades in the same location to increase communication and reduce RFI’s and change orders. The overarching goal is to create a highly collaborative management team operating toward the same goals.

2.2 BIM EXECUTION PLAN
The use of Building Information Modeling is one of the most effective ways of organizing a project from early planning and analysis to the delivery of the final product. The construction team used BIM throughout the entire process incorporating the 3D through 7D planning tools. These tools include early site analysis, scheduling, estimating, lean construction techniques, facility management, and clash detection. A total breakdown of these applications is available on CSD-B.

2.3 DECISION-MAKING PROCESS
Each of the project phases introduced numerous decisions that had to be made, most of which affected the entire team. It was important to establish a system that allowed for each team member to quantifiably rank the choices. A Decision-Making Matrix was created, detailed in Section 4.2 of the Integration Report, which quantitatively represents the different choices based on weighted rankings by the individual team members. The weights were established based on decision priority. It is inevitable that not every design team will benefit equally from the voted system and that a challenge and risk is associated with a more costly or time consuming option. How these compromises were handled and assessed is detailed further on CSD-A.

3.0 COMPUTER PROGRAMS
The assistance of computer-generated modeling is a critical tool in building design. However, the exchange of information is just as important to the success of the BIM approach as well as the IPD Method. Interoperability between programs is a key factor to increasing collaboration. The team therefore constructed a program list to ensure an efficient exchange of information between the various options and their various design software which is shown in Figure 3.

The interoperability process proved challenging in that many programs would not sync appropriately. For instance, the energy analysis software available on IES failed to properly retain material information when translated to the SketchUp massing program; a problem that caused extensive corrections and loss of critical time. Further detail is available on Drawing C-01.

4.0 ZONING & JURISDICTIONS
A vital aspect of designing and constructing a building is understanding the jurisdictional requirements related to the project. The location of the Boylston Street High Rise is already zoned as a planned development and therefore will not need to be rezoned before applying for building permits. The Boston Redevelopment Authority (BRA) will act as the main point of contact between Genesis and the Boston code department. The BRA describes zoning with respect to building height, occupancy type, setbacks, and other design criteria. Genesis Design regularly referred to the BRA when making design decisions that could affect the building from a zoning perspective. When designing the double skin façade for example, setback and property lines had to be analyzed as the new system increases the building footprint above the fourth floor. According to the project documents and drawings, there is enough room above the fourth floor to utilize a 3 foot cavity in the double skin façade. Building property lines were also consulted during the move of the north façade to encompass the columns. Through this analysis, the team were able to increase the efficiency of the Boylston Street High Rise by maximizing property usage while maintaining rentable office space and adding rentable
retail space. The BRA was also consulted when laying out the site plan, including the usage of parking spaces along Boylston Street. These are currently not intended to be public metered parking spaces; they are designated by the city of Boston as a “Cab Stand”. However, during construction, this cab stand will need to be purchased from the city of Boston for the duration of the project. This cost is built into the general conditions in the budget section of this report.

5.0 SITE ANALYSIS

The Boylston Street High Rise is located in Boston’s Back Bay neighborhood. It is situated just to the north of the Prudential Tower and will occupy the last vacant spot in the Prudential Center office and retail area. The building is situated directly between Hynes Convention Center to the west and the Shops at the Prudential Center to the east. Access to the site is limited to the one-way, three lane Boylston Street which runs west to east; See Figure 4 for visual references.

5.1 SITE CONDITIONS

The Boston area contains unique site conditions both above and below street level. As mentioned above, the Boylston Street High Rise will be integrated into a dense and bustling commercial/residential neighborhood. Additionally, the geographical location of Boston makes it susceptible to hurricanes, blizzards, and earthquakes as well as flooding from the nearby Charles River. Compiled with the compact site and unpredictable forces of nature is the subgrade conditions. The subgrade conditions at this site are perhaps the most sensitive areas of the project. All of these concerns are described in the following sections and are detailed further on Drawing C-02 as well as Section 3 of the Structural Report.

5.1.1 EXISTING GROUND CONDITIONS

The subterranean levels of the site proved unique and challenging from a construction standpoint. Below the site exists a two-level parking garage surrounded by interlocking sheet piles. Built within these parking levels is a fan exhaust room that supports I-90. The tunnel itself cuts into the southwest corner of the site causing challenges in the demolition and structural work. Each of these construction tasks must be performed while maintaining uninterrupted function of both the highway and fan room; see Drawing C-03 for these site plans.

The geotechnical report for the site was also consulted for soil types and water conditions. The existing sheet piles effectively lowered the water table which proved promising for constructability. However, a contingency plan has been built into the schedule and budget for a dewatering system as well as slower demolition and construction around the sensitive areas; see Drawing C-02 for further details.

Other construction considerations involve the deep foundation techniques. The team effectively narrowed the options down between drilled caissons or driven piles. Though driven piles are more cost effective, drilled caissons were selected. The choice to drill was directly influenced by reducing the negative impact on the surroundings. The sound pollution and impact forces associated with driving piles could disrupt surrounding businesses, building foundations, or the I-90 tunnel. Using caissons also allowed for the implementation of a geothermal system within the deep foundations. See Section 7.0 of the Structural Report and Section 7.3 of the Mechanical Report for further details.

5.1.2 SURROUNDING CONCERNS

The project site is compact and does not allow for much flexibility. A main goal of the construction team was to minimize the impact on the surroundings. Therefore, a study was conducted for nearby parking availability, traffic patterns, pedestrian routes, and other matters associated with the community. Please see Drawing C-02 for a full analysis on addressing these concerns.
5.2 SITE LOGISTICS

Site logistics is a critical aspect of all construction projects as these early plans/layouts directly effect the flow of work, space utilization, and worker/pedestrian safety. The construction team completed an extensive site conditions analysis to best prepare an efficient and safe site logistics plan for all phases of the project. The previously mentioned site conditions were taken into consideration to create the initial site procurement plan; shown in Figure 5.

![Figure 5 – Site Securement Plan](image)

The basis of this plan will continue through each of the construction phases which are detailed in full on Drawing C-03.

The first stage is the securement of pedestrian safety. The parking spaces to the north of the site will be enclosed with a concrete barrier to reroute pedestrians around the site. The inner layer of site fencing will add a secondary protection for pedestrians as well as act as a dust barrier. Two portions of this fence will remain mobile to allow for the entrance and exit of construction vehicles. An onsite Genesis Construction representative will be in charge of receiving these vehicles and ensuring pedestrians are clear of the entrance/exit.

The surrounding buildings as well as the northern Prudential Mall entrance will be secured to avoid property damage as well as pedestrian injury. This will include a temporary partition within the mall to ensure shoppers do not exit via the north. Now that the site is secured the construction process can begin (Figure 6).

![Figure 6 – Demolition/Excavation Site Plan](image)

5.3 PHASING & SEQUENCING

The Boylston Street High Rise will be constructed in six main phases: Demolition, Sub Structure, Superstructure (1-4), Superstructure (5-17), Roof, and Plaza. The erection of the transfer trusses on the fourth floor will require additional planning because a second crane will need to be brought on site. The phasing diagrams can be found on Drawing C-04.

The structural sequencing will be one of the primary tools for saving both time and money. The Just-In-Time Delivery method as well as the Matrix Schedule, detailed in Sections 9.2.2 and 10.4, will each require a continual work flow. Crane priority is also critical when sequencing as only one crane task can be performed at a time. Therefore, the plans carefully sequence crane usage to ensure an efficient use of time. The site will utilize both a permanent tower crane as well as temporary cranes brought on site. The location and sizing of this equipment was imperative for planning and safety purposes.

5.3.1 CRANE SELECTION

The Boylston Street High Rise will utilize a tower crane as well as temporary mobile cranes. Selection of the tower crane was done in tandem with the structural team based on the heaviest steel member in the building. See CSD-D on crane selection calculations and
Section 5.7 of the Structural Report in regards to the transfer truss. The transfer truss necessitates the use of a second, smaller mobile crane to assist the tower crane. This crane was sized based on the weight of the transfer truss and the combined capacity and swing radius of both the permanent tower crane and the temporary mobile crane. Figure 7 below shows the Critical Pick plan for the transfer truss.

Figure 7 – Critical Pick of the Transfer Truss

5.4 SAFETY
Safety is always an important goal for the Genesis Design construction team. The attention to safety ensures the well-being of both the workers and pedestrians. Therefore, a Site Specific Safety Program (SSSP) was created to address safety concerns during all construction phases. Also included are emergency plans in the event of a natural disaster during construction. These include worker safe zones as well as cleared paths of egress for evacuation. These plans are detailed further on CSD-C.

The construction team has also compiled an emergency plan for the building once construction is complete. The plan will focus on educating the maintenance staff on system checks as well as best-practice procedures in the event of an emergency. This portion of the safety plan is detailed further in SD-G of the Integration Report.

Lastly, the Boylston Street High Rise will function as an emergency shelter for the building occupants and surrounding community. The facility has been engineered to maintain both operation and occupant safety in the event of a disaster and therefore has been designated a safe zone. A diagram of these procedures and safe zones are also available on CSD-C.

5.5 INTEGRATION & IMPACT
Genesis Design understands that construction has a strong and often negative impact on the surrounding community; therefore, construction techniques were selected that minimize these impacts on the surroundings such as:

- Interstate 90 and Fan Room
- Adjacent Businesses
- Boylston Street & Pedestrian Walkways
- Existing Parking Garage
- Emergency Services

Design decisions were made to reduce the impact the building will have on the adjoining structures. In some cases, design choices created a unique interface between this project and the adjoining structure. This was especially the case for the Prudential Center Mall as the retail portion of the high rise will be connected to the existing shopping center. Other considerations include sound and air pollution control, techniques to maintain operation, and marketing strategies.

5.5.1 BUSINESS DEVELOPMENT & MARKETING STRATEGIES
Genesis Design understands that a construction presence will inevitably disrupt the natural flow of city life. The construction team has developed a marketing strategy to help mitigate this impact. Local businesses and future Boylston Street High Rise advertisements will be integrated onto the site fence. The free advertising will be available for adjacent businesses whose customer flow may be disrupted. The additional Boylston Street High Rise and Plaza advertisement will educate the general population about the future for their city and hopefully create a sense of anticipation for the shopping center and plaza amenities. The goal is to minimize the negative impact of our construction presence while promoting a positive atmosphere surrounding the site. A sample of the site fence advertising is shown below in Figure 8.

Figure 8 – Site Fence Advertisement Example
The graphics will also contain educational information about the Boylston Street High Rise such as energy reduction/production numbers, resiliency facts, and plaza amenities. The team wants to inform the public as much as possible about the positive impact this new facility will have on their community. Further information is detailed in Section 7.6 as well as Drawing C-08.

6.0 3D & 4D COORDINATION

The design and construction teams used a combined 3D model throughout the entire project in order to increase collaboration and system integration. System integration was tested through 3D clash detection among the MEP and structural trades. For instance, the 3D clash detection software alerted the design team to a structural and mechanical error; shown below in Figure 9. The digital design correction effectively saved the construction team both time and money for rework.

![Figure 9 – 3D Clash Detection of Structural and Mechanical Systems](image)

The construction team also utilized a 4D model in order to most efficiently sequence the building. By integrating the CPM schedule, the team effectively created a digital construction sequence for the Boylston Street High Rise. Visualizing the phases of the building allowed for the team to better plan and track the construction process. This gave the design team more control over schedule variances. Genesis Design also developed a 5D, 6D, and 7D plan which incorporates estimating, sustainability, and facility management aspects. See CSD-B for further details.

7.0 BUILDING SYSTEMS

The Genesis Design team focused on several areas in which to establish the team goals of Sustainability, Resiliency, and Integration. These areas, summarized below in Figure 10, required extensive planning from each discipline in order to successfully meet project goals. As previously mentioned, these areas of integration were analyzed, weighted, and discussed before implementation within the project. However, the decisions required trade-offs and compromises which are discussed in the following sections.

![Figure 10 – Boylston Street High Rise Systems Summary](image)

7.1 OPTIMIZED DUAL FAÇADE

The primary area of integration for the Boylston Street High Rise is the Optimized Dual Façade. The façade element provides widespread benefits to the facility in both mechanical and electrical properties; see Section 6.0 of the Mechanical Report and 5.0 and Lighting/Electrical Report. This design posed several challenges from a constructability, cost, and maintenance standpoint.

7.1.1 CONSTRUCTABILITY CHALLENGES

Unlike a conventional high rise façade, the dual façade typically requires a two-step installation process, effectively doubling installation and schedule time. In order to account for this increase, the construction and structural team designed a structural support system...
that will be installed during the prefabrication process. The support structure will allow the inner and outer layers to be connected and installed at the same time without compromising the structural integrity.

7.1.2 COST
In addition to a schedule control challenge, the dual façade also poses a critical cost control issue. The associated cost with the additional layer and components increases the façade cost by approximately 2.5X the cost of a normal façade. The justification offset was determined by performing a lifecycle energy savings analysis; calculations for the energy savings are detailed in Supporting Document G of the Mechanical Report. The annual savings calculated total approximately $3.88 million with a payback period of 8 years, which is further elaborated on CSD-I.

7.1.3 MAINTENANCE
An additional requirement for such an integrative façade requires system maintenance and component access. Such maintenance includes accessibility to window surfaces, solar panels, louvers, and automated blinds. This will be made possible through access doors located on the inner façade on each office floor. The maintenance plan will be completed systematically based on an annual glass cleaning schedule and the required maintenance on remaining façade components.

7.1.4 RESILIENCY
One of project goals is facility resilience which encapsulates quality control and commissioning. The environmental conditions for the region pose troublesome for water infiltration and debris; therefore, the construction team will be overseeing a performance test on the façade. The testing will confirm proper installment and ensure function ability when the next storm hits.

7.2 GEOTHERMAL CAISSONS
The project goals of sustainability, resiliency, and integration were prominent in the design of the geothermal caissons. The primary reason for selection is the load reduction on mechanical systems; see Supporting Document F of the Mechanical Report. However, this choice proved challenging for both the structural and construction team from a design, installation, and maintenance standpoint.

7.2.1 CONSTRUCTABILITY CHALLENGES
The added mechanical element to the caissons required an increase in caisson diameter, leading to a greater quantity of excavated soil. Additionally, the piping system requires delicate handling to ensure the system is closed once in place. Overall installation required careful planning to ensure the equipment is operational before encased in concrete. Furthermore, the removal of mat slab continuity would create water infiltration issues requiring proper dewatering; see Drawing C-02.

7.2.2 RESILIENCY
The maintenance of the caissons themselves will be minimal once the system is up and running. However, the question remains how to handle the maintenance should one of the pipes fail. The system is designed with a prefabricated, reinforced support cage and strength tested PEX tubing. The durability of the system has proven very resilient in case studies, however, should a pipe break then the particular loop will be shut off and isolated from use. The remaining loops will continue operation as the whole system was designed with redundancy in mind.

7.3 OFFICE FLOORS
Genesis Design completed extensive planning to create a high-performance office space that provided both security and comfort to the occupants. The construction team collaborated heavily on this space to ensure that all systems could be physically integrated and still function accordingly. See Figure 11 below for a visual overview of the office space.

7.3.1 CONSTRUCTABILITY CHALLENGES: RAISED FLOOR
The mechanical design requires under floor air distribution; therefore, the office spaces are equipped with a raised access floor. The installation of a RAF
CONSTRUCTION NARRATIVE

7.3.1 CONSTRUCTABILITY BENEFITS

The placement of primary MEP runs increases both worker productivity and safety by providing an up close work space and reducing overhead work. This also increases coordination between trades as mechanical and electrical crews can install on an open floor without cluttered plenum space issues.

7.4 SERVER ROOMS

Each office floor will be serviced via a server room located at the core of the building. The continual functional ability of these servers is critical to the production and success of the tenants, therefore, great consideration was taken in construction and maintenance plans for these rooms. See Figure 12 for the server room construction details.

7.4.1 CONSTRUCTABILITY CHALLENGES

Aside from the high degree of MEP coordination, each server room will require controlled isolation and assured mechanical and electrical function. The server rooms will be comprised of a perforated raised access floor that allows cool air to circulate through the servers and be exhausted through the ceiling. This area will be isolated to ensure that no excess heat enters the office space. These rooms will also require an auxiliary fire suppression system composed of Nitrogen gas. The assessment associated with this addition is detailed in the next section.

7.4.2 COST

The cost of the server rooms will be built into the cost of a typical office plan. However, the addition of Nitrogen fire suppression equipment will be an added cost of approximately $30,000 for the refilling of tanks in the event of a fire; justifiable by the protection of expensive and sensitive equipment that otherwise would be damaged beyond repair with the use of a water-based fire suppression system.

7.5 ROOF & PARKING GARAGE

Though the roof and sublevels are not the primary eye-catching features of the building, they are greatly important; they house the core equipment that allows the building to function. The Genesis Design team focused on these two spaces to ensure equipment function ability and security. Accomplishing this goal created challenges for constructability, cost, and safety.

7.5.1 CONSTRUCTABILITY CHALLENGES

The sublevels will contain a Bathtub utility room design. The Bathtub design is a specially constructed room with seamless wall and floor connections and a water-tight sealable door. This is added insurance to ensure equipment safety in the event of a hurricane, flood, or water main malfunction. Construction and acquisition of this unique system as well as testing will be an important task for the construction team.

The roof also proved challenging; aside from worker safety the roof will include a PV array, water collection system, the penthouse equipment, and proposed system add-ons (see CSD-I for add-on details). Each system will require procurement, installation, commissioning, and lifecycle maintenance. These factors have been addressed and can be found in Section 8.0.
7.5.2 COST
The roof and sublevels contain the largest and most expensive pieces of equipment. These include the switchgear, transformers, generators, mechanical units, elevator motors, and PV arrays. Each of these requires a long lead time procurement as well as a detailed cost analysis. Furthermore, the suggested add-ons for the building have a separate cost analysis; both of which can be found in Section 11 of this report and CSD-H.

7.5.3 RESILIENCY
Though the procurement and installation of these critical items poses a challenge, the real construction challenge is maintaining these pieces of equipment. The equipment effectively allows the building to operate with the designed high performance and therefore must be properly maintained; see Section 8.2 of this report.

7.6 THE PLAZA & THE PEOPLE
The plaza space provided the greatest opportunity for public outreach as Boston works to both increase and improve their public spaces. From a constructability standpoint, the plaza did not pose many challenges; however, it did provide an opportunity for the Genesis Design team to incorporate both function and education. Part of the responsibility in the field of construction is to promote building sustainability and to bring awareness to the progress made by the building industry towards creating a greener future. This was accomplished through simple techniques that brought attention to the innovative facility and plaza. See Drawing C-08 for further details.

7.6.1 EDUCATION OF SUSTAINABILITY
The building industry, according to the USGBC, is responsible for approximately 40% of the energy consumed in the United States. It is also responsible for 40% of CO₂ emissions as well as 73% of electrical consumption. The building industry has one of the largest impacts on the health of the environment and consequently, the well-being of the future.

The goal is to exhibit sustainable attributes of the Boylston Street High Rise and show how individuals within the community can help contribute to creating a more promising future.

7.6.2 THE SUSTAINABLE ASPECTS
The design of the Plaza features a wind turbine tree to function as a center piece of sustainability. The plaza also contains several subtle features that won’t be covered in this section but are described in detail in Drawing I-10 of the Integrated Report. The wind turbine tree serves several individual functions including the production of renewable energy and connection to the city population.

One tree, capable of producing 3.1 kW of electricity, will provide power to the several outlets distributed throughout the plaza. The power is available for public use whether for work or personal electronic devices. Individuals can rest beneath these trees knowing the power they use is generated directly from clean, renewable energy.

Information containing all the sustainable Plaza amenities will be available on three outdoor touch screen devices located throughout the space; shown below in Figure 13. Further details are shown on Drawing C-08. These devices will be available during the construction process to inform the community on the upcoming Boylston Street High Rise. Individuals can access information about the building and plaza. This information will then be connected to other links regarding sustainable practices that can be performed on an individual basis.

8.0 RESILIENCY
The assurances of providing a high-performance building in a reasonable duration and at a reasonable cost are only half the goals of the Genesis Construction Team. The team also strives to ensure that the design continues to perform throughout the life of the building; providing safety and serviceability for years to come. These assurances are accomplished through system operation and maintenance plans which are detailed in full in Drawing C-09.
8.1 SYSTEM OPERATION
The Boylston Street High Rise is an intricate connection of engineered systems working in tandem to provide a high-performance building. Understanding how these systems operate together is crucial for proper building function; therefore, the Total Building Reaction Plan and accompanying training programs were created.

8.1.1 TOTAL BUILDING REACTION
Total Building Reaction refers to how this building and its occupants will respond in the event of a natural or man-made disaster. From a construction standpoint, the reaction plan describes the necessary steps to ensure occupant safety as well as worker safety during the construction process. TBR details emergency egress routes, interior safe zones, and other safety measures. A diagram of this plan is summarized in Figure 14.

Figure 14 – Total Building Reaction: Emergency Egress

8.1.2 SYSTEM TRAINING
System training differs from Total Building Reaction in that this type of training focuses on the operations and maintenance staff once construction is complete. The building system optimization is only achieved through proper monitoring and maintenance; therefore, facilities management guidelines will be prepared for the Office, Retail, and Subgrade systems. A detail of this maintenance plan is on Drawing C-09.

8.2 SYSTEM MAINTENANCE
System components are accompanied with a limited lifespan; which means that at some point in the future the component will need to be replaced. These replacements can come with a high cost and even disrupt building operations. The Genesis Construction team has created a maintenance plan to better predict and correct these troublesome areas. A list of these areas and associated benefits/recommendations is located in Drawing C-09.

8.2.1 PREDICTIVE MAINTENANCE (PdM)
The demanding performance of certain building components may cause a decrease in system efficiency causing for earlier repair or replacement. The Predictive Maintenance plan determines these areas and predicts the optimal time to perform Corrective Maintenance. The PdM plan effectively:
- Increases Operational Life
- Plans/Schedules System Downtime
- Predicts Costs/Budget for Repairs
The PdM monitoring system will be integrated into the Building Automation System. The BAS, detailed further on Drawing E-05 of the Lighting/Electrical Report, monitors and records system outputs. The maintenance plan will assess these outputs for striations from optimum performance outputs. Once a pattern is determined, monthly or annual corrective maintenance can be scheduled and performed.

8.2.2 CORRECTIVE MAINTENANCE
The graph below in Figure 15 shows a component performance over a given lifespan. There are three main periods detailed including the Optimal Performance Period, the Repair Period, and the Replacement Period.

Figure 15 – Predictive and Corrective Maintenance Curve
A system in the Repair Period will continue to perform but not at the system’s optimal performance capabilities. Corrective Maintenance to these areas early on will effectively bring the system back to optimal performance without the costly need for system shut-down, removal, and replacement. Examples of these benefits are available on Drawing C-09.
9.0 SUSTAINABILITY

The Genesis construction team implemented several techniques to support the team goals while maintaining the overall sustainability status. These techniques, described in the following sections, are the construction drivers in achieving a LEED Platinum facility in a timely and cost effective manner; see CSD-J.

9.1 MATERIAL SELECTION

Locally sourced materials will be used whenever possible. This includes the use of local contractors from each of the engineering fields as well as various fabricators; see Drawing C-09. Materials were also selected based on their composition to promote durability and sustainability while decreasing the overall embodied energy. The Genesis Design approach is summarized in Figure 16.

9.1.1 REUSED, REDUCED, & RECYCLED MATERIALS

The construction goals included reduction of nonrenewable resources as well as harmful materials. For example, the team used supplementary cementitious materials (such as fly ash) in the concrete decks. This reduced the need for Portland cement, a large source of CO₂ production. This utilized manufactured waste which otherwise would be disposed.

The superstructure and finishes of the building proved ideal for the use of recycled materials. The steel utilized in the structure will be composed of recycled steel accounting for approximately 32% of building steel impact. The wood accents and finishes in the office space are purchased from, Jarmak, a Massachusetts-based company that sells reclaimed lumber from the northeast United States.

The demolition of the existing site resulted in a large quantity of reinforced concrete that will be promptly shipped 20 miles to Dedham Recycling, a local aggregate recycling facility. There the rubble will be crushed and separated to be used as aggregates.

9.1.2 Embodied Energy

Both techniques will help to reduce the embodied energy composed within the building materials. This energy includes the acquisition, manufacturing, transporting, installing, and maintaining of building materials. The overall reduction through the construction techniques is approximately 39.8%; this is detailed in full on Drawing C-09.

9.2 CONSTRUCTION METHODS

The material selection of a building is only a portion of the sustainable construction obstacles. The actual construction of the building poses its own challenges in building green while maintaining schedule, budget, and quality. The construction team implemented several techniques in order to meet these challenges with increased efficiency.

9.2.1 PREFABRICATION

Prefabrication improves the project through efficiency and added quality control. The prefabrication of construction components effectively:

- Decreases the construction schedule
- Decreases costs of rework and wages
- Increases quality
- Increases worker safety

The prefabricated units assist in the accelerated Matrix Schedule of the office floors; these are described in further detail in Section 10.4. Further benefits include the level of quality control that can be applied to the units being constructed offsite. Such control includes the environmental conditions, work plane conditions, and safety conditions; each factor promoting an efficiency of production and quality.

Such prefabricated items include the plumbing chase wall fixtures throughout the fourteen office floors as

---

**Figure 16** – Genesis Design Sustainable Material Approach

---
well as the intricate dual façade and its many detailed elements. A complete list of the prefabricated items can be found on Drawing C-06.

9.2.2 MATERIAL DELIVERY

The construction team implemented a Just-In-Time Delivery Method which best facilitated the lack of storage space on site. The tight Matrix Schedule and JIT Deliveries work in tandem to maintain an efficient flow of construction activities. This allowed for a compacted schedule and reduction of general condition costs such as staffing. However, the JIT Delivery Method poses several real-world challenges such as schedule delays, change orders, traffic conditions, and manufacturing complications. Each of these factors inhibits the JIT Delivery system which is why the team implemented Advanced Material Tracking.

9.2.3 ADVANCED MATERIAL TRACKING

An advanced material tracking system was used to support the tight schedule and demanding accuracy of the JIT Method. The advanced tracking technique tags delivery items with a label containing a code, as seen below in Figure 17.

These codes can be scanned or manually entered into any mobile device on site to gain access to valuable information regarding the element. The digital link is connected to the company servers which allows for constant updating of material status. Such construction elements that will be tagged for tracking will include primarily long lead time items. Complete details of this system are available on CSD-E.

9.3 LEED ASSESSMENT

In order to quantify the facility’s sustainable attributes, the construction team completed a full LEED analysis. The Boylston Street High Rise scored an 84/110, resulting in a LEED Platinum Certification; the highest standard for sustainable buildings. However, the Boylston Street High Rise contains many unquantifiable features that exceed the sustainable standards. These features as well as the full LEED assessment can be found on Supporting Document F of the Integration Report.

10.0 PROJECT SCHEDULE

The Construction Team understands the importance of a timely project delivery in an industry where time is money. The goal of the team is to provide the desired facility quickly and efficiently while maintaining project budget and quality. In order to accomplish these goals, the team utilized several construction techniques to predict time constraints and schedule accordingly.

10.1 COMPARISONS

The selection of primary building systems greatly affected the project schedule through the acquiring of materials and execution of construction tasks. Therefore, schedule impacts were assessed for each of the system choices to determine installation feasibility. Such systems include the sub/super structures, the façade system, and mechanical systems.

10.2 LONG LEAD TIME ITEMS

After system selection, the construction team compiled a list of items that required early planning to provide adequate time for manufacturing and delivery to site. These items, detailed on Drawings C-05 and C-06, could drastically affect the schedule if early preparation failed to occur. An example of the primary critical items is shown in Table 2.

10.3 MILESTONE & CPM

The two previous factors combined to create the baseline for the critical path schedule which detailed the primary construction tasks. This schedule was broken down into six main categories. The CPM schedule can be
found on Drawings C-05 and C-06 which further includes a link to the most critical long lead time items.

10.4 MATRIX SCHEDULING
The baseline CPM schedule was broken down into further detail and analyzed for areas containing high repetition; Floors 5-17 proved highly repetitive and therefore were utilized in the Matrix Schedule. This technique promoted an efficiency of time and labor. The calculated duration for each office floor is approximately 100 days. This efficient flow of work effectively reduced the schedule by three months. Please see Drawing C-07 for matrix schedule details.

11.0 COST CONTROL
The Construction team was challenged to create a high-performance building at a reasonable cost. An initial cost analysis was performed on a similar building in Boston, currently under construction, which provided a baseline price of approximately $583/SF or roughly $270,000,000 for the Boylston Street High Rise. Figure 18 below shows the development of project costs.

Figure 18 – Project Cost Progression

As Figure 18 depicts, the addition of solar panels and the double skin façade increased the cost of the building to about $301,000,000 for the refined systems stage. The cost model titled “All Systems” would include all add alternates and a thermal chimney which was eliminated due partly to extreme costs. Further cost analyses were performed starting at the system selection and continued throughout the lifecycle costs. Further details are available on SD-07.

11.1 COST COMPARISONS
Several cost comparisons between design options were conducted. This cost factor was taken into consideration in the decision matrix as both direct and lifecycle costs are weighted factors. However, not all systems were chosen for their low costs and therefore required both an initial and lifecycle cost analysis to determine the overall financial effect and approximated return on investment. The primary example is the concrete versus steel core with a 50% increase initial cost but a $114,000 implied cost savings. This gave the decision real-world feasibility for both the long and short term investment. Further detailing of these costs can be found in CSD-I.

11.2 INITIAL VS. LIFECYCLE COSTS
The upfront cost of a system only partially determined the feasibility of implementation. Further analysis on system performance and potential lifecycle costs or savings also needed performed. A few systems, such as the double-skin façade, proved to be a large upfront investment that seemed too costly for budget constraints. After a lifecycle costs savings analysis, it was determined that the lifecycle savings outweighed the upfront costs of implementation. Please see Supporting Document G of the Mechanical Report and SD-I. After completion of the initial and lifecycle cost analysis, the additional cost of the mechanical systems and double skin façade will have a payback period of approximately 8 years. A summary overview of the initial cost, energy cost, and energy savings are shown below.

| Tables 3 & 4 – Initial and Lifecycle Cost Analysis Summary |
|---------------|---------------------------------|----------------------------------|------------------------------|
| Energy Usage Cost Analysis | Baseline | Boylston Street High Rise |
| Energy Consumed (kWh/yr) | 36,674,491 | 17,239,906 |
| Cost of Energy ($/kWh) | $0.1999 | $0.1999 |
| Cost per year ($/yr) | $7,331,230.75 | $3,446,257.21 |
| Yearly Savings | $3,884,973.54 |

<table>
<thead>
<tr>
<th>Initial Investment</th>
<th>Cash Flow</th>
<th>Payback</th>
</tr>
</thead>
<tbody>
<tr>
<td>$30,782,707</td>
<td>$3,884,974</td>
<td>7.92 years</td>
</tr>
</tbody>
</table>

11.3 VALUE MANAGEMENT (VM)
VM is used in highly collaborative team structures and assists in achieving project goals at a minimized cost. VM is similar to the concept of Value Engineering except it is present throughout all stages of the project lifecycle and not just the design stages. Such techniques include:
- Identifying Project Goals – Tenant/City needs
- Criteria Weighing – Via the Decision Matrix
- Cost Benefit Analysis – Direct vs Lifecycle
- Process Mapping – BIM-EX Planning
- System Maintenance – PdM & Corrective Plan
- Project Delivery – Construction Techniques
These techniques contributed to the structure of the team; development of team goals and client needs; how these systems would be selected; how to quantify choices; how to construct these systems effectively; and how to maintain them. The establishment of the Value Management program allowed Genesis Design to plan efficiently in order to produce a quality product at a minimum cost.

11.4 ADD ALTERNATES
Creating a flexible building is a primary goal for the Genesis Design team. Flexibility makes a building resilient to change allowing for adaptation to city or tenant needs. The team brainstormed several innovative ideas that were initially dismissed but could one day be implemented as a building add-on. Such components include rooftop wind turbines that were initially dismissed for the cost, maintenance, and payback period challenges. A list of these add alternates are listed on CSD-I.

11.5 TOTAL BUDGET SUMMARY
The initial cost for the Boylston Street High Rise is estimated at $301,783,000 or approximately $612/SF. This cost includes all project square feet. Project cost per rentable square footage is $741/SF. This includes full fit-out of floors 4-17 and a core and shell for floors 1-3.
This fair value cost estimate is broken down by bid packages, shown in its entirety on CSD-H. The increase in cost is associated primarily with the optimized dual façade; however, this feature as well as the other cost driving items proved cost effective in the building’s extended lifespan with a quick return on investment and high energy savings.

12.0 CONCLUSION
The goals of the Genesis Design Construction Team were to create a high-performance building that could withstand the tests of time and nature. Quality control and quality assurances should also be preserved, while maintaining the project budget and schedule as well as the health of the public and surrounding environment. Through the IPD Method and highly collaborative team structure, the construction team was able to achieve each of these project goals.

The resulting Boylston Street High Rise is a high-performance facility that exhibits prestige in SUSTAINABILITY, RESILIENCY, and INTEGRATION for the tenants, developers, and community alike. Through the preliminary planning and system selection, the Boylston Street High Rise is a collection of innovative and efficient systems designed to ensure continued function through the unpredictable forces of nature and time.

The construction team was involved early in the process to facilitate system selection and ensure decisions were made based on project goals with added real-world parameters including constructability, cost, and schedule. The selection, procurement, installation, and maintenance of these systems were strictly monitored in order to construct efficiently. These systems were then tested and secured to ensure that what was promised is what was delivered.

Each of these systems was then detailed in the maintenance program to ensure continued performance throughout the lifespan of the building. These plans helped to solidify the high-performance operability even after project turnover. A summary of these successful project goals and accompanying construction techniques are highlighted in Table 5.

<table>
<thead>
<tr>
<th>Project Component</th>
<th>Value Added to Project</th>
</tr>
</thead>
</table>
| Optimized Dual Façade | Reduced mechanical load by over 50%  
Pays for itself in 8 years                       |
| Geothermal Caissos  | Reduced overall mechanical load by 8%                                              |
| Server Rooms       | Reduces chance of system failure.  
                      Allows tenants continuous operation.                                       |
| Wind Trees          | Generates electricity for public use.  
                      Draws people to plaza and building.                                           |
| Matrix Scheduling   | Reduces schedule by 7 weeks compared to baseline.                                   |
| Braced Frame        | Reduces schedule by 5 weeks compared to baseline.                                   |
| Material Tracking   | Allows for use of condensed matrix scheduling.  
                      Increases field coordination.                                                  |

The project goal summary shows that the Boylston Street High Rise successfully meets and exceeds the desired project vision by establishing goals of SUSTAINABILITY, RESILIENCY, and INTEGRATION through every facet of the building design. The Genesis Design Team strongly believes that the Boylston Street High Rise is truly a testament to high-performance buildings and stands as a benchmark for the future of Boston high rises.
DECISION MATRIX

The table below shows the major decisions that were made by the construction team in order to effectively manage this project. The decision matrix was created in order to quantitatively view the decisions that needed to be made. This process was also applied to the other design options when designing the building. Categories were first created within the three driving factors of Sustainability, Resiliency, and Integration. These categories were then weighted based on how much they affected the option being evaluated. While the scores obtained were not final decisions, it was important to quantify the decisions that were being made in order to understand that the team was not drifting from the design drivers. This was able to keep the team grounded and realistic, without sacrificing innovation.

### GENESIS DESIGN DRIVERS

<table>
<thead>
<tr>
<th>SPECIFIC OPTIONS WITHIN SYSTEM CATEGORY</th>
<th>SUSTAINABILITY</th>
<th>RESILIENCY</th>
<th>INTEGRATION</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>ENERGY REDUCTION</td>
<td>OCCUPANT WELL-BEING</td>
<td>INITIAL PROJECT COSTS</td>
</tr>
<tr>
<td></td>
<td>LIFE CYCLE COSTS</td>
<td>SAFETY &amp; SECURITY</td>
<td>OPERATIONS/MANUFACTURING</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>UNPREDICTABLE FORCES</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>WEATHER CONTROL</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>FLEXIBILITY</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>SYSTEM CONSIDERATION</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>CONSTRUCTION IMPACT</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>URBAN CONNECTION</td>
</tr>
<tr>
<td>TOTAL SYSTEM SCORE</td>
<td></td>
<td></td>
<td>SYSTEM RECOMMENDATION</td>
</tr>
</tbody>
</table>

### DECISION MATRIX

<table>
<thead>
<tr>
<th>SYSTEM CATEGORY</th>
<th>SPECIFIC OPTIONS WITHIN SYSTEM CATEGORY</th>
<th>SUSTAINABILITY</th>
<th>RESILIENCY</th>
<th>INTEGRATION</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>ENERGY REDUCTION</td>
<td>OCCUPANT WELL-BEING</td>
<td>INITIAL PROJECT COSTS</td>
</tr>
<tr>
<td></td>
<td></td>
<td>LIFE CYCLE COSTS</td>
<td>SAFETY &amp; SECURITY</td>
<td>OPERATIONS/MANUFACTURING</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>UNPREDICTABLE FORCES</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>WEATHER CONTROL</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>FLEXIBILITY</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>SYSTEM CONSIDERATION</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>CONSTRUCTION IMPACT</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>URBAN CONNECTION</td>
</tr>
<tr>
<td></td>
<td>TOTAL SYSTEM SCORE</td>
<td></td>
<td></td>
<td>SYSTEM RECOMMENDATION</td>
</tr>
</tbody>
</table>

### Project Delivery Method Decision

<table>
<thead>
<tr>
<th>Method</th>
<th>Decision</th>
<th>Explanation of Decisions</th>
</tr>
</thead>
<tbody>
<tr>
<td>CM at-Risk</td>
<td>No</td>
<td>- Not much capability for early design input</td>
</tr>
<tr>
<td>Design-Build</td>
<td>No</td>
<td>- Good design input and value management</td>
</tr>
<tr>
<td>IPD</td>
<td>Yes</td>
<td>- Most cooperative way to manage project</td>
</tr>
<tr>
<td>CM Agency</td>
<td>No</td>
<td>- More input than CM at-Risk</td>
</tr>
</tbody>
</table>

### Scheduling Techniques Decision

<table>
<thead>
<tr>
<th>Technique</th>
<th>Decision</th>
<th>Explanation of Decisions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Matrix</td>
<td>Yes</td>
<td>- Repetitive upper floors lend themselves well to matrix</td>
</tr>
<tr>
<td>After learning curve is overcome, highest levels of productivity are possible</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CPM</td>
<td>Yes</td>
<td>- Now industry standard</td>
</tr>
<tr>
<td>Helps subcontractors and superintendents with 2-week look-a-heads</td>
<td></td>
<td></td>
</tr>
<tr>
<td>IPD</td>
<td>Maybe</td>
<td>- Helps with site storage</td>
</tr>
<tr>
<td>- Small site may necessitate this technique</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Just-in-Time</td>
<td>Yes</td>
<td>- Higher quality because materials are not stored on-site</td>
</tr>
<tr>
<td>- Allows contractors to track deliveries on an hourly basis</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Site Logistics Decision

<table>
<thead>
<tr>
<th>Logistics</th>
<th>Decision</th>
<th>Explanation of Decisions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Co-Location Office</td>
<td>Yes</td>
<td>- Higher quality than on site trailer</td>
</tr>
<tr>
<td>- More collaborative environment</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Design team and construction team work together</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Off-Site Warehouse</td>
<td>Maybe</td>
<td>- Possible for higher quality construction</td>
</tr>
<tr>
<td>- Storing materials nearby instead of on-site helps logistics</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Extremely high cost of close warehouse is problematic</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Typical Trailers</td>
<td>No</td>
<td>- Not much space on site</td>
</tr>
<tr>
<td>- Low cost</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Explanation of Decisions

- MEP Racks: Yes - Reduces overhead work in corridors - Safer - More efficient
- Façade Panels: Yes - Assembled off site - Helps with complex installation procedure
- Full Bathrooms: No - Not the best project for full bathrooms - Difficult to deliver to higher floors - Better suited to low-rise structures such as senior living facilities
- Chase Walls: Yes - Same location on each floor allows for vertical chase wall pre-assembly
- No Prefabrication: No - Never truly an option; prefabrication is necessary for such an aggressive schedule.
BIM COORDINATION DURING DESIGN

In order to effectively manage the coordination of multiple trades working in the same space at the same time, it was necessary to develop a BIM coordination plan. This plan involved the use of 3D clash detection in order to more efficiently design the building systems. It was determined that the mechanical system and structural system had the most clashes, so examples of these clashes are shown below. The first two clashes were similar and happened several times per floor. They involved the layout of the underfloor air distribution supply ductwork (red) and the floor framing (green).

Clash 1 and 2: Rectangular supply ducts and structural floor framing members.

Clash 3: Supply diffuser and structural column.

TOTAL BIM MANAGEMENT

To fully utilize BIM management, Genesis Design developed a plan to utilize building information modelling throughout all phases of the project. Instead of only applying BIM to the typical 4-dimensions, Genesis established a 7 dimensional BIM management plan seen at the right. In addition to the typical site planning and scheduling used on most projects, estimating, lean construction, and facility management are also implemented into the BIM management plan. Systems were designed with lean construction in mind by running full energy simulations; cost estimates were developed using these fully designed systems, then a facility management plan was created in order to manage the comprehensive systems which are being applied. This plan includes a maintenance scheme and training plan to educate the facility managers in the building’s systems.

CLASH CORRECTIONS

To rectify clashes 1 and 2, the ductwork was resized to be made slightly more rectangular rather than square in order to fit under the floor. Changing the cross sectional layout of the ductwork necessitates a recalculation of the fan size due to the more turbulent air flow through a rectangular duct. By catching this in the design process rather than in the field during construction, the team was able to save time on the order of a few days fieldwork. Clash three shows a supply diffuser clashing with a structural column. This also happened several times per floor and simply required moving the diffusers.
SITE SPECIFIC SAFETY PLAN (SSSP)

The purpose of this Site Specific Safety Program is to help facilitate a safe and healthy working environment for all workers involved in this project. A safe team is happy and efficient, leading to a higher quality of work which Genesis Design strives to achieve. While this program is expansive, it is not all encompassing; safety must be a top priority of every employee working on this project. Communication and a strict adherence to the rules outlined below will lead to a safe environment, however it is the responsibility of every contractor to implement and enforce their own safety plan to act as a supplement to this program.

This project will have a designated on-site safety representative to oversee all safety aspects of the project. This safety representative will be in frequent contact with all of the foreman involved in the project. He will be present at all foreman and project manager’s meetings and will be consulted with respect to sequence of work and other areas of construction safety. In addition to these meetings, he will conduct daily meetings (toolbox talks) with foreman in charge of the day’s work to go over any safety precautions that should be taken.

According to osha.gov, a competent person is someone who is:

Capable of identifying existing and predictable hazards in the surrounding; or working conditions which are unsanitary, hazardous, or dangerous to employees, and who has authorization to take prompt corrective measures to eliminate them. Each trade must have a competent person during all aspects of their work in order to help prevent any unnecessary unsafe working conditions. This person should be able to recognize and avert any potential dangers that may present themselves throughout the course of work.

Upon the arrival of any new employees to the jobsite, they will undergo a safety orientation conducted by the Genesis Design’s designated safety representative. It will include common practices and pitfalls of working on a site of this nature. It will focus mostly on hazards related to foundation work and structural steel erection. The goal of this orientation is to provide each employee who will work on site with a thorough analysis of hazards that may occur in relation to this project. Upon the completion of the safety orientation, each employee will be given an identification number to place inside their hardhat. Each employee will be logged into a system and each foreman will note on his daily report who was present that day. This is done to ensure that all employees are accounted for and safe. Each worker will also sign a release, stating that they understand all the rules set forth in the safety program, and that they will not hold the contractor or owner responsible for any damages that may occur. The safety representative will also sign the identification card to be placed inside the employee’s hardhat, recognizing that this employee has completed the safety orientation. It is the responsibility of each trade to adhere to the guidelines set forth by the safety representative in the safety orientation.

In case of any type of emergency or injury, certain protocol must be followed. The map on this page indicates the nearest two hospitals to the project, Tufts University Medical Center and Massachusetts General Hospital. In case of an injury the operator and/or a worker from working, but doesn’t require immediate medical attention, the designated safety representative should be notified to be sure that medical attention is not necessary. The accident will be reported, logged, and brought to the attention of all workers at the next foreman’s meeting. In case of a more serious injury, emergency medical services should be contacted first by dialing 911. While this is occurring, the safety representative should be notified too, in order to provide medical assistance until qualified medical professionals arrive on scene.

It is the responsibility of each trade to maintain a clean and safe working environment. At each day’s end, each trade should clean up the area in which they were working. Unsafe working conditions often are the result of unclean jobsites and this should be avoided at all costs. If the construction manager deems an area unsafe to work in because of construction debris, the offending trade will first be notified of the situation and given until the end of the day to clean the area. If the area is consistently not maintained, the construction manager will provide labor to clean the area and back charge the offending contractor.

Cranes Usage:

All cranes and lift operators shall be licensed by the Commonwealth of Massachusetts to operate this machinery.

All cranes and lifts shall comply with OSHA regulations, 29 CFR 1910.179, regarding overhead and gantry cranes operation.

A competent person shall be in charge of all lifts involving cranes.

A pre-lift plan shall be in place prior to any significant lifts which will occur using a crane. This includes major mechanical equipment and members of the transfer truss. This pre-lift plan shall include the operators name, proof of certification, survey of surrounding area, description of the crane, list of equipment being lifted, appropriate sketches, and a pre-lift meeting shall occur for proper coordination among the trades.

Proper hand signals shall be enforced among people on the ground directing the operator.

Fall Protection:

All workers are required to have fall protection when working at elevations ≥ 6’.

A competent person must equip and maintain the fall protection system.

Fall protection equipment shall be inspected before each use for wear or fraying.

Guardrails on the roof shall be at least 42” in height with toe boards.

Any work opening with an elevation ≥ 6’ shall have proper protection present.

Designated On-Site Safety Representative

This project will have a designated on-site safety representative, employed by Genesis Design, to oversee all safety aspects of the project. Once employed, his contact information will be as follows:

Name: Bob Smith
Cell Phone Number: 555-484-4858
Email: bob.smith@genesis-design.com

Nearest Hospitals

Tufts University Medical Center
800 Washington St
Boston, MA 02111
1.5 miles from project site

Massachusetts General Hospital
55 Fruit St
Boston, MA 02114
1.6 miles from project site

Emergency Evacuation Route/Safe Zones

The above plan shows evacuation procedures in case of a disaster situation. Evacuation routes are shown in red. The area highlighted in gold is a designate ‘safe zone’. This is the safest area of the building which employees should report to in case of a shelter in place scenario. The meeting location across Boston Street is the point where all employees can meet to be accounted for.

SUPPORTING DOCUMENT C: SITE SPECIFIC SAFETY PLAN & EMERGENCY EVACUATION

AIEI TEAM 02-2016 © CONSTRUCTION SUBMITTAL © PAGE 161
TOWER CRANE

There were several items that went into selecting cranes for this project. The main element that drove crane selections was the transfer truss located on the fourth floor of the building. The crane selected for this project is the Terex CTL 630-32 HD23, the specs of which can be seen highlighted in the table below. A tower crane was selected because of the small site and high-rise nature of the project. The crane had to be capable of lifting 27.5 US tons, the heaviest steel element in the project (part of the steel transfer truss). This crane also had to be able to span 175 feet, the distance from the crane pad to the farthest member of the building. Additional considerations when sizing the crane included the powerful year-round winds prone to the Boston area. The factor of wind sail played a large role in order to ensure constant control and safety during each pick. The wind during the winter months is approximately 13 MPH or 2 MPH higher than in the summer. This fact coincides with the choice to erect the bulk of the steel during the summer months rather than the winter months; to partially mitigate the negative schedule impacts due to wind forces.

<table>
<thead>
<tr>
<th>MODEL</th>
<th>LOAD DOWNTONEL</th>
<th>MAX. CAPACITY, (131)</th>
<th>JIB TIP MAX. CAPACITY @ FULL JIB (131)</th>
<th>MAX. JIB LENGTH, m (ft)</th>
<th>MIN. JIB LENGTH, m (ft)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CTL 140-8 TS</td>
<td>140</td>
<td>8 (6.8)</td>
<td>1.8 (2.0)</td>
<td>50 (164.0)</td>
<td>30 (98.4)</td>
</tr>
<tr>
<td>CTL 140-10 TS</td>
<td>140</td>
<td>10 (11.2)</td>
<td>1.8 (2.0)</td>
<td>50 (164.0)</td>
<td>30 (98.4)</td>
</tr>
<tr>
<td>CTL 180-16 HD2</td>
<td>180</td>
<td>16 (17.6)</td>
<td>2.0 (2.2)</td>
<td>55 (180.4)</td>
<td>30 (98.4)</td>
</tr>
<tr>
<td>CTL 180-16 HD23</td>
<td>180</td>
<td>16 (17.6)</td>
<td>2.0 (2.2)</td>
<td>55 (180.4)</td>
<td>30 (98.4)</td>
</tr>
<tr>
<td>CTL 180-16 TS23</td>
<td>180</td>
<td>16 (17.6)</td>
<td>2.0 (2.2)</td>
<td>55 (180.4)</td>
<td>30 (98.4)</td>
</tr>
<tr>
<td>CTL 260-16 HD23</td>
<td>260</td>
<td>18 (19.6)</td>
<td>3.1 (3.4)</td>
<td>55 (180.4)</td>
<td>30 (98.4)</td>
</tr>
<tr>
<td>CTL 260-16 TS23</td>
<td>260</td>
<td>18 (19.6)</td>
<td>3.1 (3.4)</td>
<td>55 (180.4)</td>
<td>30 (98.4)</td>
</tr>
<tr>
<td>CTL 340-24 HD23</td>
<td>340</td>
<td>24 (26.5)</td>
<td>4.0 (4.4)</td>
<td>60 (199.9)</td>
<td>35 (114.8)</td>
</tr>
<tr>
<td>CTL 340-24 TS23</td>
<td>340</td>
<td>24 (26.5)</td>
<td>4.0 (4.4)</td>
<td>60 (199.9)</td>
<td>35 (114.8)</td>
</tr>
<tr>
<td>CTL 440-24 HD23</td>
<td>440</td>
<td>24 (26.5)</td>
<td>5.5 (6.1)</td>
<td>60 (199.9)</td>
<td>35 (114.8)</td>
</tr>
<tr>
<td>CTL 440-24 HD23</td>
<td>440</td>
<td>24 (26.5)</td>
<td>5.5 (6.1)</td>
<td>60 (199.9)</td>
<td>35 (114.8)</td>
</tr>
<tr>
<td>CTL 630B</td>
<td>630</td>
<td>32 (55.3)</td>
<td>6.7 (7.3)</td>
<td>65 (213.3)</td>
<td>35 (114.8)</td>
</tr>
<tr>
<td>CTL 650F</td>
<td>650</td>
<td>45 (49.6)</td>
<td>7.0 (7.7)</td>
<td>65 (213.3)</td>
<td>35 (114.8)</td>
</tr>
</tbody>
</table>

T340-1 XL Truck Crane

USA Model - 8000 Personne/Material Hoist

MATERIAL HOIST

Another important piece of equipment that will be needed on this project is a material hoist. It was decided that the material hoist should be placed at the North-West corner of the building. This location is ideal because it is close to the delivery location on the site. The hoist location and delivery area can also be found on the figure above. A schematic of the hoist selected is shown at left. It is a USA Hoist model USA-8000 Personnel/Material Hoist. The capacity of the hoist is 8000 lbs, and it moves at 300 feet/minute. meaning that a trip to the highest floor of the building can be made in under one minute. The hoist has two cabs which run independently of one another, allowing for continuous operation. Costs for all of these items can be found in the General Conditions Estimate.

TEMPORARY CRANE TRUSS

This project has a designated “critical pick”. This critical pick is the heaviest element of the project, this proved to be the two steel transfer truss located on the fourth floor. Identifying the heaviest element of the building is important because it is usually the most dangerous pick of the entire project. For this reason, Genesis Design decided that it was in the best interest of safety and productivity that a second, temporary crane be brought to the site in order to assist the main tower crane with placing the transfer truss. The crane selected for this task was the Terex telescoping T340-1 XL truck crane. This crane and the tower crane are capable of lifting the truss together. The temporary crane has a 40 ton maximum lifting capacity, as well as a 130 ft radius at 20”, more than enough length and capacity to erect the truss. A site logistics plan for the critical pick is below, showing the location of both the temporary and tower cranes. This task has a dedicated line item in the schedule and both cranes have been budgeted for.
MATERIAL TRACKING

The compact urban site and tightly scheduled Just-in-time Delivery method were entirely dependent on the handling of materials. This includes the entire process of material selection through material installation. The organizational flow chart to the right shows the overall process that Genesis Construction took to ensure that the critical items were properly secured.

The critical items include primarily system equipment that require long lead times for ordering, manufacturing, and delivery to site. These items are listed in Step 1. The next step was ordering the materials and assigning them with customized tracking labels.

The tracking labels allow for the management team to monitor materials in all stages of the construction process. The first is tracking the critical items for exact delivery dates to the site which is acquired through activation of the label once the material is tagged at the manufacturer’s location. Once the material arrives on site, the Genesis Representative will receive the item, scan the code, and immediately be presented with information; see the figure in the bottom center of the page.

Should the item be stored, such as equipment that is not yet ready to be installed, the label will detail the location of the storage area as well as any storage conditions that may be required. Once the item is ready for installation the on-site foreman or installer can simply find the stored item, scan the code, and immediately be informed of where the item is to be installed and the trade responsibilities. Overall, the process is meant to create quality assurances for the materials as well as increase efficiency of the material acquisition and installation process.

Once systems and materials were selected, we made a list of critical items to be tracked. These items are critical in that they can affect the critical path or are considered long lead time items that may need extensive tracking over a long period of time. The labels will be attached to the units and wait for the delivery date. The labels will also serve as a tracking system for suppliers to ensure each item is accounted for. Suppliers can also scan the label to acquire valuable information on the item such as shipping date and location; if the item should be stored, the label will detail the location on site to be stored until installed.

If the item is ready for installation the on-site foreman or installer can simply find the stored item, scan the code, and immediately be informed of where the item is to be installed and the trade responsibilities. Overall, the process is meant to create quality assurances for the materials as well as increase efficiency of the material acquisition and installation process.

Each critical item is tagged with a custom Genesis Design Tracking label. The label contains both a scannable barcode and unit code. Each can be entered into any mobile device to connect to the company servers. This will provide a link to valuable item information such as:

- Drawing References
- Location Stored
- Installation Date
- Warnings (e.g., Flammable)
- Storage Requirements
- Contractor Responsibility

This information is readily and easily available for representatives on site.
PREDICTIVE AND CORRECTIVE MAINTENANCE

One of the primary Genesis Design goals is the Resiliency of the facility. The systems were designed to perform against the unpredictable forces of nature; however, the unrelenting forces of time also cause detrimental damage to the performance of a system. Therefore, the Genesis Construction team developed a Predictive and Corrective Maintenance Plan to best handle the inevitable wear and tear of system components. The predictive maintenance portion of the program is perhaps the most challenging due to the number of systems and their variety of components. Therefore, we implemented the Honeywell management program. The Honeywell software program monitors system outputs which can then be compared to the expected performance output levels. The monitoring of these values will alert the maintenance staff when a system reaches below an acceptable output level. The system will then require CORRECTIVE maintenance to resolve the problem. This maintenance may include changing oil, changing filters, cleaning the system, or replacing a component. The monitoring of each system will create a pattern that the maintenance crew then regularly schedule to ensure minimal system interruption during prime working hours. A further list of these benefits are listed below in the system diagram.

CORRECTIVE MAINTENANCE CURVE

The yellow curve above shows the typical lifespan of system equipment. The component will begin working at 100% design capacity and progressively decrease due to natural wear and tear of system components. This is especially true for moving system components such as the inner workings of elevator equipment. The system continual to deteriorate until the equipment reaches the projected service lifespan and needs replaced. The replacement of equipment is often very costly for material and loss of productivity time due to system shutdown.

However, with our Predictive and Corrective Maintenance Plan we can effectively monitor these critical systems for signs of deterioration and plan schedule down-times for corrective maintenance. This corrective maintenance will then bring the system back to near 100% working condition. The graph below shows a simplified representation of the time benefits associated with corrective maintenance.

INCREASE IN SYSTEM LIFESPAN

- System components are subject to wear giving the component a limited lifespan. The maintenance of these components reduces the wear and allows the system to operate longer without replacement.

INCREASE IN SYSTEM PERFORMANCE

- The gradual wear on system components will decrease the system’s ability to operate at full capacity. Maintenance of these components increases performance.

REDUCTIONS IN MAINTENANCE COSTS

- Predicts/Detects minor maintenance issues before they become a major and costly maintenance repair.

REDUCTION IN SYSTEM SHUTDOWNS

- Creates a scheduled system down time to perform maintenance or replacement during off hours.

REDUCTION IN EQUIPMENT DAMAGE

- The continual maintenance of system components will allow for the equipment to operate more efficiently while minimizing system strain.

MECHANICAL/FP EQUIPMENT

- Rooftop Units (RFU)
- Fans/Motors
- Water Pumps
- VESDA Alarm System
- Ceiling Smoke Detectors
- Fire Suppression Heads

LIGHTING/ELECTRICAL EQUIPMENT

- Occupancy Sensors
- Daylight Photosensors
- Lighting Fixtures
- Louver Tilt Control
- Uninterruptible Power Supply

The Honeywell manager is a monitoring system that detects and records system outputs. Our management team will monitor these outputs for to determine when the system needs maintenance.

ELEVATOR/ESCALATOR EQUIPMENT

Monitoring System Output

- Maintenance of: Motors
- Bearings
- Governor
- Brakes
- Cables
- Shafts

COGENERATION SYSTEM EQUIPMENT

Monitoring System Output

- Wind Turbine Trees
- PV Roof Array
- PV Façade Array
### General Conditions

One of the first areas of the budget created for this project was the general conditions. Staffing a project of this magnitude and depth is very challenging. By developing the general conditions costs early, the owner is able to see where these costs are coming from. As expected, staffing the project is where most of the general conditions costs are held. The general expenses portion of the general conditions budget is also significant, however, this is mainly due to the general contingency. If not fully utilized, this money will return to the owner, further reducing the overall project cost. Highlighted in red are several general conditions items that are very important to the project. An explanation of these line items can be found in the table below. The general conditions account for about 5.5% of the total project cost.

#### SUPPORTING DOCUMENT G: GENERAL CONDITIONS

#### General Conditions

<table>
<thead>
<tr>
<th>Spec. Name</th>
<th>Project Tasks</th>
<th>Lab. Cost/Unit</th>
<th>Mat. Cost/Unit</th>
<th>LAB.</th>
<th>UNITS</th>
<th>MAT. COST ($)</th>
<th>Lab. Cost ($)</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Building Permit</strong></td>
<td><strong>$4,800.00</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td><strong>4,800.00</strong></td>
<td><strong>4,800.00</strong></td>
</tr>
<tr>
<td><strong>Mechanical Permit</strong></td>
<td><strong>$4,500.00</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td><strong>4,500.00</strong></td>
<td><strong>4,500.00</strong></td>
</tr>
<tr>
<td><strong>Electrical Permit</strong></td>
<td><strong>$7,200.00</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td><strong>7,200.00</strong></td>
<td><strong>7,200.00</strong></td>
</tr>
<tr>
<td><strong>Plumbing Permit</strong></td>
<td><strong>$12,000.00</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td><strong>12,000.00</strong></td>
<td><strong>12,000.00</strong></td>
</tr>
<tr>
<td><strong>Fire Suppression Permit</strong></td>
<td><strong>$5,000.00</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td><strong>5,000.00</strong></td>
<td><strong>5,000.00</strong></td>
</tr>
<tr>
<td><strong>Warrant of Survey for Curbs/Sidewalks</strong></td>
<td><strong>$1,000.00</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td><strong>1,000.00</strong></td>
<td><strong>1,000.00</strong></td>
</tr>
<tr>
<td><strong>Sidewalk Encroachments</strong></td>
<td><strong>$300.00</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td><strong>300.00</strong></td>
<td><strong>300.00</strong></td>
</tr>
<tr>
<td><strong>Street Encroachments (Cab Stand)</strong></td>
<td><strong>$300.00</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td><strong>300.00</strong></td>
<td><strong>300.00</strong></td>
</tr>
<tr>
<td><strong>Street Closures</strong></td>
<td><strong>$5,000.00</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td><strong>5,000.00</strong></td>
<td><strong>5,000.00</strong></td>
</tr>
<tr>
<td><strong>Public Service Road Closure</strong></td>
<td><strong>$3,000.00</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td><strong>3,000.00</strong></td>
<td><strong>3,000.00</strong></td>
</tr>
<tr>
<td><strong>Field Office</strong></td>
<td><strong>$2,484.44</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td><strong>2,484.44</strong></td>
<td><strong>2,484.44</strong></td>
</tr>
<tr>
<td><strong>Scheduling</strong></td>
<td><strong>$250.00</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td><strong>250.00</strong></td>
<td><strong>250.00</strong></td>
</tr>
<tr>
<td><strong>Project visibility</strong></td>
<td><strong>$304.00</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td><strong>304.00</strong></td>
<td><strong>304.00</strong></td>
</tr>
<tr>
<td><strong>Plotting</strong></td>
<td><strong>$2,000.00</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td><strong>2,000.00</strong></td>
<td><strong>2,000.00</strong></td>
</tr>
<tr>
<td><strong>Project Signs</strong></td>
<td><strong>$5,000.00</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td><strong>5,000.00</strong></td>
<td><strong>5,000.00</strong></td>
</tr>
<tr>
<td><strong>General Clean-Up</strong></td>
<td><strong>$1,000.00</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td><strong>1,000.00</strong></td>
<td><strong>1,000.00</strong></td>
</tr>
<tr>
<td><strong>Final Clean-Up ($1.00 per ft)</strong></td>
<td><strong>$2,500.00</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td><strong>2,500.00</strong></td>
<td><strong>2,500.00</strong></td>
</tr>
<tr>
<td><strong>Consultants</strong></td>
<td><strong>$250.00</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td><strong>250.00</strong></td>
<td><strong>250.00</strong></td>
</tr>
<tr>
<td><strong>Printing Costs</strong></td>
<td><strong>$500.00</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td><strong>500.00</strong></td>
<td><strong>500.00</strong></td>
</tr>
<tr>
<td><strong>Engineering &amp; Layout</strong></td>
<td><strong>$5,000.00</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td><strong>5,000.00</strong></td>
<td><strong>5,000.00</strong></td>
</tr>
<tr>
<td><strong>Street/Sidewalk Repairs</strong></td>
<td><strong>$5,000.00</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td><strong>5,000.00</strong></td>
<td><strong>5,000.00</strong></td>
</tr>
<tr>
<td><strong>Field Office Equipment</strong></td>
<td><strong>$1,000.00</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td><strong>1,000.00</strong></td>
<td><strong>1,000.00</strong></td>
</tr>
<tr>
<td><strong>Silt Conservation</strong></td>
<td><strong>$5,000.00</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td><strong>5,000.00</strong></td>
<td><strong>5,000.00</strong></td>
</tr>
<tr>
<td><strong>Security Services</strong></td>
<td><strong>$1,500.00</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td><strong>1,500.00</strong></td>
<td><strong>1,500.00</strong></td>
</tr>
<tr>
<td><strong>Mid/Full/Express</strong></td>
<td><strong>$1,500.00</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td><strong>1,500.00</strong></td>
<td><strong>1,500.00</strong></td>
</tr>
<tr>
<td><strong>Miscellaneous Safety</strong></td>
<td><strong>$2,000.00</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td><strong>2,000.00</strong></td>
<td><strong>2,000.00</strong></td>
</tr>
<tr>
<td><strong>General Contingency</strong></td>
<td><strong>$2,705,010.00</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td><strong>2,705,010.00</strong></td>
<td><strong>2,705,010.00</strong></td>
</tr>
</tbody>
</table>

#### PERFORMANCE BOND

- **Performance Bond**: $2,000,000

A performance bond is included in the general conditions estimate although it is unknown if this will be required by the owner. The bond was calculated at 2% total project cost. If no bond is required, the cost will be deducted from the budget.

#### Project Field Office

- **Project Field Office**: $136,800

The field office for this project is located 4.5 blocks away on Newbury Street. It was decided that a higher quality field office would lead to better communication among the team members.

#### Electronic Submittals

- **Electronic Submittals**: $13,000

Electronic submittal system will be utilized; now almost industry standard for saving paper and time by reducing RFI turnaround time and submittal approval.

#### Educational Kiosks

- **Educational Kiosks**: $9,750

Educational touch screen kiosks will be implemented into the final design as well as during construction.

#### General Contingency

- **General Contingency**: $2,000,000

Existing interlocking steel sheet pile wall may require repairs upon inspection.

#### Façade Testing

- **Façade Testing**: $120,000

Local MA based testing facility will test façade mock-up for wind/water loads.

#### Host

- **Host**: $575,000

USA Host estimate for delivery, set-up, dismantle. Also includes pad and electricity.

#### Tower Crane

- **Tower Crane**: $936,000

Estimate for the Terex Tower Crane specified for 16 months. Includes pad and electricity.

#### Temporary Crane

- **Temporary Crane**: $20,000

Estimate for 2 day rental of Terex telescoping T340-1 XL truck crane.
### Boylston Street Highrise Estimate

**BID PACKAGES & COST MODEL**
The table to the right represents the overall budget for the Boylston Street Highrise. This estimate was broken down by bid packages based on Masterformat Specification sections. This fair value estimate is what the owner can expect to pay for each area of the building. Areas of note include bid packages 05 and 08. These sections are somewhat inflated due to the expensive nature of the double skin façade. The graph below is a trending cost model of how the estimate developed over time for this project. The refined systems represents the final cost estimate, after applying value management tactics to the design.

#### MONTHLY COSTS DIAGRAM
This graph is a visual representation of how the owner can expect to budget for this project on a month by month basis. As expected, the majority of the costs will be incurred during the middle portion of the project as the façade is installed and finishes are begun on the lower floors.

**Trending Cost Model**

<table>
<thead>
<tr>
<th>Bid Package</th>
<th>% of Total</th>
<th>Cost per SF</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>EXISTING CONDITIONS</td>
<td>1.10%</td>
<td>$7.05</td>
<td>$2,888,528</td>
</tr>
<tr>
<td>CONCRETE</td>
<td>7.5%</td>
<td>$48.06</td>
<td>$19,558,148</td>
</tr>
<tr>
<td>MASONRY</td>
<td>0.10%</td>
<td>$0.64</td>
<td>$260,775</td>
</tr>
<tr>
<td>METALS</td>
<td>10.5%</td>
<td>$67.28</td>
<td>$27,381,407</td>
</tr>
<tr>
<td>GENERAL TRADES</td>
<td>0.85%</td>
<td>$5.45</td>
<td>$2,216,590</td>
</tr>
<tr>
<td>WALL PANELS</td>
<td>4.5%</td>
<td>$28.83</td>
<td>$11,734,889</td>
</tr>
<tr>
<td>MEMBRANE ROOFING</td>
<td>0.3%</td>
<td>$1.92</td>
<td>$782,326</td>
</tr>
<tr>
<td>APPLIED FIREPROOFING</td>
<td>0.45%</td>
<td>$2.88</td>
<td>$1,173,489</td>
</tr>
<tr>
<td>OPENINGS</td>
<td>14%</td>
<td>$89.71</td>
<td>$36,508,543</td>
</tr>
<tr>
<td>FINISHES</td>
<td>4%</td>
<td>$25.63</td>
<td>$10,431,012</td>
</tr>
<tr>
<td>FURNISHINGS</td>
<td>3%</td>
<td>$19.22</td>
<td>$7,823,259</td>
</tr>
<tr>
<td>CONVEYING EQUIPMENT</td>
<td>5.2%</td>
<td>$33.32</td>
<td>$13,560,316</td>
</tr>
<tr>
<td>FIRE SUPPRESSION</td>
<td>2.4%</td>
<td>$15.38</td>
<td>$6,258,607</td>
</tr>
<tr>
<td>PLUMBING</td>
<td>3.9%</td>
<td>$24.99</td>
<td>$10,170,237</td>
</tr>
<tr>
<td>HVAC</td>
<td>12.7%</td>
<td>$81.38</td>
<td>$33,118,464</td>
</tr>
<tr>
<td>ELECTRICAL</td>
<td>15.7%</td>
<td>$100.60</td>
<td>$40,941,723</td>
</tr>
<tr>
<td>COMMUNICATIONS</td>
<td>2%</td>
<td>$12.82</td>
<td>$5,215,506</td>
</tr>
<tr>
<td>ELECTRONIC SAFETY &amp; SECURITY</td>
<td>2%</td>
<td>$12.82</td>
<td>$5,215,506</td>
</tr>
<tr>
<td>EARTHWORK</td>
<td>6.4%</td>
<td>$41.01</td>
<td>$16,689,620</td>
</tr>
<tr>
<td>EXTERIOR IMPROVEMENTS</td>
<td>3.4%</td>
<td>$21.79</td>
<td>$8,866,360</td>
</tr>
</tbody>
</table>

**Hard Costs Total** 100% $640.76 $260,775,305

**Soft Costs Total**
- Architectural Design Fees Inc'd In Design Fees $30,000
- Geotechnical Borings Inc'd In Design Fees $5,215,506.10
- Civil Engineering Inc'd In Design Fees $19,558,147.88
- Structural Engineering Inc'd In Design Fees $16,203,748.59
- MEP Engineering General Contingency 2% $12.82
- IPD Design Fees General Conditions 7.5% $19,558,147.88
- General Conditions 6.2% $16,203,748.59

**Grand Total** $41,007,403 $301,782,707.57
SUPPORTING DOCUMENT I: LIFECYCLE SAVINGS & ADD ALTERNATES

LIFECYCLE COST ANALYSIS

While the importance of innovative design solutions to complex problems cannot be understated, they are necessarily usually costly. Genesis Design made every effort to make decisions which made financial sense to the property owner. Higher up front costs for highly efficient systems leads to lower energy bills. In order to quantify these savings, the total building energy usage had to be calculated against a baseline building. In the Energy Use Cost Analysis table below, Genesis Design was able to reduce the energy cost per year by about $3.88 MM. This over 50% reduction was due mostly to the redesigned façade and mechanical systems. As no surprise, this is also where most of the additional cost figures come into play. As detailed in the Exterior Envelope Cost Comparison table below, the difference between a typical glazing system and the optimized dual skin façade with integrated photovoltaics is about $750/SF glazing area. This is significant, but as shown in the payback period graph, this expense can be payed off within the lifespan of the building.

OPTIMIZED DUAL FAÇADE COST ANALYSIS

While the double skin façade had numerous positive impacts on the mechanical loads for the building, it comes at a high initial cost. To calculate the construction cost of this system, the exterior enclosure cost was first estimated per square foot of glazing area. The double skin portion was then estimated to be 2.5 times the cost of a typical system based on the recommendation of a façade manufacturer. This includes a unitized system with integrated photovoltaics. This number was then applied to 40% of the total exterior enclosure, the portion of the building which has the double skin façade. This cost will be payed back however, due to the mechanical savings that it will achieve.

ADD ALTERNATES

The table below consists of additions to the project which were not included in the original budget, but could be added for the listed price. Wind turbines were value engineered out of the project due to a lengthy payback period, however they can be included for an additional cost. One wind turbine tree is included in the estimate, but the plaza could support up to four. The front (north) façade of the project could be enhanced by the addition of either: (1) a perforated aluminum panel system or (2) a living green wall in between the three main retail entrances. The added cost of a green roof is also included as an add-alternate. The green roof would take the place of the occupiable outdoor green spaces located on the 4th and mechanical penthouse levels. If the owner wishes to use aluminum panels, in lieu of spandrel glass on the east façade, there would be a cost savings of roughly $110,000.

<table>
<thead>
<tr>
<th>Energy Usage Cost Analysis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy Consumed (kWh/yr)</td>
</tr>
<tr>
<td>Cost of Energy ($/kWh)</td>
</tr>
<tr>
<td>Cost per year ($/yr)</td>
</tr>
<tr>
<td>Yearly Savings</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Exterior Envelop Cost Comparison</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unit Quantity % Total</td>
</tr>
<tr>
<td>Typical Curtainwall System SF</td>
</tr>
<tr>
<td>Double Skin System SF</td>
</tr>
<tr>
<td>Boylston Street High Rise Total</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Add Alternates</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unit Quantity</td>
</tr>
<tr>
<td>Wind Turbines ea</td>
</tr>
<tr>
<td>Additional Wind Turbine Trees ea</td>
</tr>
<tr>
<td>Green Wall (Front Façade) SF</td>
</tr>
<tr>
<td>Perforated Panels (Front Façade) SF</td>
</tr>
<tr>
<td>Green Roof SF</td>
</tr>
<tr>
<td>Metal Panels (East Façade) SF</td>
</tr>
</tbody>
</table>

PAYBACK PERIOD CALCULATION

In order to calculate payback period, an initial investment had to first be calculated. The cost differential between the baseline building and the Genesis Design model was used as the investment total. The cash flow used to calculate payback is the savings generated by the efficient design. While the analysis made represents a linear payback model, in reality the payback would flatten after 10 or so years due to the replacement and regular maintenance of system components. This expected actual return is modeled by the green curve on the graph.

Baseline Building | Boylston Street High Rise | Initial Investment | Cash Flow | Payback |
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>$271,000,000.00</td>
<td>$301,782,707.00</td>
<td>$30,782,707</td>
<td>$3,884,974</td>
<td>7.92 years</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Payback Period</th>
</tr>
</thead>
<tbody>
<tr>
<td>Expected actual return</td>
</tr>
<tr>
<td>$3,884,974</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Years</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
</tr>
<tr>
<td>1</td>
</tr>
<tr>
<td>2</td>
</tr>
<tr>
<td>3</td>
</tr>
<tr>
<td>4</td>
</tr>
<tr>
<td>5</td>
</tr>
<tr>
<td>6</td>
</tr>
<tr>
<td>7</td>
</tr>
<tr>
<td>8</td>
</tr>
<tr>
<td>9</td>
</tr>
<tr>
<td>10</td>
</tr>
<tr>
<td>11</td>
</tr>
<tr>
<td>12</td>
</tr>
<tr>
<td>13</td>
</tr>
<tr>
<td>14</td>
</tr>
<tr>
<td>15</td>
</tr>
<tr>
<td>16</td>
</tr>
<tr>
<td>17</td>
</tr>
<tr>
<td>18</td>
</tr>
<tr>
<td>19</td>
</tr>
<tr>
<td>20</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Add Alternates</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unit Quantity</td>
</tr>
<tr>
<td>Wind Turbines ea</td>
</tr>
<tr>
<td>Additional Wind Turbine Trees ea</td>
</tr>
<tr>
<td>Green Wall (Front Façade) SF</td>
</tr>
<tr>
<td>Perforated Panels (Front Façade) SF</td>
</tr>
<tr>
<td>Green Roof SF</td>
</tr>
<tr>
<td>Metal Panels (East Façade) SF</td>
</tr>
</tbody>
</table>
LEED SPECIALTY AREAS

The table below shows the LEED categories analyzed for the Boylston Street High Rise. It is not all inclusive, but rather it shows significant areas of interest. These are the areas where the majority of our points came from and they are the most interesting and exciting categories.

<table>
<thead>
<tr>
<th>Category</th>
<th>Credit</th>
<th>Points</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sustainable Site</td>
<td>Development Density and Community Connectivity</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>Alternative Transportation Access</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>Other Sustainable Sites Credits</td>
<td>10</td>
</tr>
<tr>
<td>Water Efficiency</td>
<td>Water Efficient Landscaping</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>Other Water Efficiency Credits</td>
<td>6</td>
</tr>
<tr>
<td>Energy &amp; Atmosphere</td>
<td>Optimized Energy Performance</td>
<td>19</td>
</tr>
<tr>
<td></td>
<td>On-Site Renewable Energy</td>
<td>7</td>
</tr>
<tr>
<td></td>
<td>Other Energy &amp; Atmosphere Credits</td>
<td>9</td>
</tr>
<tr>
<td>Materials &amp; Resources</td>
<td>Construction Waste Management</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Regional Materials</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Other Materials &amp; Resources Credits</td>
<td>2</td>
</tr>
<tr>
<td>Indoor Environmental Quality</td>
<td>Controllability of Systems – Lighting &amp; Thermal Comfort</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Daylight &amp; Views</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Other Indoor Environmental Quality Credits</td>
<td>8</td>
</tr>
</tbody>
</table>

84 Points Total – LEED Platinum

COMMUNITY CONNECTIVITY & ALTERNATIVE TRANSPORTATION

The map to the left shows the abundance of local basic services in the project vicinity. LEED requires at least 10 basic services within 1/2 mile of the project site. This credit also requires a dense residential zone within 1/2 mile of the project site as well. This project location is ideal from a sustainable site perspective. There are many businesses and services within walking distance as well as residences nearby which could allow employees to walk to work. The MBTA Back Bay train station is located 0.48 miles to the south east of the project site, within the LEED mandated 1/2 miles to qualify for the Alternative Transportation Access credits.

ENERGY, MATERIALS, ENVIRONMENTAL QUALITY

The Boylston Street High Rise has several sustainable features which help to produce on site energy (PV integrated façade, wind turbine trees), and help optimize energy performance (double skin façade, geothermal caissons). From a construction standpoint, Genesis Design will be able gain LEED points by fulfilling the construction waste management credit. This project requires an extensive demolition of the existing concrete plaza. 37 miles to the south is a concrete and gravel recycling company which accepts demolished concrete and produces aggregate.
BIM EXECUTION PLANNING

In order to successfully implement Building Information Modelling on this project, Genesis Design developed a BIM Execution Plan. Table 1 illustrates which areas of the project BIM Execution Plan aims to address.

### Table 1: BIM Goal Use Analysis

<table>
<thead>
<tr>
<th>BIM Use</th>
<th>Value to Project</th>
<th>Responsible Party</th>
<th>Value to Responsible Party</th>
<th>Capability Rating</th>
<th>Additional Resources Required to Implement</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maintenance Scheduling</td>
<td>Low</td>
<td>Facility Manager/Owner</td>
<td>High</td>
<td>4</td>
<td>Building Automation System (BAS)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>High efficiency</td>
<td></td>
</tr>
<tr>
<td>Building Systems Analysis</td>
<td>High</td>
<td>Architect, Engineer</td>
<td>High</td>
<td>3</td>
<td>Project vacation design</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>High efficiency</td>
<td></td>
</tr>
<tr>
<td>Project Modeling</td>
<td>Med</td>
<td>Architect</td>
<td>Med</td>
<td>2</td>
<td>Site visit experience</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Project vacation design</td>
<td></td>
</tr>
<tr>
<td>Coordination/Coordination</td>
<td>High</td>
<td>Architect, Engineer</td>
<td>High</td>
<td>3</td>
<td>Project vacation design</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>High efficiency</td>
<td></td>
</tr>
<tr>
<td>Engineering Analysis</td>
<td>Med</td>
<td>Lighting/Elec. Engineer</td>
<td>Med</td>
<td>2</td>
<td>Training in purchase of BIM software</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Engineering software may be necessary</td>
<td></td>
</tr>
<tr>
<td>Site Analysis</td>
<td>Med</td>
<td>Structural Engineer</td>
<td>Med</td>
<td>3</td>
<td>Site visit experience</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Project vacation design</td>
<td></td>
</tr>
<tr>
<td>Coordination/Design</td>
<td>High</td>
<td>Architect, Engineer</td>
<td>High</td>
<td>3</td>
<td>Design team training required if input is</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>necessary for efficient flow of work</td>
<td></td>
</tr>
<tr>
<td>Engineering Analysis</td>
<td>Med</td>
<td>Lighting/Elec. Engineer</td>
<td>Med</td>
<td>2</td>
<td>Training in purchase of BIM software</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Engineering software may be necessary</td>
<td></td>
</tr>
<tr>
<td>Site Analysis</td>
<td>Med</td>
<td>Structural Engineer</td>
<td>Med</td>
<td>3</td>
<td>Site visit experience</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Project vacation design</td>
<td></td>
</tr>
</tbody>
</table>

**Table 2: BIM Meetings**

- **MEETING TYPE:**
  - Progress Update & Weekly Look-a-Head
  - Design Brainstorming
  - Collaborative Work Time
  - Project Compilation

- **LOCATION:**
  - Middle Quarters
  - Final Quarter

- **Time:**
  - Wednesdays & Fridays: 3:30 - 5:30

**Table 3: Project Deadlines**

- **PROJECT PHASE:**
  - Complete Design Documents
  - Design Coordination
  - Design Scheduling

- **ESTIMATED COMPLETION DATE:**
  - 9/7/2015
  - 9/10/2015

- **PROJECT STAKEHOLDERS INVOLVED:**
  - All Team Members

---

**STAKEHOLDERS**

- **ARCHITECT**
  - High
  - Med
  - Low

- **CONSTRUCTION TEAM**
  - High
  - Med
  - Low

- **MEETING TYPE PROJECT STAGE PARTICIPANTS LOCATION Time**
  - Progress Update & Weekly Look-a-Head: All Team Members
  - Design Brainstorming: First Quarter: All Team Members
  - Collaborative Work Time: Middle Quarter: All Team Members
  - Project Compilation: Final Quarter: All Team Members

---

**THE BOYSLAND STREET HIGH RISE**

**BOSTON, MA 02115**

**DRAWING TITLE:**

**BIM EXECUTION PLANNING**

**DRAWING NO.:**

**2016**

**MEETING NO.:**

**02 - 2016**

**DATE:**

**17 FEB 2016**

**C-01 169**
CAISSON CONSTRUCTION

One reason that caissons were selected to use as the deep foundation system for this project was their height of the water table. According to the geotechnical report provided, measured groundwater levels typically ranged from elevation -8.6 to -2.7, while the top of the garage mat foundation (green level) sits at elevation -2.0. During wet seasons, bedrock typically was encountered about 40-50 feet below the mat foundation slab. This means that the caisson excavation will go below the water table. Consequently, the developing caissons will be inserted through the footings, and the excavation below will be filled with the geothermal mud, reinforcement cage, and concrete. The caisson shafts will be drilled with a drilling dury, slurry will prevent water from entering the caisson shaft. As the caissons are excavated, temporary steel cages will be used to maintain the stability of the surrounding soil as the local granular fill and marine sand strata will most likely cause cave-ins at the required depths of the deep foundations (fig. 2). After reaching the appropriate depth, a steel cage with geothermal slurry will be inserted into the shaft (fig. 4). Following this, the shaft can be filled with concrete, displacing the slurry, and completing the caisson (fig. 4).

SITE DEVATERING SCHEME

Measured groundwater levels within the interior of the Prudential Center Garages are typically 3 to 11 feet lower than the surrounding area. This is due to the existing, interlocking steel sheet piles which was installed during the original Prudential Center construction previously. Due to this, it is unnecessary to design a complete devatering scheme of the entire site. Instead, a contingency of $2,000,000 has been added to the project budget. This is for unforeseen circumstances, especially those related to the foundation system. Part of this contingency can be used for inspection (and possible remediation) of the previously installed sheet piles. While there is no reason to believe that these sheet piles will be inadequate for this project, it is important to account for the possibility that they may not be up to par in the event that the general contingency is not used in full, the owner will receive the differential.

BRACED FRAME CONSTRUCTION

Another structural and construction decision that had to be made was the lateral system of the building. The choice was made to use a steel braced frame instead of a concrete shear wall. Although the up front cost of a steel braced frame is $1,200,000 more than a concrete shear wall, there are several reasons why this decision was made. First and foremost, meeting the braced frame can occur at the same time as the rest of the steel erection; the concrete core would have to be completed first, then allow the steel to commence. By acquiring the braced frame into the steel erection, the team was able to open 5 weeks on the schedule. This translates to general conditions savings of $1,200,000. Using a braced frame also allowed the structural team to design a damping system in the building, creating a more resilient structure.

SITE CONDITIONS

Possibly the most complex construction aspect of the project is its relationship with the Massachusetts Turnpike running directly adjacent to the southwest corner of the building. It is imperative that the traffic on the road be moved temporarily throughout the construction process. The north wall of the tunnel acts as the roof of the Boylston St. High Rise. However, it is not structurally intact. The building is essentially hung by two transfer trusses which transfer column loads around the tunnel and down to the columns. Connected to the tunnel, and a part of the project building, is a two-story tunnel fan room (highlighted below in red). This room must be avoided during the construction demolition of the existing parking garage. This room will be maintained throughout the duration of the project to ensure full capacity of the exhaust system.

DEALING WITH INTERSTATE 90

As stated above, Interstate 90 runs along the south perimeter of this project. This forced the structural design to incorporate column loads around the roadway. This was accomplished by using two transfer trusses on the fourth floor. These are highlighted in red in the image below. This effectively takes the column load from the columns in the south-west corner and transfers them to the columns which are leading to the deep foundations. From a construction standpoint, everything on the site will be temporarily demolished. The image below shows the site with everything demolished except for the fan room.

SURROUNDING CONCERNS

Before designing the Boylston Street High Rise, an in-depth study of the surrounding community was performed. This was necessary for both design and construction challenges which may occur during the construction of the project. Some of the studies performed are shown below.

SURROUNDING COMMUNITY

Above shows the project highlighted in green. The surrounding buildings were modeled in order to perform solar and wind studies. These were necessary for the design of the mechanical system as well as the photovoltaics which are present on the south and west façade of the building.

TRAFFIC PATTERNS

This plan shows the streets surrounding the project and their traffic volumes. Red indicates the streets with the highest volume of traffic. Yellow has a medium amount, and green the lowest. It is important to note that Boylston Street runs west to east one way in front of the project, meaning drivers will have to come from the west.

NEARBY RAIL LINES

The trolley shows local rail lines running near the project. A TED credit can be earned by having access to an alternative means of transport to the building. A major train station, Back Bay, is located at the east side of the map, meaning a large volume of pedestrians will be in that area.

UNDERGROUND HIGHWAY

Interstate 90 running below the south-west corner of the building is shown on the above map. This is a highly trafficked roadway which must not be disturbed at any cost in this project. The deep foundation system combined with two transfer trusses allow the building to hang over this underground structure.

GREEN LEVEL

Location of the existing mat slab foundation. This will be the top of the caissons. Typical elevation: 26.9 ft.

WATER TABLE

Location of groundwater at this location was typically at elevation -3.8 to -2.7.

SUBSURFACE STRATA

The subsurface strata encountered during test borings was typically granular fill, marine sand, marine clay, glacial till, then bedrock. This soil needs to be removed with the use of temporary shoring during caisson excavation.

CAISSON

The caissons themselves act as the base for the building’s columns. They are drilled to bedrock, a reinforcing cage with geothermal tubing is then inserted and the caissons are filled with concrete to complete the deep foundation system.

STEEL CASING

This temporary steel casing acts as an excavation support as the caisson shaft is drilled.

BEDROCK

In order to have a stable foundation, the caissons must be drilled into bedrock. Typical elevation: 134.9 to 132.8 ft.

Below shows the Genesys Design of the Boylston Street High Rise in Boston, MA 02115.
Site Logistics Explained

The existing site along with it's surroundings is shown above. The site is surrounded by buildings on three sides with the heavily trafficked Boylston Street on the fourth side. The existing plaza contains heavy foot traffic for access to the plaza amenities as well as the Prudential Center Shops.

The first site logistics plan shows the existing conditions for the site including the vehicular traffic patterns along Boylston Street as well as the two adjoining roads. The sides of the street are for parking and bus islands. The green arrows show the pedestrian traffic in and around the site which is rather extensive given the plaza and shopping centers.

The Site Securement portion of site logistics shows the introduction of site fencing along the north and west portions of the site. The north end is the most intricate as this side of the site deals with heavy pedestrian and vehicular traffic as well as all the entrances and exits of deliveries. The pedestrian traffic is redirected around the site in the parking zone. Construction vehicles will pass through this zone into the site. This entrance and exit zone will be monitored by an on-site Genesis Design representative to ensure pedestrian safety during vehicle deliveries.

Primary Considerations

The first site factor includes the continued function of the I-90 exhaust fan room during demolition and excavation. Additionally, the south-west portion of the site conflicts with the underground I-90 tunnel. Both features need to remain fully operational during all phases of construction. This was accomplished by demolishing and excavating around the existing fan room. This was further handled through our structural design by overhanging the tunnel via a transfer truss, shown in the bottom right.

Temporary Shoring

Additional considerations include the need for temporary bracing of the plaza substructure. The primary design for the temporary shoring will be sized for the mobile crane. The mobile crane will be used during the critical pick of the transfer truss as the mobile crane needs to be on the plaza. The temporary shoring will continue through the remaining plaza to take into consideration any other vehicles or structural loads applied to the plaza. See structural report for further load details.
PROJECT PHASING AND STEEL SEQUENCING

To effectively implement the matrix schedule developed for this project, a condensed steel sequence and phasing plan had to be developed. To do this, the project schedule was synced to the 3D model developed by the design options. The output is a 4D model of the construction project from groundbreaking to owner turnover. Seen below are several still images from the 4D model. Items of note include the transfer truss installation in late March, the partial turnover of the first three floors in July, and steel topping out by October 2017. The total project duration is scheduled to last just over 18 months from early June 2016 to December 2017.

1. The first stage is the demolition of the existing site. This was exceptionally challenging in order to preserve the existing 1-90 tunnel and fan room. This was achieved through the selective demolition of the structure surrounding the fan room and portion of the tunnel that enters the building footprint.

2. The drilling of the caissons was chosen to mitigate the noise vibrations as well as the potential impact damages to the surrounding foundations. During this phase, the dewatering system will be in place to resist hydrostatic pressure.

3. At the point of construction, the tower crane is erected and ready for steel placement for the first three floors. These floors are scheduled to be completed with a shell and core scope with MEP rough-ins. This phase will be completed and turned over to the owner for retail fit out and first work.

4. The team was faced with the challenge to build atop of the existing 1-90 highway which will be done using a transfer truss on the fourth floor. This will complete with the tower crane and assisting temporary mobile crane.

5. The commencement of floors S-17 represent the matrix portion, of the schedule and will be completed using a compact flow of work. The steel sequencing as well as the decking and concrete will be completed as two floors per week.

6. At this phase of construction, the first three floors are enclosed and the MEP rough-ins are complete. The retail space can now be turned over. Meanwhile, the matrix schedule will continue.

7. At this stage, the matrix schedule continues while the mall construction phases comes to a close.

8. The matrix portion of the schedule comes to a close while the roof construction begins. During this stage, the penthouse equipment will be lifted; completing the need for the tower crane.

9. Once the tower crane is disassembled, the plaza construction will commence as well as the rooftop solar array hookup.

10. The final finishes are completed and the Boylston Street High Rise is turned over.

Demolition of site is underway.

Steel transfer trusses are in place on level 4.

Caissons installed and parking garage beginning.

Superstructure continues as matrix portion begins.

Exterior enclosure begins. Floors 1-3 turned over for tenant fit-out.

Matrix schedule learning curve is overcome. Peak production levels.
**CPM SCHEDULE FOR SITE SECUREMENT, DEMOLITION, AND SUBSTRUCTURE**

<table>
<thead>
<tr>
<th>Task Name</th>
<th>Duration</th>
</tr>
</thead>
<tbody>
<tr>
<td>SITE SECUREMENT</td>
<td>6 days</td>
</tr>
<tr>
<td>SITE PLAN REVIEW</td>
<td>1 day</td>
</tr>
<tr>
<td>SITE CRANE INSTALLATION</td>
<td>2 days</td>
</tr>
<tr>
<td>SAFETY PLAN</td>
<td>1 day</td>
</tr>
<tr>
<td>MOBILE CRANE MOBILIZATION</td>
<td>1 day</td>
</tr>
<tr>
<td>MOBILE CRANE MOBILIZATION</td>
<td>1 day</td>
</tr>
<tr>
<td>EXHAUST ROOM DEMOLITION</td>
<td>2 days</td>
</tr>
<tr>
<td>BUILDING LAYOUT</td>
<td>1 day</td>
</tr>
<tr>
<td>MOBILE CRANE MOBILIZATION</td>
<td>1 day</td>
</tr>
<tr>
<td>MOBILE CRANE MOBILIZATION</td>
<td>1 day</td>
</tr>
<tr>
<td>ARIELE GRACE SITE DEMOLITION</td>
<td>4 days</td>
</tr>
<tr>
<td>ELKINGTON FOUNDATION</td>
<td>3 days</td>
</tr>
<tr>
<td>HAYES STREET FOUNDATION</td>
<td>2 days</td>
</tr>
<tr>
<td>SELECTED FOUNDATION</td>
<td>1 day</td>
</tr>
<tr>
<td>INSTALL TEMP UTILITY</td>
<td>1 day</td>
</tr>
<tr>
<td>MOBILE CRANE MOBILIZATION</td>
<td>1 day</td>
</tr>
</tbody>
</table>

**LONG LEAD TIME ITEMS**

- **SWITCHGEARS**: 16-20 weeks
- **GENERATORS**: 12-15 weeks
- **TRANSFORMERS**: 12-15 weeks
- **CO2 ABSORBER**: 10-12 weeks

**CPM SCHEDULE FOR RETAIL FLOORS 1-3**

<table>
<thead>
<tr>
<th>Task Name</th>
<th>Duration</th>
</tr>
</thead>
<tbody>
<tr>
<td>EAST COLUMN (L-1)</td>
<td>2 weeks</td>
</tr>
<tr>
<td>EAST COLUMN (R-1)</td>
<td>2 weeks</td>
</tr>
<tr>
<td>PLACING/STL EROSION (E1)</td>
<td>2 weeks</td>
</tr>
<tr>
<td>INSTALL SAFETY RIGHT</td>
<td>1 week</td>
</tr>
<tr>
<td>EAST COLUMN (L-2)</td>
<td>2 weeks</td>
</tr>
<tr>
<td>EAST COLUMN (R-2)</td>
<td>2 weeks</td>
</tr>
<tr>
<td>PLACING/STL EROSION (E2)</td>
<td>2 weeks</td>
</tr>
<tr>
<td>INSTALL SAFETY RIGHT</td>
<td>1 week</td>
</tr>
<tr>
<td>EAST COLUMN (L-3)</td>
<td>2 weeks</td>
</tr>
<tr>
<td>EAST COLUMN (R-3)</td>
<td>2 weeks</td>
</tr>
<tr>
<td>PLACING/STL EROSION (E3)</td>
<td>2 weeks</td>
</tr>
<tr>
<td>INSTALL SAFETY RIGHT</td>
<td>1 week</td>
</tr>
<tr>
<td>EAST COLUMN (L-4)</td>
<td>2 weeks</td>
</tr>
<tr>
<td>EAST COLUMN (R-4)</td>
<td>2 weeks</td>
</tr>
<tr>
<td>PLACING/STL EROSION (E4)</td>
<td>2 weeks</td>
</tr>
<tr>
<td>INSTALL SAFETY LEFT</td>
<td>1 week</td>
</tr>
</tbody>
</table>

**LONG LEAD TIME ITEMS**

- **STRUCTURAL STEEL**: 6-10 weeks
- **CUSTOM TRUSS**: 12-15 weeks
- **SEISMIC DAMPERS**: 6-8 weeks
- **METAL STAIRS**: 6-8 weeks
The prefabricated items include the bathroom chase walls, MEP racks, and dual façades. Prefabrication assisted in the development of the matrix schedule. These items were fabricated off-site and shipped ready for installation. The primary prefabricated items are shown in the figures to the right.

The dual façade proved to be a unique opportunity to save both installation and valuable crane time. The typical installation of these façades is completed in two parts. The first stage in erecting the dual façade is the interior panels. These panels are first hoisted and secured through the use of the crane; once secured, the outer layer is then hoisted in place and fastened to the first panel. This two-step process is both time and labor intensive, and it effectively doubles the installation time and crane usage time as compared to a regular façade.

The construction team, working in tandem with the structural team, composed a structural bracing scheme for the prefabricated unit. By structurally binding the two layers, we can effectively place both layers at the same time, cutting the labor and crane time in half.

The prefabricated bathroom chase walls were also a critical design aspect that promoted the compact matrix schedule. Each office floor houses a back-to-back male and female restroom. The combined fixtures included in these restrooms is ten water closets, two urinals, and six sinks. The plumbing for each of these fixtures resides in the same space and therefore provided the perfect opportunity for a prefabricated chase wall unit.

The overall benefit of adding these prefabricated units covers categories of cost, time, safety, and quality. The time and cost associated with these savings comes out of the labor and scheduled savings. The additional aspect of constructing these items off-site will reduce the risk of onsite worker safety as well as increase the quality control of the products.

**Main Structural Façade Support**
- Supports both layers of glass paneling
- Supports the maintenance access grate
- Connection to the slab anchors

**Maintenance Considerations**
- Cleaning of the interior/exterior panels
- Cleaning/maintenance of the blinds
- Maintenance of the solar panels

**Quality Control Considerations**
- Hurricane testing for water sealing
- Maintenance monitoring of solar array

**Prefabrication Installation**
- Units assembled and placed with crane
- Placed in one unit per floor
- Quick and efficient installation
- Decreases installation times
- Increases quality control
- Supports the matrix schedule
The matrix schedule was applied to 13 of the 14 office floors (5-17) due to the highly repetitive nature of construction. Floor four was not included in the matrix schedule due to the uniqueness of the structure; the transfer truss overhanging the Interstate 90 tunnel is located on this floor. The schedule in the top left shows the primary flow of work for each of the floors broken down into two main categories which include the main structural elements and the envelope/interior work. This division of work was done due to the difference in productivity rates; the structural columns are erected with spikes every two floors which are supported by the connection of the steel beams. Once the two floors of steel, decking, and concrete are complete the flow of work moves to one floor per week activity. This transition occurs during the envelope construction as the panels are placed one floor at a time. This transition is shown above in Task 4 on the detailed schedule above. Once the envelope is complete, the remaining work within can commence, and the flow of work continues upward. The remaining activities include MEP rough-ins, floor, wall, and ceiling rough-ins, MEP fit outs; and interior finishes.

The figures to the left show three-dimensional cut sections to visually show the relationship between elements. The uniqueness in scheduling occurred in the underfloor MEP installation rather than overhead. This was handled by completing overhead work first and then completing the floor work which was promptly covered by the raised access floor to allow for the finishing work to commence. This same pattern of structure, core stairs, envelope, core rough-ins, main floor rough-ins, and finish continues throughout each floor in a continual flow of work.

The matrix schedule was made possible through several implemented construction techniques. These techniques not only improved the efficiency of the schedule but also supported the small construction site and lack of material storage.

- The condensed matrix schedule was supported by Just-In-Time Deliveries to ensure a consistent flow of work. The additional benefit of material tracking further improved the process efficiency by supplying these materials to their appropriate locations without onsite delays or confusion.
- The prefabricated items also increased efficiency by reducing the labor hours in the field. These items include the bathroom chase wells, MEP racks, and dual façade components. Each item is ordered to specifications, fully manufactured, and shipped to the site ready for installation.

Although these techniques are meant to assist in the flow of work to maintain schedule, the construction team realizes the inevitability of project delays. These delays may come from weather complications, change orders, or manufacturing delays; however contingency plans have been built into the schedule to minimize the negative impacts these factors may have on the project. These include the advanced material tracking for manufacturer delays; the stakeholders are brought on early in the design to reduce change orders; and weather delays are scheduled in for the reduction in time needed on the 13th floor should the schedule need pushed back.

Overall, the matrix schedule effectively reduced the baseline schedule by 9 weeks. The savings for this type of scheduling efficiency can be found in the general conditions costs (i.e. Administrative/labor wages, equipment costs, utility usage, and office rentals). Additionally, the tenants can begin operations earlier than expected which is a benefit financially. This decrease in time also reduces the construction impact by reducing the time in the field and allowing the city flow to commence as before.
OUR PROJECT AND THE PUBLIC

The construction process within a community often has a negative connotation for being something new and often disruptive to the normal functions of city life. These include impacts on the surrounding businesses, vehicle/pedestrian traffic, and the general city population. Part of the Genesis Design goal is to minimize this disruptive process through several different simple and interactive techniques.

The first stage of the community integration plan includes the advertisement of local businesses on the site fence. Our presence within the community will inevitably affect the surrounding businesses through traffic and pedestrian flow around the site. In order to reduce this impact, the Genesis Design team has created a site fence that incorporates opportunities to advertise for local businesses. These advertisement spots will be available to the surrounding businesses for whichever advertisement they deem appropriate. The prime advertisement will be free of charge throughout the duration of the project. A sample of these advertisements are shown below.

The introduction of this site fence advertisement will also include information about us, Genesis Design. Such information will include our Sustainable, Resilient, and Integrative aspects to our design team and the soon-to-be Boylston Street High Rise. Further design ideas to relay this information is described in the section to the right.

One of the driving causes for construction negativity also includes the idea of change to a community. Whether good or bad the idea of change is often met with opposition. In order to decrease this effect, the Genesis Design team has decided to inform the general public on the immense benefits that this new facility has to offer on both a public and environmental level. This information will be displayed through the site fence graphics as well as an interactive touch screen kiosk. The kiosk will be outside the site fence during construction to allow for individuals to learn about the new facility and what it has to offer.

The touch screen kiosk is essentially an interactive display screen that provides valuable information on three main aspects of the site. The primary information tab is in regards to the Boylston Street High Rise and accompanying Plaza. The remaining links will include a map of Boston and the many attractions and the Prudential Shopping Center’s shops and deals. As pedestrians pass the site they will have the opportunity to stop and interact with the touch screen display to learn more about the building under construction.

The display will progress interested individuals through a series of pages to better narrow down their search interest. The images below show this series of screens that someone may traverse as well as how this kiosk will interact with the site and people. As an individual touches the Genesis logo on the front screen, the program will progress to the following page which shows our three main design drivers: Sustainability, Resiliency, and Integration. These kiosks that are available during the construction process will then be implemented into the plaza design to further reinforce the educational and interactive relationship between the Boylston Street High Rise, the Plaza, and the city of Boston.

Interactive Kiosk

Screen 1

Screen 2

Screen 3

Screen 4

**gen**
EMBODIED ENERGY

The lifecycle of construction materials requires an exorbitant amount of energy through material procurement, refinement, transportation, installation, and operation. The Genesis Construction team goal is to reduce this energy impact through several techniques including the reuse, reduction, and recycling of materials. This process is shown in the flow chart below how we structured our construction process, shown in the flow chart to the right.

The primary materials used in construction were analyzed in detail for the potential for embodied energy reduction. These material break downs are shown in the tables at the bottom of the page. The primary materials include concrete, steel, glass, finishes, and synthetic materials. The initial percentage breakdown between concrete and steel was drastically reduced in the substitution of the concrete core with a steel core. This effectively reduced the amount of concrete needed by 2,480 Cubic Yards and the overall building saving percentage of 8%. The concrete item was then further broken down to analyze the elevated energy associated with cement production. Each of these materials are represented by their percent in the building as well as the material and hauling energy. These values were assumed to be 90% and 10% due to the close proximity to the site.

The table above shows the percent reduction of each ingredient. The 30% cement reduction is based on the percent substitution of Portland by Fly Ash. The 35% stone reduction is based on the values of recycled content. Lastly, the hauling energy is reduced based on the close proximity to the site. Altogether, the Boylston Street High Rise Construction was reduced to approximately 540,665 BTUs/TON, approximately 34% of the original embodied energy within the concrete.

MATERIAL SELECTION

One of the Genesis design drivers is SUSTAINABILITY. This is usually accomplished through system design and performance throughout the life span of the building. However, these stages of sustainability usually occur in the design phase and performance after turnover. Therefore, the construction team was challenged to introduce sustainable aspects into the construction of the building as well.

The main techniques utilized by the Genesis Construction team to achieve sustainability was through the handling of materials. The handling of materials involves the recycling of demolition rubble, the location of building material suppliers, and the composition of those building materials. Shown below is a map to the recycling, concrete, and wood suppliers in respect to the Boylston Street High Rise.

DEMONSTRATIONS & SOURCES OF CONCRETE

The first phase of construction involved the demolition of the existing plaza and two underground parking garages. Each of these areas was comprised of reinforced concrete and natural vegetation. All concrete was delivered to Dedham Recycled Gravel. A multi-use aggregate company approximately 20 miles from the site. The company accepts both reinforced and non-reinforced concrete to be sorted and sold for aggregate fill. All demolished concrete will be shipped to this site for recycling and redistribution. The recycling of these materials was taken into account in the reduction of embodied energy.

CONCRETE REUSE & REDUCTION

This section deals with the concrete foundations and elevated slabs. The normal composition of this material is Portland cement, sand, stone, and water. The primary issue with this composition is the Portland cement; the process to make Portland involves extensive energy and produces an exorbitant amount of greenhouse gas emissions; approximately 5% of all CO2 emissions produced. Therefore, the Genesis Construction team is looking for alternate sustainable ingredients while still maintaining structural resiliency.

The concrete for the Boylston Street High Rise will be supplied by Boston Sand & Gravel approximately 3.5 miles from the site. The company is LEED accredited for the use of sustainable materials and Portland substitutes. The primary material that will be used during construction is the Ready Mix Concrete with Recycled Fly Ash and Slag. Fly Ash and Slag are industrial by-products that were previously seen as industrial waste. However, they can be an effective substitute within a concrete mixture while simultaneously reducing the waste from other industries.

Shown in the embodied energy tables is the percent reduction of embodied energy through the replacement of Portland cement and the proximity to the site for transportation waste. The total reduction in concrete production is approximately 34% as compared to the baseline building embodied energy calculations.
PROJECT COLLABORATION

The construction team is comprised of numerous parties each with their own agendas. Maintaining the relationships of these individuals throughout the life of the project is often one of the most challenging aspects of a successful project delivery. The challenge mostly occurs within the collaboration and exchange of information. The cooperation between members of the construction management team is often segmented; each member works from their own office, coming together once a week to discuss progress and potential roadblocks. We at Genesis believe that this degree of communication and collaboration is not adequate enough to drive project efficiency and success. In order to increase our collaboration and efficiency, we have decided to proceed with an Integrated Project Delivery method (IPD) and a corresponding off-site co-location office. The organizational chart below shows the primary members of the IPD team and how each of the members connects and interacts with other members.

CO-LOCATION OFFICE: 39 NEWBURY STREET

The Genesis Construction Team has established an off-site office for the construction management team. The decision to establish the management office off-site was due to the limited space available on the site as well as the need for an expanded space to account for all members of the IPD team. The site office is located at 39 Newbury Street in Back Bay, Boston. The map below shows the office location to be four and a half city blocks away from the site or approximately a 10 minute walk. The office space is approximately 1800 SF and supports a collaborative workspace, private meeting room, conference room, and break room. A floor plan layout for this co-location office is shown below.

By creating a close-quarter collaborative space, communication is increased between team members who may be working on individual portions of the project. This will additionally create the possibility of change orders which can have a drastic effect on material waste, schedule efficiency, and cost. The cost of this off-site office location is approximately $136,000 for the entire project which is detailed further in the general conditions cost analysis section. The benefit of having this co-location set up allows for an increased efficiency of construction. This efficiency through planning led to a decrease in schedule of 9 weeks which resulted savings of two months rent on the office space.

TEAM COLLABORATION

The team also incorporated a highly collaborative organizational structure to increase communication. It was understood from the beginning that constant and effective communication between team members would be the key to the team’s success. To best reach the goal, the team established set meeting times three days a week in the thesis computer lab. The primary meeting was held on Monday to establish the tasks for the upcoming week and corresponding responsibilities. Potential design concerns were discussed along with the prioritization of work. The team also planned for upcoming presentations and established critical deadlines. The meeting times functioned as a way for the team to work in close proximity and collaborate on any design questions that may arise.

Through this teamwork, the team’s increased productivity and information exchange. Below is an example of a meeting topic outline. It was important to have very specific meeting agendas in order to keep on track. Also below is an image of the room used to complete this project. Working in close proximity forced collaboration and communication within the disciplines. A whiteboard for upcoming tasks and a tack board with design ideas and business cards of professional contacts help develop an efficient information exchange.