EXECUTIVE SUMMARY:

The August Wilson Center for African American Culture is designed to become a signature element in a revitalized downtown Pittsburgh. From the former site of run-down buildings and a barren parking lot will raise a beacon of Pittsburgh art that highlights the culture and history of African Americans. Prominently located on Liberty Avenue near the new convention center, the center will be home to a performance theater, exhibit spaces, a lecture room, gathering spaces, and a café.

In this report, the essence of the synthesis of architecture and engineering will be examined through detailed research, design, and analysis. The core of the report is an analysis and redesign of the lighting and electrical systems for four spaces within the building: the Liberty Avenue Façade, the main lobby, the education and lecture room, and the meeting room. To create a distinct appearance that relates to the streetscape, the transparency of the building has been utilized to allow the building to embody its core performing arts function. As the building cycles between unoccupied and occupied, the lighting system will shift and the patrons will become actors in a live performance. At the end of the night, the 'curtains' will close and the building will rest.

To accomplish the goals set forth in the conceptual lighting design, the electrical system required alteration to allow for greater and more varied control. Additional investigations into the electrical system revealed a substantial costs savings is possible by redesigning part of the system at a higher voltage. In contrast, a feasibility study of photovoltaics indicates such a system is not cost effective due predominantly to the building's location.

Attempting to add to the dynamic spaces which already exist, a roof terrace has been designed to provide another venue for exhibitions and gatherings. Additionally, the design integrates with the goals for the lighting redesign, helping to bring together the composition that is seen from Liberty Avenue.

Finally, the acoustic properties of two spaces, the Music Café and the multipurpose room, have been analyzed and a new design has been generated. As a signature building filled with performance spaces, the acoustics of the August Wilson Center are a key element to the building's success.

Any great building is comprised of many parts which all function together to produce an outstanding result. The August Wilson Center looks to be Pittsburgh's next great building and therefore the systems within the building all must perform at a very high level.

CONTENTS

APPENDICES

This report, along with addition information, is available in electronic format at:
http://www.engr.psu.edu/ae/thesis/portfolios/2008/mpr184/

THE AUGUST WILSON CENTER FOR AFRICAN AMERICAN CULTURE

LIBERTY AVENUE PITTSBURGH, PA

ARCHITECT:
PERKINS + WILL

CIVIL ENGINEER:
A&A CONSULTANTS

STRUCTURAL ENGINEER:
ATLANTIC ENGINEERING

CONSULTANTS:
ARUP
ATS CHESTER ENGINEERS
AUERBACK+POLLACK+FRIEDLANDER
DUQUESNE LIGHT
HORNFECK ENGINEERING
MIDDLEBROOK+LOUIE
SEXTANT GROUP
THE STDUIO I COMPANY
TIMOTHY ENGINEERING

CONSTRUCTION MANAGEMENT:
TURNER CONSTRUCTION
STERLING CONTRACTING, LCC
EBONY DEVELOPMENT, LLC

OWNERS REPRESENTATIVE:
OXFORD DEVELOPMENT COMPANY

DELIVERY METHOD:
CM AGENT
24 PRIME CONTRACTS

architecture

The 63,000 SF faciliity located in downtown Pittsburgh features a 500 seat performance venue, permanent and temporary exhibit spaces, educational and meeting spaces, a cafe, a book store and offices. The building consists of two levels above grade and is scheduled to be constructed between August 2007 and May 2009 at a budgeted cost of 23 million dollars.

lighting

Aside from the fully functional theatre lighting system, light is provided by a wide variety of systems including, fluorescent and HID fixtures and a full range of distribution types. Exposed interior structure dictates interior fixture selection in many spaces, while the sail and banners are accented on the exterior.

building systems

The building rests on a cast-in-place concrete foundation system to grade (partial basement). A combination moment frame and braced frame steel stystem with reinforced conrete slabs is used for the two upper floors. The building is serviced by Duquesne Light electrical service which is converted to a 208Y/120 system. Theatre and building loads are serviced from seperate main boards. Multiple dimming systems are utlized and a backup generator protects the entire system. The mechanical system is forced air heating and cooling with stem to steem humidification. Five AHUs are housed on the roof.

an architectural engineering senior thesis portfolio

MICHAEL PATRICK ROYER
lighting and electrical option

Rendering by Perkins + Will

SECTION TWO | Project Background and Overview

Prominently located on Liberty Avenue, The August Wilson Center for African American Culture is designed to be a signature element of downtown Pittsburgh. Rich materials and bold geometric forms set the stage for a magnificent cultural experience in which any visitor is sure to participate. Beyond the aesthetic beauty of the architecture lie structural, mechanical, acoustical, electrical, and lighting systems that must perform precisely and efficiently in order to make the building function. The synthesis of aesthetics and functionality is the pinnacle of great design.

The project architect, Perkins+Will, describes the August Wilson Center as follows:

> *Allison Williams, Lead Designer for the architectural firm of Perkins+Will has designed this home for the August Wilson Center as a conceptually transparent, flexible container in which the accomplishments and artifacts, the activities and traditions of this culture can be proudly celebrated layered and displayed. The building opens itself to educating people about the important contribution of African Americans to Pittsburgh and beyond. It is timeless, flexible and powerful in its simplicity.*
>
> *The signature character of the building comes as a result of its content, in response to the program and is in continuous transformation as a result of the changing exhibits and activities within. It is through the design element at the corner of Liberty Avenue and William Penn Way that the architects position the building as a distinct icon, and abstraction of this culture and a new landmark for Pittsburgh. This is where the August Wilson Center finds its voice, its identity, its energy and its distinct signature quality.*

This capstone design project and Architectural Engineering senior thesis involved a substantial analysis of the existing building approach, specifically in the areas of lighting and electrical systems. This analysis provided goals for redesigning these systems for four spaces: the Liberty Avenue façade, the main lobby, the education and lecture room, and the meeting room. These four spaces surround the main theater and are critical to the appearance and function of the building.

Additional studies in architectural design resulted in the design of a roof terrace to create a new venue for performance and culture. An analysis of room acoustics provided the basis for a new design for the Music Café and the multipurpose room.

SECTION THREE | Building Statistics for Existing Design

GENERAL BUILDING DATA:

Building Name: August Wilson Center for African American Culture
Location and Site: Liberty Avenue and William Penn, Pittsburgh, Pennsylvania
Building Occupant Name: August Wilson Center for African American Culture
Occupancy or Function Types: The building will open in phases. The first phase to open will be gallery and display space. A 500 seat performance theater will be opened second.
Size: 63,000 Square Feet
Number of Stories Above Grade: Two
Primary Project Team:

- **Architect:** Perkins + Will (http://www.perkinswill.com)
- **Engineering:**
  - Civil: A&A Consultants (http://aaconsultinc.com/)
  - Structural: Atlantic Engineering Services (http://www.aespj.com)
- **Consultants:**
  - ARUP (http://www.arup.com)
  - ATS Chester Engineers (http://www.atschester.com)
  - Auerbach + Pollack + Friedlander (http://www.auerbackconsultants.com)
  - Duquesne Light (http://www.duqlight.com)
  - Hornfeck Engineering (http://www.hornfeck.com)
  - Middlebrook + Louie (http://www.MplusL.com)
  - Sextant Group (http://www.thesextantgroup.com)
  - the studio i company (http://www.studioilighting.com)
  - Timothy Engineering (http://www.timothyengineering.com)
- **Construction Management:**
  - Ebony Development, LLC (http://www.ebonydevelopment.com)
  - Sterling Contracting, LLC (http://www.sterlingcontractingllc.com/)
  - Turner Construction (http://www.turnerconstruction.com/)
- **Law Firm:**
  - Buchanan Ingersoll & Rooney, PC (http://www.bipc.com)
- **Owner's Representative:**
  - Oxford Development Company (http://www.oxforddevelopment.com)

Dates of Construction: Start Date – August 2, 2007. Expected Duration – 18 months.
Cost: The budget cost decided by the owner is 23 million dollars. The project has come in over budget and value engineering is taking place in order to achieve a final cost that is acceptable to the owner.

Project Delivery Method: The project began with a GMP contract. However, it is currently structured as a CM agent with approximately 23-24 prime contracts.

ARCHITECTURAL INFORMATION:

Design and Functional Components: The program consists of a central performing arts theater surrounded by lobby and gallery space. There is space allocated for both permanent and temporary exhibits. There is a café off of the ground floor lobby. The second level also includes a multi-purpose room, classrooms and an open office area for administrative activities related to the center.

Major National Model Codes: IBC 2003

Zoning: Commercial

Historical Requirements: None. The site is owned by the Urban Redevelopment Authority (URA) of Pittsburgh. Requirements must be met during the demolition and site preparation in order for the ownership to transfer to the August Wilson Center.

Building Envelope: The building features several exterior wall systems. The foundation and basement is cast-in-place concrete to grade. Above grade structural steel with concrete/steel decking and 6" metal stud walls forms the building envelope. The exterior of the building features several materials including 2" insulated aluminum panel, ACM (Aluminum Composite) panels, ribbed metal panels, aluminum/glass curtain wall, and 8" CMU cavity wall. These systems are integrated and used in various combinations throughout the building. The walls are insulated with R19 batt insulation, and surfaced with 5/8" sheathing and waterproof membrane. The roof is an EPDM system over tapered insulation to provide adequate drainage. Parapet walls are used as necessary and capped with metal coping.

CONSTRUCTION METHOD:

Turner Construction Company is the primary construction management firm for this project. The delivery method was original GMP with a project budget of 23.5 million dollars. When the project came in over budget, the method was switched to CM Agent with Turner as the CM and 23-24 prime contracts between the August Wilson Center and the contractor. This switch occurred in the summer of 2007.

With a location in downtown Pittsburgh, the site had previously been occupied and it was therefore necessary to complete demolition prior to beginning new construction. The site was owned by the Pittsburgh Urban Redevelopment Authority (URA). When excavation began, soil contamination was discovered and the agreement with the URA stated that it must be remedied before the land ownership would be transferred.

A set of permit review drawings was released October 2, 2007. Due to the late shift in delivery method, Turner had to pre-purchase materials for early bid packages, such as the steel. The estimated length of construction is 18 months.

ELECTRICAL SYSTEM:

The building runs on a 208Y/120V, 3 phase, 4 wire electrical system and is connected to the Duquesne Light system. Service enters the building on the south side of the building where two transformers are located. Each transformer supplies a main switchboard. One of these switchboards supplies predominantly mechanical and equipment loads while the second switchboard supplies mainly lighting and other end-user loads.

Dimming equipment is necessary to accommodate theatre equipment and is also used for some of the general purpose spaces. The most unique part of the system is a motorized orchestra pit lift. However, this piece of equipment is slated to be added at a later time.

A 200KW diesel generator provides emergency power to certain parts of the system through two automatic transfer switches.

LIGHTING STSTEMS:

The building's lighting system is faced with the challenge of responding to the building's unique architectural form and varying materials. With open plenum ceiling that have open grids and vertical metal baffles, indirect lighting is not an option. Black acoustical blanket on the ceiling means the reflectance is very low.

Regular arrays of round downlights light the upper and lower lobbies. Accent and interest is provided by varying lighting in the adjacent spaces that connect to the lobby and by highlighting the oval shaped drum of the theater that protrudes through the entire building.

In the gallery spaces track lighting is used to provide a very flexible solution. Dimming systems are used in spaces such as the education room and meeting room to provide variable light levels. Motorized blackout shades are used to address the large amounts of daylight that will enter the spaces through the Liberty Avenue Façade.

The exterior lighting design is focused on accenting special elements rather than washing the entire façade. The building glows from the inside due to the large expanses of clear glass. The corner sail is highlight from inside and from in-grade recessed fixtures.

MECHANICAL SYSTEM:

Building heating and cooling is handled by five air handling units (condenser capacities: 735, 608, 727, 530, 951 MBH) that are housed on the roof of the structure. The units contain DX coiling coils and glycol preheat and reheat hot water heating coils. One of these units is also connected to the backup emergency system. Four small split AC units serve mechanical and equipment rooms. Additional heating is provided by electric baseboard heaters in the exhibit hall.

A steam and water room in basement of the building houses plumbing equipment, heating coils and other water related mechanical equipment.

STRUCTURAL SYSTEM:

The foundation of the building is provided by 10 to 12 inch poured concrete foundation walls which rest on grade beams. Concrete piles are used to support the columns. The basement level is only a portion of the area of the first level. On grade floors are concrete slab on grade. Where the basement level exists, the first floor is a two way structural concrete slab that is 10 inches thick or a 15-20" thick one way slab.

W shape steel columns support the second floor and roof loads. The column arrangement is not regular due to the generally triangular shape of the overall building and the oval shape of the theater core. The triangular system is a moment frame construction while the inner oval shape of the theater is a braced frame construction. Bent beams are used to make the curved theater walls.

The second level floor is framed with structural steel with steel decking and concrete slab. The roof uses a similar system but is sloped for drainage and includes rigid insulation on top. The balcony seating area is a series of cantilevered concrete slabs.

FIRE PROTECTION:

With only two stories, the building does not require d to have active fire protection throughout. Fire protection (1HR) is provided around egress stairwells and elevators. The theatre stage area has a two hour rating. Several other walls, including exterior walls bordering other buildings have a one hour rating. Many of the electrical/mechanical spaces are also protected by a one hour fire rated wall assembly. Steel is protected by cementious fireproofing where necessary. The building utilizes a sprinkler system throughout. A separate water service for the sprinkler system enters the building from the south where a main control system is located. A dry system is used to protect the two exhibit spaces while a wet system is used for the remainder of the building.

TRANSPORTATION SYSTEM:

The transportation system includes three elevators, one of which is a large elevator that can be used to move equipment. Only two of these elevators service the basement. The larger elevator connects through to the basement and two exhibit spaces.

The building has three standard egress stairwells one of which connects the basement. A grand staircase connects the two lobbies while two staircases provide direct pedestrian access to the balcony seating in the theatre.

A service entrance to the building is located on the south side of the structure and comes off of William Penn Place. This entrance provides a two bay loading dock with access to the stage area of the main theatre.

TELECOMMUNICATIONS:

The building communication systems consist of standard ethernet, and phone systems with a few items related to projectors and audio systems. The theatrical communication and audio systems will not be considered for this report. The main control and distribution panels are located in room 111 on the south side of the building. This is where service from Verizon enters the building below grade from the street. A secondary control station, room 211, is located directly above room 111.

The voice and data network runs throughout the building. This system will provide internet connectivity as well as phone lines to the various building spaces. This is especially relevant for the open office area. Various types of outlet boxes are used depending on the constraints of mounting locations. Everything from wall to floor to ceiling boxes are used, with various numbers of both voice and data jacks mounted together.

The overall audio and video system includes a regular array of speakers located through the lobbies of the building. Separate audio systems are in place for the café, education/lecture room, and meeting room. Audio system control for the lobbies is provided by an AV rack in the gift shop. Video projection systems are used in the café, gift shop, and education and lecture room, with two projectors in each space.

The security system consists of cameras located throughout the buildings lobbies and hallways. These are mostly in the first level of the main lobby with a few on the second level and some at the building entrances. Many of the building's doors are operated with electronic card swipes. Some also have audio alarms.

LEED CERTIFICATION:

This project is seeking LEED certification.

SECTION FOUR | Lighting

For a multipurpose building such as the August Wilson Center, the lighting design is especially critical. Various uses place varying demands on the lighting system which the lighting designer must identify in order to produce a successful design. As a public venue, the lighting is a key for creating a welcoming ambiance and enhancing the overall user experience.

In redesigning four of the primary building spaces (the main Liberty Avenue façade, the main lobby, the education and lecture room, and the meeting room), I have focused on using light and luminaires to create a high-class, welcoming appearance while using sophisticated control systems to offer great flexibility for varied uses. The main motivation for the overall design was the transparency of the façade which creates interaction between all the spaces and likens the building to an open stage. I have centered my design on creating continuity between spaces with clean layouts and simple luminaires.

DAYLIGHT CONDITIONS

Daylighting has become an increasingly desired feature for newly designed buildings. As a LEED building, The August Wilson Center could earn points for daylighting. Beyond LEED, however, considering the orientation of the building is imperative to any good design. The following images show the project site and surrounding buildings on multiple dates (December 21, March/September 21 and June 21) under a clear sky. The images are in sequence from sunrise to sunset.

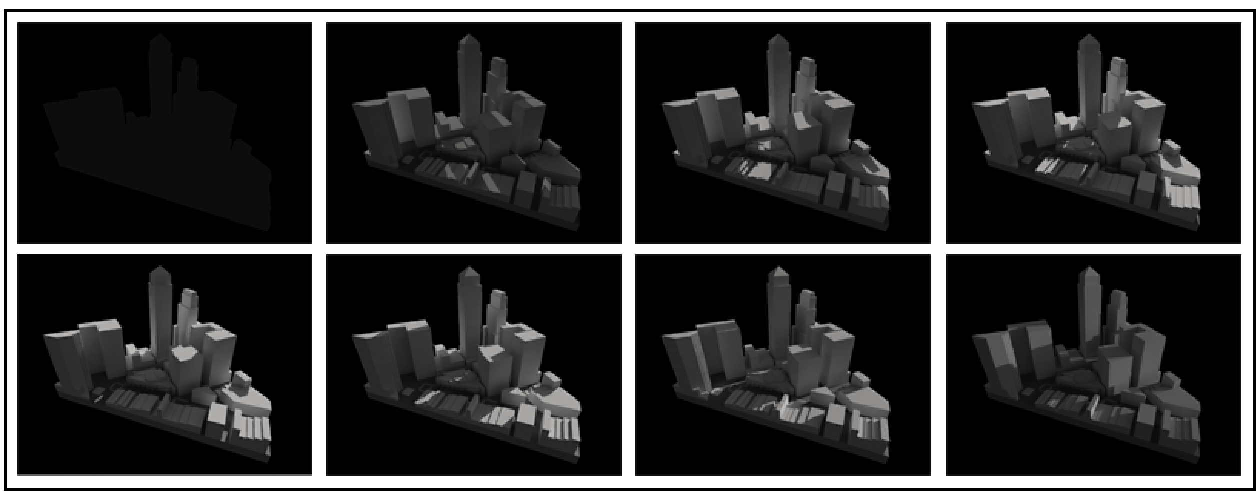

Figure 4.0.1 | December 21 Shadow Study

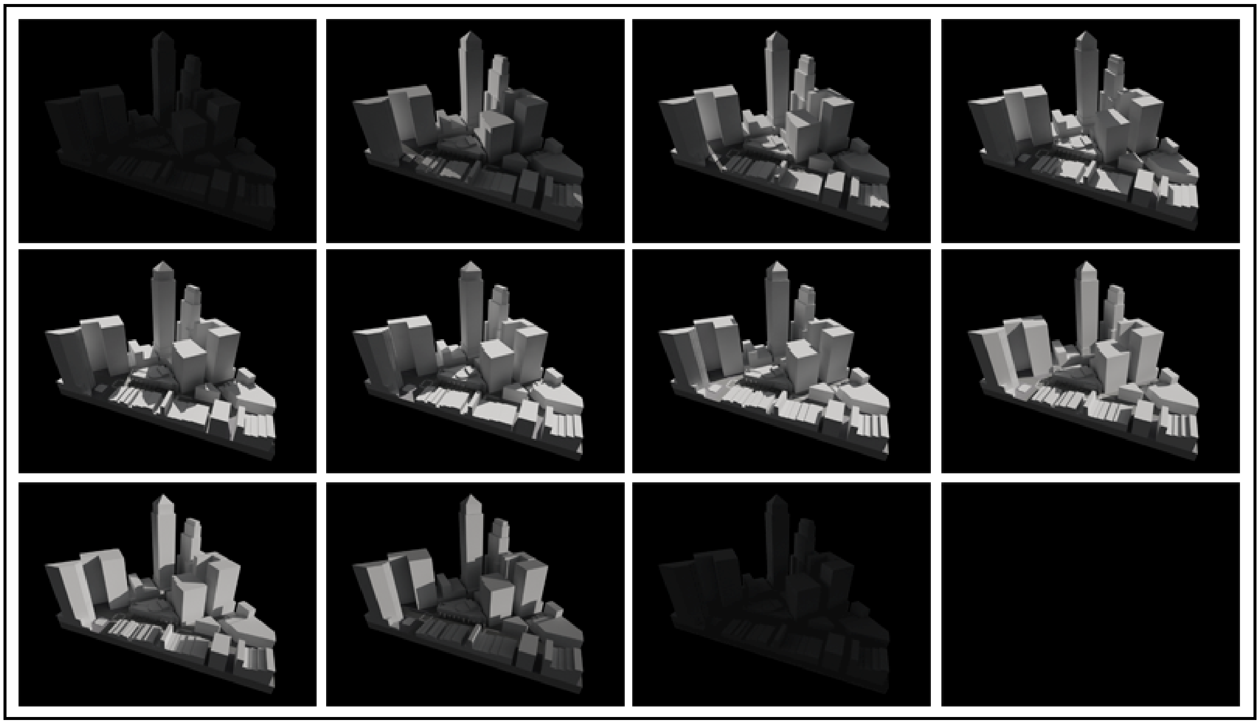

Figure 4.0.2 | March/September 21 Shadow Study

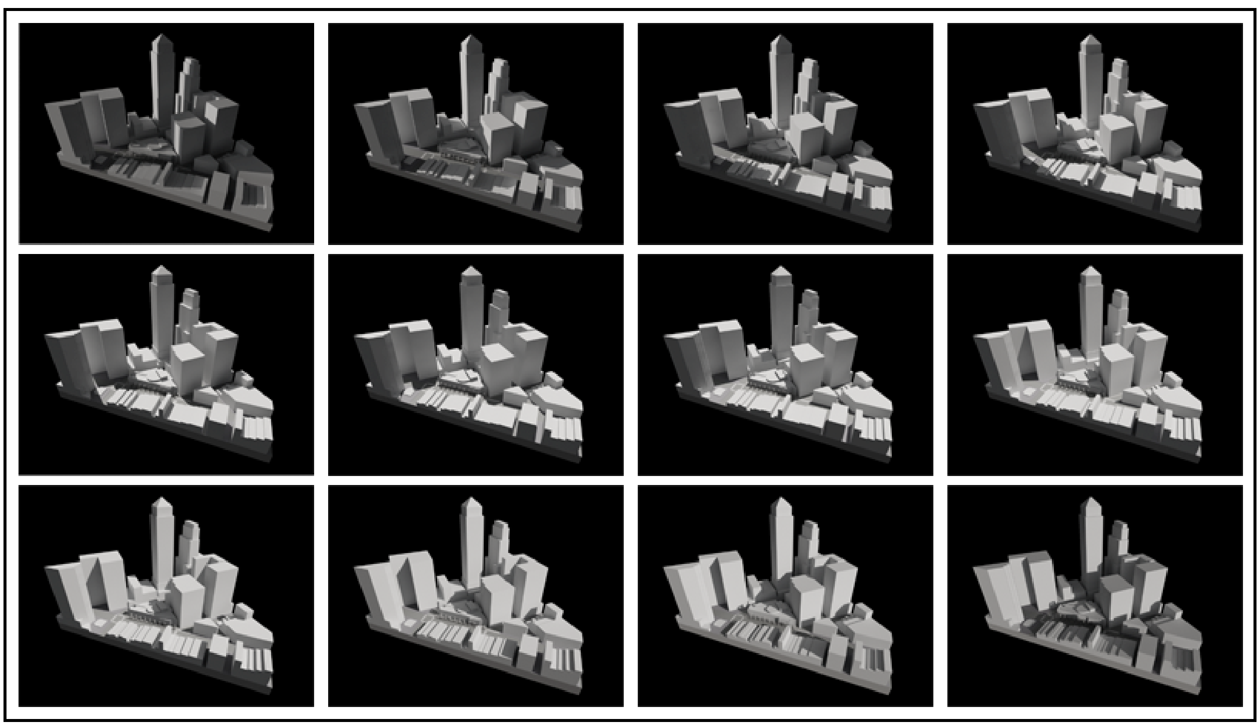

Figure 4.0.3 | June 21 Shadow Study

Figures 4.0.1, 4.0.2, and 4.0.3 show that the Liberty Avenue Façade receives very little direct sunlight. The only time that it does receive direct sunlight is very early in the day and very late in the day during the summer months. At these times the sun is very low, which results in the possibility that the direct light would be blocked by buildings beyond the extents of the model. However, if it is not blocked, it will penetrate deep into the building creating the potential for harsh glare.

Despite the fact that very little direct light reaches the façade, a plentiful amount of daylight is able to penetrate the space. This is shown in figures 4.0.4 and 4.0.5. This cross section through the education room and the lower main lobby illustrates the daylight levels at midday on March 21st with an overcast sky. Since the glazing is north facing, this condition will provide some of the highest daylight levels. Because of the urban setting, however, sunlight reflected from buildings across the street will be an important consideration. This condition is not easily modeled because it relies heavily on the reflectance values of the building materials for the various surrounding buildings.

Figure 4.0.4 | Building cross-section rendered at midday on March 21 under an overcast sky. [Note: lower level ceiling baffles omitted for clarity]

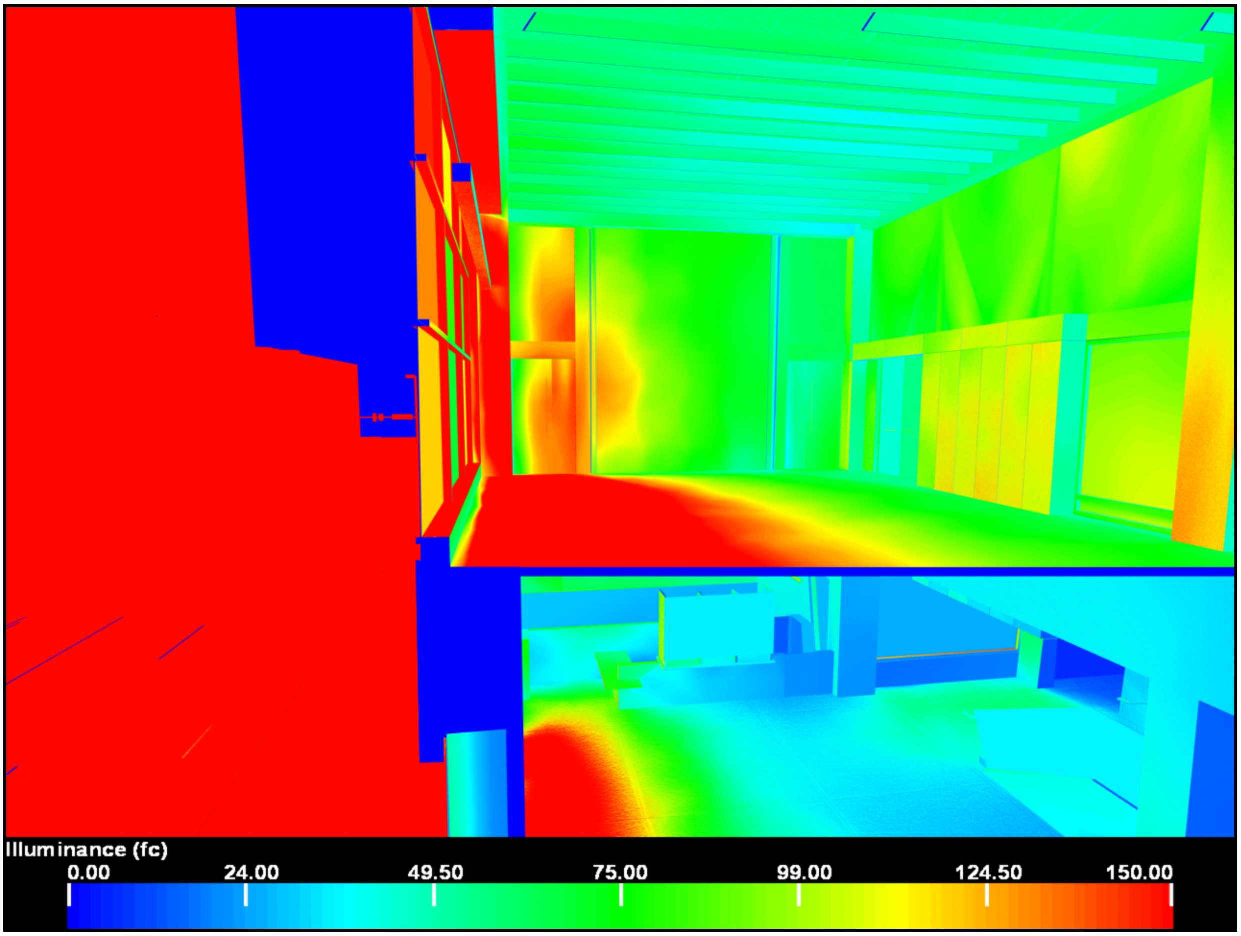

Figure 4.0.5 | Building cross-section rendered with pseudo color exposure at midday on March 21 under an overcast sky. [Note: lower level ceiling baffles omitted for clarity]

The daylight cross section illustrates that daylight is plentiful in the space on the north side of the building. The northerly orientation of the glazing will provide predominantly glare-free light. The difference between the upper level and lower level is quite significant. The ceiling height for the upper level is five feet higher than that of the lower level. Additionally, an overhang of approximately two feet exists for the lower level. These factors, as well as a lower floor reflectance, reduce the amount of daylight that is able to penetrate deep into the space.

For both the upper and lower levels, it is reasonable to conclude that photosensors could be employed to reduce energy consumption during daytime hours. Figure 4.0.5 shows that no electric light is required during the day to reach the desired illuminance levels discussed in the following sections. While these spaces are not ones that would be used on a typical working day schedule, therefore reducing the effectiveness of the photosensors in reducing energy consumption, they will be occupied at certain times during the day. With the new control scheme that has been designed for the building, the addition of photosensors will not require additional upgraded equipment other than the photosensors themselves. Thus, it is logical to provide this equipment even if the occupancy conditions are less than ideal.

1. LIBERTY AVENUE FAÇADE

***Description*:**

The Liberty Avenue façade is approximately 150' long and two stories (47') tall, making it appear very horizontal. It is punctuated by a sail shaped feature on the corner of Liberty Avenue and William Penn Place which forms the focal point of the building's exterior. The façade is book-ended on the opposite end by a protruding cube that cantilevers out from the plane of the façade by nine feet. Also at this end of the building is a small seating area outside the café which occupies the corner of Liberty Avenue and Smithfield Street. The façade sits approximately 25' back from the curb. A row of deciduous trees will run the length of the façade. Spaced approximately 35' apart, these trees are significant when viewing the façade. As the façade normal is oriented only a few degrees off of due north, it will almost always been in shadow. This is confirmed by shadow studies of the building site representing key dates of the year.

The crux of the liberty avenue façade is its function as a visual opening into the heart of the building. With clear glass as the predominant material, passersby will have a view into the building day and night. This condition is particularly relevant to the lighting design. This façade is at the heart of the architect's vision of a "conceptually transparent, flexible container."

***Surface Materials*:**

Material descriptions and assumed reflectance properties are available in Appendix E.

This façade is arranged in horizontal bands of clear curtain wall (MATERIAL GLZ-1) and aluminum composite panels (foamed in place) (MATERIAL MTL-3). Spandrels (MATERIAL GLZ-2) are used where necessary. The large sail structure is also clad with metal panels and glass but uses fritted glass for the top section (MATERIAL GLZ-5). It has a black stone base (MATERIAL STN-1).

Irregular façade features are faced with a different but visually similar metal panel system (MATERIAL MTL-1). Protrusions extending out the top of the building are surfaced in an exposed fastener profiled metal panel system (MATERIAL MTL-2). The far right section of the facade is faced with a concealed fastener metal panel system (MATERIAL MTL-4). The sidewalk in front of the building is the standard concrete that is required by the city of Pittsburgh.

Design Criteria:

Space Type: Building Exteriors – Prominent Structures

IESNA Very Important Criteria:

- Appearances of Space and Luminaires
- Light Distribution on Surfaces
- Light Pollution / Trespass
- Point(s) of Interest
- Reflected Glare
- Shadows
- Source/Task/Eye Geometry

Surface Characteristics
Category A (3 FC) Vertical Illuminance

IESNA Important Criteria:
Color Appearance (and Color Contrast)
Direct Glare
Modeling of Faces or Objects
Category B (5 FC) Horizontal Illuminance

IESNA Somewhat Important Criteria:
Peripheral Detection
Sparkle/Desirable Reflected Highlights

ASHRAE/IESNA 90.1 Regulations:

According to table 9.4.5, building facades are allowed 0.2 W/ft^2 for each illuminated surface or 5.0 W/linear foot for each illuminated wall. Also, building entrances and exits are allowed 30W/linear foot of door width (main entrances) or 20 W/linear foot of door width (other doors). For walkways 10' wide or greater and plaza areas, an allowance of 0.2 W/ft^2 is granted. Several exceptions are granted by section 9.4.5 but none are applicable to this project.

Pre-Design Criteria Analysis:

This façade is very important and prominent. Simply washing this surface would downplay the dynamic nature of the architecture and do little to create a signature appearance. Accentuating the sail feature at the end of the façade is a perhaps the most important consideration as it is the keystone of the design.

The placement of luminaires is also a very important consideration. Improper placement can create harsh glare and can also lead to light pollution. With taller buildings on adjacent sites, it is important to avoid stray light that may disturb neighbors. Placing luminaires in a way that does not clutter the clean lines of the architecture will be vital and a significant challenge for the sail feature.

It is very important to consider the overall effect that the lighting will have on the surrounding environment. Lighting to the appropriate level provides an inviting environment that will encourage visitors to the site. Lighting the sidewalk to levels that are too high will anger area residents as well as create a spotlight effect that may make pedestrians uncomfortable.

Design Goals:

1. Help to develop the signature nature of the design
2. Enhance integration between spaces as a response to the transparency of the façade
3. Create focal points to guide patrons and add visual interest
4. Define a 'theatre stage' theme which allows the building to interact with the streetscape
5. Help to define the various volumes of space

Design Approach:

1. Using the appropriate levels and punctuating the design with accents will help create a signature appearance. Most importantly, it is necessary to avoid a 'cheap' appearance such as a flat wash.
2. The interior luminaires will be equally as important to the appearance of the façade as the exterior luminaires. Placement and consistency throughout the building is paramount.
3. The sail feature is a natural focal point which can be accentuated with lighting. Additionally, pools of light based on proper luminance ratios will guide patrons to the entrances.
4. Allow the façade to become silhouetted by the light coming from within.
5. Using varying light levels and washing selected surface will highlight the theater drum volume and sail structure.

Schematic Design Images:

These images represent pre-design schematic concepts and are not necessarily representative of the final design.

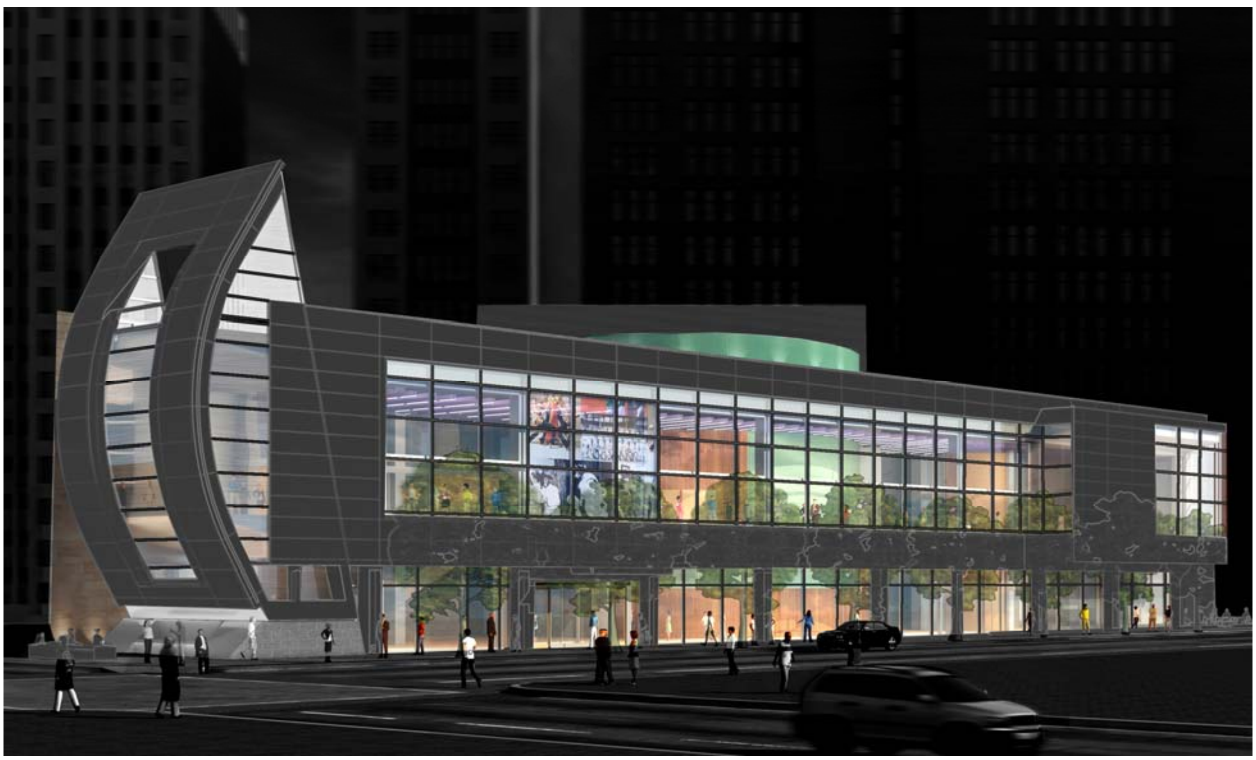

Figure 4.1.1 | Schematic Photoshop rendering showing the standard appearance of the building at night.

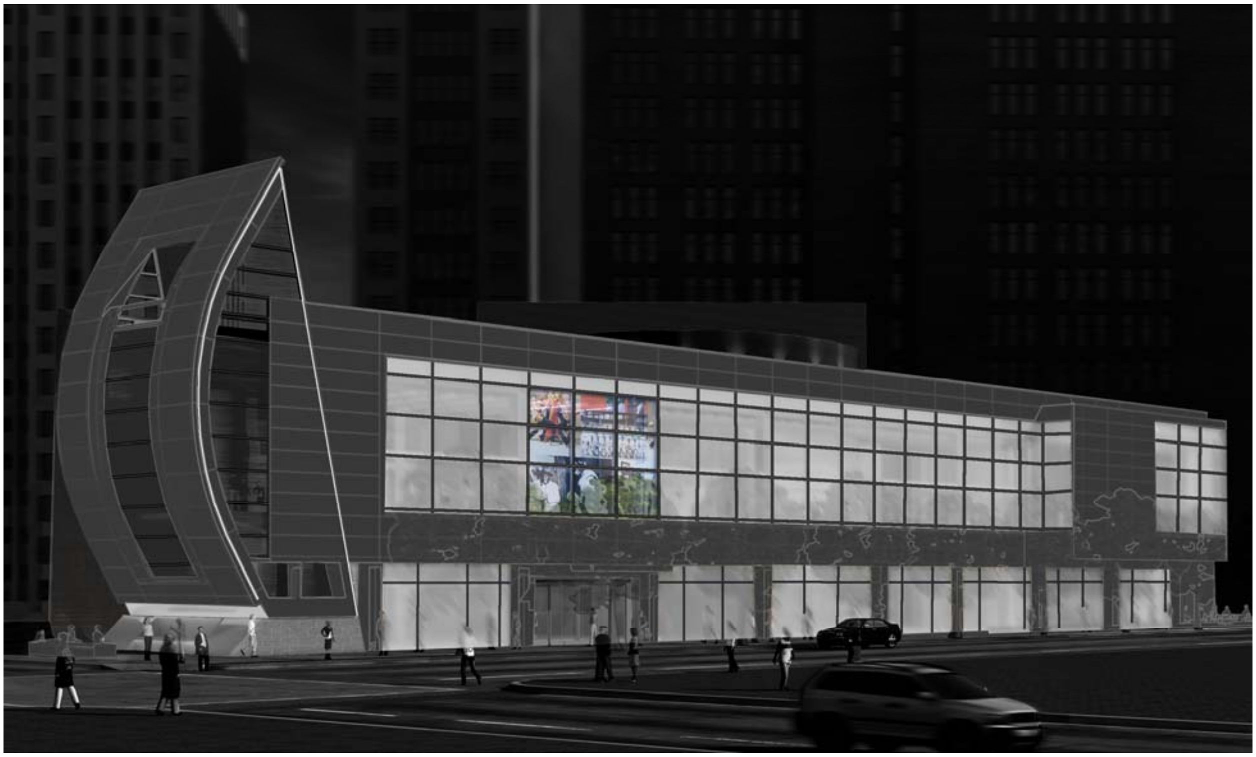

Figure 4.1.2 | Schematic Photoshop rendering showing the building after hours.

<u>The Redesign:</u>

The Liberty Avenue façade lighting system is divided into two scenes: one for use during standard operating times and a second for when the building is closed. The intent of this design is to highlight the transparency of the façade, allowing the occupants to serve as actors in a performance. The only exterior lighting fixtures that are used on this façade are a strip of color changing LEDs to further accentuate the sail and downlights to provide a higher illuminance at the main entrance, attracting and directing patrons. While few exterior fixtures are used, careful attention towards all the interior fixtures was absolutely necessary in order to achieve the desired appearance.

The second scene utilizes a small amount of light to accentuate building elements but clearly indicates that the building is not in operation. Color changing fixtures were used to allow various dynamic modes to correspond to varying events or holidays. This scene provides a distinct contrast to the standard lighting scheme.

One of the goals for this space was to highlight the various volumes of space that the architect has created. In creating schematic designs for this space, renderings from the architect were used. However, when the space was modeled to correct dimensions, it became apparent that the theater drum was not very visible by someone walking on the street. By incorporating lighting design goals into the design of a roof terrace (see Section Six | Architecture), the goals for the lighting design could be achieved.

Computer Renderings:

Images generated using AutoDesk VIZ 2008 Radiosity and Raytracing. Full size images are available in Appendix D.

Figure 4.1.3 | View from Liberty Avenue during active lighting state.

Figure 4.1.4 | View from Liberty Avenue during un-active lighting state.

Figure 4.1.5 | View along Liberty Avenue during active lighting state.

Figure 4.1.6 | View along Liberty Avenue during un-active lighting state.

<u>Luminaires:</u>

[Note: The distinction of luminaires used for the façade is difficult to derive due to the nature of the design. The luminaires listed below are those whose primary function is related to the view from Liberty Avenue. The full luminaire schedule in Appendix A provides a more comprehensive listing. Product Information for luminaires, lamps, and ballasts is available in Appendix B.]

TYPE M: Exterior grade 7” Recessed Downlight (4); Main Entrance Canopy
TYPE N: Burial Uplight (5); Stone Wall
TYPE O: Flood Light (19); Exterior Theater Drum Fence
TYPE R: RGB LED Striplight (170’); Interior for Night Scene
TYPE S: RGB LED Striplight, Flexible (60’); Sail Outline

<u>Controls:</u>

All fixtures for the Liberty Avenue Façade are connected to Dimmer Rack DR101/201. Control for the color changing LED fixtures is provided by a DMX controller, allowing management to change the night scene colors to correspond to various events or holidays. Control for the façade lighting is via an architectural preset and dimming system located in the box office area. The location will limit access by patrons while serving as a logical central point of control. A full schedule of controls with accompanying specification sheets is provided in Appendix K.

Lighting Plans:

See Appendix B for scale lighting plans.

Performance Data Numerical Summary:

THEATER DRUM ILLUMINANCE, EXTERIOR:	30 FC
THEATER DRUM ILLUMINANCE, SECOND LEVEL:	30-40 FC (at maximum)
THEATER DRUM ILLUMINANCE, LOWER LEVEL:	30 FC (at maximum)
HORIZONTAL ILLUMINANCE LEVEL - TARGET | PROVIDED:	5 FC | 6 FC
ILLUMINANCE RATIO - TARGET | PROVIDED:	3:1 | 4:1 (Main Entrance to Surround)
NIGHT SCENE ILLUMINANCE ON SOFFIT:	9 FC
TOTAL NUMBER OF FIXTURES:	NA
TOTAL WATTS USED / ALLOWABLE:	NA
POWER DENSITY:	NA

Performance Data Images:

Images generated using AutoDesk VIZ 2008 Radiosity and Raytracing with pseudo color exposure control as indicated.

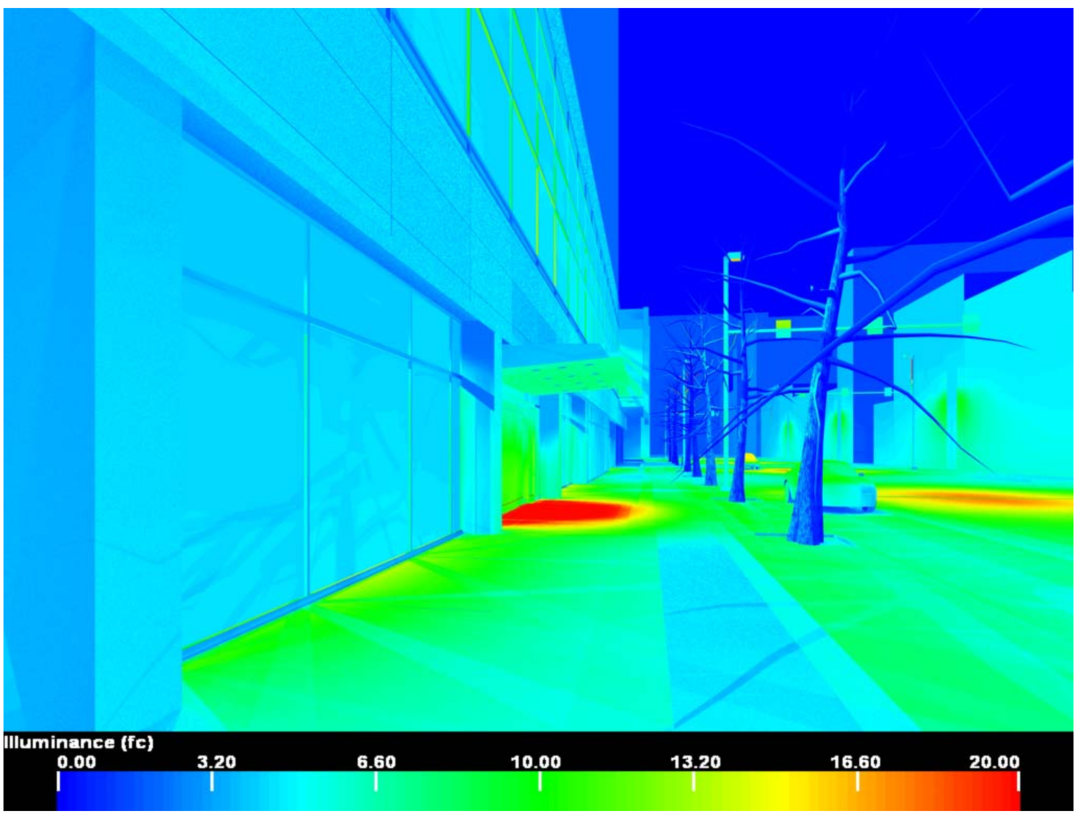

Figure 4.1.7 | Illuminance (fc) pseudo color exposure of view along Liberty Avenue [Note: glass does not appear transparent in images with pseudo color exposure.]

Summary Performance Evaluation:

While there are few fixtures dedicated to strictly lighting the façade, it was certainly one of the most complex challenges of this project. The transparency of the façade, a design feature emphasized by the architect, means that every space on the Liberty Avenue side of the building effects the impression of the building from the exterior. Thus, the 'Liberty Avenue Façade' design is more a result of the design of other spaces. The transparency and intersecting volumes of space dictate a uniform luminance be achieved on multiple surfaces with varying luminaires in order for the façade view to have a sense of continuity. This situation most notably occurs with the theater drum, on which the design is fairly successful in achieving a uniform illuminance (and luminance based on similar reflectance properties) of 30 footcandles.

The sail feature also provided a significant challenge. The shape itself makes it impossible to illuminate the surface without using a complex array of poles to mount fixtures at different locations. Even with poles, uniform illumination may be impossible. Therefore, I chose to accent this signature element with a strip of LED lights while also illuminating the interior ceiling with indirect pendants during the active scene. While this solution does not provide the punch that illuminating the sail itself would, it is a more practical solution that is comfortable for the patrons both inside and outside the building.

From the earliest schematic designs, it was a goal to create two scenes that alternate to illustrate the theatrical nature of the building. The final design also utilizes two scenes, but it is notably different from the schematic design. The original goal was to incorporate the shading system into the night scene to provide a soft uniformity to the transparent areas, contrasting the depth and openness of the active scene. In pursuing this design, it became apparent that this would require too many fixtures and too many watts to be of interest to the owner who would have to pay for the system. Instead of abandoning the idea, a simpler system was developed that integrates with an existing beam and soffit on the second level. By uplighting the white soffit, a unique pattern is created that is distinctly different from the active scene.

Another item from the schematic design that required changes was the illumination of the theater drum fence on the roof. As noted, from the renderings provided by the architect, it appeared that this surface would be visible from the street. When it became apparent that this surface was only slightly visible, the alteration of this surface became an essential piece of the architecture study of adding a roof terrace. Once the changes were made, the continual illumination of the theater drum became possible and became a powerful core element of the façade design.

Overall, the façade design is inherently reliant on the architect's vision for the building which may or may not have considered the integration of the lighting system. Based on the circumstances, I feel the design is successful and while not explicitly achieving all of the schematic design goals, it does provide solutions to the challenges presented.

2. MAIN LOBBY

Description:

The lobbies, both on the upper and lower levels, act as the main circulation core for the building. From the main lobby on the first floor, one can reach the permanent exhibit space, theater, gift shop, box office, and the main grand staircase to the second level. It totals 4,429 square feet of irregularly shaped space that is defined by surrounding spaces rather than walls. The lobby runs most of the length of the Liberty Avenue façade, approximately 120'. An open plenum ceiling exists through much of both the first and second level lobbies.

The most notable design element in this space is the large elliptical wall that forms the back of the theater space. This 'drum,' can be seen as a volume from the exterior that protrudes through the first and second levels and out the roof of the structure.

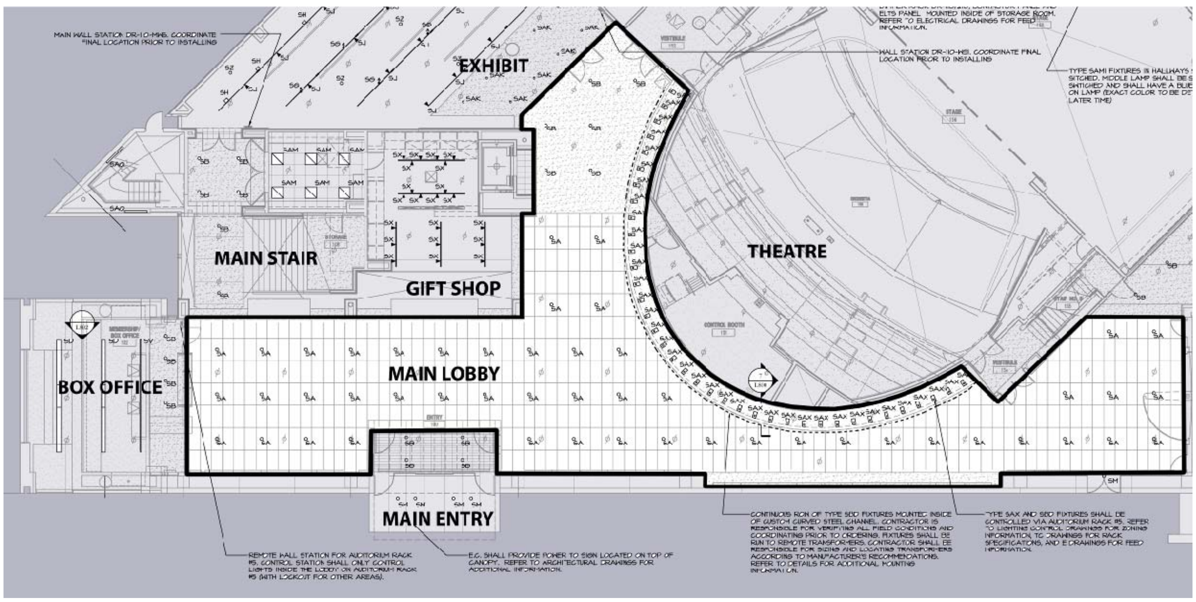

Figure 4.2.1 | Schematic view of the main lobby.

Surface Materials:

Material descriptions and assumed reflectance properties are available in Appendix E.

The true definition of materials for this space relies heavily on adjacent spaces. In general, the floor is a finished concrete (MATERIAL CONC-2) while the ceiling is a combination of an open 4' by 4' black grid with 8" metal baffles running perpendicular to the Liberty Avenue facade spaced every 2'. The baffles hang (MATERIAL XPC-1) at approximately 14'-6" above the finished floor. Above the grid system is the structure which is covered with black acoustical blanket, as well as mechanical systems which are painted black (MATERIAL PT-2).

The grand staircase, on the south end of the space, is framed by a multi-story stone wall, comprised of three types of stone (MATERIALS STN-1, STN-2, STN-3). The main walls are painted white (MATERIAL PT-1), while accents are metal (MATERIALS MP-1, MP-2) and wood (MATERIALS WD-1, WD-2). The north wall is almost entirely curtain wall (MATERIAL GLZ-1). Shades are not provided for this glazing. The prominent theater drum is painted green (MATERIAL PT-5) with sections of wood (MATERIAL WD-2).

Furnishings:

No furnishings are currently specified by the architect as they are under a separate contract. Where applicable, benches have been modeled as seen fit.

Design Criteria:

Space Type: Offices – Lobbies, Lounges, and Reception Areas (IESNA Chapter 15)

IESNA Very Important Criteria:

Appearances of Space and Luminaires

IESNA Important Criteria:

Color Appearance (and Color Contrast)
Direct Glare
Light Distribution on Surfaces
Luminances of Room Surfaces
Modeling of Faces or Objects
Surface Characteristics
Category A (3 FC) Vertical Illuminance (at the entrance)

IESNA Somewhat Important Criteria:

Daylighting Integration and Control
Flicker (and Strobe)
Reflected Glare
Shadows
Category C (10 FC) Horizontal Illuminance

ASHRAE/IESNA 90.1 Regulations:

According to table 9.6.1 a lobby for a performing arts theater has an LPD (W/ft^2) of 3.3. This is much higher than other types of lobbies which have an LPD of 1.1. Additionally, section 9.6.3 allows for an additional 1.0 W/ft^2 for lighting installed for decorative appearance.

Pre-Design Criteria Analysis:

The IESNA recommendations are accurate in suggesting that the appearance of the space and luminaires is very important for this space. As the main lobby, everyone will see this space and thus the lighting must accentuate the style of the architecture.

The IESNA Illuminance levels, based on an office lobby, are too low for this space. Looking at recommendations for theater lobbies, the 20 footcandle level is more appropriate. Phototropism, or the tendency for humans to be attracted to brighter areas, is certainly important. Creating points of interest will draw patrons to the building and to the different spaces within.

The IENSA also recommends general illuminance levels before and after performances to be 5-15 footcandles. Therefore, I believe this space needs to be flexible in order to provide proper conditions depending on the function that is occurring at the time. This space is not only the lobby for the theatre, but also for the galleries, gift shop, and café. This all indicates an advanced control system is necessary.

It is important that the lighting in this space creates a relaxed environment to welcome patrons. Layers of light can be used to create a variety of conditions that may be controlled with a preset system. A relaxing environment can be created with non-uniform and peripheral lighting. This mood will be created by highlighting the points of interest within the space. The ticket booths should be highlighted to draw the attention of patrons. Higher illuminances in the gift shop will make it another point of interest. The large curved wall that forms the back of the theatre can also be highlighted to create a visual centerpiece for the lobby.

Design Goals:

1. Create a relaxing and welcoming environment
2. Draw patrons to points of interest
3. Flexibility for various uses of the building and of the lobby
4. Smooth and appropriate transitions to surrounding spaces
5. Energy efficiency

Design Approach:

1. Use layers of light that draw focus to perimeter focal points.
2. In synergy with design approach one, the perimeter emphasis that creates a relaxing environment will draw patrons to the points of interest.
3. The control system will be instrumental to the success of the design. By utilizing dimming, the space can be illuminated to the desire level based on the current building use.
4. A smooth transition can be created by using similar systems throughout the spaces. This relates to the overall goal of building integration.
5. The use of photo sensors integrated with the control system will save energy when ample daylight is available due to the plentiful glazing. Glare will not be a problem since it is north facing. It will not be a large increase in cost because dimming is already being used to meet other goals.

Schematic Design Images:

These images represent pre-design schematic concepts and are not necessarily representative of the final design.

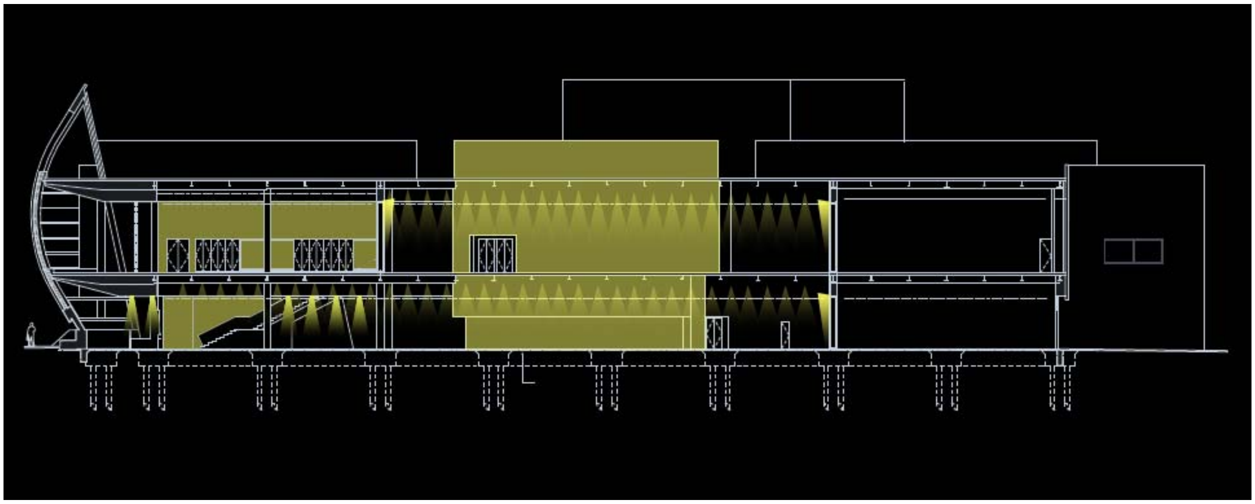

Figure 4.2.2 | Schematic section of the lighting in the lower and upper lobby areas.

The Redesign:

The key elements of the lobby lighting scheme are actually the areas surrounding the lobby. In the lobby itself, regular arrangements of inconspicuous linear luminaires integrate with the metal baffle ceiling, providing adequate lighting for a theatrical lobby. The key elements which extend through both the lower and upper lobbies, the drum and the stone wall, are washed to high levels to clearly define them for the exterior viewing condition and to create points of interest. Along with redesigning the main lobby lighting system, the adjacent spaces which are essential to the design were changed as necessary. These spaces include the box office, gift shop, grand staircase, vestibule, and upper lobby. While these spaces are not specifically documented as a redesigned space, they are visible in the computer renderings and are included in the fixture schedule and lighting plans.

Computer Renderings:

Images generated using AutoDesk VIZ 2008 Radiosity and Raytracing. Full size images are available in Appendix D.

Figure 4.2.3 | Lower Lobby looking west.

Figure 4.2.4 | Lower Lobby looking East

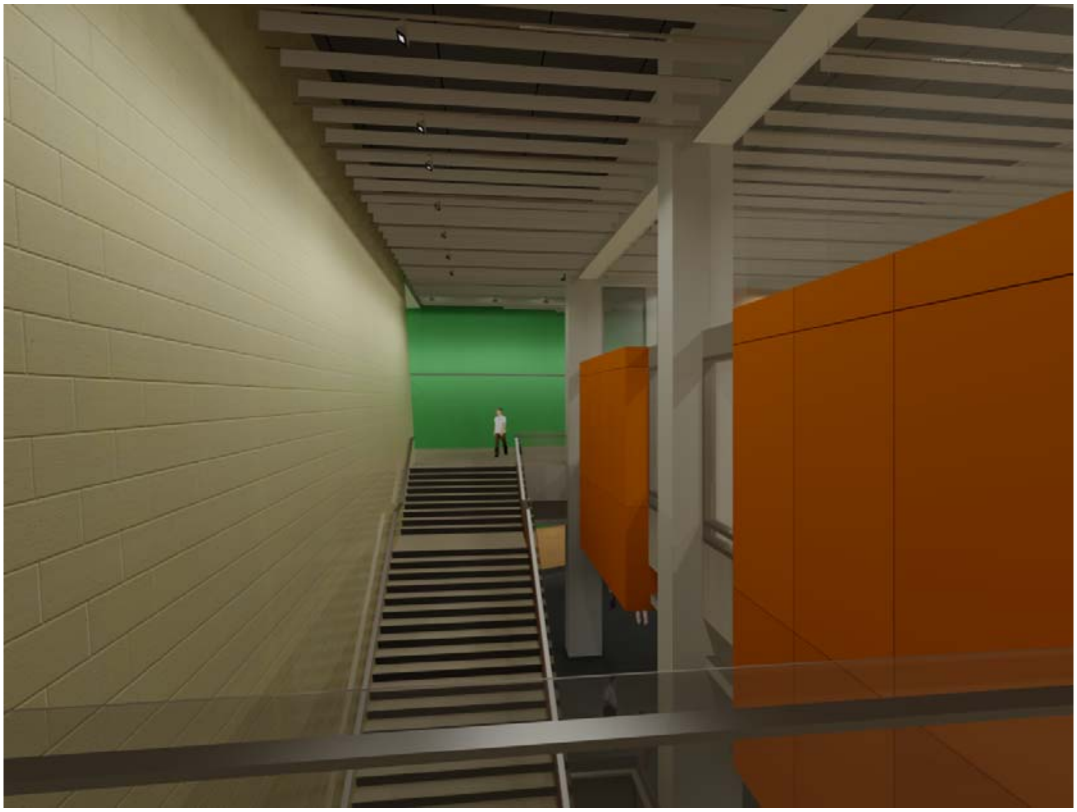
Figure 4.2.5 | View of grand staircase from the bridge.


Figure 4.2.6 | View of Upper Lobby from the top of the grand staircase.

Luminaires:

TYPE B: Linear Fluorescent Downlight (40); General Downlighting
TYPE D: Halogen Track Head on Curved Track, Flood Optic (50); Theater Drum Wash
TYPE E: 7" Compact Fluorescent Recessed Downlight (15); General Downlighting
TYPE F: Compact Fluorescent Pendant (4); General Downlighting
TYPE H: MR16 Pinhole Downlight (7); Downlighting Under Cabinets from Above
TYPE G: Lensed Linear Fluorescent Slot (2); Accent at Main Entrance

A full luminaire schedule, light loss factor calculations, and power density information can be found in Appendix A. Product information for luminaires, lamps, and ballasts can be found in Appendix B.

Controls:

The entire lobby system, as well as the key adjoining spaces, are connected to a single dimmer rack, DR101/201 and are controlled from a central wall station located in the box office area. This simple setup allows for easy management of many lighting systems from one central point. An additional wall station is provided for the Gift Shop to allow for precise control as necessary. This control system creates a flexible lighting system, satisfying one of the goals for the design.

Lighting Plans:

See Appendix B for scale lighting plans.

Performance Data Numerical Summary:

ILLUMINANCE LEVEL - TARGET | PROVIDED:	20 FC |22 FC (at maximum light output)
LUMINANCE RATIO, THEATER DRUM:	3:1
LUMINANCE RATIO: BOX OFFICE:	3:1
LUMINANCE RATIO, GIFT SHOP:	2:1
POWER DENSITY – ALLOWABLE | ACTUAL:	3.3 W/SF | 1.07 W/SF

Performance Data Images:

Images generated using AutoDesk VIZ 2008 Radiosity and Raytracing with pseudo color exposure control as indicated.

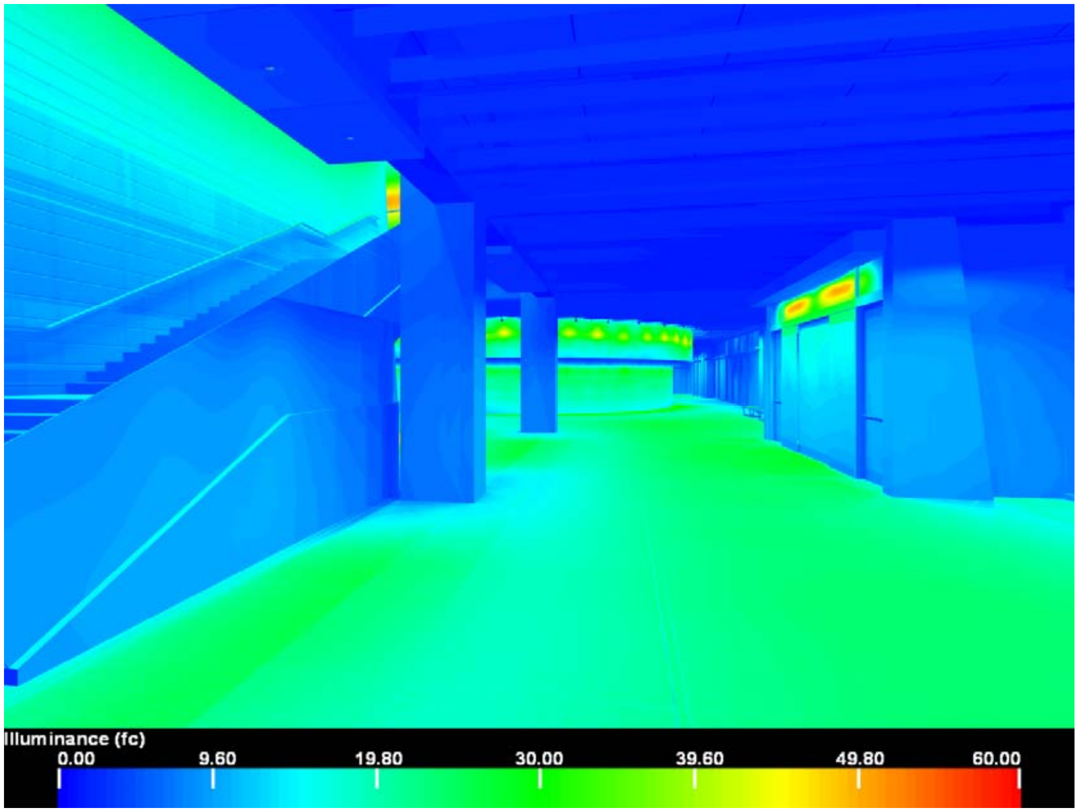

Figure 4.2.7 | Illuminance (fc) pseudo color rendering of the Lower Lobby looking west.

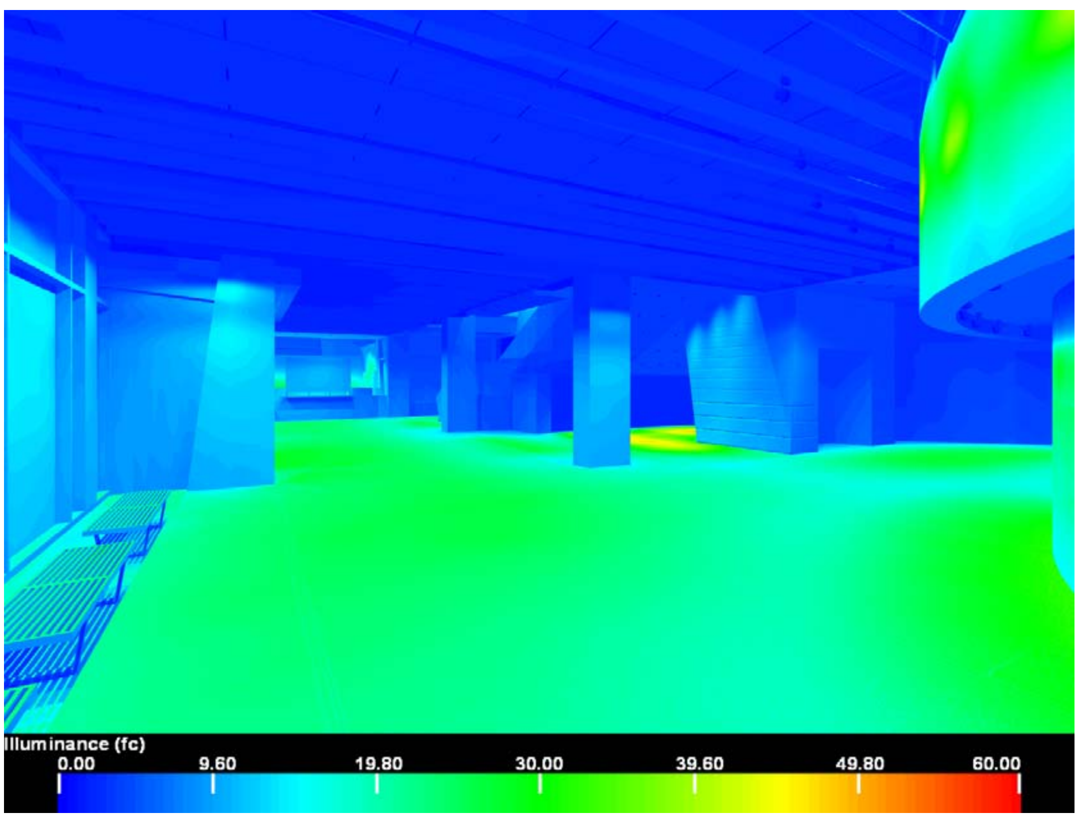

Figure 4.2.8 | Illuminance (fc) pseudo color rendering of the Lower Lobby looking east.

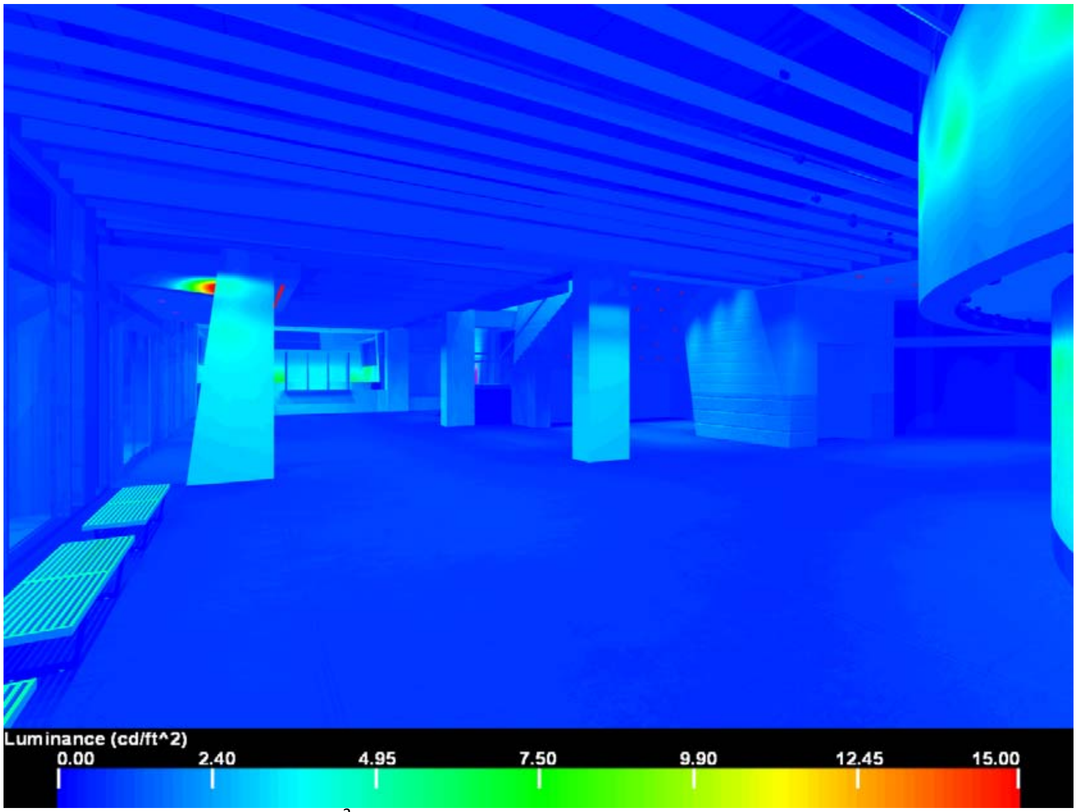

Figure 4.2.9 | Luminance (cd/ft^2) pseudo color rendering of the Lower Lobby looking east.

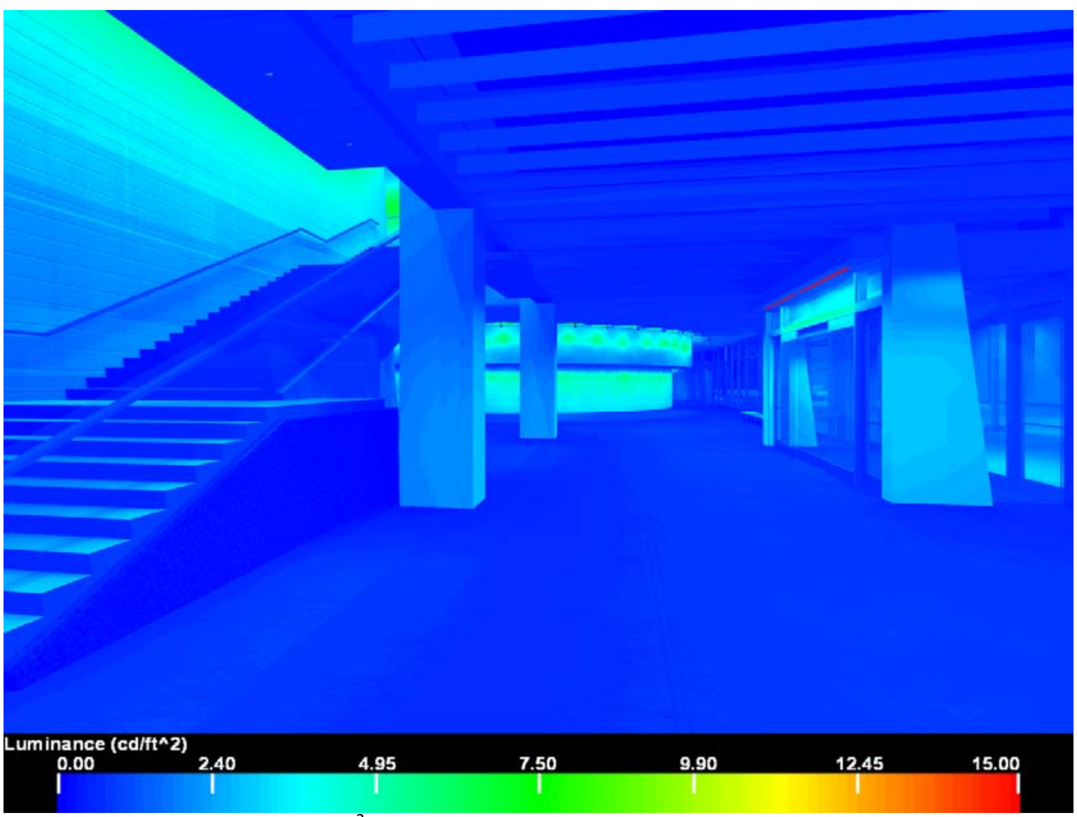

Figure 4.2.10 | Luminance (cd/ft^2) pseudo color rendering of the Lower Lobby looking west.

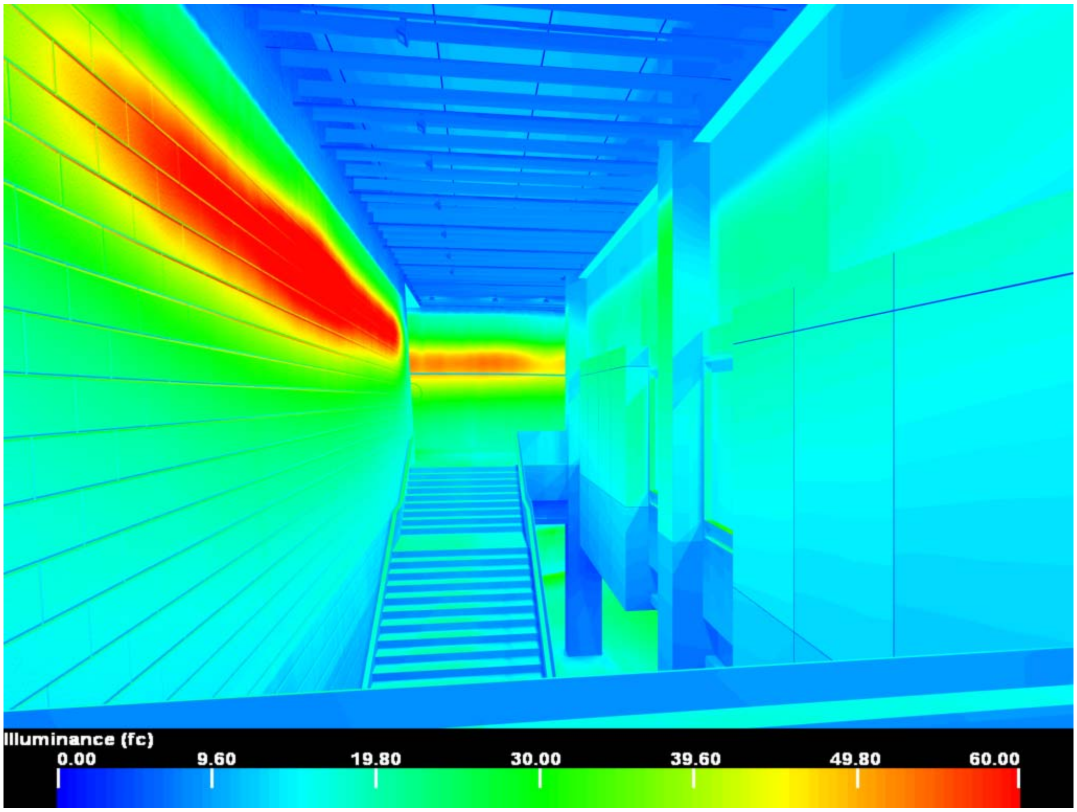

Figure 4.2.11 | Illuminance (fc) pseudo color rendering of the grand staircase looking from the bridge.

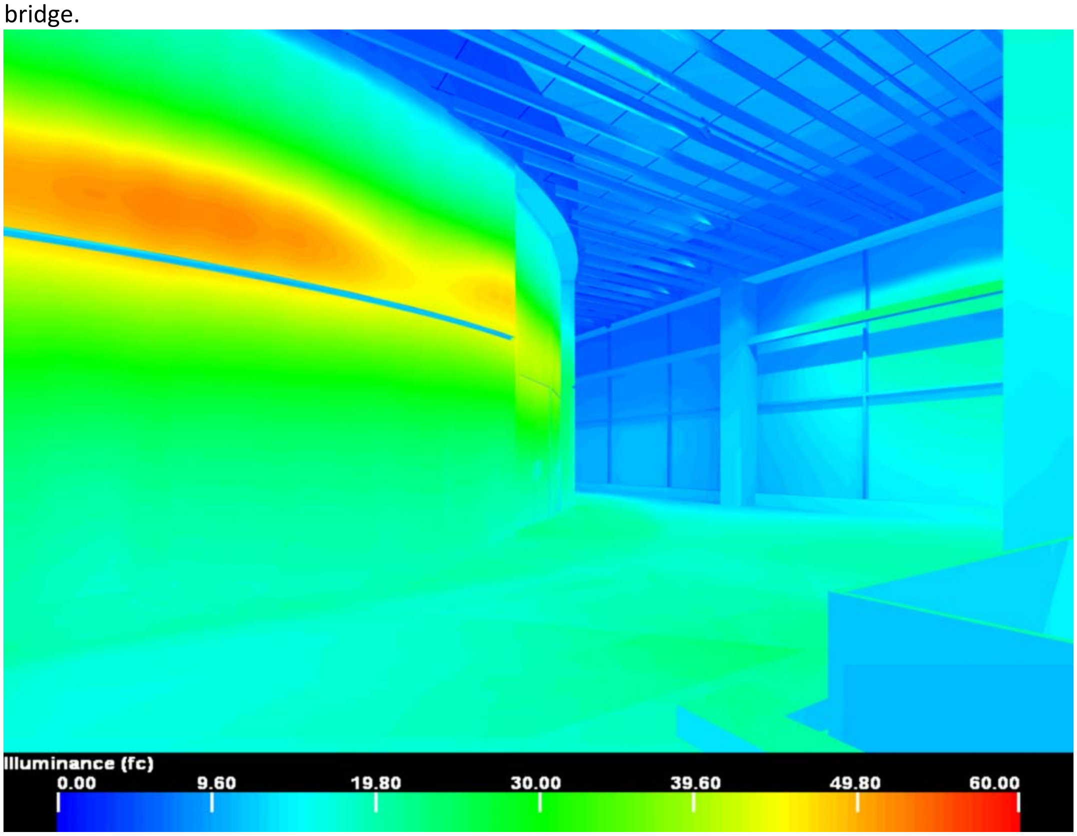

Figure 4.2.12 | Illuminance (fc) pseudo color rendering of the Upper Lobby from the top of the grand staircase.

Summary Performance Evaluation:

The lobby areas, both upper and lower, comprise a large portion of the building and their unique, undefined boundaries make the relationship between the lobby lighting and lighting of the surrounding spaces critical. The ceiling system employed in the lobby and into other spaces in the building also is very restrictive to the selection of luminaires. Furthermore, on the first floor, the very dark floor is a particular characteristic that influences the lighting design.

Creating a relaxing environment is more difficult when it isn't possible to provide any indirect lighting from the ceiling. In a compromise, discreet linear fixtures provide general lighting that isn't too harsh to walk under. The fixtures also have a favorable cut-off angle which limits the visibility of the lamp. Combined with a strong emphasis on perimeter lighting, this space should be comfortable for gathering before a performance. The control system allows for the high level of flexibility that will be required in this space. As a theater lobby, light levels must be critically controlled to provide a comfortable level and transition for patrons entering a very dark space. Furthermore, theater lobby lights are often used as a signal to indicate the start of a performance. The dimming and control system that is specified will allow for these cues to be made.

While normally a very dark floor would hinder achieving proper illuminance levels, the floor in the lower lobby aides in achieving contrast ratios that will draw patrons to points of interest. Generally, these ratios are about three to one, an acceptable value. The main entrance is also accented by lensed linear downlights above the doors to draw attention to this key location that is otherwise unremarkable.

While ASHRAE Standard 90.1-2003 allows for 3.3 W/SF for a theater lobby, this very high number seems excessive. This space has been designed at a power density of 1.07 W/SF, less than a third of the maximum allowable value. As a project seeking LEED accreditation, this provides significant energy savings and will allow for other areas with more complicated lighting schemes to exceed allowances, if necessary.

The light design for the Lower Lobby is notably effective in achieve the goals for the space. All levels and ratios are achieved at a power density far below the ASHRAE standard.

3. EDUCATION AND LECTURE ROOM

Description:

The education and lecture room is an approximately 64' by 32' rectangular room located on the north side of the second level. The main entrance is from the second level lobby through either two standard doors or a large, mechanically operated pivot door. A second means of egress is provided via a bridge to a separate egress stairwell. The space is almost completely transparent with large amounts of glazing on all sides. As all the glass is clear, this transparency exists both looking into the space and looking out of the space. All of the glass can be covered with mechanically operated black-out shades.

The meeting room is accessed directly from this space, meaning it will partially function as a circulation space. Access to the meeting room is provided via two glass doors as well as another mechanically operated pivot door.

The south wall features built-in cabinets which break the plane of the glass wall. These provide storage as well as a kitchen sink. The room will primarily be used for lectures and presentations. Retractable presentation screens are available on both the east and west walls.

***Surface Materials*:**

Material descriptions and assumed reflectance properties are available in Appendix E.

North Wall: The north wall is an exterior wall which is entirely curtain wall (MATERIAL GLZ-1). A painted gypsum board soffit (MATERIAL PT-1) houses a recessed window shade. Three structural columns are finished with gypsum board (MATERIAL PT-1) while a beam running the length of the space at approximately 12' above the finished floor is shielded by a formed metal cover. Radiant heaters are located along the base of this wall.

South Wall: The south wall is a combination of red/orange painted casework (MATERIAL PT-3) and glazing (MATERIAL GL-1). The casework surfaces extend approximately 18" into the room, adding depth to the wall. The glass looks into the grand staircase and onto a stone wall beyond.

West and East Walls: The west and east walls, which are identical, are predominantly a massive, mechanically operated pivot door with a slightly curved wood face (MATERIAL WD-2) and metal trim (MATERIAL MP-2). A column on either side of the door is finished with gypsum board (MATERIAL PT-1). Also to either side is a glass passage door in a glass partition wall (MATERIAL GL-2).

Ceiling: A ceiling grid hangs at 19'-6" above the finished floor. The grid consists of a 4' by 4' black square grid as well as 8" metal baffles spaced 2' apart that run perpendicular to the Liberty Avenue façade . The bottom of the structure above is covered in black acoustic blanket. The ductwork is left exposed and is painted black (MATERIAL PT-2).

Floor: The floor is carpeted (MATERIAL CPT-1) wall-to-wall.

Furnishings:

The room is furnished with stackable chairs that could be removed if necessary. They are oriented in rows facing the east wall.

Design Criteria:

Space Type: Educational Facilities – Lecture Halls – Audience (Reading – Printed Tasks)

IESNA Very Important Criteria:

Reflected Glare

IESNA Important Criteria:

Category D (30 FC) Horizontal Illuminance

IESNA Somewhat Important Criteria:

Shadows

Source\Task\Eye Geometry

Light Distribution on Task Plane (Uniformity)

ASHRAE/IESNA 90.1 Regulations:

Table 9.6.3 allows for and LPD of 1.4 W/ft^2 for classroom / lecture / training rooms. An additional 1.0 W/ft^2 can be used strictly for decorative lighting.

Pre-Design Criteria Analysis:

Very few criteria are listed for this type of space. In general, the design must be efficient while avoiding problem situations with glare or non-uniformity. The IESNA recommends 30 horizontal footcandles for a reading area (printed tasks). This lecture room may have a more varied range of activities, however, so providing the flexibility to raise illuminance levels above or below the target value would be advisable.

After uniformity, the most critical aspect of the lighting for this space is the integration and control of daylight. With one entire wall of this space being north facing curtain wall, glare-free daylight is available to reduce electric lighting load. However, it is also important to consider that this light could be unwanted during a presentation. Thankfully, black-out shades are specified by the architect. Daylight harvesting will work hand-in-hand with the dimming flexibility that is required of this space due to the multiple functions it may serve.

Since it is an educational space, visual clarity should be a primary concern. Achieving this will involve eliminating or reducing glare and ensuring proper levels for the task plane. A 'clean' design will also contribute to an impression of visual clarity. As an upscale space, another factor not listed by the IESNA that is important to consider is the appearance of the luminaires.

Keeping with the overall goals, it is very important that this space integrates well with its adjoining spaces, the second level lobby and the meeting room. A continuity of luminaires from space to space will help maintain a consistent appearance from the exterior as well as maintaining a clean visual appearance inside since the space boundaries are transparent.

Design Goals:

1. Create visual clarity
2. Provide even and adequate light to the work plane
3. Design a flexible system for varied presentations and activities
4. Use controls to allow the system to respond to the environment
5. Match the existing room aesthetics and compliment the baffle system

Design Approach:

1. Utilize a uniform layout of direct luminaires with peripheral emphasis
2. Ensure proper levels through numerical verification
3. Utilize aimable fixtures and circuit fixtures in proper zones to allow for proper scene control
4. Use a dimming system and daylight sensors to maximize energy savings
5. Use a thin linear fixture with a modern and stylish appearance

Schematic Design Images:

These images represent pre-design schematic concepts and are not necessarily representative of the final design.

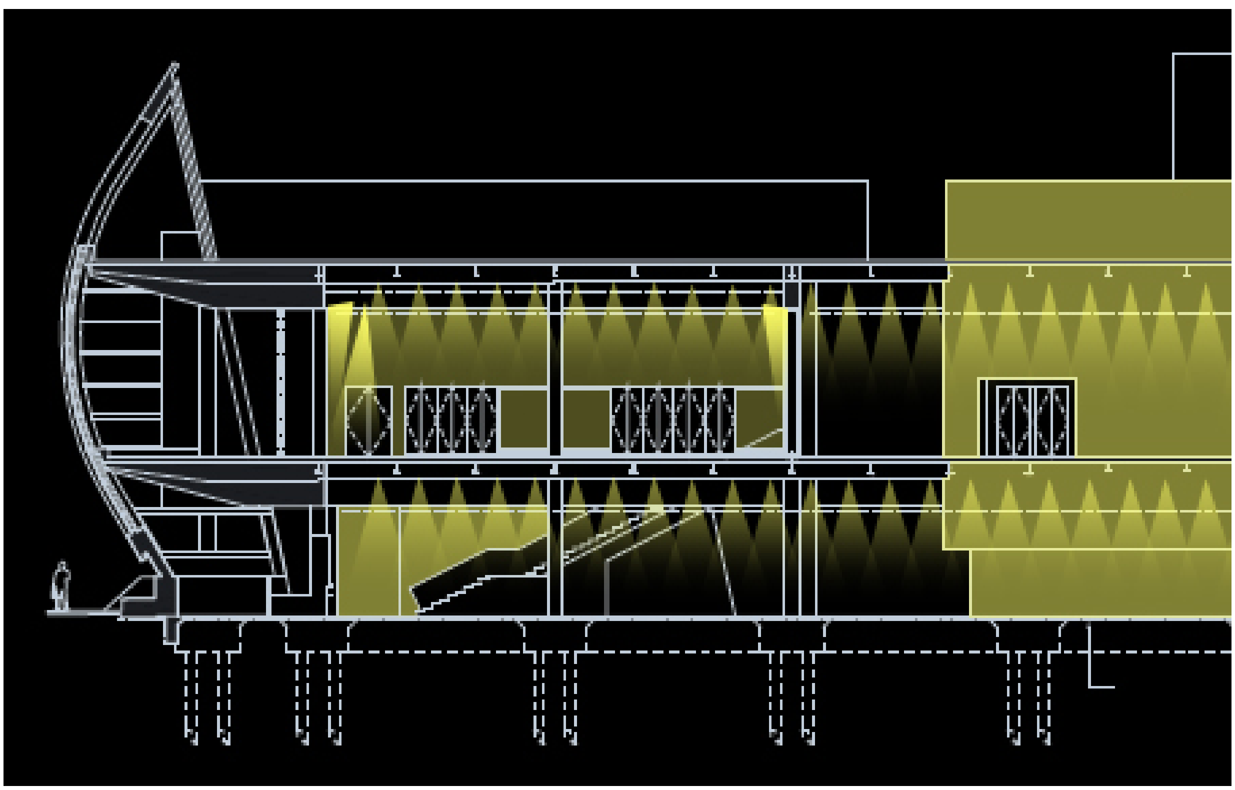

Figure 4.3.1 | Schematic section of the lighting in the education and lecture room.

The Redesign:

The new lighting system for the Education and Lecture Room utilizes a variation of the fixture that is used throughout the upper and lower lobbies. The fixtures in this room are simply grouped two together to allow for closer spacing necessary to meet higher illuminance level recommendations. This maintains a uniform appearance that is critical to the exterior view and also maintains the consistency from space to space that is necessary because of the glass partitions. The design is streamlined and efficient, integrating with the linear baffles that define the ceiling plenum. A complicated design is not necessary for this space and would likely be a distraction.

Computer Renderings:

Images generated using AutoDesk VIZ 2008 Radiosity and Raytracing. Full size images are available in Appendix D.

Figure 4.3.2 | Rendering of the Education and Lecture Room. [Note: scallops on the wood are more severe than would occur in reality due to rendering lights as point sources]

Luminaires:

TYPE A: T5 Linear Fluorescent Downlight (20); General Downlighting

A full luminaire schedule, light loss factor calculations, and power density calculations can be found in Appendix A. Luminaire, Lamp, and Ballast specification sheets can be found in Appendix B.

Controls:

This space will be controlled by an architectural preset system that will have a secondary control unit at the back of the space where exiting will be more common. The room is divided into zones by quadrant, which will also allow the exterior zones to be dimmed with photosensors. The control system will incorporate the window shades.

Lighting Plans:

See Appendix B.

Performance Data Numerical Summary:

ILLUMINANCE LEVEL - TARGET | PROVIDED: 30 FC |38 FC (at maximum light output)

POWER DENSITY – ALLOWABLE | ACTUAL: 1.4 W/SF | 1.24 W/SF

Performance Data Images:

Images generated using AutoDesk VIZ 2008 Radiosity and Raytracing with pseudo color exposure control as indicated.

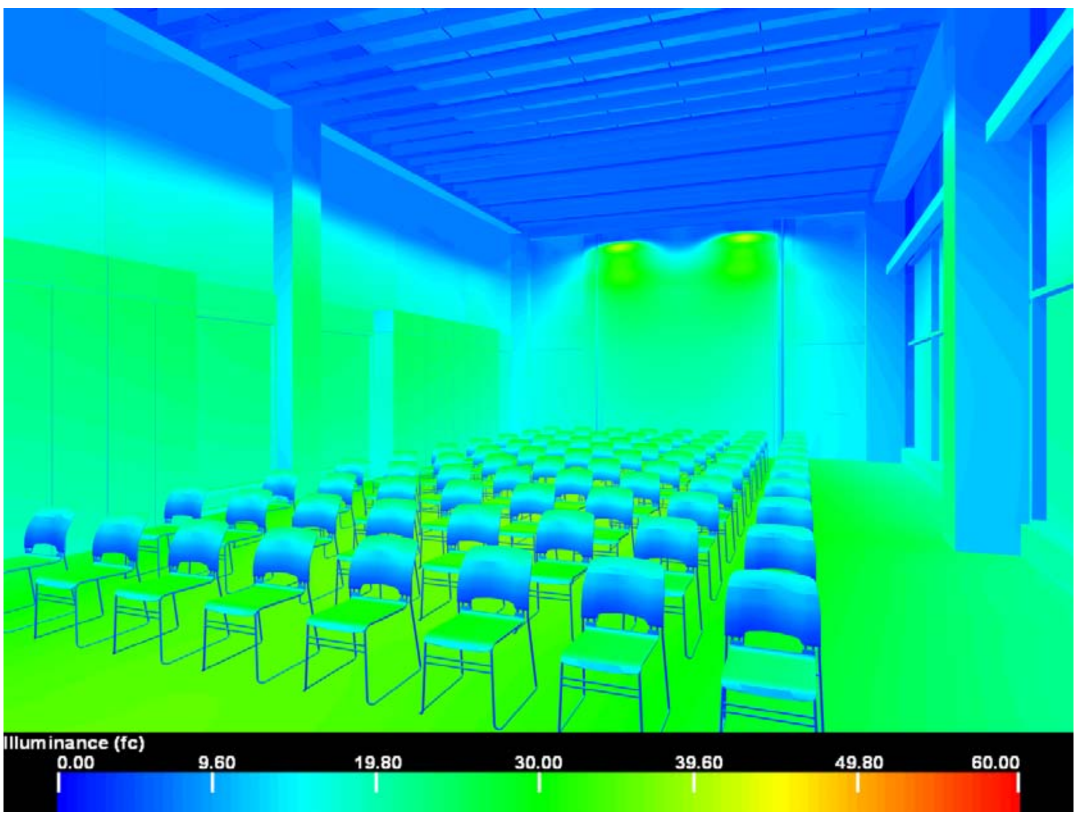

Figure 4.3.3 | Illuminance (fc) pseudo color rendering of the education and lecture room.

Summary Performance Evaluation:

The major criteria for this classroom space are performance based, rather than appearance based. The design uses only one type of luminaire but controls will allow the flexibility for varied uses that is required of this space. The light output of the system is ideal. At maximum output, just under 40 footcandles is provided, but dimming will allow the level to be set lower as desired. The control system also will make use of the plentiful daylight reaching the space. The small aperture and louvers of the selected luminaires, as well as the uniform layout, will limit glare. Overall, the lighting design for this space is simplistic, yet it successfully meets all performance requirements.

4. MEETING ROOM

Description:

The meeting room is prominently situated within the sail on the second level, in the northeast corner of the building. The room is approximately 24' by 32' and is accessed from the education and lecture room by standard doors or a large mechanical pivot door. Because it is in the sail the east wall is arched (in section view). Large sections of curtain wall exist on the south, east, and north sides of the space which will provide plenty of daylight. Shading is provided for all of the glazing. The ceiling slopes, opening to the curved wall of the sail. While the meeting room label is ambiguous, the primary function of the space would be to host donors or hold other small, private events.

***Surface Materials*:**

Material descriptions and assumed reflectance properties are available in Appendix E.

North and South Walls: Mirror images of each other, the north and south walls are half curtain wall (MATERIAL GLZ-1) and half painted gypsum (MATERIAL PT-1). There is a column at approximately the third point of the walls at which the ceiling begins to slope upwards towards the sail.

East Wall: The east wall curves as it is a portion of the sail that forms the corner of the building. Curved curtain wall (MATERIAL GLZ-3) forms the center of this wall while the left and right sides are painted gypsum (MATERIAL PT-1).

West Wall: The west wall is the same as the East and West walls of the education and lecture room.

Ceiling: The ceiling in this space is painted gypsum (MATERIAL PT-1). Moving from west to east, it is level before beginning to slope at column line A1. This creates an aperture effect opening the view looking out of the sail.

Floor: This space is fully carpeted (MATERIAL CPT-1).

Furnishings:

Furnishings for this space are not provided on the drawings. It is assumed that the furniture would include somewhat informal seating arrangements.

Design Criteria:

Space Type: Conference Rooms – Meeting

IESNA Very Important Criteria:

- Appearance of Space and Luminaires
- Direct Glare
- Modeling of Faces and Objects

IESNA Important Criteria:

Color Appearance (and Color Contrast)
Light Distribution on Surfaces
Light Distribution on Task Plane (Uniformity)
Luminances of Room Surface
Reflected Glare
Surface Characteristics
Illuminance Category D (30 FC) Horizontal
Illuminance Category B (5 FC) Veritcal

IESNA Somewhat Important Criteria:

Daylighting Integration and Control
Flicker (and Strobe)
Shadows
Source/Task/Eye Geometry

ASHRAE/IESNA 90.1 Regulations:

Table 9.6.3 allows for and LPD of 1.3 W/ft^2 for conference / meeting / multipurpose spaces. An additional 1.0 W/ft^2 can be used strictly for decorative lighting.

Pre-Design Criteria Analysis:

The meeting room's location within the building makes it one of the most dynamic and interesting spaces. Sitting within the sail, it will receive a lot of daylight, making integration and control of daylight an extremely important issue. However, it is also important to consider how this is controlled, because the view from this space should also be considered. One of the other important factors is the flexibility of the chosen lighting system. The nebulous nature of the space means the lighting may have to respond to a wide variety of uses. A preset control system will likely be beneficial for this space.

The appearance of the luminaires will also be important as they could possibly be a decorative element for the space. This would also allow for an additional w/sf allowance according to the ASHRAE 90.1 Standard. It is important to create a high class appearance in this space. The suggested Illuminance levels seem accurate for this space, but again, flexibility is essential.

As previously stated, this space must show some sense of continuity with the education room, as they are separated by a glass partition. The contribution of the interior lighting system of this space will have a great impact on the exterior appearance of the building.

Design Goals:

1. Create a warm and relaxing ambiance
2. Design for an upscale appearance
3. Provide strong facial rendering
4. Help make the space a signature room

Design Approach:

1. Utilize non-uniformity, peripheral emphasis, and low color temperature sources
2. Use decorative luminaires to provide a distinct style
3. Avoid direct, overhead downlight
4. Use decorative, stylish luminaires with a modern appearance

Schematic Design Images:

These images represent pre-design schematic concepts and are not necessarily representative of the final design.

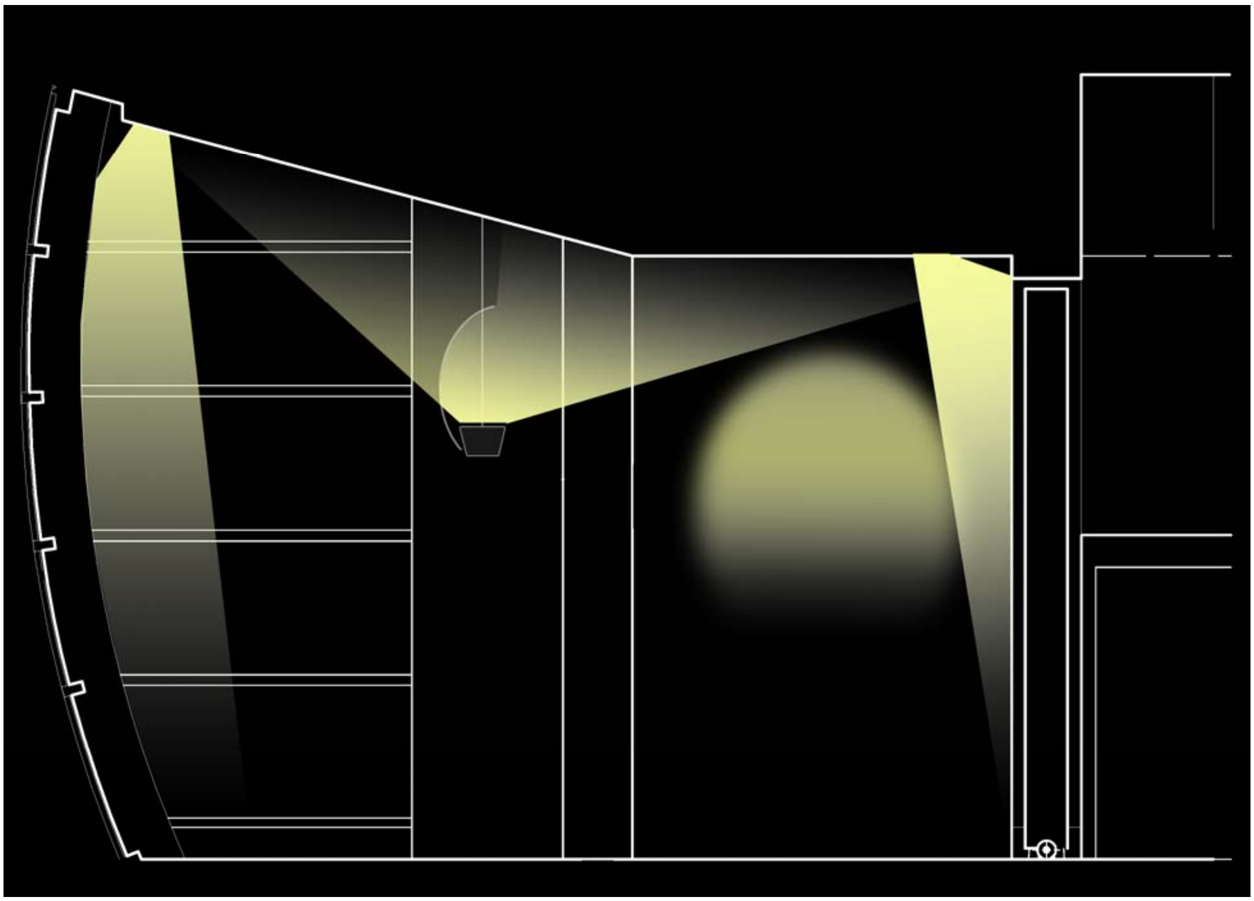

Figure 4.4.1 | Schematic section of the lighting in the meeting room.

The Redesign:

The redesigned system for the meeting room attempts to create a more relaxed atmosphere for a lounge space rather than a business-like atmosphere for a conference room. For the original design, the function of the space was somewhat undefined but labeled as 'Meeting Room.' As the project progressed, a donor was found to sponsor the room as a lounge area.

The lighting design focuses on creating a relaxing atmosphere by using as much indirect light as possible. This is somewhat difficult because the revolving door does not allow suspended fixtures in a good portion of the space. Additionally, nearly all the walls are washed to create an emphasis away from the central seating area. The pendants were chosen based on scale and the need to fill a large volume of space while also upholding the aesthetic of the space.

Computer Renderings:

Images generated using AutoDesk VIZ 2008 Radiosity and Raytracing. Full size images are available in Appendix D.

Figure 4.4.2 | Meeting room view looking west with all fixtures at full light output.

Figure 4.4.3 | Meeting room view with pendants (30%) and downlights (10%) dimmed to create a more relaxed environment.

Figure 4.4.4 | Meeting room looking east with all lights at full light output.

Luminaires:

TYPE F: 7" Compact Fluorescent Recessed Downlight (4); General Downlighting

TYPE I: Halogen Recessed Gimbal Spotlight (13); Wallwash for Door and Sail

TYPE J: Linear Fluorescent Recessed Wallwasher (4); Wallwash for recess

TYPE K: Decorative Pendant (3); General Indirect Lighting

A full luminaire schedule, light loss factor calculations, and power density calculations can be found in Appendix A. Luminaire, Lamp, and Ballast specification sheets can be found in Appendix B.

Controls:

Four zones will be used to allow maximum flexibility and scene control, which will be provided by an architectural preset control unit. The direct lights, indirect lights, linear wallwashers, and gimbal spotlights will be placed on separate zones allowing the user to create many different scenes. The window shades will also be controlled by the architectural preset control unit.

Lighting Plans:

See Appendix B.

Performance Data Numerical Summary:

ILLUMINANCE LEVEL - TARGET | PROVIDED: 30 FC |35 FC (at maximum light output)

POWER DENSITY: 1.3 W/SF | 1.61 W/SF

Performance Data Images:

Images generated using AutoDesk VIZ 2008 Radiosity and Raytracing with pseudo color exposure control as indicated.

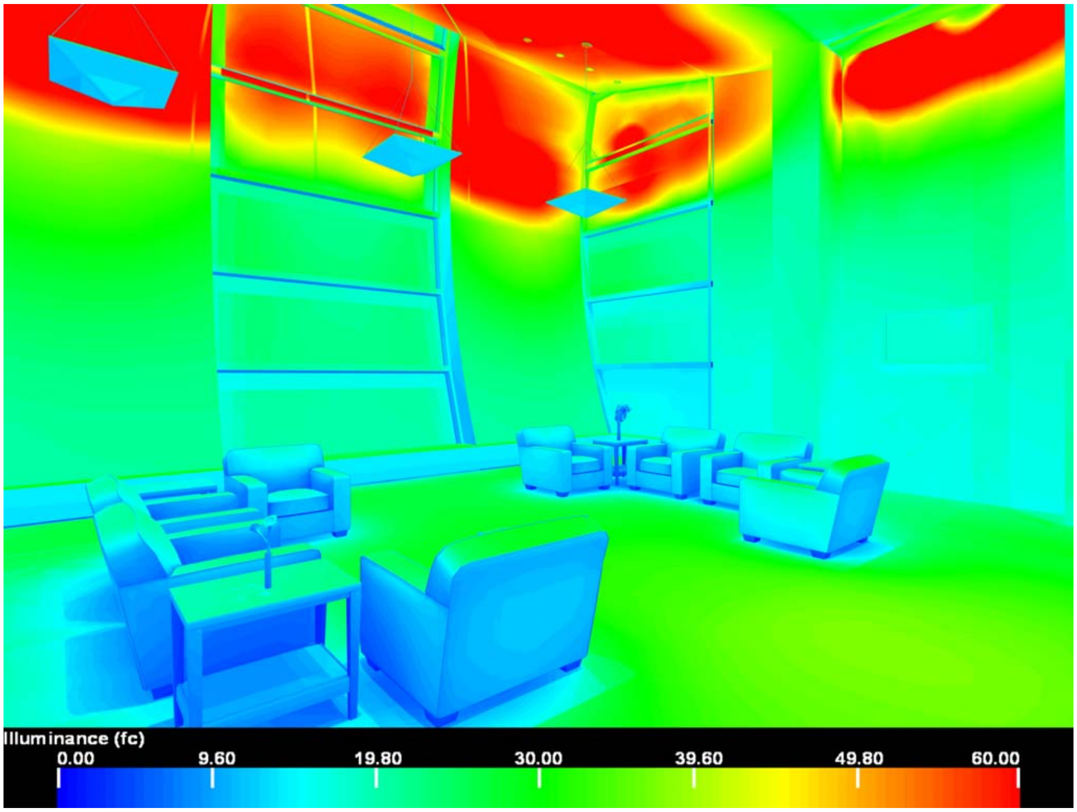

Figure 4.4.3 | Illuminance (fc) pseudo color rendering of the Meeting Room

Summary Performance Evaluation:

The meeting room is a signature space in a signature building and the lighting must represent this accordingly. The pendants used in this space coordinate effectively with the architecture while illuminating the ceiling, a critical requirement for the exterior appearance. This also creates a soft even light to help generate an inviting space.

In contrast to the education and lecture room, the lighting system in this space is all about appearance. However, the appropriate lighting levels are achieved. The power density is above ASHRAE allowance, but this is more than made up for in the other spaces. Overall, the building falls well under the ASHRAE standard using the space by space method.

The controls for this space are essential for creating a comfortable environment based on daylight levels and room function, both of which will change often.

1A. MAIN LOBBY and LIBERTY AVENUE FACADE [with SECOND LEVEL LOBBY, GIFT SHOP, BOX OFFICE, GRAND STAIRCASE]

Existing Design

The main lobby is a large space with few distinct boundaries that flows through most of the first floor of the building. It is a very important space in the building and control systems will be essential to a strong lighting and electrical system design.

The existing electrical design for the main lobby utilizes three separate lighting panels (1N1, 1E1, ALDR5). These panels are in various locations and control is split between dimming and switching. The other spaces that will be combined with the main lobby for the redesigned control system also use the three previously mentioned panels, as well as 2N1 and 2E1.

Redesigned System

The new electrical system for the lower and upper lobbies, as well as connected spaces, will combine many lighting loads onto a single dimming system. More dimming control was a goal for the redesigned lighting system and therefore it was a logical choice to combine these loads into a complete system, rather than using a collection of panels to supply power. A new dimming rack has been specified that is large enough to handle all the aforementioned loads. It also eliminates the need for separation of loads onto normal and emergency circuits due to an automatic emergency transfer switch located in the dimmer rack assembly. The panel specified for these spaces has eight modules with four control circuits per module with a maximum of 20A connected load per circuit. The panel is main lugs only and is protected at the distribution panel. Specifications are available in Appendix K.

The new system utilizes 27 circuits with a total of 27.07 KW of connected load and has six circuits of spare capacity. A total demand load of 93.99 A, including a 1.25 growth multiplier, was used to size the feeder and protection. The feeder has been sized at (4) #3 wires of type THW copper in 1.25” conduit. The breaker protecting the feeder on distribution panel 1NDP1 is sized at 100 A.

The 27 circuits are divided into 19 control zones. 16 of the 19 zones, those of the interior spaces, will be controlled by a single head unit located in the box office. The remaining zones will be controlled by a separate unit in the box office. These units will be linked together.

Dimmer rack/panelboard layouts for both the existing and new system are provided below. Electrical plans are available in Appendix F. Product Information for the dimmer racks and control units is available in Appendix H.

Redesign Analysis

The redesigned system offers incredible flexibility and greatly simplifies the existing system. Utilizing a main point of control will provide management with the ability to set and alter various scenes on the fly, creating a dynamic environment. Electrically, the system is convenient and centralized. The lighting loads are grouped together and are separated from the auditorium dimmer racks. The dimmer rack is located in a central location to help minimize cost and complexity of feeders.

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Area	Control Channel #	Circuit / Dimmer #	Description	Fixt. Type	Approx. # Fixt.	Watts / Fixture	Approx. Total Connected Load (Watts)	Load Type	E Circuit
Lobby	1	1	1st Floor Drum Lower	SAX	17	50	1063	ELV	
		2	1st Floor Drum Lower	SAX	17	50	1063	ELV	
	2	3	1st Floor Drum Upper		70	15	1313	NEON	
		4	1st Floor Drum Upper		70	15	1313	NEON	
	3	5	Art Lights Lobby	SBC	10	65	813	ELV	
	4	6	2nd Floor Drum	SAF	6	225	1350	INC	
		7	2nd Floor Drum	SAF	6	225	1350	INC	
		8	2nd Floor Drum	SAF	6	225	1350	INC	
		9	2nd Floor Drum	SAZ	6	225	1350	INC	
		10	Spare				0		
		11	Spare				0		
		12	Spare				0		

TOTAL:	10.96	k W

NOTE: **Contractor must pull separate neutrals for each circuit.**
A factor of 1.25 has been added to all LV, FL, & HID loads.

Figure 5.1A.1 | Dimmer Rack DR-201 – Existing Design – Layout Provided by Studio i Lighting. Yellow highlighting indicated loads involved in the redesign.

(SECOND FLOOR) PANEL 2N1

PANEL TYPE MAIN LUGS ______ PANEL ☐ BUS RATING 208/120V 3Ø 4W

DESCRIPTION	WIRE SIZE	K.W.	AMPS	TRIP	POLE	CIRC.	CIRC	POLE	TRIP	AMPS	K.W.	WIRE SIZE	DESCRIPTION
TELE 211, ELEC 212, 215 - LTG		.960		20	1	1	2	1	20		.605		OPEN OFFICE 220 LTG
LOBBY 201 & BRIDGE 200 - LTG		.320				3	4				1.10		OPEN OFFICE 220 LTG
LOBBY 201 - LTG		.448				5	6				.320		HALLWAY 230 - LTG
LOBBY 201 - LTG		.512				7	8				.832		MENS 245 WOMENS 243 LTG
STAIR 204 - LTG		1.38				9	10				.924		CONF. RM. 240 - LTG
STAIR 204 - LTG		.500				11	12				.972		MULTI-PURPOSE 247 - LTG
SPARE						13	14				.840		MULTI-PURPOSE 247 - LTG
						15	16						SPARE
						17	18						
DIMMER ROOM LTG.		.128				19	20						
SPARE						21	22						
						23	24						
						25	26						
						27	28						
						29	30						
						31	32	1	60		3.2		TEMP. EXHIBIT 210 - BUS DUCT
						33	34	1	60		3.2		TEMP. EXHIBIT 210 - BUS DUCT
						35	36	1	60		3.2		TEMP. EXHIBIT 210 - BUS DUCT
AREA PROTECTION PANEL			20			37	38	1	60		3.2		TEMP. EXHIBIT 210 - BUS DUCT
						39	40	1	20				SPARE
					3	41	42	1	20				SPARE

4.3 KW 18.4 KW

TOTAL LOAD ______ PHASE A ______ POSITION SIZE
K.W. ______ AMPS ______ PHASE B ______ AT DIST. BOARD ______
FEEDER SIZE ______ PHASE C ______ FUSE OR TRIP ______
VOLTAGE

TOTAL = 22.7 KW

Figure 5.1A.2 | Panel 2N1 – Existing Design – Layout Provided by Hornfeck Engineering.

(FIRST FLOOR) PANEL 1N1

PANEL TYPE MAIN LUGS ______ PANEL ☐ BUS RATING 208/120V 3Ø 4W (LIGHTING PANEL)

DESCRIPTION	WIRE SIZE	K.W.	AMPS	TRIP	POLE	CIRC.	CIRC	POLE	TRIP	AMPS	K.W.	WIRE SIZE	DESCRIPTION
HALLWAY 115 - LTG		1.20		20	1	1	2	1	20		.80		HALLWAY 131 - LTG
LOBBY 101 - LTG		.320				3	4				1.39		DRESSING RMS 126 - LTG
LOBBY 101 - LTG		1.12				5	6				1.60		DRESSING RMS 121 - LTG
LOBBY 101 - LTG		.448				7	8				.940		CHORUS DRESS RM 123 - LTG
GIFT SHOP 103 - LTG		1.20				9	10				.512		INNER LOBBY - LTG
GIFT SHOP 103 - LTG		.900				11	12				.832		MENS RM 145 WOMENS 143-LTG
COAT CLOSET 107 - LTG		.480				13	14				.510		KITCHEN 140 - LTG
MEMBERSHIP BOX 102 - LTG		.810				15	16						SPARE
ENTRY 100 - LTG		.232				17	18						
SPARE						19	20						
SPARE						21	22						
EXTERIOR MAIN ENTRY		.052				23	24						
EXTERIOR LOAD DOCK LTG		.156				25	26	20					AREA PROTECTION
EXTERIOR TYPE SAY		.312				27	28						SPARE
EXTERIOR TYPE SAR		.35				29	30			3			SPARE
EXTERIOR TYPE SAR-A		.35				31	32	1	60		3.2		PERM. EXHIBIT 110 - BUS DUCT
EXTERIOR TYPE SAG		.36				33	34	1	60		3.2		PERM. EXHIBIT 110 - BUS DUCT
EXTERIOR TYPE SAG		.36				35	36	1	60		3.2		PERM. EXHIBIT 110 - BUS DUCT
EXTERIOR TYPE SAB		.36				37	38	1	60		3.2		PERM. EXHIBIT 110 - BUS DUCT
SPARE						39	40						SPARE
SPARE						41	42						SPARE

9.0 KW 19.4 KW

TOTAL LOAD ______ PHASE A ______ POSITION SIZE
K.W. ______ AMPS ______ PHASE B ______ AT DIST. BOARD ______
FEEDER SIZE ______ PHASE C ______ FUSE OR TRIP ______
VOLTAGE

TOTAL = 28.4 KW

Figure 5.1A.3 | Panel 1N1 – Existing Design – Layout Provided by Hornfeck Engineering

LIFE SAFETY (SECOND FLOOR) PANEL 2E1

PANEL TYPE MAIN LUGS ______ PANEL ☐ BUS RATING ______

DESCRIPTION	WIRE SIZE	K.W.	AMPS	TRIP	POLE	CIRC.	PHASE A B C	CIRC	POLE	TRIP	AMPS	K.W.	WIRE SIZE	DESCRIPTION
PASSAGE WAY		.448		20	1	1		2	1	20		.36		FIRE SMOKE DAMPER
OPEN OFFICE HALLWAY		.672				3		4				.36		FIRE SMOKE DAMPER
REST ROOMS		.064				5		6				.36		SECURITY PANEL
SPARE						7		8				.36		AV RACK
						9		10				.36		AV RACK
						11		12						SPARE
STAIR NO. 1		.320				13		14				.36		FIRE ALARM NOTIFICATION (2)
SPARE						15		16						SPARE
						17		18						
						19		20						
						21		22						
						23		24						
						25		26						
						27		28						
						29		30						
						31		32						
						33		34						
						35		36						
						37		38						
						39		40						
						41		42						

1.50 KW 2.16 KW

TOTAL LOAD ______ PHASE A ______ POSITION SIZE
K.W. ______ AMPS ______ PHASE B ______ AT DIST. BOARD ______
FEEDER SIZE ______ PHASE C ______ FUSE OR TRIP ______
VOLTAGE

TOTAL = 3.66 KW

Figure 5.1A.4 | Panel 2E1 – Existing Design – Layout Provided by Hornfeck Engineering

LIFE SAFETY (FIRST FLOOR) PANEL 1E1

PANEL TYPE MAIN LUGS ______ PANEL ☐ BUS RATING ______

DESCRIPTION	WIRE SIZE	K.W.	AMPS	TRIP	POLE	CIRC.	PHASE A B C	CIRC	POLE	TRIP	AMPS	K.W.	WIRE SIZE	DESCRIPTION
HALLWAY 113		.448		20	1	1		2	1	20		.360		FIRE SMOKE DAMPER
HALLWAY 131		.563				3		4				.360		FIRE SMOKE DAMPER
DRESSING RMS		.624				5		6				.360		SECURITY PANEL
LOBBY 100		.320				7		8				.360		AV RACK
LOBBY 101		.444				9		10				.360		AV RACK
STAIR NO. 6						11		12				.360		AV RACK
SPARE						13		14				.360		FIRE ALARM NOTIFICATION (1)
						15		16				.360		FIRE ALARM CONTROL PANEL
						17		18						SPARE
EXTERIOR LTG		.256				19		20						
SPARE						21		22						
						23		24						
						25		26						
						27		28						
						29		30						
						31		32						
						33		34						
						35		36						
						37		38						
						39		40						
						41		42						

2.65 KW 2.88 KW

TOTAL LOAD ______ PHASE A ______ POSITION SIZE
K.W. ______ AMPS ______ PHASE B ______ AT DIST. BOARD ______
FEEDER SIZE ______ PHASE C ______ FUSE OR TRIP ______
VOLTAGE

TOTAL = 5.53 KW

Figure 5.1A.5 | 1E1 – Existing Design – Layout Provided by Hornfeck Engineering

DIMMER RACK LAYOUT: DR101/201										
AREA	CONTROL CHANNEL	CIRCUIT / DIMMER	DESCRIPTION	FIXT. TAG	NO. OF FIXT.	WATTS/ FIXTURE	MULT.	TOTAL WATTS	PHOTO CELL?	EMER. CRCT?
LOWER LOBBY	1	1	Theater Drum Upper	D	25	50	1.0	1250		
	2	2	Theater Drum Lower	D	25	50	1.0	1250		
	3	3	Downlights - Linear - 101	A	11	63	1.25	866	■	■
		4	Downlights - Linear - 101	A	17	63	1.25	1339		■
LOWER LOBBY	4	5	Downlights - Linear - 106	A	4	63	1.25	315		■
		6	Downlights - Linear 106 + P	A/F	8/4	63/32	1.25	790	■	
	5	7	Downlights - Round	E	15	49	1.25	919		
	6	8	Downlights - Cabinets	E1/H	7/4	50/49	1.25	683		
GIFT SHOP	7	9	Downlights	H	20	50	1.25	1250		
		10	Downlights	H	17	50	1.25	1063		■
Box Office	8	11	Downlights	E1/I	15/3	49/38	1.25	1061		
SPARE	9	12								
VESTIBULE	10	13	Downlights	I	6	38	1.25	285	■	■
STAIRCASE	11	14	Wallwash	C	4	300	1.0	1200		
		15	Wallwash	C	4	300	1.0	1200	`	
	12	16	Downlights	B	10	64	1.25	800		■
UPPER LOBBY	13	17	Theater Drum + Track	C	5	300	1.0	1800		
		18	Theater Drum + Track	C	5	300	1.0	1800		
		19	Theater Drum + Track	C	5	300	1.0	1800		
		20	Theater Drum + Track	C	4	300	1.0	1800		
UPPER LOBBY	14	21	Downlights - Linear	A	10	63	1.25	788	■	■
		21	Downlights - Linear	A	10	63	1.25	788		■
	15	22	Downlights - Round	E	13	49	1.25	796		■
	16	23	Downlights - Pendant	F	6	32	1.25	240		
EXTERIOR	17	25	Inside	R	85	10	1.25	1063		
		26	Inside	R	85	10	1.25	1063		
	18	27	Sail LED	S	120	3	1.25	450		
	19	28	Downlights - Exterior	M	15	22	1.25	413		
SPARE		29								
SPARE		30								
SPARE		31								
SPARE		32								

Panel Type: Lutron LP8/16-1204ML-20 — LOAD = 27.07 kW

Distribution Panel Power Supply: 1NDP1 — (125% GROWTH FACTOR) DEMAND LOAD = 93.99 A

Emergency Panel Power Supply: BE1 — FEEDER SIZE = (4) #3 in 1.25" Conduit

Location: Control Booth (151) — PROTECTION = 100 A

Figure 5.1A.6 | New Dimmer Rack DR101/201

1B. EDUCATION AND LECTURE ROOM and MEETING ROOM

Existing Design

The education and lecture room is a classroom space located on the Liberty Avenue side of the second level. The meeting room is adjacent to this space, located in the sail structure at the northeast corner of the building.

The current design for the education and lecture room and meeting room uses a dimmer rack (DR202) connected to a distribution panel (1N1). DR202 serves both spaces but no others. In total between the two rooms, 5 circuits were used. The total connected load was 5.13 KW, which was protected by a 100A three pole circuit breaker on panel 1NDP1. This system was controlled by a main control unit in room 202 with two satellite control units, one in each space. An emergency dimmer transfer rack, located in the same closet, was used to provide emergency power to the rack.

Redesigned System

The new system for the education and lecture room will utilize the same organization as the previous system. The lighting design is not extremely different and the load is nearly identical. There are new fixtures and different zones, but the total load is still very small. A new dimming rack has been specified that eliminates the need for a second emergency transfer panel. The panel specified for these spaces has four modules with four control circuits per module with a maximum of 20A connected load per circuit. The panel is main lugs only and is protected at the distribution panel. Specifications and additional information can be found in Appendix H.

The new system utilizes 8 circuits with a total of 6.48 KW of connected load and has eight circuits of spare capacity. A total demand load of 27A, including a 1.5 growth multiplier, was used to size the feeder and protection. The feeder has been sized at (4) #10 THW 75 C copper conductors in ½" conduit. The breaker protected the feeder on distribution panel 1NDP1 is still sized at 30A.

The system will be controlled by two main wall panels, one in the meeting room and one in the education room. The education room will also feature a secondary control panel. These panels will control both the lights and the window shades that are present in both rooms. Photosensors will be added to the education room to dim the exterior zones because daylight analysis shows that ample daylight is available in the space.

Dimmer rack layouts for both the existing and new system are provided below. See Electrical plans are available in Appendix F.

Redesign Analysis

The new system does not differ dramatically from the existing system, but the system is simplified slightly by eliminating an external emergency power transfer rack. The streamlined control system will allow for control of both lighting and shading devices. Extra room is left should the need to expand the system arise.

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Area	Control Channel #	Circuit / Dimmer #	Description	Fixt. Type	Approx. # Fixt.	Watts / Fixture	Approx. Total Connected Load (Watts)	Load Type	E Circuit
Educ. Class	1	1	Linear Fluorescent	SK	3	324	1215	FL	
		2	Linear Fluorescent	SK	4	324	1620	FL	
	2	3	Low Voltage Downlight	SK-a	21	50	1313	MLV	*
Conf. Room	3	4	Linear Fluorescent	SD1	8	54	540	FL	
	4	5	Linear Fluorescent	SD1	8	54	540	FL	*
		6	Spare				0		
		7	Spare				0		
		8	Spare				0		
		9	Empty				0		
		10	Empty				0		
		11	Empty				0		
		12	Empty				0		
						TOTAL:	5.23	kW	

NOTE: Contractor must pull separate neutrals for each circuit.
A factor of 1.25 has been added to all LV, FL, & HID loads.

Figure 5.1B.1 | Dimmer Rack DR-202/207 – Existing Design – Layout Provided by Studio i Lighting

DIMMER RACK LAYOUT: DR202/207										
AREA	CONTROL CHANNEL	CIRCUIT / DIMMER	DESCRIPTION	FIXT. TAG	NO. OF FIXT.	WATTS/ FIXTURE	MULT.	TOTAL WATTS	PHOTO CELL?	EMER. CRCT?
EDUCATION	1	1	Northwest Downlights + Track	A	5	125	1.25	1141.25	■	
	2	2	Northeast Downlights + Track	A	5	125	1.25	1141.25	■	
	3	3	Southwest Downlights + Track	A	5	125	1.25	1141.25		■
	4	4	Southeast Downlights + Track	A	5	125	1.25	1141.25		■
MEETING	5	5	Pendants	L	3	116	1.25	435		
	6	6	Downlights	E1	8	49	1.25	490		■
	7	7	Accent - Wood/Sail	J	13	50	1.25	812.5		
	8	8	Linear Wallwasher	K	4	35	1.25	175		
SPARE										
SPARE										
SPARE										
SPARE										
SPARE										
SPARE										
SPARE										
SPARE										
Panel Type: Lutron LP4/16-1204ML-20							LOAD =	6.48	kW	
Distribution Panel: 1NDP1							(200% GROWTH FACTOR) DEMAND LOAD =	26.99	A	
Emergency Panel: BE1							FEEDER SIZE =	(3) #10	in .5" Conduit	
Location: 202 Closet							PROTECTION =	30	A	

Figure 5.1B.2 | New Dimmer Rack DR-202/207

2. PHOTOVOLTAIC ARRAY ANALYSIS

With the growth of the LEED movement, photovoltaic (PV) systems are surging as a popular 'green' choice for owners who want an energy conscious design. With numerous government incentives available, the cost-effectiveness of implementing such a system can become complex. As a building seeking LEED certification, a PV system is something that should at least be considered by the designer.

This analysis was conducted utilizing RETScreen, an analysis tool for energy design. Since enough area is not available to provide power for the entire building, the system needs to be an on-grid system. The designed system would not use a battery supply and excess energy would be transferred back to the grid. The following is a summary of the analysis:

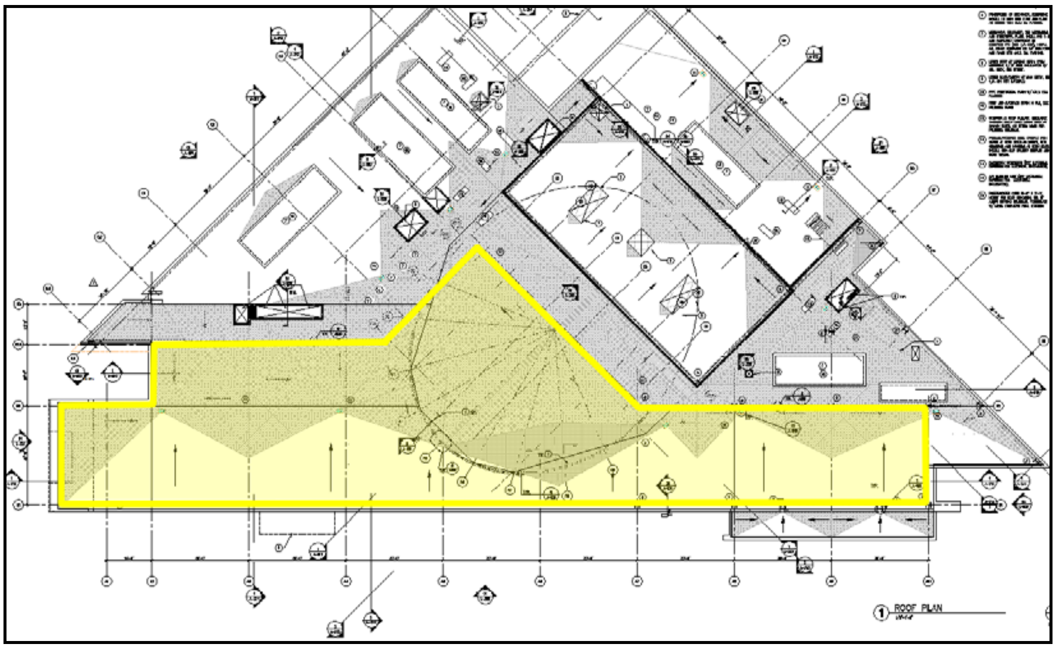


Figure 5.2.1 | Available Area for PV Array

Roof Area available for PV array: Approximately 12,000 ft^2 (1115 m^2)

Product: BP Solar 5170S

Power Produced: 192KWh

Physical Size: 1.26 m^2

Efficiency: 13.5%

Total System Efficiency (Combined Panel and System): 3%

Unit Cost: $5,750

Maintenance Costs: $10,000/10 Years

Design Costs: $15,000

Other Equipment Costs (inverter and power equipment): $100,000

Annual Energy Available (Pittsburgh): 1.53MWh/m^2

Energy Rate: .1236 cents/KWh

Energy Savings/Year/Panel: $28

Financial Incentives:

- *Federal tax incentives* do not apply since the August Wilson Center is a non-profit organization.
- The *Pennsylvania Energy Harvest Grant,* or any other state incentive, is no longer available.
- *Duquesne Light* does not currently offer any incentives for implementation of renewable energy.

Payback Period: This installation will never provide a return on the investment.

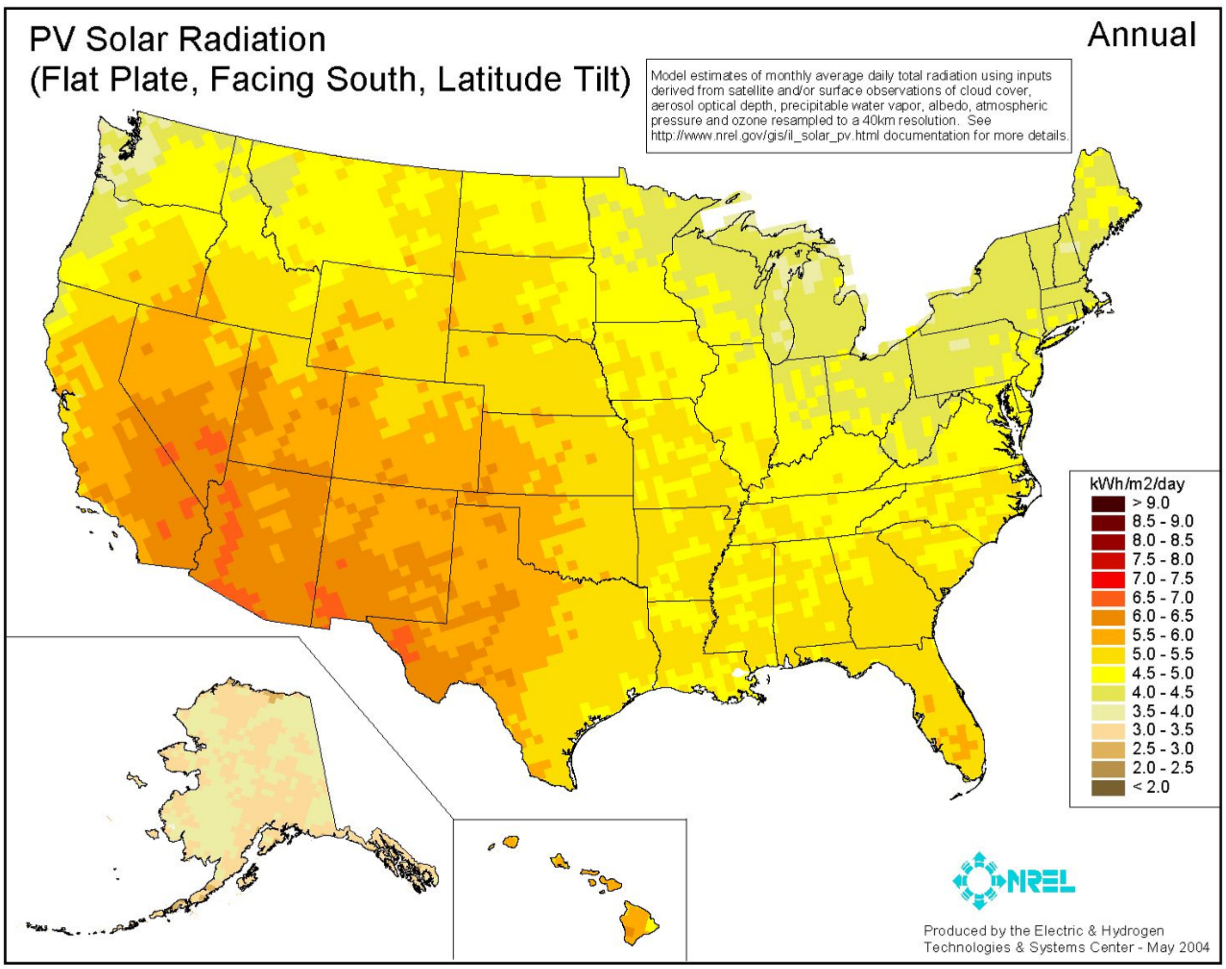


Figure 5.2.2 | PV Solar Radiation Map (From Electric & Hydrogen Technologies & Systems Center – May 2004)

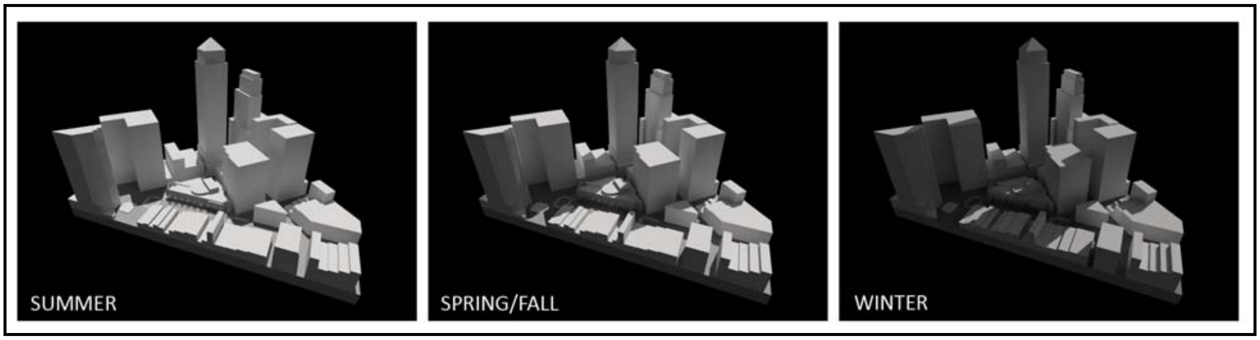


Figure 5.2.3 | Site shadow conditions midday throughout the year. The August Wilson Center is at the center of the model.

Photovoltaic Array Feasibility Conclusion:
Based on the calculations, it is certainly not feasible to use a photovoltaic array for this project. Figure 5.2.2 shows that Pittsburgh does not receive a substantial amount of solar energy. Additionally based on the buildings location in the urban center of Pittsburgh and the shadowing by adjacent buildings (Figure 5.2.3), the actual energy savings would likely be less that the model predicts. The PV array would likely receive direct sunlight at noon on less than half of the days during the year.

Another factor affecting the feasibility is the low utility rate that this property receives. Finally, since the August Wilson Center is a non-profit organization, it cannot receive federal and state tax incentives for solar energy. This places the full cost of the initial installation on the owner, significantly affecting the payback of the system. Even without considered specific system characteristics, it is evident that PV energy production is not a cost effective choice for the August Wilson Center. In order for the system to have reasonable payback period, the panels would have to be far more efficient than what is currently available.

3. SYSTEM TYPE CONVERSION STUDY

The existing design for the August Wilson Center utilizes two parallel service entrances, providing redundancy should one fail through a collector bus which connects to two main switchboards. One of the switchboards (MSB1) feeds primarily mechanical loads and the emergency power system while the second switchboard (MSB2) feeds predominantly lighting and receptacle loads. Both switchboards are currently designed at 280Y/120V.

Studying the single line diagram revealed that MSB1 could be changed to a 480/277V system with minimal disruption to the system. One drawback to this change is the elimination of the point of redundancy, however. In order to make a justifiable decision on the advantage of the system conversion, a comparative cost analysis was conducted.

The Existing System:

The portion of the existing system being studied includes the following equipment. The Duquesne Light Transformer has not been included in the cost comparison because it is the responsibility of the utility company.

Table 5.3.1: Existing Design Equipment Schedule

TYPE	TAG	LOCATION	DESCRIPTION
Transformer	*NA*	Transformer Vault	Duquesne Light Transformer
Main Switchboard	MSB1	Basement (013)	208Y/120, 3000A MCB
Distribution Panel	BNDP1	Basement (013)	208Y/120, 1200A MLO
Distribution Panel	BNDP2	Basement (013)	208Y/120, 400A MLO
Branch Circuit Panel	2P1	Electrical Room (212)	208Y/120, 225A MLO
Branch Circuit Panel	1KN1	Kitchen (140)	208Y/120, 400A MLO
Branch Circuit Panel	1KN2	Kitchen (140)	208Y/120, 225A MLO

A portion of the existing single line diagram as well as the panelboards that will change are shown on the following pages.

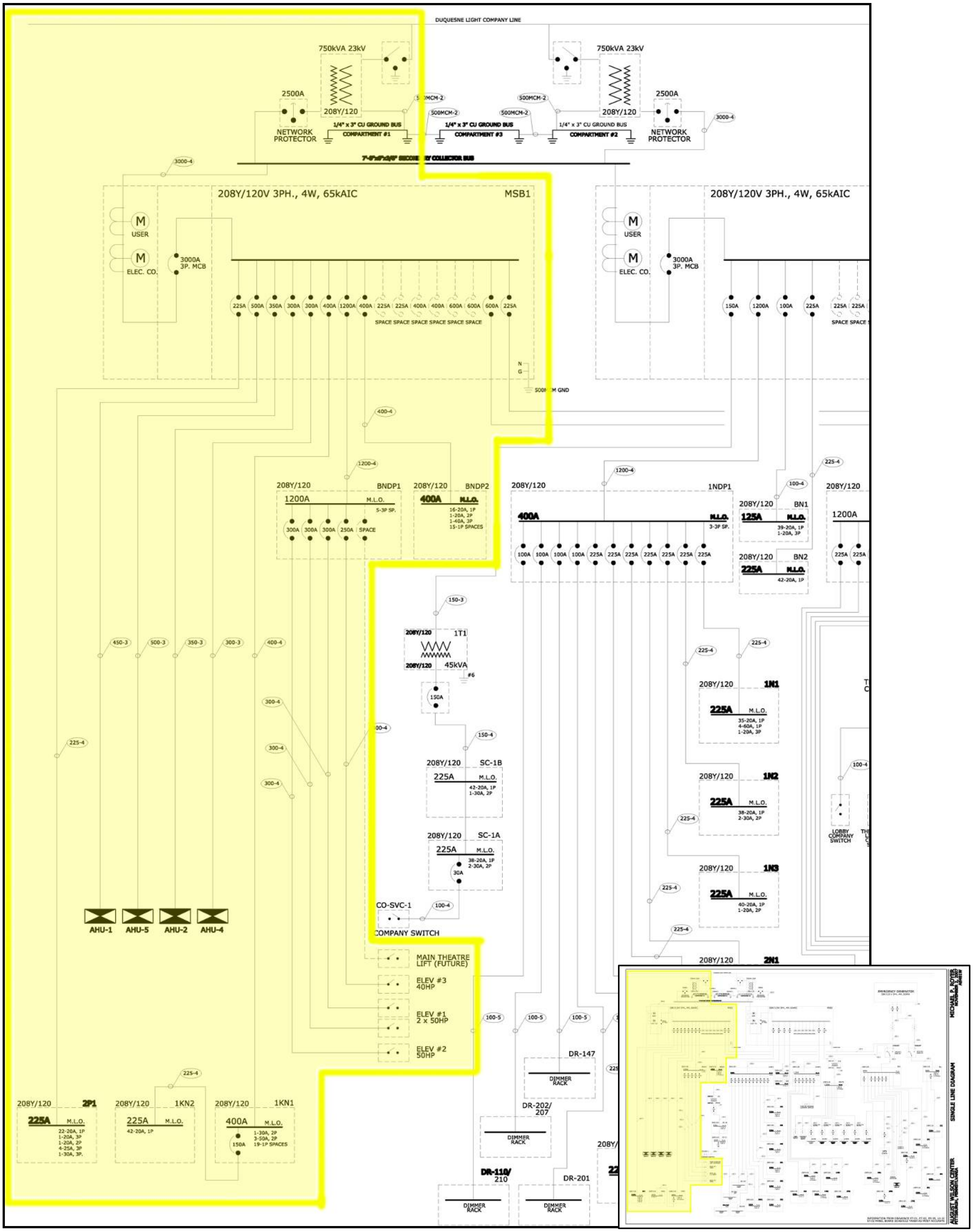
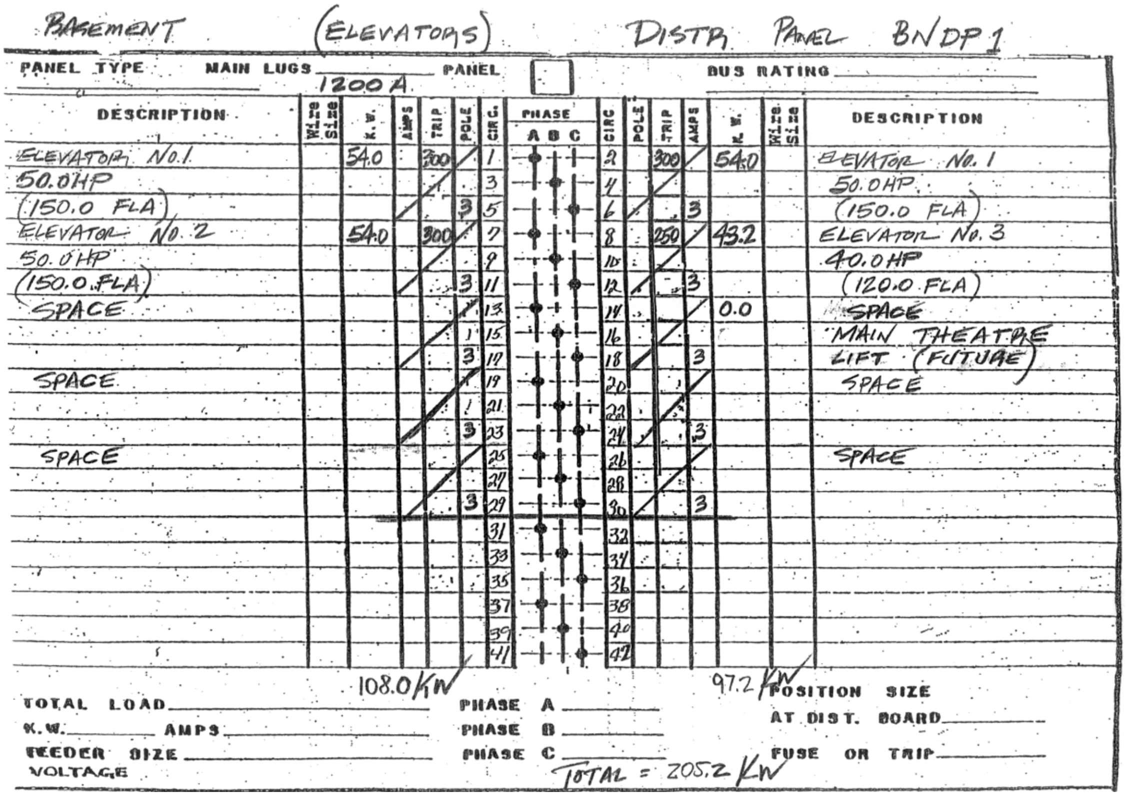


Figure 5.3.1 | Single Line Diagram for existing system. Highlight shows area to be redesigned. Existing and new Single Line Diagrams are available at a larger scale in Appendix G.



BASEMENT (ELEVATORS) DISTR. PANEL BNDP 1

PANEL TYPE MAIN LUGS 1200 A PANEL BUS RATING

DESCRIPTION	K.W.	TRIP	POLE	CIRC.	CIRC.	POLE	TRIP	AMPS	K.W.	DESCRIPTION
ELEVATOR No.1	54.0	300		1	2		300		54.0	ELEVATOR No. 1
50.0HP				3	4					50.0HP
(150.0 FLA)			3	5	6			3		(150.0 FLA)
ELEVATOR No. 2	54.0	300		7	8		250		43.2	ELEVATOR No. 3
50.0HP				9	10					40.0HP
(150.0 FLA)			3	11	12			3		(120.0 FLA)
SPACE				13	14				0.0	SPACE
			1	15	16					MAIN THEATRE
			3	17	18			3		LIFT (FUTURE)
SPACE				19	20					SPACE
			1	21	22					
			3	23	24			3		
SPACE				25	26					SPACE
				27	28					
			3	29	30			3		
				31	32					
				33	34					
				35	36					
				37	38					
				39	40					
				41	42					

108.0 KW — 97.2 KW

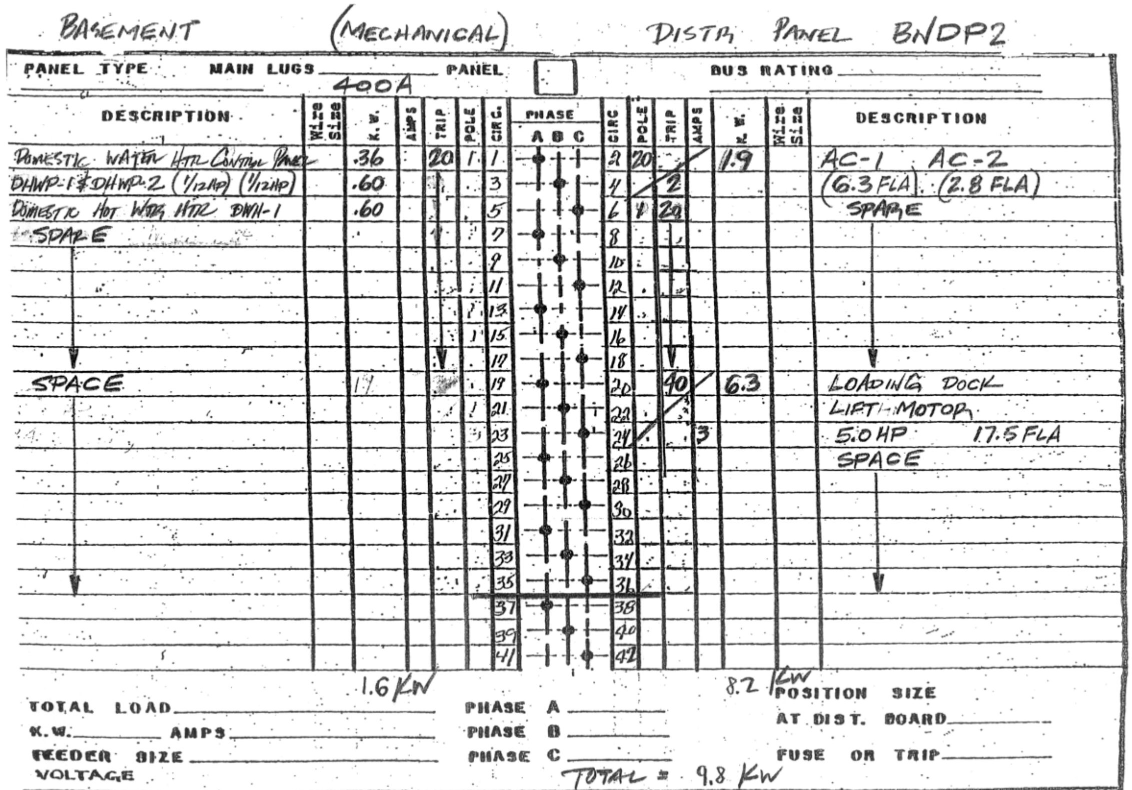
TOTAL LOAD — PHASE A — POSITION SIZE

K.W. AMPS — PHASE B — AT DIST. BOARD

FEEDER SIZE — PHASE C — FUSE OR TRIP

VOLTAGE — TOTAL = 205.2 KW

Figure 5.3.2 | BNDP1 – Existing Design – Layout Provided by Hornfeck Engineering



BASEMENT (MECHANICAL) DISTR. PANEL BNDP2

PANEL TYPE MAIN LUGS 400A PANEL BUS RATING

DESCRIPTION	K.W.	TRIP	POLE	CIRC.	CIRC.	POLE	TRIP	AMPS	K.W.	DESCRIPTION
DOMESTIC WATER HTR CONTROL PANEL	.36	20	1	1	2	20			1.9	AC-1 AC-2
DHWP-1 & DHWP-2 (1/12HP) (1/12HP)	.60			3	4		2			(6.3 FLA) (2.8 FLA)
DOMESTIC HOT WTR HTR DWH-1	.60			5	6	1	20			SPARE
SPARE				7	8					
				9	10					
				11	12					
			1	13	14					
			1	15	16					
				17	18					
SPACE				19	20		40		6.3	LOADING DOCK
			1	21	22					LIFT MOTOR
			3	23	24			3		5.0 HP 17.5 FLA
				25	26					SPACE
				27	28					
				29	30					
				31	32					
				33	34					
				35	36					
				37	38					
				39	40					
				41	42					

1.6 KW — 8.2 KW

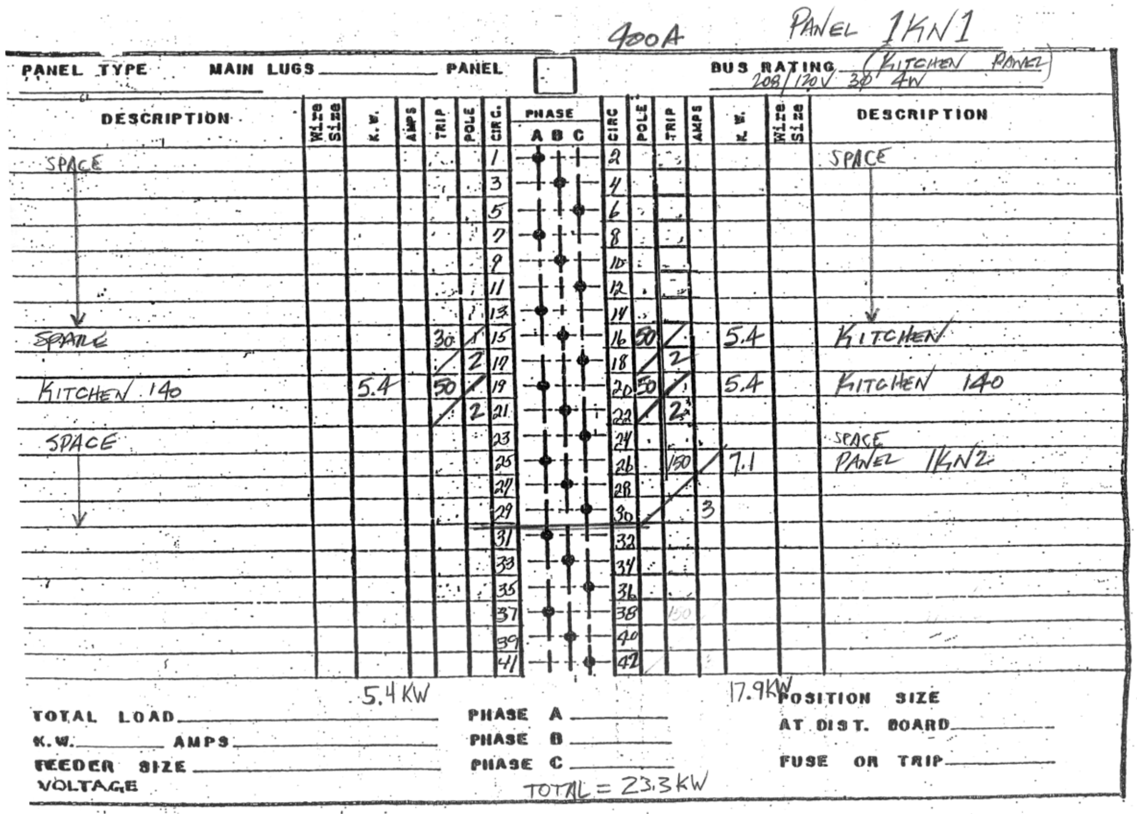
TOTAL LOAD — PHASE A — POSITION SIZE

K.W. AMPS — PHASE B — AT DIST. BOARD

FEEDER SIZE — PHASE C — FUSE OR TRIP

VOLTAGE — TOTAL = 9.8 KW

Figure 5.3.3 | BNDP2 – Existing Design – Layout Provided by Hornfeck Engineering



400A PANEL 1KN1

PANEL TYPE MAIN LUGS ___ PANEL ☐ BUS RATING (KITCHEN PANEL) 208/120V 3Ø 4W

DESCRIPTION	KW	TRIP	POLE	CIRC	CIRC	POLE	TRIP	AMPS	KW	DESCRIPTION
SPACE				1–13	2–14					SPACE
SPARE		30	1	15	16	50	2		5.4	KITCHEN
			2	17	18					
KITCHEN 140	5.4	50	2	19	20	50	2		5.4	KITCHEN 140
				21	22					
SPACE				23–41	24					SPACE
					26		150	3	7.1	PANEL 1KN2
					28–42					

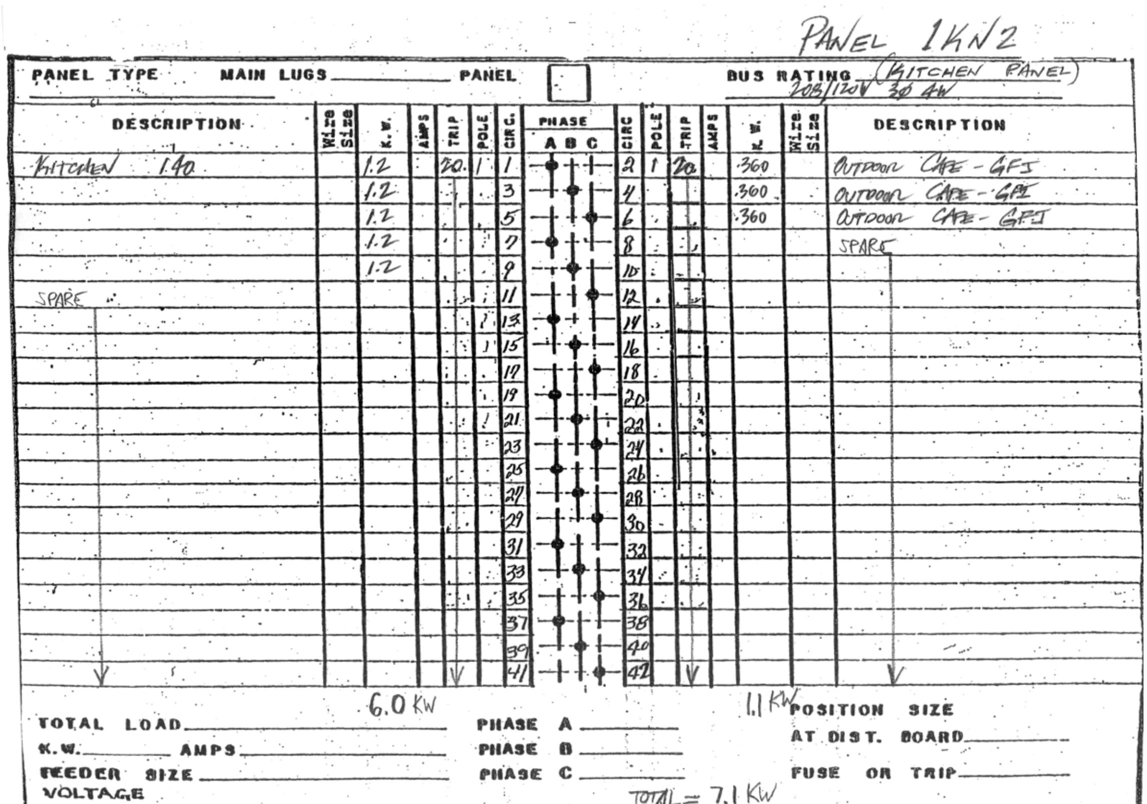
TOTAL LOAD 5.4 KW | 17.9 KW

K.W. ___ AMPS ___ PHASE A ___ PHASE B ___ PHASE C ___ POSITION SIZE AT DIST. BOARD ___ FUSE OR TRIP ___

FEEDER SIZE ___ VOLTAGE

TOTAL = 23.3 KW

Figure 5.3.4 | 1KN1 – Existing Design – Layout Provided by Hornfeck Engineering



PANEL 1KN2

PANEL TYPE MAIN LUGS ___ PANEL ☐ BUS RATING (KITCHEN PANEL) 208/120V 3Ø 4W

DESCRIPTION	KW	TRIP	POLE	CIRC	CIRC	POLE	TRIP	KW	DESCRIPTION
KITCHEN 140	1.2	20	1	1	2	1	20	.360	OUTDOOR CAFE - GFI
	1.2			3	4			.360	OUTDOOR CAFE - GFI
	1.2			5	6			.360	OUTDOOR CAFE - GFI
	1.2			7	8–42				SPARE
	1.2			9					
SPARE				11–41					

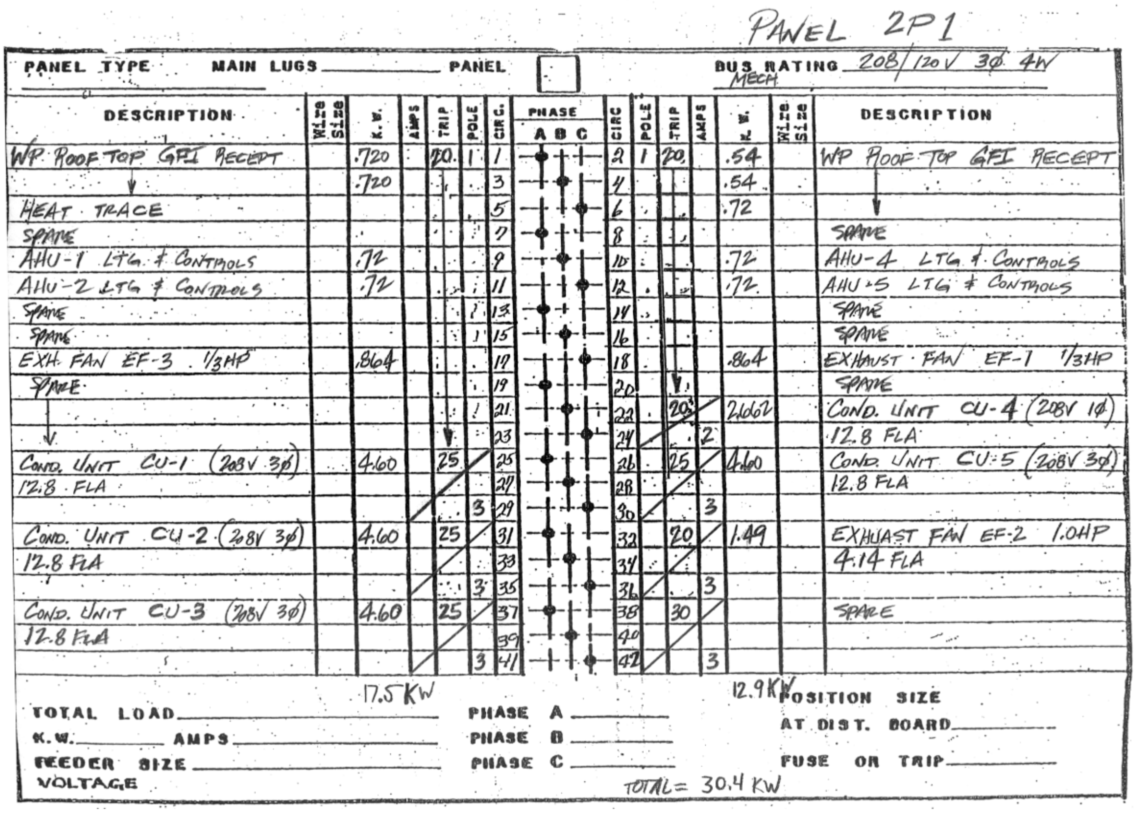
TOTAL LOAD 6.0 KW | 1.1 KW

K.W. ___ AMPS ___ PHASE A ___ PHASE B ___ PHASE C ___ POSITION SIZE AT DIST. BOARD ___ FUSE OR TRIP ___

FEEDER SIZE ___ VOLTAGE

TOTAL = 7.1 KW

Figure 5.3.5 | 1KN2 – Existing Design – Layout Provided by Hornfeck Engineering



PANEL 2P1

PANEL TYPE — MAIN LUGS — PANEL — BUS RATING 208/120V 3Ø 4W — MECH

DESCRIPTION	K.W.	TRIP	POLE	CIRC.	CIRC.	POLE	TRIP	AMPS	K.W.	DESCRIPTION
WP ROOF TOP GFI RECEPT	.720	20	1	1	2	1	20		.54	WP ROOF TOP GFI RECEPT
↓	.720			3	4				.54	
HEAT TRACE				5	6				.72	↓
SPARE				7	8					SPARE
AHU-1 LTG & CONTROLS	.72			9	10				.72	AHU-4 LTG & CONTROLS
AHU-2 LTG & CONTROLS	.72			11	12				.72	AHU-5 LTG & CONTROLS
SPARE			1	13	14					SPARE
SPARE			1	15	16					SPARE
EXH. FAN EF-3 1/3HP	.864			17	18				.864	EXHAUST FAN EF-1 1/3HP
SPARE				19	20					SPARE
			1	21	22		20		2.662	COND. UNIT CU-4 (208V 1Ø)
↓				23	24			2		12.8 FLA
COND. UNIT CU-1 (208V 3Ø)	4.60	25		25	26		25		4.60	COND. UNIT CU-5 (208V 3Ø)
12.8 FLA				27	28					12.8 FLA
			3	29	30			3		
COND. UNIT CU-2 (208V 3Ø)	4.60	25		31	32		20		1.49	EXHUAST FAN EF-2 1.0HP
12.8 FLA				33	34					4.14 FLA
			3	35	36			3		
COND. UNIT CU-3 (208V 3Ø)	4.60	25		37	38		30			SPARE
12.8 FLA				39	40					
			3	41	42			3		

TOTAL LOAD 17.5 KW — 12.9 KW
K.W. — AMPS — PHASE A — PHASE B — PHASE C
FEEDER SIZE — POSITION SIZE AT DIST. BOARD — FUSE OR TRIP
VOLTAGE — TOTAL = 30.4 KW

Figure 5.3.6 | 2P1 – Existing Design – Layout Provided by Hornfeck Engineering

The Redesigned System:

Redesigning the system involved recalculating the loading on each panelboard in order to resize the bus and the feeder. Also, the addition of two transformers is necessary to accommodate loads that must run at 120V. Below is the new equipment schedule and panelboard schedules. A new single line diagram is available in Appendix G

Table 5.3.2: Redesign Equipment Schedule			
TYPE	TAG	LOCATION	DESCRIPTION
Transformer	*NA*	*Trans. Vault*	*Duquesne Light Transformer*
Transformer	2T1	Electrical Room (212)	9 KVA, 480V to 108Y/120V
Transformer	1T3	Kitchen (140)	30 KVA, 480V to 108Y/120V
Main Switchboard	MSB1	Basement (013)	480/277, 1600A MCB
Distribution Panel	BNDP1	Basement (013)	480/277, 400A MLO
Distribution Panel	BNDP2	Basement (013)	480/277, 100A MLO
Branch Circuit Panel	2P1	Electrical Room (212)	480/277, 100A MLO
Branch Circuit Panel	2P1A	Electrical Room (212)	480/277, 60A MLO
Branch Circuit Panel	1KN1	Kitchen (140)	208Y/120, 400A MCB
Branch Circuit Panel	*1KN2*	*Kitchen (140)*	*208Y/120, 225A MLO (Unchanged)*

Table 5.3.3: Feeder Sizes For Converted System							
TAG	FROM	TO	SETS	NO. WIRES	TYPE	SIZE	CONDUIT
A	TRANS.	MSB1	4	4	CU THWN	500	3" EMT
B	MSB1	2P1	1	4	CU THWN	#6	1" EMT
C	MSB1	AHU-1	1	4	CU THWN	2/0	2" EMT
D	MSB1	AHU-5	1	4	CU THWN	3/0	2" EMT
E	MSB1	AHU-2	1	4	CU THWN	#1	1.5" EMT
F	MSB1	AHU-4	1	4	CU THWN	#2	1.25" EMT
G	MSB1	1T3	1	4	CU THWN	#3	1.25" EMT
H	MSB1	BNDP1	1	4	CU THWN	400	3" EMT
I	MSB1	BNDP2	1	4	CU THWN	#8	1" EMT
J	BNDP1	ELEV 2	1	4	CU THWN	#4	1.25" EMT
K	BNDP1	ELEV 1	1	4	CU THWN	#4	1.25" EMT
L	BNDP1	ELEV 1	1	4	CU THWN	#4	1.25" EMT
M	BNDP1	ELEV 3	1	4	CU THWN	#6	1" EMT
N	2P1	2T1	1	4	CU THWN	#10	1/2" EMT
O	2T1	2P1A	1	4	CU THWN	#10	1/2" EMT
P	1KN1	1KN2	1	4	CU THWN	#6	1" EMT
Q	1T3	1KN1	1	4	CU THWN	#2	1.25" EMT

P A N E L   B O A R D   S C H E D U L E

VOLTAGE: 480/277V,3PH,4W SIZE/TYPE BUS: 400A SIZE/TYPE MAIN: M.L.O	PANEL TAG: BNDP1 PANEL LOCATION: BASEMENT B013 PANEL MOUNTING: SURFACE	MIN. C/B AIC: 25K OPTIONS:

DESCRIPTION	LOAD (W)	C/B SIZE	POS. NO.	A	B	C	POS. NO.	C/B SIZE	LOAD (W)	DESCRIPTION
ELEVATOR NO. 1 (50 HP)	18000	150A/3P	1	*			2	150A/3P	18000	ELEVATOR NO. 1 (50 HP)
[65 FLA]	18000		3		*		4		18000	[65 FLA]
	18000		5			*	6		18000	
ELEVATOR NO. 2 (50 HP)	18000	150A/3P	7	*			8	100A/3P	14400	ELEVATOR NO. 3 (40HP)
[65 FLA]	18000		9		*		10		14400	[52 FLA]
	18000		11			*	12		14400	
SPARE		150A/3P	13	*			14	150A/3P		*FUTURE LIFT*
			15		*		16			
			17			*	18			
SPARE		150A/3P	19	*			20	150A/3P		SPARE
			21		*		22			
			23			*	24			
SPARE		100A/3P	25	*			26	100A/3P		SPARE
			27		*		28			
			29			*	30			

CONNECTED LOAD (KW) - A	68.40	TOTAL DESIGN LOAD (KW)	205.20
CONNECTED LOAD (KW) - B	68.40	SPACE (GROWTH) FACTOR	1.35
CONNECTED LOAD (KW) - C	68.40	TOTAL DESIGN LOAD (A)	333

Figure 5.3.7 | New Panel BNDP1

P A N E L   B O A R D   S C H E D U L E

VOLTAGE: 480/277V,3PH,4W SIZE/TYPE BUS: 100A SIZE/TYPE MAIN: M.L.O.	PANEL TAG: BNDP2 PANEL LOCATION: BASEMENT B013 PANEL MOUNTING: SURFACE	MIN. C/B AIC: 25K OPTIONS:

DESCRIPTION	LOAD (W)	C/B SIZE	POS. NO.	A	B	C	POS. NO.	C/B SIZE	LOAD (W)	DESCRIPTION
DOMESTIC WATER HTR CONTL	360	20A/1P	1	*			2	20A/2P	950	AC-1 & AC-2
DHWP-1 & DHWP-2 (1/12 HP EA)	600	20A/1P	3		*		4		950	[2.73 + 1.21 FLA]
DOMESTIC HOT WATER HTR DHW-1	600	20A/1P	5			*	6	20A/1P		SPARE
SPARE		20A/1P	7	*			8	20A/1P		SPARE
SPARE		20A/1P	9		*		10	20A/1P		SPARE
SPARE		20A/1P	11			*	12	20A/1P		SPARE
SPARE		20A/1P	13	*			14	20A/1P		SPARE
SPARE		20A/1P	15		*		16	20A/1P		SPARE
SPARE		20A/1P	17			*	18	20A/1P		SPARE
SPACE			19	*			20	20A/3P	2100	LOADING DOCK LIFT MOTOR (5 HP)
SPACE			21		*		22		2100	[7.58 FLA]
SPACE			23			*	24		2100	
SPACE			25	*			26			SPACE
SPACE			27		*		28			SPACE
SPACE			29			*	30			SPACE
SPACE			31	*			32			SPACE
SPACE			33		*		34			SPACE
SPACE			35			*	36			SPACE

CONNECTED LOAD (KW) - A	3.41	TOTAL DESIGN LOAD (KW)	9.76
CONNECTED LOAD (KW) - B	3.65	SPACE (GROWTH) FACTOR	1.50
CONNECTED LOAD (KW) - C	2.70	TOTAL DESIGN LOAD (A)	20

Figure 5.3.8 | New Panel BNDP2

P A N E L   B O A R D   S C H E D U L E

VOLTAGE: 480/277V,3PH,4W SIZE/TYPE BUS: 100A SIZE/TYPE MAIN: M.L.O.	PANEL TAG: 2P1 PANEL LOCATION: ELECTRICAL ROOM 212 PANEL MOUNTING: SURFACE	MIN. C/B AIC: 22K OPTIONS:

DESCRIPTION	LOAD (W)	C/B SIZE	POS. NO.	A	B	C	POS. NO.	C/B SIZE	LOAD (W)	DESCRIPTION
EXH FAN EF-3 (1/3 HP)	864	20A/1P	1	*			2	20A/1P	864	EXH FAN EF-1 (1/3 HP)
SPARE		20A/1P	3		*		4	20A/1P		SPARE
SPARE		20A/1P	5			*	6	20A/2P	1331	COND UNIT CU-4
SPARE		20A/1P	7	*			8		1331	[5.54 FLA]
COND UNIT CU-1	1533	20A/3P	9		*		10	20A/3P	1533	COND UNIT CU-5
[5.54 FLA]	1533		11			*	12		1533	[5.54 FLA]
	1533		13	*			14		1533	
COND UNIT CU-2	1533	20A/3P	15		*		16	20A/3P	497	EXH FAN EF-2 (1.0 HP)
[5.54 FLA]	1533		17			*	18		497	[1.79 FLA]
	1533		19	*			20		497	
COND UNIT CU-3	1533	20A/3P	21		*		22	20A/3P	2500	PANEL 2P1A
[5.54 FLA]	1533		23			*	24		2500	
	1533		25	*			26		2500	
SPACE			27		*		28			SPACE
SPACE			29			*	30			SPACE
SPACE			31	*			32			SPACE

CONNECTED LOAD (KW) - A	12.19	TOTAL DESIGN LOAD (KW)	31.78
CONNECTED LOAD (KW) - B	9.13	SPACE (GROWTH) FACTOR	1.25
CONNECTED LOAD (KW) - C	10.46	TOTAL DESIGN LOAD (A)	51

Figure 5.3.9 | New Panel 2P1

PANEL BOARD SCHEDULE

VOLTAGE: 208Y/120V,3PH,4W SIZE/TYPE BUS: 60A SIZE/TYPE MAIN: M.L.O.	PANEL TAG: 2P1A PANEL LOCATION: ELECTRICAL ROOM 212 PANEL MOUNTING: SURFACE	MIN. C/B AIC: 22K OPTIONS:

DESCRIPTION	LOAD (W)	C/B SIZE	POS. NO.	A	B	C	POS. NO.	C/B SIZE	LOAD (W)	DESCRIPTION
WP ROOF TOP GFI RCPT	720	20A/1P	1	*			2	20A/1P	540	WP ROOF TOP GFI RCPT
WP ROOF TOP GFI RCPT	720	20A/1P	3		*		4	20A/1P	540	WP ROOF TOP GFI RCPT
HEAT TRACE	0	20A/1P	5			*	6	20A/1P	720	WP ROOF TOP GFI RCPT
SPARE	0	20A/1P	7	*			8	20A/1P	0	SPARE
AHU-1 LTG & CONTROLS	720	20A/1P	9		*		10	20A/1P	720	AHU-4 LTG & CONTROLS
AHU-2 LTG & CONTROLS	720	20A/1P	11			*	12	20A/1P	720	AHU-5 LTG & CONTROLS
SPARE	0	20A/1P	13	*			14	20A/1P	0	SPARE
SPARE	0	20A/1P	15		*		16	20A/1P	0	SPARE
SPARE	0	20A/1P	17			*	18	20A/1P	0	SPARE
SPACE			19	*			20			SPACE
SPACE			21		*		22			SPACE
SPACE			23			*	24			SPACE

CONNECTED LOAD (KW) - A	1.26	TOTAL DESIGN LOAD (KW)	7.50
CONNECTED LOAD (KW) - B	2.70	POWER FACTOR	1.00
CONNECTED LOAD (KW) - C	2.16	TOTAL DESIGN LOAD (AMPS)	21

Figure 5.3.10 | New Panel 2P1A

Sample Calculations for New Sizing:

Brach Circuit Breaker for Motor (Sample for Elevator No. 2):

MCA (NEC 2005 430.250) = 65A * 1.25 (First Motor) = 81.25A

MOPD (NEC 2005 430.52) = 250% (Inverse Time Breaker)

2.5 * 65A = 162.5A

BREAKER SIZE: 150A

WIRE SIZE: (3) #4 Conductors

Transformer (Sample for Panel 1KN1):

Calculated Design Load: 23.3 KW, 28.8A

Transformer: 30 kVA

Secondary Protection: 83.3*1.25 = 104.1A [110A] (NEC Table 450.3 (B) = 125%)

Primary Protection: 36.1*2.5 = 90.25A [100A] (NEC Table 450.3 (B) = 250%)

*Feeder Calculation (From MSB1 to BNDP1) *Not the size used for cost comparison*

Design Load (Includes Growth) = 333A

Feeder Size = 400 MCM THW Copper in 3” Conduit (335A Capacity)

Cost Analysis:

The cost comparison between the new and existing systems was completed using *R.S. Means 2008 Electrical Cost Data*. The existing system from the most recent set of drawings is designed and sized for the original contract, which was a guaranteed maximum price (GMP). Because of this, all equipment and feeders were grossly oversized. Feeders were sized to match bus size. In order for the cost estimate to provide comparable results, this same method was utilized. The bus sizes have all been resized based on the new panel demand loads, however, greatly reducing the feeder sizes.

As noted previously, the utility transformer has not been included in this analysis because it is the responsibility of Duquesne Light. Additionally, feeders N, O, P, and Q have been omitted due to insignificant lengths.

The cost comparison is broken down in the following table:

Table 5.3.3: Electrical System Redesign - 208/120V to 480/277V - Cost Analysis

PANELS

Label	Load (KW)	Ex. Size (A)	Ex. Cost	New Size (A)	New Cost
MSB1	-	3000	$40,600.00	1600	$26,100.00
MSB2	NO CHANGE IN SIZE				
BNDP1	205.2	400	$1,750.00	100	$900.00
BNDP2	9.8	1200	$5,275.00	400	$1,750.00
1KN1	23.2	400	$3,125.00	100	$1,300.00
1KN2	NO CHANGE IN SIZE				
2P1	30.4	225	$1,175.00	100	$900.00
2P1A	NA	NA	NA	60	$700.00
		Subtotal =	$48,800.00	Subtotal =	$30,350.00

FEEDERS — Per 100' — (All feeders 75 C type THWN)

Label	Length (ft)	No. Wires	Ex. Size	Ex. Cost/Unit	Ex. Cost	New Size	New Cost/Unit	New Cost
A	30	4	(4) 500	$1,550.00	$7,440.00	(4) 500	$1,550.00	$7,440.00
B	35	4	4/0	$755.00	$1,063.04	3	$244.00	$343.55
C	129	4	(2) 4/0	$755.00	$7,773.48	2/0	$505.00	$2,599.74
D	248	4	(2) 250	$870.00	$17,226.00	3/0	$620.00	$6,138.00
E	76	4	500	$1,550.00	$4,705.80	1	$350.00	$1,062.60
F	190	4	350	$1,150.00	$8,753.80	2	$291.00	$2,215.09
G	242	4	(2) 3/0	$620.00	$12,003.20	2	$291.00	$2,816.88
H	15	4	(4) 350	$1,150.00	$2,760.00	(2) 3/0	$620.00	$744.00
I	15	4	(2) 3/0	$620.00	$744.00	3	$244.00	$146.40
J	35	4	350	$1,150.00	$1,610.00	4	$209.00	$292.60
K	35	4	350	$1,150.00	$1,610.00	4	$209.00	$292.60
L	35	4	350	$1,150.00	$1,610.00	4	$209.00	$292.60
M	35	4	350	$1,150.00	$1,610.00	6	$152.00	$212.80
				Subtotal =	$68,909.32		Subtotal =	$24,596.86

OTHER

Item	Existing	Existing Cost	New Size	New Cost
1TKN1	NA	NA	30 kVA	$3,425.00
2TP1A	NA	NA	9 kVA	$2,200.00
			Subtotal =	$5,625.00

Existing System Total =	$117,709.32
New System Total =	$60,571.86
COST DIFFERENCE =	$57,137.46

System Conversion Conclusion:

As shown in Table 5.3.3, converting MSB1 and its connected loads to a 480/277V system saves a significant amount of money. For a project that is trying to reduce the bottom line, this change seems to be a viable option. The tabulated data does not include further cost savings that would result from a reduction of individual breakers for branch circuits.

The second factor that must be considered in the conversion of this system is the loss of redundancy provided by the collector bus. Since the system includes a substantial emergency generator and the system does not include critical loads, it is my opinion that using a 480/277V system for switchboard MSB1 is an appropriate choice for this project.

4. PROTECTIVE DEVICE COORDINATION STUDY and FAULT CURRENT ANALYSIS

As a sample calculation, a protective device coordination study and a fault current analysis was performed for a selected path through the system. The calculations that follow summarize these two procedures. That path is as follows:

Utility Transformer > Main Switchboard (MSB1) > Distribution Panel (1NDP1) > End-Use Panel (1N1)

The results show that the currently designed system uses has equipment specified which, in one case, is less than that required by the calculations. Branch circuit panelboard 1TN1 requires 25000 AIC but the specified equipment is rated at 22,000 AIC. It is likely that a fault current analysis was not conducted for the production of this set of documents.

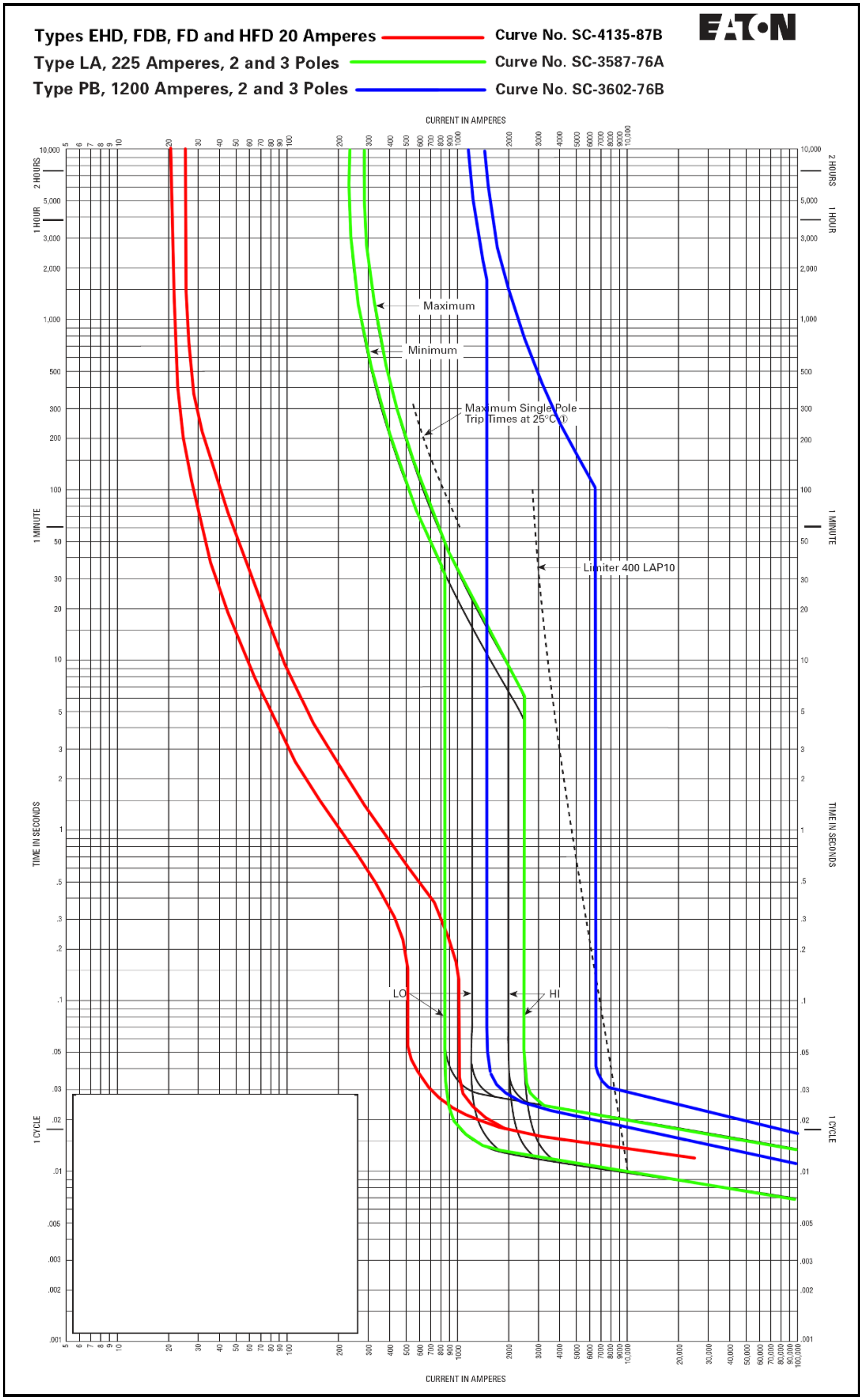


Figure 5.4.1 | Protective Device Coordination Study

Table 5.4.1: Summary Results of Fault Analysis			
Point	Location	Available Fault (A)	Standard Breaker Rating (A)
A	Utility Company Secondary	41630	42000
B	Switchboard (MSB2)	40197	42000
C	Distribution Panel (1NDP1)	34195	42000
D	End Use Panel (1N1)	24599	25000

Table 5.4.2: Fault Current Analysis (Per Unit Method)							
	System Voltage	=	208				
	Base KVA	=	10000				
	Utility Company Available Fault	=	100000000	ΣX	ΣR	ΣZ	I_{sc} (A)
Utility Primary							
	$X_{(p.u.)}$ = KVA_{base} / Utility S.C. KVA	=	0.0001	0.000	0.000	0.000	**277572245**
	$R_{(p.u.)}$	=	0.0000				
Transformer Secondary							
%Z = 5.00	$X_{(p.u.)}$ = %X * KVA_{base} / 100 * KVA_{xfrmr}	=	0.5951	0.595	0.301	0.667	**41630**
X/R = 1.98	$R_{(p.u.)}$ = %R * KVA_{base} / 100 * KVA_{xfrmr}	=	0.3005				
%X = 4.46							
%R = 2.25							
kVA = 750							
Switchboard MSB1							
Wire = 500	X = (L/1000) * X_L * (1/Sets), $X_{(p.u.)}$	=	0.0202	0.615	0.313	0.691	**40197**
Length = 15	R = (L/1000) * R * (1/Sets), $R_{(p.u.)}$	=	0.0127				
Sets = 8							
X = 0.047							
R = 0.029							
Panel Board 1NDP1							
Wire = 400	X = (L/1000) * X_L * (1/Sets)), $X_{(p.u.)}$	=	0.0991	0.714	0.385	0.812	**34195**
Length = 35	R = (L/1000) * R * (1/Sets), $R_{(p.u.)}$	=	0.0720				
Sets = 4							
X = 0.049							
R = 0.036							
Panel Board 1N1							
Wire = 4/0	X = (L/1000) * X_L * (1/Sets)), $X_{(p.u.)}$	=	0.2068	0.921	0.652	1.128	**24599**
Length = 18	R = (L/1000) * R * (1/Sets), $R_{(p.u.)}$	=	0.2663				
Sets = 1							
X = 0.050							
R = 0.064							

SECTION SIX | Architecture

1. OVERVIEW

At its heart, the August Wilson Center is a focal point for the performing arts and a celebration of African American culture. The design team at Perkins+Will has crafted elegant and meaningful forms that look to become a new icon in downtown Pittsburgh. In an effort to add additional functionality and a new facet to the design, a roof terrace has been designed.

The terrace will be used for outdoor gatherings and performances, with the sail feature acting as a backdrop for temporary stage equipment. A catering/food service/bar area will serve patrons when the space may is used for banquets or other gatherings. When it is not in use for a specific function, the terrace will serve to expand the existing exhibit spaces by housing outdoor art pieces. Both temporary seating and fixed benches are used to help shape the space. Additionally, the terrace may be opened during intermissions from performances to allow patrons a chance to get some fresh air.

The terrace design incorporates approximately 8150 SF of space on the roof that currently did not house other mechanical equipment. This allows for minimal disruption of the existing system. The space is along the Liberty Avenue side of the building, and is ideal for this application.

Based on an initial code analysis, this space will fall under occupancy classification A-3 with an occupant load of one person per 15 square feet. This results in a total occupancy of 543. This is a very large number; however, for certain purposes it may be considered simultaneous occupancy. Logical vertical circulation points exist for two staircases and one elevator. It would be possible to reach additional stair towers if necessary. For the purposes of this design, it will be considered acceptable that the existing restrooms have the capacity to serve this space.

The structural system will be the engineered system most influenced by this addition. With increased loads, the steel framing members will increase in size and the decking system will all require additional support. The roof drainage system will also require additional work as a result of the changes. Finally, the electrical system may require a small expansion. These additional ramifications are not within the scope of this study, however.

The following photographs show the buildings adjacent to the site:

Figure 6.1.1 | The Duquesne Light building rises 16 storey directly adjacent to the west end of the August Wilson Center.
[Personal Photo]

Figure 6.1.2 | The streetscape of Liberty Avenue beyond the future site of the August Wilson Center [Personal Photo]

2. GOALS

The goals for the design of the roof terrace are not simply to create habitable space on the roof, but rather to create the feeling that the design always intended for such a space to exist. Creating a sense of enclosure for this exterior space will be paramount to the user satisfaction and comfort level. Furthermore, it is essential that the elements of the roof terrace do not interfere with the bold volumes of the existing building. In contrast, the design of the roof terrace must integrate with and enhance the volumes by creating additional opportunities to light surfaces.

3. CONCEPTS

Four main elements combine to describe the layout of the terrace. The first element is the top of the prominent sail structure that dominates the Liberty Avenue façade. This feature serves as a logical backdrop for a performance or speaker and the overhanging shape will aid in projecting sound to the audience. The second defining element is the rectangular, slightly out-of-plane wall that extends through the entire building, forming the boundary of the grand staircase. This stone-clad volume houses both a staircase and elevator, creating a logical motivation for extruding this volume and allowing it to become the main access for the roof terrace. The third key element is the curve of the theater drum that already projects from the ground level through the roof. In order to further emphasize this elliptical volume projecting through the rectilinear volume of the building façade, this projection will be extended further to make it more visible from street level. At night, this surface will be illuminated to enhance the perception of intersecting volumes. Finally, the void of space created by Liberty Avenue also is important in defining this space. With the other three key elements closing in the terrace, the treatment of this boundary is essential to completing the design.

4. THE DESIGN

The design for the roof terrace creates two distinct areas which have varying purposes. On the east side of the roof is a public gathering area that will be host to most of the activities. This space has direct access to stairs and the elevator. Four separate storage areas are provided to enable temporary seating or tables to be kept in a convenient location. A food service area is along the south end of the space. The second area is more remote area where exterior sculpture may be exhibited. A schematic floor plane is provided in figure 6.4.1. More detailed drawings are available in Appendix I.

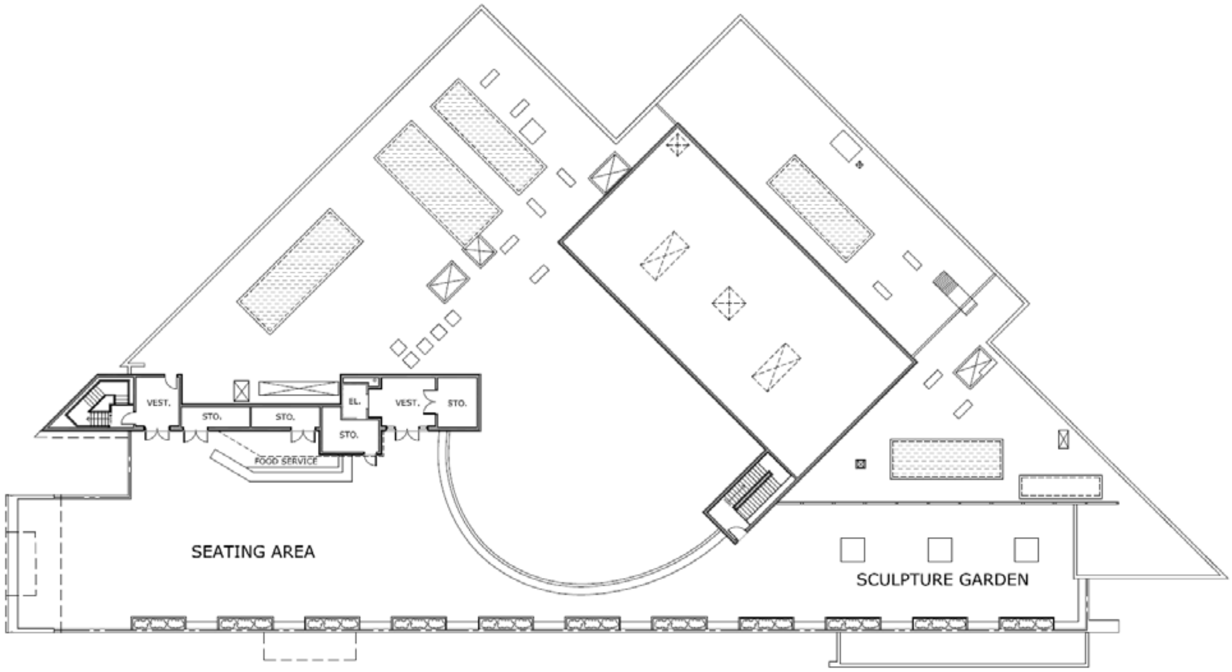


Figure 6.4.1 | Schematic plan of the Roof Terrace. Please see Appendix L for more detailed drawings.

The fence that forms the extension of the theater drum has been extended to a height of 16', making it clearly visible from the street. To prevent this large wall from towering over the space and to provide a discreet, glare-free location for light fixtures, a step-down fence has been created at a height of six feet. The service core has been face in the same stone that continuous from below. A small roof area has been designed to better define the food service area and allow for lighting equipment. Along the south edge of both spaces an alternating system of benches and planters has been established to give the space some color and eliminate any unease that may be created by the drop to the sidewalk below. To meet IBC code requirements of 42" for guardrails, a tempered and laminated glass guard has been added to increase the height of the parapet. Glass was chosen for its distinct appearance from the street level. The floor will be finished with 2' by 2' concrete tiles with a slightly polished finished. This allows for the necessary durability while maintaining and appearance that is more finished than a sidewalk.

The following renderings show the conceptual design for the roof terrace.

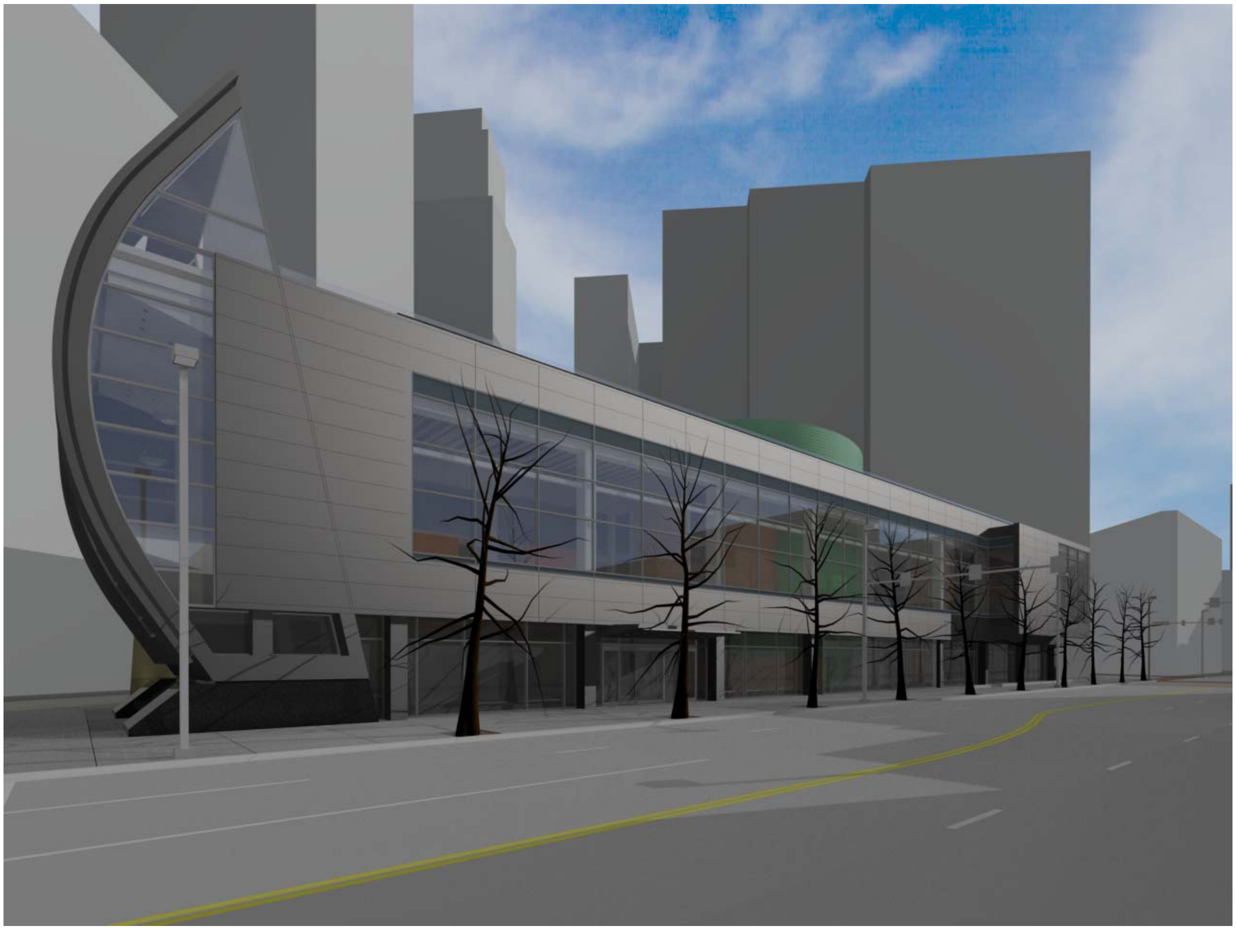


Figure 6.4.2 | The view from Liberty Avenue with the roof terrace addition. The only visible elements are the extended theater drum and the glass guardrail at the top of the parapet. Both of these features enhance the existing architecture while serving a practical purpose.

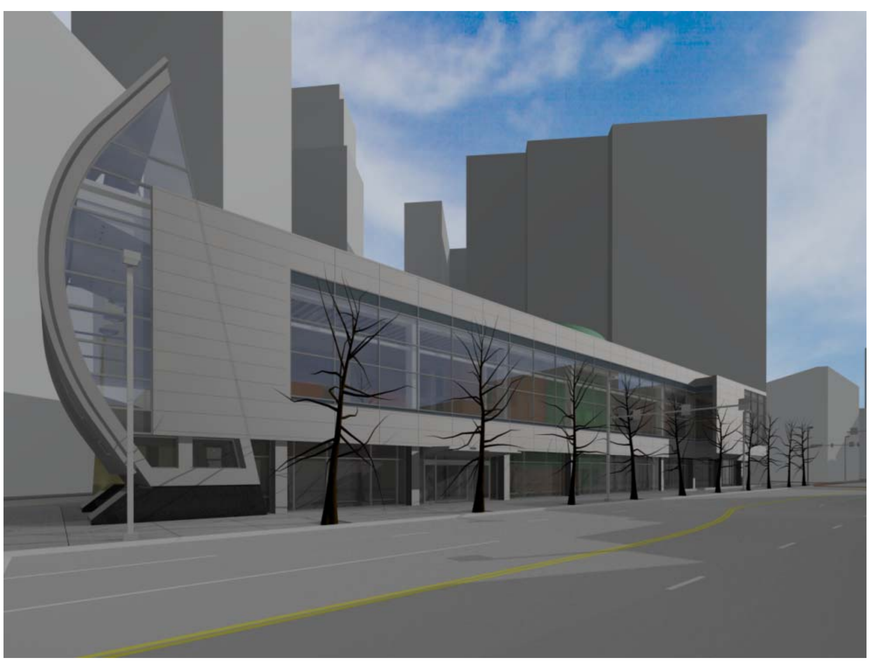


Figure 4.6.3 | View from Liberty Avenue of the existing design for the August Wilson Center.

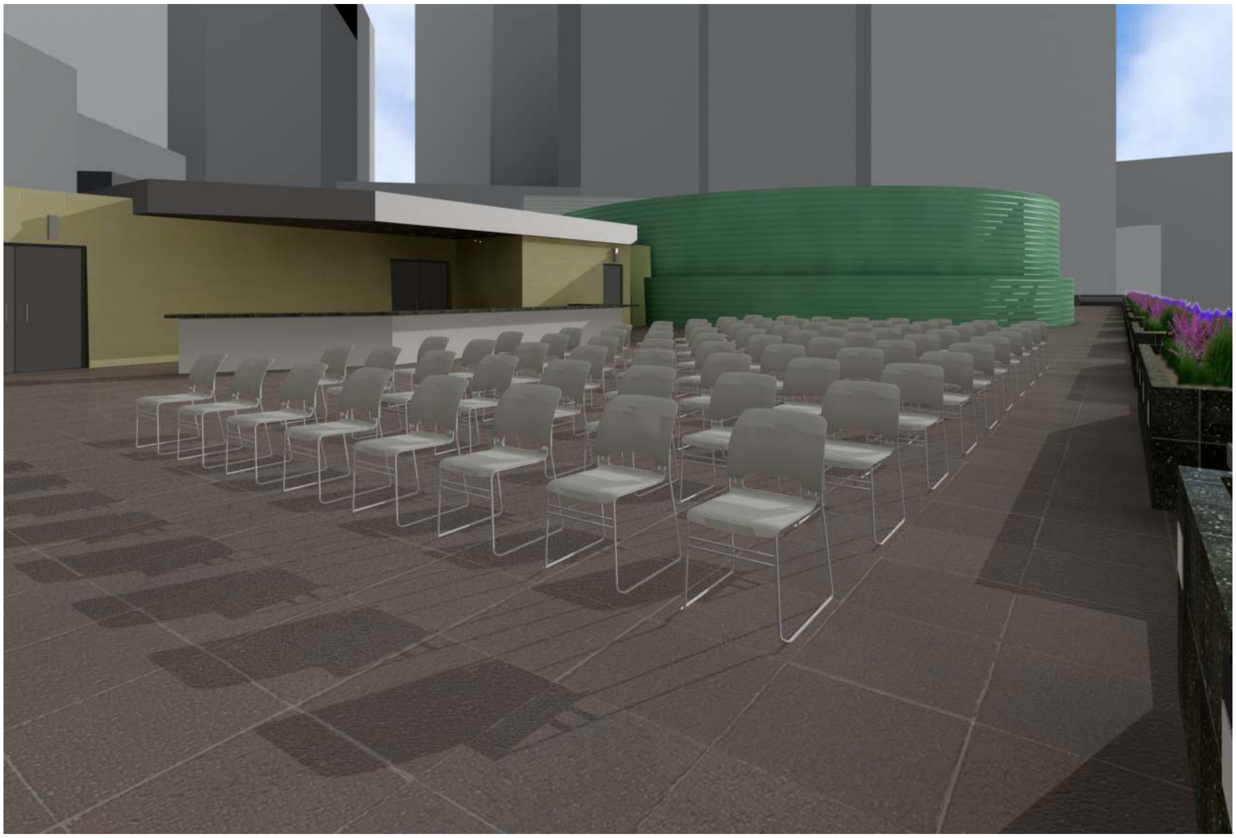


Figure 6.4.4 | Late afternoon view of the roof terrace looking west with temporary seating for a performance.

Figure 6.4.5 | Late afternoon view of the roof terrace looking east with the top of the sail as a backdrop.

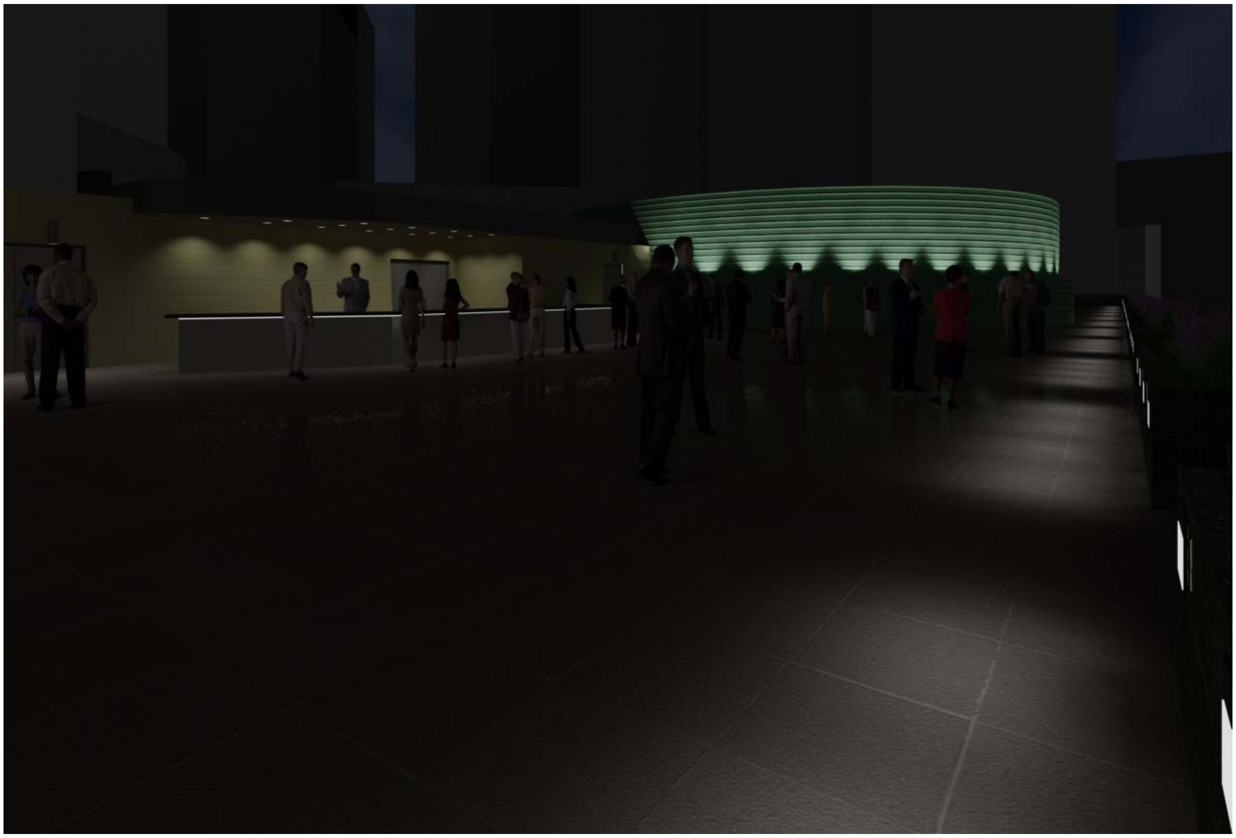


Figure 6.4.6| Night view of the roof terrace looking west.

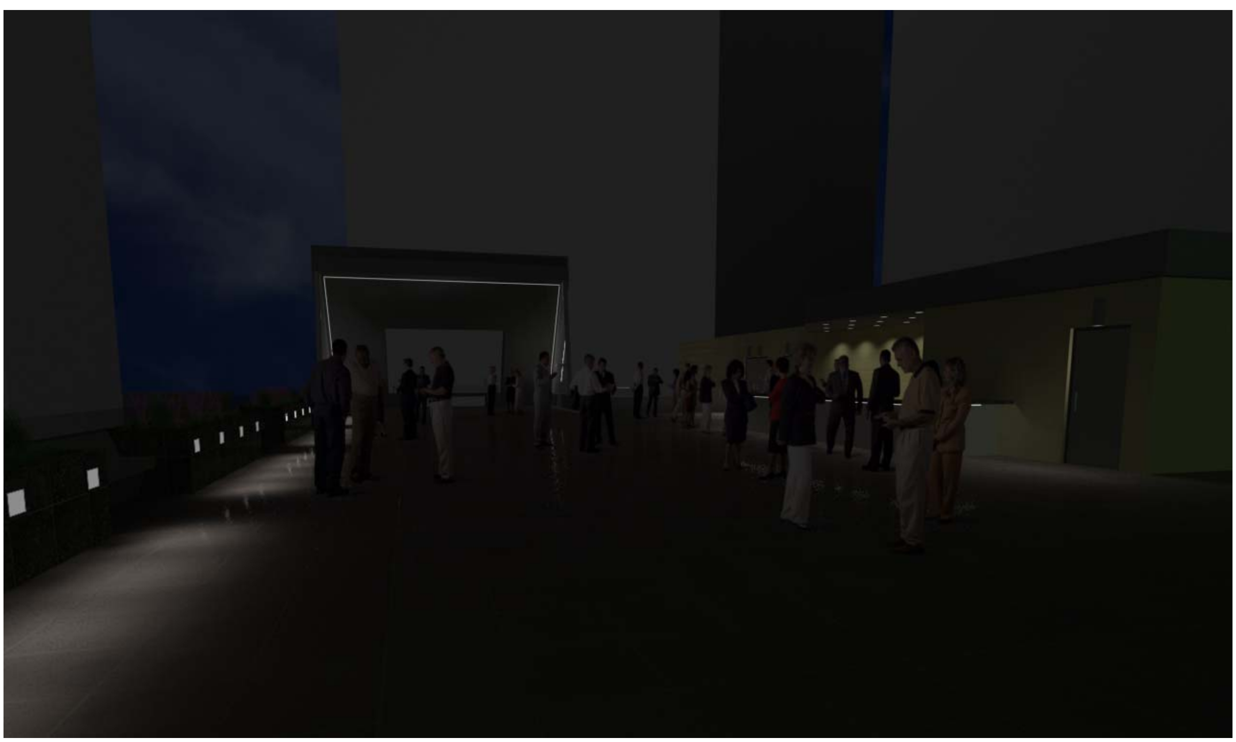


Figure 6.4.7 | Night view of the roof terrace looking east.

5. ANALYSIS AND CONCLUSIONS

With any proposed add-on feature, the owner must decide if the additional functionality is worth the additional cost. For the August Wilson Center, the addition of a roof terrace will add a great deal of useable space that provides a different venue than what is already designed. The design imposes minimally on the existing architecture while creating certain enhancements that integrate with other building systems. Specifically, the vertical extrusion of the theater drum is essential to the lighting design.

The only significant architectural changes would come in the form of egress width and restroom quantity requirements. These areas would have to be accounted for in the design of the whole building. Because of the larger scope of this work, these requirements were not entirely met for this study. Egress and restroom requirements mean that the roof terrace, as currently designed, would not function well as a post-construction addition. Changes to the structural system would also occur, but if designed concurrently with the existing building, these changes would not have a costly impact on the building.

Overall, the roof terrace would be worth pursuing if it were considered at the time of the initial design. However, as a post-construction addition, there are several setbacks that would have to be overcome.

SECTION SEVEN | Acoustics

Acoustics is an important but often overlooked element of architectural design. In certain cases, a poor acoustical design can ruin an otherwise well designed space. For the August Wilson Center, acoustics is certainly paramount. As a center for arts and culture, the center will be home to a variety of acoustical situations from spoken word performances to small recitals to lectures to full theatrical performances. For this analysis, two of the critical spaces were selected, analyzed, and if necessary, redesigned. Detailed calculations of reverberation time and sound transmission coefficients (STC) were used to make conclusions about the acoustical effectiveness of the designs.

1. THE MUSIC CAFÉ

The Music Café is characterized by Perkins + Will as follows:

> *The café is located at sidewalk level, accessible directly from the street and from within the center. It will function as a traditional museum café and sidewalk café during the day. A seating terrace is located outside and adjacent to the café. Wired for internet access and designed to accommodate a wide range of emerging technologies, the Café provides an electronic link to visitors worldwide.*
>
> *Modeled after New York's BAM café or Joe's Pub the Café is also designed to accommodate an on-going menu of programs and to function as an alternative performance space for intimate performances with limited seating for jazz, spoken word, poetry and other new performance forms in a club setting at night. A portable stage and theatrical lighting will be imported to support such performances as required.*

This space is essential a large rectangular box with three glass sides, a hard floor, and sound absorbing treatment on the ceiling (although behind baffles and ductwork). It is evident design does recognizes the need for acoustical design elements, with hanging metal baffles and acoustical blanket over 80% of the underside of the floor structure above.

Based on the use description provided by the architect, a reverberation time of approximately 1.0 second would be ideal. This would place the space somewhere between speech and speech/music use. According to the *Architectural Acoustics: Principles and Design* a very high STC value (60+) between the Music Café and lobby would be desirable. This is important to both spaces, as a spoken word performance in the café could suffer if a large crowd was gathering in the lobby for a performance in the main theater, while the lobby must remain quiet during a performance in the main theater if patrons are entering or exiting the auditorium since a main set of doors is directly across from the café.

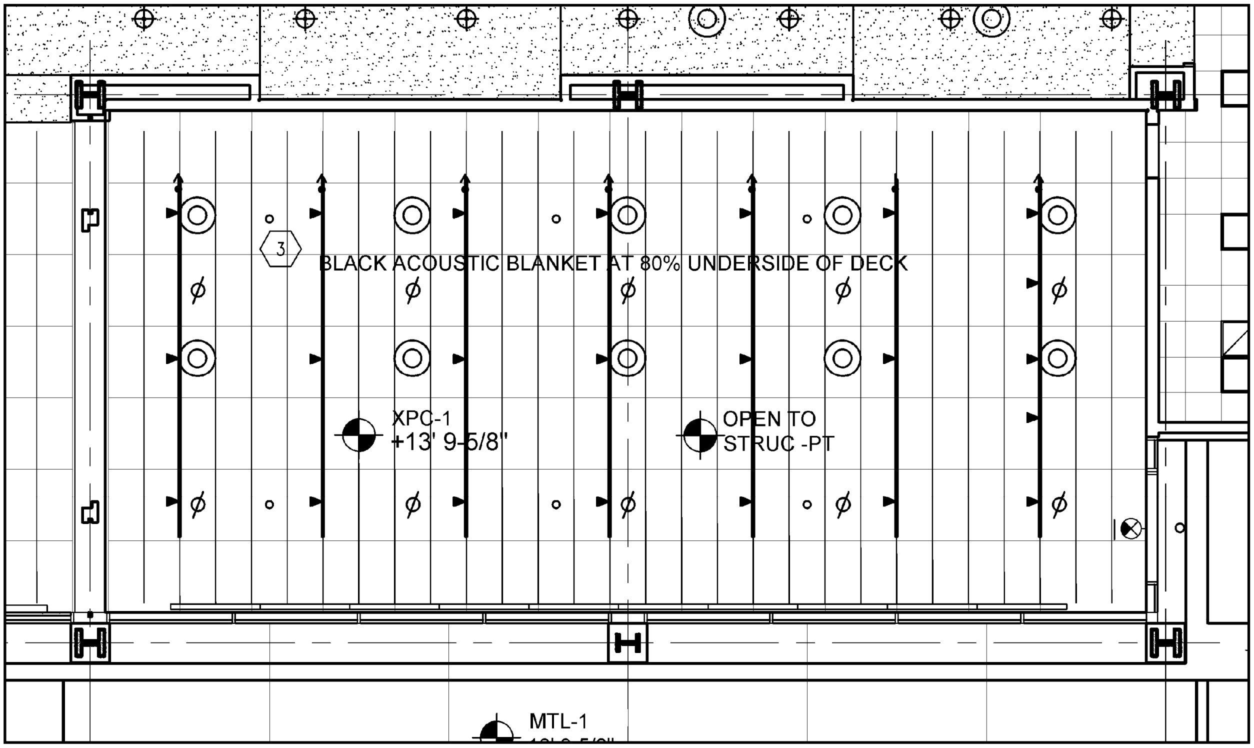


Figure 7.1.1 | Music Café Reflected Ceiling Plan – Existing Design [Not to Scale]

REVERBERATION TIME SUMMARY: MUSIC CAFÉ (EXISTING)						
Freq. (Hz.)	125	250	500	1000	2000	4000
T_{60} =	**1.677**	**2.596**	**0.801**	**0.798**	**0.807**	**0.752**

Figure 7.1.2 | Music Café Reverberation Time – Existing Design. Full calculation available in Appendix J.

Figure 7.1.2 illustrates that the existing reverberation times are far from ideal. One important consideration, however, is that the manufacturer of the metal baffle ceiling system (Chicago Metallic) does not have acoustical data for the product. Therefore, the product has been omitted from the calculations. Including the baffles in the calculation would likely reduce the very high reverberation times at the lower frequencies, but it would also reduce the reverberation times at the higher frequencies which are already lower than ideal.

Additional analysis of the sound transmission class (STC) on the wall between the café and the main lobby reveals a potential for unwanted noise transfer between the spaces. At 46, the calculated STC falls far below the ideal value of 60+ (See Appendix J for STC calculations). This problem is generated by the use of glass doors and partitions between the spaces. Changing the glass type from ½" tempered glass to ½" laminated glass improves the STC to 49, but this is only a marginal increase. To really improve this potentially negative situation, significant changes to the architecture are required. These changes may include changing the glass to another material such as wood or creating a small vestibule at the entrances. These changes, however, would significantly alter the architecture. It would be appropriate to point out the problem to the architect, but it is unlikely that the changes would be made.

Improving the reverberation time is a much more realistic change. In order to do this, I have eliminated the metal baffles and acoustical blanket, replacing them with floating fiberglass sound absorbing panels that are faced in perforated metal (See Appendix K for product specifications). This product is pictured in Figure 7.1.3. This change will most likely reduce cost by replacing two materials with one. Some changes were necessary in the location and type of HVAC diffusers and sprinkler heads. However, these changes should not require significant changes to the overall system. Figure 7.1.5 shows the new reverberation times based on 900 square feet of the new acoustical panels. Figure 7.1.4 shows the proposed layout of these panels.

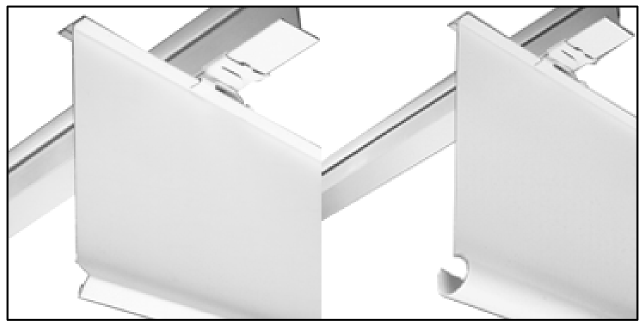


Figure 7.1.3|Left: Alpro Metal Acoustical Baffles for the new design. (www.alproacoustics.com) Above: Existing hanging metal baffle system from Chicago Metallic.

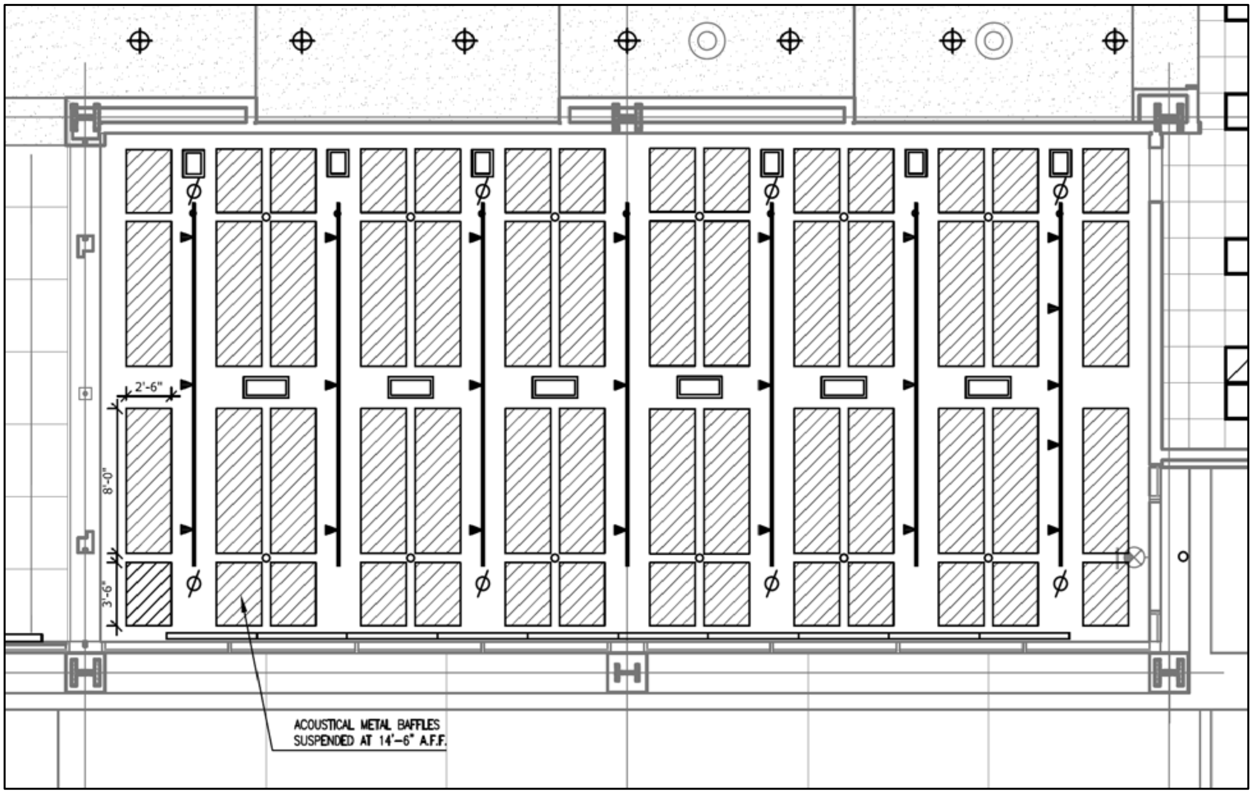


Figure 7.1.4| Music Café Reflected Ceiling Plan – New Design

REVERBERATION TIME SUMMARY: MUSIC CAFÉ (NEW)						
Freq. (Hz.)	125	250	500	1000	2000	4000
T_{60} =	**1.620**	**1.243**	**0.984**	**1.054**	**1.077**	**1.065**

Figure 7.1.5 | Music Café Reverberation Time – New Design. Full calculation available in Appendix J.

BAFFLES - MUSIC CAFE			
TAG	QUANTITY	LENGTH (FT)	WIDTH (FT)
PANEL TYPE A	28	8'-0"	2'-6"
PANEL TYPE B	28	3'-6"	2'-6"

Figure 7.1.6 | Music Café New Baffle Schedule of Materials

The new reverberation times are very close to the desired values. According to *Architectural Acoustics: Principles and Design* optimum reverberation times at 125 hertz should be 1.3 times the ideal reverberation time at 500 hertz and a multiplier of 1.15 should be used at 250 hertz. These multipliers are used to correct for the fact that the human ear is less sensitive at lower frequencies. With these factors included, the new design is very near the target. The new ceiling system will provide superior acoustical performance at a reduced cost.

2. MULTIPURPOSE ROOM

The multipurpose room is characterized by Perkins + Will as follows:

> *Located at the second level, the multipurpose room functions as a flexible performance space and with its sprung hardwood floors also serves as the Center's rehearsal hall. It will be available for programming of special events including dance parties and social events such as weddings, fundraisers, birthday parties and other celebrations. Theatrical lighting and sound systems, portable stage and portable practice bar can be imported as required per activity requirements. The room benefits from significant daylighting due to large areas of north facing windows overlooking Liberty Avenue and can also be fully darkened.*

Based on the description from Perkins + Will, this will be a very dynamic space with a variety of uses. This makes acoustical design more complex. A reverberation time of 1.2 seconds would satisfy the majority of uses for this space.

The construction and materials of the multipurpose room are the same as the Music Café with the exception of the ceiling. In this space, the ceiling is completely open to the underside of the floor decking, which is fully covered in black acoustical blanket, and a theatrical style steel pipe grid is suspended at 19'-6". Additionally, a gypsum soffit forms the ceiling where the room cantilevers out beyond the rest of the structure. The space is also 20% higher, 24.5' compared to 19.5', compared to the Music Café. The increased volume changes the acoustical properties of the space, requiring slightly different amounts of absorbing materials. The figures below show the existing reflected ceiling plan and reverberation times.

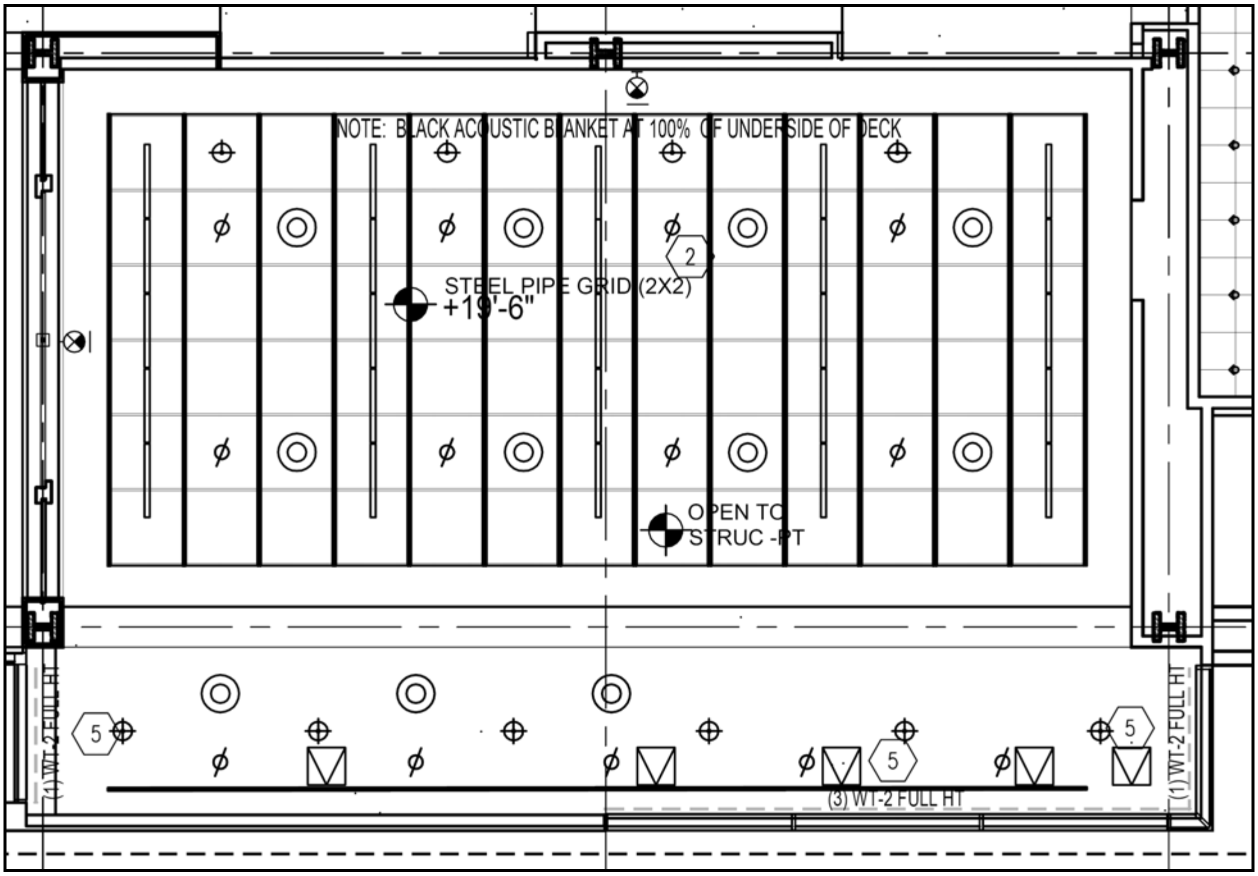


Figure 7.2.1 | Multi Purpose Room Reflected Ceiling Plan – Existing Design [Not to Scale]

REVERBERATION TIME SUMMARY: MULTI-PURPOSE (EXISTING)						
Freq. (Hz.)	125	250	500	1000	2000	4000
T_{60} =	**1.732**	**2.471**	**1.011**	**1.036**	**1.042**	**0.941**

Figure 7.2.2 | Multi Purpose Room Reverberation Time – Existing Design. Full calculation available in Appendix J.

The redesign for the multipurpose room works with the pipe grid design to achieve improved acoustical performance. The new design uses the previous identified metal faced baffle panels at the perimeter of the space to avoid interfering with the pipe grid which remains at the center of the room, although slighting reduced in size. The new design incorporates the new lighting design. Some of the diffusers and sprinklers were shifted slightly, but this should not be a serious concern.

To achieve the improved reverberation time, some of the black acoustical blanket remains, covering the area above the pipe grid. The combination and layout of materials gives the room a more interesting appearance while improving acoustical conditions. Thus, it is a win-win situation. Similar to the improvements made in the Music Café, the reverberation times were evened across the frequency spectrum and are very close to the desired values.

A new reflected ceiling plan and summary of the new reverberation times are shown below. A schedule of materials for the panels is also provided.

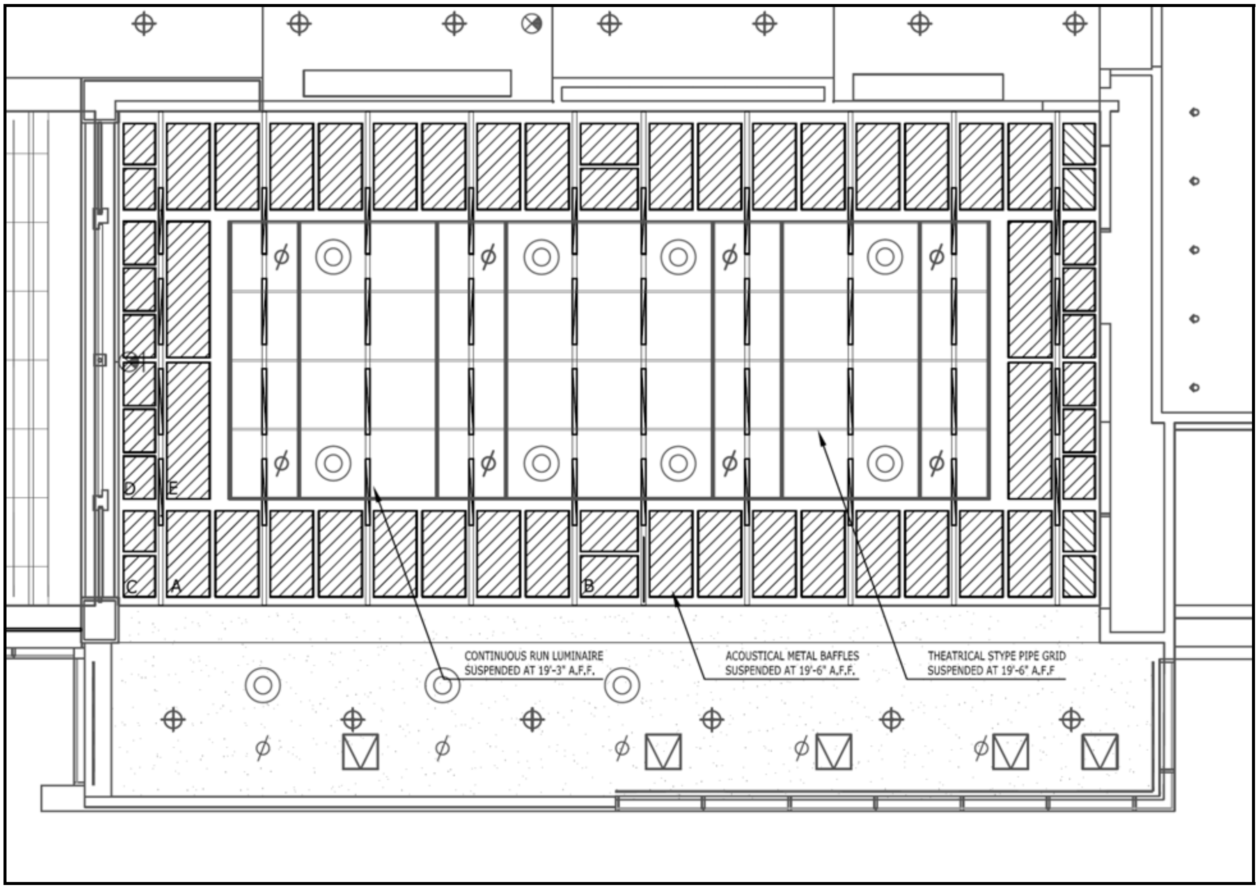


Figure 7.2.3 | Multi Purpose Room Reflected Ceiling Plan – Existing Design (Not To Scale)

REVERBERATION TIME SUMMARY: MULTI-PURPOSE (NEW)						
Freq. (Hz.)	125	250	500	1000	2000	4000
T_{60} =	**1.714**	**1.723**	**1.122**	**1.200**	**1.213**	**1.120**

Figure 7.2.4 | Multi Purpose Room Reverberation Time – Existing Design. Full calculation available in Appendix J.

BAFFLES - MULTI-PURPOSE ROOM			
TAG	**QUANTITY**	**LENGTH (FT)**	**WIDTH (FT)**
PANEL TYPE A	32	5'-0"	2'-6"
PANEL TYPE B	4	3'-4"	2'-4.5"
PANEL TYPE C	8	1'-10"	2'-4.5"
PANEL TYPE D	12	1'-10"	2'-6"
PANEL TYPE E	4	7'-11"	2'-6"

Figure 7.2.5 | Multi Purpose Room - New Baffles Schedule of Materials

SECTION EIGHT | Summary and Conclusions

Just as any one member of a group can ruin a performance, any system in a building can prevent the building from reaching its potential. In analyzing the August Wilson Center for African American Culture, nothing could be more true. The architect's vision of a "conceptually transparent, flexible container" leads to many challenges in the design of the building systems. Speaking specifically towards lighting, this architectural style means that each space must be treated as part of a system, rather than a single room that must meet a defined set of criteria. The redesigned lighting system attempts to maintain the integrity of the architect's vision while meeting the performance standards required of any lighting system. Furthermore, the lighting design attempts to reiterate the architect's vision that "The signature character of the building comes as a result of its content." With varied appearances, the building will reflect its inner-state and become a performance for those around to witness.

The electrical system changes have been designed to facilitate the goals of the lighting design. Specifically a more flexible and simpler control system results from centralization of lighting loads onto dimming panels. A study of voltage systems has revealed that a significant cost savings can be achieved by distributing electricity to mechanical equipment at a higher voltage. A cost study of a photovoltaic array shows that this system does not have any financial incentive, however.

The designed addition of a roof terrace provides a new venue for the center while also helping the lighting design to meet its objectives. This design is certainly feasible, but a more comprehensive design involving the lower levels would be required in order for the design to meet all occupancy related code requirements. If included from the initial design, this space would be of great value to the center with minimal additional costs.

Finally, the acoustical analysis has identified two spaces which may not exhibit ideal acoustical properties. The proposed solution for improving reverberation times in both spaces is both economical and aesthetically pleasing. The noise reduction qualities of the barriers separating these spaces from the lobbies that surround them have also been identified as problematic, but solutions to these problems are far more complex and are not feasible within the current architectural design. As a designer working with an architect, it is ultimately the architect's decision to maintain a visual quality or sacrifice appearance for performance.

Overall, the biggest challenge in analyzing and working with the systems of the August Wilson Center has been the unique character of the architecture. The spaces created are far from standard and certainly strive to embody signature qualities. However, as is often the case, this unyielding visual character makes the engineering of the building systems a complex task. In the redesign that is part of this senior thesis project, I believe this unique challenge has been faced and a successful design has been created.

SECTION NINE | References

The following software was used for calculations and production of rendered images:

AGI-32, Autodesk VIZ 2008, Autodesk AutoCAD 2008, Adobe Photoshop CS3, RetScreen

Information from the following resources was utilized during the research and design process:

The IESNA Lighting Handbook, 9th ed., Illuminating Engineering Society of North America, New York, NY, 2000

ASHRAE Standard 90.1-2004. Atlanta, GA: American Society of Heating, Refrigerating and Air Conditioning Engineers, Inc., 2004

National Electric Code 2005, Quincy, MA: National Fire Protection Association, Inc., 2004

Long M., *Architectural Acoustics*, San Diego, CA: Elsevier, Inc., 2006

Mehta, M et al. *Architectural Acoustics: Principles and Design* Prentice-Hall, Inc. Upper Saddle River, New Jersey, 1999

The Database of State Incentives for Renewable & Efficiency (DSIRE). http://www.dsireusa.org

SECTION TEN | Acknowledgements

Thank you to the following individuals and companies that have helped, directly or indirectly, in the production of this senior thesis project:

Dr. Richard Mistrick – Thesis Advisor and Lighting Consultant

Ted Dannerth – Electrical Consultant

Professor Robert Holland – Architecture Consultant, Thesis Advisor

Professor Moses Ling – Acoustics Consultant

Professor Kevin Parfitt – Thesis Advisor

Dr. Kevin Houser – Lighting Consultant

Mike Prioletto, **Mike Weniger** and **Turner Construction Company** – sponsors

Steve Iski of **Studio i Lighting** – project lighting design

Hornfeck Engineering – project electrical engineering

Perkins + Will – project architect

Lutron Technologies, Inc. – schematic design presentation host

Charles Stone – schematic design presentation panelist

Luke Tigue – schematic design presentation panelist

Fellow AE students, specifically the Lighting/Electrial Option

Friends

Family