final report

angelica santana | lighting/electrical

princeton neuroscience and psychology complex, princeton, new jersey

Architectural Engineering Senior Thesis Final Report

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. Executive Summary .

The Princeton Neuroscience & Psychology Complex will be a state-of-the art lab and educational facility and the newest addition to the science community at Princeton University housing both the Neuroscience Institute and the Psychology Department.

Concepts inspired by the occupants and the architecture are used to design the lighting in four spaces. The core of the report covers the design and analysis of these four spaces (North Entry, Lobby, Lecture Hall, and Cafeteria) and the electrical changes that accompany it. Main concepts include themes that relate to the brain and psychology like “connection, mirroring opposites, static motion, and building as brain activity”. The lighting not only satisfies the themes but also meets human needs and is energy compliant. The report first analyses the existent systems and then proposes a different solution to the problem. It includes the entire lighting design process from concepts to criteria to design development and finally documentation.

Because lighting cannot be achieved without electrical, another mayor portion of this report includes electrical design. The four spaces where the lighting changed consequently caused changes in the circuits where the original lighting was. The panelboards affected are redesigned, and voltage drop calculations are performed as well as a short circuit analysis through one path of the system. Also, a motor control center design is included as well as a bus duct study that compares aluminum to copper.

For the breadth topics, the ceiling in the Lecture Hall is re-designed using the lighting concepts to fully integrate architecture and lighting. Because of the functions of the space, acoustics is an important part. Therefore, an acoustical analysis is shown calculating reverberation time for speaker-type settings.

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lighting/electrical

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www.engr.psu.edu/ae/thesis/portfolios/2011/azs168

project team

design architect	Rafael Moneo Valles Arquitecto
architect	Davis Brody Bond, LLP
structural/mep	Ove Arup & Partners
contractor	Barr & Barr, Inc.
lighting	Fisher Marantz Stone

statistics

occupancy	academic
size	248,000 sf
levels	6 one side, 5 other
construction	summer 2010-spring 2013
delivery	design-bid-build

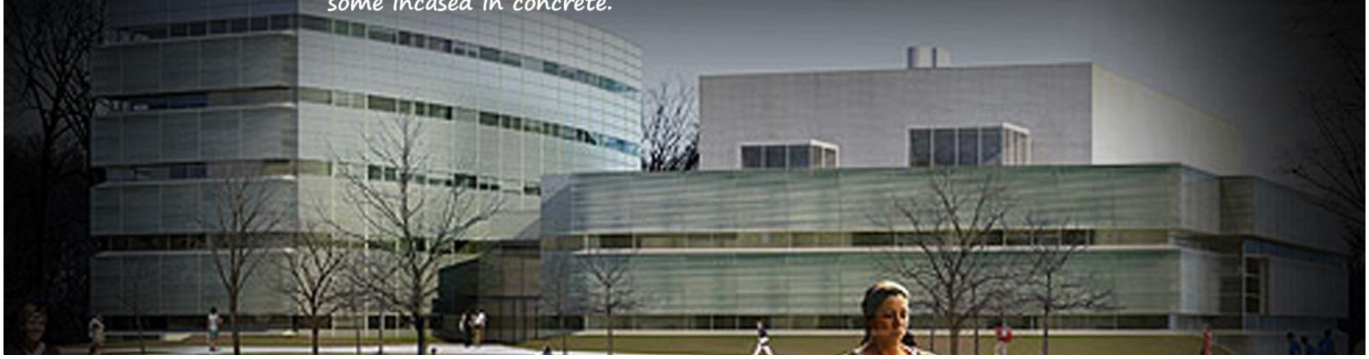
architecture The Neuroscience & Psychology Complex at Princeton University is comprised of two modern structures joined by a common space. The buildings' design not only connects with the complex landscape but also binds the two separate disciplines. Bridging the two sciences is essential for collaboration and community The complex facade carries the theme of connection by having rain screens in between floors hiding where the slab separation would be.

lighting Lighting in the non-laboratory spaces includes recessed linear fluorescent wall grazers, troffers, and channels accompanied by recessed compact flourescent and halogen downlights and accent lights. Metal halide floodlights highlight the light monitors. Through the circulation spaces, Cirkul fixtures by Louis Poulsen provide diffuse illumination. Lab space lighting is provided by flourescent sources including surgical troffers, high-bay, sealed, and downlights. Controls include daylight and occupancy sensors.

electrical The utility company, PSE&G, supplies electricity at 4160V to campus main location which feeds each building. Two service entrances feed two double-ended substations; one with 480Y/277V 3P 4W and the other with 208Y/120V 3P 4W secondary service. The 4160V generator provides emergency power. Both voltage systems are carried up the building in busways.

mechanical Nine air handling units (AHU) provide a total flow rate capacity of 137,000 cfm. Seven units are in Level 3 Penthouse and serve the north and south variable air volume (VAV) system, laboratories, and the Neuroscience chilled beams. The remaining two are in Level C/B and serve the Psychology chilled beams and the lecture hall.

structural The structural system includes column, wall, and braced frame concrete pad footings with reinforcing in both directions. Nine braced frames run along the height of the buildings. Level C/B has from 6''-12'' one-way and two-way concrete slabs on grade. The upper levels mostly have composite deck rib slabs and steel wide flange beams. All levels are supported with steel wide flanges, some incased in concrete.



. General Building Statistics .

Building General Data

Name | Neuroscience & Psychology Building Complex

Location | Princeton, NJ
Campus location: south of Icahn Laboratory on the current site of Lot 20, next to Roberts Stadium

Occupants | Neuroscience Institute and the Psychology Department

Function | Educational: state-of-the-art labs, faculty offices, and classrooms

Size | 248,000 sq.ft.

Stories | Psychology building is six stories high, while the neuroscience building is five stories

Design architect | Rafael Moneo Valles Arquitecto

Executive architect | Davis Brody Bond, LLP | http://www.davisbrody.com/

Laboratory planning | GPR / Jacobs Consultancy | http://www.jacobsconsultancy.com/

Structural/MEP | Ove Arup & Partners Consulting Engineers, P.C. | http://www.arup.com/

Landscape architects | Michael Van Valkenburgh Associates, Inc. | http://www.mvvainc.com/

Civil/site engineers | Van Note–Harvey Associates, P.C. | http://www.vannoteharvey.com/

Construction manager | Barr & Barr, Inc Builders | http://www.barrandbarr.com/

Princeton project manager | Ahmed Sultan

Princeton program manager | Mark Wilson

Date of construction | Summer 2010 to Spring 2013

Cost | Approximately 180 million dollars, exact cost not available at this time

Project delivery method | Design-Bid-Build

Architecture

The Neuroscience & Psychology Complex at Princeton University is comprised of two modern structures joined by a common space. Designed by Jose Rafael Moneo Valles who is known for "integrating contemporary architecture into rich physical contexts", the buildings' design not only connects with the intricate landscape but also binds the two separate disciplines housed within with a literal bridge-like shared area. Linking the two sciences is essential for collaboration and community which is enhanced by the location of the site adjacent to the physics, chemistry, and genomics buildings. The buildings' facades carry the theme of connection by having rain screens in between floors hiding where the slab separation would be. The lighting, another key feature of the design, will join the exterior to the interior. Where the light does not penetrate through the glass skins of the façade, there will be light monitors spanning the entire height of the building allowing the light to cascade down connecting all the different levels.

SITE UNDER CONSTRUCTION, ICAHN LAB TO THE LEFT

Codes

IBC 2006, NSPC 2006, IMC 2006, NEC 2008, N.J.A.C. 5-70 and 5:23-7, ASHRAE 90.1 2004 | New Jersey Building Codes

Building Enclosure

"The outer walls, composed of two "skins" of glass with a three-foot-wide airspace sandwiched between them, will have a luminous quality and will be energy-efficient". The façade curtain wall's main feature is the rain screen modules made of cast glass with an air gap and insulating spandrel translucent glass

units behind. In between these bays, there is vision glass that allow light to reach each floor. (Princeton University News). The roofing consists of 4lb lead flashing set in asphalt mastic, “tremco” burmastic-200, 4 ply roofing system, ½” densdeck, and polyisocyanurate insulation.
Zoning | Township of Princeton Municipality

Sustainability

Princeton is very concerned with the environment and all new construction is expected to meet LEED Silver standards. To do so, the complex will include:

- Natural lighting, automatic lighting controls
- Storm water reclamation system for non-potable use
- High performance exterior façade featuring outer ribbed glass sunscreen and inner high-performance
- Energy efficient HVAC system including heat-recovery system
- Low flow plumbing fixtures

Construction

Construction for the Neuroscience & Psychology Complex began in May 2010 and is expected to be completed in spring of 2013. The estimated cost for the buildings is 180 million dollars. Actual costs have been withheld by the Princeton. The construction manager is Barr & Barr Builders, Inc. and the project delivery method is design-bid-build. Within the campus, the building was strategically located adjacent to other science buildings to enhance and promote collaboration between them. The complex is located south of Icahn Laboratory on the current site of Lot 20, next to Roberts Stadium.

Lighting

There are two separate lighting systems in the building. Lighting for public spaces was designed by Fisher Marantz Stone. The general lighting is mostly fluorescent. Classrooms and corridors have fully recessed linear fluorescent wall grazers to highlight perimeter walls and provide lighting for circulation. Classrooms and seminar rooms include fully recessed linear fluorescent troffer for high ambient illuminance levels necessary for reading and writing. The circulation spaces (corridors, nodes, stairs, cafeteria, and vestibules) are lit with Cirkul fixtures by Louis Poulsen in several sizes and mountings depending on the location. There are fully recessed compact fluorescent downlight with 7” aperture throughout the offices. Linear fluorescent channels provide the necessary levels in the restrooms and are used as perimeter lighting for the cafeteria. The main lecture hall light source changes to low voltage tungsten halogen donwlights and steplights to highlight the wooden panels and dim correctly for the projector mode. Ceramic metal halide floodlights were used on all light monitors (stairways).
The rest of the complex, including the laboratory spaces, was done by Ove Arup. Lab lighting systems are completely fluorescent with some LED tasklights. Fluorescent systems include troffers, recessed downlights, high-bay fixtures, suspended utility fixtures (electrical rooms), sealed single and double lamp fixtures, and surgical troffers.
Complex controls are located throughout the building. They include daylight photocell sensors (off or dimming), occupancy sensors, manual dimming, and building timelocks.

Electrical

The Neuroscience & Psychology complex has an intricate electrical system design due to its large area and complicated laboratory spaces. The electricity supplied by the utility is bought by Princeton University at 4160 primary voltage. There are two service entrances that feed two double ended substations; one distributes electricity to the building at 408Y/277V and the other at 208Y/120V. The 480/277V system includes the following general loads: lighting, AHUs, and mechanical. The 208/120V system feeds the following general loads: receptacles, server racks, and VAV boxes (single-fed). The most common over current devices are draw-out circuit breakers. Emergency power comes from the exterior generator that feeds the emergency transformer, switchboard, and fire pump. The grounding system is very complex. Special equipment includes uninterrupted power supply systems and transient voltage surge suppressors.

Mechanical

There are a total of nine air handling units that provide air conditioning to the entire complex with a total flow rate capacity of 137,000 cubic feet per minute (cfm). Seven are located in Level 3 (penthouse MER) and serve the following areas: south variable air volume (VAV) system, laboratories, Neuroscience building chilled beams, and north VAV system. The remaining two are located in level C/B (MER) serve the following areas: Psychology Building chilled beams, and Lecture Hall. The air handling units include a supply fan, preheat coil, cooling coil, heating coil, return fan, glycol hr. (heat recovery) coil, humidifier, pre-filter, and a final filter.

Labs are required to have 100% outside air. The rest of the spaces have return air or heat recovery wheels. There are 25 fan coil units from International Environmental (IEC). Variable air volume boxes capacities range from 0-4500 cfm. Their sizes range from 5”-16” diameters and up to 24x16 rectangular areas. There are a total of four chilled beam types, three hot water cabinet/unit heaters, and 13 chillers. The mechanical system also includes three radiators with a total capacity of 1400 BTUH/LF.

Chilled water supply and return is rated at 300 psi and comes through the CHW main service valve provided by Princeton University. Steam supply is also rated at 300psi and enters through the service valve also provided by Princeton University.

Structural

The main structural systems for the Princeton Neuroscience and Psychology systems are described below. Level C/B has a slab on grade that includes 6” and 12” two way concrete slabs, 6”/11”/12” one way concrete slabs, and composite deck rib (D1). There are also some grade beams, typically GB1 and GB2. Steel wide flange and HSS columns encased in concrete support the floors above. The upper levels mostly have composite deck rib (D2 and D3) and are supported with steel wide flange beams. For moment support, there are a total of nine braced frame systems with braced frame footings. Column footings have both long and short direction reinforcing and exist in two options throughout the building ranging in 20 different sizes. Wall footings have dowels to match wall reinforcing and exist in four different sizes.

For vibration attenuation in important laboratory spaces, the floor structures are suspended. They are composed of suspended steel framing with composite slab and are limited to displacements of 2000 and 4000 micro-inches per second.

Fire Protection

For Fire Protection compliance, the New Jersey Uniform Construction Code, IBC 2006, U.C.C listed editions of National Fire Protection Standards were used. The objective of the fire alarm system is to provide safety for the occupants during an emergency.

Because of the building size and complexity of the spaces, the fire sprinkler system is extensive. There are several sprinkler head types including concealed pendant, upright, sidewall, extended sidewall, and window sprinkler heads. To supply water to the sprinkler heads, several piping systems were used. Wet, Pre-action, and Dry piping comprise the intricate fire protection piping system. Flow switches and tamper switches control the flow throughout the building as well as the different types of valves (gate, air release, casing relief, control with tamper switch, shut-off, check, OS and Y with TS, angle hose, dry, pre-action, and sprinkler alarm check). There is both a fire pump and a jockey pump with respective automatic fire pump controller with automatic transfer switch and jockey pump controller.

Transportation

To connect all the floors, six elevators, two doubles and two singles, and eight main stairways run up through of the complex. Several other stairways (18) connect single levels, especially in the C/B Level of the building and the exterior. The main transportation nodes are located in the following places; three in the Psychology building, one is the main Lobby, and four in the Neuroscience building. Some of the main stairways are also light monitors.

Three of the elevators are passenger, and three are service elevators. Only one is a Passenger Borehole Hydraulic elevator with an oil machine type with a 3000lbs capacity. The rest are Geared Traction elevators. The Service ones have a 5000lbs capacity while the Passenger ones have a 3000lbs one.

Telecommunications

There is a main server room located on level c/b which bonds with 8 Intermediate Distribution Frame (IDF) Rooms and one Building Distribution Frame (BDF)/IDF Room to form the backbone of the telecommunication system. These rooms cover every zone of the complex. There are several outlet types throughout the building including wall-phone, weather proof, standard IT, high density IT, and security camera outlets.

The server room has 40 racks in 6 rows with alternating cool and hot aisles and the necessary spacing for their accessibility and maintenance. A 12”x4” cable tray runs through the building’s corridors carrying all the necessary communication cables to most rooms.

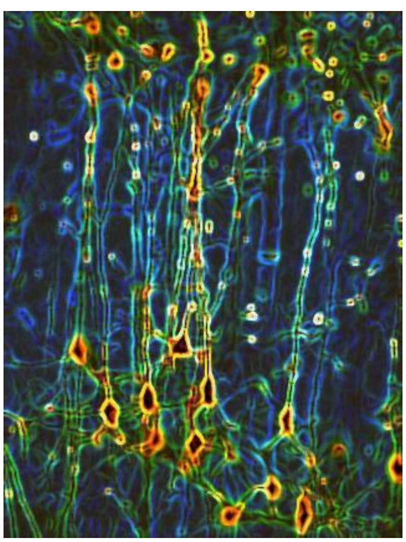
Audiovisuals

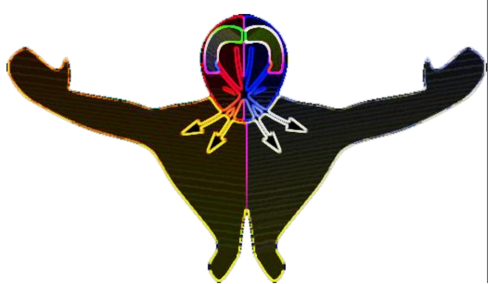
Audiovisual systems are located in all conference rooms in the building. They include a ceiling mounted data/visual projector with a projection screen with an electronic lower/raise switch, and ceiling speaker assemblies varying with room size. Several classrooms also have a similar arrangement.

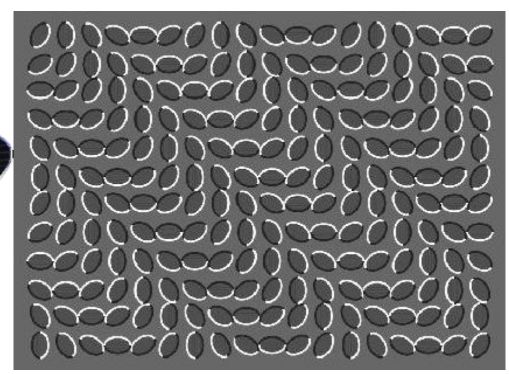
The main lecture hall has a projection booth at the rear of the room with ceiling mounted three projectors and screens that raise/lower in front of the chalkboards. There are speakers dispersed through the ceiling and in-wall stereo speaker assembly on both sides of the projection screens. There are also in-wall subwoofer assemblies below the projection screens.

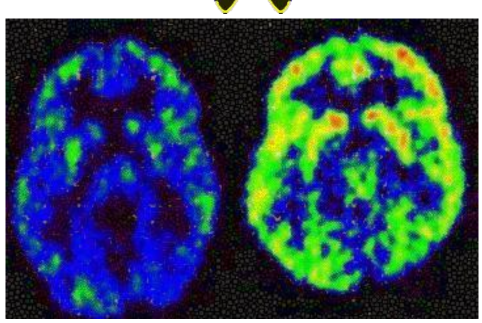
. Overall Concepts .

Lighting concepts were generated to catapult the schematic design of the Princeton Neuroscience & Psychology Complex in a way that represents its occupants and the architecture. Since the building is occupied by two sciences that deal with the brain, the main inspiration for the concepts was drawn from this. The first concept is ***connection***. There are 50-100 billion neurons in the brain linked with up to 10,000 synaptic connections each. Furthermore, the objective of placing both sciences in a complex together was to promote interaction between them while still maintaining their individual identities. That is why the building has two "towers" with a core lobby connecting them and with shared underground floors. The location of the building adjacent to other science buildings was to promote a sense of community between all sciences. Rafael Moneo Valles, the architect, is also known for integrating modern structures with intricate landscapes. The second concept is ***mirroring opposites***. The right side of the brain controls the left side of the body and vice-versa. There are two hemispheres in the brain just like in this building. The architecture has two sides, the "towers", which are not exactly alike but resemble each other which give the building"almost" symmetry. Also, the Neuroscience Institute and the Psychology Department are to interact and mirror each other while still being different. The third concept is ***static motion***. Synaptic connections in the brain appear as light moving through different paths. There is no movement, but the appearance of it through light. Appearance and perception is a major part of psychology as well as lighting. The last concept is ***building as brain activity***. Like a brain scan, where parts of the brain where there is activity are lit up, the building will represent the users and show the exterior what is happening in the interior. Control of the users and interaction of the lighting with the users will support this concept.









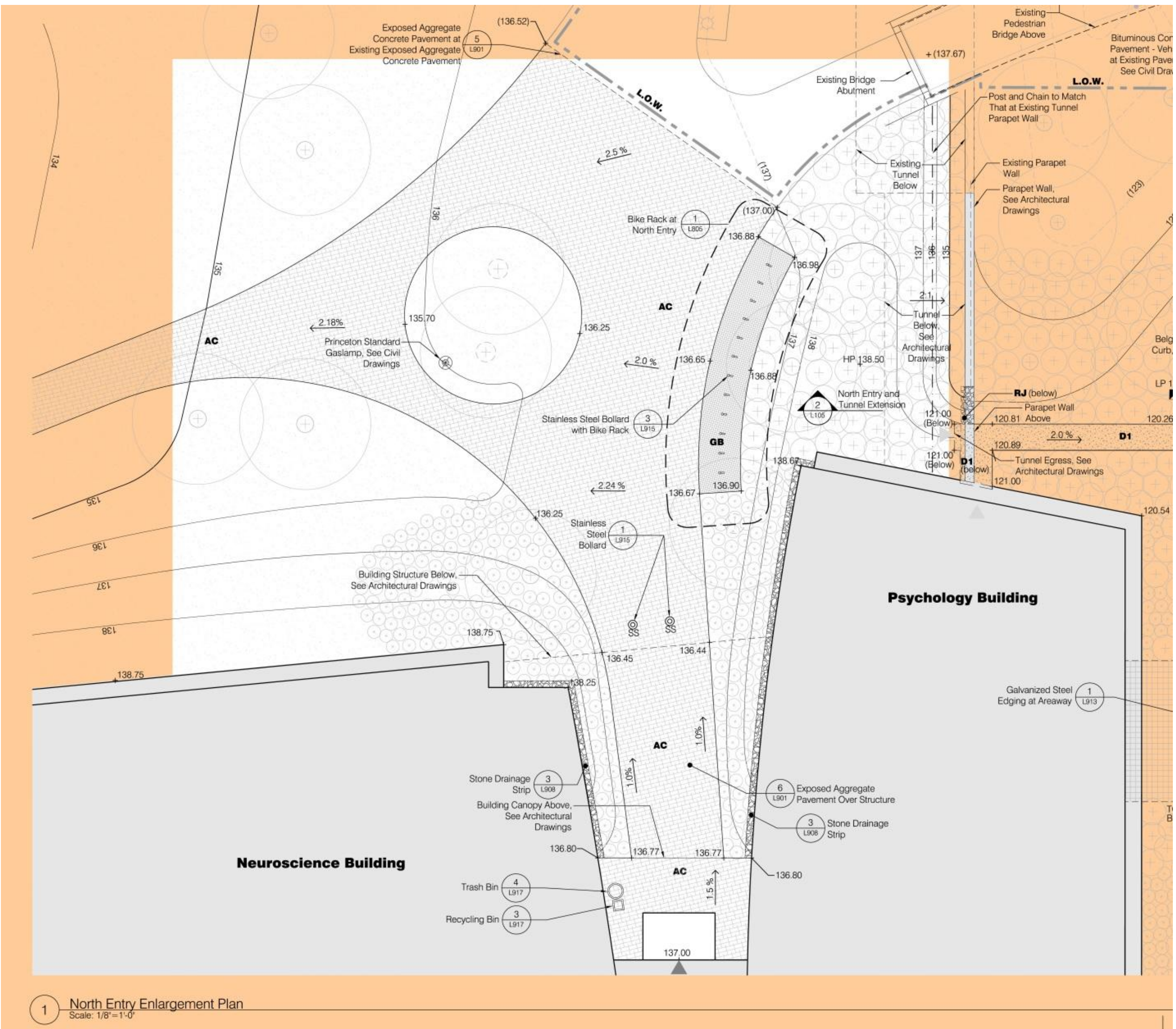
. Lighting Depth .

Exterior Space | North Entry

Existing Conditions

Description of Space

The north (main) entrance to the building is accessible by several pathways that connect in one node and lead you in. The walkways are surrounded by landscaping with many trees and smaller shrubs. The north vestibule leads into the lobby and is sandwiched by the Neuroscience and Psychology buildings. “The outer walls, composed of two "skins" of glass with a three-foot-wide airspace sandwiched between them, will have a luminous quality and will be energy-efficient” (Princeton University News). The façade curtain wall’s main feature is the rain screen modules.

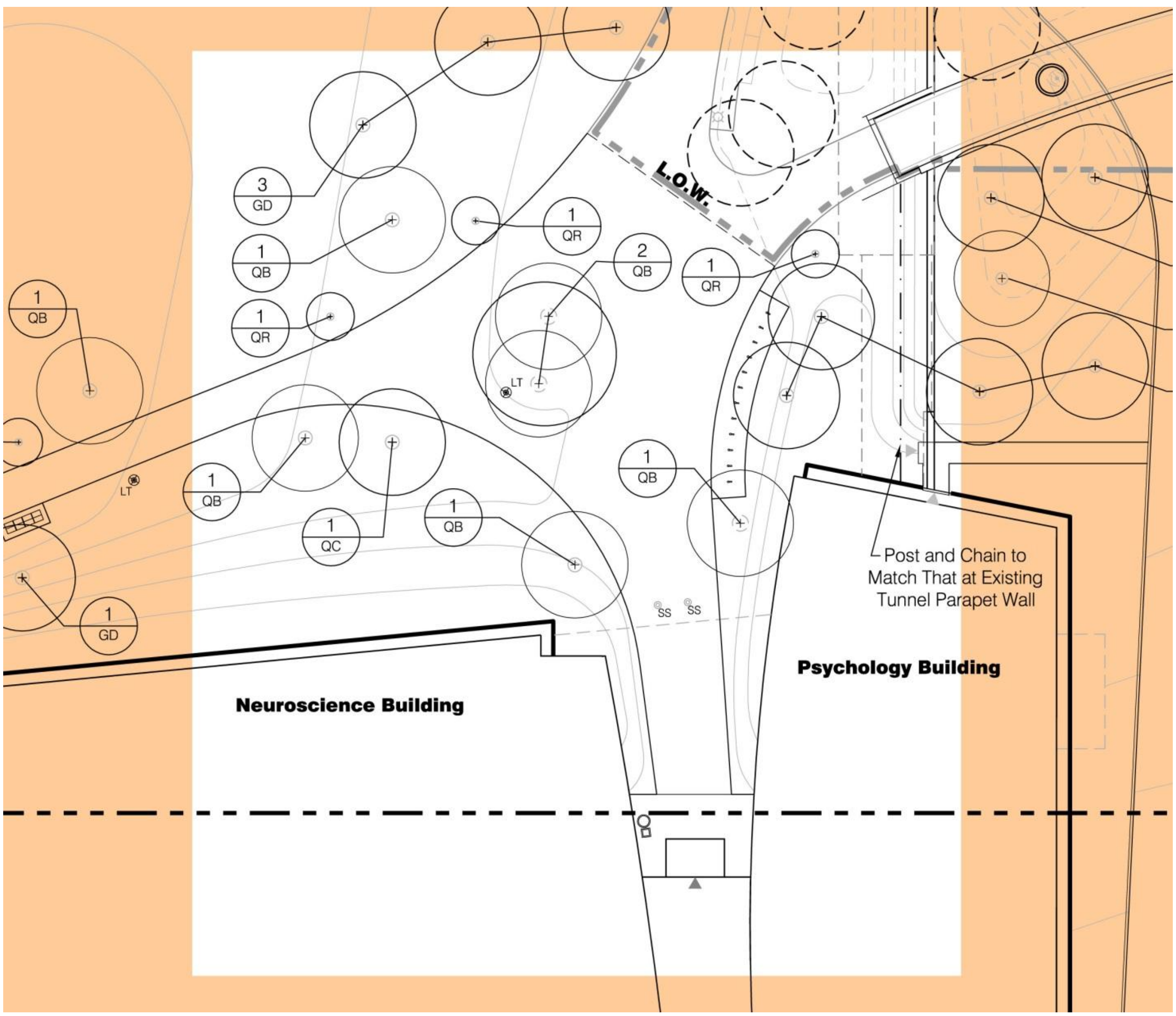


NORTH ENTRANCE, LANDSCPAE PLAN, NTS

Furniture and Surface Materials

Material	Reflectance *	Specifications #	Location
Exposed aggregate concrete pavement	0.35		Walkways
Granular pavement	0.30		Landscape
River jacks	0.26		Neuroscience and Psychology Buildings
Granite block	0.26		Bike racks
Stainless steel	0.60		Bollards, bike rack
Aluminum louver	0.65	08900	Curtain wall, façade
Vision glass	0.10	08800	Curtain wall, façade
Cast glass	0.20	08800	Curtain wall, façade
Translucent glass	0.25	08800	Curtain wall, façade
Spandrel glass	0.70	08800	Curtain wall, façade

*Assumed, some from Figure 1-36 from IESNA Handbook Page 1-22 and some from 3ds Max.



NORTH ENTRANCE, TREE PLANTING PLAN

Design Considerations

The façade has a very interesting curtain wall that acts as a rain screen. It includes several different types of glass (listed is the finish schedule above). The north vestibule exits at a pedestrian pathway that guides the way to the building. Night outdoors environments present several design challenges. The eye works differently at low light levels, people experience different emotions, and control of the light is expected. The façade must be illuminated in a way that attracts attention and enhances the architecture but at the same time complying with light pollution criteria and energy efficiency. The pathways must be illuminated to promote safety and security.

Visual Tasks

Guided circulation is the main visual task. The walkways need to be illuminated, and the entrance should have even higher levels to attract pedestrians. Safety and security needs to be addressed as well.

Qualitative System Performance Considerations

The following lists in order of importance the design issues that are of consideration for an exterior façade of a prominent building. The ninth edition of The IESNA Lighting Handbook was referenced ("Exterior Lighting", Chapter 21 and "Emergency, Safety, and Security Lighting", Chapter 29).

Very Important | Appearance of space and luminaires | Lighting should enhance the building's appearance at night and should attract attention to the entrance and make a favorable impression on the viewer. The lighting should render the structure otherwise lost without the sun, enhance the architecture, and guide pedestrians towards the main entrance. The architecture of the complex is very interesting and the curtain wall/rain screen is the main component and should be subtlety highlighted. The paths around the building intertwine and come together on nodes that resemble brain connections and the lighting should mimic this.

Very Important | Color appearance and color contrast | The natural colors of foliage and flowers is beautiful and the lighting should not omit it. Therefore, the CRI of lamps in the landscape should be good enough for pedestrians to see the full colors of their surrounding correctly.

Very Important | Direct and Reflected glare | Glare can be discomforting and impair visibility reducing safety and security.

Very Important | Light pollution/trespass | To control light pollution, the flux above the horizontal must be limited, non-target illumination minimized, and some of outdoor lighting turned off during hours of low use. To control light trespass, areas adjacent to the lighting design must be inspected, full-cut off reflectors and refractors and well shielded luminaires must be used, and floodlight angles must be kept low. All construction in Princeton University is expected to attain LEED Silver Accreditation. The point that deals with Light Pollution Reduction is not required to add up to the Silver rating therefore it is not required. However, light trespass and community affect the community so it must still be taken into account.

Very Important | Modeling of faces or objects | It is important to model faces of pedestrians walking around the entrance at night to increase security in the area.

Very Important | Peripheral detection | The lighting of the entrance should attract attention from people passing by on foot or car and should leave a positive impression. To better attract attention, the building entrance should be able to be detected from the peripheral view. With regards to security, being able to see peripheral movement for pedestrians is important.

Very Important | Points of interest | The main point of interest of a building exterior is usually the entrance. Therefore, the lighting design should guide the visitors to the entrance, either the north or south vestibules. The second point of interest will be the architecture and landscape, especially the nodes of the pedestrian walkways. Effective exterior lighting includes minimal ambient levels with highlights on points of interest such as destinations, architectural features, and hazards.

Very Important | Shadows | Patterns of light will highlight certain parts of the building leaving others in shadows. Without shadow, there is no light, and the use of both makes for an interesting exterior lighting design. See the description of Light distribution on surfaces above for more information.

Very Important | Source/task/eye geometry | When lighting the exterior, bollards should not be the only light source because they do not address higher vertical surfaces, like faces, and source/task/eye geometry would be hindered.

Very Important | Surface characteristics | Surface luminance is important for an exterior environment. It adds interest and depth to the scene while providing good visibility and security. Some of the surfaces in the exterior to be lit include landscape surfaces. Special attention must be paid to plant shape, size, foliage characteristic, branching pattern, trunk conditions, rood depth, growth rate, and seasonal changes.

Very Important | Illuminance (horizontal) | Horizontal illuminance is important for safety and security on pedestrian walkways and entrances around the building, especially the north and south vestibules. It is not of concern for the façade itself. The illuminance value required is listed below.

Very Important | Illuminance (Vertical) | Vertical illuminance is important for security and safety because it provides facial recognition and aids in peripheral vision. The sense of security provides a lighting that will allow enough response time to escape from a potential threat.

Important | Light distribution on surfaces | Patterns of light and shadow affect task visibility on interior spaces but they increase contrast on exterior spaces making them interesting. Therefore, uniformity is not a criterion in this case.

Important | Sparkle/desirable reflected highlights | Reflected highlight and sparkle can be discomforting in interior situations but can add character to an exterior environment by highlighting certain surfaces. Here, the building will have more a uniform and subdued glowing feel and contrast, with few reflections and sparkle.

Quantitative System Performance Considerations

Illuminance (horizontal) | 5fc (50lux) for Building Entrances

Illuminance (vertical) | 3fc (30lux) for Building Entrances

Illuminance (Building and Grounds Security) | 0.5-2fc

Luminance ratios | High luminance differences in exterior night settings can cause annoyance, impair task visibility, create safety hazards, and disrupt the surrounding community. Therefore luminance levels should be lowered and the ratio should be set in accordance to the setting and the community. It should not exceed 20:1.

Energy

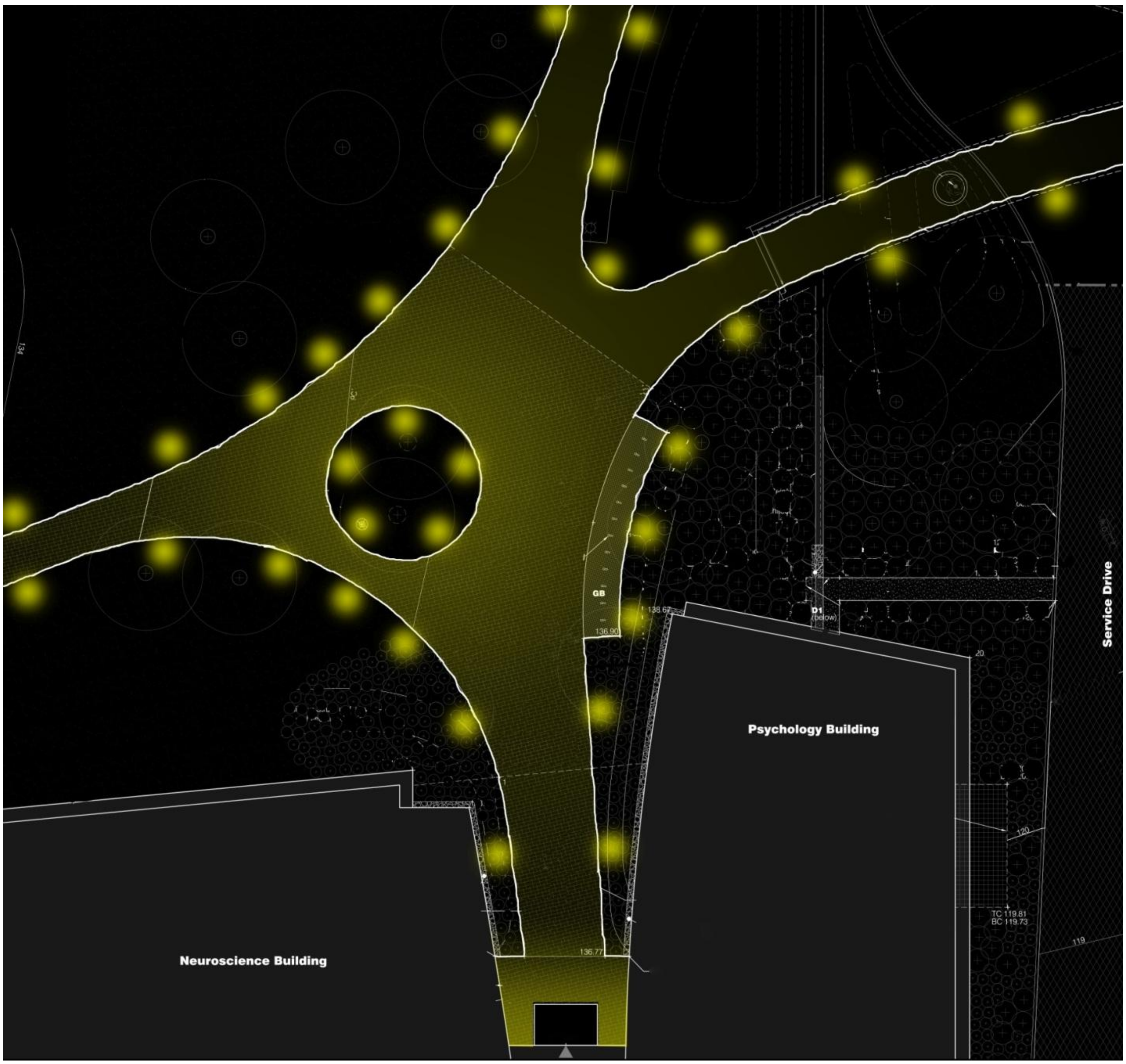
ASHRAE 90.1 2004

Building Exterior Lighting Power Densities | Walkways less than 10 feet wide: 1.0 W/lf
Walkways 10 feet wide or greater,
Special feature areas: 0.2 W/sq.ft.
Main entries: 30 W/lf of door width
Canopies: 1.25 W/sq.ft.
Building facades: 0.2 W/sq.ft. or 5.0 W/lf

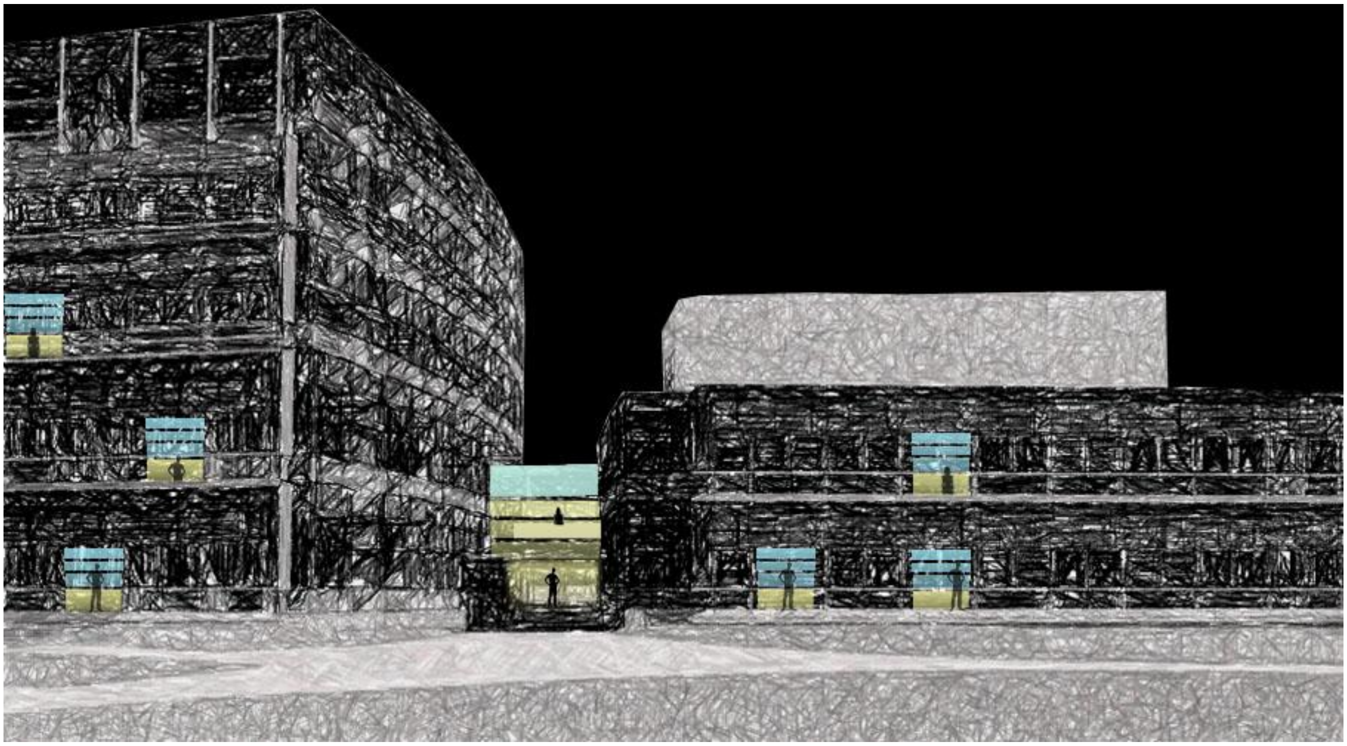
Lighting Redesign

Lighting Solutions

The objective of the lighting in the North Entry pathway is to safely guide pedestrians to the building and to the nodes where they can take different routes. To do this, LED in-ground luminaires were places along the walkways with their spacing decreasing as they approach the nodes and the building. This spacing difference creates a ***static motion*** effect. For safe circulation, pedestrian light poles whose shape resemble brain ***connection***, the walkways, and the Streicker bridge, were distributed evenly along the opposite side of the pathway were the small LED circles are. To add more attention to the nodes, up-lights graze the tree trunks. The façade will remain unlit so that the lighting from the spaces within cause the translucent panels to glow and the clear vision glass will provide the transparency showing the ***activity*** within.



CONCEPTUAL SKETCH PLAN OF LIGHTING



CONCEPTUAL SKETCH OF FAÇADE LIGHTING

Controls

The exterior luminaires will be controlled using time-clock capabilities to save energy when the system is not being used but keeping it simple without the need for daylight sensors.

Summary Performance Evaluation

Overall the new lighting design works adequately to meet criteria for safety and security. Pedestrian lamp-posts provide vertical illumination for face recognition and more than the required levels on the ground for circulation. Higher levels at the entrance attract people this way as well as towards the nodes by up lighting the trees. The LEED points regarding light trespass and night sky are not required for their certification so up-lights can be used for landscape lighting but they will still be kept to a minimum. The LED decorative fixtures placed at different intervals enhance the static motion effect.

Documentation

Lighting Schedule / Ballast Schedule

Type	Description	Lamp	Watt	Volt	Mfr	Catalog #
AB	Recessed compact fluorescent downlight with 6" nominal diameter aperture with aluminum, bright anodized reflector with plastic, translucent diffuser and integral electronic ballast, 3000k	PHILIPS PL-T 18W/830/4 P/ALTO 82CRI	18.4	277/120	Edison Price	TRPV 18/6
AM	Pole top metal halide exterior indirect adjustable luminaire with die-cast aluminum optical housing and 31.5" diameter and .25" thick aluminum plate secured by two die-cast aluminum "saddle" with maximum 30 degrees tilt and IP65 classification.	PHILIPS CDM Elite 70/T6/ 930 90CRI	88	277	Bega	8200MH
AP	Recessed exterior round drive-over in-ground halogen up light for foliage with stainless steel housing, convex tempered glass diffuser, anodized matte reflector, and natural bronze casting finish, rated IP67, with integral electronic transformer.	35W T4 GY6.35 12V	46	120/11.6	Bega	8702
AR	Fully Recessed LED indicator in-ground luminaire for both outdoor and indoor applications, with remote constant 6V driver, stainless steel housing, rated IP67, and visible nominal diameter of 7/8" with the base being nominal 5".	LED	0.08	277	MP Lighting	L06-WS27S-X-X-S6

Type	Location	PF	Input Current	Input Wattage	Lamp Wattage	Other	BF
AB	page 17-5 GE catalog	0.97	0.08	20	18	ProLine CFL Electronic Ballasts	1.05
AM	page 18-11 GE	0.9	0.4	88		86847	1
AP		1		46	46		1
AR		1		0.08	0.08		1

Lighting Plan

REFER TO APPENDIX L FOR FULL SIZE DRAWING WITH SCALE

Visual Performance | Visual Quality

Zone	Average Illuminance	Maximum	Minimum	Max/Min	Coeff. Variation
Pathways	1.72	3.90	0.60	6.50	0.42
Entrance	10.00	21.80	4.50	4.84	0.61

Light Loss Factor Calculations

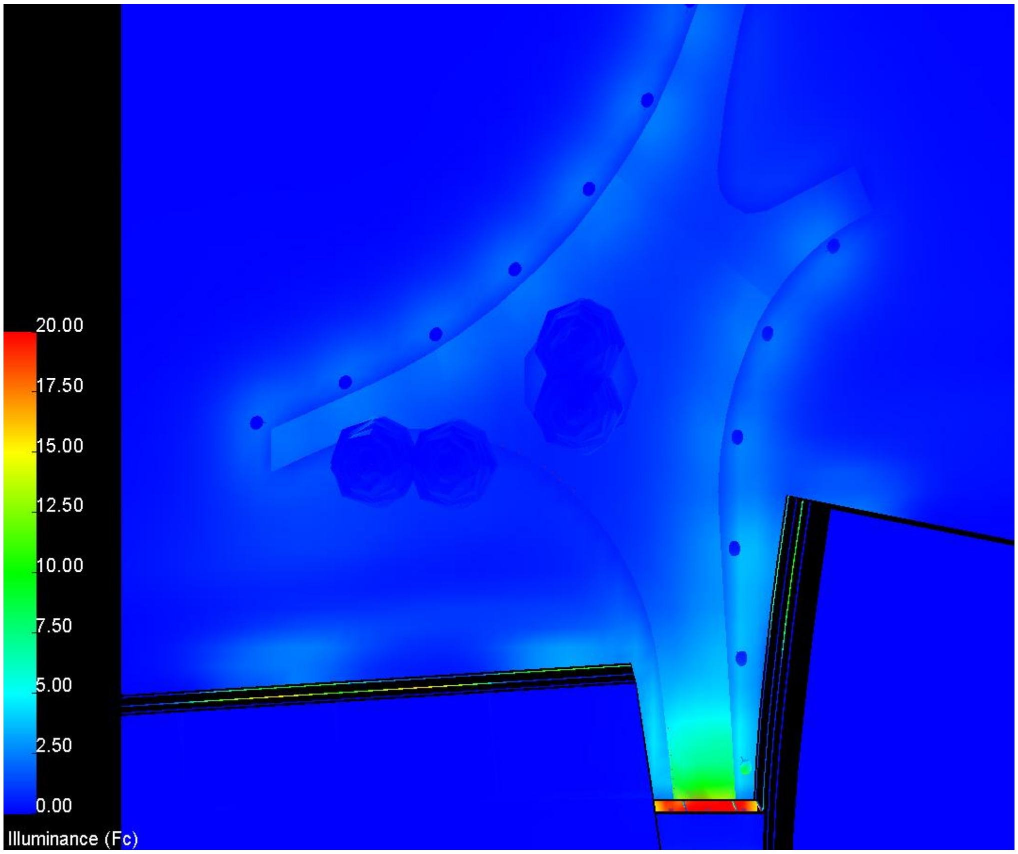
Luminaire Type	Lamp Lumen Depreciation	Ballast Factor	Lamp Dirt Depreciation	Total Light Loss Factors
AB	0.86	1.05	0.95	0.86
AM	0.89	1.00	0.75	0.67
AP	1.00	1.00	0.75	0.75
AR	0.70	1.00	0.75	0.53

Energy Calculations

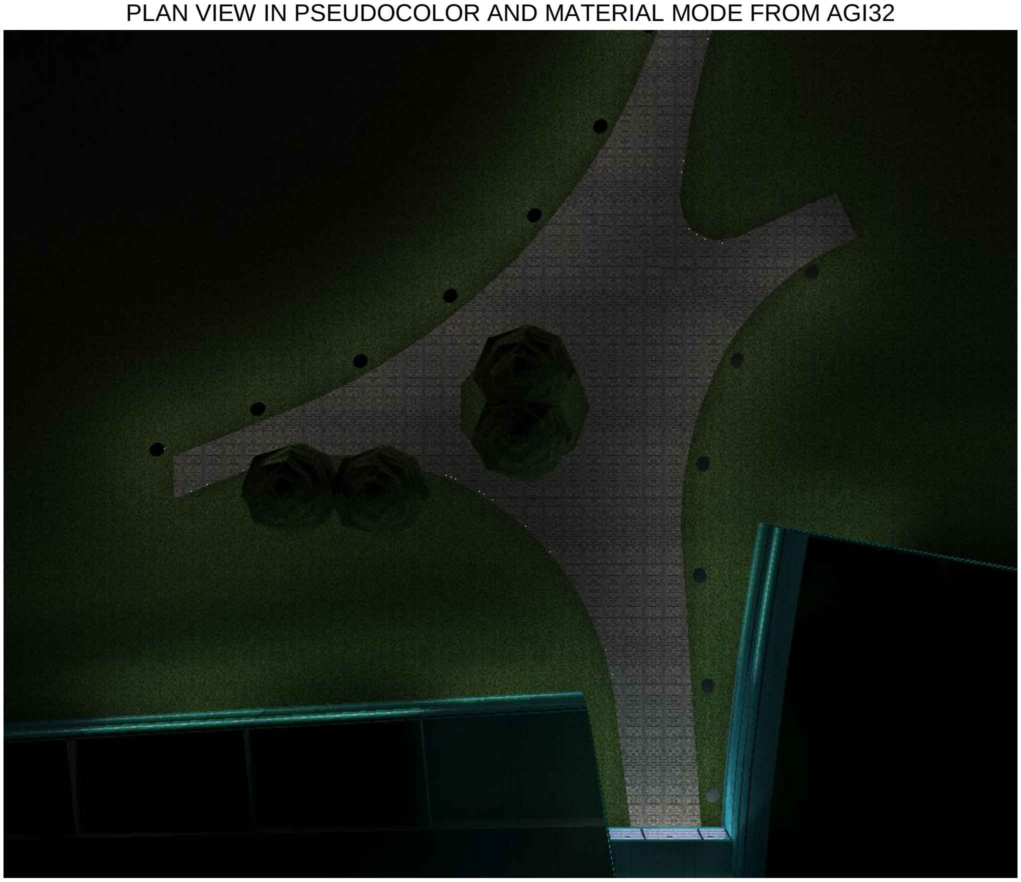
	Walkways (>10ft wide) W/sq.ft.	Main Entry W/lf	Canopies W/sq.ft.	Building Façade W/sq.ft.
Allowable LPD	0.14	30	1.25	0.2
		Total Allowable Watts		1414.54
		Actual Watts		1239.84
		Percentage		12.350

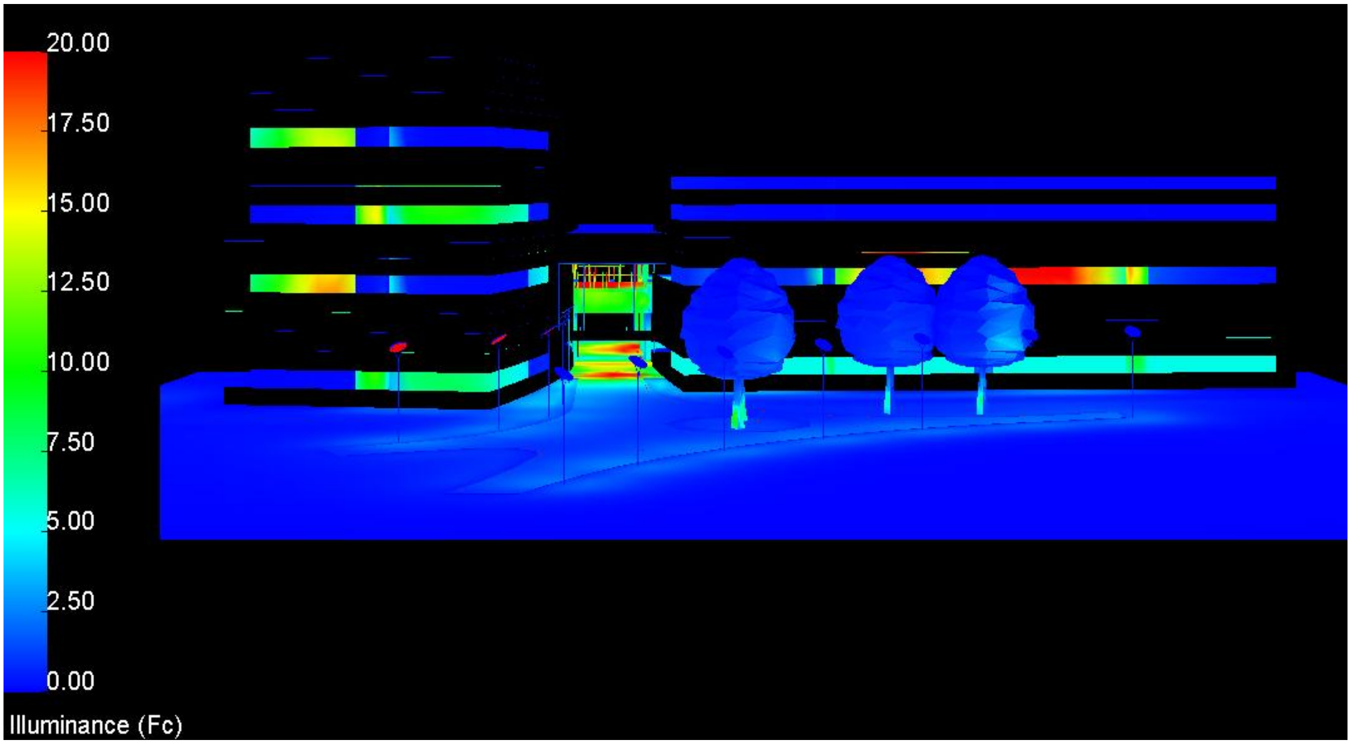
Area Pathways	Main Entry Length	Canopy Area	Façade Area
5461	7	352	0

Luminaire Type	Watts/ Luminaire	Amount	Total Wattage
AB	18.4	4	73.6
AM	88	9	792
AP	46	8	368
AR	0.08	78	6.24
		TOTAL WATTAGE =	1239.84

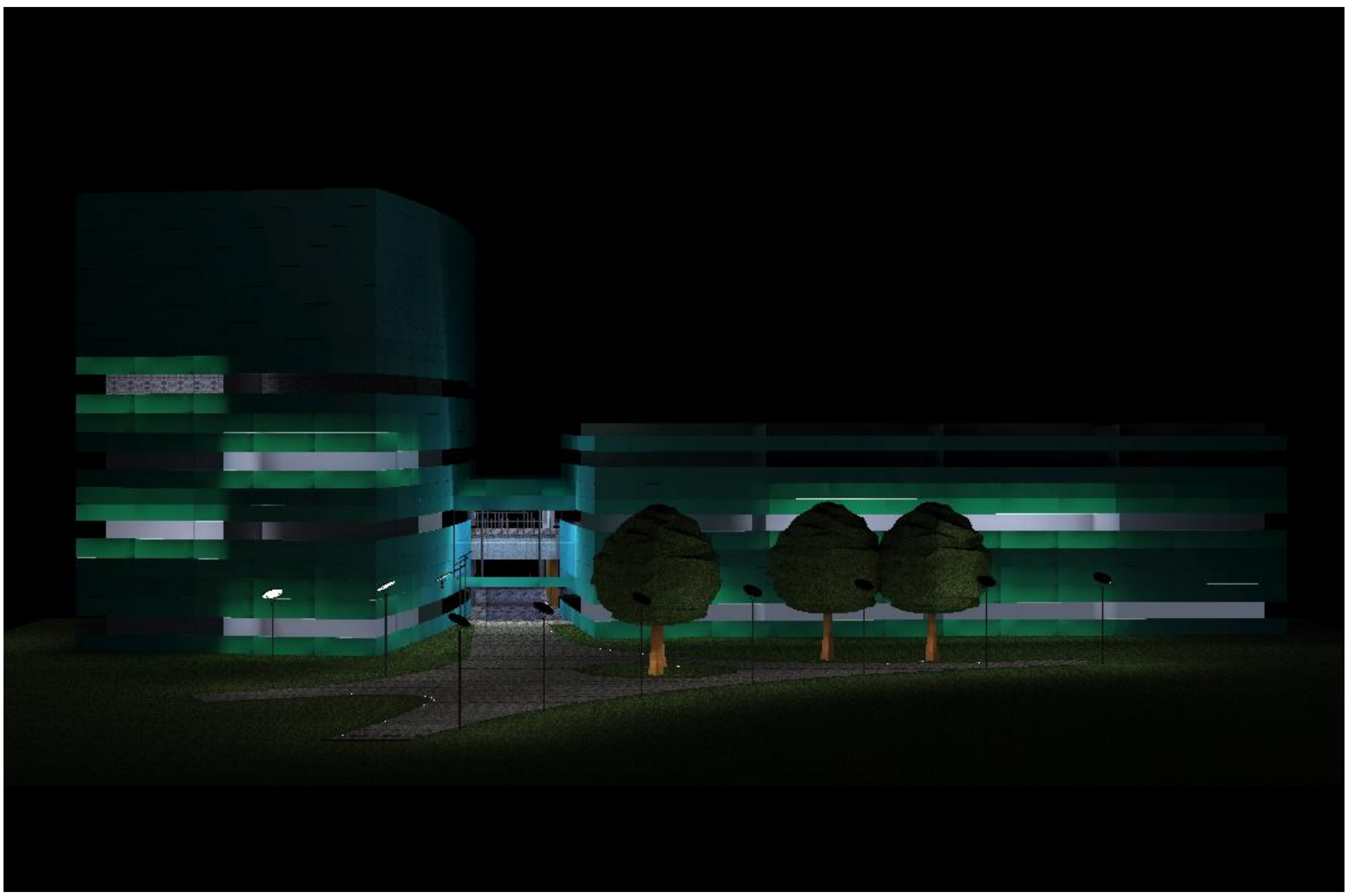


PLAN VIEW IN PSEUDOCOLOR AND MATERIAL MODE FROM AGI32

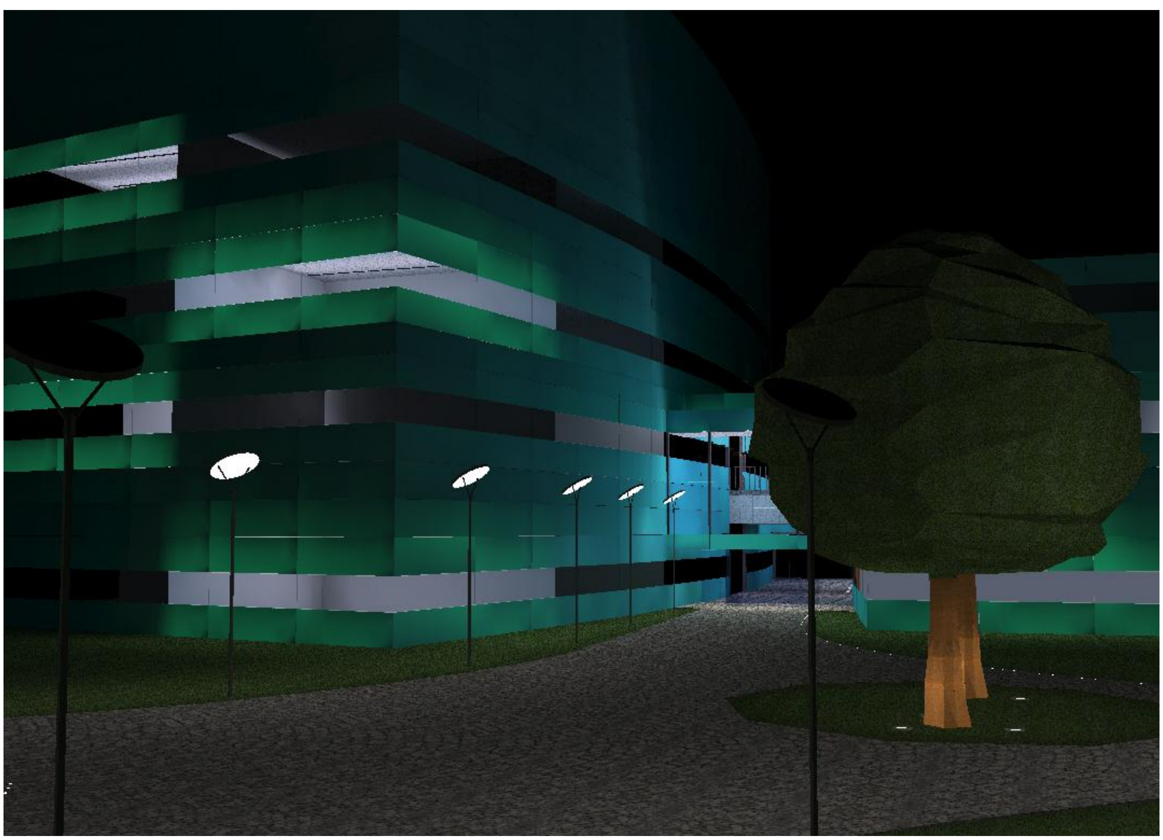




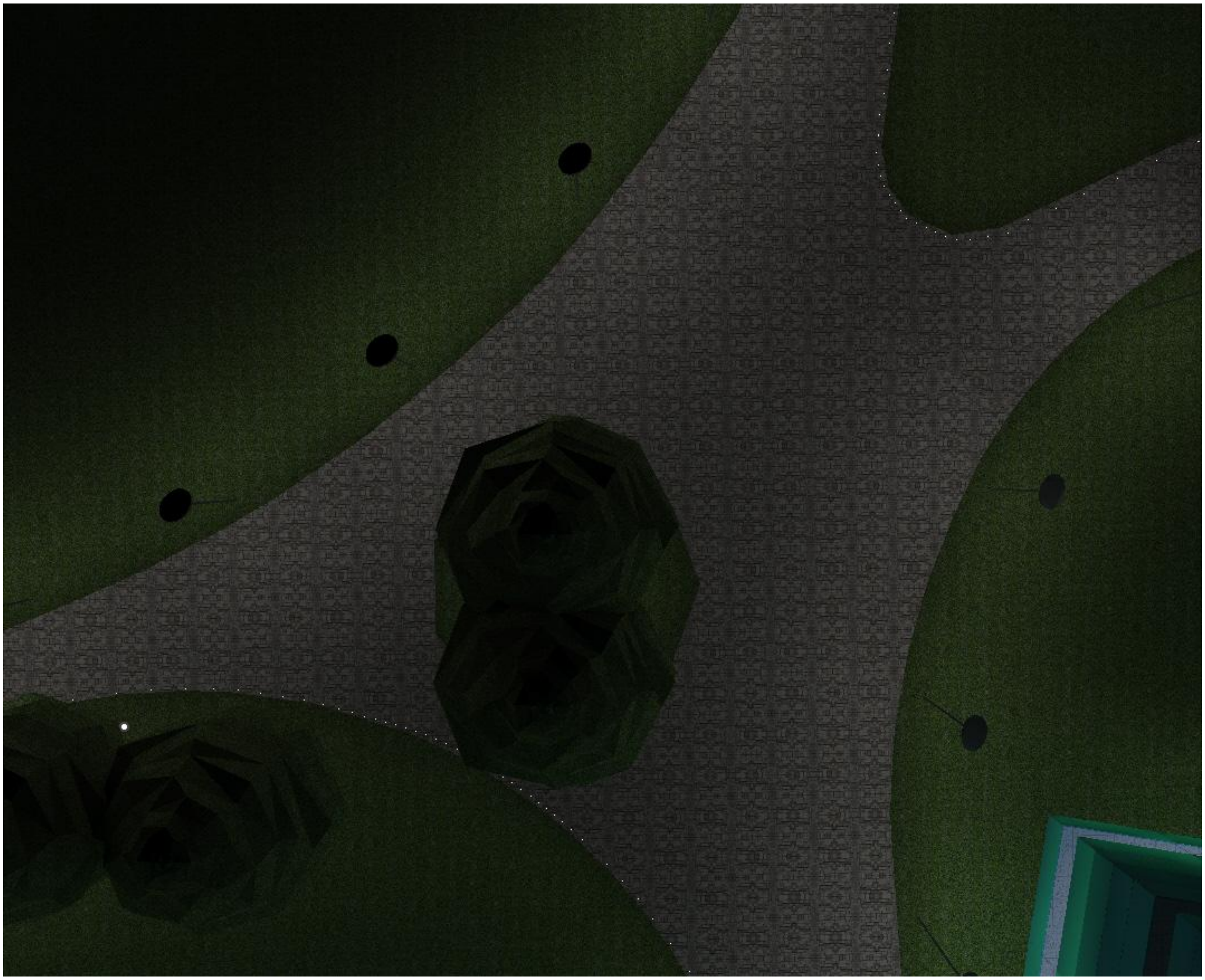
VIEW FROM ICAHN LAB IN PSEUDOCOLOR AND MATERIAL MODE FROM AGI32



VIEW FROM PEDESTRIAN LEVEL TOWARDS NORTH ENTRY



VIEW FROM PEDESTRIAN LEVEL TOWARDS NORTH ENTRY



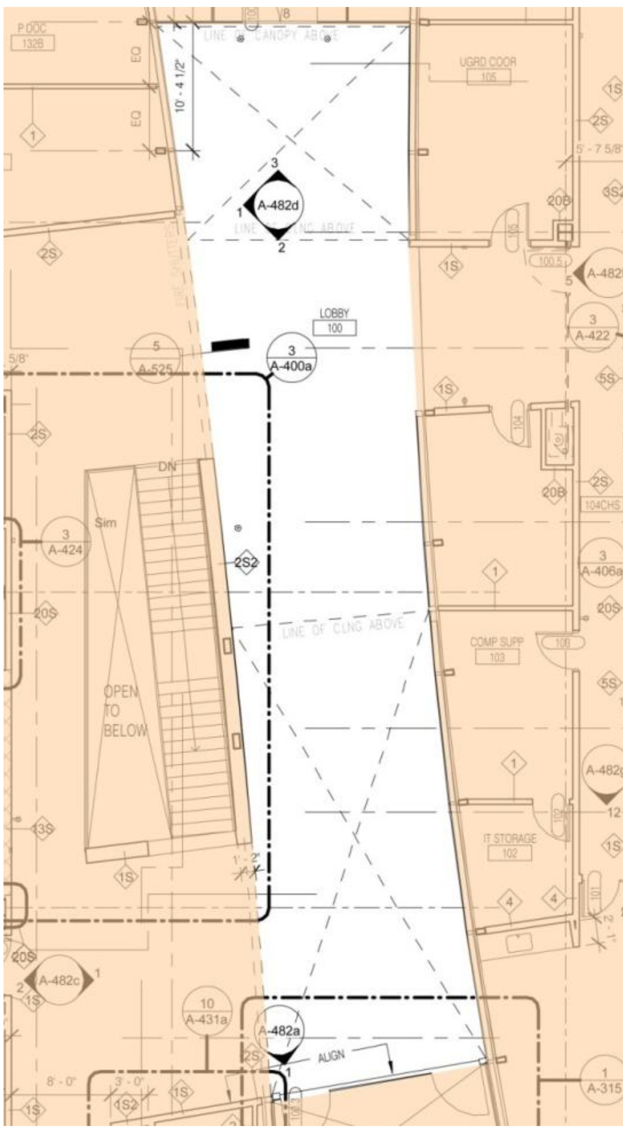
VIEW FROM ABOVE TO SHOW SPACING OF FIXTURE TYPE AR

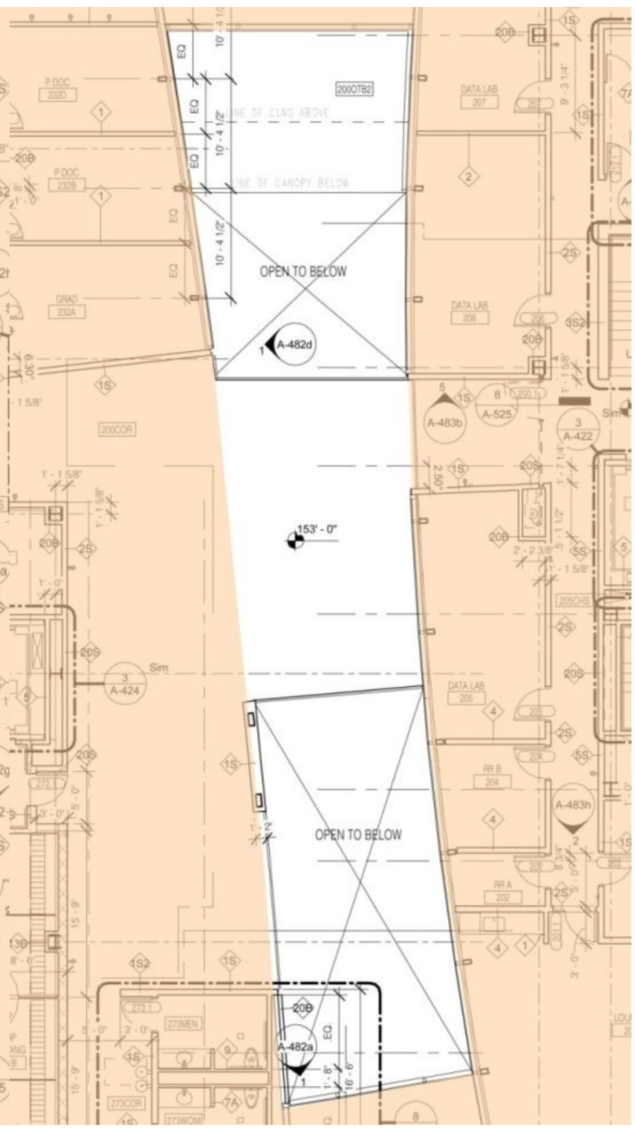
Circulation Space | **Lobby |** Three Schematic Design Concepts

Existing Conditions

Description of Space

This space brings both the Neuroscience and Psychology buildings together. It fills the gap and ties the architecture of both buildings connecting physically the science departments and bridging the exterior to the interior. Geometrically, it resembles the Streicker Bridge shown below which also provides a pedestrian connection between science facilities and is adjacent to the complex. It has curved walls on both sides and is capped by two vestibules on the north and south entrances. The lobby is two stories high and the first floor is more of a reception and circulation area while the second is a lounging space. The brain has millions of connections. Because this building deals with the science of the brain, this space of connection will be a key element in the entire lighting design and will carry the theme of the connection of the entire building.





LOBBY FIRST FLOOR PLAN LOBBY SECOND FLOOR PLAN

Furniture and Surface Materials

Stone covers several walls and the floor making contrast with the glass from the interior curtain wall of both buildings. A key feature is the wooden panel wall. Below is a complete list of the materials and their reflectances:

Material	Reflectance *	Specifications #	Location
Glazing	0.10	08900	Interior and exterior curtain wall
Aluminum framing	0.65	08900	Interior and exterior curtain wall
Painted gypsum wall board	0.70	09250	Part of Walls
Vision glass	0.10	08800	Interior and exterior curtain wall
Opaque glass	0.25	08800	Interior and exterior curtain wall
Glacier Blue Devonian Sandstone, honed finish on all exposed surfaces	0.30	04401	Part of Walls
Stone	0.30	09600	Floor
Wood panels	0.25	06400	Special Wall

*Assumed, some from Figure 1-36 from IESNA Handbook Page 1-22 and some from 3ds Max.

Design Considerations

The lobby is the first impressions visitors get of the building so it must be aesthetically pleasing and the lighting should enhance the architecture. Since it is a transition space from the exterior to the interior, illuminance levels need to make the change comfortable. Walls are the most important part of the lobby and they should be highlighted. Here, some walls are made of stone which will look good grazed while the rest of the walls are glass. The ones that have translucent glass will be able to glow while the clear ones will allow light from adjacent rooms to trespass. Since there was no criteria for lobbies in educational facilities, the criteria for office lobby was used.

Three Schematic Designs

Since the lobby space is the most important space for the theme of connection in the complex, there will be three schematic lighting designs done to represent the idea. All designs will carry the theme of connection and circulation in different ways. The designs will explore guided and random circulation, neuroscience and the millions of brains connections as a theme, psychology and the effects lighting has on humans, and architecture.

Visual Tasks

The main task will be guided circulation. When a visitor walks into this space, he has several options of where he could go. The lighting will help guide visitors in and through the space. Another task is to show the theme of connection with the lighting. This is also a space that will be used for egress in case of emergencies. Therefore, the lighting must comply with safety requirements. As the main entrance to the building, security requirements must also be met.

Qualitative System Performance Considerations

The following lists in order of importance the design issues that are of consideration for a lobby. The ninth edition of The IESNA Lighting Handbook was referenced (Offices; Lobbies, lounges, and reception areas).

Very Important | Appearance of space and luminaires | Coordination between the space, the luminaires, and the architecture can produce visually appealing spaces leaving a positive impression on visitors. Since the architecture is modern and interesting, the fixtures should either appear invisible or complement the architectural design while guiding pedestrians through the building.

Important | Color appearance and color contrast | Usually the lobby has the most expensive finishes and surfaces. To render their color appearance properly, lamps must have a good CRI. This will enhance the first impression of the building.

Important | Direct glare | Direct glare is uncomfortable. The lighting should provide a safe transition from the outside to the inside by not blinding the pedestrians as they enter the building. Overhead glare is also annoying but since people will be circulating through the space, the effects of it will not be too bothersome. To minimize glare, luminaires luminances should not more than 100 times of those of the surrounding surfaces.

Important | Light distribution on surfaces | Patterns of light and shadows cause discomfort and affect visibility. Therefore, uniform light distribution is desirable and luminances levels should be within 3:1 ratio for different surfaces within the room.

Important | Luminances of room surfaces | Most wall surfaces on the lobby have low reflectances; therefore, more light will be needed for them to have higher luminances.

Important | Modeling of faces or objects | As a circulation space, the lobby will be full of people. Without good modeling of faces, they will look flat and unattractive. The lighting should make people feel and look better. Modeling of objects helps reveal the shape, depth, and texture. One of the main walls in the lobby is made of stone and the lighting should add depth by enhancing its texture. Modeling of faces is also important for security reasons.

Important | Surface characteristics | Surfaces have a profound effect on the interaction between the light and the space. Therefore, the lighting designers should coordinate with the architect to select building material and lighting systems that complement each other and achieve a good impression on the visitors.

Important | Illuminance (vertical) | In a lobby, even though the circulation plane is horizontal, people look at vertical surfaces to see where they are headed. Vertical illuminance highlights these surfaces. Also, the walls are the most important feature of the lobby and their plane of illuminance is vertical.

Quantitative System Performance Considerations

Illuminance (horizontal) | 10fc (100lux)

Illuminance (vertical) | 3fc (30lux)

Reflectances | The IESNA Handbook lists no specific criteria dealing with reflectances of surfaces in a lobby.

Luminance ratios | Since the lobby is next to the exterior, the luminance ratio from the interior to exterior varies with the time of day. During the daytime, the interior walls need to be brighter to be perceived from the outside, while at night the luminance levels should greatly decrease. There are no specific luminance ratios for a lobby listed in the IESNA handbook to use as criteria.

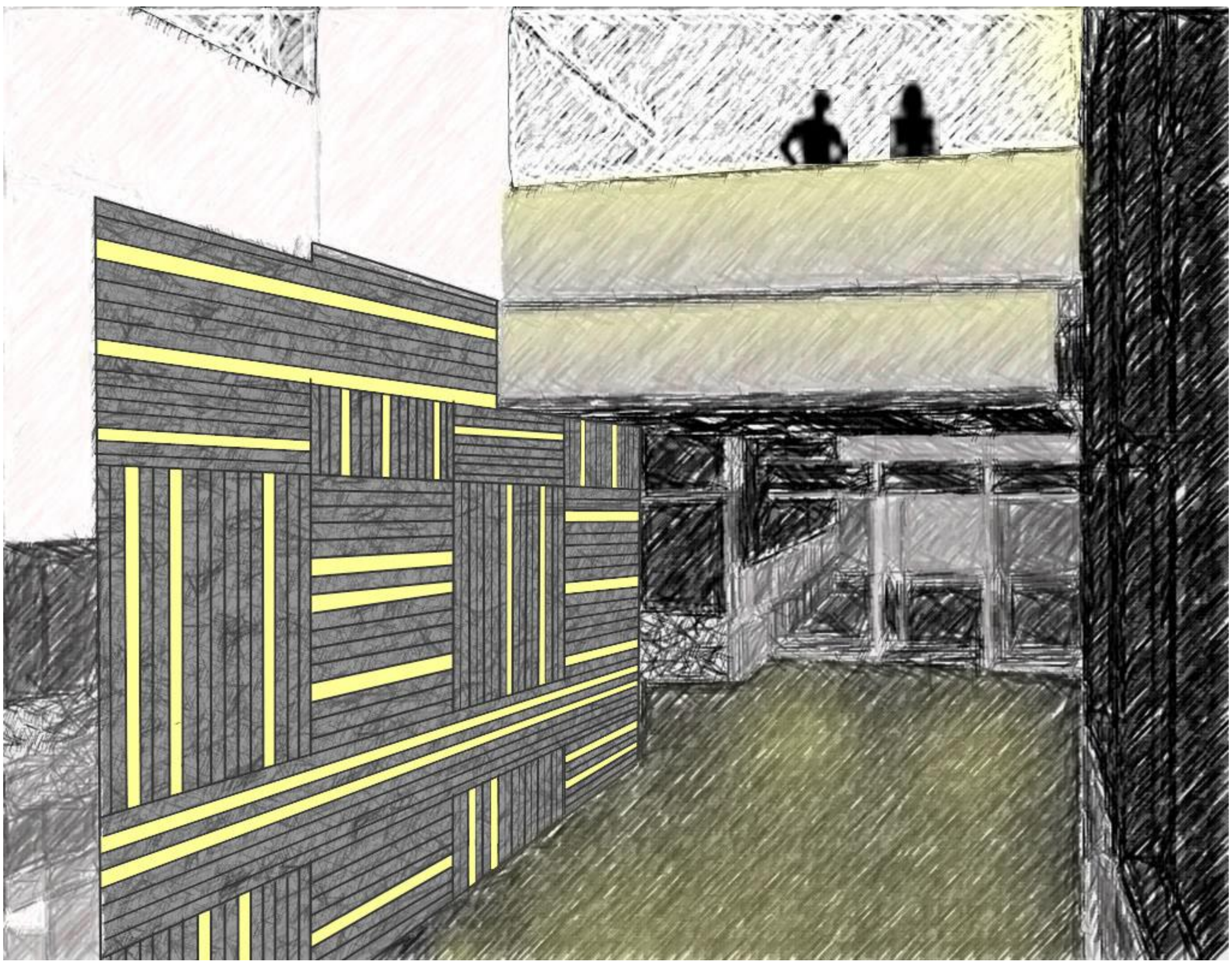
Energy

ASHRAE 90.1 2004
Building Area Method Lighting Power Densities, School/University | 1.2 W/sq.ft.
Space-by-Space Method Lighting Power Densities, Lobby | 1.3 W/sq.ft.

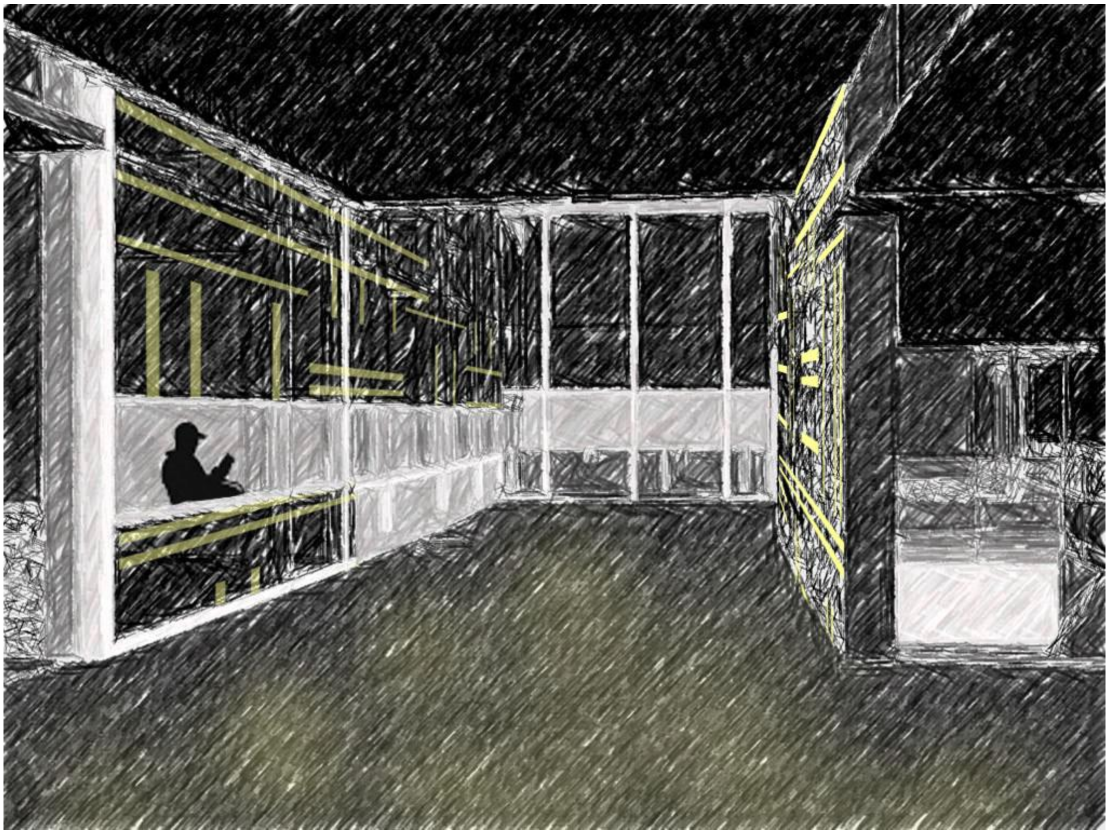
Lighting Redesign

Lighting Solutions

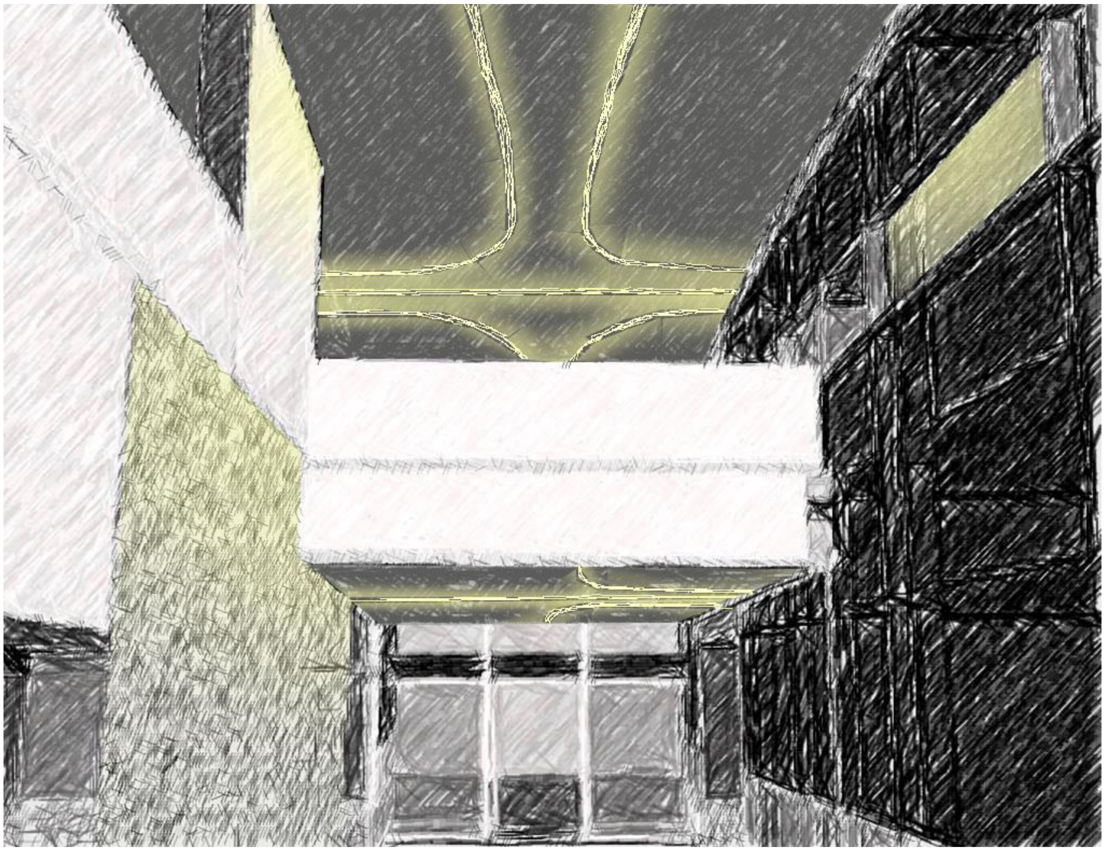
To add interest, exalt the architecture, and promote circulation, three schematic designs were created for the Lobby space. The first was based on architecture and it highlights architectural masses like the crossing bridge on the second level and the ceiling. The main focus is on the stone wall where lights are integrated into the woodwork at random places and they interact with people passing by. This creates an effect of ***static motion*** while encouraging interactive circulation. The material opposite to the wood is glass, both translucent and clear, so it will reflect the effects happening on the wood wall creating ***mirroring opposites****.* The second schematic design was based on Neuroscience. Still highlighting vertical elements and providing enough light for circulation, the main focus is now the ceiling. With curving strips of light that randomly light up in a continuous motion mimicking synaptic ***connections*** and encouraging guided circulation. The third schematic design was based on psychology and the Flynn impressions of Openness and Enclosure. Higher light levels and peripheral emphasize attract the occupants while darker space repel them indirectly promoting circulation.



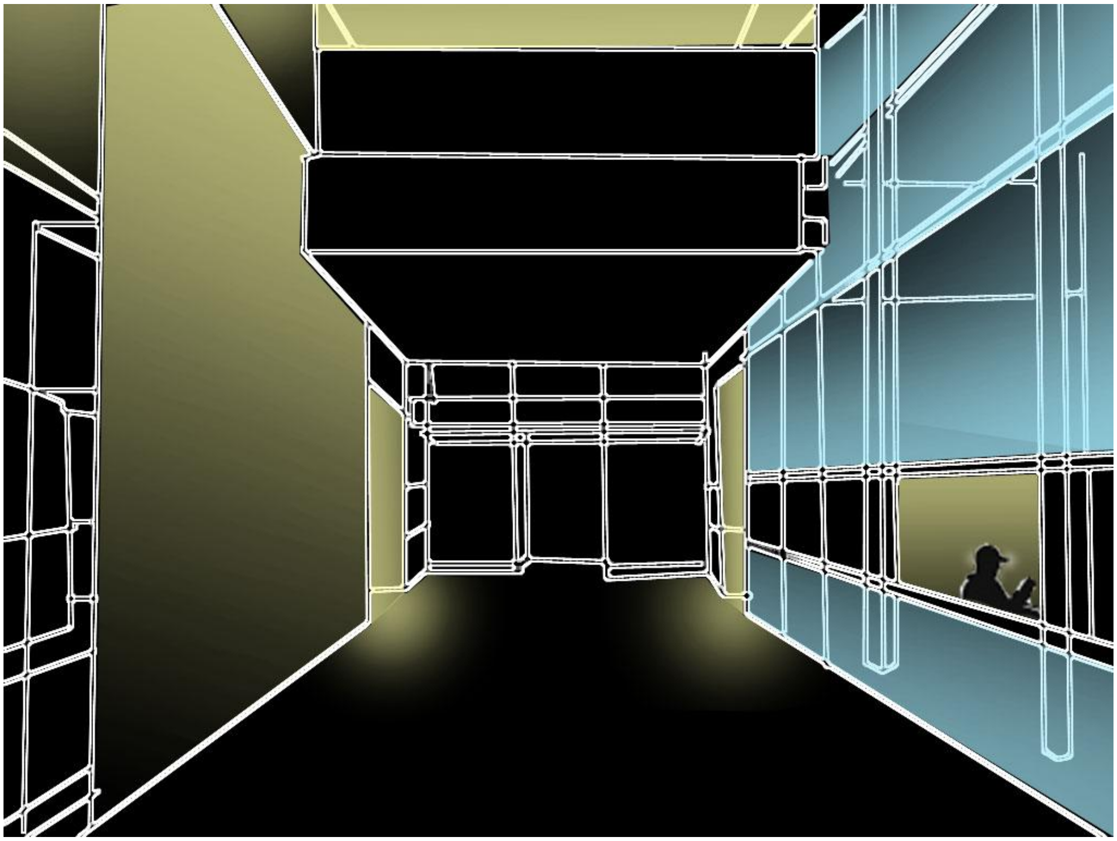
CONCEPTUAL SKETCH, FIRST SCHEMATIC DESIGN: ARCHITECTURE



CONCEPTUAL SKETCH, FIRST SCHEMATIC DESIGN: ARCHITECTURE



CONCEPTUAL SKETCH, SECOND SCHEMATIC DESIGN: NEUROSCIENCE



CONCEPTUAL SKETCH, THIRD SCHEMATIC DESIGN: PSYCHOLOGY

For the final design, a combination of all three schematic designs was selected. From the first schematic design, the ceiling was illuminated as well as some walls while keeping the main attention on the wooden wall. From the second, a line a of light was placed on the first floor ceiling for guided circulation on this floor while providing required levels on the floor. From the third, high levels on the ceiling influence you to look above and indirectly guide you throughout the space. The entrances to the corridors that leave from this central space also have higher levels to attract attention and serve as guidance.

Controls

The general lobby lighting will be ON probably all the time, therefore no time-clock setting is necessary. However, for the decorative elements, such as the in-ground specialty wall grazer and the recessed second floor wall grazers, do not need to be on during the daytime. When sunlight is coming in, the levels of these grazer elements will most likely not be enough to be noticeable. Therefore, these zones will be on time-clock capabilities like the north entrance and will turn ON/OFF simultaneously.

Summary Performance Evaluation

Overall the new lighting design works adequately to meet the most important criterion which is safe circulation with an average of 10fc. Also, it enhances the space by bringing attention to important architectural features, such as key walls and the ceiling. It provided guided circulation because the wooden wall encourages movement and the first level ceiling lighting points you in possible direction. The lit ceiling draws the attention up to tell the users that there are multiple floors in the building.

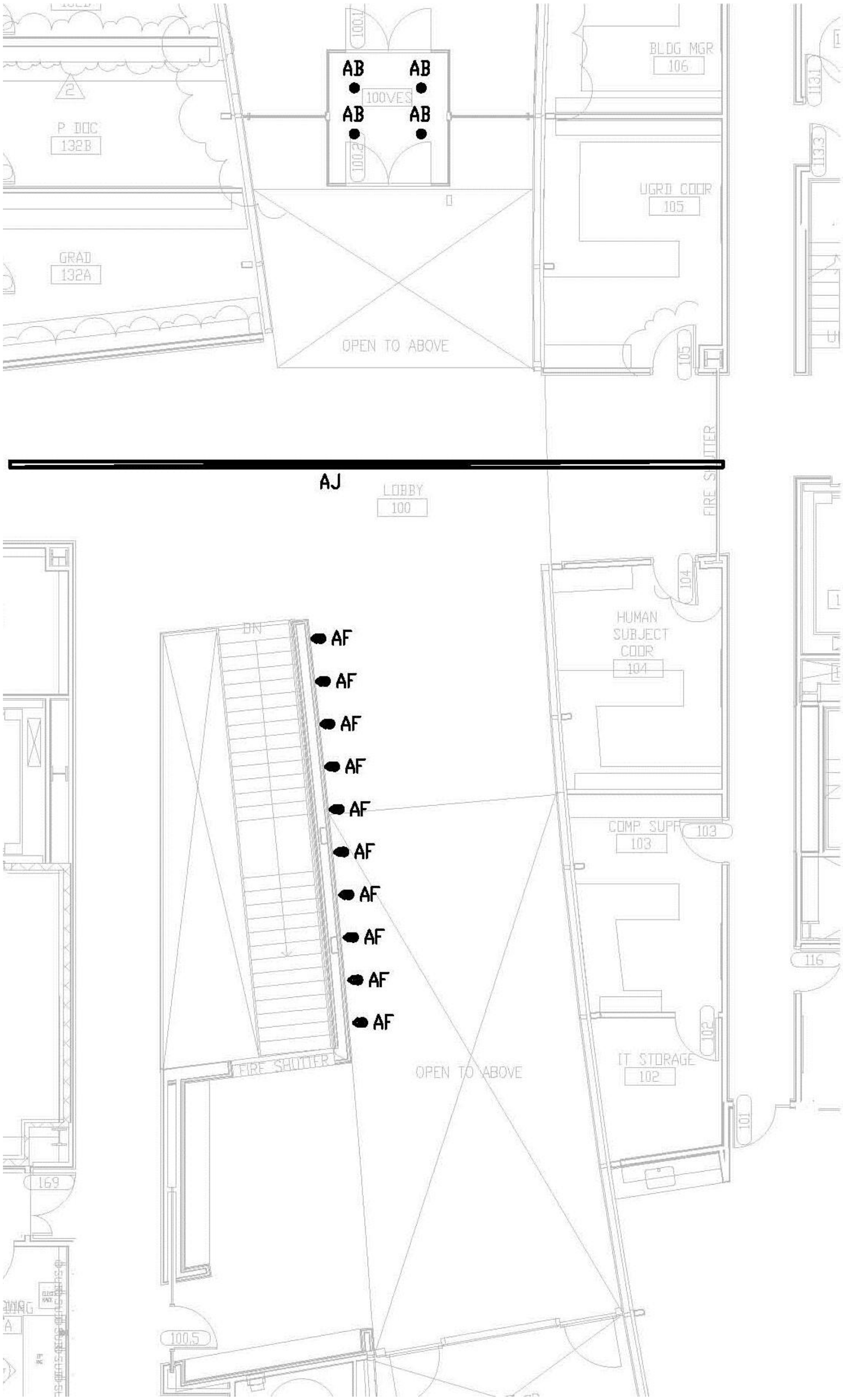
Documentation

Lighting Schedule / Ballast Schedule

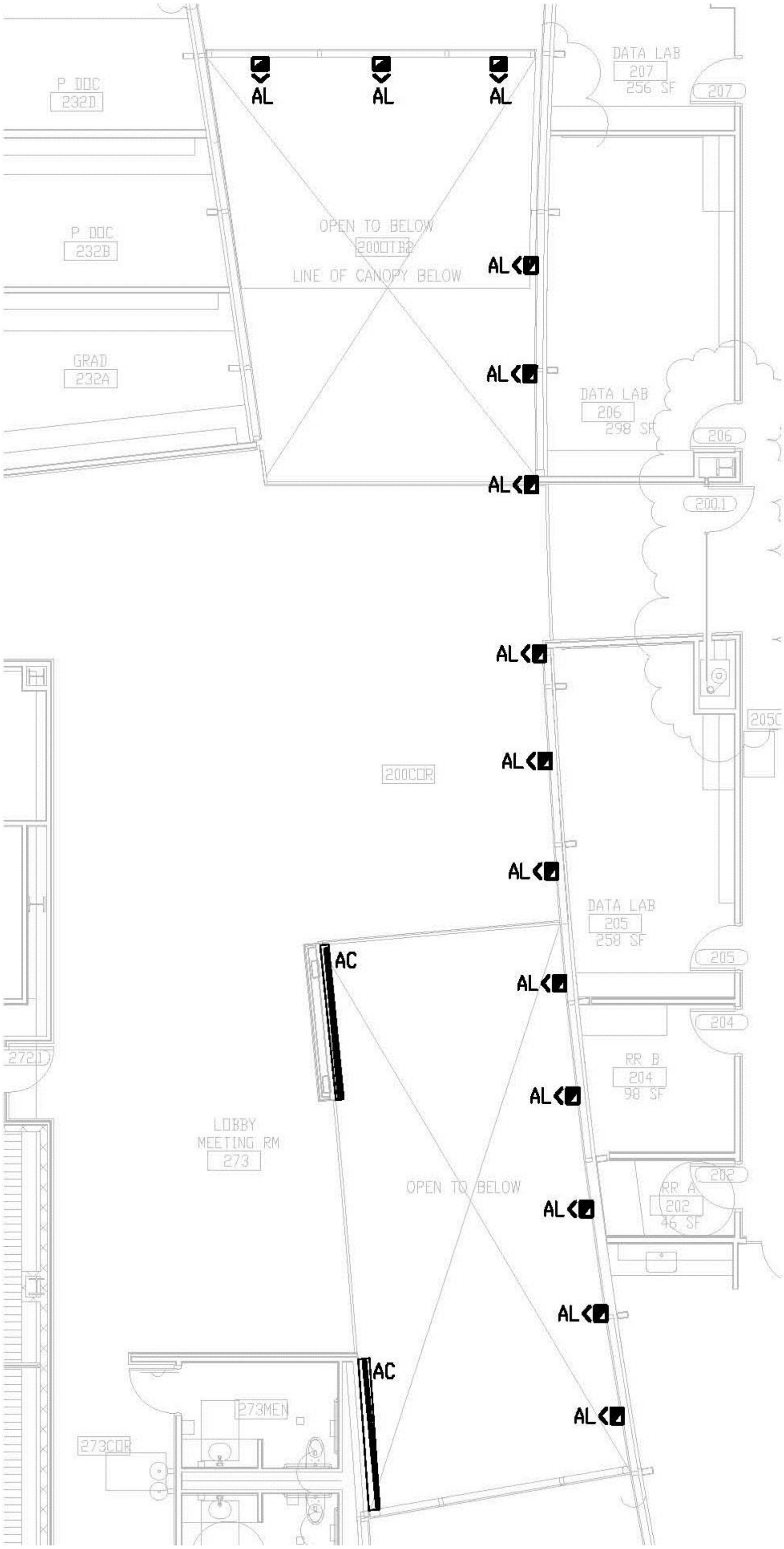
Type	Description	Lamp	Watt	Volt	Mfr	Catalog #
AC	Surface mounted LED strip approximately 0.75"x0.75" in cross section and incremental nominal lengths ranging from 6" to 96" with extruded aluminum housing and acrylic optics, 96W driver supplied, 3000k. Consult factory for high CRI option availability.	High CRI option LED	2.92 W/lf	277	Cooper IO	0.03.1.3k.45.101. 1.XX.2.277V
AD	Surface mounted high-performance LED grazing fixture , 1.5" diameter by 2.1" high and 1ft increments with die-cast aluminum white powder coated finish housing and polycarbonate lens	LED 83CRI	13.5	277	Color Kinetics	eW Fuse Powercore 3000K, 10 by 60 degree beam angle
AF	Recessed in-ground low-voltage halogen wall-washer with cast aluminum body and outer casing and double tempered glass and nominal 5" diameter with integral electronic transformer.	PHILIPS 10W/T 3/12V	10	12-277	iGuzzini	I.B001-277-13
AJ	Fully recessed and flangeless linear fluorescent slotlight nominal 6" wide with extruded aluminum housing, powder coated high-reflectance which finish, and joiner system allowing uniform appearance with frosted acrylic lens. Lengths as required by architecture.	PHILIPS F28T5/ 835/AL TO 85CRI	30	277	Zumtobel	SLR6NX-XX-1285-XX-OLP-DX
AL	Surface wall mounted elliptipar metal halide ceiling uplight mounted to the mullions of the exterior façade inside the lobby with bright clear anodized aluminum reflector with mill finish aluminum door and end plates and black yoke/mounting plate and remote electronic ballast.	PHILIPS CDM15 0/T6/9 42 96CRI	150	277	The Lighting Quotient	1403-150G-W-00-2-00-0

Type	Location	PF	Input Current	Input Wattage	Lamp Wattage	Other	BF
AC		1.00		2.92 W/lf	2.92 W/lf		1
AD		1.00		13.5	13.5		1
AF		1		10	10		1
AJ	page 13-3 GE	0.92	0.17	43		T5 High Efficiency - Programmed Start	1.22
AL	page 18-14 GE	0.9	0.7	186		86718 - GEM150MLTLC3D-5	1

Lighting Plans

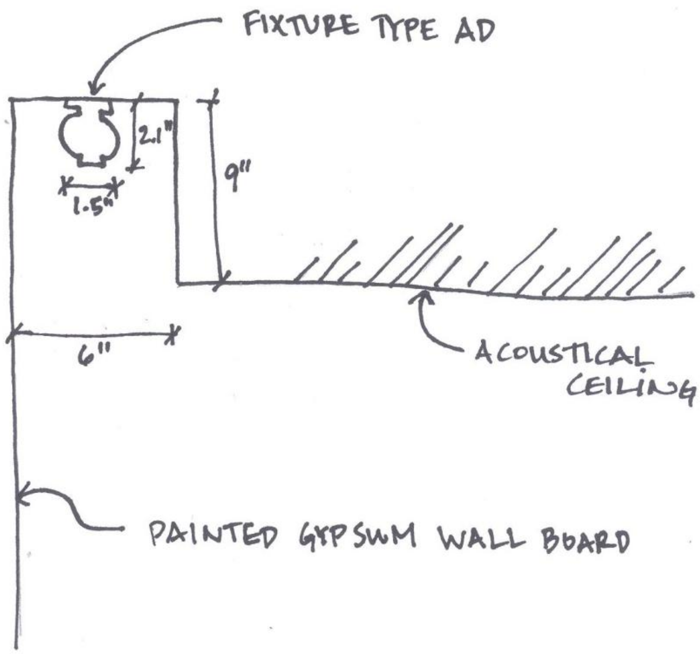


REFER TO APPENDIX L FOR FULL-SIZE DRAWING AND SCALE



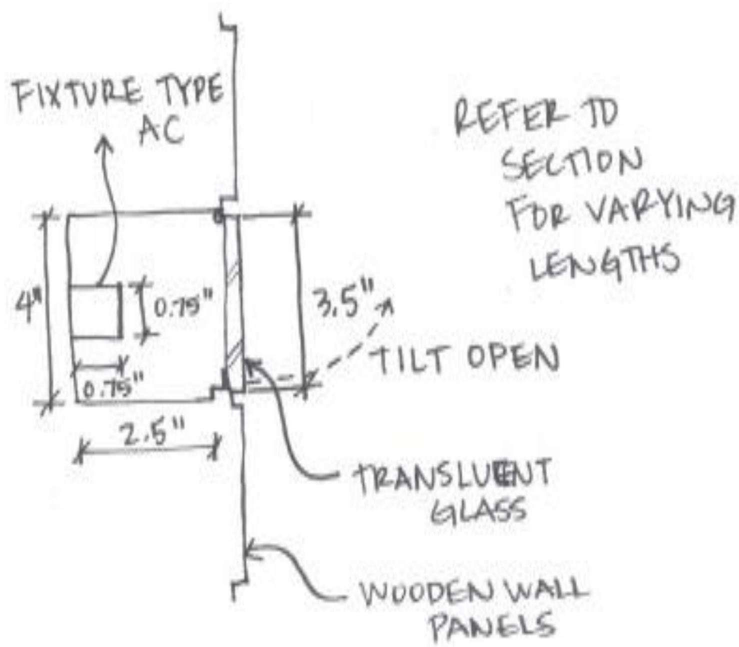
REFER TO APPENDIX L FOR FULL-SIZE DRAWING AND SCALE

Mounting Details



LOBBY COVE DETAIL

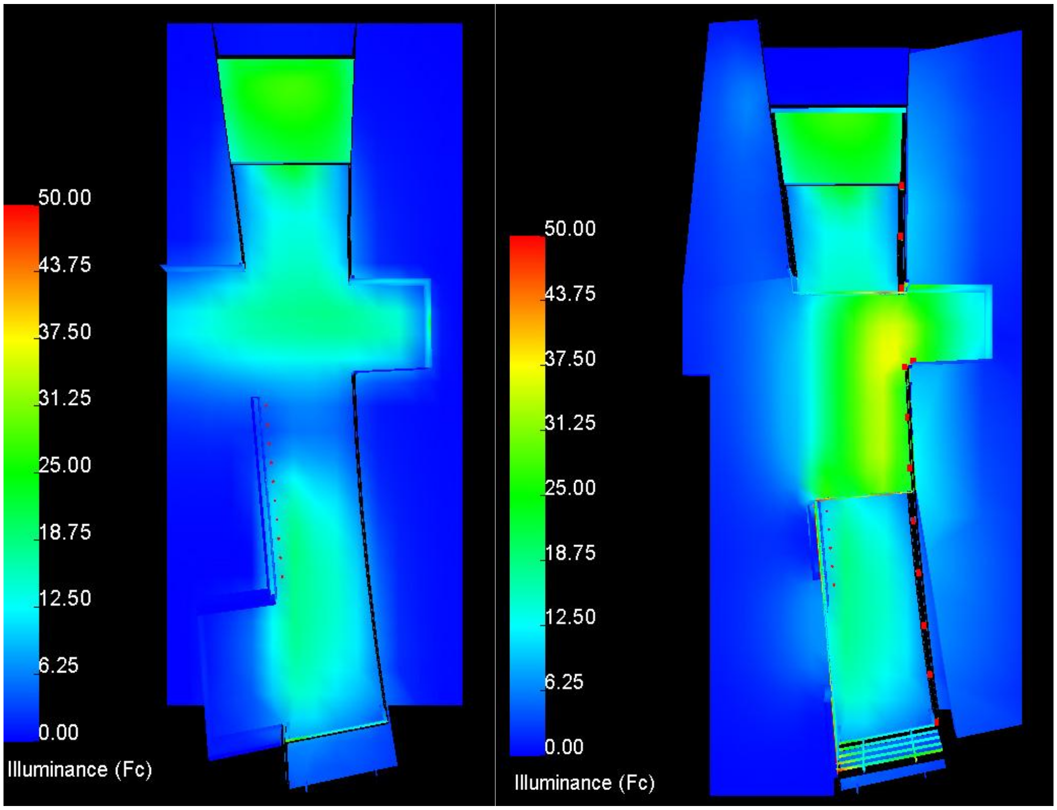
SCALE: NTS



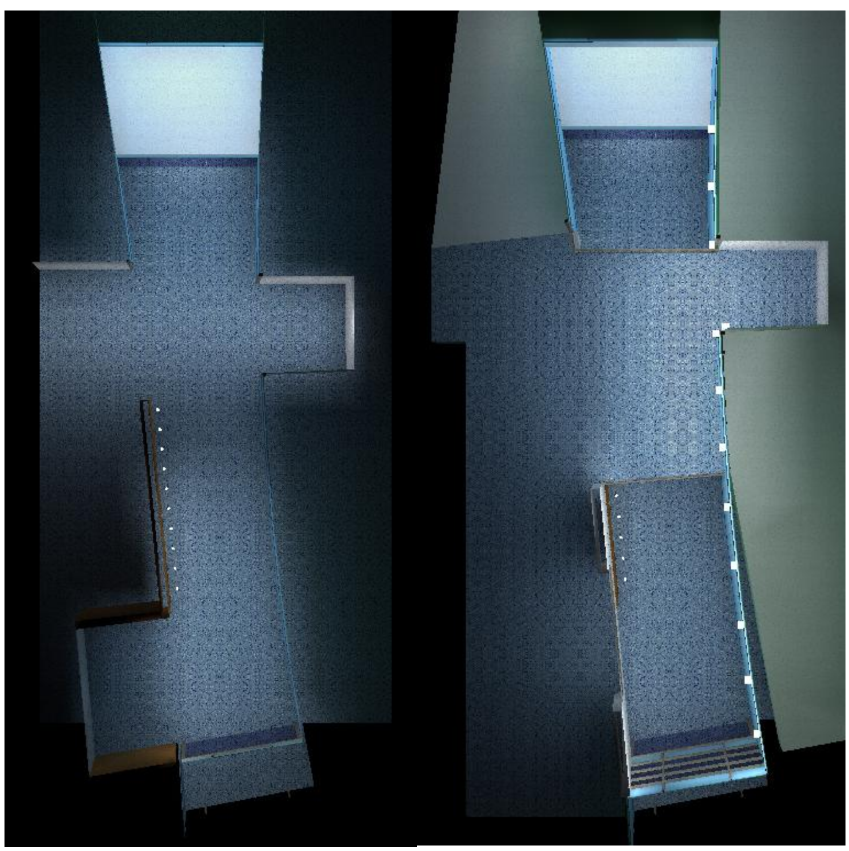
LOBBY WOODEN WALL DETAIL

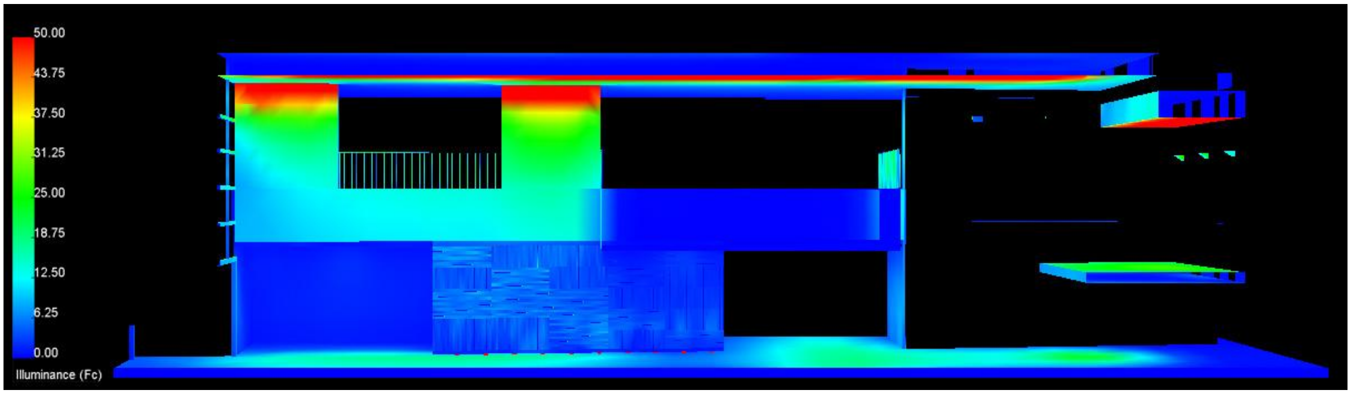
SCALE: NTS

Visual Performance | Visual Quality



PLAN VIEW IN PSEUDOCOLOR AND MATERIAL MODE FROM AGI32





ELEVATION VIEW LOOKING TOWARDS WOODEN WALL IN PSEUDOCOLOR AND MATERIAL MODE FROM AGI32

Results:

Zone	Average Illuminance	Maximum	Minimum	Max/Min	Coeff. Variation
First Floor	12.69	22.70	4.70	4.83	
Second Floor	26.50	37.10	10.60	3.50	
Ceiling	47.03	176.00	4.20		0.87
Vestibule	20.93	26.00	16.60	1.57	0.14

Light Loss Factor Calculations

Luminaire Type	Lamp Lumen Depreciation	Ballast Factor	Lamp Dirt Depreciation	Total Light Loss Factors
AC	0.70	1.00	0.95	0.67
AD	0.70	1.00	0.95	0.67
AF	1.00	1.00	0.95	0.95
AJ	0.95	1.22	0.95	1.10
AL	0.70	1.00	0.95	0.67

Energy Calculations

	Building Area	Space-by-Space
Allowable LPD (W/sq.ft.)	1.2	1.3
Actual LPD (W/sq.ft.)	0.816	0.816
Percentage	32.028	37.256

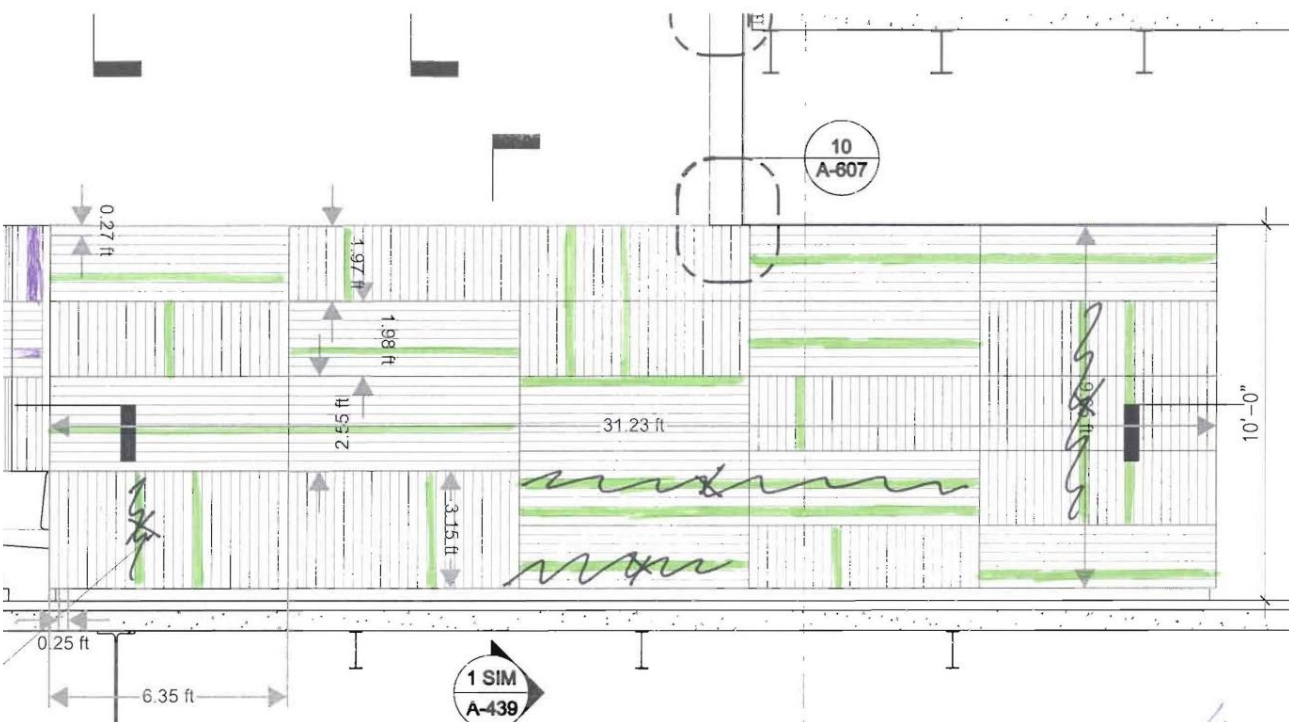
Area (sq.ft.)
3447

Luminaire Type	Watts/ Luminaire	Amount	Total Wattage
AB	18.4	4	73.6
AD	11.9	20	238
AF	10	10	100
AJ	30	5	150
AL	150	15	2250
AC	19.6	25	490
		TOTAL WATTAGE =	2811.6

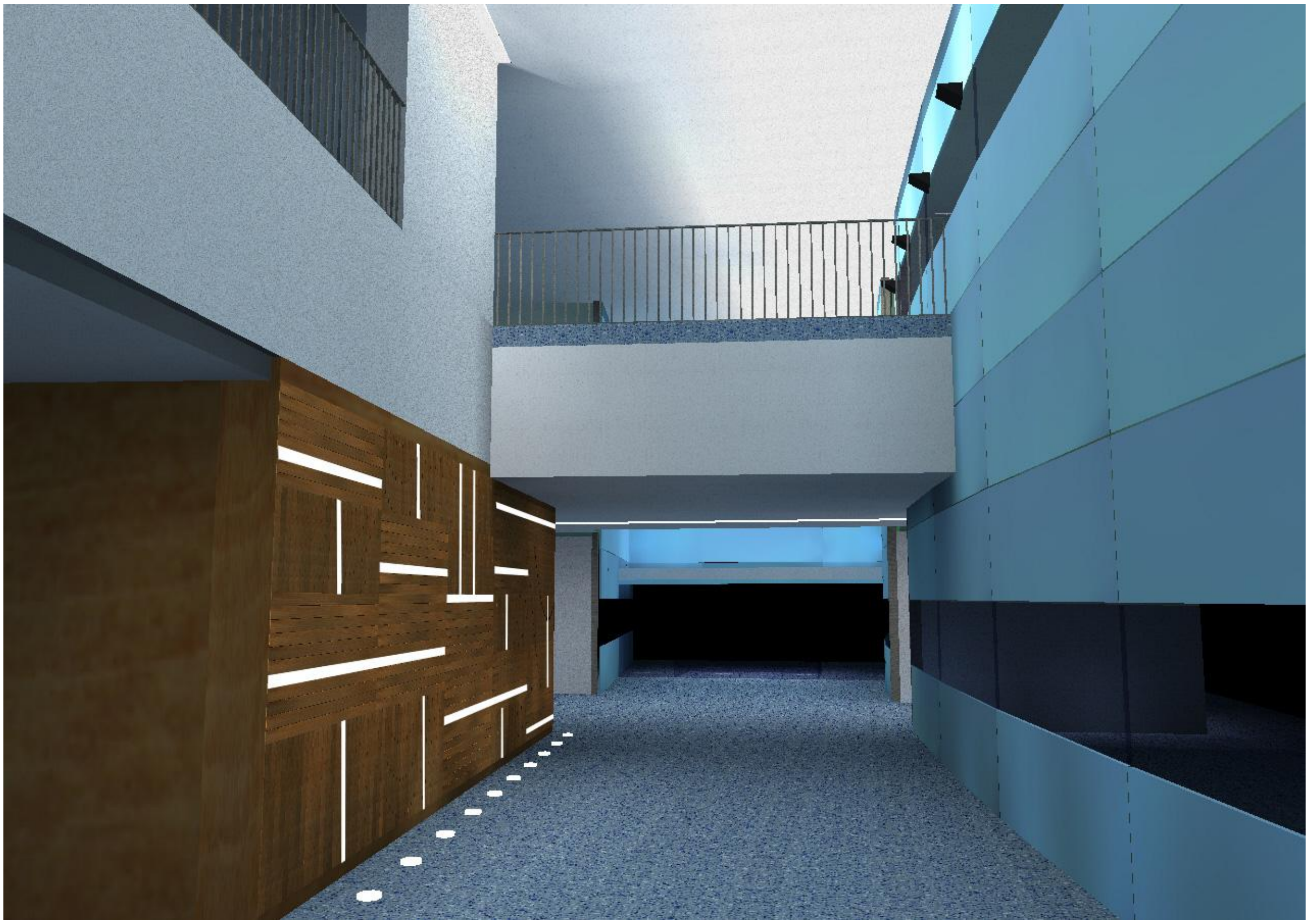
*Decorative Allowance
1.0
0.142
85.785

TOTAL WATTAGE

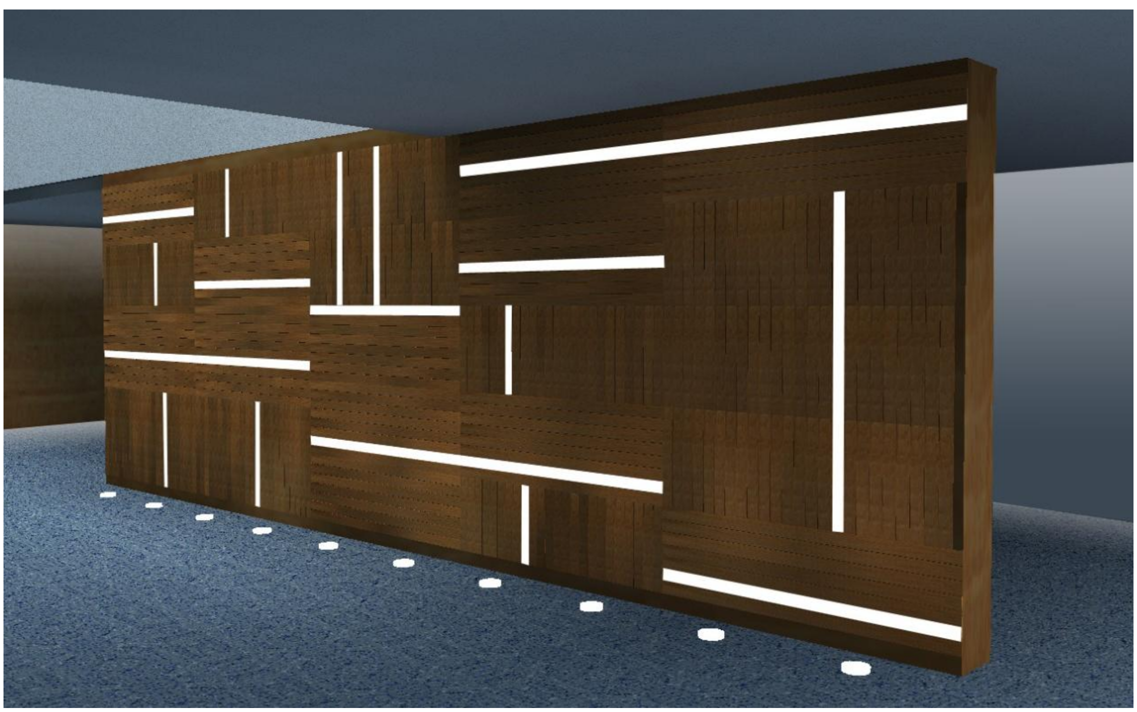
3301.6



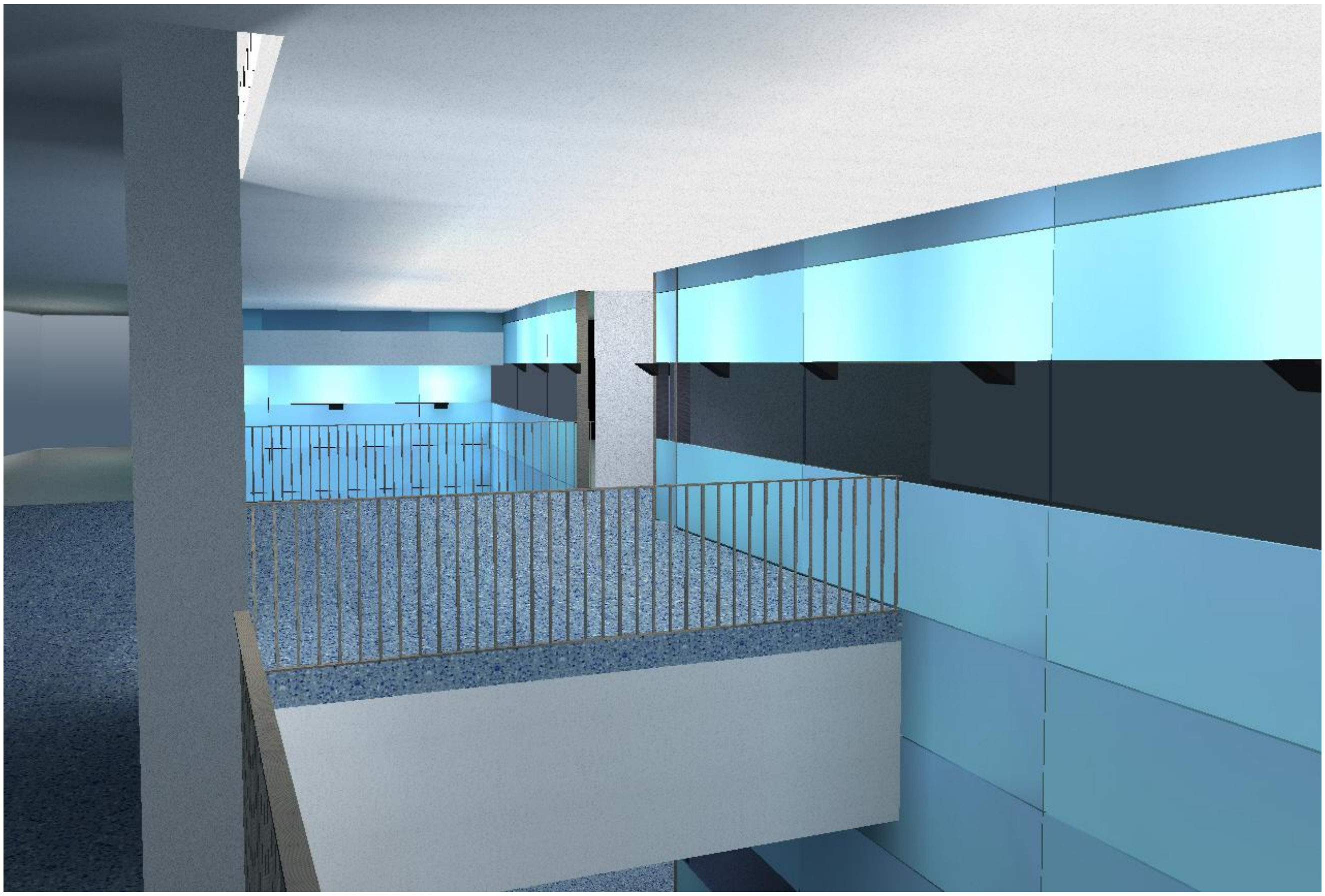
SKETCH OF WOODEN WALL LIGHTING



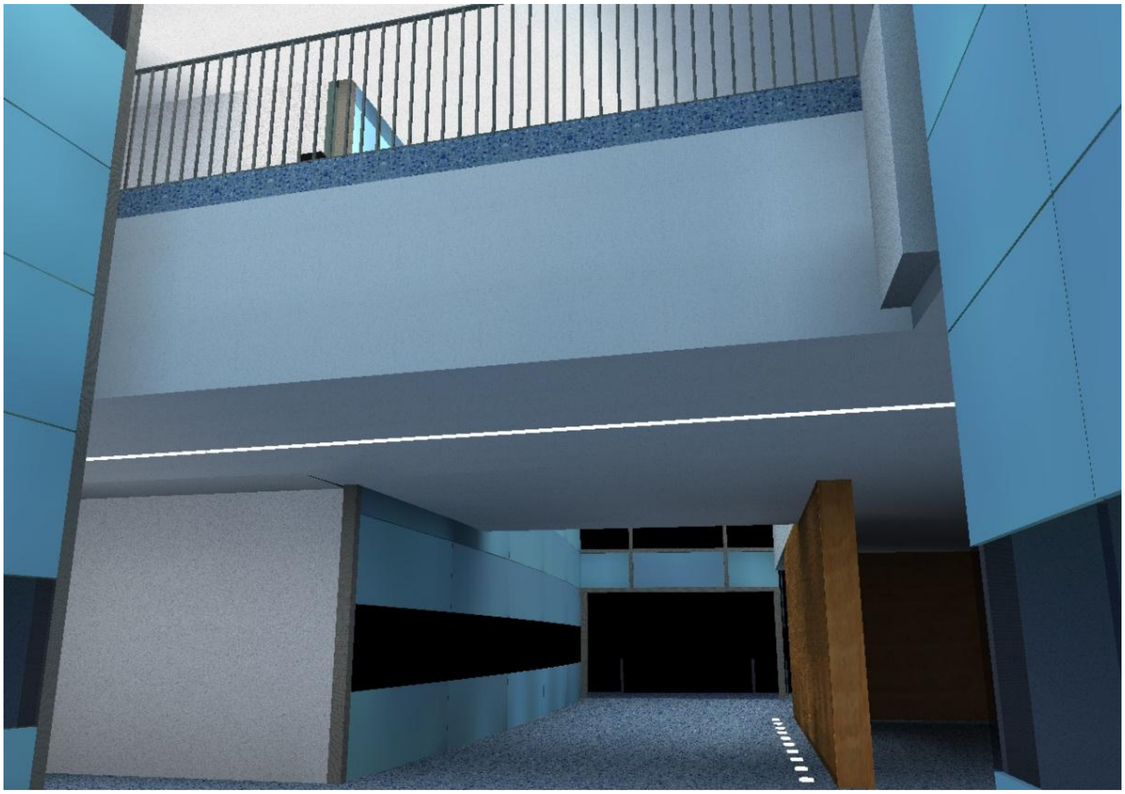
VIEW LOOKING TOWARDS SOUTH ENTRY FROM FIRST LEVEL



WOODEN WALL LIGHTING



VIEW LOOKING TOWARDS SOUTH ENTRY FROM SECOND LEVEL



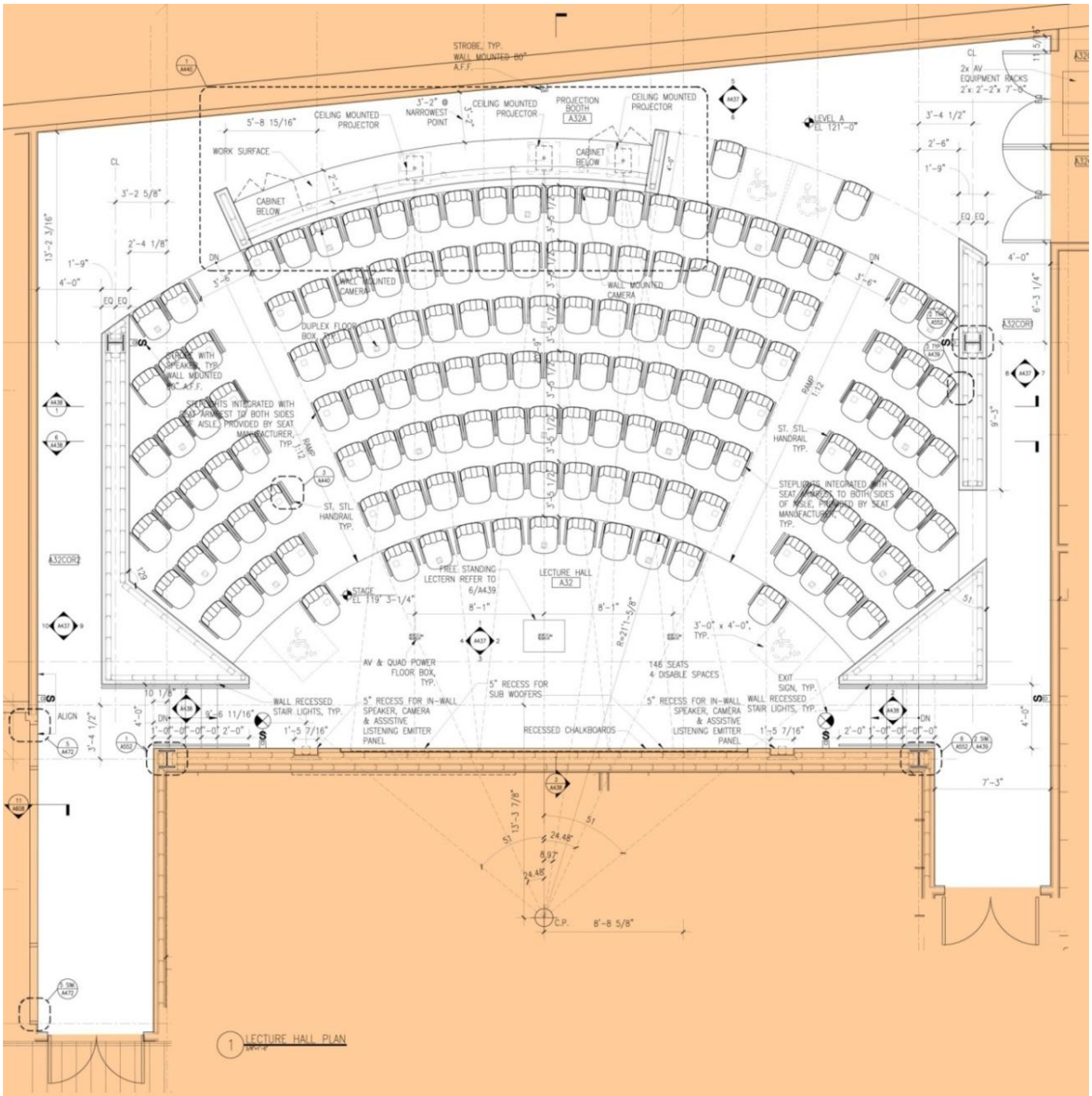
VIEW LOOKING TOWARDS NORTH ENTRY FROM FIRST LEVEL

Large Work Space | Lecture Hall A32

Existing Conditions

Description of Space

Half radially symmetric, the lecture hall has 145 seats with an inclination of 1:12. There is a projector booth on the rear of the room (north) with three ceiling mounted projectors. There are two entrances and the seating area is enclosed by corridors on three sides with the teaching space at the front (south). The main surface of the ceiling and walls is wood. The lecture hall is located in the northeast part of Level A in the Neuroscience portion of the complex.



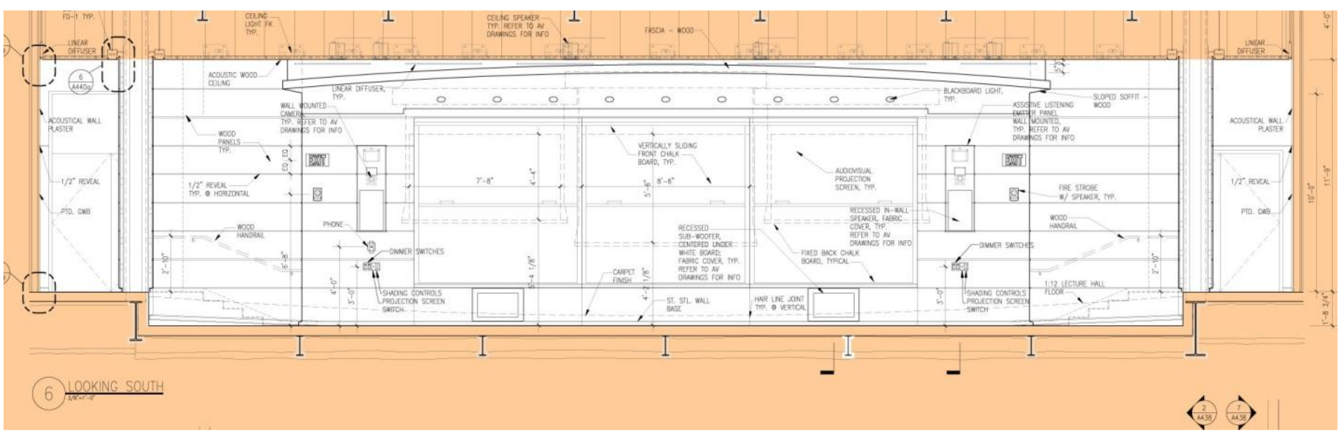
LECTURE HALL, PLAN, NTS

Furniture and Surface Materials

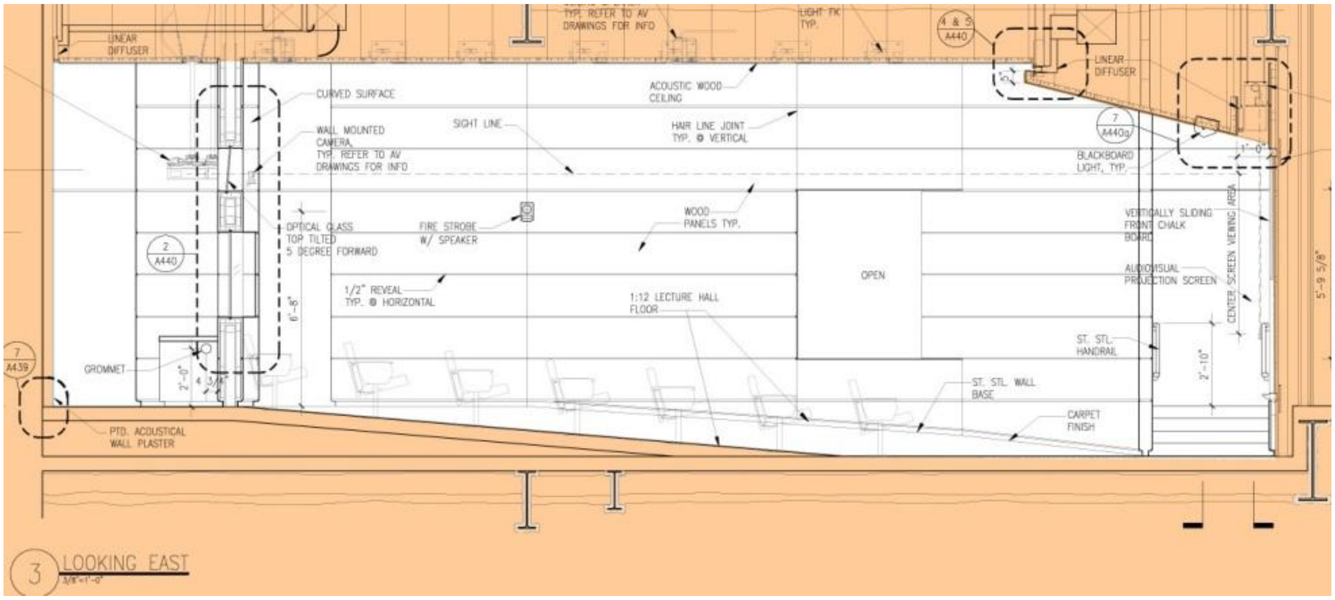
Auditorium chairs are the main furnishing of the lecture hall accompanied by a free standing lectern, chalkboards, and projection booth cabinets. Materials in the room include the following:

Material	Reflectance *	Specifications #	Location
Glazing	0.1	08910	A32COR west elevation
Painted acoustic wall plaster	0.8	09900	A32COR west elevation
Painted gypsum wall board	0.7	09250	A32COR
Wood panels	0.25	06400	Throughout
Acoustic wood ceiling	0.3	06400	Throughout
Carpet, Grama 44025 by Monterey Carpets, Color to be chosen by Architect	0.3	09681	Throughout
Chalk board	0.1		South elevation
Projection screen	0.8		South elevation
Curved glass	0.1	08800	Projection area
Auditorium seats, Irwin Seating Company Allegro Model No. 27.17.80.150, Color chosen by Architect	0.3	12710	Throughout

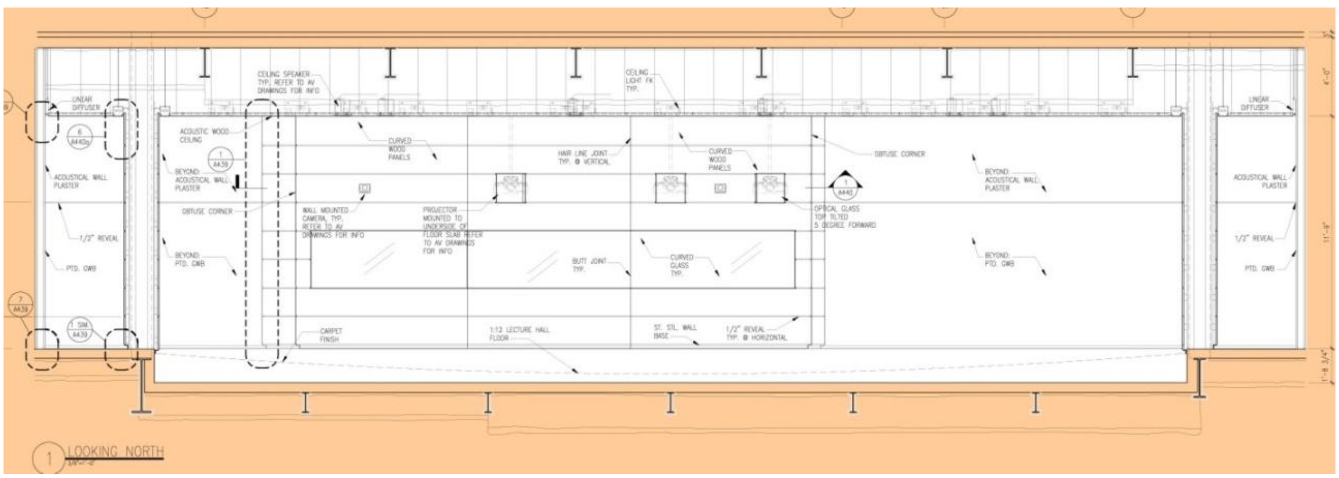
*Assumed, some from Figure 1-36 from IESNA Handbook Page 1-22, others from AGI32



LECTURE HALL, SECTION LOOKING SOUTH, NTS



LECTURE HALL, SECTION LOOKING EAST, NTS



LECTURE HALL, SECTION LOOKING NORTH, NTS

Design Considerations

The objective of the lighting design in an educational environment is to promote the learning processes. Education can be promoted by designing a lighting system that evokes the emotional and psychological responses of the learners making them feel pleasant and comfortable while accurately viewing the visual tasks necessary for learning. In a lecture hall, special attention must be paid to the horizontal illuminance, the vertical illuminance, and the uniformity of the light distribution on the work plane. Specifically in a lecture hall, there must be at least flexibility for two scenarios: one for note-taking/reading and the other for demonstrations. Since many of the surfaces are wood, the lighting should bring out the material with good CRI and warm CCT.

Visual Tasks

Reading and writing are the most important tasks and students are required to adjust rapidly from near to faraway visual tasks. Enough general lighting shall be provided and the recommendations are listed under the quantitative considerations below. Projection onto screen will also occur and the entire audience must be able to see it clearly. To successfully light the speaker/demonstration, directional downlights should be located 40-60 degree angle from the horizontal to the speaker. This minimizes glare and models well the facial expressions.

Qualitative System Performance Considerations

The following lists in order of importance the design issues that are of consideration for a Lecture Hall both for reading and demonstration. The ninth edition of The IESNA Lighting Handbook was referenced (Educational Facility Lighting, Lecture Hall both Reading and Demonstration).

Very Important | Light distribution on a task plane (uniformity) | It is important that the task area have an illuminance 1.5 to 3 times higher than the surroundings but not too much to cause visual fatigue. Uniform light distribution on the task plane increases visibility, comfort, and perception for demonstration settings in the Lecture Hall.

Very Important | Illuminance (horizontal) | Horizontal illuminance is crucial for note-taking and reading, both of which are horizontal tasks. High values of illuminance are necessary for these tasks to be performed diligently and effectively. Below are the values necessaries to achieve this.

Very Important | Illuminance (vertical) | When something is projected on the screen in the front of the lecture room, low illuminance is desirable. On the other hand, when the lecturer is utilizing the board, the audience, even from far away, must be able to see it. The values necessary for this will be listed below.

Important | Direct glare | Glare causes discomfort and distraction. This is something not desirable in a space where the objective is to promote learning and concentration. To minimize glare, luminaires luminances should not more than 100 times of those of the surrounding surfaces.

Important | Light distribution on surfaces | Patterns of light and shadows cause discomfort and affect visibility. Therefore, uniform light distribution is preferred and luminances levels should be within 3:1 ratio for different surfaces within the room.

Important | Points of interest | The main point of interest is the lectern space and the chalkboard and these will be highlighted with illumination when required. If the audience is required to take notes, the lecture hall will be more uniformly lit but there should still be emphasis on the front of the room. When the projector is in use, the light from the projector will be enough to attract attention while maintaining the rest of the space at low illuminance levels.

Important | Reflected glare | Reflected glare reduces task visibility. To reduce it, light sources can be placed on the sides of the task and the ratio of illuminance on the task from the mirror angle relative to the total illuminance on the task should be less than 0.3.

Important | Shadows | Shadows also reduce task visibility. To diminish them, linear or area sources can be used instead of point sources.

Important | Source/task/eye geometry | This relationship is critical for reading and writing. Coordination between the light source and the location of the task must be made.

Important | Appearance of space and luminaires | The lighting should give clues as to where areas of special attention are. Here, special attention should be paid to the front where the lectern is. Light should also enhance the architecture and this space has interestingly textured wooden walls that can be highlighted with illumination. The aesthetics are important for the entire building, designed by a world renowned architect; therefore, the lecture hall should maintain a lighting that carries the aesthetic themes of the building's design.

Very Important | System control and flexibility | Since several different tasks will occur on the Lecture Hall, different light settings are required. There is a necessity for flexibility in the space, as the lighting for a speaker is not the same for projections onto a screen. Flexibility can be achieved with the use of controls and dimmers.

Quantitative System Performance Considerations

The following quantitative levels are recommended by The IESNA Handbook for successful design of a Lecture Hall.

Illuminance (horizontal) | 100fc (1000lux) for demonstration
30fc (300lux) for reading
5fc (50fc) for simple orientation for short visits

Illuminance (vertical) | 50fc (500lux) for demonstration

Reflectances | Walls: Non-specular surfaces with 40-60% reflectance
Wall above luminaires: 80%
Ceiling: >80%, Non-specular
Floor: 25%, Non-specular

Luminance ratios | These ratios are critical for the lecture hall because the eye is constantly shifting from one task with one luminance to a different one. The background also takes an important role as it creates contrast against the task luminance. The luminance of a surface looked directly should not be greater than five times the luminance of the task for good visual performance. Any large area should not exceed three times the luminance of the task. Surfaces immediately adjacent to the task should have a lower luminance than the task but at least 1/3 of it; the closer the better. For good luminance ratios, the reflectances of the surfaces should be increased as well as the light on them.

Between surface looked directly and task:	max 5:1
Between large area and task:	max 3:1
Between adjacent surfaces and task:	lower but at least 1/3

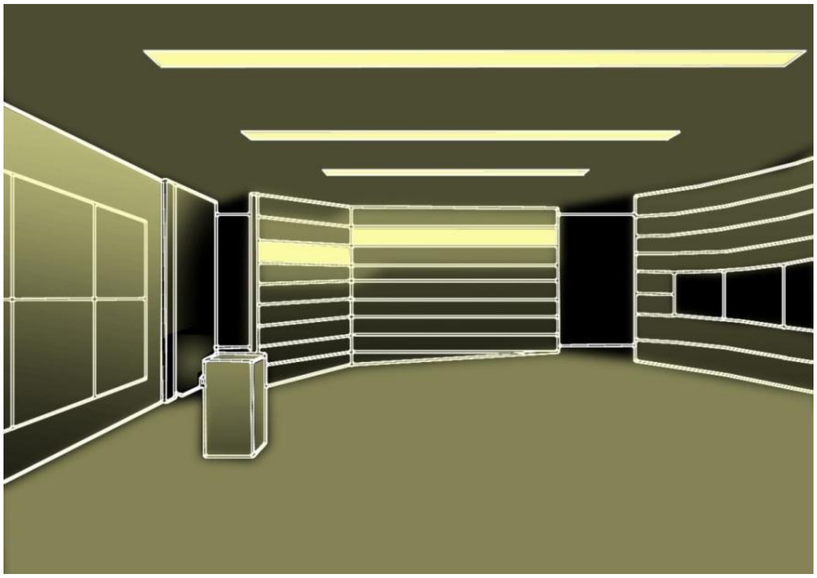
Energy

ASHRAE 90.1 2004
Building Area Method Lighting Power Densities, School/University | 1.2 W/sq.ft.
Space-by-Space Method Lighting Power Densities, Classroom/Lecture | 1.4 W/sq.ft.

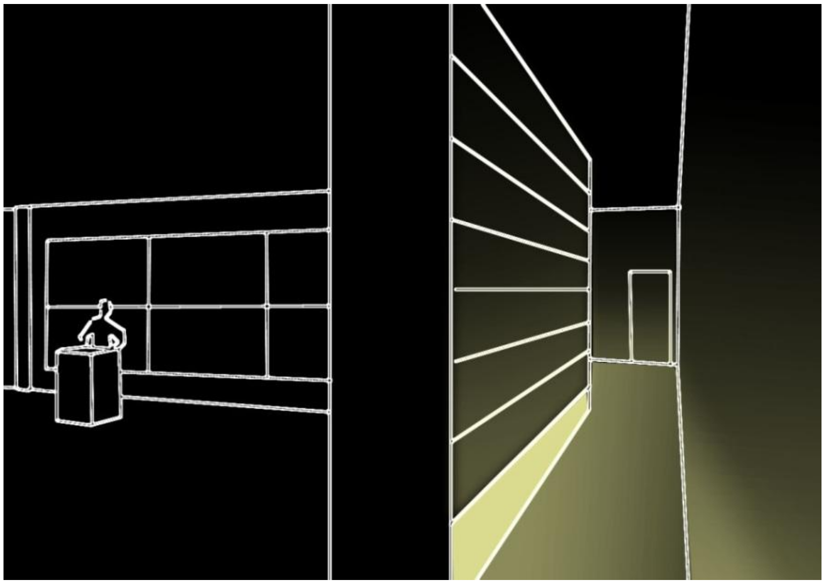
Lighting Redesign

Lighting Solutions

To achieve a more interesting space in the Lecture Hall, the idea was to add lines of light to the side wooden walls as well as to the ceiling. In the end, since the ceiling was re-designed for the architectural breadth, the lines in the ceiling shifter to a radial pattern (refer to architectural breadth for more information). These provide high general levels of illumination for the reading/writing tasks while following of ***static motion*** and ***mirroring opposites*** concepts. The diffuse nature of the acrylic frosted lens will remove problems of veiling reflections, glare, and shadows. The front wall with the chalkboards was washed to reach higher levels than the rest of the space and act as a point of attention. When the projector screen is used, controls will allow for dimming and turning off of the front wall-washer. The corridor will also have a linear light element to account for circulation without interfering with the seating area of the space. Step lighting will provide the adequate levels for safety.



CONCEPTUAL SKETCH, SEATING AREA



CONCEPTUAL SKETCH, CORRIDOR

Controls

Lutron Grafik Eye control system was specified for the Lecture Hall. Since the space must satisfy the needs for several scenarios, this seemed like a good solution. There will be six control zones and three scenes. The control zones are grouped in the following fashion: step light, corridors, projection booth, new ceiling coves, lectern area, and chalkboard area. The scenes are reading/writing/demonstration, projection, and enter/exit mode. All fixtures will be dimmable and they are all fluorescent 0-10V with the exception of the step lights (Fixture Type AG) which are incandescent. The control station will be by the chalkboard near the lecturer so that he can control the scenes. There will also be switches located at both entrances which will control the corridor, step lights, and the cove lights throughout to provide safe travel to the lecture hall. The system will also be connected to a time-clock device to turn on/off the lights at the appropriate times. Refer to Appendix C for One Line Diagram, Bill of Materials, Button Engraving Form, Load Schedule, Preset Dimming Control, and Full-size Image.

GRAFIK Eye. QS　　　　Load Schedule

Model Number: QSGRJ-6P

Phase Control Zones

Zone	Name	Load Type	No. Fixtures	Wattage/Fixture	Total Wattage
1	chalkboard	Fluorescent 0-10V	11	17	187
2	lectern	Fluorescent 0-10V	6	17	102
3	lines coves +	Fluorescent 0-10V	28	57	1596
4	proj booth +	Fluorescent 0-10V	6	18	108
5	corridor	Fluorescent 0-10V	3	57	171
6	steplights	Inc / Hal	33	10	330

Summary Performance Evaluation

Overall the new lighting design works adequately to meet the most important criteria. The reading and writing criteria of 30fc was met with an average of 29fc. Focus was drawn to the front stage part of the lecture hall not only with the new ceiling design but also with higher levels of illumination as seen below. The desired 100fc horizontal level for demonstration was not met but it could be done by hiding a theatrical source four fixture in one of the coves if the owner finds that this is a pertinent criterion. Circulation criteria were exceeded as well as higher vertical levels at the chalkboard area.

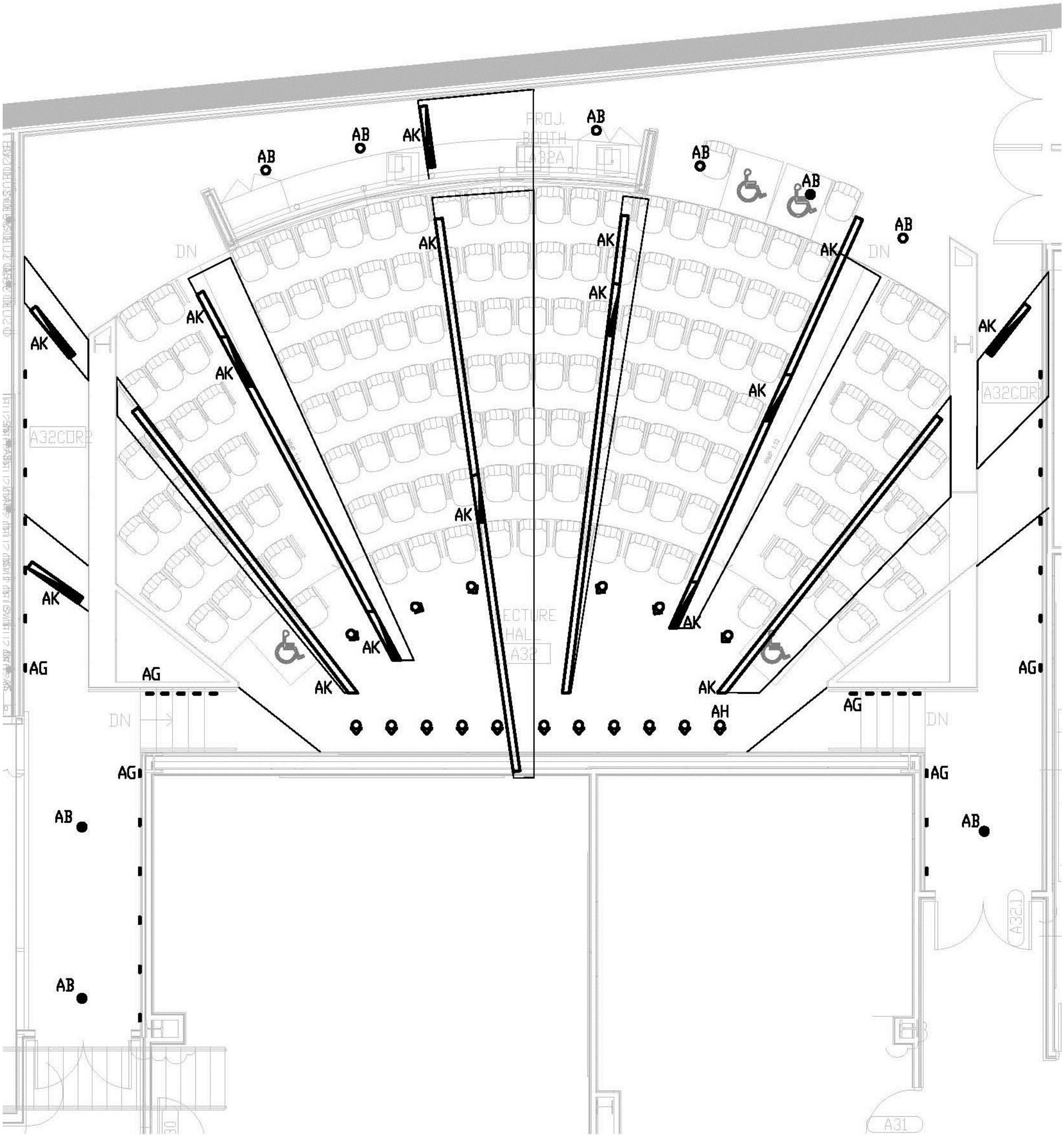
Documentation

Lighting Schedule / Ballast Schedule

Type	Description	Lamp	Watt	Volt	Mfr	Catalog #
AB	Recessed compact fluorescent downlight with 6" nominal diameter aperture with aluminum, bright anodized reflector with plastic, translucent diffuser and integral electronic ballast, 3000k	PHILIPS PL-T 18W/830/4P/AL TO 82CRI	18.4	277/ 120	Edison Price	TRPV 18/6
AG	Recessed low voltage halogen wall luminaire with die-cast aluminum housing with integral wiring compartment, impact resistant satin matte crystal glass, requires a remote Class 2, 12V transformer, nominal 3 in square.	PHILIPS 10W/T3/12V	10	120/ 12	Bega	2303
AH	Recessed compact fluorescent wall-washer with 6" nominal diameter aperture with aluminum, bright anodized reflector with plastic, translucent diffuser and integral electronic ballast, 3000k	(2) PHILIPS PL-T 26W/830/4P/AL TO 82CRI	46	120	Edison Price	WLX 226/6
AK	Fully recessed and flangeless linear fluorescent slotlight nominal 6" wide with extruded aluminum housing, powder coated high-reflectance which finish, and joiner system allowing uniform appearance with frosted acrylic lens. Lengths as required by architecture.	PHILIPS F54T5/ 835/HO/ALTO 85CRI	57	120	Zumtobel	SLR6NX-XX-1545-XX-OLP-DX

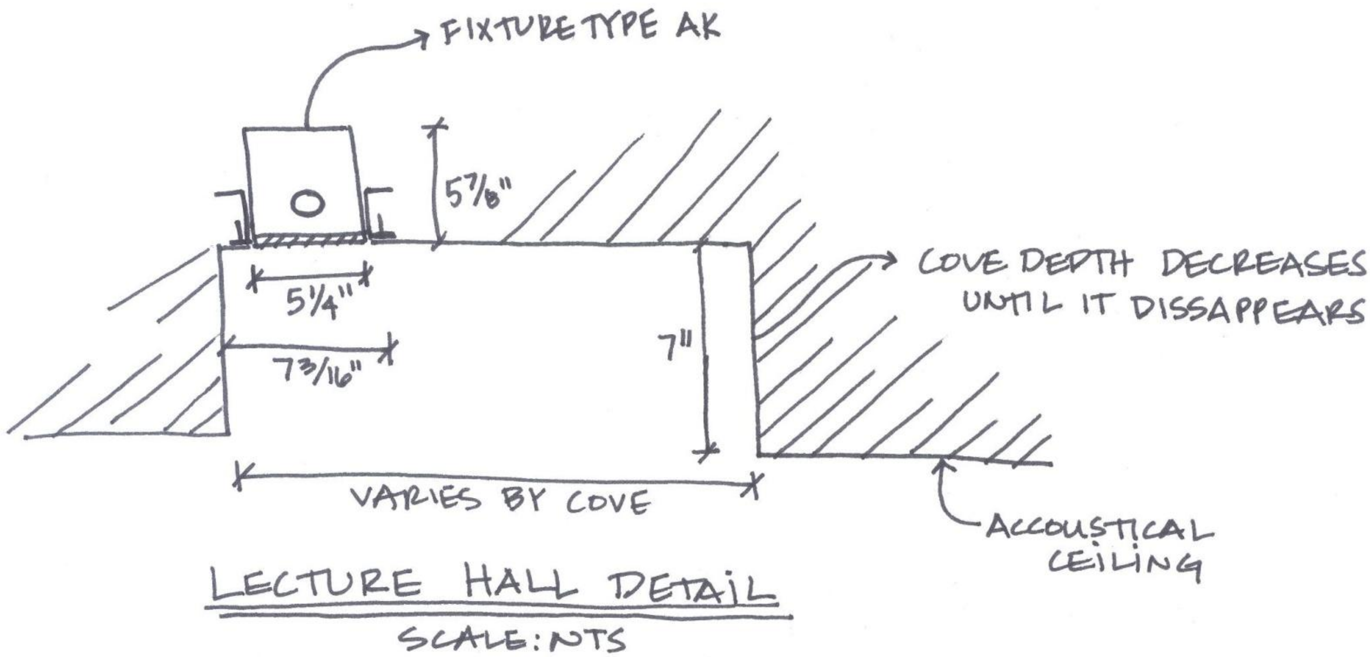
Type	Location	PF	Input Current	Input Wattage	Lamp Wattage	Other	BF
AB	page 17-5 GE catalog	0.97	0.08	20	18	ProLine CFL Electronic Ballasts	1.05
AG		1		10	10		1
AH	page 17-6 GE catalog	0.99	0.2	54	46	ProLine CFL Electronic Ballasts	1
AK	page 13-6 GE	0.97	0.26	71			1.11

Lighting Plans

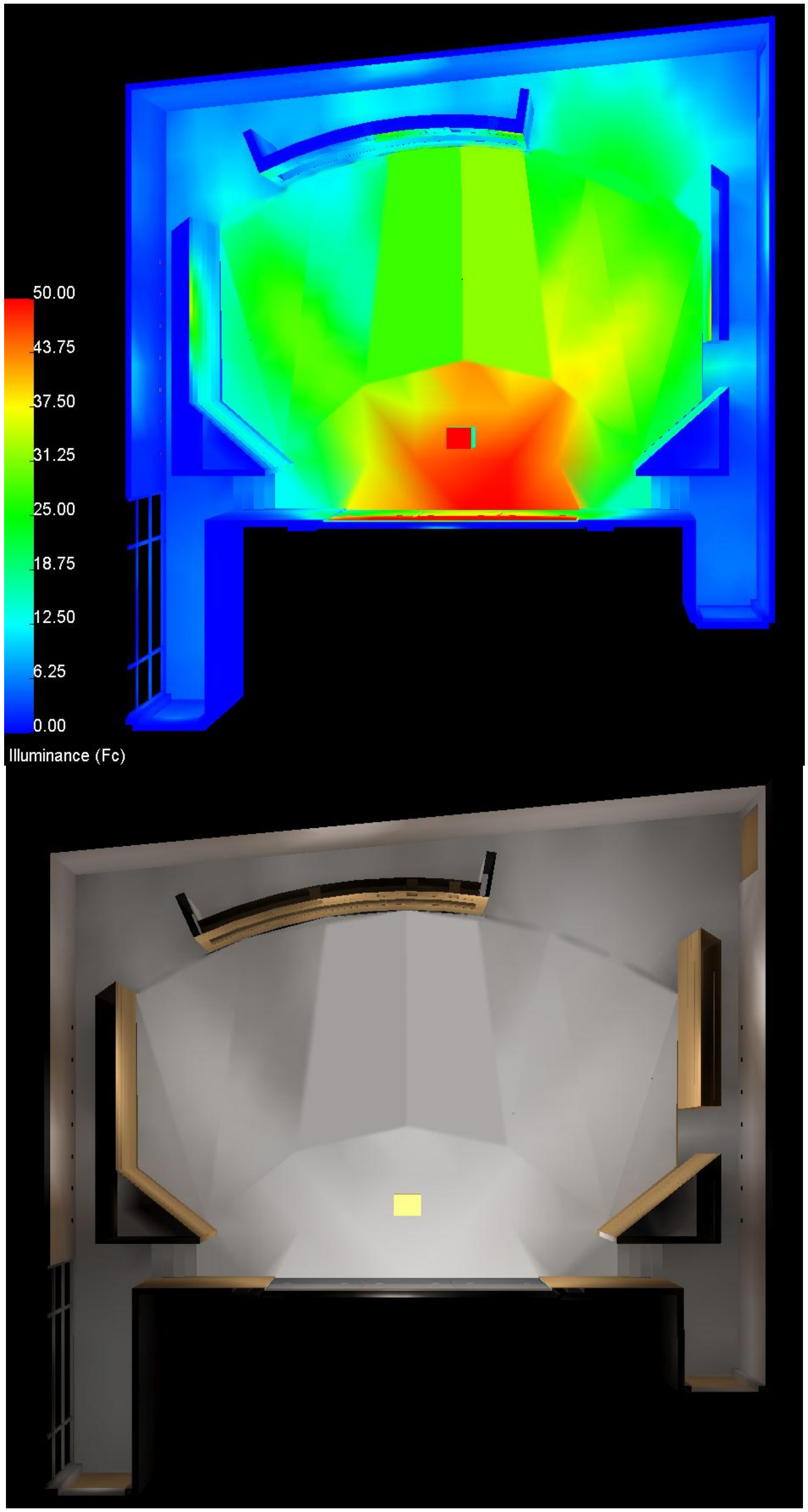


REFER TO APPENDIX L FOR FULL-SIZE DRAWING AND SCALE

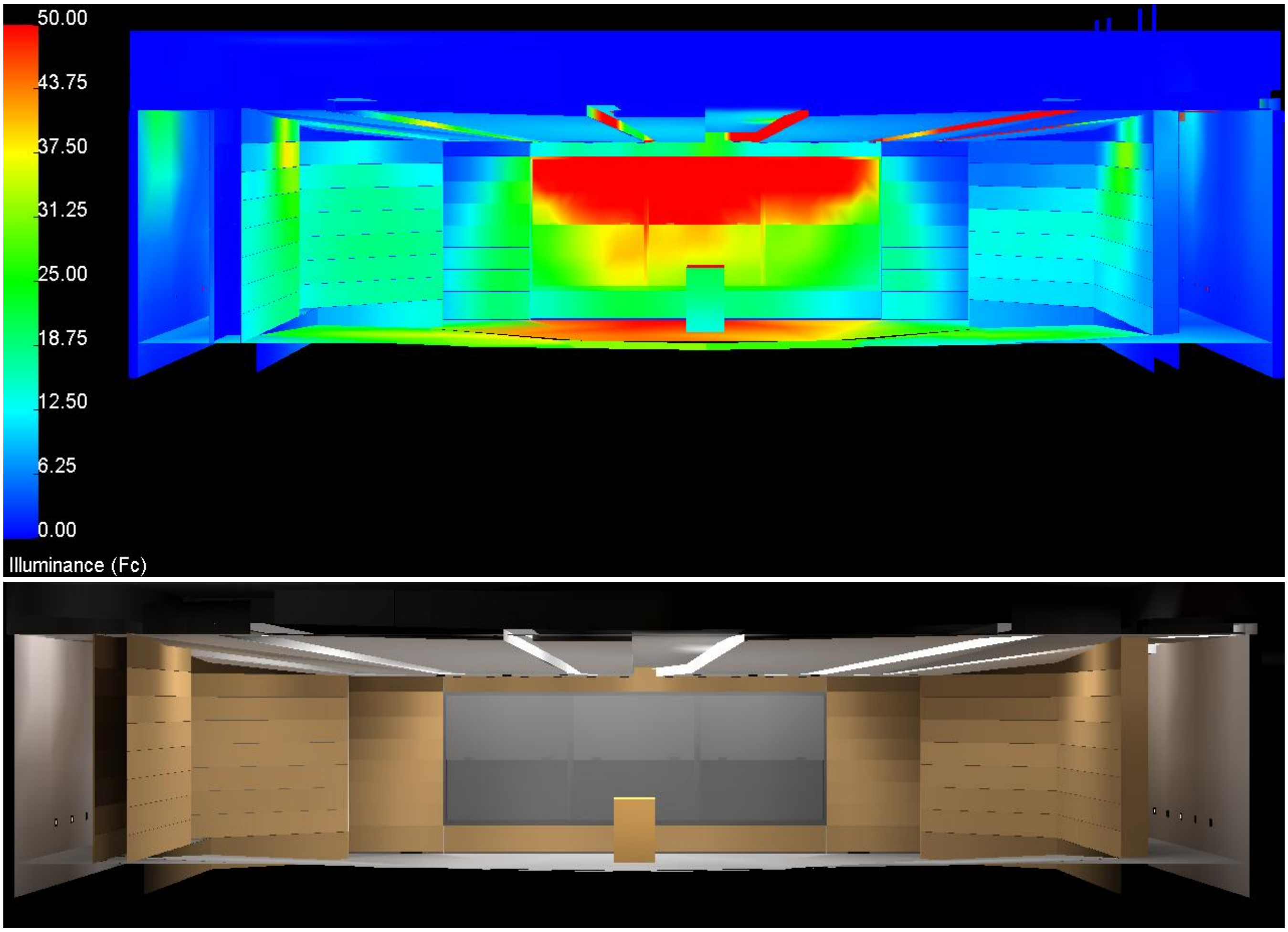
Mounting Details



Visual Performance | Visual Quality



PSEUDOCOLOR AND MATERIAL MODE IN AGI32 FOR FLOOR PLAN WITH ALL LUMINAIRES ON



ELEVATION LOOKING TOWARDS BLACKBOARD WITH ALL LUMINAIRES ON IN PSEUDOCOLO AND MATERIAL MODE IN AGI32

Results:

Zone	Average Illuminance	Maximum	Minimum	Max/Min	Coeff. Variation
Reading	28.48	59	9.1	6.48	
Lectern	67.82	83.2	47.9	1.74	
Lectern Vertical	30.81	36.1	19.7	1.83	
Stairs	6.72	10.4	4.6	2.26	
Corridors	6.57	15	2.7	5.56	
Chalkboard	45.88	83.7	19.6	4.27	0.36

Light Loss Factor Calculations

Luminaire Type	Lamp Lumen Depreciation	Ballast Factor	Lamp Dirt Depreciation	Total Light Loss Factors
AB	0.86	1.05	0.95	0.86
AG	1.00	1.00	0.95	0.95
AH	0.86	1.00	0.95	0.82
AK	0.95	1.11	0.95	1.00

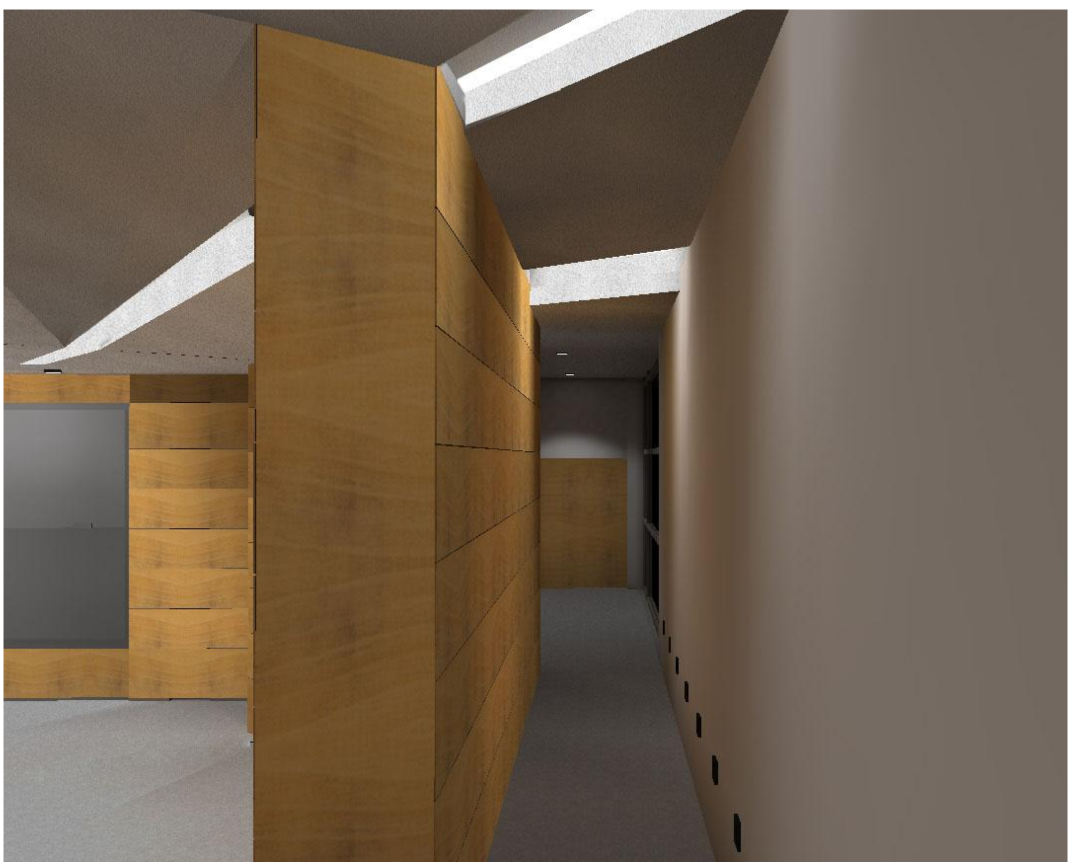
Energy Calculations

	Building Area	Space-by-Space
Allowable LPD (W/sq.ft.)	1.2	1.4
Actual LPD (W/sq.ft.)	1.156	1.156
Percentage	3.669	17.431

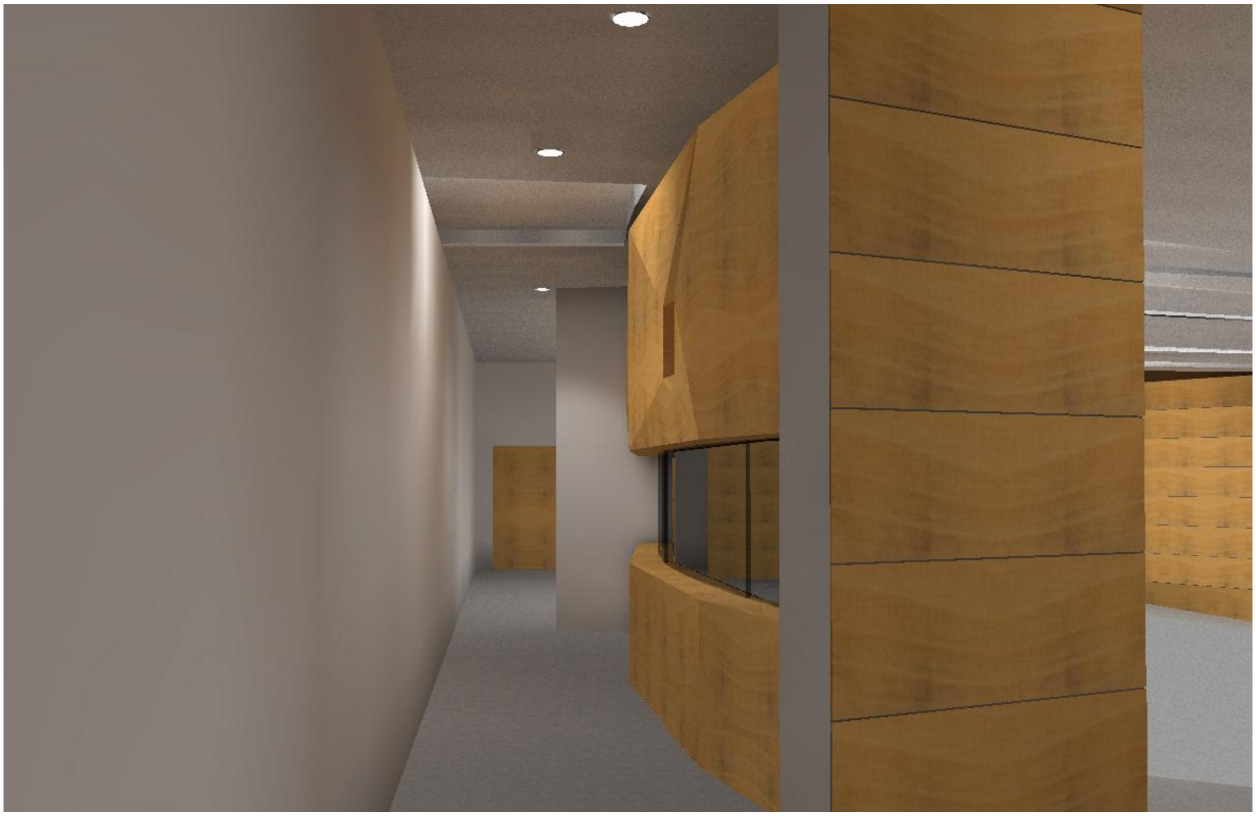
Area (sq.ft.)
3075

Luminaire Type	Watts/ Luminaire	Amount	Total Wattage
AB	18.4	9	165.6
AG	10	33	330
AH	46	17	782
AJ	30	17	510
AK	57	31	1767
		TOTAL WATTAGE =	3554.6

VIEW FROM SEATING AREA LOOKING TOWARDS BLACKBOARD



VIEW OF CORRIDOR



VIEW OF PROJECTION BOOTH AREA

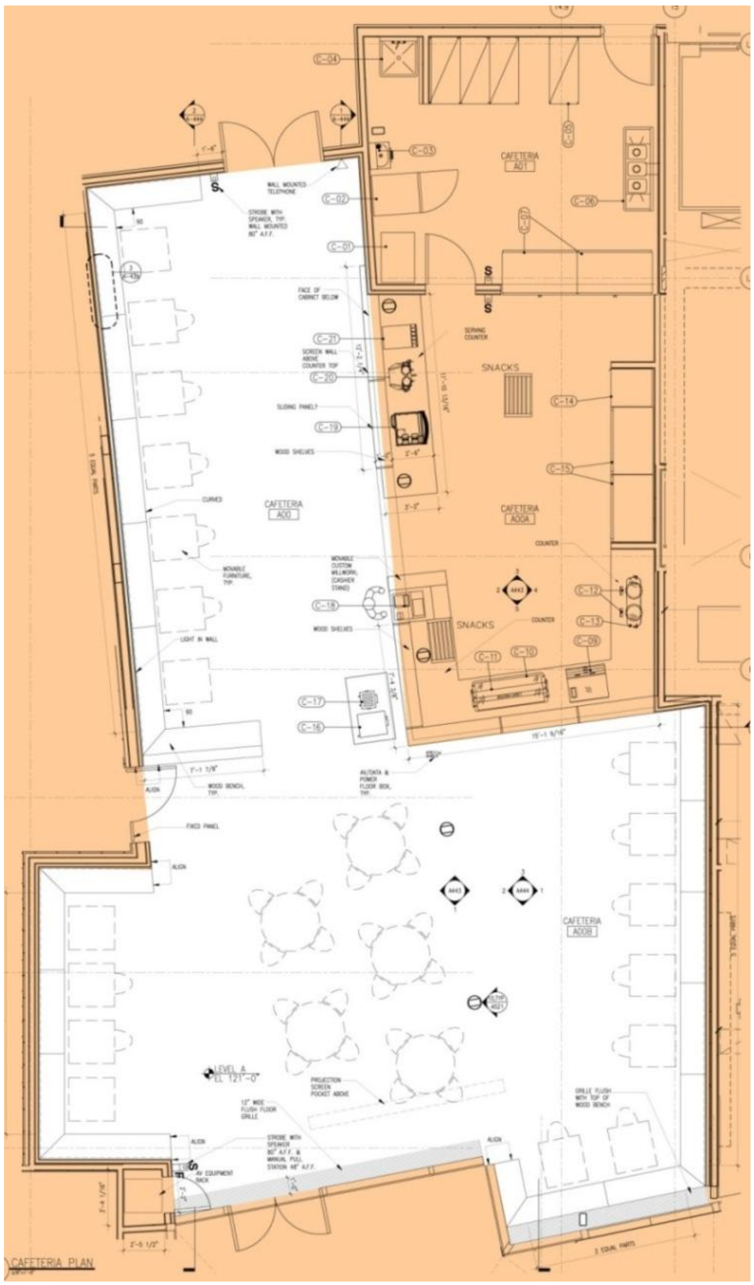
VIEW OF STEPS INTO LECTERN AREA

Special Purpose Space | **Cafeteria A00** | Psychological Reinforcement

Existing Conditions

Description of Space

The cafeteria is full of odd angles and corners. There is a separate area for serving with several counters and the cashier surrounded by wood shelving and the seating area of the space. There are 18 smaller tables around the perimeter wooden bench. There are also several center tables and that can be moved when the projection screen needs to be used. The southern wall is part of the exterior curtain wall. Since this café is within a university scene, studying and lounging will occur and the space can be accommodated to hold special seminars or other gatherings.



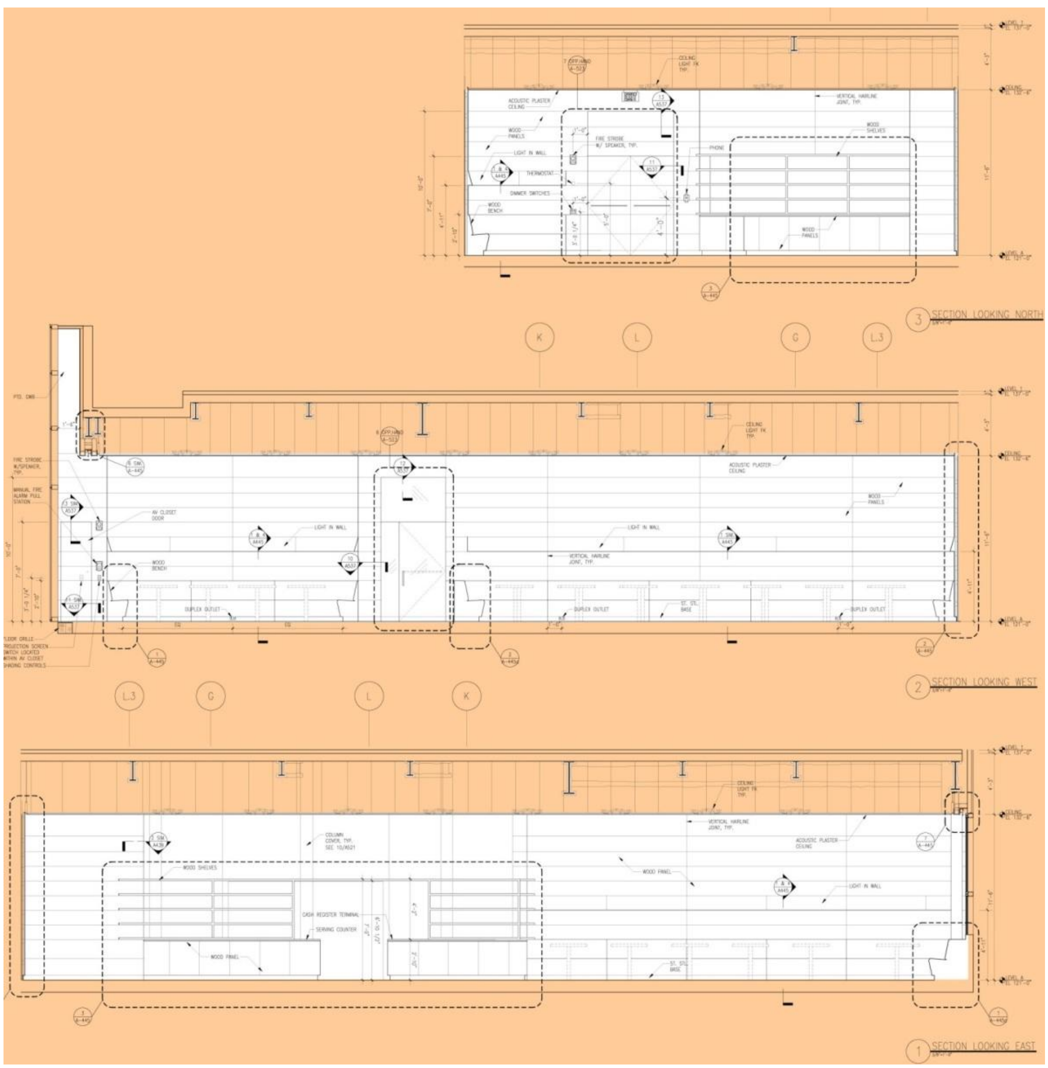
CAFETERIA PLAN, NTS

Furniture and Surface Materials

The space is full of seating areas which include wooden benches, tables, and chairs. There are also wooden bookshelves around the food preparation area and there is a projector screen that drops from the ceiling when needed.

Material	Reflectance *	Specifications #	Location
Exterior curtain wall	0.10	08910	South wall
Acoustic plaster	0.78	09900	Throughout
Painted gypsum wall board	0.70	09250	Food preparation area
Wood	0.25	06400	Wall panels, benches, shelves
Painted glass fiber reinforced plaster	0.76		
Stone	0.30	09600	Floor
Projection screen	0.80		

*Assumed, some from Figure 1-36 from IESNA Handbook Page 1-22, some from 3ds Max



CAFETERIA SECTIONS, NTS

Design Considerations

The cafeteria will be designed as a leisure type of dining area and the Flynn Mode of Privacy will be enforced. Lounging will be encouraged. For those students who might want to read as well, some areas will have slightly higher illuminance values to accommodate for this task but it will not be the main focus of the space. Because of the projector screen, the room must have the flexibility to switch from a dining space to a demonstration one.

Psychological Reinforcement

Dr. John Flynn developed criteria for evaluating the lighting in spaces by determining users' subjective response. For a space to feel "relaxed" according to his studies, the lighting would include non-uniform distribution, wall lighting, and lower light levels. The idea here is to enforce the criteria of a leisure dining type spaces using Flynn's Mode of Relaxation.

Visual Tasks

The most important visual tasks will be eating. Secondary visual tasks will include lounging and studying. In cafeterias, color is important for food appearance. Projector viewing will not be a regular task but since the space is equipped for it, the lighting must be able to accommodate for it.

Qualitative System Performance Considerations

The following lists in order of importance the design issues that are of consideration for a cafeteria, specifically the dining area, not the food preparation area. The ninth edition of The IESNA Lighting Handbook was referenced (Both Dining area and Reading area). For the dining task, the leisure type was chosen for the criteria selection. For the Reading task, it was assumed that most of the writing would be from #2 pencil and 8-10 point type. If one of the design issues appears under both reading and dining, then the dining criteria will be followed because it is the primary objective of the space.

Very Important (Dining) | Color appearance and color contrast | Color contributes to the enjoyment of food and it affects visibility and aesthetics. Several factors contribute to color appearance like the spectral power distribution (SPD) of light sources, perception ability of viewers, and the surfaces' transmission and reflection properties. Lighting designers can control the SDP by choosing a source that has a high Color Rendering Index (CRI). Lamps with a CRI higher than 80 must be used to ensure a pleasant appearance of food.

Important (Dining) | Appearance of space and luminaires | In dining areas, it is important to have an aesthetic appeal. The style of luminaires when coordinated with the architecture can enhance the design of the space. Lighting can evoke emotions and create an image. In a leisure type dining area, the lighting can promote relaxation.

Important (Dining) | Direct glare | Direct glare includes "discomfort glare" and "overhead glare". Both of these are undesirable in a place of relaxation. To minimize glare, luminaires luminances should not more than 100 times of those of the surrounding surfaces.

Important (Dining) | Points of interest | Even though the food is the most important part of a dining area, the focus should be kept away from the people to increase a sense of relaxation in accordance with the Flynn mode of relaxation.

Important (Dining) | System of control and flexibility | Control and flexibility are very important in dining environments were the illuminance levels are lower during the dining time and then need to increase for cleaning. Because this is a multi-function room, controls are necessary. There needs to be flexibility to change from a demonstration environment to a reading one as well as a leisure dining area.

Important (Dining) | Sparkle/desirable reflected highlights | Small points of bright light can add interest to a space. For example, in dining areas, light creates sparkle on silverware adding a sense of elegance.

Somewhat Important (Dining) | Illuminance (vertical) | Vertical illuminance helps for face modeling and can be desirable for dining situations.

Quantitative System Performance Considerations

Illuminance (horizontal) | 5-10fc (50-100lux) for leisure types of dining spaces

Illuminance (vertical) | 3fc (30lux) for dining

Energy

ASHRAE 90.1 2004

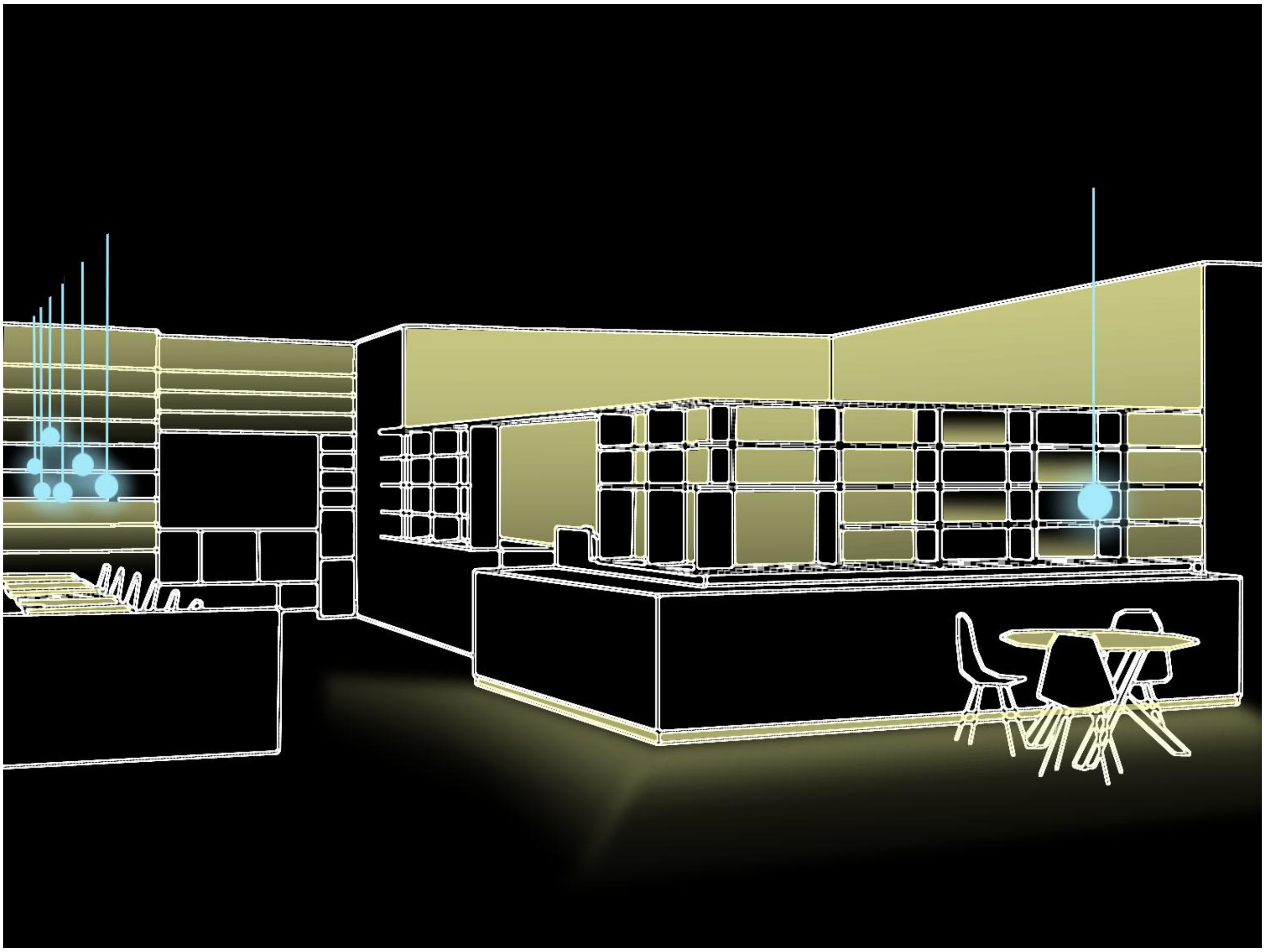
Building Area Method Lighting Power Densities, School/University | 1.2 W/sq.ft.

Space-by-Space Method Lighting Power Densities, Dining Area, Leisure Dining | 1.4 W/sq.ft.

Lighting Redesign

Lighting Solutions

To promote the Flynn mode of relaxation in the Cafeteria, a non-uniform lighting scheme was created that focused away from the users. Higher levels at the food preparation station will attract attention to this area as well as the under-lit cabinets surrounding it. Perimeter lighting includes grazing the surrounding wooden panel walls. Suspended luminaires will be hung and controlled by the users promoting the concept of ***building as brain activity***. These suspended elements will have lamps with a higher CRI because they will be lighting the food purchased by the occupants.



CONCEPTUAL SKETCH

Controls

This space will give a lot of control to the individual users to support the concept of building as brain activity. Each suspended luminaire will have its own ON/OFF switch, no dimming required, as well as be connected to the main 3 way switching. The downlights throughout must be dimmable for projector screen presentation mode but the wood grazing luminaires do not need to dim. The three switches will be located close to the two entrances and by the food preparation area.

Summary Performance Evaluation

The levels required for leisure type of dining spaces were obtained without the pendant luminaires ON which is shown below. The pendant luminaires bring the levels much higher, enough for reading/writing, for those who need it. The lamp used, halogen, has a very high CRI which will enhance the appearance of food and as point sources will add sparkle. The food preparation area levels of 30fc were also achieved with the addition of downlights. The rest of the space has enough illumination to provide safe circulation. The wood panels were highlighted with the use of linear LED luminaires and this brings the attention away from the user as desired. All the criteria stated were met for this space.

Documentation

Luminaire Schedule

Type	Description	Lamp	Watt	Volt	Mfr	Catalog #
AA	Surface mounted linear fluorescent lamp and extruded aluminum housing with nominal 2.5" height by 2" wide, integral electronic ballast and T6 lamps for end-to-end smooth continuous illumination mounted within architectural cove, 3000k. Lengths as required by architecture.	NIPPO T6 FL 88CRI	9-10 W/lf	277	Nippo	SAL-UW-XXXX/FRT-XXXX-EL30
AB	Recessed compact fluorescent downlight with 6" nominal diameter aperture with aluminum, bright anodized reflector with plastic, translucent diffuser and integral electronic ballast, 3000k	PHILIPS PL-T 18W/830/4P /ALTO 82CRI	18.4	277/ 120	Edison Price	TRPV 18/6
AC	Surface mounted LED strip approximately 0.75"x0.75" in cross section and incremental nominal lengths ranging from 6" to 96" with extruded aluminum housing and acrylic optics, 96W driver supplied, 3000k. Consult factory for high CRI option availability.	High CRI option LED	2.92 W/lf	277	Cooper IO	0.03.1.3k.45.101.1 .XX.2.277V
AD	Surface mounted high-performance LED grazing fixture , 1.5" diameter by 2.1" high and 1ft increments with die-cast aluminum white powder coated finish housing and polycarbonate lens	LED 83CRI	13.5	277	Color Kinetics	eW Fuse Powercore 3000K, 10 by 60 degree beam angle
AE	Suspended halogen pendant with extruded and die-cast aluminum housing, grey finish, suspension cable included, designed by Roberto Pamio.	GE Q75G9	75	277	iGuzzini	Cup SM19

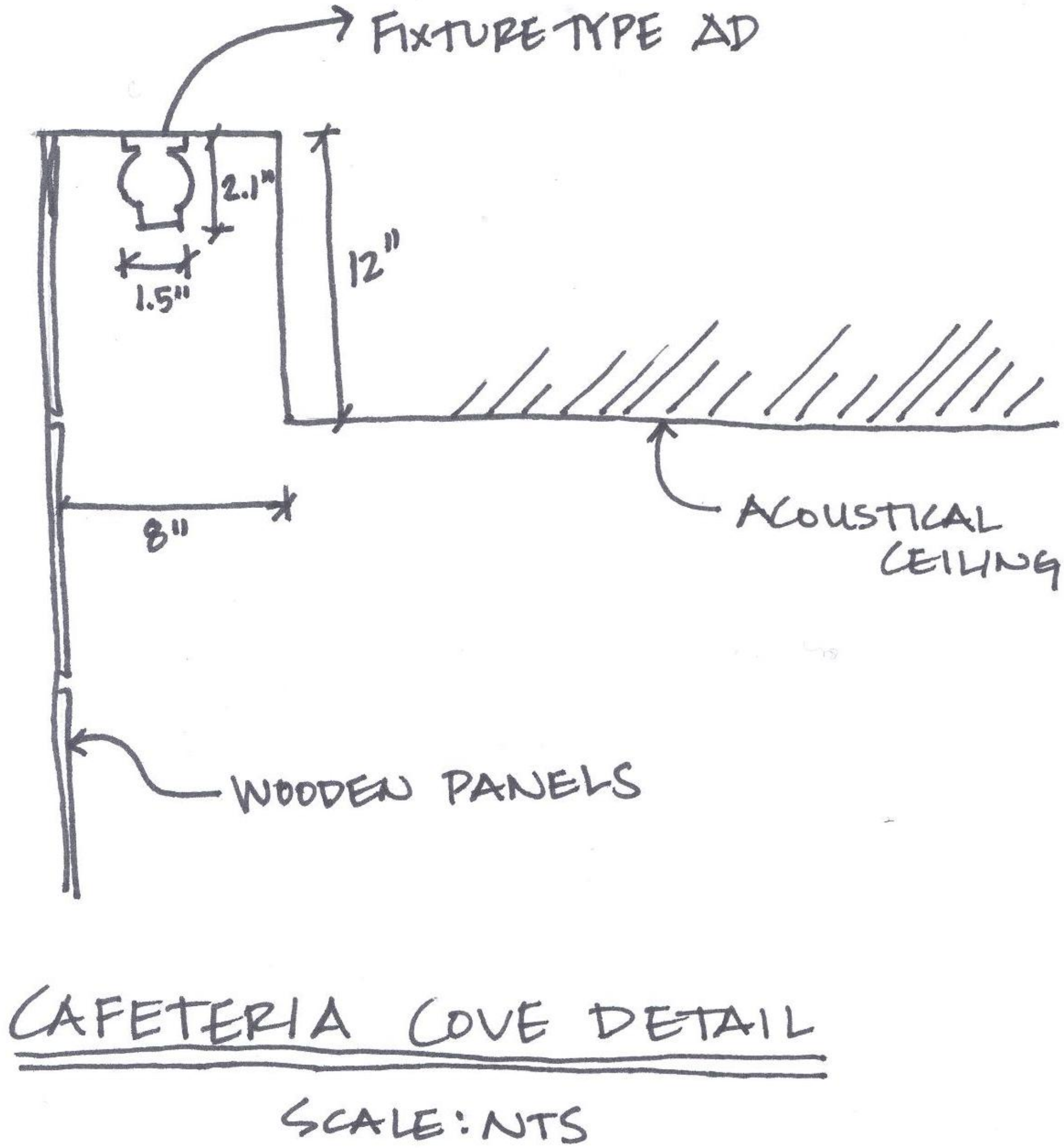
Ballast Schedule

Type	Location	PF	Input Current	Input Wattage	Lamp Wattage	Other	BF
AA	Nippo Specs	0.98	0.17 for 4ft section (1250cm)	47	39	Advance Xfmr, non-dimming	
AB	page 17-5 GE catalog	0.97	0.08	20	18	ProLine CFL Electronic Ballasts	1.05
AC		1.00		2.92 W/lf	2.92 W/lf		1
AD		1.00		13.5	13.5		1
AE	page 17-5 GE catalog	0.97	0.08	20	18	ProLine CFL Electronic Ballasts	1.05

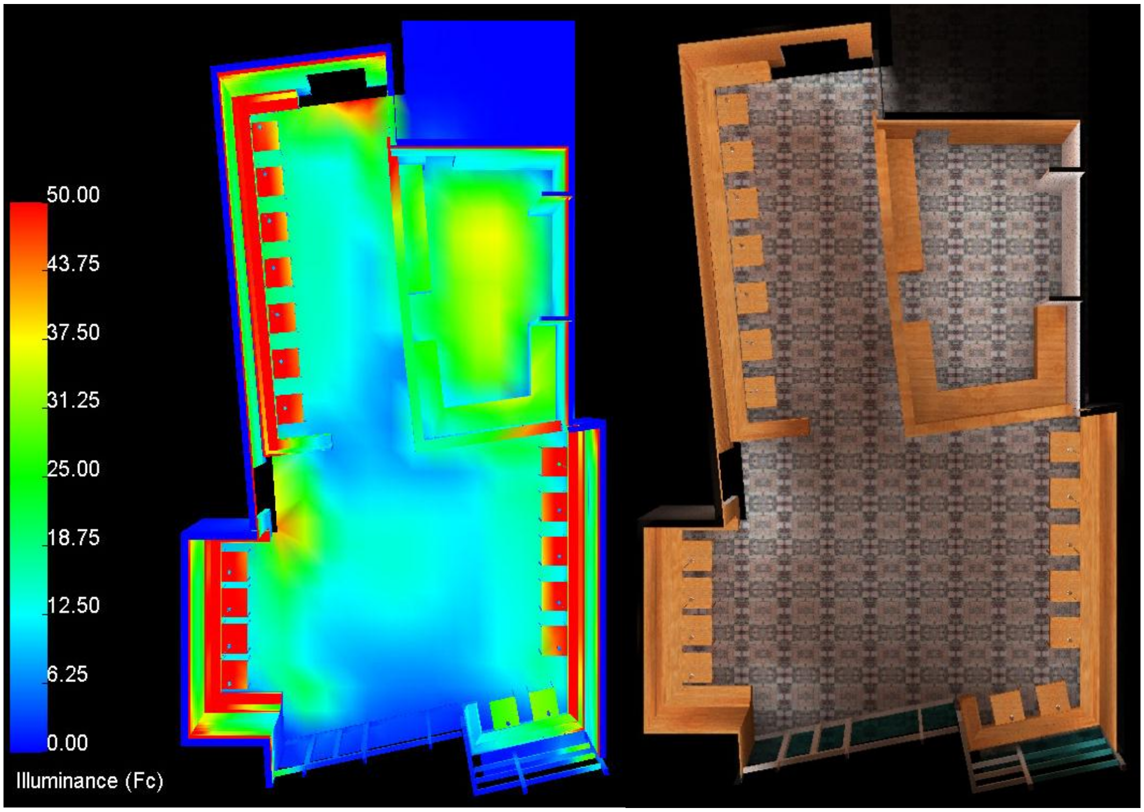
Lighting Plans

REFER TO APPENDIX L FOR FULL-SIZE DRAWING AND SCALE

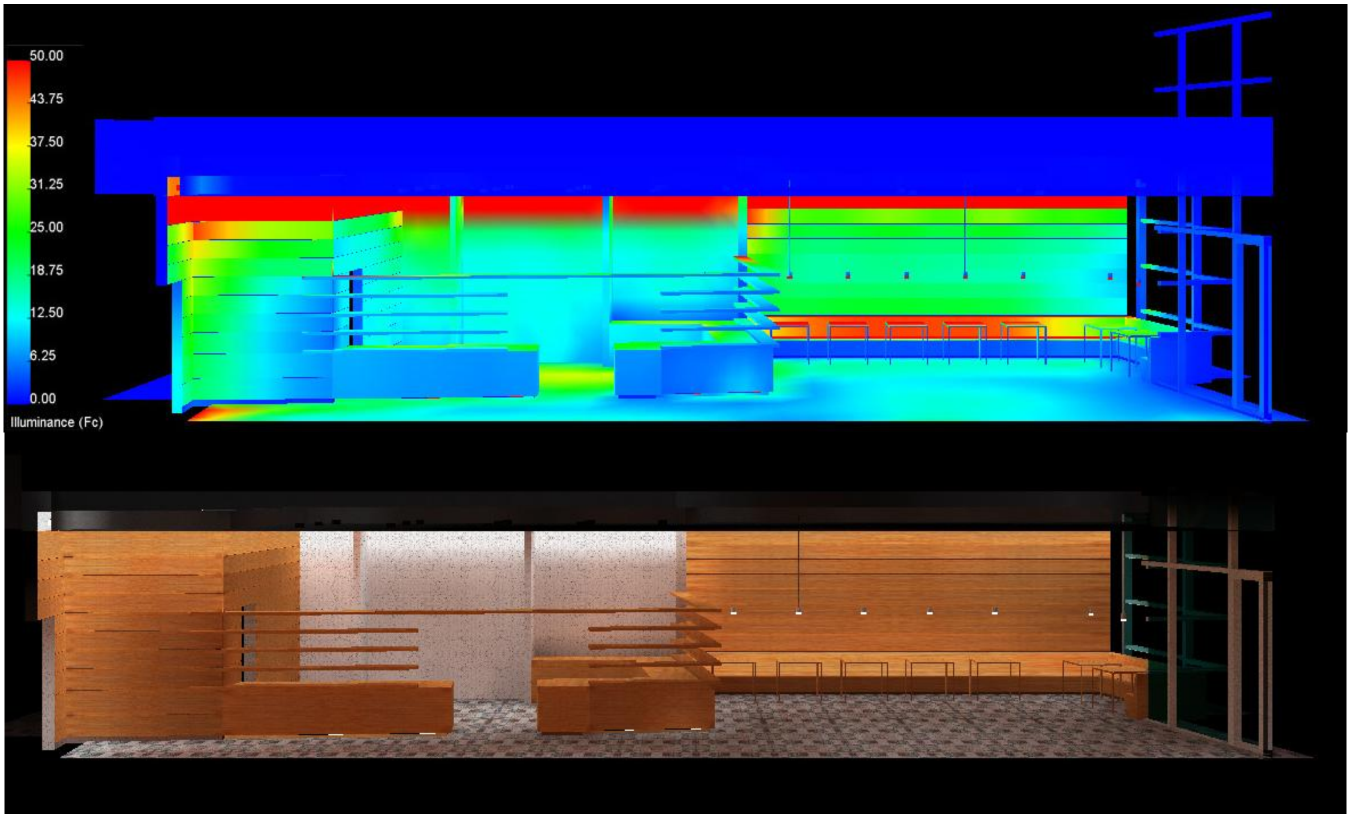
Mounting Details



Visual Performance | Visual Quality



PLAN VIEW IN PSEUDOCOLOR AND MATERIAL MODE FROM AGI32



ELEVATION VIEW IN PSEUDOCOLOR AND MATERIAL MODE FROM AGI32

Zone	Average Illuminance	Maximum	Minimum	Max/Min	Coeff. Variation
Tables	9.05	27.20	2.00	13.60	0.61
Lounge	11.79	15.20	5.80	2.62	
Food Prep	30.55	41.10	15.50	2.65	

Pendant luminaires OFF

Zone	Average Illuminance	Maximum	Minimum	Max/Min	Coeff. Variation
Tables	39.74	62.00	25.90	2.39	0.20
Lounge	12.95	16.30	6.90	2.36	
Food Prep	31.11	41.40	16.30	2.54	

Pendant luminaires ON

Light Loss Factor Calculations

Luminaire Type	Lamp Lumen Depreciation	Ballast Factor	Lamp Dirt Depreciation	Total Light Loss Factors
AA	0.92	0.88	0.95	0.77
AB	0.86	1.05	0.95	0.86
AC	0.70	1.00	0.95	0.67
AD	0.70	1.00	0.95	0.67
AE	1.00	1.05	0.95	1.00

Energy Calculations

	Building Area	Space-by-Space
Allowable LPD (W/sq.ft.)	1.2	1.4
Actual LPD (W/sq.ft.)	1.001	1.001
Percentage	16.586	28.503

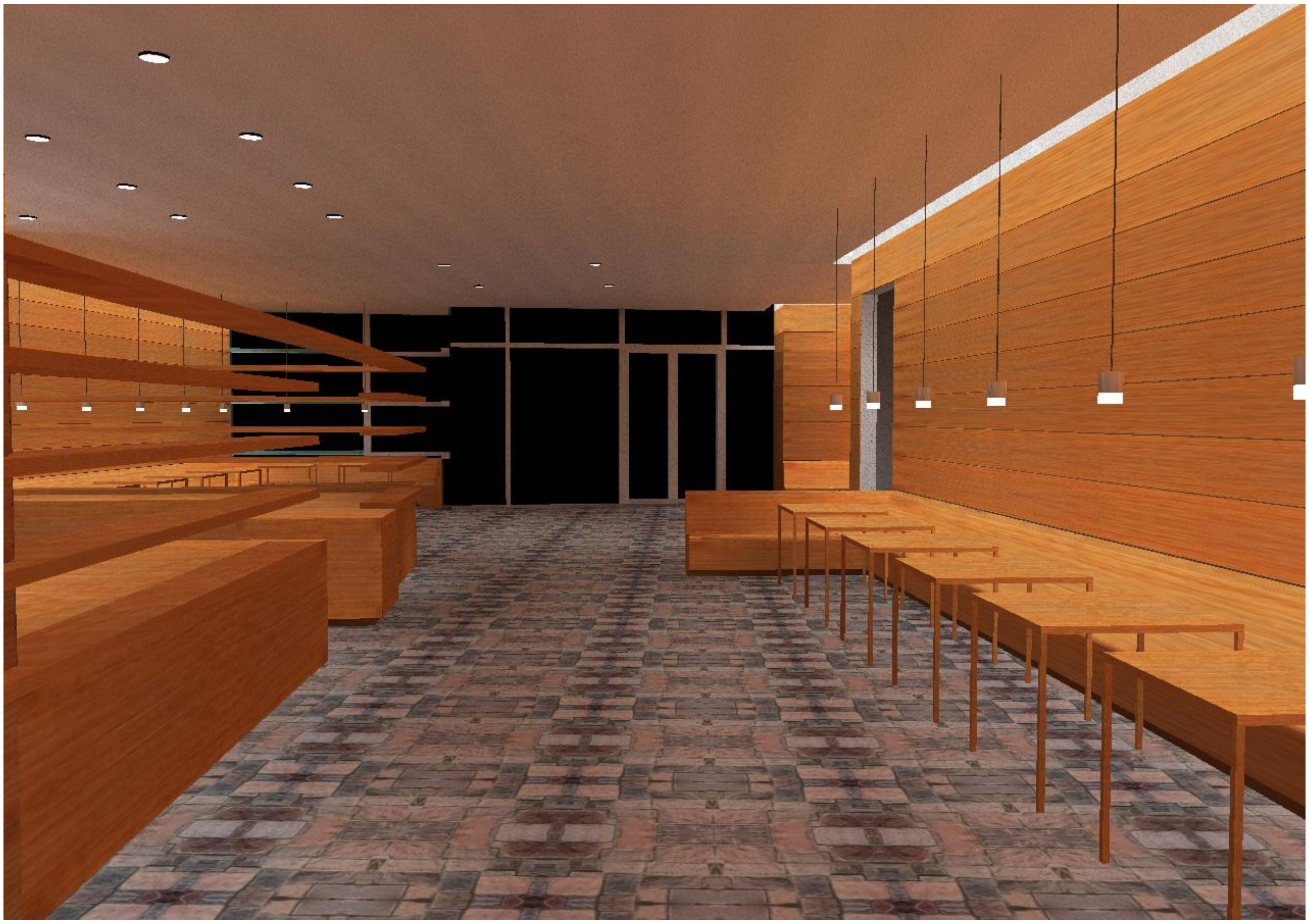
Area (sq.ft.)
2283

Luminaire Type	Watts/ Luminaire	Amount	Total Wattage
AA	37	13	481
AB	18.4	19	349.6
AC	19.6	5	98
AD	11.9	114	1356.6
AE*	75	18	1350
		TOTAL WATTAGE* =	2285.2

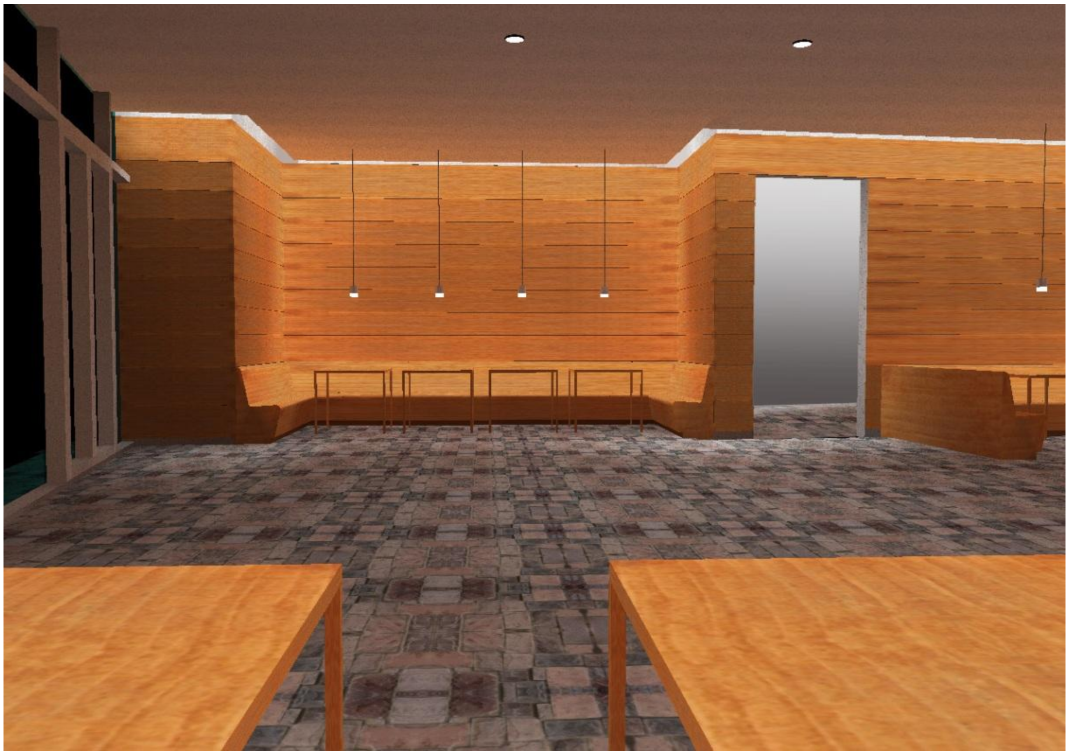
*Decorative Allowance
1.0
0.591
40.867

TOTAL WATTAGE

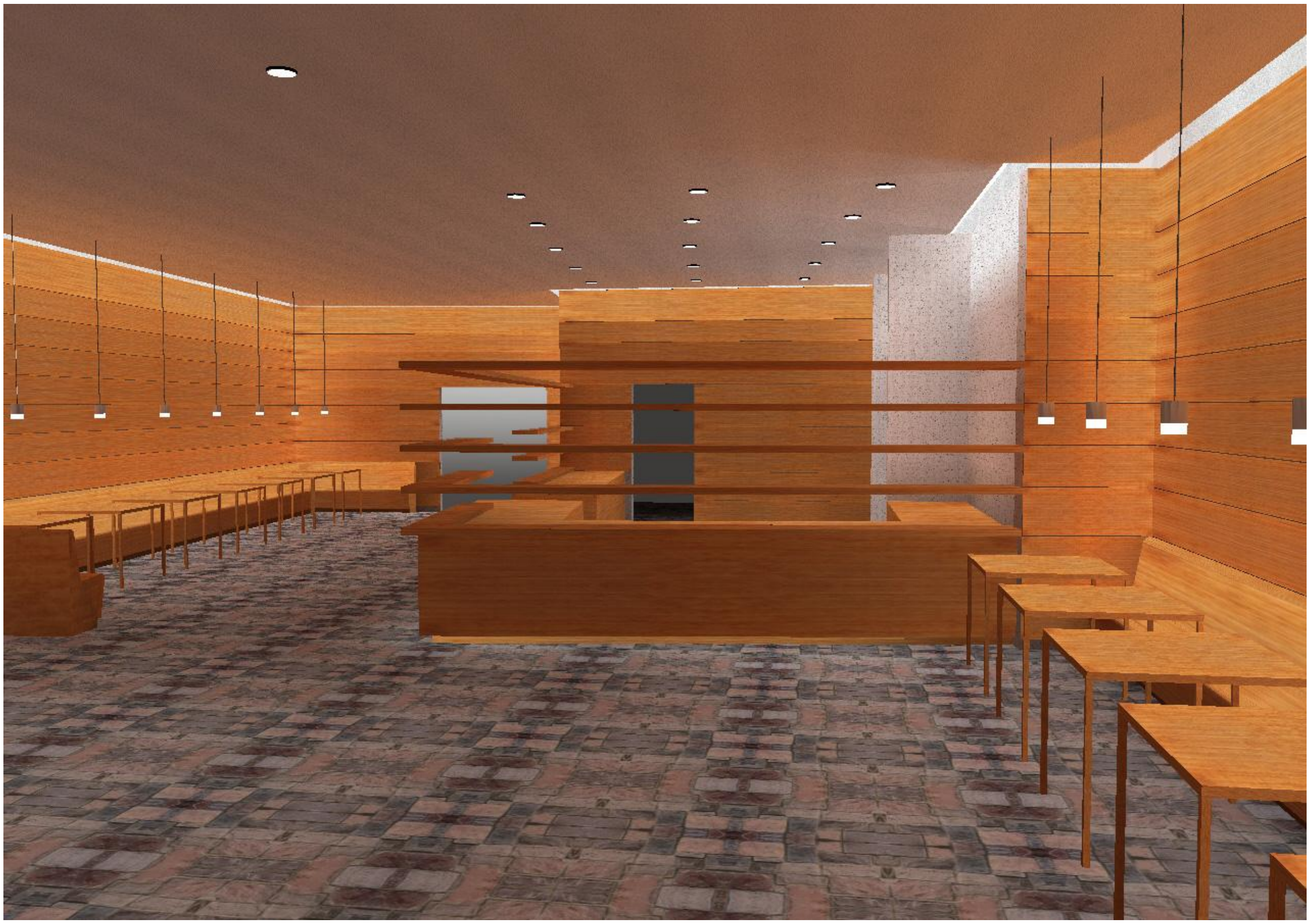
3635.2



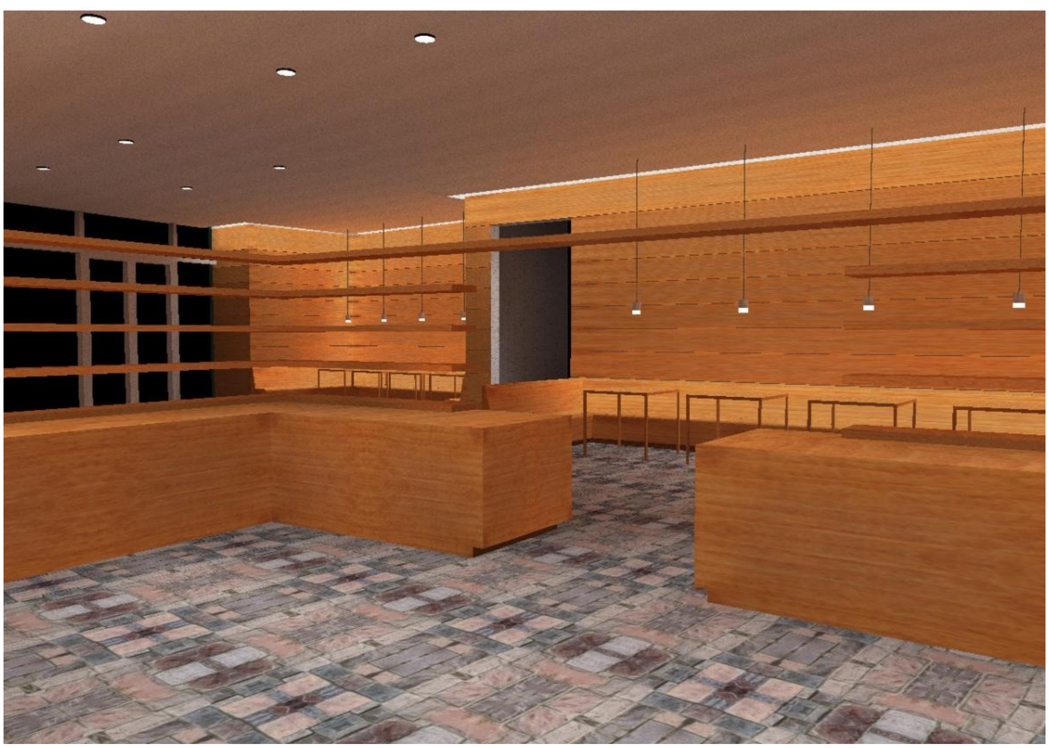
VIEW LOOKING NORTH



VIEW LOOKING EAST



VIEW LOOKING SOUTH INTO FOOD PREPARATION AREA



VIEW LOOKING TO CAFERTERIA SEATING FROM FOOD PREPARATION AREA

. Electrical Depth .

Four Lighting Spaces

Introduction

The four spaces in the Princeton Neuroscience & Psychology Complex where the lighting will be designed are the North Entrance, Lobby, Lecture Hall, and Cafeteria. Since the lighting will change, the electrical loads of the spaces will also be altered and therefore a redesign of the branch circuit distribution is necessary. The North Entrance has some pathways that lead to the lobby. There is only one Princeton standard gas lamp in the walkway areas in addition to the canopy LED downlights and fluorescent vestibule downlights. The lighting in the Lobby, Lecture Hall, and Cafeteria is composed of fluorescent downlights. The redesign of the North Entrance includes the addition of pedestrian light poles for safety and security. The Lobby scheme will completely change and will include a decorative installation in the main wooden wall. The Lecture Hall ceiling was redesigned for the architectural breadth therefore the downlights will be substituted with linear elements. The Cafeteria downlights were substituted with linear elements that bring emphasis to the perimeter creating a more comfortable and relax environment. The objective of the electrical design is to incorporate all these lighting design changes and make it work with the existing panelboards while reducing the energy consumption as a whole.

Panelboards						
Panel Tag	Voltage	System	North Entry	Lobby	Lecture Hall	Cafeteria
LP-AA	480Y/277V, 3P, 4W	N				X
ELP-AA	480Y/277V, 3P, 4W	N/E				X
LPD-AAL	208Y/120V, 3P, 4W	N			X	
ELPD-AAL	208Y/120V, 3P, 4W	N/E			X	
ELP-2B	480Y/277V, 3P, 4W	N/E	X	X		

Luminaire Schedule

Type	Description	Lamp	Watt	Volt	Mfr	Catalog #
AA	Surface mounted linear fluorescent lamp and extruded aluminum housing with nominal 2.5" height by 2" wide, integral electronic ballast and T6 lamps for end-to-end smooth continuous illumination mounted within architectural cove, 3000k. Lengths as required by architecture.	NIPPO T6 FL 88CRI	9-10 W/lf	277	Nippo	SAL-UW-XXXX/FRT-XXXX-EL30
AB	Recessed compact fluorescent downlight with 6" nominal diameter aperture with aluminum, bright anodized reflector with plastic, translucent diffuser and integral electronic ballast, 3000k	PHILIPS PL-T 18W/830/4P/ALTO 82CRI	18.4	277/120	Edison Price	TRPV 18/6
AC	Surface mounted LED strip approximately 0.75"x0.75" in cross section and incremental nominal lengths ranging from 6" to 96" with extruded aluminum housing and acrylic optics, 96W driver supplied, 3000k. Consult factory for high CRI option availability.	High CRI option LED	2.92 W/lf	277	Cooper IO	0.03.1.3k.45.101.1.XX.2.277V
AD	Surface mounted high-performance LED grazing fixture , 1.5" diameter by 2.1" high and 1ft increments with die-cast aluminum white powder coated finish housing and polycarbonate lens	LED 83CRI	13.5	277	Color Kinetics	eW Fuse Powercore 3000K, 10 by 60 degree beam angle
AE	Suspended halogen pendant with extruded and die-cast aluminum housing, grey finish, suspension cable included, designed by Roberto Pamio.	GE Q75G9	75	277	iGuzzini	Cup SM19
AF	Recessed in-ground low-voltage halogen wall-washer with cast aluminum body and outer casing and double tempered glass and nominal 5" diameter with integral electronic transformer.	PHILIPS 10W/T3/12V	10	12-277	iGuzzini	I.B001-277-13

Type	Description	Lamp	Watt	Volt	Mfr	Catalog #
AG	Recessed low voltage halogen wall luminaire with die-cast aluminum housing with integral wiring compartment, impact resistant satin matte crystal glass, requires a remote Class 2, 12V transformer, nominal 3 in square.	PHILIPS 10W/T3/12V	10	120/12	Bega	2303
AH	Recessed compact fluorescent wall-washer with 6" nominal diameter aperture with aluminum, bright anodized reflector with plastic, translucent diffuser and integral electronic ballast, 3000k	(2) PHILIPS PL-T 26W/830/4P/ALTO 82CRI	46	120	Edison Price	WLX 226/6
AJ	Fully recessed and flangeless linear fluorescent slotlight nominal 6" wide with extruded aluminum housing, powder coated high-reflectance which finish, and joiner system allowing uniform appearance with frosted acrylic lens. Lengths as required by architecture.	PHILIPS F28T5/ 835/ALTO 85CRI	30	277	Zumtobel	SLR6NX-XX-1285-XX-OLP-DX
AK	Fully recessed and flangeless linear fluorescent slotlight nominal 6" wide with extruded aluminum housing, powder coated high-reflectance which finish, and joiner system allowing uniform appearance with frosted acrylic lens. Lengths as required by architecture.	PHILIPS F54T5/ 835/HO/ALTO 85CRI	57	120	Zumtobel	SLR6NX-XX-1545-XX-OLP-DX
AL	Surface wall mounted elliptipar metal halide ceiling uplight mounted to the mullions of the exterior façade inside the lobby with bright clear anodized aluminum reflector with mill finish aluminum door and end plates and black yoke/mounting plate and remote electronic ballast.	PHILIPS CDM150/T6/942 96CRI	150	277	The Lighting Quotient	1403-150G-W-00-2-00-0

Type	Description	Lamp	Watt	Volt	Mfr	Catalog #
AM	Pole top metal halide exterior indirect adjustable luminaire with die-cast aluminum optical housing and 31.5" diameter and .25" thick aluminum plate secured by two die-cast aluminum "saddle" with maximum 30 degrees tilt and IP65 classification.	PHILIPS CDM Elite 70/T6/ 930 90CRI	88	277	Bega	8200MH
AP	Recessed exterior round drive-over in-ground halogen up light for foliage with stainless steel housing, convex tempered glass diffuser, anodized matte reflector, and natural bronze casting finish, rated IP67, with integral electronic transformer.	35W T4 GY6.35 12V	46	120/11.6	Bega	8702
AR	Fully Recessed LED indicator in-ground luminaire for both outdoor and indoor applications, with remote constant 6V driver, stainless steel housing, rated IP67, and visible nominal diameter of 7/8" with the base being nominal 5".	LED	0.08	277	MP Lighting	L06-WS27S-X-X-S6

Ballast Information for each luminaire:

Type	Location	PF	Input Current	Input Wattage	Lamp Wattage	Other	BF
AA	Nippo Specs	0.98	0.17 for 4ft section (1250cm)	47	39	Advance Xfmr, non-dimming	
AB	page 17-5 GE catalog	0.97	0.08	20	18	ProLine CFL Electronic Ballasts	1.05
AC		1.00		2.92 W/lf	2.92 W/lf		1
AD		1.00		13.5	13.5		1
AE	page 17-5 GE catalog	0.97	0.08	20	18	ProLine CFL Electronic Ballasts	1.05
AF		1		10	10		1
AG		1		10	10		1
AH	page 17-6 GE catalog	0.99	0.2	54	46	ProLine CFL Electronic Ballasts	1
AJ	page 13-3 GE	0.92	0.17	43		T5 High Efficiency - Programmed Start	1.22
AK	page 13-6 GE	0.97	0.26	71			1.11
AL	page 18-14 GE	0.9	0.7	186		86718 - GEM150MLTLC3D-5	1
AM	page 18-11 GE	0.9	0.4	88		86847	1
AP		1		46	46		1
AR		1		0.08	0.08		1

Controls

The North Entry luminaires will be controlled with line-voltage switching as well as the Cafeteria. The Lecture Hall requires several pre-set scenes therefore low-voltage dimming will be used to control it with the use of Lutron Grafik Eye Control System. The Lobby will be mostly ON always; therefore it will also be controlled using line-voltage switching and time-clock capabilities.

Electrical Plans

Refer to Appendix E for full size Electrical Plans with scale.

Existing Panelboard Schedules

The branch circuit to be redesigned is highlighted according to the colors in the chart at the beginning.

ELP-2B

PANEL:	ELP-2B	X	M.C.B. 60	X	SURFACE MOUNT	X	100% RATED NEUTRAL BUS
FED FROM	ELP-AB		M.L.O. -		FLUSH MOUNT		DOUBLE NEUTRAL BUS
BUS AMPS =	225		MIN AIC 25000 AMPS	-	FEED THRU PANEL		VOLTAGE: 277 /480 3 PHASE, 4 WIRE
LOCATION	ELECTRICAL ROOM					X	EQUIPMENT GROUND BUS
							ISOLATED GROUND BUS

CKT/BKR #	POLE	TRIP	LOAD DESCRIPTION	KVA/PHASE A	B	C	FEEDER No.	SIZE	GRD	CDT	COMMENTS	L	R	N	C	M
1	1	20	LOBBY	2.3			-	-	-	-		2.3				
3	1	20	STR 3,4, ELEV 1,5,6		0.0		-	-	-	-						
5	1	20	SPARE			0.0	-	-	-	-						
7	1	20	SPARE	0.0			-	-	-	-						
9	1	20	SPARE		0.0		-	-	-	-						
11	1	20	SPARE			0.0	-	-	-	-						
13	1	20	SPARE	0.0			-	-	-	-						
15	1	20	SPARE		0.0		-	-	-	-						
17	1	20	SPARE			0.0	-	-	-	-						
19	1	20	SPARE	0.0			-	-	-	-						
21	1	20	SPARE		0.0		-	-	-	-						
23	1	20	SPARE			0.0	-	-	-	-						
25	3	20	EPF-4	3.0			-	-	-	-						3.0
27	-	-	-		3.0		-	-	-	-						3.0
29	-	-	-			3.0	-	-	-	-						3.0
												2.3	0.0	0.0	0.0	9.0

M	C	N	R	L	COMMENTS	CDT	GRD	SIZE	FEEDER No.	KVA/PHASE A	B	C	LOAD DESCRIPTION	CKT/BKR TRIP	POLE	#
				2.0		-	-	-	-	2.0			PENTHOUSE MEC	20	1	2
				1.2		-	-	-	-		1.2		LEVEL 2 NORTH	20	1	4
				1.4		-	-	-	-			1.4	LEVEL 2 CENTER	20	1	6
				1.2		-	-	-	-	1.2			LEVEL 1 NORTH	20	1	8
				1.5		-	-	-	-		1.5		LEVEL 1 MIDDLE	20	1	10
						-	-	-	-			0.0	SPARE	20	1	12
						-	-	-	-	0.0			SPARE	20	1	14
						-	-	-	-		0.0		SPARE	20	1	16
						-	-	-	-			0.0	SPARE	20	1	18
						-	-	-	-	0.0			SPARE	20	1	20
						-	-	-	-		0.0		SPARE	20	1	22
						-	-	-	-			0.0	SPARE	20	1	24
1.3						-	-	-	-	1.3			EPF-2	20	3	26
1.3						-	-	-	-		1.3		-	-	-	28
1.3						-	-	-	-			1.3	-	-	-	30
4.0	0.0	0.0	0.0	7.3												

	A	B	C				A	B	C	
CONNECTED KVA	5	3	3	PHASE A	10 KVA	35 AMPS	5	4	3	CONNECTED KVA
CONNECTED AMPS	19	11	11	PHASE B	7 KVA	25 AMPS	16	15	10	CONNECTED AMPS
				PHASE C	6 KVA	21 AMPS				
				TOTAL	23 KVA	27 AMPS				

CONNECTED LOADS	
TOTAL CONNECTED LIGHTING LOAD	10 KVA
TOTAL CONNECTED RECEPTACLE LOAD	0 KVA
TOTAL CONNECTED NON-CONTINOUS LOAD	0 KVA
TOTAL CONNECTED CONTINOUS LOAD	0 KVA
TOTAL CONNECTED MECHANICAL LOAD	13 KVA

DEMAND LOADS	DEMAND FACTORS
10 KVA	1
0 KVA	0.7
0 KVA	0.8
0 KVA	1
10 KVA	0.75
19 KVA	TOTAL DEMAND KVA
23 A	DEMAND AMPS

EQUIPMENT AND FEEDER SIZING

	LIGHTING x 125% =	12 KVA
	10KVA x 100% + 50% =	0 KVA
	NON-CONT. LOAD x 100% =	0 KVA
	CONTIN LOAD x 125%=	0 KVA
	MOTOR LOADS=	13 KVA
	25% OF LARGEST MOTOR=	KVA
	FEEDER LOAD=	25 KVA
	FEEDER LOAD (AMPS)=	30 A
20 %	SPARE FEEDER LOAD (AMPS)	36

PANEL:	ELP-2B	X	M.C.B. 60	X	SURFACE MOUNT
FED FROM	ELP-AB		M.L.O. -		FLUSH MOUNT
BUS AMPS =	225		MIN AIC 25000 AMPS	-	FEED THRU PANEL
LOCATION	ELECTRICAL ROOM				

CKT/BKR #	POLE	TRIP	LOAD DESCRIPTION	KVA/PHASE A	B	C	FEEDER No.	SIZE	GRD	CDT	COMMENTS	L	R	N	C	M
1	1	20	LOBBY	2.3			-	-	-	-		2.3				
3	1	20	STR 3,4, ELEV 1,5,6		0.0		-	-	-	-						
5	1	20	SPARE			0.0	-	-	-	-						
7	1	20	SPARE	0.0			-	-	-	-						
9	1	20	SPARE		0.0		-	-	-	-						
11	1	20	SPARE			0.0	-	-	-	-						
13	1	20	SPARE	0.0			-	-	-	-						
15	1	20	SPARE		0.0		-	-	-	-						
17	1	20	SPARE			0.0	-	-	-	-						
19	1	20	SPARE	0.0			-	-	-	-						
21	1	20	SPARE		0.0		-	-	-	-						
23	1	20	SPARE			0.0	-	-	-	-						
25	3	20	EPF-4	3.0			-	-	-	-						3.0
27	-	-	-		3.0		-	-	-	-						3.0
29	-	-	-			3.0	-	-	-	-						3.0
												2.3	0.0	0.0	0.0	9.0

	A	B	C		
CONNECTED KVA	5	3	3	PHASE A	10 KVA
CONNECTED AMPS	19	11	11	PHASE B	7 KVA
				PHASE C	6 KVA
				TOTAL	23 KVA

CONNECTED LOADS	
TOTAL CONNECTED LIGHTING LOAD	10 KVA
TOTAL CONNECTED RECEPTACLE LOAD	0 KVA
TOTAL CONNECTED NON-CONTINOUS LOAD	0 KVA
TOTAL CONNECTED CONTINOUS LOAD	0 KVA
TOTAL CONNECTED MECHANICAL LOAD	13 KVA

DEMAND LOADS
10 KVA
0 KVA
0 KVA
0 KVA
10 KVA
19 KVA
23 A

LPD-AAL

PANEL:	LPD-AAL	X	M.C.B.	50	X	SURFACE MOUNT	X	100% RATED NEUTRAL BUS	X	EQUIPMENT GROUND BUS
FED FROM	DP-AA		M.L.O.	-		FLUSH MOUNT		DOUBLE NEUTRAL BUS		ISOLATED GROUND BUS
BUS AMPS =	175		MIN AIC	22000 AMPS	-	FEED THRU PANEL		VOLTAGE:		120 /208 3 PHASE, 4 WIRE
LOCATION	ELECTRICAL ROOM									

CKT/BKR #	POLE	TRIP	LOAD DESCRIPTION	KVA/PHASE A	B	C	FEEDER No.	SIZE	GRD	CDT	COMMENTS	L	R	N	C	M	M	C	N	R	L	COMMENTS	CDT	FEEDER GRD	SIZE	No.	KVA/PHASE A	B	C	LOAD DESCRIPTION	CKT/BKR TRIP	POLE	#
1	1	20	FK (MLV)	1.2			-	-	-	-		1.2											-	-	-	-	0.0			SPACE	20	1	2
3	1	20	FK (MLV)		1.2		-	-	-	-		1.2											-	-	-	-		0.0		SPACE	20	1	4
5	1	20	FAB (INC)			0.3	-	-	-	-		0.3											-	-	-	-			0.0	SPACE	20	1	6
7	1	20	FD-1 (FL)	0.3			-	-	-	-		0.3											-	-	-	-	0.0			SPACE	20	1	8
9	1	20	FY (ELV)		0.2		-	-	-	-		0.2											-	-	-	-		0.0		SPACE	20	1	10
11	1	20	FZ (ELV)			0.2	-	-	-	-		0.2											-	-	-	-			0.0	SPACE	20	1	12
13	1	20	FAA (NON-DIM)	0.4			-	-	-	-		0.4											-	-	-	-	0.0			SPACE	20	1	14
15	1	20	SPARE		0.0		-	-	-	-													-	-	-	-		0.0		SPACE	20	1	16
17	1	20	SPARE			0.0	-	-	-	-													-	-	-	-			0.0	SPACE	20	1	18
19	1	20	SPARE	0.0			-	-	-	-													-	-	-	-	0.0			SPACE	20	1	20
21	1	20	SPARE		0.0		-	-	-	-													-	-	-	-		0.0		SPACE	20	1	22
23	1	20	SPARE			0.0	-	-	-	-													-	-	-	-			0.0	SPACE	20	1	24
												3.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0												

	A	B	C					A	B	C	
CONNECTED kVA	2	1	1	PHASE A	2 KVA	16	AMPS	0	0	0	CONNECTED kVA
CONNECTED AMPS	16	11	4	PHASE B	1 KVA	11	AMPS	0	0	0	CONNECTED AMPS
				PHASE C	1 KVA	4	AMPS				
				TOTAL	4 KVA	11	AMPS				

CONNECTED LOADS	
TOTAL CONNECTED LIGHTING LOAD	4 kVA
TOTAL CONNECTED RECEPTACLE LOAD	0 kVA
TOTAL CONNECTED NON-CONTINOUS LOAD	0 kVA
TOTAL CONNECTED CONTINOUS LOAD	0 kVA
TOTAL CONNECTED MECHANICAL LOAD	0 kVA

DEMAND LOADS	DEMAND FACTORS
4 kVA	1
0 kVA	0.7
0 kVA	0.8
0 kVA	1
0 kVA	0.75
4 kVA	TOTAL DEMAND kVA
11 A	DEMAND AMPS

EQUIPMENT AND FEEDER SIZING

	LIGHTING x 125% =	5 kVA
	10kVA x 100% + 50% =	0 kVA
	NON-CONT. LOAD x 100% =	0 kVA
	CONTIN LOAD x 125%=	0 kVA
	MOTOR LOADS=	0 kVA
	25% OF LARGEST MOTOR=	kVA
	FEEDER LOAD=	5 kVA
	FEEDER LOAD (AMPS)=	13 A
20 %	SPARE FEEDER LOAD (AMPS)	16

PANEL:	LPD-AAL	X	M.C.B.	50	X	SURFACE MOUNT
FED FROM	DP-AA		M.L.O.	-		FLUSH MOUNT
BUS AMPS =	175		MIN AIC	22000 AMPS	-	FEED THRU PANEL
LOCATION	ELECTRICAL ROOM					

CKT/BKR #	POLE	TRIP	LOAD DESCRIPTION	KVA/PHASE A	B	C	FEEDER No.	SIZE	GRD	CDT	COMMENTS	L	R	N	C	M
1	1	20	FK (MLV)	1.2			-	-	-	-		1.2				
3	1	20	FK (MLV)		1.2		-	-	-	-		1.2				
5	1	20	FAB (INC)			0.3	-	-	-	-		0.3				
7	1	20	FD-1 (FL)	0.3			-	-	-	-		0.3				
9	1	20	FY (ELV)		0.2		-	-	-	-		0.2				
11	1	20	FZ (ELV)			0.2	-	-	-	-		0.2				
13	1	20	FAA (NON-DIM)	0.4			-	-	-	-		0.4				
15	1	20	SPARE		0.0		-	-	-	-						
17	1	20	SPARE			0.0	-	-	-	-						
19	1	20	SPARE	0.0			-	-	-	-						
21	1	20	SPARE		0.0		-	-	-	-						
23	1	20	SPARE			0.0	-	-	-	-						
												3.8	0.0	0.0	0.0	0.0

	A	B	C		
CONNECTED kVA	2	1	1	PHASE A	2 KVA
CONNECTED AMPS	16	11	4	PHASE B	1 KVA
				PHASE C	1 KVA
				TOTAL	4 KVA

CONNECTED LOADS	
TOTAL CONNECTED LIGHTING LOAD	4 kVA
TOTAL CONNECTED RECEPTACLE LOAD	0 kVA
TOTAL CONNECTED NON-CONTINOUS LOAD	0 kVA
TOTAL CONNECTED CONTINOUS LOAD	0 kVA
TOTAL CONNECTED MECHANICAL LOAD	0 kVA

DEMAND LOADS	D
4 kVA	
0 kVA	
0 kVA	
0 kVA	
0 kVA	
4 kVA	
11 A	

ELPD-AAL

PANEL:	ELPD-AAL	X	M.C.B. 50	X	SURFACE MOUNT
FED FROM	T-EAL VIA ELP-AA		M.L.O. -		FLUSH MOUNT
BUS AMPS =	175		MIN AIC 10000 AMPS	-	FEED THRU PANEL
LOCATION	ELECTRICAL ROOM				

X	100% RATED NEUTRAL BUS	
	DOUBLE NEUTRAL BUS	
		VOLTAGE:

X	EQUIPMENT GROUND BUS
	ISOLATED GROUND BUS
	120 /208 3 PHASE, 4 WIRE

CKT/BKR #	POLE	TRIP	LOAD DESCRIPTION	KVA/PHASE A	B	C	No.	FEEDER SIZE	GRD	CDT	COMMENTS	L	R	N	C	M	M	C	N	R	L	COMMENTS	CDT	GRD	FEEDER SIZE	No.	KVA/PHASE A	B	C	LOAD DESCRIPTION	CKT/BKR TRIP	POLE	#
1	1	20	SPACE	0.0			-	-	-	-											1.4		-	-	-	-	1.4			FK (MLV)	20	1	2
3	1	20	SPACE		0.0		-	-	-	-											0.2		-	-	-	-		0.2		FL (CFL)	20	1	4
5	1	20	SPACE			0.0	-	-	-	-											0.4		-	-	-	-			0.4	FD-1 (FL)	20	1	6
7	1	20	SPACE	0.0			-	-	-	-											0.3		-	-	-	-	0.3			FK VEST. (MLV)	20	1	8
9	1	20	SPACE		0.0		-	-	-	-													-	-	-	-		0.0		SPARE	20	1	10
11	1	20	SPACE			0.0	-	-	-	-													-	-	-	-			0.0	SPARE	20	1	12
13	1	20	SPACE	0.0			-	-	-	-													-	-	-	-	0.0			SPARE	20	1	14
15	1	20	SPACE		0.0		-	-	-	-													-	-	-	-		0.0		SPARE	20	1	16
17	1	20	SPACE			0.0	-	-	-	-													-	-	-	-			0.0	SPACE	20	1	18
19	1	20	SPACE	0.0			-	-	-	-													-	-	-	-	0.0			SPACE	20	1	20
21	1	20	SPACE		0.0		-	-	-	-													-	-	-	-		0.0		SPACE	20	1	22
23	1	20	SPACE			0.0	-	-	-	-													-	-	-	-			0.0	SPACE	20	1	24
												0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.4												

	A	B	C				A	B	C	
CONNECTED kVA	0	0	0	PHASE A	2 KVA	15 AMPS	2	0	0	CONNECTED kVA
CONNECTED AMPS	0	0	0	PHASE B	0 KVA	2 AMPS	15	2	3	CONNECTED AMPS
				PHASE C	0 KVA	3 AMPS				
				TOTAL	2 KVA	7 AMPS				

CONNECTED LOADS	
TOTAL CONNECTED LIGHTING LOAD	2 kVA
TOTAL CONNECTED RECEPTACLE LOAD	0 kVA
TOTAL CONNECTED NON-CONTINOUS LOAD	0 kVA
TOTAL CONNECTED CONTINOUS LOAD	0 kVA
TOTAL CONNECTED MECHANICAL LOAD	0 kVA

DEMAND LOADS	DEMAND FACTORS
2 kVA	1
0 kVA	0.7
0 kVA	0.8
0 kVA	1
0 kVA	0.75
2 kVA	TOTAL DEMAND kVA
7 A	DEMAND AMPS

EQUIPMENT AND FEEDER SIZING

	LIGHTING x 125% =	3 kVA
	10kVA x 100% + 50% =	0 kVA
	NON-CONT. LOAD x 100% =	0 kVA
	CONTIN LOAD x 125%=	0 kVA
	MOTOR LOADS=	0 kVA
	25% OF LARGEST MOTOR=	kVA
	FEEDER LOAD=	3 kVA
	FEEDER LOAD (AMPS)=	8 A
20 %	SPARE FEEDER LOAD (AMPS)	10

X	100% RATED NEUTRAL BUS	X	EQUIPMENT GROUND BUS
	DOUBLE NEUTRAL BUS		ISOLATED GROUND BUS
	VOLTAGE:		120 /208 3 PHASE, 4 WIRE

M	C	N	R	L	COMMENTS	CDT	GRD	FEEDER SIZE	No.	KVA/PHASE A	B	C	LOAD DESCRIPTION	CKT/BKR TRIP	POLE	#
				1.4		-	-	-	-	1.4			FK (MLV)	20	1	2
				0.2		-	-	-	-		0.2		FL (CFL)	20	1	4
				0.4		-	-	-	-			0.4	FD-1 (FL)	20	1	6
				0.3		-	-	-	-	0.3			FK VEST. (MLV)	20	1	8
						-	-	-	-		0.0		SPARE	20	1	10
						-	-	-	-			0.0	SPARE	20	1	12
						-	-	-	-	0.0			SPARE	20	1	14
						-	-	-	-		0.0		SPARE	20	1	16
						-	-	-	-			0.0	SPACE	20	1	18
						-	-	-	-	0.0			SPACE	20	1	20
						-	-	-	-		0.0		SPACE	20	1	22
						-	-	-	-			0.0	SPACE	20	1	24
0.0	0.0	0.0	0.0	2.4												

	A	B	C	
15 AMPS	2	0	0	CONNECTED kVA
2 AMPS	15	2	3	CONNECTED AMPS
3 AMPS				
7 AMPS				

MAND FACTORS
1
0.7
0.8
1
0.75
TOTAL DEMAND kVA
DEMAND AMPS

EQUIPMENT AND FEEDER SIZING

	LIGHTING x 125% =	3 kVA
	10kVA x 100% + 50% =	0 kVA
	NON-CONT. LOAD x 100% =	0 kVA
	CONTIN LOAD x 125%=	0 kVA
	MOTOR LOADS=	0 kVA
	25% OF LARGEST MOTOR=	kVA
	FEEDER LOAD=	3 kVA
	FEEDER LOAD (AMPS)=	8 A
20 %	SPARE FEEDER LOAD (AMPS)	10

LP-AA

PANEL:	LP-AA	-	M.C.B.	-	X	SURFACE MOUNT	X	100% RATED NEUTRAL BUS	X	EQUIPMENT GROUND BUS
FED FROM	BUSWAY	X	M.L.O.	-		FLUSH MOUNT		DOUBLE NEUTRAL BUS		ISOLATED GROUND BUS
BUS AMPS =	225		MIN AIC	25000 AMPS	-	FEED THRU PANEL		VOLTAGE:		277 /480 3 PHASE, 4 WIRE
LOCATION	ELECTRICAL ROOM									

CKT/BKR #	POLE	TRIP	LOAD DESCRIPTION	KVA/PHASE A	B	C	FEEDER No.	SIZE	GRD	CDT	COMMENTS	L	R	N	C	M	M	C	N	R	L	COMMENTS	CDT	GRD	FEEDER SIZE	No.	KVA/PHASE A	B	C	LOAD DESCRIPTION	CKT/BKR TRIP	POLE	#
1	1	20	ROOMS	2.6			-	-	-	-		2.6									2.6		-	-	-	-	2.6			CAFETERIA	20	1	2
3	1	20	ROOMS		1.3		-	-	-	-		1.3									0.6		-	-	-	-		0.6		OFFICE	20	1	4
5	1	20	ROOMS			1.5	-	-	-	-		1.5									1.0		-	-	-	-			1.0	CORRIDOR	20	1	6
7	1	20	LVL BC MER	3.5			-	-	-	-		3.5									1.2		-	-	-	-	1.2			TUNNEL	20	1	8
9	1	20	LVL BC BOH		2.6		-	-	-	-		2.6											-	-	-	-		0.0		SPARE	20	1	10
11	1	20	SPARE			0.0	-	-	-	-													-	-	-	-			0.0	SPARE	20	1	12
13	1	20	SPARE	0.0			-	-	-	-													-	-	-	-	0.0			SPARE	20	1	14
15	1	20	SPARE		0.0		-	-	-	-													-	-	-	-		0.0		SPARE	20	1	16
17	1	20	SPARE			0.0	-	-	-	-													-	-	-	-			0.0	SPARE	20	1	18
19	1	20	SPARE	0.0			-	-	-	-													-	-	-	-	0.0			SPARE	20	1	20
21	1	20	SPARE		0.0		-	-	-	-													-	-	-	-		0.0		SPARE	20	1	22
23	1	20	SPARE			0.0	-	-	-	-													-	-	-	-			0.0	SPARE	20	1	24
25	1	20	SPARE	0.0			-	-	-	-													-	-	-	-	0.0			SPARE	20	1	26
27	1	20	SPARE		0.0		-	-	-	-													-	-	-	-		0.0		SPARE	20	1	28
29	1	20	SPARE			0.0	-	-	-	-													-	-	-	-			0.0	SPARE	20	1	30
												11.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.3												

	A	B	C				A	B	C	
CONNECTED kVA	6	4	2	PHASE A	10 KVA	35 AMPS	4	1	1	CONNECTED kVA
CONNECTED AMPS	22	14	5	PHASE B	5 KVA	16 AMPS	14	2	4	CONNECTED AMPS
				PHASE C	3 KVA	9 AMPS				
				TOTAL	17 KVA	20 AMPS				

CONNECTED LOADS	
TOTAL CONNECTED LIGHTING LOAD	17 kVA
TOTAL CONNECTED RECEPTACLE LOAD	0 kVA
TOTAL CONNECTED NON-CONTINOUS LOAD	0 kVA
TOTAL CONNECTED CONTINOUS LOAD	0 kVA
TOTAL CONNECTED MECHANICAL LOAD	0 kVA

DEMAND LOADS	DEMAND FACTORS
17 kVA	1
0 kVA	0.7
0 kVA	0.8
0 kVA	1
0 kVA	0.75
17 kVA	TOTAL DEMAND kVA
20 A	DEMAND AMPS

EQUIPMENT AND FEEDER SIZING

	LIGHTING x 125% =	21 kVA
	10kVA x 100% + 50% =	0 kVA
	NON-CONT. LOAD x 100% =	0 kVA
	CONTIN LOAD x 125%=	0 kVA
	MOTOR LOADS=	0 kVA
	25% OF LARGEST MOTOR=	kVA
	FEEDER LOAD=	21 kVA
	FEEDER LOAD (AMPS)=	25 A
20 %	SPARE FEEDER LOAD (AMPS)	30

X	100% RATED NEUTRAL BUS		X	EQUIPMENT GROUND BUS
	DOUBLE NEUTRAL BUS			ISOLATED GROUND BUS
		VOLTAGE:		277 /480 3 PHASE, 4 WIRE

M	C	N	R	L	COMMENTS	CDT	GRD	FEEDER SIZE	No.	KVA/PHASE A	B	C	LOAD DESCRIPTION	CKT/BKR TRIP	POLE	#
				2.6		-	-	-	-	2.6			CAFETERIA	20	1	2
				0.6		-	-	-	-		0.6		OFFICE	20	1	4
				1.0		-	-	-	-			1.0	CORRIDOR	20	1	6
				1.2		-	-	-	-	1.2			TUNNEL	20	1	8
						-	-	-	-		0.0		SPARE	20	1	10
						-	-	-	-			0.0	SPARE	20	1	12
						-	-	-	-	0.0			SPARE	20	1	14
						-	-	-	-		0.0		SPARE	20	1	16
						-	-	-	-			0.0	SPARE	20	1	18
						-	-	-	-	0.0			SPARE	20	1	20
						-	-	-	-		0.0		SPARE	20	1	22
						-	-	-	-			0.0	SPARE	20	1	24
						-	-	-	-	0.0			SPARE	20	1	26
						-	-	-	-		0.0		SPARE	20	1	28
						-	-	-	-			0.0	SPARE	20	1	30
0.0	0.0	0.0	0.0	5.3												

35 AMPS	4	1	1	CONNECTED kVA
16 AMPS	14	2	4	CONNECTED AMPS
9 AMPS				
20 AMPS				

EMAND FACTORS
1
0.7
0.8
1
0.75
TOTAL DEMAND kVA
DEMAND AMPS

EQUIPMENT AND FEEDER SIZING

	LIGHTING x 125% =	21 kVA
	10kVA x 100% + 50% =	0 kVA
	NON-CONT. LOAD x 100% =	0 kVA
	CONTIN LOAD x 125%=	0 kVA
	MOTOR LOADS=	0 kVA
	25% OF LARGEST MOTOR=	kVA
	FEEDER LOAD=	21 kVA
	FEEDER LOAD (AMPS)=	25 A
20 %	SPARE FEEDER LOAD (AMPS)	30

ELP-AA

PANEL:	ELP-AA	-	M.C.B.	-	X	SURFACE MOUNT	X	100% RATED NEUTRAL BUS	X	EQUIPMENT GROUND BUS
FED FROM	DP-LS-BA	X	M.L.O.	-		FLUSH MOUNT		DOUBLE NEUTRAL BUS		ISOLATED GROUND BUS
BUS AMPS =	225		MIN AIC	25000 AMPS	-	FEED THRU PANEL		VOLTAGE:		277 /480 3 PHASE, 4 WIRE
LOCATION	ELECTRICAL ROOM									

CKT/BKR #	POLE	TRIP	LOAD DESCRIPTION	KVA/PHASE A	B	C	FEEDER No.	SIZE	GRD	CDT	COMMENTS	L	R	N	C	M
1	1	20	LVL BC MER	1.3			-	-	-	-		1.3				
3	1	20	LVL BC/A ELEV/STR		0.7		-	-	-	-		0.7				
5	1	20	EXITS LVL BC			0.1	-	-	-	-		0.1				
7	1	20	SPARE	0.0			-	-	-	-						
9	1	20	SPARE		0.0		-	-	-	-						
11	1	20	SPARE			0.0	-	-	-	-						
13	1	20	SPARE	0.0			-	-	-	-						
15	1	20	SPARE		0.0		-	-	-	-						
17	1	20	SPARE			0.0	-	-	-	-						
19	3	30	SPARE	0.0			-	-	-	-						
21	-	-	-		0.0		-	-	-	-						
23	-	-	-			0.0	-	-	-	-						
25	3	30	TRANS	0.0			-	-	-	-						
27	-	-	TO		0.0		-	-	-	-						
29	-	-	ELPD-AAL			0.0	-	-	-	-						
												2.1	0.0	0.0	0.0	0.0

M	C	N	R	L	COMMENTS	CDT	GRD	FEEDER SIZE	No.	KVA/PHASE A	B	C	LOAD DESCRIPTION	TRIP	POLE	CKT/BKR #
				1.0		-	-	-	-	1.0			LVL A CORR	20	1	2
				0.4		-	-	-	-		0.4		TUNNEL	20	1	4
				1.3		-	-	-	-			1.3	CAFE / LOBBIES	20	1	6
						-	-	-	-	0.0			SPARE	20	1	8
						-	-	-	-		0.0		SPARE	20	1	10
						-	-	-	-			0.0	SPARE	20	1	12
						-	-	-	-	0.0			SPARE	20	1	14
						-	-	-	-		0.0		SPARE	20	1	16
						-	-	-	-			0.0	SPARE	20	1	18
						-	-	-	-	0.0			SPARE	20	1	20
						-	-	-	-		0.0		SPARE	20	1	22
						-	-	-	-			0.0	SPARE	20	1	24
						-	-	-	-	0.0			TRANS	30	3	26
						-	-	-	-		0.0		TO	-	-	28
						-	-	-	-			0.0	ERP-AA	-	-	30
0.0	0.0	0.0	0.0	2.6												

	A	B	C				A	B	C	
CONNECTED kVA	1	1	0	PHASE A	2 KVA	8 AMPS	1	0	1	CONNECTED kVA
CONNECTED AMPS	5	3	0	PHASE B	1 KVA	4 AMPS	3	2	5	CONNECTED AMPS
				PHASE C	1 KVA	5 AMPS				
				TOTAL	5 KVA	6 AMPS				

CONNECTED LOADS	
TOTAL CONNECTED LIGHTING LOAD	5 kVA
TOTAL CONNECTED RECEPTACLE LOAD	0 kVA
TOTAL CONNECTED NON-CONTINOUS LOAD	0 kVA
TOTAL CONNECTED CONTINOUS LOAD	0 kVA
TOTAL CONNECTED MECHANICAL LOAD	0 kVA

DEMAND LOADS	DEMAND FACTORS
5 kVA	1
0 kVA	0.7
0 kVA	0.8
0 kVA	1
0 kVA	0.75
5 kVA	TOTAL DEMAND kVA
6 A	DEMAND AMPS

EQUIPMENT AND FEEDER SIZING

	LIGHTING x 125% =	6 kVA
	10kVA x 100% + 50% =	0 kVA
	NON-CONT. LOAD x 100% =	0 kVA
	CONTIN LOAD x 125%=	0 kVA
	MOTOR LOADS=	0 kVA
	25% OF LARGEST MOTOR=	kVA
	FEEDER LOAD=	6 kVA
	FEEDER LOAD (AMPS)=	7 A
20 %	SPARE FEEDER LOAD (AMPS)	9

X	100% RATED NEUTRAL BUS		X	EQUIPMENT GROUND BUS
	DOUBLE NEUTRAL BUS			ISOLATED GROUND BUS
		VOLTAGE:		277 /480 3 PHASE, 4 WIRE

M	C	N	R	L	COMMENTS	CDT	GRD	FEEDER SIZE	No.	KVA/PHASE A	B	C	LOAD DESCRIPTION	TRIP	POLE	CKT/BKR #
				1.0		-	-	-	-	1.0			LVL A CORR	20	1	2
				0.4		-	-	-	-		0.4		TUNNEL	20	1	4
				1.3		-	-	-	-			1.3	CAFE / LOBBIES	20	1	6
						-	-	-	-	0.0			SPARE	20	1	8
						-	-	-	-		0.0		SPARE	20	1	10
						-	-	-	-			0.0	SPARE	20	1	12
						-	-	-	-	0.0			SPARE	20	1	14
						-	-	-	-		0.0		SPARE	20	1	16
						-	-	-	-			0.0	SPARE	20	1	18
						-	-	-	-	0.0			SPARE	20	1	20
						-	-	-	-		0.0		SPARE	20	1	22
						-	-	-	-			0.0	SPARE	20	1	24
						-	-	-	-	0.0			TRANS	30	3	26
						-	-	-	-		0.0		TO	-	-	28
						-	-	-	-			0.0	ERP-AA	-	-	30
0.0	0.0	0.0	0.0	2.6												

	A	B	C	
8 AMPS	1	0	1	CONNECTED kVA
4 AMPS	3	2	5	CONNECTED AMPS
5 AMPS				
6 AMPS				

MAND FACTORS
1
0.7
0.8
1
0.75
TOTAL DEMAND kVA
DEMAND AMPS

EQUIPMENT AND FEEDER SIZING

	LIGHTING x 125% =	6 kVA
	10kVA x 100% + 50% =	0 kVA
	NON-CONT. LOAD x 100% =	0 kVA
	CONTIN LOAD x 125%=	0 kVA
	MOTOR LOADS=	0 kVA
	25% OF LARGEST MOTOR=	kVA
	FEEDER LOAD=	6 kVA
	FEEDER LOAD (AMPS)=	7 A
20 %	SPARE FEEDER LOAD (AMPS)	9

Revised Panelboard Schedules

Since 20 amp circuits will be used, the branch circuits must be sized accordingly. Here is the calculation made to obtain the maximum load allowable in each 20 amp circuit:

20 amps x 80% (NEC) = 16 amps x 80% (good engineering practice) = 12.8 amps per circuit max allowable
VA = 12.8amps x 277V x 3 = 10,637 VA = 10.6 kVA load in each circuit allowable

In the following table are the revised lighting loads for each of the four lighting spaces:

Luminaire Type	Watts/ Luminaire	Amount	Total Wattage
AB	18.4	4	73.6
AM	88	9	792
AP	46	8	368
AR	0.08	78	6.24
		TOTAL WATTAGE =	1239.84

Luminaire Type	Watts/ Luminaire	Amount	Total Wattage
AB	18.4	4	73.6
AD	11.9	20	238
AF	10	10	100
AJ	30	5	150
AL	150	15	2250
AC	19.6	25	490
		TOTAL WATTAGE =	2811.6

*Decorative Allowance
1.0
0.142
85.785

TOTAL WATTAGE	LOBBY+CAFÉ
3301.6	6936.8

Luminaire Type	Watts/ Luminaire	Amount	Total Wattage
AB	18.4	9	165.6
AG	10	33	330
AH	46	17	782
AJ	30	17	510
AK	57	31	1767
		TOTAL WATTAGE =	3554.6

Lecture Hall - Emergency

Luminaire Type	Watts/ Luminaire	Amount	Total Wattage
AB	18.4	4	73.6
AG	10	10	100
AH	46	0	0
AJ	30	0	0
AK	57	10	570
		TOTAL WATTAGE =	743.6

Luminaire Type	Watts/ Luminaire	Amount	Total Wattage
AA	37	13	481
AB	18.4	19	349.6
AC	19.6	5	98
AD	11.9	114	1356.6
AE*	75	18	1350
		TOTAL WATTAGE* =	2285.2

*Decorative Allowance
1.0
0.591
40.867

TOTAL WATTAGE

3635.2

Lighting Loads	
Space	VA = W/PF
Cafeteria	3747.6
Lecture Hall	3664.5
Lobby	3403.7
North Entrance	1278.2
* SINCE ALL ARE LESS THAN 10.6 KVA, EACH SPACE ONLY REQUIRES ONE CIRCUIT	

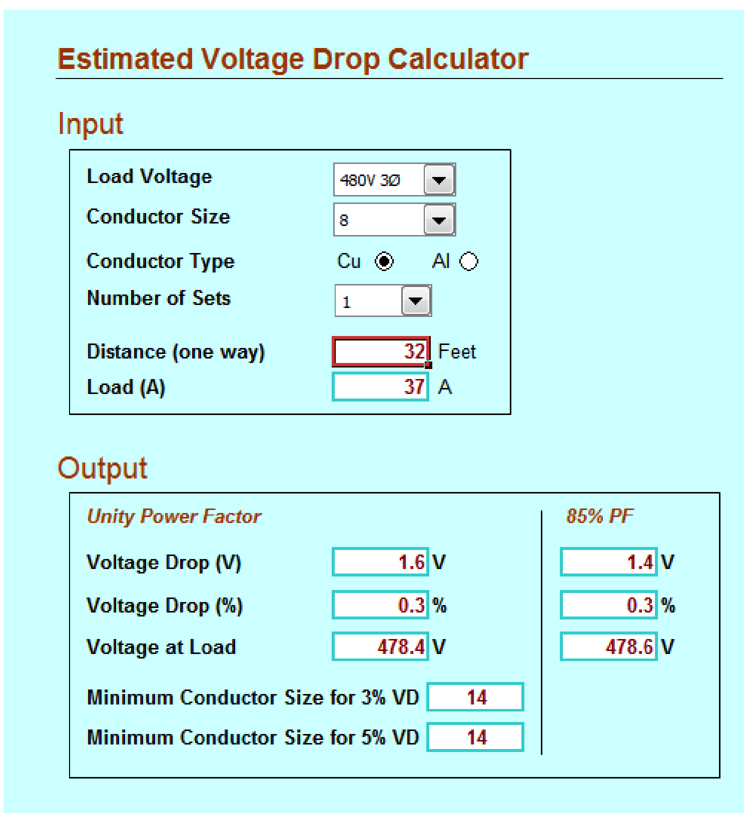
PANELBOARD SCHEDULE

VOLTAGE:	480Y/277V,3PH,4W	PANEL TAG:	ELP-2B	MIN. C/B AIC:	10K
SIZE/TYPE BUS:	60A	PANEL LOCATION:	ELECTRICAL ROOM	OPTIONS:	MCB
SIZE/TYPE MAIN:	60A/3P C/B	PANEL MOUNTING:	SURFACE		

DESCRIPTION	LOCATION	LOAD (WATTS)	C/B SIZE	POS. NO.	A	B	C	POS. NO.	C/B SIZE	LOAD (WATTS)	LOCATION	DESCRIPTION
SPARE		0	20A/1P	1	*			2	20A/1P	1800		PENTHOUSE MEC
STR 3,4 ELEV 1,5,6		36	20A/1P	3		*		4	20A/1P	1104		LVL 2 NORTH
SPARE		0	20A/1P	5			*	6	20A/1P	1288		LVL 2 CENTER
SPARE		0	20A/1P	7	*			8	20A/1P	1104		LVL 1 NORTH
SPARE		0	20A/1P	9		*		10	20A/1P	1380		LVL 1 MIDDLE
SPARE		0	20A/1P	11			*	12	20A/1P	0		SPARE
SPARE		0	20A/1P	13	*			14	20A/1P	0		SPARE
SPARE		0	20A/1P	15		*		16	20A/1P	1240		NORTH ENTRY LGT
LOBBY LIGHTING		3302	20A/1P	17			*	18	20A/1P	0		SPARE
SPARE		0	20A/1P	19	*			20	20A/1P	0		SPARE
SPARE		0	20A/1P	21		*		22	20A/1P	0		SPARE
SPARE		0	20A/1P	23			*	24	20A/1P	0		SPARE
EPF-4		2700	20A/1P	25	*			26	20A/1P	1170		EPF-2
EPF-4		2700	20A/1P	27		*		28	20A/1P	1170		EPF-2
EPF-4		2700	20A/1P	29			*	30	20A/1P	1170		EPF-2
		0	20A/1P	31	*			32	20A/1P	0		
		0	20A/1P	33		*		34	20A/1P	0		
		0	20A/1P	35			*	36	20A/1P	0		
		0	20A/1P	37	*			38	20A/1P	0		
		0	20A/1P	39		*		40	20A/1P	0		
		0	20A/1P	41			*	42	20A/1P	0		

CONNECTED LOAD (KW) - A Ph.	6.77	TOTAL DESIGN LOAD (KW)	27.44
CONNECTED LOAD (KW) - B Ph.	7.63	POWER FACTOR	0.88
CONNECTED LOAD (KW) - C Ph.	8.46	TOTAL DESIGN LOAD (AMPS)	37

ELP-2B is fed from ELP-AB.



SIEMENS

PANELBOARD SCHEDULE

VOLTAGE:	208Y/120V,3PH,4W	PANEL TAG:	LPD-AAL	MIN. C/B AIC:	10K
SIZE/TYPE BUS:	60A	PANEL LOCATION:	ELECTRICAL ROOM	OPTIONS:	M.C.B.
SIZE/TYPE MAIN:	60A/3P C/B	PANEL MOUNTING:	SURFACE		

DESCRIPTION	LOCATION	LOAD (WATTS)	C/B SIZE	POS. NO.	A	B	C	POS. NO.	C/B SIZE	LOAD (WATTS)	LOCATION	DESCRIPTION
LECTURE HALL		3555	20A/1P	1	*			2	20A/1P	0		SPARE
SPARE		0	20A/1P	3		*		4	20A/1P	0		SPARE
SPARE		0	20A/1P	5			*	6	20A/1P	0		SPARE
SPARE		0	20A/1P	7	*			8	20A/1P	0		SPARE
SPARE		0	20A/1P	9		*		10	20A/1P	0		SPARE
SPARE		0	20A/1P	11			*	12	20A/1P	0		SPARE
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
SPARE		0	20A/1P	19	*			20	20A/1P	0		SPARE
SPARE		0	20A/1P	21		*		22	20A/1P	0		SPARE
SPARE		0	20A/1P	23			*	24	20A/1P	0		SPARE
SPARE		0	20A/1P	25	*			26	20A/1P	0		SPARE
SPARE		0	20A/1P	27		*		28	20A/1P	0		SPARE
SPARE		0	20A/1P	29			*	30	20A/1P	0		SPARE
		0	20A/1P	31	*			32	20A/1P	0		
		0	20A/1P	33		*		34	20A/1P	0		
		0	20A/1P	35			*	36	20A/1P	0		
		0	20A/1P	37	*			38	20A/1P	0		
		0	20A/1P	39		*		40	20A/1P	0		
		0	20A/1P	41			*	42	20A/1P	0		

CONNECTED LOAD (KW) - A Ph.	3.56	TOTAL DESIGN LOAD (KW)	4.27
CONNECTED LOAD (KW) - B Ph.	0.00	POWER FACTOR	0.97
CONNECTED LOAD (KW) - C Ph.	0.00	TOTAL DESIGN LOAD (AMPS)	12

LPD-AAL is fed from DP-AA.

Estimated Voltage Drop Calculator

Input

Load Voltage	208V 3Ø
Conductor Size	12
Conductor Type	Cu ◉ Al ○
Number of Sets	1
Distance (one way)	20 Feet
Load (A)	12 A

Output

	Unity Power Factor	*85% PF*
Voltage Drop (V)	0.8 V	0.7 V
Voltage Drop (%)	0.4 %	0.3 %
Voltage at Load	207.2 V	207.3 V
Minimum Conductor Size for 3% VD	14	
Minimum Conductor Size for 5% VD	14	

PANELBOARD SCHEDULE

VOLTAGE:	208Y/120V,3PH,4W	PANEL TAG:	ELPD-AAL	MIN. C/B AIC:	10K
SIZE/TYPE BUS:	60A	PANEL LOCATION:	ELECTRICAL ROOM	OPTIONS:	M.C.B.
SIZE/TYPE MAIN:	60A/3P C/B	PANEL MOUNTING:	SURFACE		

DESCRIPTION	LOCATION	LOAD (WATTS)	C/B SIZE	POS. NO.	A	B	C	POS. NO.	C/B SIZE	LOAD (WATTS)	LOCATION	DESCRIPTION
SPARE		0	20A/1P	1	*			2	20A/1P	744		LECTURE HALL
SPARE		0	20A/1P	3		*		4	20A/1P	0		SPARE
SPARE		0	20A/1P	5			*	6	20A/1P	0		SPARE
SPARE		0	20A/1P	7	*			8	20A/1P	0		SPARE
SPARE		0	20A/1P	9		*		10	20A/1P	0		SPARE
SPARE		0	20A/1P	11			*	12	20A/1P	0		SPARE
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
SPARE		0	20A/1P	19	*			20	20A/1P	0		SPARE
SPARE		0	20A/1P	21		*		22	20A/1P	0		SPARE
SPARE		0	20A/1P	23			*	24	20A/1P	0		SPARE
SPARE		0	20A/1P	25	*			26	20A/1P	0		SPARE
SPARE		0	20A/1P	27		*		28	20A/1P	0		SPARE
SPARE		0	20A/1P	29			*	30	20A/1P	0		SPARE
		0	20A/1P	31	*			32	20A/1P	0		
		0	20A/1P	33		*		34	20A/1P	0		
		0	20A/1P	35			*	36	20A/1P	0		
		0	20A/1P	37	*			38	20A/1P	0		
		0	20A/1P	39		*		40	20A/1P	0		
		0	20A/1P	41			*	42	20A/1P	0		

CONNECTED LOAD (KW) - A Ph.	0.74	TOTAL DESIGN LOAD (KW)	0.89
CONNECTED LOAD (KW) - B Ph.	0.00	POWER FACTOR	0.97
CONNECTED LOAD (KW) - C Ph.	0.00	TOTAL DESIGN LOAD (AMPS)	3

ELPD-AAL is fed from T-EAL via ELP-AA.

Estimated Voltage Drop Calculator

Input

Load Voltage	208V 3Ø	
Conductor Size	12	
Conductor Type	Cu (selected) / Al	
Number of Sets	1	
Distance (one way)	12	Feet
Load (A)	3	A

Output

	Unity Power Factor	*85% PF*
Voltage Drop (V)	0.1 V	0.1 V
Voltage Drop (%)	0.1 %	0.1 %
Voltage at Load	207.9 V	207.9 V
Minimum Conductor Size for 3% VD	14	
Minimum Conductor Size for 5% VD	14	

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

VOLTAGE:	480Y/277V,3PH,4W	PANEL TAG:	LP-AA	MIN. C/B AIC:	10K
SIZE/TYPE BUS:	60A	PANEL LOCATION:	ELECTRICAL ROOM	OPTIONS:	M.C.B.
SIZE/TYPE MAIN:	60A/3P C/B	PANEL MOUNTING:	SURFACE		

DESCRIPTION	LOCATION	LOAD (WATTS)	C/B SIZE	POS. NO.	A	B	C	POS. NO.	C/B SIZE	LOAD (WATTS)	LOCATION	DESCRIPTION
ROOMS		2392	20A/1P	1	*			2	20A/1P	0		SPARE
ROOMS		1196	20A/1P	3		*		4	20A/1P	552		OFFICE
ROOMS		1380	20A/1P	5			*	6	20A/1P	920		CORRIDOR
LVL BC MER		3150	20A/1P	7	*			8	20A/1P	0		SPARE
LEVEL BC BOH		2340	20A/1P	9		*		10	20A/1P	1104		TUNEL
SPARE		0	20A/1P	11			*	12	20A/1P	3635		CAFETERIA LGT
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
SPARE		0	20A/1P	19	*			20	20A/1P	0		SPARE
SPARE		0	20A/1P	21		*		22	20A/1P	0		SPARE
SPARE		0	20A/1P	23			*	24	20A/1P	0		SPARE
SPARE		0	20A/1P	25	*			26	20A/1P	0		SPARE
SPARE		0	20A/1P	27		*		28	20A/1P	0		SPARE
SPARE		0	20A/1P	29			*	30	20A/1P	0		SPARE
		0	20A/1P	31	*			32	20A/1P	0		
		0	20A/1P	33		*		34	20A/1P	0		
		0	20A/1P	35			*	36	20A/1P	0		
		0	20A/1P	37	*			38	20A/1P	0		
		0	20A/1P	39		*		40	20A/1P	0		
		0	20A/1P	41			*	42	20A/1P	0		

CONNECTED LOAD (KW) - A Ph.	5.54	TOTAL DESIGN LOAD (KW)	20.00
CONNECTED LOAD (KW) - B Ph.	5.19	POWER FACTOR	0.92
CONNECTED LOAD (KW) - C Ph.	5.94	TOTAL DESIGN LOAD (AMPS)	26

LP-AA is fed from BUSWAY.

Estimated Voltage Drop Calculator

Input

Load Voltage 480V 3Ø

Conductor Size 10

Conductor Type Cu (selected) Al

Number of Sets 1

Distance (one way) 24 Feet

Load (A) 26 A

Output

	Unity Power Factor	*85% PF*
Voltage Drop (V)	1.3 V	1.2 V
Voltage Drop (%)	0.3 %	0.2 %
Voltage at Load	478.7 V	478.8 V

Minimum Conductor Size for 3% VD 14

Minimum Conductor Size for 5% VD 14

PANELBOARD SCHEDULE

VOLTAGE:	480Y/277V,3PH,4W	PANEL TAG:	ELP-AA	MIN. C/B AIC:	10K
SIZE/TYPE BUS:	60A	PANEL LOCATION:	ELECTRICAL ROOM	OPTIONS:	M.C.B.
SIZE/TYPE MAIN:	60A/3P C/B	PANEL MOUNTING:	SURFACE		

DESCRIPTION	LOCATION	LOAD (WATTS)	C/B SIZE	POS. NO.	A	B	C	POS. NO.	C/B SIZE	LOAD (WATTS)	LOCATION	DESCRIPTION
LVL BC MER		1170	20A/1P	1	*			2	20A/1P	0		SPARE
EXITS LVL BC		90	20A/1P	3		*		4	20A/1P	360		TUNNEL
SPARE		0	20A/1P	5			*	6	20A/1P	3635		CAFÉ
LVL BC/A ELEV		630	20A/1P	7	*			8	20A/1P	0		SPARE
LVL A CORR		900	20A/1P	9		*		10	20A/1P	0		SPARE
SPARE		0	20A/1P	11			*	12	20A/1P	0		SPARE
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
SPARE		0	20A/1P	19	*			20	20A/1P	0		SPARE
SPARE		0	20A/1P	21		*		22	20A/1P	0		SPARE
SPARE		0	20A/1P	23			*	24	20A/1P	0		SPARE
SPARE		0	20A/1P	25	*			26	20A/1P	0		SPARE
SPARE		0	20A/1P	27		*		28	20A/1P	0		SPARE
SPARE		0	20A/1P	29			*	30	20A/1P	0		SPARE
		0	20A/1P	31	*			32	20A/1P	0		
		0	20A/1P	33		*		34	20A/1P	0		
		0	20A/1P	35			*	36	20A/1P	0		
		0	20A/1P	37	*			38	20A/1P	0		
		0	20A/1P	39		*		40	20A/1P	0		
		0	20A/1P	41			*	42	20A/1P	0		

CONNECTED LOAD (KW) - A Ph.	1.80	TOTAL DESIGN LOAD (KW)	8.14
CONNECTED LOAD (KW) - B Ph.	1.35	POWER FACTOR	0.94
CONNECTED LOAD (KW) - C Ph.	3.64	TOTAL DESIGN LOAD (AMPS)	10

ELP-AA is fed from DP-LS-BA.

Estimated Voltage Drop Calculator

Input

Load Voltage	480V 3Ø
Conductor Size	10
Conductor Type	Cu (selected) / Al
Number of Sets	1
Distance (one way)	8 Feet
Load (A)	10 A

Output

	Unity Power Factor	*85% PF*
Voltage Drop (V)	0.2 V	0.2 V
Voltage Drop (%)	0.0 %	0.0 %
Voltage at Load	479.8 V	479.8 V

Minimum Conductor Size for 3% VD 14

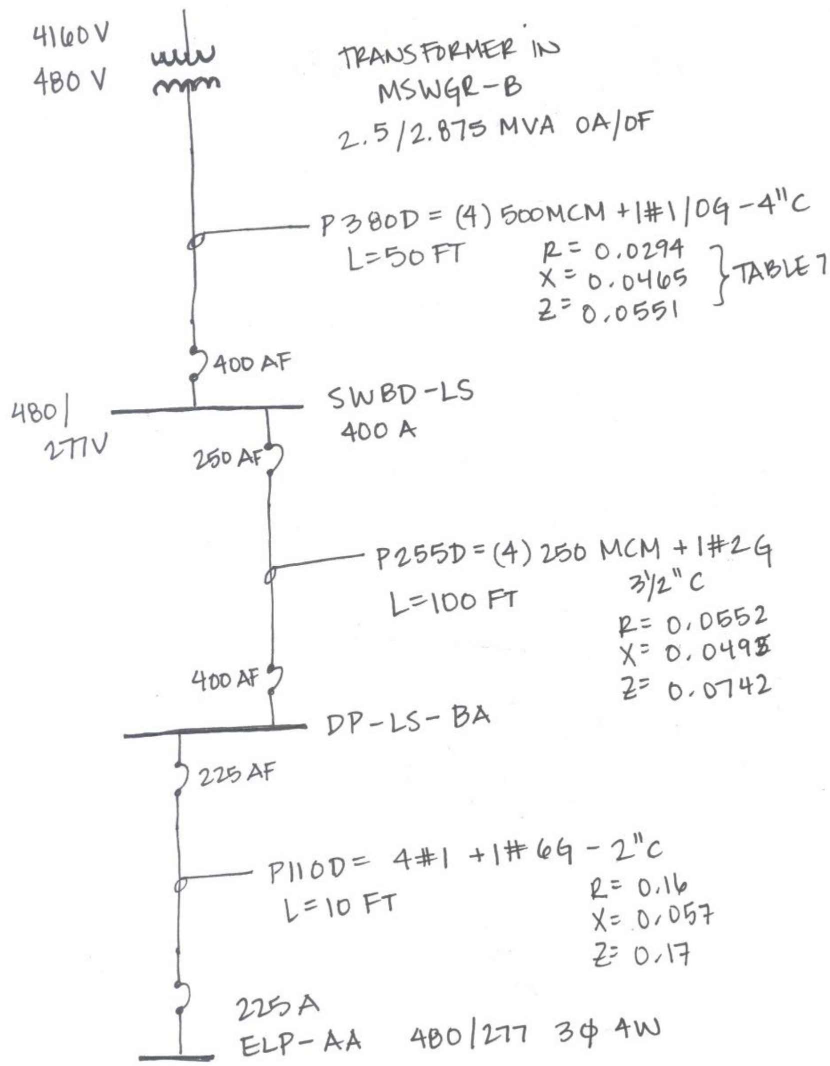
Minimum Conductor Size for 5% VD 14

Wire and Conduit Sizing			
Panel Tag	Phase Wire Size	Ground Wire Size	Conduit Size
LP-AA	10	10	0.75" EMT
ELP-AA	12	12	0.75" EMT
LPD-AAL	12	12	0.75" EMT
ELPD-AAL	12	12	0.75" EMT
ELP-2B	8	10	0.75" EMT

Manufacturer's panel board information is located in Appendix P.

Short Circuit

The short circuit calculation follows one path starting at the secondary end of the transformer in one of the substations MSWGR-B to a single panelboard ELP-AA. The sketch below illustrates the path and all its components: MSWGR-B, SWBD-LS, DP-LS-BA, and ELP-AA. The results of the analysis on the following page show that the existing short circuit protection does not cover the short circuit current for the distribution panel DP-LS-BA so this needs to be revised.



SINGLE-LINE AREA CHOSEN AS PATH FOR SHORT CIRCUIT CALCULATION

Summary Results of Fault Current				
Point	Location	Available Fault (A)	Standard Breaker Rating (A)	Standard Breaker Rating (A) Existing
A	MSWGR-B	52318	65000	65000
B	SWBD-LS	35029	65000	65000
C	DP-LS-BA	24604	35000	18000
D	ELP-AA	15063	22000	

Fault Current Analysis (Per Unit Method)

Utility Transformer Primary Side MSWGR-B

System Voltage =	0.48
Base KVA =	1000
Utility S.C. KVA =	1E+08

Utility Primary

X(P.U.)=baseKVA/utilityS.C.KVA=	0.00001
R(P.U.)=	0

Transformer Secondary

				ΣX	ΣR	ΣZ	Isc(A)
%Z =	5.75	X(P.U.)=(%X*baseKVA)/(100*KVAxfmr)=	0.02264	0.02264	0.004	0.02299	52318
X/R =	2.38?	R(P.U.)=(%R*baseKVA)/(100*KVAxfmr)=	0.004				
%X =	5.66						
%R =	1						
KVA =	2500						
KV =	0.48						

Switchboard SWBD-LS

					ΣX	ΣR	ΣZ	Isc(A)
Wire =	500	X=(L/1000)*XL*(1/SETS)	=	0.00233	0.03273	0.01038	0.03434	35029
Length =	50	R=(L/1000)*R*(1/SETS)	=	0.00147				
Sets =	1							
XL =	0.0465	X(P.U.)=(X*baseKVA)/(1000*KV^2)=		0.01009				
R =	0.0294	R(P.U.)=(R*baseKVA)/(1000*KV^2)=		0.00638				
KV =	0.48							

Distribution Panelboard DP-LS-BA

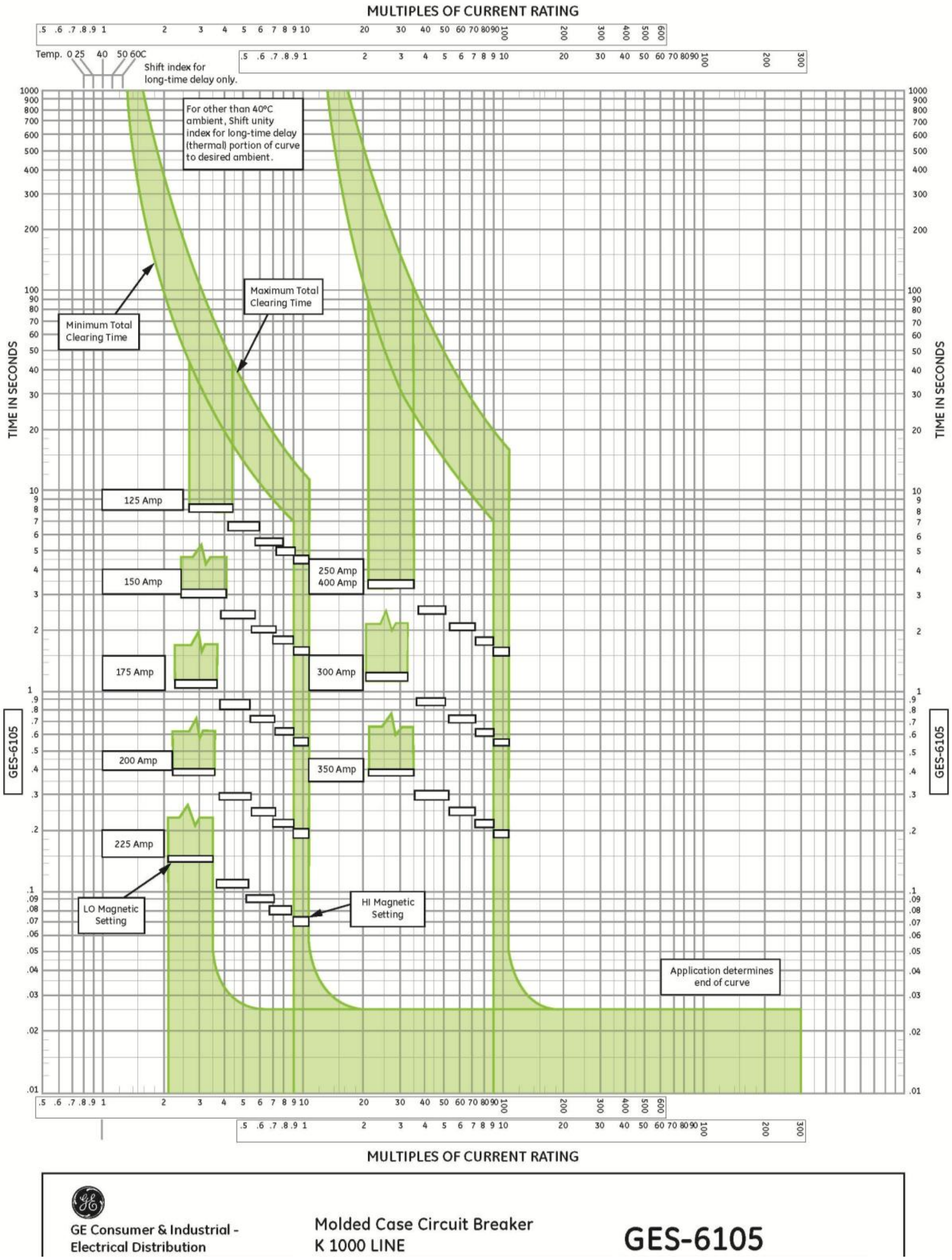
					ΣX	ΣR	ΣZ	Isc(A)
Wire =	250	X=(L/1000)*XL*(1/SETS)	=	0.00248	0.04347	0.02236	0.04889	24604
Length =	100	R=(L/1000)*R*(1/SETS)	=	0.00276				
Sets =	1							
XL =	0.0495	X(P.U.)=(X*baseKVA)/(1000*KV^2)=		0.01074				
R =	0.0552	R(P.U.)=(R*baseKVA)/(1000*KV^2)=		0.01198				
KV =	0.48							

Panelboard ELP-AA

					ΣX	ΣR	ΣZ	Isc(A)
Wire =	1	X=(L/1000)*XL*(1/SETS)	=	0.00285	0.05584	0.05708	0.07985	15063
Length =	10	R=(L/1000)*R*(1/SETS)	=	0.008				
Sets =	1							
XL =	0.057	X(P.U.)=(X*baseKVA)/(1000*KV^2)=		0.01237				
R =	0.16	R(P.U.)=(R*baseKVA)/(1000*KV^2)=		0.03472				
KV =	0.48							

Coordination Study

The chart below shows the overcurrent time delay curves for all the circuit breaker ratings available through the path followed for the short circuit study. This shows the 225A and 250/400A time curves do not overlap but the 250A and 400A are the same curve. This means that the 225A breaker will trip before the 250/400A ones.



Depth 1 | **Motor Control Center Design**

To consolidate all the separate motors in the Penthouse Mechanical and Electrical Room (MER), a motor control center was designed. It ended up having 25 vertical units, some 36” wide and some 24” wide because of the amount of motors in this one room. Below are the loads for each separate unit and the design for each.

LEVEL 3 PENTHOUSE MER MOTOR CONTROL CENTER LOADS

Load Tag	Description	Magnitude	Units	NEC Motor Amps	Voltage	Phase	Assumed Power Factor	Load in KVA	Load in KW	Qty.	Total Load in KW	VFD	CB Type HMCP	Starter Type	NEMA Starter Size	Standard Unit Space (in)
AHU-1	air handling unit	5	HP	7.6	480	3	0.75	6.311	4.733	2	9.4666	X	15	AFD	1	24
AHU-2	air handling unit	7.5	HP	11	480	3	0.95	9.134	8.678	9	78.099	X	30	AFD	1	24
AHU-3	air handling unit	7.5	HP	11	480	3	0.95	9.134	8.678	9	78.099	X	30	AFD	1	24
AHU-4	air handling unit	7.5	HP	11	480	3	0.95	9.134	8.678	9	78.099	X	30	AFD	1	24
AHU-5	air handling unit	7.5	HP	11	480	3	0.95	9.134	8.678	9	78.099	X	30	AFD	1	24
AHU-6	air handling unit	7.5	HP	11	480	3	0.95	9.134	8.678	6	52.066	X	30	AFD	1	24
AHU-7	air handling unit	5	HP	7.6	480	3	0.75	6.311	4.733	8	37.866	X	15	AFD	1	24
RF-1	return fan	10	HP	14	480	3	0.95	11.63	11.04	1	11.044	X	35	AFD	1	24
LEX-1	exhaust	20	HP	27	480	3	0.95	22.42	21.3	1	21.3	X	50	AFD	2	36
LEX-2	exhaust	20	HP	27	480	3	0.95	22.42	21.3	1	21.3	X	50	AFD	2	36
LEX-3	exhaust	20	HP	27	480	3	0.95	22.42	21.3	1	21.3	X	50	AFD	2	36
LEX-9	exhaust	20	HP	27	480	3	0.95	22.42	21.3	1	21.3	X	50	AFD	2	36
LEX-8	exhaust	20	HP	27	480	3	0.95	22.42	21.3	1	21.3	X	50	AFD	2	36
LEX-7	exhaust	20	HP	27	480	3	0.95	22.42	21.3	1	21.3	X	50	AFD	2	36
LEX-6	exhaust	20	HP	27	480	3	0.95	22.42	21.3	1	21.3	X	50	AFD	2	36
LEX-5	exhaust	20	HP	27	480	3	0.95	22.42	21.3	1	21.3	X	50	AFD	2	36
LEX-4	exhaust	20	HP	27	480	3	0.95	22.42	21.3	1	21.3	X	50	AFD	2	36
HDX-1	heat exchanger pump	25	HP	34	480	3	0.95	28.23	26.82	1	26.822	X	50	AFD	2	36
HDX-2	heat exchanger pump	25	HP	34	480	3	0.95	28.23	26.82	1	26.822	X	50	AFD	2	36
HDX-3	heat exchanger pump	25	HP	34	480	3	0.95	28.23	26.82	1	26.822	X	50	AFD	2	36
HDX-4	heat exchanger pump	25	HP	34	480	3	0.95	28.23	26.82	1	26.822	X	50	AFD	2	36
HRM-1	AHU-6	30	HP	40	480	3	0.95	33.25	31.59	1	31.592	X	100	AFD	3	36

Notes:
1. EATON 2100 Series Motor Control Centers, 30.1
2. SVX9000 1 - 30hp at 480 V Plug-in Adjustable Frequency Drive Units

Quantity of 24" Units	Quantity of 36" Units
53	14

# of Vertical Sections	
18	7

Motor Control Center: MCC						Location: PENTHOUSE 3RD FLOOR MECHANICAL ROOM			
Amps: 1600		Volts: 480Y/277 3PH 4W, 60HZ				NEMA: 2		AIC: 160,000	
Unit #	Circuit	HP	FLA	Starter		Circuit Protection		Feeder	Notes
				Type	Size	Type	Trip		
A1	AHU-1	5	10	AFD	1	HMCP	15	3#14 + 1#14G AND 3/4"C	-
A2	AHU-1	5	10	AFD	1	HMCP	15	3#14 + 1#14G AND 3/4"C	-
A3	AHU-2	7.5	14	AFD	1	HMCP	30	3#10 + 1#10G AND 3/4"C	-
B1	AHU-2	7.5	14	AFD	1	HMCP	30	3#10 + 1#10G AND 3/4"C	-
B2	AHU-2	7.5	14	AFD	1	HMCP	30	3#10 + 1#10G AND 3/4"C	-
B3	AHU-2	7.5	14	AFD	1	HMCP	30	3#10 + 1#10G AND 3/4"C	-
C1	AHU-2	7.5	14	AFD	1	HMCP	30	3#10 + 1#10G AND 3/4"C	-
C2	AHU-2	7.5	14	AFD	1	HMCP	30	3#10 + 1#10G AND 3/4"C	-
C3	AHU-2	7.5	14	AFD	1	HMCP	30	3#10 + 1#10G AND 3/4"C	-
D1	AHU-2	7.5	14	AFD	1	HMCP	30	3#10 + 1#10G AND 3/4"C	-
D2	AHU-2	7.5	14	AFD	1	HMCP	30	3#10 + 1#10G AND 3/4"C	-
D3	AHU-3	7.5	14	AFD	1	HMCP	30	3#10 + 1#10G AND 3/4"C	-
E1	AHU-3	7.5	14	AFD	1	HMCP	30	3#10 + 1#10G AND 3/4"C	-
E2	AHU-3	7.5	14	AFD	1	HMCP	30	3#10 + 1#10G AND 3/4"C	-
E3	AHU-3	7.5	14	AFD	1	HMCP	30	3#10 + 1#10G AND 3/4"C	-
F1	AHU-3	7.5	14	AFD	1	HMCP	30	3#10 + 1#10G AND 3/4"C	-
F2	AHU-3	7.5	14	AFD	1	HMCP	30	3#10 + 1#10G AND 3/4"C	-
F3	AHU-3	7.5	14	AFD	1	HMCP	30	3#10 + 1#10G AND 3/4"C	-
G1	AHU-3	7.5	14	AFD	1	HMCP	30	3#10 + 1#10G AND 3/4"C	-
G2	AHU-3	7.5	14	AFD	1	HMCP	30	3#10 + 1#10G AND 3/4"C	-
G3	AHU-4	7.5	14	AFD	1	HMCP	30	3#10 + 1#10G AND 3/4"C	-
H1	AHU-4	7.5	14	AFD	1	HMCP	30	3#10 + 1#10G AND 3/4"C	-
H2	AHU-4	7.5	14	AFD	1	HMCP	30	3#10 + 1#10G AND 3/4"C	-
H3	AHU-4	7.5	14	AFD	1	HMCP	30	3#10 + 1#10G AND 3/4"C	-
I1	AHU-4	7.5	14	AFD	1	HMCP	30	3#10 + 1#10G AND 3/4"C	-
I2	AHU-4	7.5	14	AFD	1	HMCP	30	3#10 + 1#10G AND 3/4"C	-
I3	AHU-4	7.5	14	AFD	1	HMCP	30	3#10 + 1#10G AND 3/4"C	-
J1	AHU-4	7.5	14	AFD	1	HMCP	30	3#10 + 1#10G AND 3/4"C	-
J2	AHU-4	7.5	14	AFD	1	HMCP	30	3#10 + 1#10G AND 3/4"C	-
J3	AHU-5	7.5	14	AFD	1	HMCP	30	3#10 + 1#10G AND 3/4"C	-
K1	AHU-5	7.5	14	AFD	1	HMCP	30	3#10 + 1#10G AND 3/4"C	-
K2	AHU-5	7.5	14	AFD	1	HMCP	30	3#10 + 1#10G AND 3/4"C	-
K3	AHU-5	7.5	14	AFD	1	HMCP	30	3#10 + 1#10G AND 3/4"C	-
L1	AHU-5	7.5	14	AFD	1	HMCP	30	3#10 + 1#10G AND 3/4"C	-
L2	AHU-5	7.5	14	AFD	1	HMCP	30	3#10 + 1#10G AND 3/4"C	-
L3	AHU-5	7.5	14	AFD	1	HMCP	30	3#10 + 1#10G AND 3/4"C	-
M1	AHU-5	7.5	14	AFD	1	HMCP	30	3#10 + 1#10G AND 3/4"C	-
M2	AHU-5	7.5	14	AFD	1	HMCP	30	3#10 + 1#10G AND 3/4"C	-
M3	AHU-6	7.5	14	AFD	1	HMCP	30	3#10 + 1#10G AND 3/4"C	-
N1	AHU-6	7.5	14	AFD	1	HMCP	30	3#10 + 1#10G AND 3/4"C	-
N2	AHU-6	7.5	14	AFD	1	HMCP	30	3#10 + 1#10G AND 3/4"C	-
N3	AHU-6	7.5	14	AFD	1	HMCP	30	3#10 + 1#10G AND 3/4"C	-
O1	AHU-6	7.5	14	AFD	1	HMCP	30	3#10 + 1#10G AND 3/4"C	-
O2	AHU-6	7.5	14	AFD	1	HMCP	30	3#10 + 1#10G AND 3/4"C	-
O3	AHU-7	5	10	AFD	1	HMCP	15	3#14 + 1#14G AND 3/4"C	-
P1	AHU-7	5	10	AFD	1	HMCP	15	3#14 + 1#14G AND 3/4"C	-
P2	AHU-7	5	10	AFD	1	HMCP	15	3#14 + 1#14G AND 3/4"C	-
P3	AHU-7	5	10	AFD	1	HMCP	15	3#14 + 1#14G AND 3/4"C	-

Q1	AHU-7	5	10	AFD	1	HMCP	15	3#14 + 1#14G AND 3/4"C	-
Q2	AHU-7	5	10	AFD	1	HMCP	15	3#14 + 1#14G AND 3/4"C	-
Q3	AHU-7	5	10	AFD	1	HMCP	15	3#14 + 1#14G AND 3/4"C	-
R1	AHU-7	5	10	AFD	1	HMCP	15	3#14 + 1#14G AND 3/4"C	-
R2	RF-1	10	20	AFD	2	HMCP	35	3#10 + 1#10G AND 3/4"C	-
AA1	LEX-1	20	36	AFD	2	HMCP	50	3#8 +1#10G AND 3/4"C	-
AA2	LEX-2	20	36	AFD	2	HMCP	50	3#8 +1#10G AND 3/4"C	-
BB1	LEX-3	20	36	AFD	2	HMCP	50	3#8 +1#10G AND 3/4"C	-
BB2	LEX-9	20	36	AFD	2	HMCP	50	3#8 +1#10G AND 3/4"C	-
CC1	LEX-8	20	36	AFD	2	HMCP	50	3#8 +1#10G AND 3/4"C	-
CC2	LEX-7	20	36	AFD	2	HMCP	50	3#8 +1#10G AND 3/4"C	-
DD1	LEX-6	20	36	AFD	2	HMCP	50	3#8 +1#10G AND 3/4"C	-
DD2	LEX-5	20	36	AFD	2	HMCP	50	3#8 +1#10G AND 3/4"C	-
EE1	LEX-4	20	36	AFD	2	HMCP	50	3#8 +1#10G AND 3/4"C	-
EE2	HDX-1	25	45	AFD	2	HMCP	50	3#8 +1#10G AND 3/4"C	-
FF1	HDX-2	25	45	AFD	2	HMCP	50	3#8 +1#10G AND 3/4"C	-
FF2	HDX-3	25	45	AFD	2	HMCP	50	3#8 +1#10G AND 3/4"C	-
GG1	HDX-4	25	45	AFD	2	HMCP	50	3#8 +1#10G AND 3/4"C	-
GG2	HRM-1	30	53	AFD	3	HMCP	100	3#3 + 1#8G AND 1-1/4"C	-

TOTAL AMPS 1279

Drawings of Motor Control Center in Appendix P include elevation, 3D view, and details.

Depth 2 | Bus Duct Analysis

There are six existing copper bus ducts that run the length of the building. A study was made comparing copper vs. aluminum materials for their construction. There are benefits to both materials but from a first cost perspective, aluminum is the better option. The trends show that the price for copper have been steadily increasing in the past years whereas the aluminum prices have been increasing slower which might make aluminum even a better option for future construction. However, copper is stronger and a better conductor.

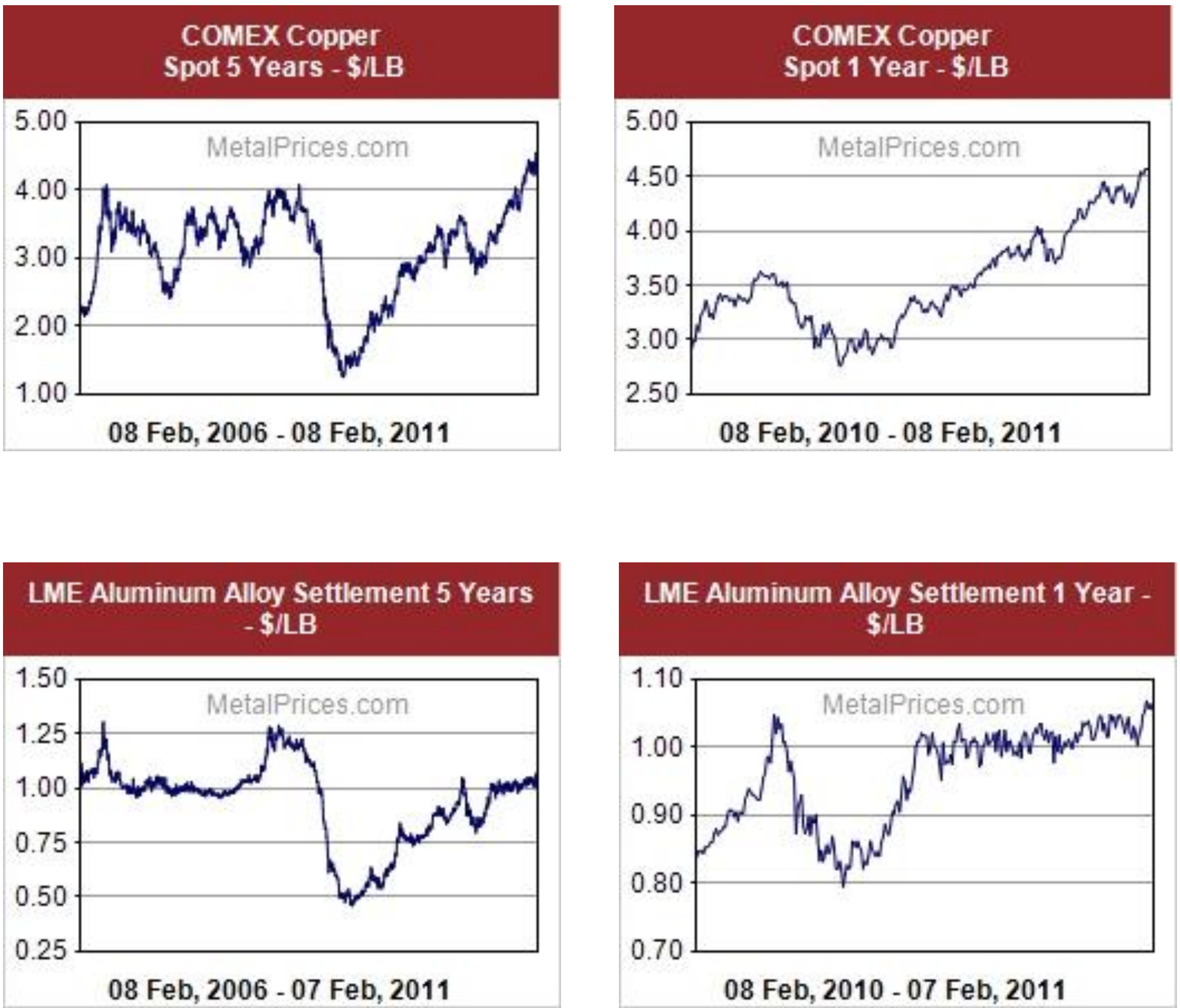
Existing Bus Ducts - Copper						
Tag	Amps	Voltage	Rating (kAIC)	Starting Level	Ending Level	Length (ft.)
A1	400	208Y/120V, 3P, 4W, 1G	22	A	5	74
A2	1000	480Y/277V, 3P, 4W, 1G	50	A	5	74
B9	400	480Y/277V, 3P, 4W, 1G	42	A	2	32
B11	1600	208Y/120V, 3P, 4W, 1G	50	A	2	32
C1	400	480Y/277V, 3P, 4W, 1G	42	A	3	46
C4	1600	208Y/120V, 3P, 4W, 1G	50	A	3	46

RSMeans Data 2009 (page 227-241)			
Aluminum Straight		Copper Straight	
Total Cost / 10LF	Total Cost	Total Cost / 10LF	Total Cost
$213	$1,576	$239	$1,769
$286	$2,116	$330	$2,442
$213	$682	$239	$765
$480	$1,536	$530	$1,696
$213	$980	$239	$1,099
$480	$2,208	$530	$2,438
	$9,098		$10,209

Percent Difference : 10.9%

RSMeans Data 2011 (page 230-244)			
Aluminum Straight		Copper Straight	
Total Cost / 10LF	Total Cost	Total Cost / 10LF	Total Cost
$220	$1,628	$247	$1,827.80
$295	$2,183	$340	$2,516.00
$220	$704	$247	$790.40
$495	$1,584	$545	$1,744.00
$220	$1,012	$247	$1,136.20
$495	$2,277	$545	$2,507.00
	$9,388		$10,521

Percent Difference : 10.8%

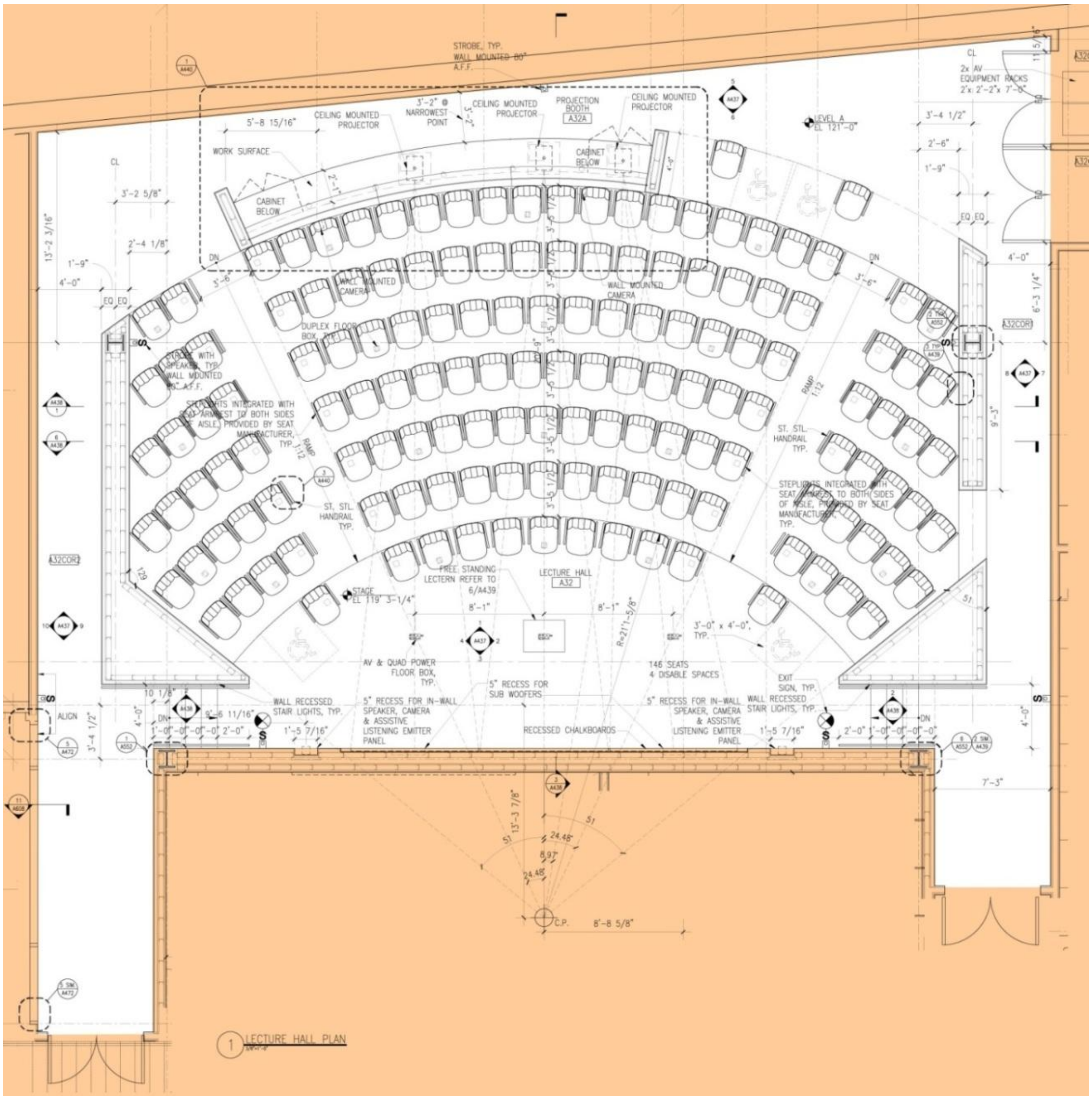


COPPER VS ALUMINUM PRICES IN THE LAST FIVE YEARS

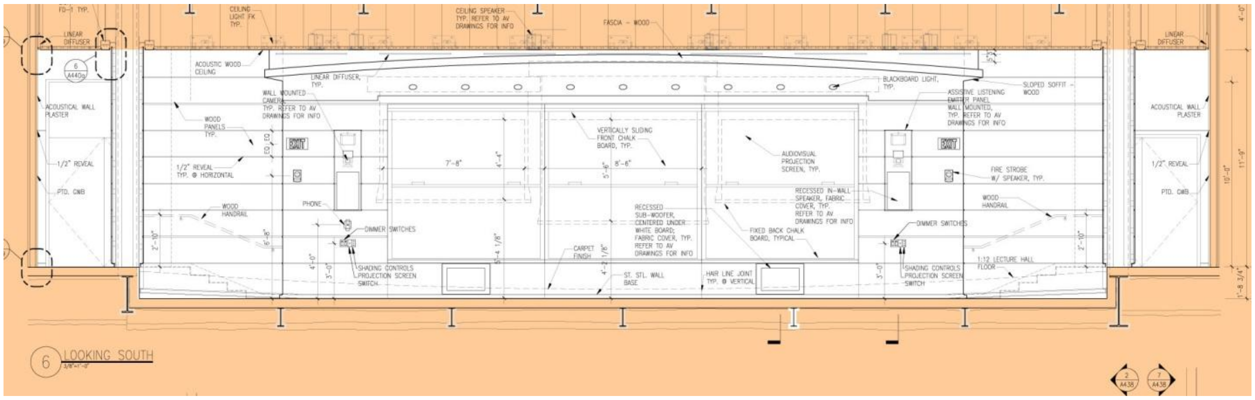
. Breadth Studies .

Introduction

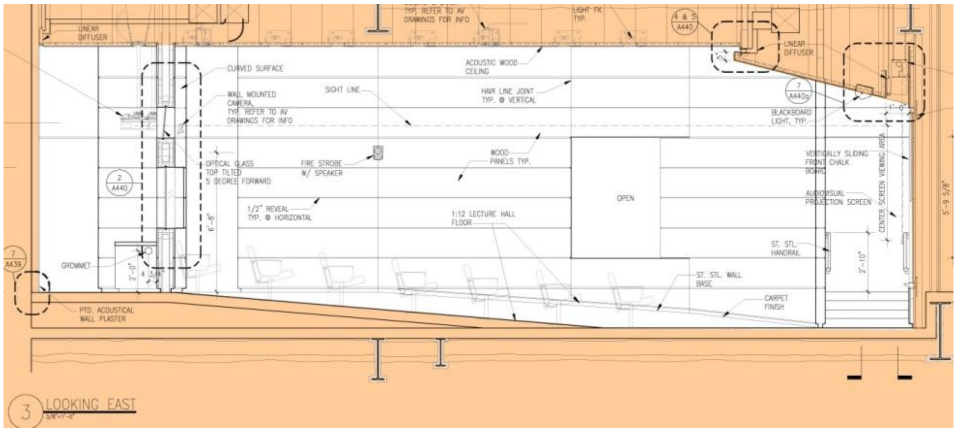
Half radially symmetric, the lecture hall has 145 seats with an inclination of 1:12. There is a projector booth on the rear of the room (north) with three ceiling mounted projectors. There are two entrances and the seating area is enclosed by corridors on three sides with the teaching space at the front (south). The main surface of the ceiling and walls is wood. The lecture hall is located in the northeast part of Level A in the Neuroscience portion of the complex.



LECTURE HALL PLAN, NTS



LECTURE HALL SECTION LOOKING SOUTH, NTS



LECTURE HALL SECTION LOOKING EAST, NTS

This space, as shown before in the report, was chosen as one of the lighting redesign rooms. To integrate the breadth with the lighting depth, an architectural redesign of the ceiling was done accompanied by an acoustical study.

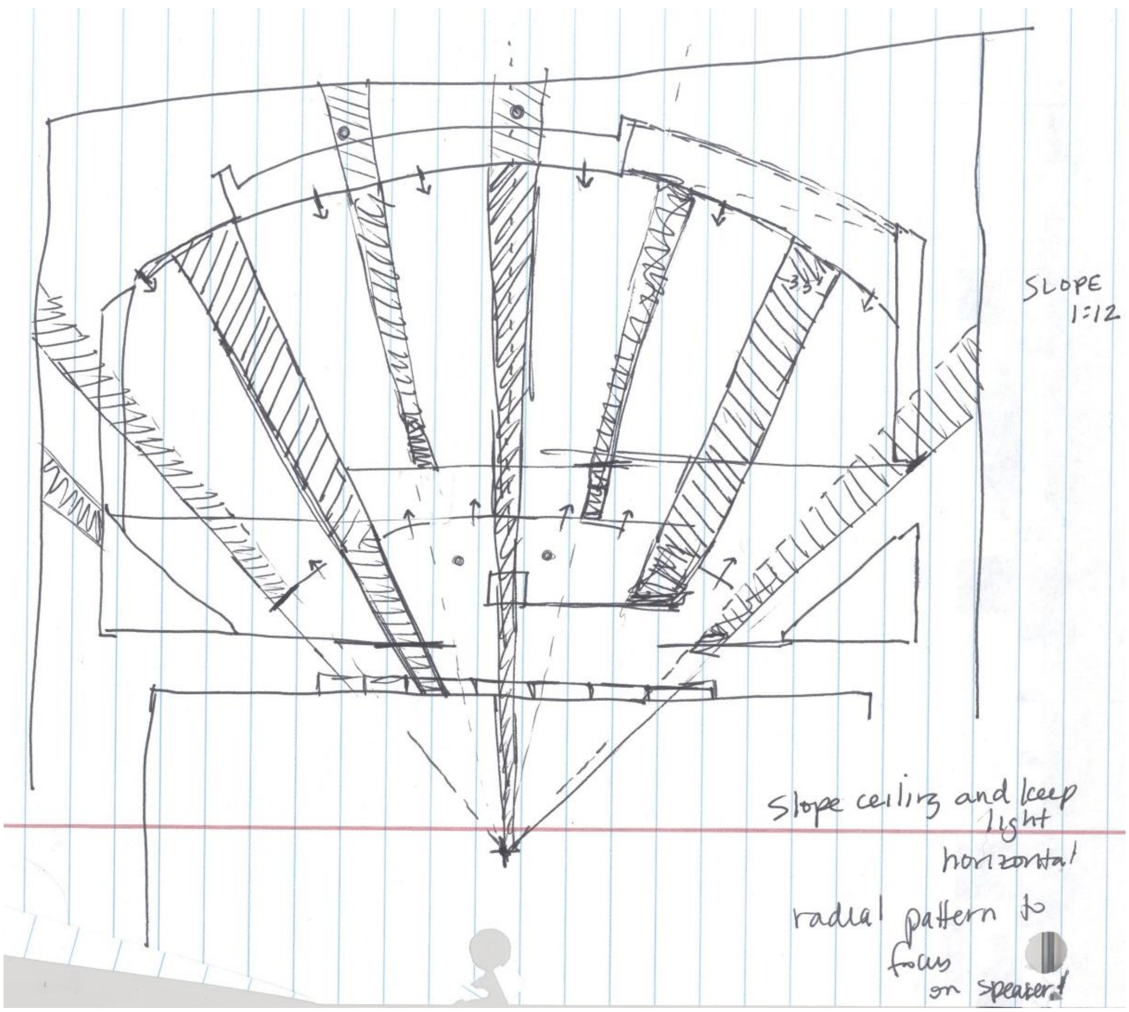
Architectural | **Lecture Hall Ceiling Redesign**

Problem

The lighting in the lecture hall will be changing from circular spot elements to linear ones that provide diffuse lighting to remove multiple shadows caused by many downlights. The ceiling in this space has a curved element towards the front of the room. The idea was to re-design the ceiling to create different levels and linear elements that match the linearity of the wooden panels that surround the entire seating area. The changes in elevation in the ceiling re-design will allow for the lighting to be fully integrated while still concealing mechanical and structural elements. This would unite architecture and light into one and will add visual interest to the space as well as functionality.

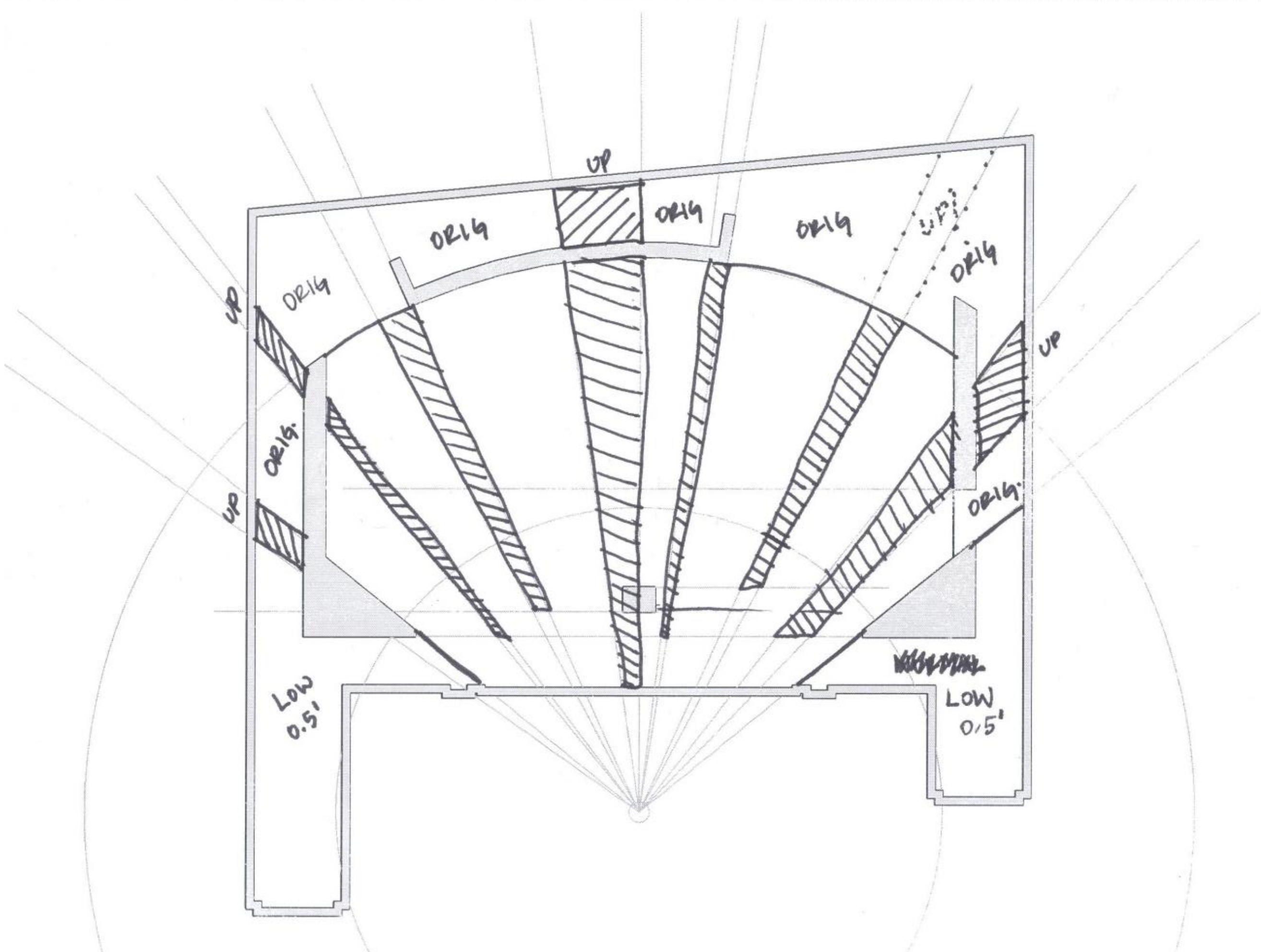
Solution

The ceiling designs concepts match the lighting ones of ***connection*** and ***static motion.*** By using the same circle used to design the rest of the architecture, there is an immediate connection formed between the ceiling and the rest of the space because they flow into one. The center of the circle was kept the same and rays were drawn to create voids in the ceiling.



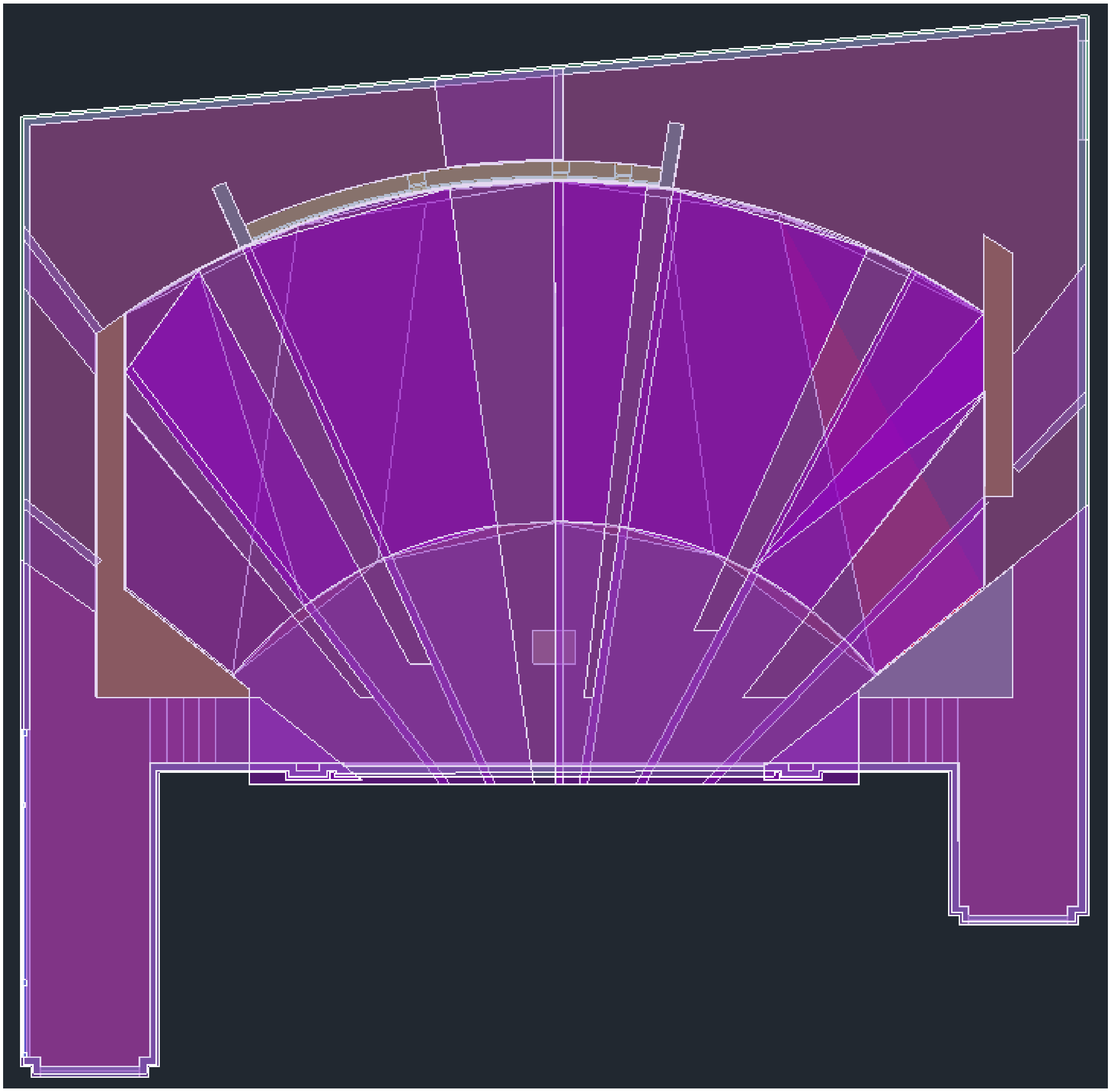
PRELIMINARY SKETCH OF NEW CEILING COVES

The original ceiling had a cavity of about four feet which is more than enough to maneuver the rest of the systems around. However, to ensure that the coves did not create a problem with other systems, the ceiling was sloped and in some parts lowered, never raised, creating more area in the cavity. At its highest point, the original ceiling was almost fourteen feet high. With the new sloped ceiling, the ceiling height is constant throughout the seating area with 11'-9". The ceiling was lowered six inches more at the entrances to encourage people to move towards the higher ceiling. The concept of static motion is not only supported by the latter statement, but also the lines created by the coves in the seating area all moving towards one common central point, when filled with the light, create a wormhole effect that draws the users attention to the front of the room.

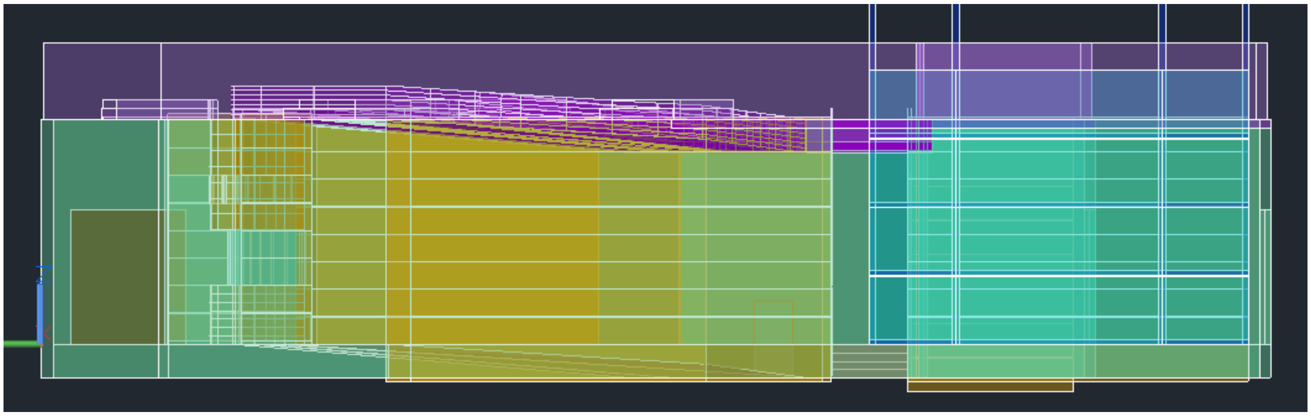


FINAL SKETCH OF NEW CEILING COVES AND REST OF THE CEILING HEIGHTS

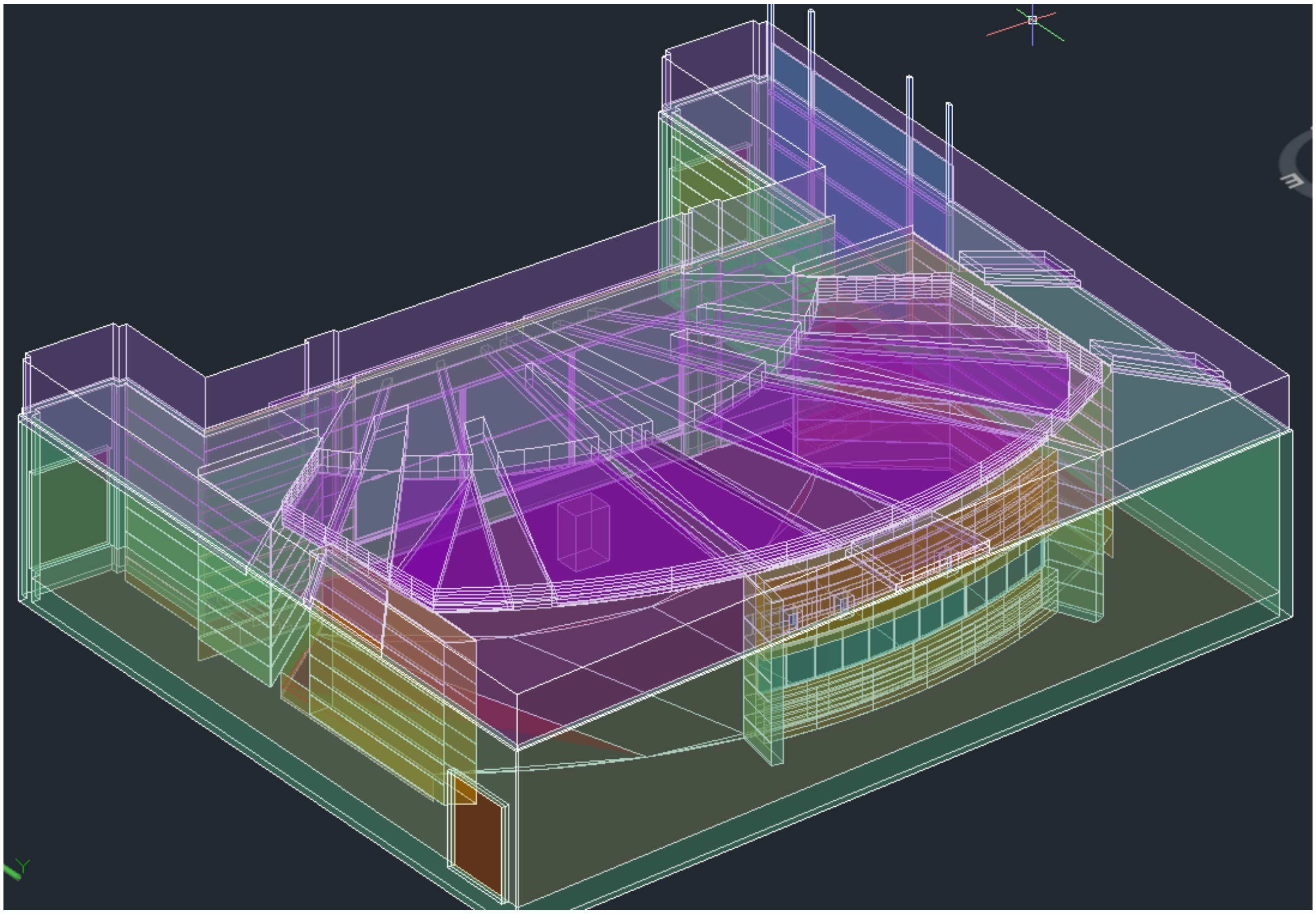
A Model was created in AutoCAD to achieve the design. The slope of the ceiling is 1:12 like that of the floor. The coves are not symmetrical but form a balance that makes the non-uniformity interesting and in its own way is balanced. The linearity of the coves with their radial alignment joins both circular and rectilinear elements that were already present in the room into one. The lines of light on each cove provide enough illumination for reading/writing with enough uniformity and add more interest to the space because they are fully integrated into the architecture.



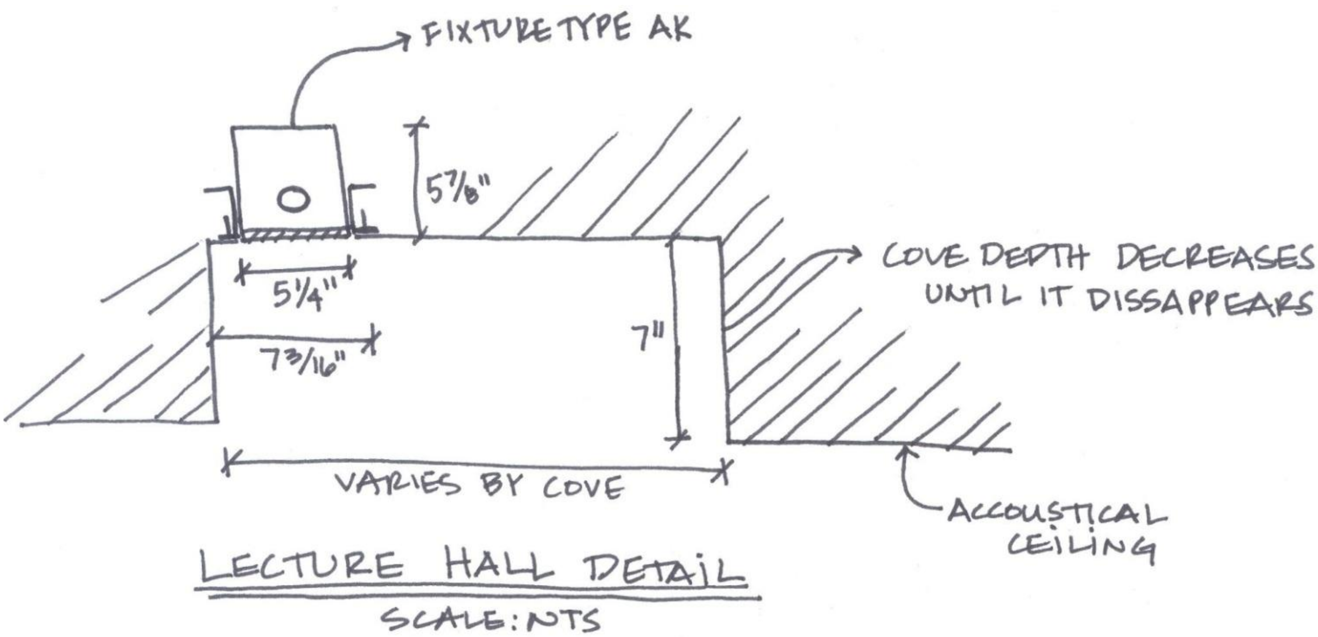
PLAN VIEW OF NEW COVES IN AUTOCAD



SECTION VIEW OF NEW COVES IN AUTOCAD



3D VIEW OF NEW COVES IN AUTOCAD LOOKING TOWARDS BLACKBOARD AND ENTRANCES



LIGHTING MOUNTING DETAIL

Acoustical | **Lecture Hall Analysis and Redesign**

Problem

The architectural alteration in the ceiling accompanied with the new lighting design created changes in the acoustical properties of the space. The idea was to ensure that the space could still provide good acoustics, assuming it already had adequate acoustics, for speech setting in a lecture and conference room. The range of the reverberation time that will ensure this is in between 0.7 and 1.1 seconds.

Solution

An acoustical study was conducted to calculate reverberation time in the space. First, the calculation was done with the original architecture and materials. All material data was taken from "Sound Absorption Data for Lecture Hall Finishes" (Architectural Acoustics by M. David Egan, page 52) because specific finish information was not provided by the architect/owner as well as formulas and desired ranges (Architectural Acoustics by M. David Egan, page 64).

Existing Conditions:

α Absorption Coefficient of Materials							
Material	**Frequency (Hz)**						
	125	250	500	1000	2000	4000	NRC #
acoustic gypsum wall board	0.55	0.14	0.08	0.04	0.12	0.11	0.1
wood panels	0.42	0.21	0.10	0.08	0.06	0.06	0.1
acoustic wood ceiling	0.10	0.60	0.80	0.82	0.78	0.60	0.75
carpet	0.02	0.06	0.14	0.37	0.60	0.65	0.3
curved glass	0.35	0.25	0.18	0.12	0.07	0.04	0.15
opening	0.50	0.50	0.50	0.50	0.50	0.50	
auditorium seats with students	0.30	0.41	0.49	0.84	0.87	0.84	

S Surface Area (sq.ft.)
279
1194
1608
441
89
517
1167

a = S*α Room Absorption (sabins)						
Frequency (Hz)						
125	250	500	1000	2000	4000	
153.5	39.1	22.3	11.2	33.5	30.7	
501.5	250.7	119.4	95.5	71.6	71.6	
160.8	964.8	1286.4	1318.6	1254.2	964.8	
8.8	26.5	61.7	163.2	264.6	286.7	
31.2	22.3	16.0	10.7	6.2	3.6	
258.5	258.5	258.5	258.5	258.5	258.5	
350.1	478.5	571.8	980.3	1015.3	980.3	
1464.3	**2040.3**	**2336.2**	**2837.9**	**2904.0**	**2596.1**	**Σa**

V Room Volume (ft^3)
19296

T = 0.05*(V/a) Reverberation Time					
Frequency (Hz)					
125	250	500	1000	2000	4000
0.7	**0.5**	**0.4**	**0.3**	**0.3**	**0.4**

Then, the new ceiling was added. Because of the coves, the surface area of the ceiling increased but the volume decreased because the new ceiling is lower. Materials were kept the same, the only exception was that acoustic gypsum wall board was added as the finish of the new ceiling.

Scenario 1:

α
Absorption Coefficient of Materials

Material	Frequency (Hz) 125	250	500	1000	2000	4000	NRC #
acoustic gypsum wall board	0.55	0.14	0.08	0.04	0.12	0.11	0.1
wood panels	0.42	0.21	0.10	0.08	0.06	0.06	0.1
acoustic wood ceiling	0.10	0.60	0.80	0.82	0.78	0.60	0.75
carpet	0.02	0.06	0.14	0.37	0.60	0.65	0.3
curved glass	0.35	0.25	0.18	0.12	0.07	0.04	0.15
opening	0.50	0.50	0.50	0.50	0.50	0.50	
auditorium seats with students	0.30	0.41	0.49	0.84	0.87	0.84	

a = S*α
Room Absorption (sabins)

S Surface Area (sq.ft.)	Frequency (Hz) 125	250	500	1000	2000	4000	
279	153.5	39.1	22.3	11.2	33.5	30.7	
1194	501.5	250.7	119.4	95.5	71.6	71.6	
1608	160.8	964.8	1286.4	1318.6	1254.2	964.8	
441	8.8	26.5	61.7	163.2	264.6	286.7	
89	31.2	22.3	16.0	10.7	6.2	3.6	
517	258.5	258.5	258.5	258.5	258.5	258.5	
1167	350.1	478.5	571.8	980.3	1015.3	980.3	
	1464.3	**2040.3**	**2336.2**	**2837.9**	**2904.0**	**2596.1**	**Σa**

T = 0.05*(V/a)
Reverberation Time

V Room Volume (ft^3)	Frequency (Hz) 125	250	500	1000	2000	4000
19296	**0.7**	**0.5**	**0.4**	**0.3**	**0.3**	**0.4**

As shown, the ceiling redesign did not affect the room acoustics. However, the reverberation time does not fall in the range desired for good acoustics for speech. Therefore, new materials were chosen that could substitute the older ones to improve this. Highlighted in yellow are the changes made.

Scenario 2:

α
Absorption Coefficient of Materials

Material	Frequency (Hz) 125	250	500	1000	2000	4000	NRC #
gypsum wall board (0.5 in thick)	0.29	0.10	0.05	0.04	0.07	0.09	0.05
wood panels	0.42	0.21	0.10	0.08	0.06	0.06	0.1
plaster ceiling	0.14	0.10	0.06	0.05	0.04	0.03	0.05
carpet	0.02	0.06	0.14	0.37	0.60	0.65	0.3
curved glass	0.18	0.06	0.04	0.03	0.02	0.02	0.15
opening	0.50	0.50	0.50	0.50	0.50	0.50	
auditorium seats with students	0.30	0.41	0.49	0.84	0.87	0.84	

a = S*α
Room Absorption (sabins)

S Surface Area (sq.ft.)	Frequency (Hz) 125	250	500	1000	2000	4000	
279	80.9	27.9	14.0	11.2	19.5	25.1	
1194	501.5	250.7	119.4	95.5	71.6	71.6	
1608	225.1	160.8	96.5	80.4	64.3	48.2	
441	8.8	26.5	61.7	163.2	264.6	286.7	
89	16.0	5.3	3.6	2.7	1.8	1.8	
517	258.5	258.5	258.5	258.5	258.5	258.5	
1167	350.1	478.5	571.8	980.3	1015.3	980.3	
	1441.0	**1208.2**	**1125.5**	**1591.7**	**1695.7**	**1672.2**	**Σa**

T = 0.05*(V/a)
Reverberation Time

V Room Volume (ft^3)	Frequency (Hz) 125	250	500	1000	2000	4000
19296	**0.7**	**0.8**	**0.9**	**0.6**	**0.6**	**0.6**

These changes did make a significant impact on the reverberation time calculation, making the room acoustics better. However, even more improvements could be made to ensure that all frequencies fall in the desired range of 0.7-1.1 seconds. Below, another type of wood installation was chosen to see if it made a difference in the reverberation time; the change is highlighted in green. The new wood did make things a little better, especially in the 125 Hz frequency but there is still some improvement that could be done and this could either be by achieved by either installing even less absorptive materials or altering the architecture further.

Scenario 3:

α Absorption Coefficient of Materials							
Material	**Frequency (Hz)**						
	125	250	500	1000	2000	4000	NRC #
gypsum wall board (0.5 in thick)	0.29	0.10	0.05	0.04	0.07	0.09	0.05
wood panels, 1 in paneling	0.19	0.14	0.09	0.06	0.06	0.05	0.1
plaster ceiling	0.14	0.10	0.06	0.05	0.04	0.03	0.05
carpet	0.02	0.06	0.14	0.37	0.60	0.65	0.3
curved glass	0.18	0.06	0.04	0.03	0.02	0.02	0.15
opening	0.50	0.50	0.50	0.50	0.50	0.50	
auditorium seats with students	0.30	0.41	0.49	0.84	0.87	0.84	

S Surface Area (sq.ft.)
279
1194
1608
441
89
517
1167

a = S*α Room Absorption (sabins)						
Frequency (Hz)						
125	250	500	1000	2000	4000	
80.9	27.9	14.0	11.2	19.5	25.1	
226.9	167.2	107.5	71.6	71.6	59.7	
225.1	160.8	96.5	80.4	64.3	48.2	
8.8	26.5	61.7	163.2	264.6	286.7	
16.0	5.3	3.6	2.7	1.8	1.8	
258.5	258.5	258.5	258.5	258.5	258.5	
350.1	478.5	571.8	980.3	1015.3	980.3	
1166.3	**1124.6**	**1113.5**	**1567.8**	**1695.7**	**1660.3**	**Σa**

V Room Volume (ft^3)
19296

T = 0.05*(V/a) Reverberation Time					
Frequency (Hz)					
125	250	500	1000	2000	4000
0.8	**0.9**	**0.9**	**0.6**	**0.6**	**0.6**

In conclusion, the new reverberation times are better suited for the activity happening in the space and the changes had a positive impact in the lecture hall. Below is shown the summary of the calculations for the existing conditions vs. the new ones:

Existing Condition:

T = 0.05*(V/a) Reverberation Time					
Frequency (Hz)					
125	250	500	1000	2000	4000
0.7	**0.5**	**0.4**	**0.3**	**0.3**	**0.4**

Scenario 3:

T = 0.05*(V/a) Reverberation Time					
Frequency (Hz)					
125	250	500	1000	2000	4000
0.8	**0.9**	**0.9**	**0.6**	**0.6**	**0.6**

. Appendices .

Appendix L

Appendix S

Appendix C

Appendix E

Appendix P