tony esposito

Lighting / Electrical

Faculty Consultant:
Dr. Richard Mistrick

Wednesday, April 4, 2012

Final Thesis Report

Hunter' Point South Intermediate School and High School
Queens, NY

Executive summary

This report provides a detailed outline and discussion of all work and analysis performed during the AE 897G senior thesis. In short, included are lighting and electrical designs for four spaces, two electrical depth topics, two breadth topics, and one MAE breath topic. The redesigns and this report in general, is not indentured to suggest that there are any problems with the existing designs of the lighting and electrical system; and all other disciplines for that matter. This senior thesis project was, however, intended to research and investigate alternative design solutions, budget-free.

The redesign of the electrical and lighting systems was performed for the following four spaces; The façade, auditorium, high school art room, and intermediate school café. See the appropriate sections for specific details on the goals and strategies of the lighting designs. The lighting redesign in general aimed to achieve a sense of connection with the building, and with the people in the surrounding neighborhood. See specific sections for elaborations.

Electrical depth 1 conducted an analysis of the distribution method with which the rooftop mechanical equipment is fed. The current method, which is to feed each piece of equipment individually from the first floor, is inefficient and cost-ineffective. In an attempt to save money, a rooftop switchboard is added to that a single feed may be routed to the roof, as opposed to the 6 previously. The redesign of the distribution system amounts to a savings of **$205,540.83.**

The MAE breadth conducted an analysis of the available daylight in the space using the software DAYSIM 3.0. The results from DAYSIM were used to design a skylight system that supplements the shading system that was designed to block direct sun throughout the year. The addition of the skylight increased the daylight and spatial daylight autonomy of the space so that most of the points in the room met the target illuminance of 250 lux during 90 percent of the occupancy schedule.

The addition of the skylights into the high school art room introduce addition load onto the heating and cooling systems. As such, a mechanical analysis of had to be done to determine the cost implications, if any, of increasing the mechanical systems due to the increase in load. It was found that the heating system was adequate to combat the addition load, but the cooling system was not. An additional diffuser had to be added and selective ductwork upsized. The total cost increase due to the skylighting loads is **$246.50**

Removing the drop ceiling to implement the skylights into the system required coordination of the MEP systems located in the ceiling space. The systems were modeled and coordinated in REVIT MEP 2012. It was shown that reorganizing the layout of the systems in the space decreased the obstruction of the skylights by approximately **37%**. In addition, the increase of open area of skylight amounted to an approximately 40% increase in illuminance into the space.

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Building statistics

General Building Data

BUILDING NAME | Hunters Point South Intermediate School and High School

LOCATION | Queens, NY

SITE | 1-50 51st Avenue, Long Island City

OCCUPANT NAME | NYC Department of Education (PS287 Queens)

OCCUPANT TYPE | (E) Education: Combined Intermediate School High School

SIZE | 154,000 ft^2

NUMBER OF STORIES | 5 Stories

CONSTRUCTION DATE | January 10th, 2011 – October 2013

BUILDING COST | $61, 098, 000

PROJECT DELIVERY | Guaranteed Maximum Price (GMP)

Project Team

OWNER | NYC Construction Authority

ARCHITECT | FXFOWLE Architects, PC

MEP/FIRE PROTECTION | Kallen & Lamelson, LLP

ACOUSTICAL / AV CONSULTANT | Cerami & Associates, LLP

GENERAL CONTRACTOR / CM | Skanska

STRUCTURAL ENGINEER | Ysreale A. Seinuk, PD

LIGHTING DESIGNER | Tillotson Design Associates

SITE-CIVIL ENGINEERING | Langan Engineering

Architecture

The Hunter's Point South Intermediate School & High School is a new, 5 story public school for grades 5 through 12. Located in the PS 287 Queens School District, Hunter's Point will house roughly 1,000 students. The building will contain 26 classrooms, 8 special education classrooms, several laboratories, library, full size gymnasium, cafeteria, kitchen, auditorium, and most architecturally significant, a nearly 4000sf roof terrace.

As part of the Hunters Point South Project (a redevelopment of the Queens area) this building will be architecturally modern, as to blend in with the new developing community. A large cantilever hovering over the roof terrace, polygonal depressions in the building, and trapezoidal shaped windows make this building architecturally interesting. Blending grey brick, slate veneer, perforated steel panels, orange aluminum composite panels, and glass curtain walls adds to the aesthetics of the building.

Zoning

Hunter's Point South School is located in zone M1-4. This zone is designated as a light manufacturing zone, which allows light industrial and public access structures. Hunter's Point South School does not have any historical significance, and thus has no special zoning requirements.

Major Codes

- New York State codes:
    - 2008 New York City Building Code
    - 2007 Building Code
    - 2007 Mechanical Code
    - 2007 Plumbing Code
    - 2007 Fire Code
    - 2007 Conservation Construction Code
    - 2007 Fuel Gas Code
- 2005 National Electric Code (NEC2005)

Façade

The building façade consists of multiple materials. On the upper floors, grey Manganese Ironspot smooth modular brick over 6" lightweight CMU was used. The first floor, with a 2" honed finished slate stone veneer, is supported by a 6" CMU wall along the north, south, and west facades.

Curtain wall glazing and windows are aluminum framed with a 1" preassembled clear annealed float glass system (comprised of a 1/8" annealed exterior sheet, 60mil polyvinyl Butyral interlayer, and 1/8" interior sheet with low-e coating). On the first and second floors, an Insulated Translucent Sandwich Panel System (ISTSPS) was used. This system allows for 15% light transmission, and has a NFRC certified U factor of 0.28. Surrounding the curtain walls are 4mm thick aluminum composite panels with cupral 913 fluoropolymer finish.

Roofing
The roof structure for this building consists of concrete on metal deck (preformed aluminum deck in some places), finished with 24”x24”x2” thick concrete paver with 4” rigid insulation. For weather resistant covering, there is a 215mil fabric reinforced, rubberized asphalt membrane.

Sustainability
Hunter’s Point South School, a LEED Silver building, follows the NYC Green Schools Guide in lieu of the USGBC approach. Some notable sustainability features of this building include (but not limited to) the following:

- Occupancy Sensor controlled lighting
- Self-adjusting ventilation systems
- Solar shading
- Use of local materials (within 500 mile radius)
- Use of recycled materials

Primary Engineering Systems

Lighting
The typical lighting system in this building consists of primarily fluorescent lighting. This is a combination of 32W linear fluorescents and 32W compact fluorescents (CFL’s). In addition to these, there are a few other sources which include: incandescent, halogen, metal halide, ceramic metal halide, and LED.

There are multiple control zones used in this building, most of which are organized by space type/classification. All instruction spaces, which include IS/HS classrooms, art rooms and project rooms, are all to be controlled by a timer/occupancy sensor with manual override switch. The gym, library, auxiliary exercise, IS/HS café and student locker rooms, are all to be controlled by a timer with key override switch. The general/principal office and custodian office are to be controlled by occupancy sensor with manual override switch. All public toilets and restrooms are a timer, with no manual override switch. The lighting in the stair wells are given two zones – one for normal lights, and one for emergency lights. The emergency lights are on a timer with key override switch, whereas the normal lights are operated solely on a timer with no manual override switch. All mechanical, electrical and plumbing spaces are to be operated by a wall switch. All other interior spaces that do not fall into the previously mentioned categories are controlled with a timer/occupancy sensor or a wall switch. The following areas are all controlled by a timer/photo sensor: main entrance exterior (emergency lights), exit door exterior (emergency lights), exterior sidewalk lights and exterior roof terrace lights. The roof exterior lighting is controlled simply by a wall switch. The fire rescue area, which includes the emergency lighting, is controlled by a timer/occupancy sensor with override switch. All of the exit signs located throughout the building remains on at all times.

Electrical
This buildings electrical distribution system is a simple radial system in that there is a single entry point into the building, and everything else branches out radially from there. The main service entry point for this building is in the main electric closet located on the (plan) North wall of the building. “Main Switchboard #1 (MS1)” is the center point of this radial system. It is from MS1 that all other loads in the building are connected. The two side-

by-side electric rooms on each floor serve as the main means of routing conduit and wire. One room is dedicated to panelboards that only connect to normal power, and the other contains panelboards connected to the emergency generator. Each room contains its own riser shaft for wire and conduit. This keeps the normal power and emergency power wiring separate. The generator, located on the roof of the building in the emergency generator room, provides power to the critical building loads in the event of a power outage. Some of these loads include: emergency/egress lighting, two (2) elevators, telecom equipment, and the fire and jockey pump which are critical to the operation of the schools sprinkler system.

Structural

A geotecnical survey performed by Langan Engineering shows soil types ranging from silty sand to clay. Bedrock, consisting of Gneiss, starts at 40 feet below grade. The base floor of the building is a 12-inch, 4000 psi reinforced concrete slab on grade which is supported by grade and strap beams, steel H-piles, and 14" caissons.

The floor system in this building is 3 1/4" thick 3500 psi lightweight conrete on a 3" deep composite galvanized metal deck (18 gauge). All cast-in-place concrete slabs are reinforced with #4 gauge rebar, spaced 12" on-center.

Mechanical

Conditioned air is delivered via six air handling units (AHU's) located on the roof of the building. The first 3 units (1, 2, and 3), are variable air volume (VAV) AHU's that service the corridors, non-public spaces, office, and classrooms. The additional 3 units (3, 4, and 5), are constant air volume (CAV) AHU's that serve the gymnasium, cafeteria/kitchen, and auditorium. All of the air handling units utilize preheat coils and cooling coils with a 35% and 30% propylene glycol-water mixture, respectively.

Additional Systems

Tele/Data

There are vertically stacked telecommunication closets on each floor. These rooms are located at the rear of the elevators on each floor, and hold the primary ladder trays allowing for the vertical circulation of the system through the building. An “LON data enclose,” “LDF data rack,” and “IDF system backboard” in each floors telecom closet serves as the main termination point for horizontal tele/data runs. The main radial point for these is the “LON Cabinet,” “Main Data Rack,” and “MFD,” all located in the first floor telecommunication closet.

Video Surveillance

Located in the main telecom closet on the first floor is the “Video Surveillance Equipment cabinet” and the “Main Data Rack (MDR)” that serve as the main radial point for the video security system. Located in the other telecom closets on the 2-5th floors serve as the main horizontal termination points for the dome enclosed PTZ surveillance cameras. These cameras are strategically located at the interior and exterior of all entrances to the building, as well as in the main corridors of the building.

Auxiliary Alarm

Stacked panels in the telecom closets on each floor serve the auxiliary indicator panels, low voltage push buttons, the general office auxiliary momentary program signal push buttons, and remote A/V signaling devices for the auxiliary alarm system.

Intrusion Alarm

Stacked panels in the telecom closets on each floor serve the intrusion alarm control panels, wide angle passive infrared motion detectors, long range passive infrared motion detectors, intrusion alarm siren/strobes, magnetic door contacts, and remote keypads.

Fire Rescue Intercom

The stacked electrical closets serve as the vertical circulation for the fire rescue intercom system. There are three (3) master intercom stations located in the 3rd and 4th floor principal’s office, as well as the custodian’s office on the first floor. Staff intercom stations are located in rooms 213, 317, 417/419, and 517.

Audiovisual

Junction boxes located in each telecom closet provides connections to the building’s clock and sound system. This system serves the administrative control stations, microphone cables, loudspeaker/clock cables, privacy/call-in switches, AM/FM antennas, analog clocks, and the local sound system (which includes 2 loudspeakers and 1 microphone).

Fire Protection

This system contains both upright and concealed sprinkler heads, with a wet standpipe. Two 8" pipes leading into the building serve as the main water feed, and terminate in the Fire Pump/Plumbing/Lab Support Room on the first floor - all piping for this system is served from this room. The 1000 gpm split case pump initially pressures the system, while multiple centrifugal jockey pumps sustain the pressure in the system.

Transportation

The vertical circulation needs of this building are accomplished with four stairwells and two elevators. There is one stairwell located at the North entrance, one at the South entrance vestibule, and another in the East of the building. The North stairwell extends to the roof where the mechanical penthouse is located. There is another (smaller) stairwell that connects only the gymnasium on the first floor, and the excercise facility on the second floor. The two elevators are located in the center of the building at the intersection of the two major hallways.

Lighting

It was the original design intent of the architect to combine the two individual programs (Intermediate and High school) and the students contained within these two programs. As such, it is a main goal of my lighting design to connect the **people + programs** within this building. Such a goal is achieved by my choice of spaces, which are the spaces the architect designed specifically to be connecting points of the two programs

Second, as this building is part of a redevelopment of the Hunters Point area of Queens, it is a goal to connect the **building + community**. This can be achieved by two things: designing the façade such that neighborhood residents can freely and safely navigate the base of the building, and allowing the diverse culture of NY to influence my design.

It is the last overall goal of my lighting design to connect **lighting + architecture**. Any good lighting design is reflective of the architecture of the space. My designs aim to consider not only the physical architecture, but also the main usage, and occupant makeup of each space.

1 | Façade

This section, dedicated to the documentation of the lighting design solution for the Façade, contains all information pertinent to fully describing the space and lighting design. Included are the design goals and criteria, utilized fixtures and equipment schedules, control description, calculation summary as quantitative evaluation of the design, renderings of appropriate views, and an evaluation comparing the design solution against the design goals set at the outset of the design. This section is outlined as follows:

Description

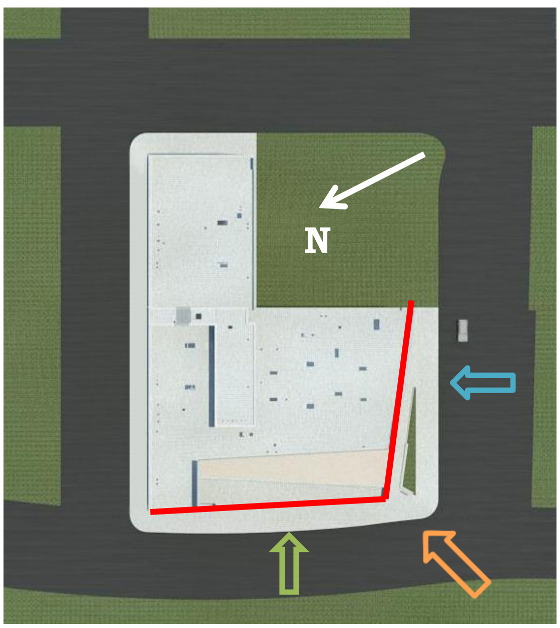
Area: 14,000 ft^2 + 10,300 ft^2 = 24,300 ft^2

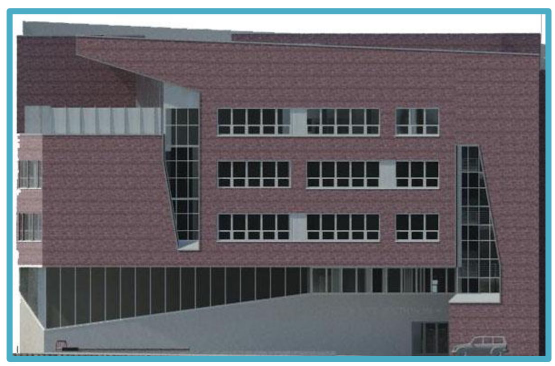
Façade faces designed: Plan South, and Plan East (Highlighted in the location section below)

Façade length = 350 ft.

Location

The building is located in the square created by the intersection of four streets; Second Street to the north, Center Boulevard to the south, Borden Avenue to the east, and 51st avenue to the west. The two main (and most important) faces of the building, deemed so as they are the main entry and exit points of the building, are that which will be considered in the presented redesign. The plan below highlights the two facades—the plan south and plan east façades—that will be addressed in the redesign:

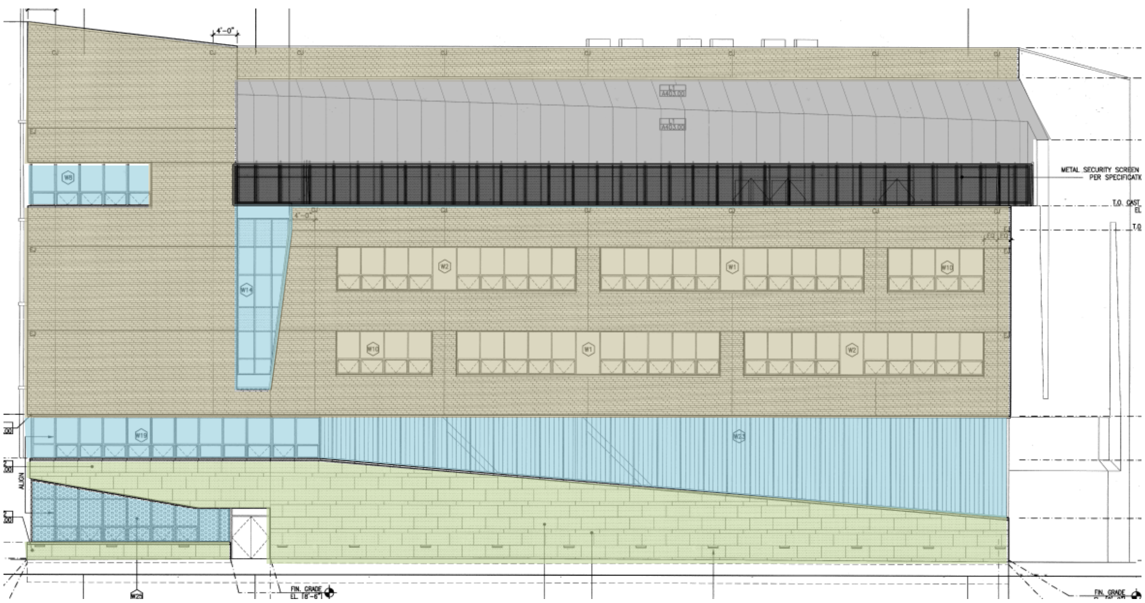


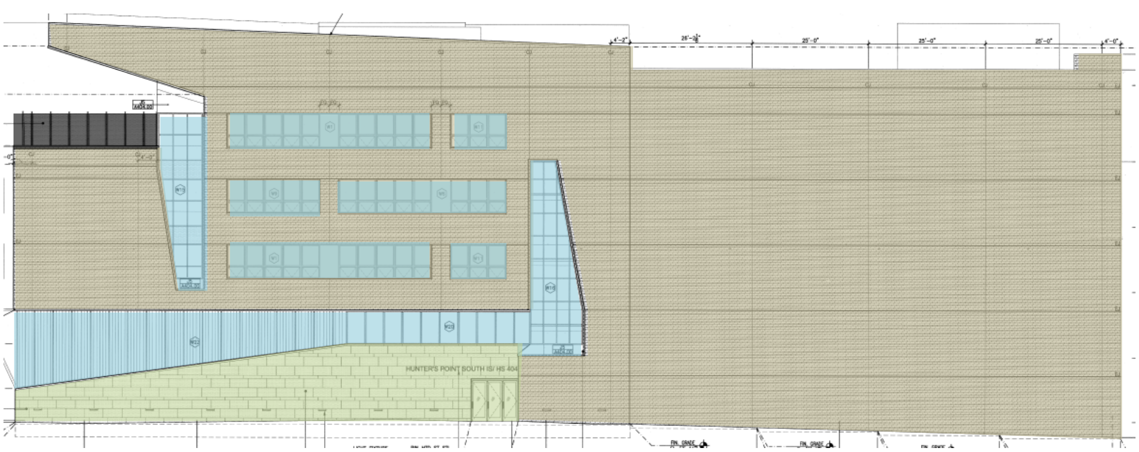


The image below shows and elevation of the building including the two faces of the façade to be redesigned:

Finishes

The façade of the Hunters Point School is comprised of multiple finish materials. The largest (by area) is the utility brick, highlighted in brown on the figure below. The utility brick is approximately 4”x4”x12” and is dark grey in color. The 2” exterior cut stone, highlighted in green below, wraps around the base of the building. The grey shading on the figures below represents aluminum composite panels, which comprise the overhang the sits about the large, 4500 square foot roof terrace on the fifth floor. The black area highlighted below represents the metal security screen that lines the perimeter of the fifth floor roof terrace. This security screen is grey in color, and stands approximately ten feet above finished floor (AFF). Lastly, highlighted in blue, is the glazing component of the façade. A small portion of the glazing, located on the fifth floor behind the metal security screen, is hidden from this point of view.

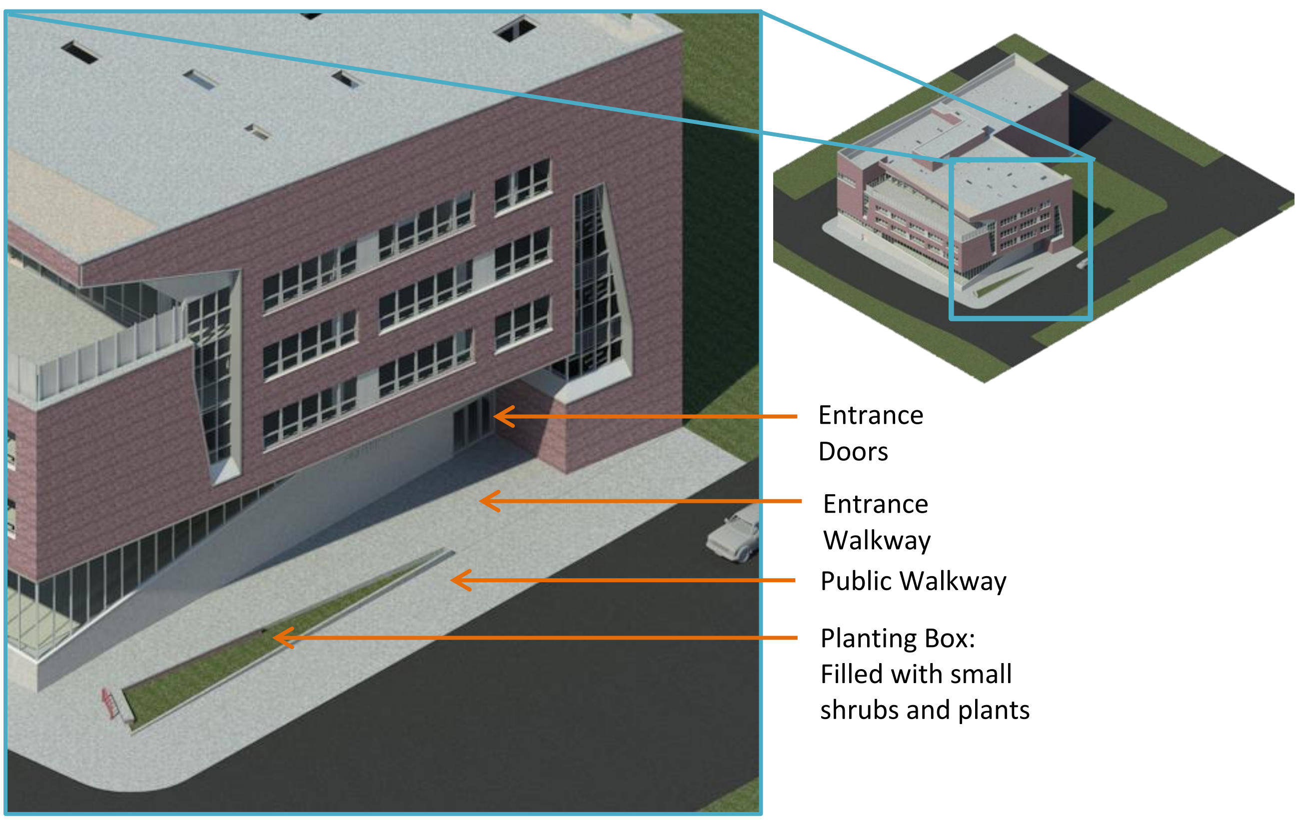


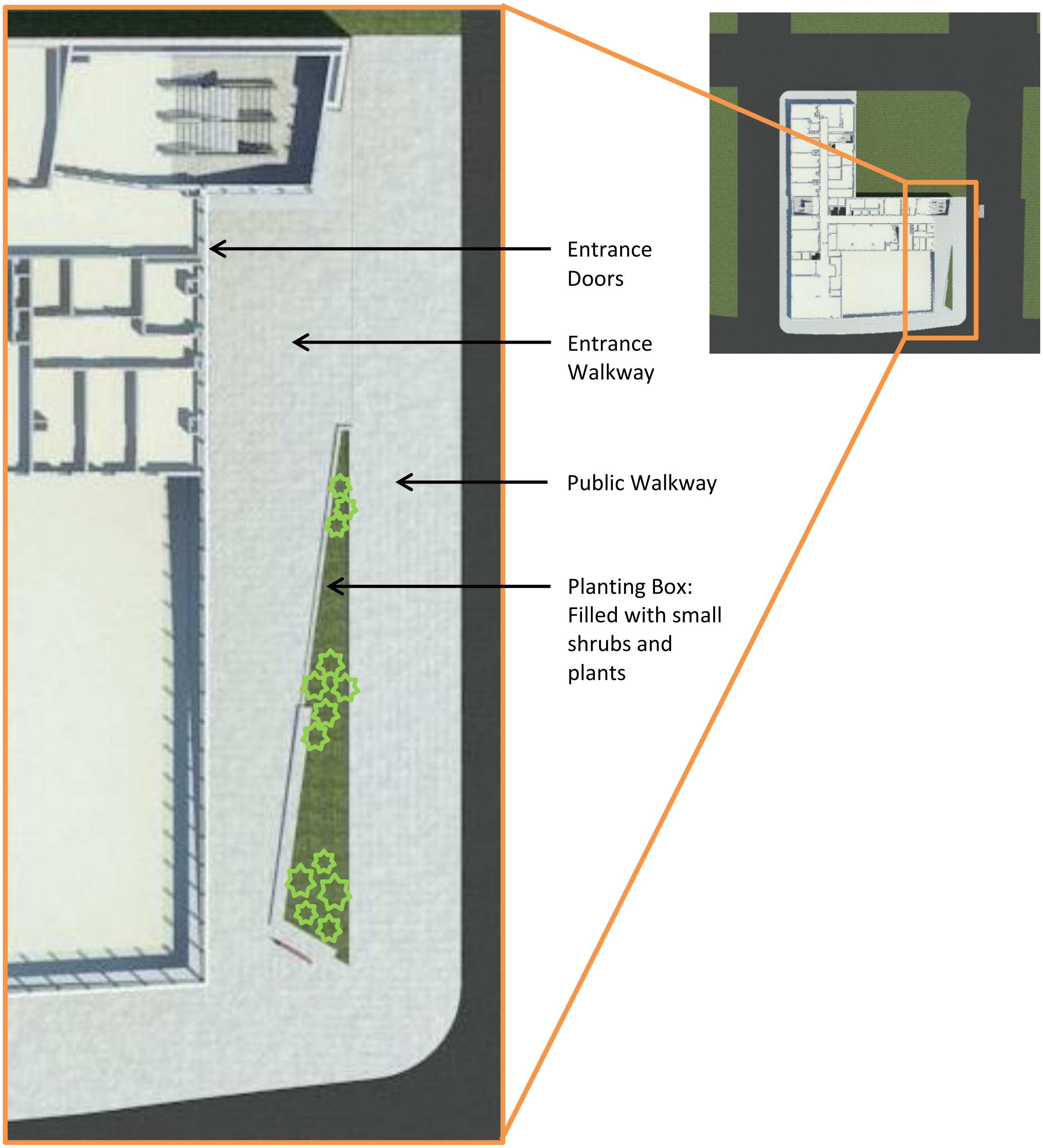


Material			
Symbol/ Swatch	Description	Style/Color	Reflectance
	3-5/8" x 3-5/8" x 11-5/8" Utility Brick	Dark Grey	0.10
	2" Thick Exterior Cut Stone	Grey	0.15
	Aluminum Composite Panel	Aluminum	0.50
	Metal Security Screen	Grey	-
	Glazing	Glass/Transparent	-

Landscape

Located near the entrance of the building, short raised brick walls—approximately 1’8” high on the entrance walkway side and 4” high on the public walkway side—enclose a small area of plants and small shrubs. The enclosure is trapezoidal, and mimics the shape of the triangular overhang directly above the public walkway.



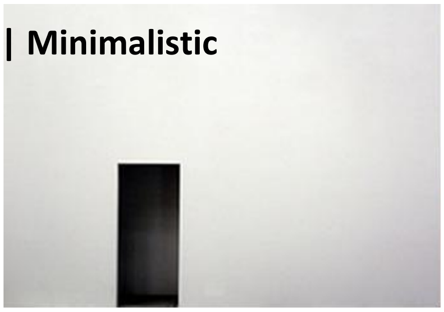


Tasks/Activities

The exterior area of the building has no real tasks or activities besides walking around it. The building sits flush with the property line, and as such, the public walkway is directly against the façade. The small landscape planter box, which is an attempt to break up the public walkway, separates the entrance way of the building from the public walkway. Navigating around the building should be easy and engaging.

Overall Design Goals

As this building is along the riverfront, and is part of a redevelopment project of the Long Island City portion of New York, the façade and building will be very prevalent. The façade lighting should be welcoming, facilitate navigation around the building, and direct the public towards the building entrance. The design should achieve the overall design goal of connecting the **building + community**. The design goals for the façade are as follows:



Minimalistic: The design should not aim to be be minimalistic in the sense that it is unimportant. Minimalistic, in terms of sustainability, means to achieve the maximum aesthetic or psychological effect with as little energy as possible.

High Visibility from River: As the building directly fronts the river, it should be easily seen from the water. It should be designed as so it is easily seen driving down the river.

Vandal Proof: As thebuilding is located is a possible vandal zone, the lighting should be designed in such a way that it is vandal proof.

Focal Point at entrance: the entrance of the building is very small and tucked away. The lighting design should not only direct the user to the entrance, but the entrance should be a focal point of the building.

Design Criteria/Considerations

Illuminance Recommendations

Horizontal Illuminance – *Important*

Entrance

- IES Classification: Common Applications – Building Entries – Paths to curb – Low Activity – LZ3
  - Category C: 2 lux (0.2 fc)
  - Avg/Min: 3:1

Horizontal illuminance is importance for walking the site and entering the building at night. Although there will not be heavy traffic into this building at night, it may be possible to have a few sporting events take place at this school at night. Also, where there are dances or proms, there will be a large number of students back at the building at night.

Vertical Illuminance – *Very Important*

Entrance

- IES Classification: Common Applications – Building Entries – Paths to curb – Low Activity – LZ3
  - Category C: 2 lux (0.2 fc),
  - Avg/Min: 3:1

The vertical illuminance at night is listed here as more important than horizontal illuminance due to the importance of facial recognition. With this building being located (possibly) in an area of mid to high crime rate, facial recognition is important.

Facade

- IES Classification: Exteriors – Facades –High Activity – LZ3
  - Category O: 100 lux (10 fc)
  - Gauge: Max

The illuminance values stated here are allotted values for key elements or details of the building. These apply to less than 25% of the building façade.

Design Considerations

Color Appearance and Color Contrast – *Somewhat Important*

As the lighting on the façade is primarily used at night, and is mostly functional, color rendering, and color in general, is of little importance. With that being said, this may depend on the weight color is put on the original lighting design. For this design, color is of little importance.

Flicker – *Somewhat Important*

Flicker itself is an important design consideration and should be avoided whenever possible. However, there is no added importance of flicker for the façade than normal. That is, there are no critical tasks that require additional attention to flicker.

Light Distribution on Task Plane – *Somewhat Important*

Sufficient illuminance should be provided on the sidewalk as to permit passer-by to walk comfortably and safely. Meeting the IES recommendations for both vertical and horizontal illuminance should be sufficient.

Modeling of Faces or Objects – *Very important*

Due to the area the building is in, vandal and crime are a possibility. The lighting should model faces very well to facility easy facial recognition.

Shadows – *Somewhat Important*

The façade lighting will be active primarily at night. As such, shadows are of little concern. However, facial modeling is very important. See previous section.

Special Considerations –*Very important*

As mentioned in the overall design goals of the façade, the building may be subject to vandals. The lighting, and any other system installed on the exterior of the building within reach of the public, should consider the possibility of vandalism; graffiti more specifically. The lighting shall be resistant and graffiti and impact rated.

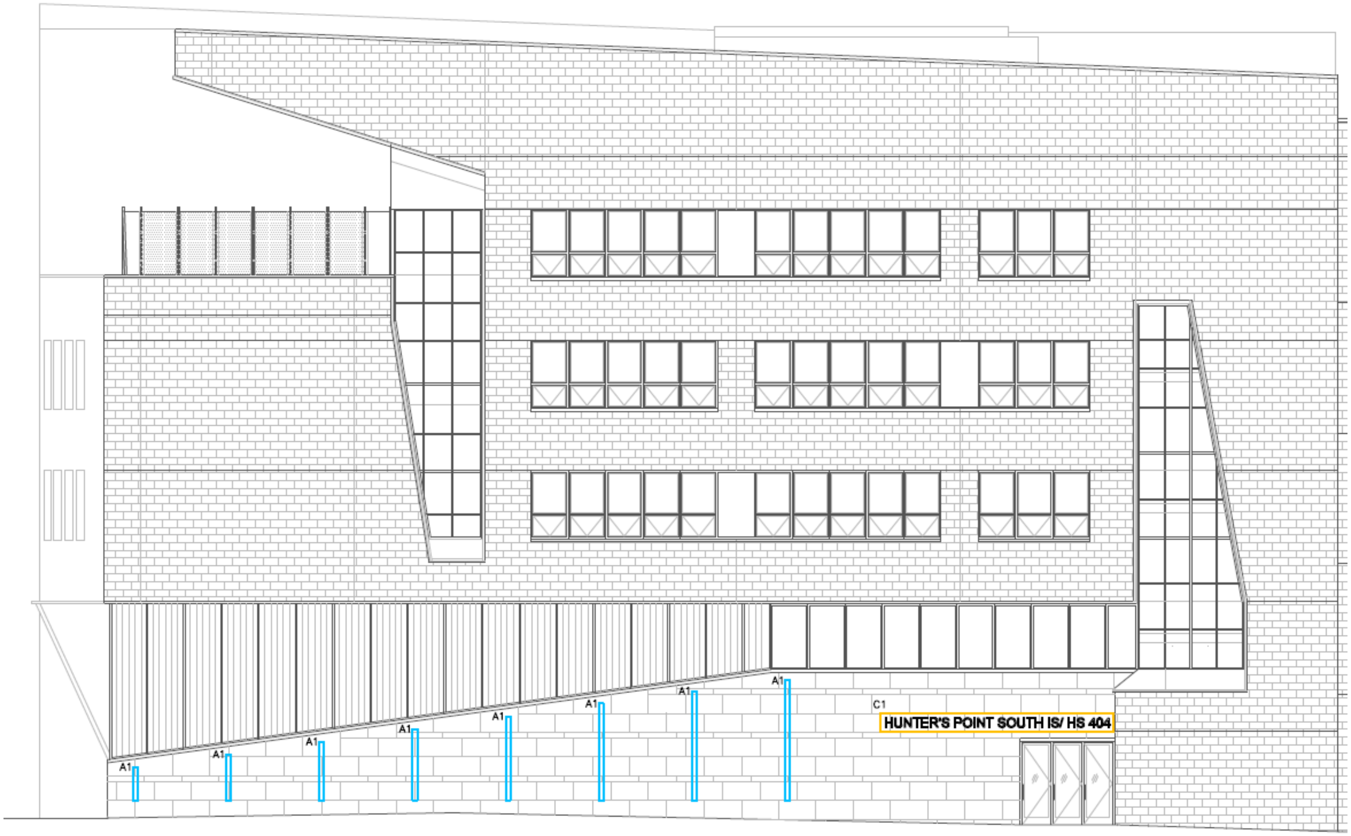
Daylighting Integration and Controls – *Somewhat Important*

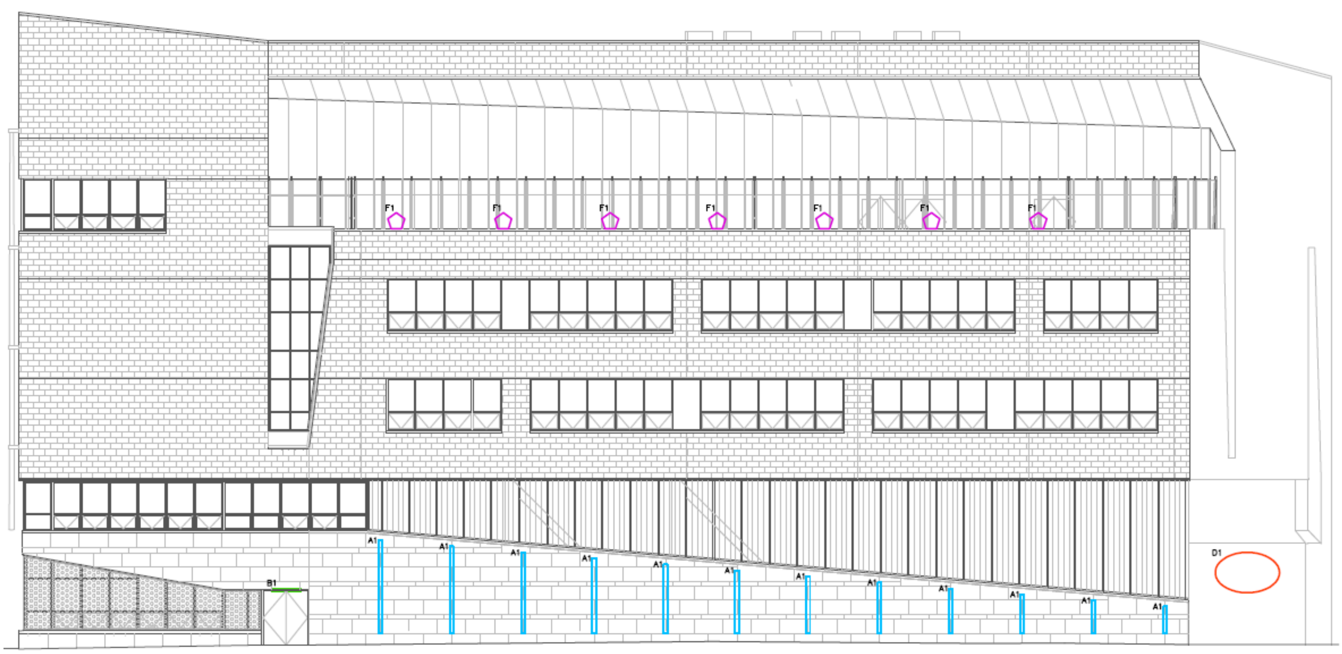
As the façade lighting will be used at night, daylight integration is not applicable. However, the lighting will be attached to the buildings time clock which is controlled by a rooftop photocell.

Glare – *Important*

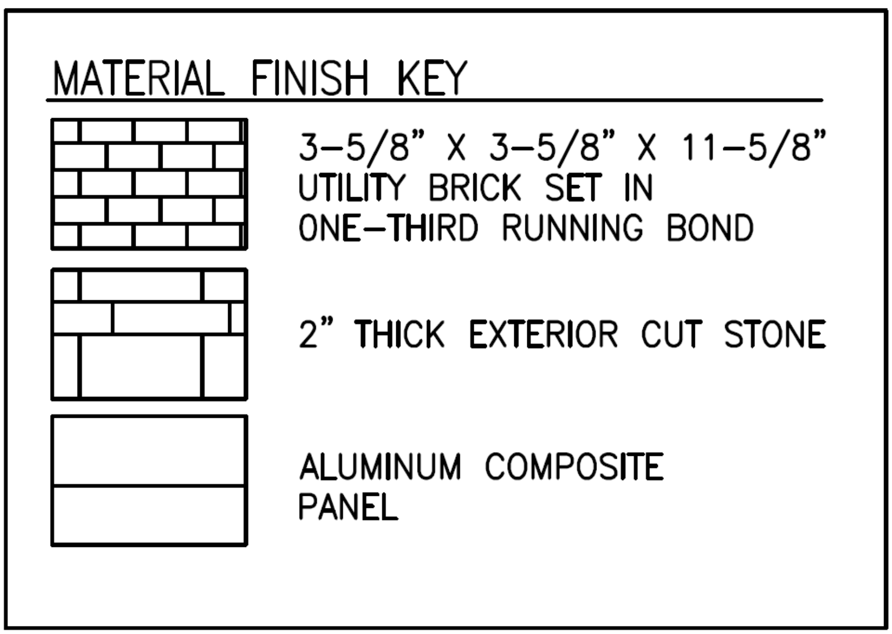
Glare is important as the lighting should be unobtrusive to the buildings passers-by. Luminaires should be positioned or designed in a way as to not impose direct glare on the public.

Fixtures and Equipment





Fixture Schedule			
Type		**Description**	**Manufacturer**
A1		Recessed linear LED strip. Stainless steel luminaire housing with sealed enclosure - wet listed for exterior. 6500k white LED's. Various fixture lengths, 4W/foot.	HessAmerica
B1		Surface mounted, F32T8 direct linear fluorescent. High impact radial lense (outdoor appropriate) with tamper resistant screws. 4 foot, die-formed, gloss white (YGW) 20-gauge steel housing	Prudential Lighting
C1		Surface mounted, flexible LED strip. Super bright, white (3500K), LED's. 2.4W/ft for LED of white output.	Cooper - RSA Lighting
D1		Acrylic, 0.3 inch, surface-mounted LED lighting panel. Ellipse shaped: long radius 4'6", short radius 2'10". White (3500k) LED's. Reflective opaue white backing to maximize optical brightness	Rosco Architectural
F1		Recessed, in-ground rated, 150W PSMH floodlight. One-piece, die-cast aluminum housing, with white premium polyester powder coat paint for protection. Include top visor.	Cooper Lighting



The tables below provide information regarding the energy consumption, assumed light loss factors, and load for the lamp-ballast combinations used for each of the luminaires used in the façade lighting (which includes the exterior roof terrace). The facade contains 1 linear fluorescent fixture near the exit and 242 linear feet of LED's throughout. The façade lighting consumes a total of 938 Watts (see ASHRAE/IESNA 90.1 under evaluation section).. The roof terrace, although technically considered a separate space, was included in the façade design, and utilizes 7 pulse-start metal halides. The roof terrace lighting consumes a total of 1,148 Watts.

FAÇADE VA CALCULATION								
Location	Type	Lamp	Qty	W/Fixture	Total Watts	PF	VA/Fixture	Total VA
Façade	A1	LED	168 ft	4 W/ft	672	0.7	5.7 VA/ft	960
	B1	(1) F32T8	1	38	38	0.9	42	42
	C1	LED	50 ft	2.4 W/ft	120	0.7	3.9 VA/ft	171
	D1	LED	24 ft	4.5 W/ft	108	0.7	6.4 W/ft	154
Terrace	F1	(1) PSMH	7	164	1312	0.9	182	1458

FAÇADE LIGHT LOSS FACTORS						
	Lamp Lumens		Light Loss Factors			
Type	Initial	Mean	LLD	LDD	BF	Total
A1	-	-	0.70	0.90	-	0.63
B1	3000	2850	0.95	0.90	1.20	1.0
C1	-	-	0.70	0.90	-	0.7
D1	14500	11600	0.80	0.90	1.00	0.7

ROOF TERRACE LIGHT LOSS FACTORS						
	Lamp Lumens		Light Loss Factors			
Type	Initial	Mean	LLD	LDD	BF	Total
F1	14500	11600	0.80	0.90	1.00	0.7

Controls

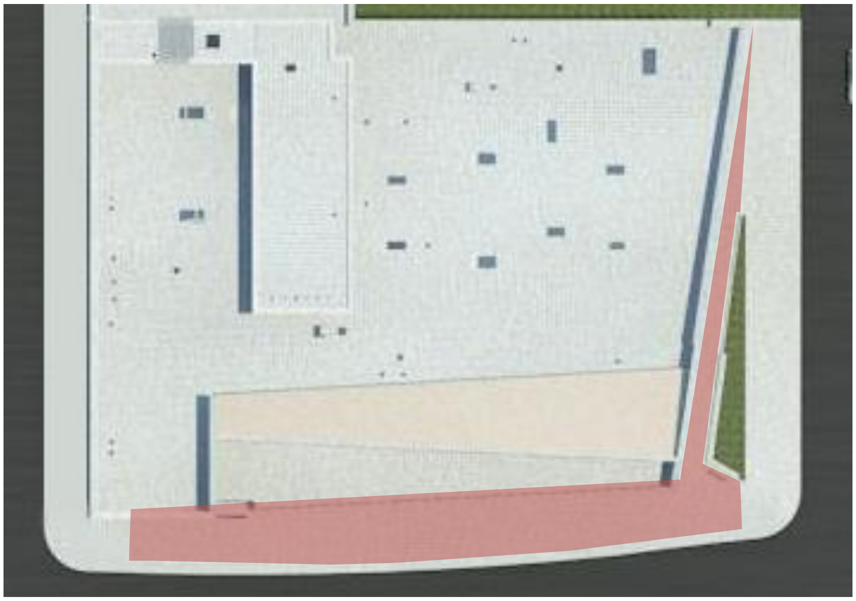
None of the façade lighting is controlled via occupancy sensors. All façade lighting, with a few exceptions, are connected to the buildings photocell time clock. The lighting attached to the time clock comes on at night, and shuts off in the morning. The exceptions are the fixtures located at the entrance and exit of the building. That is, the linear fluorescent over the exit of the building, and the signage at the entrance door. These fixtures are attached to the buildings emergency generator, and as such, are always on.

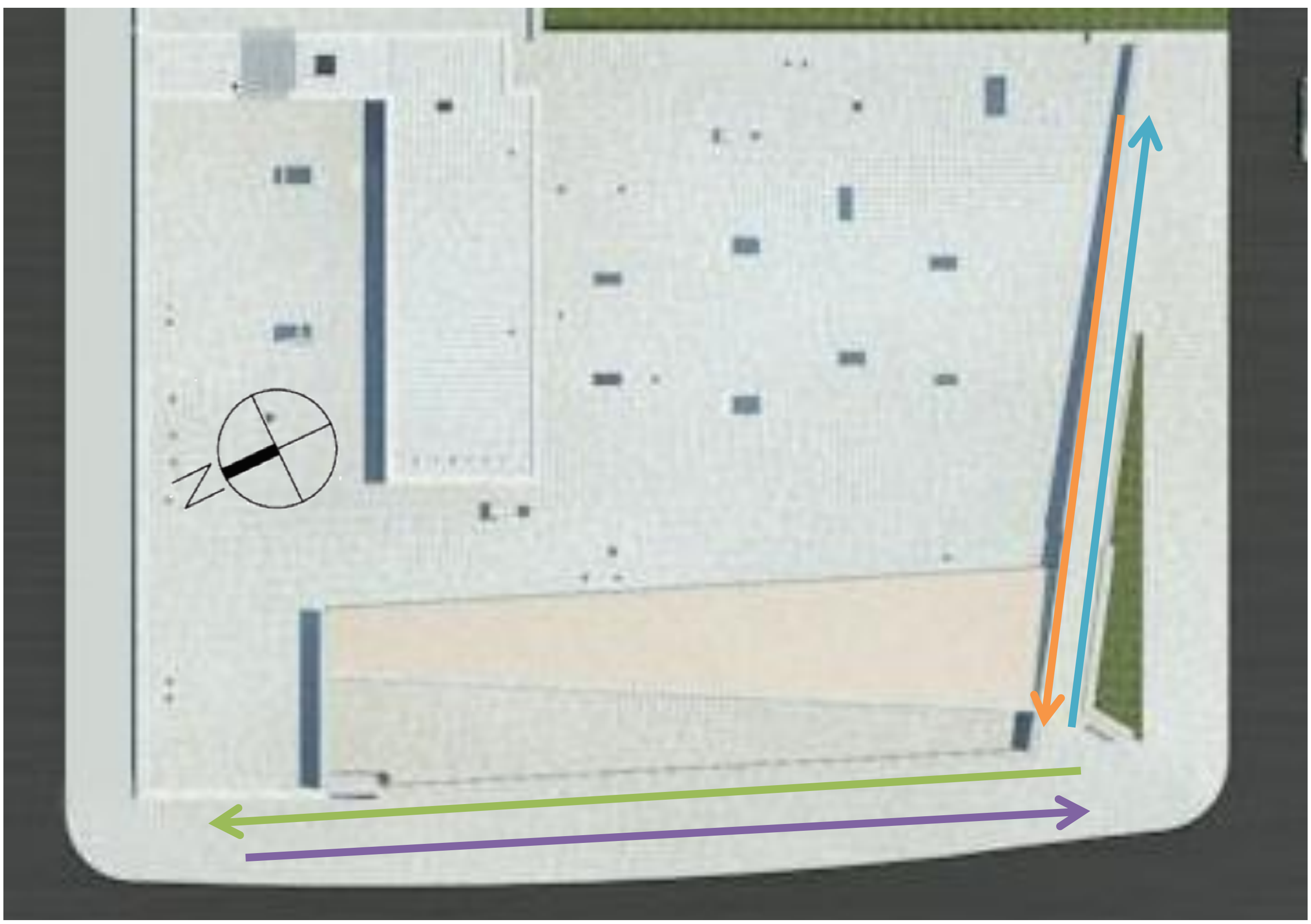
Calculation summary

The table below shows the calculation summary for the walkway around the building. Included in this table is the summary for 5 different calculation scenarios. The first is the vertical illuminance on the pavement. This is to ensure there is adequate illuminance for walking. The following 4 are vertical illuminance calculation to see if the vertical illuminance meets the IES requirements. There are two columns within each section (horizontal and vertical) labeled recommended and achieved. This shows the values recommended by the Illuminating Engineering Society, and the value actually achieved by design.

Façade illuminance criteria: Recommended vs. Achieved					
Category		Horizontal Illuminance (fc)		Vertical Illuminance (fc)	
Set	Quantity	Recommended	Achieved	Recommended	Achieved
Ground/ Walkway	Average	0.2	0.33	n/a	n/a
	Maximum	-	14.8	n/a	n/a
	Minimum	-	0.1	n/a	n/a
	Avg/Min	3:1	3.3	n/a	n/a
	Max/Min	-	148	n/a	n/a
Vertical 1	Average	n/a	n/a	0.2	0.18
	Maximum	n/a	n/a	-	1.0
	Minimum	n/a	n/a	-	0.1
	Avg/Min	n/a	n/a	3.0	1.8
	Max/Min	n/a	n/a	-	10
Vertical 2	Average	n/a	n/a	0.2	0.32
	Maximum	n/a	n/a	-	2.1
	Minimum	n/a	n/a	-	0.1
	Avg/Min	n/a	n/a	3.0	3.2
	Max/Min	n/a	n/a	-	21
Vertical 3	Average	n/a	n/a	0.2	0.19
	Maximum	n/a	n/a	-	0.3
	Minimum	n/a	n/a	-	0.1
	Avg/Min	n/a	n/a	3.0	1.9
	Max/Min	n/a	n/a	-	3
Vertical 4	Average	n/a	n/a	0.2	0.19
	Maximum	n/a	n/a	-	0.4
	Minimum	n/a	n/a	-	0.1
	Avg/Min	n/a	n/a	3.0	1.9
	Max/Min	n/a	n/a	-	4

The images below show the location (or area of coverage) of the sets of calculation points presented in the table on the previous page. Highlighted in **red** in the figure directly below is the area that was included in the Ground/Walkway calculation. This calculation was taken on the ground plane and was aimed at guaranteeing adequate illuminance levels for walking at night. The second image, with colored arrows, shows the location of the vertical calculation grids. Each arrow has a color that corresponds to the vertical calculation that it represents. The path (or line) of the arrow indicated the line along which the calculation was performed. The arrow, or direction in which it points, indicated the direction the light meter faces for the calculation. All vertical illuminance calculations were taken at 5 foot above finished grade (5' AFG).





Evaluation

Summary

The lighting of the exterior façade successfully achieves most of the design goals designated at the outset of design. The entrance of the building, which is small and hidden, has been highlighted with two forms of signage; the first, an LED backlit sign representing the name of the school; the second, a backlit sign showing the school's mascot. This creates a high illuminance ratio (>10:1) between the entrance and the surrounding area, which in turn, achieves the original design goal of forcing the entrance to be a focal point.

That most of the fixtures are either out of reach of the public, or are specified vandal-grade fixtures, achieves the design goal of a vandal-proof design. This was important not only for inherent cleaning cost implications of graffiti, but also because damaged or vandalized fixtures hurts the aesthetics and appearance of the building in general. The metal halide spotlights uplighting the large trapezoidal overhang on the fifth floor exterior roof terrace aims to make the building dominant on the riverfront. Persons docking boats nearby, or merely passing by on the river, should easily notice and locate the building. It may be used as a wayfinding device or landmark, and achieves the overall design goal of being visible from the river.

In general, as the façade goes over power density, the minimalistic design goal has not been achieved. Due to tradability of power densities of exterior surfaces, this is not against ASHRAE code, but it does not achieve the design goals as efficiently as maybe it could.

ASHRAE/IESNA 90.1

As mentioned in the previous paragraph, the design of the "façade" lighting does exceed the allotted power density specified by ASHRAE 90.1. The word façade is quoted because the roof terrace was included in the "façade" design, although according to ASHRAE, is a separate space. The actual façade and path-to-curb areas meet the allotted power densities as provided in the code; it is the roof terrace that exceeds its allowable power consumption. That is, because the roof terrace is an exterior space, it is considered tradable. That is, power consumption from the exterior roof terrace can be moved to the façade classification. As shown on the tables on the next page, The original

The table below shows the total input wattage for the actual façade portion of the lighting design.

FAÇADE TOTAL INPUT WATTS				
Type	Lamp	Qty	Input W	Total W
A1	LED	168 ft	4 W/ft	672
B1	(1) F32T8	1	38	38
C1	LED	50 ft	2.4 W/ft	120
D1	LED	24 ft	4.5 W/ft	108
			Total:	**938**

The table below shows the total input wattage for the fifth floor exterior roof terrace.

ROOF TERRACE TOTAL INPUT WATTS				
Type	Lamp	Qty	Input W	Total W
F1	PSMH	7	164	1148
			Total:	**1148**

The table below shows a comparison of the actual power consumption of the façade lighting design against the allowable consumption as designated by ASHRAE/IESNA 90.1.

Façade ASHRAE/IESNA 90.1		
Category	Allowable	Actual
Perimeter (Linear Ft.)	-	350
Input Watts (W)	1750	938
Power Density (W/ft)	5.0	**2.68**

The table below shows a comparison of the actual power consumption of the roof terrace lighting design against the allowable consumption as designated by ASHRAE/IESNA 90.1. As shown (highlighted in white) the roof terrace exceed allowable power density.

Roof Terrace ASHRAE/IESNA 90.1		
Category	Allowable	Actual
Area (sq.ft.)	-	4300
Input Watts (W)	688	1148
Power Density (W/sqft)	0.16	**0.27**

The table below shows that, although the roof terrace goes over allowable power density, it meets code when combined with the extra façade wattage.

Space	**Total Wattage**	
	Allowable	**Actual**
Façade	1750	938
Roof Terrace	688	1148
Total:	2438	2086
% Under:	14.44	

2 | Auditorium

This section, dedicated to the documentation of the lighting design solution for the auditorium, contains all information pertinent to fully describing the space and lighting design. Included are the design goals and criteria, utilized fixtures and equipment schedules, control description, calculation summary as quantitative evaluation of the design, renderings of appropriate views, and an evaluation comparing the design solution against the design goals set at the outset of the design. This section is outlined as follows:

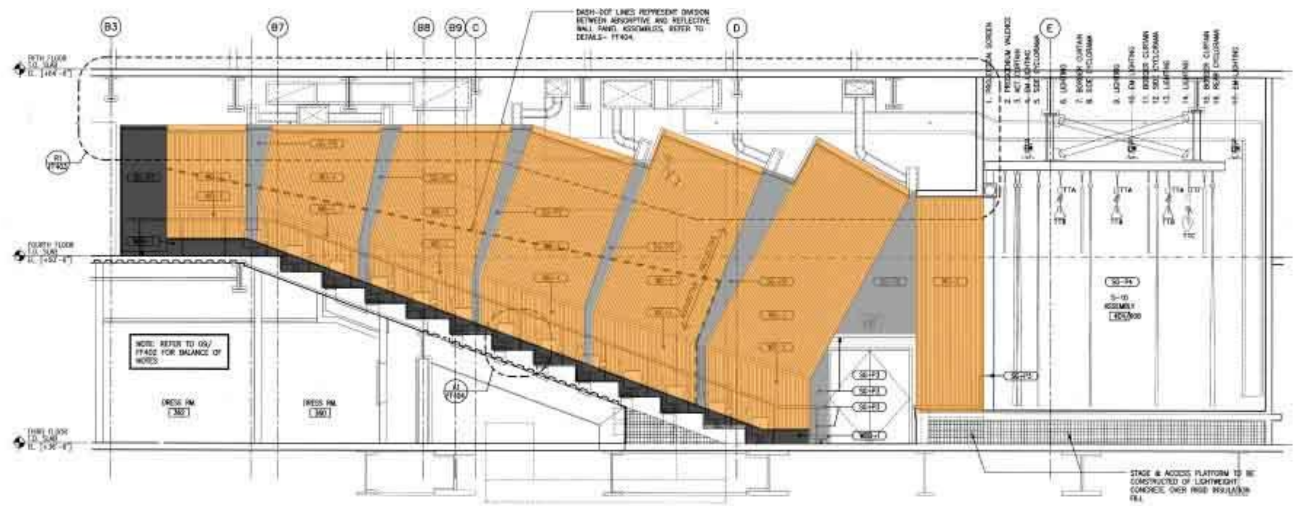
Description

Location (in building)

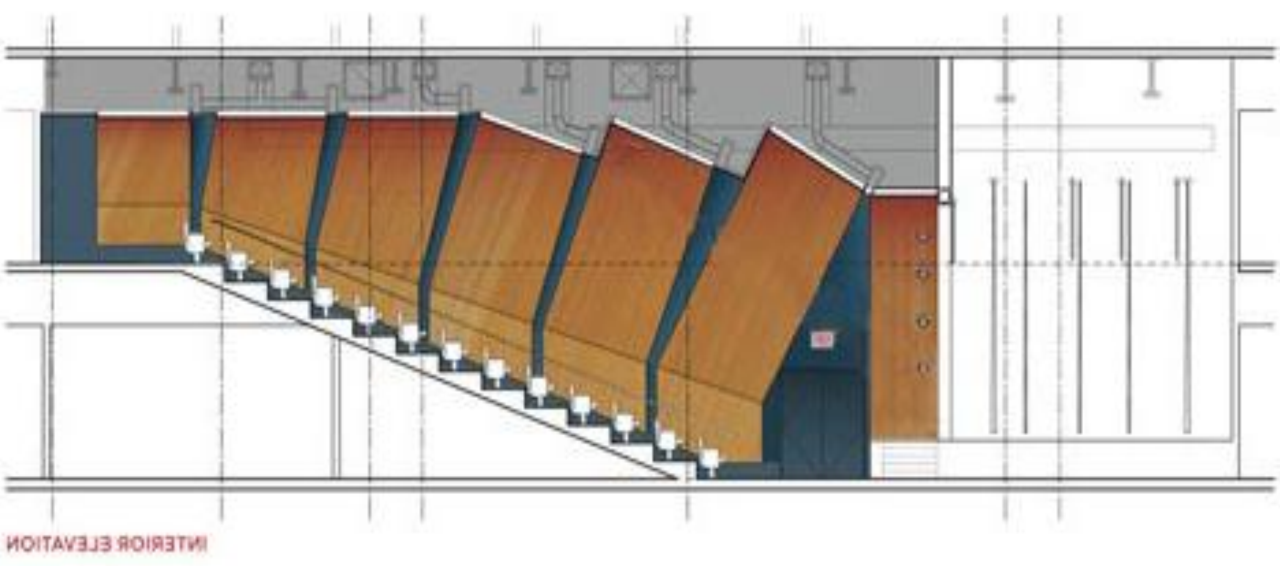
The auditorium, which is two stories high, in the center-point that connects the third and fourth floor of the building. It is accessible from both floors and is the point at which the two schooling types are connected. That is, the third floor houses the intermediate school students, and the fourth is dedicated to the high school students.

Finishes

The auditorium is comprised of wood paneling and painted gypsum wall board (GWB). Highlighted in orange in the figure below are the beech wood panels that are tilted at 11 degrees into the space, and are tuned acoustically so sound quality in the space is desirable. Both shades of gray in the image below represents painted GWB. The light grey is painted "evening dove" whereas the black highlight is a painted a similar shade but had a wooden baseboard. The stage and back-of-house area is also GWB painted white. Overhead panels (i.e. the ceiling) are beech wood panels as well.

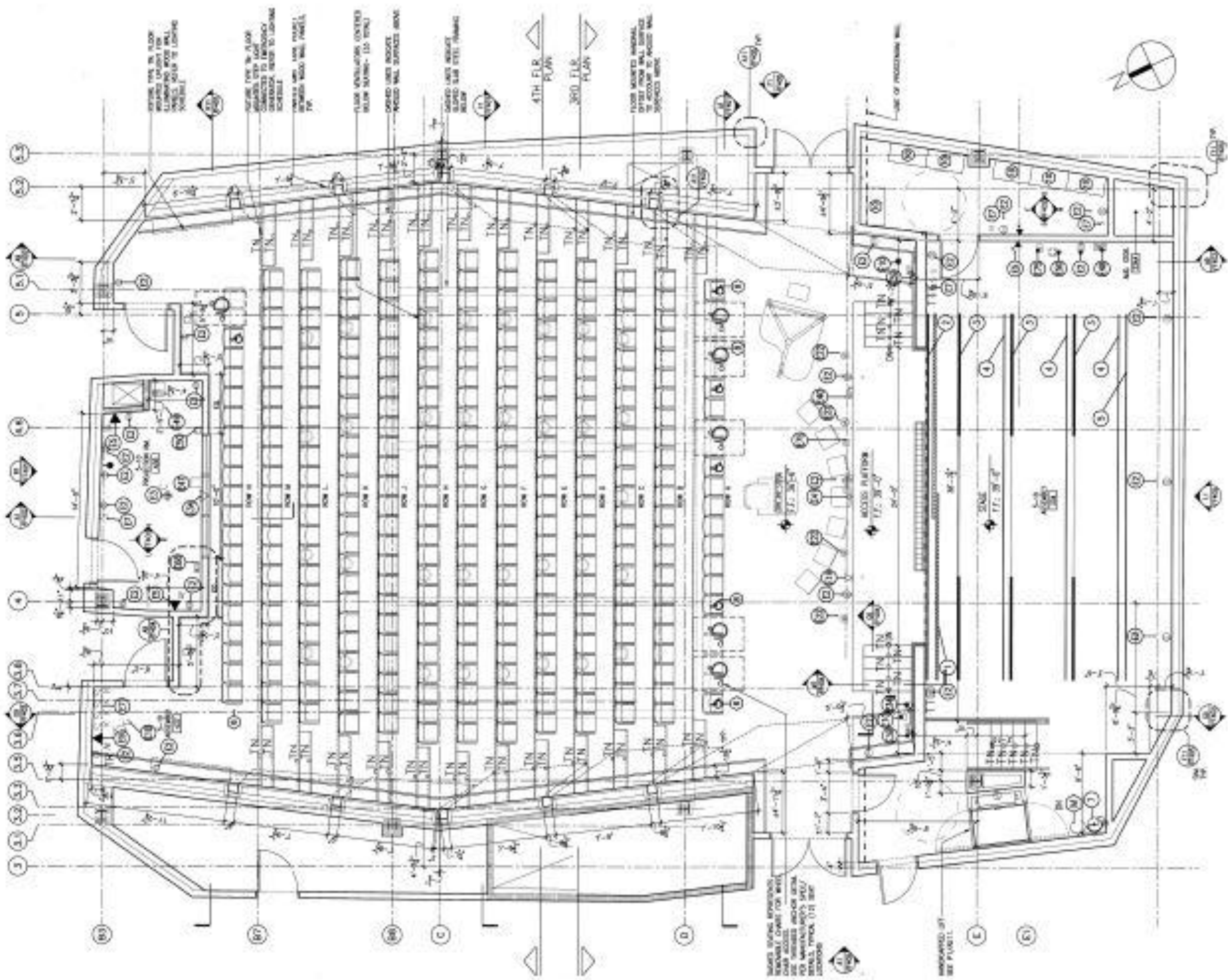


The image below shows a section rendering of the auditorium space. This figure shows the color choice of the architect. You can get a feeling of how the architect imagined the space to feel.



Furnishings

Center of the space has general auditorium seating that holds approximately 300 people, a handful being handicapped. In the front of the space, there is a piano and area for an orchestra. There is few other furniture in the space.



Tasks/activities

The space will house multiple types of activities. General town meeting will be a large collection of students with the goal of providing information to large numbers of students. These can be about upcoming events, current happening, or information about things such as graduation. In addition, the space can support performances, plays, and/or talent shows. Because of the dedicated orchestra space and piano in the front, the space is equipped to hold musical performances and choir events. Because the space is acoustically tuned, musical events in the space should be a great experience for all.

Overall design goals

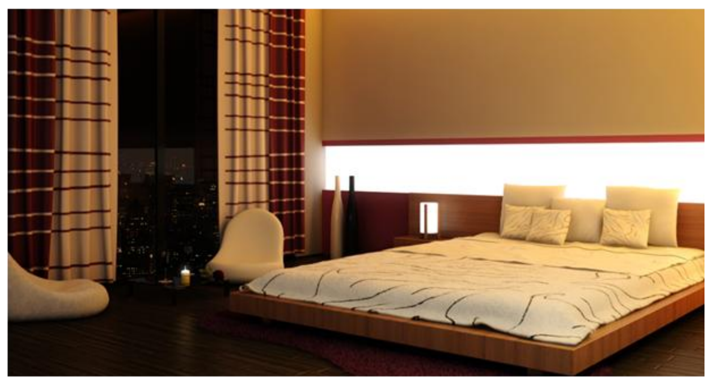
The goal in the auditorium is to achieve a flexible lighting design that can be changed depending on the event that is happening in the space. As this is an intermediate school and high school auditorium, it inherently needs to be flexible. The lighting should have the ability to be altered depending on the function of the space, and from a designers point of view, these can be labeled via the opposing Flynn impressions **public and private**. The public scenario needs to have high brightness with uniform light levels and have little to no peripheral emphasis. The public scenario should have little emphasis of particular points in general. The public scene would typically be used for large public meetings with the students. The private scenario, opposing the public scenario, should have non-uniform lighting, with emphasis on the area of importance. The private Flynn impression is typically defined by non-uniform lighting with high peripheral wall emphasis. Warm tones tend to enhance private feelings, which are further enhanced by the orange/brown word panels lining the auditorium.

The images below graphically represent (and list) the opposing Flynn impressions.

Public

- Uniform Light levels
- High brightness
- Small to no Peripheral Emphasis

Private



- Non-Uniform Lighting
- High Brightness Remote From User
- Peripheral (Wall) Emphasis
- Warm Tones

Design Criteria/Considerations

Illuminance recommendations

Horizontal Illuminance – *Important*

- **Audience**
    - IES Classification: Hospitality and Entertainment –Theatres, Stages –House
        - During Production
            - Category R: 1 lux (0.1 fc)
            - Avg/Min: 2:1
    - IES Classification: Hospitality and Entertainment –Theatres, Stages –House
        - Pre/Post-Show, Intermisssion
            - Category R: 50 lux (5 fc)
            - Avg/Min: 2:1

- **Circulation**
    - IES Classification: Hospitality and Entertainment –Theatres, Stages –House
        - During Production
            - Category R: 2 lux (0.2 fc)
            - Avg/Min: 2:1
    - IES Classification: Hospitality and Entertainment –Theatres, Stages –House
        - Pre/Post-Show, Intermisssion
            - Category R: 50 lux (5 fc)
            - Avg/Min: 2:1

Horizontal Illuminance – *Important*

- **Audience**
  - IES Classification: Hospitality and Entertainment –Theatres, Stages –House
    - During Production
      - Category R: .5 lux (0.05 fc)
      - Avg/Min: 2:1
  - IES Classification: Hospitality and Entertainment –Theatres, Stages –House
    - Pre/Post-Show, Intermisssion
      - Category R: 15 lux (1.5 fc)
      - Avg/Min: 2:1

- **Circulation**
  - IES Classification: Hospitality and Entertainment –Theatres, Stages –House
    - During Production
      - Category R: 2 lux (0.2 fc)
      - Avg/Min: 2:1
  - IES Classification: Hospitality and Entertainment –Theatres, Stages –House
    - Pre/Post-Show, Intermisssion
      - Category R: 15 lux (1.5 fc)
      - Avg/Min: 2:1

Design Considerations

Appearance of Space and Luminaires – *Very Important*

Appearance of space has been more or less dictated by the architect. However, the luminaires should be chosen so that they not only achieve the overall design goal of the space, but also that they do not conflict with the architecture.

Color Appearance and Color Contrast – *Very Important*

The surfaces in the space vary in color, and contain oranges and blues. The luminaires and lamps should be chosen with high rendering so as not to take away from the architecture.

Daylighting Integration and Controls – *Not applicable*

The space has no windows to the exterior. As such, daylighting integration and controls is not applicable to this space.

Direct and Reflected Glare – *Important*

Direct and reflected glare are important in this space especially for performance venues. The performers on the stage should not experience glare, either direct or reflected. Glare can be distracting and irritating, but in the case of an auditorium with a stage, can present safety hazards.

Flicker – *Somewhat Important*

Flicker itself is an important design consideration and should be avoided whenever possible. However, there is no added importance of flicker in this space than normal. That is, there are no critical tasks in this space that require additional attention to flicker.

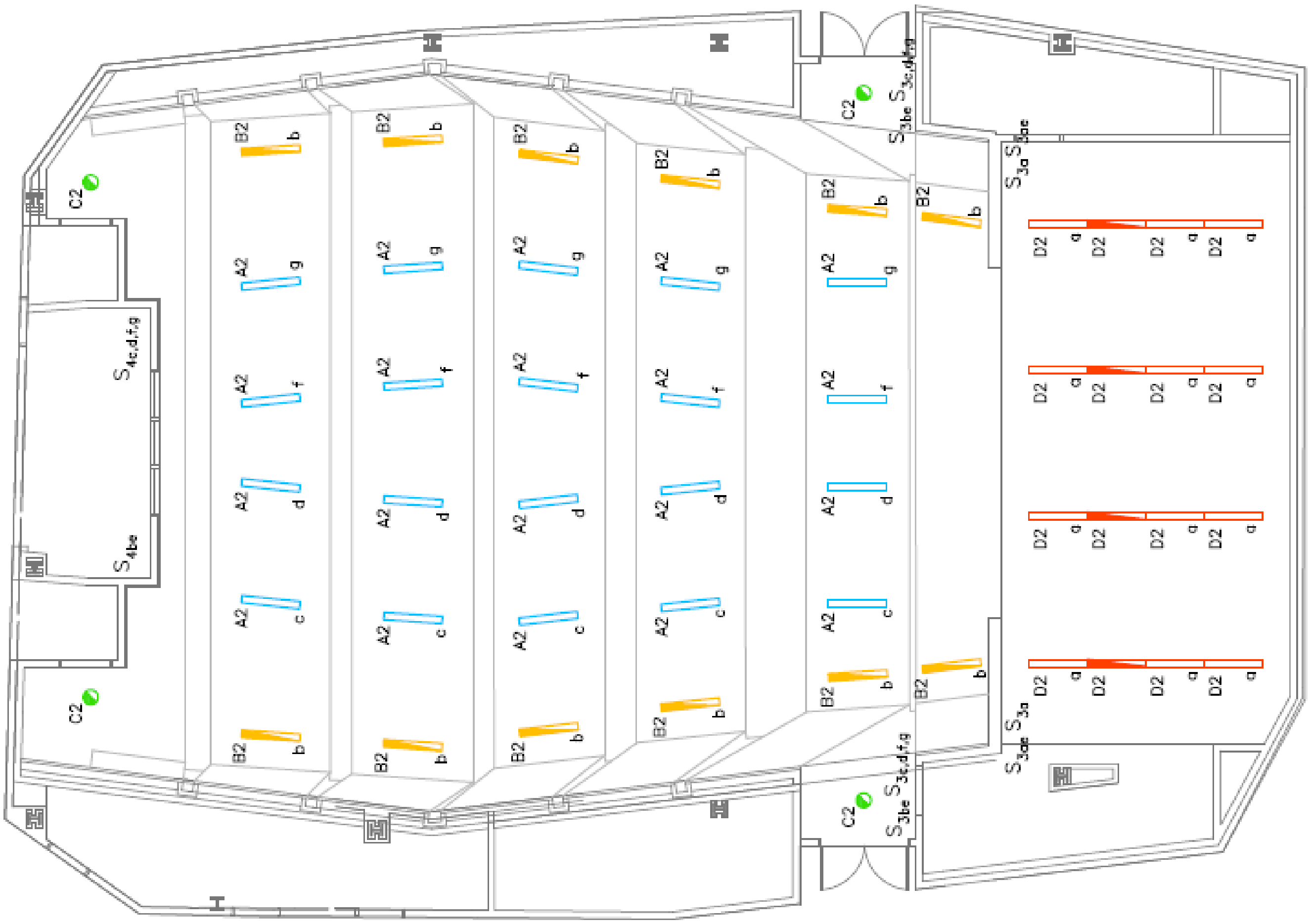
Light Distribution on Task Plane – *Somewhat Important*

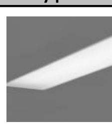
As long as the illuminance levels and uniformity meets the IES recommendations, no real problems should happen.

Shadows – *Somewhat Important*

Shadows are of little importance especially that there are few tasks in the auditorium that it could hinder. The theatrical lighting system should be designed so that shadows are implemented and extracted when desired and/or when appropriate for a performance. The general lighting in the seating area needs little regard to shadow problems.

Fixtures and equipment



Fixture Schedule				
Type			Description	Manufacturer
A2			Recessed linear fluorescent with flush .07" thick acrylic lens with opal satin finish. 22 ga. steel reflectors with high reflectance white powder coat. Matte White finish	Focal Point
B2			Recessed linear fluorescent **wall-washer** with flush .07" thick acrylic lens with opal satin finish. 22 ga. steel reflectors with high reflectance white powder coat. Matte White finish	Focal Point
C2			Single-lamp, recessed compact fluorescent downlight with 7 3/8" aperture. Matte white finished flange with 16 ga. aluminum, wide distribution refelctor.	Lightolier
D2			Single-lamp, suspended linear T8 linear fluorescent downlight. 4' length bosy of formed and welded die-formed 20-gauge steel. Gloss white (YGW) polyester power paint finish.	Prudential

The tables below provide information regarding the energy consumption, assumed light loss factors, and load for the lamp-ballast combinations used for each of the luminaires used in the auditorium lighting. The auditorium contains a total of 57 lighting fixtures (including the exit signs). The lighting solution in the auditorium consumes a total of 1,993 Watts (see ASHRAE/IESNA 90.1 under evaluation section). A light loss factor was not included for the exit sign (fixture 'EX') as is does not provide useful illumination to the room, and was not considered in any lighting calculations. It was, however, included in the energy consumption calculation of the space.

AUDITORIUM VA CALCULATION								
Location	Type	Lamp	Qty	W/Fixture	Total Watts	PF	VA/Fixture	Total VA
Auditorium	A2	(1) F32T8	20	38	760	0.9	42	844
	B2	(1) F32T8	12	38	456	0.9	42	507
	C2	(1) 32CFTR	4	36	144	0.9	40	160
	D2	(1) F32T8	16	38	608	0.9	42	676
	EX	LED	5	5	25	0.7	7	36

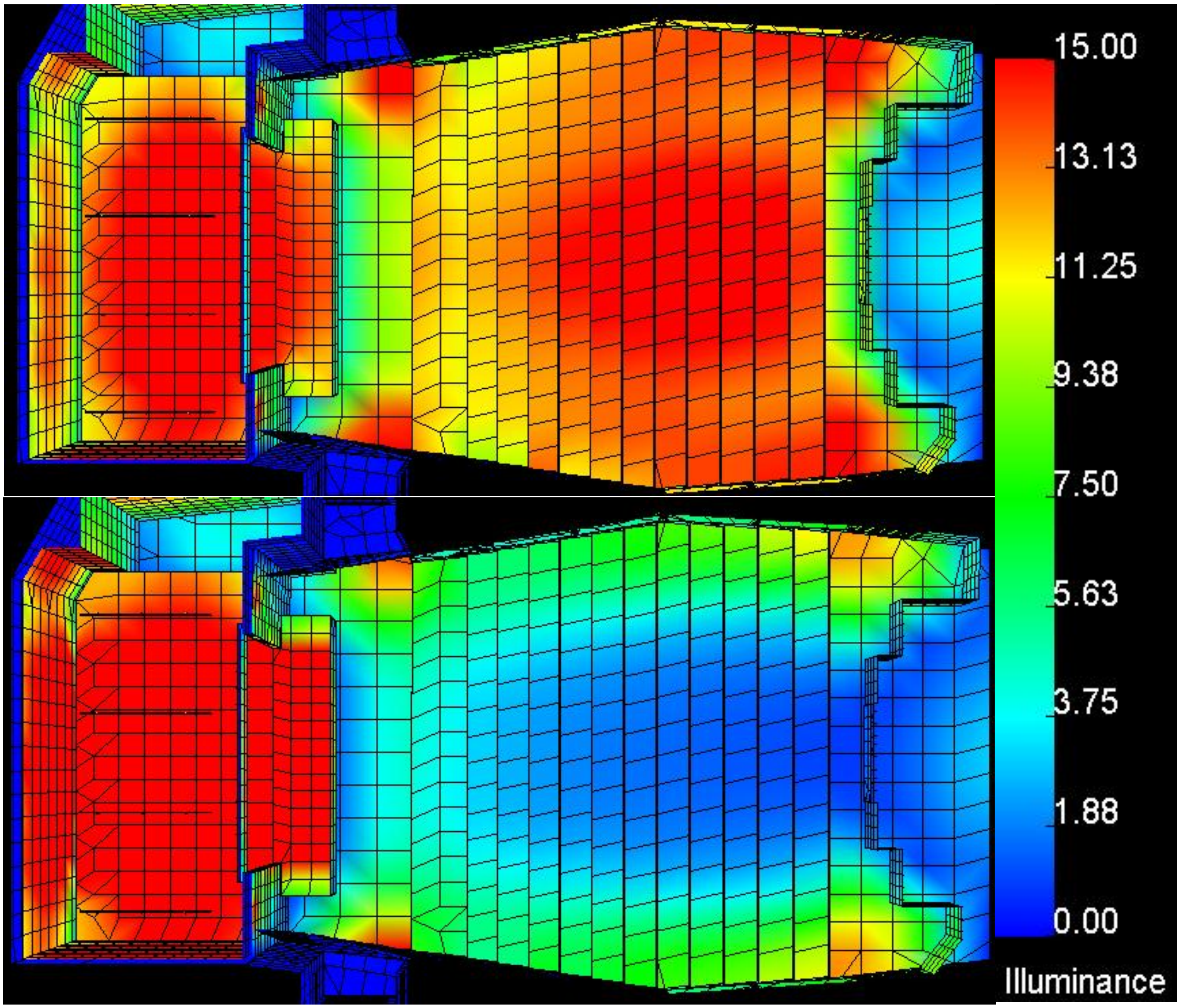
LIGHT LOSS FACTORS						
Type	Lamp Lumens		Light Loss Factors			
	Initial	Mean	LLD	LDD	BF	Total
A2	3000	2850	0.95	0.90	1.20	1.0
B2	3000	2850	0.95	0.90	1.20	1.0
C2	2400	2065	0.86	0.90	1.00	0.8
D2	3000	2850	0.95	0.90	1.20	1.0
EX	-	-	-	-	-	-

Controls

The auditorium is split into multiple zones, all with dimming capabilities. The fixtures in the space that are deemed emergency fixtures are dimmable as well and are fed from a dimming panel connected to the emergency system. These fixtures may be dimmed as desired—in the event of a power outage the control system will force them back to full output. The stage lighting is split into two zones; 4 of the 16 fixtures dedicated to emergency, the rest dimmable, general illumination stage lighting. The recessed downlights located near the entrance and exits of the space, zoned separately, are connected to the emergency system and are set to be always on at full output. The lighting over the general seating area, is split into four zone, with each row of lighting being its own zone. This gives large flexibility in the lighting in the space, allowing the lighting and illuminance levels to be altered depending on the event.

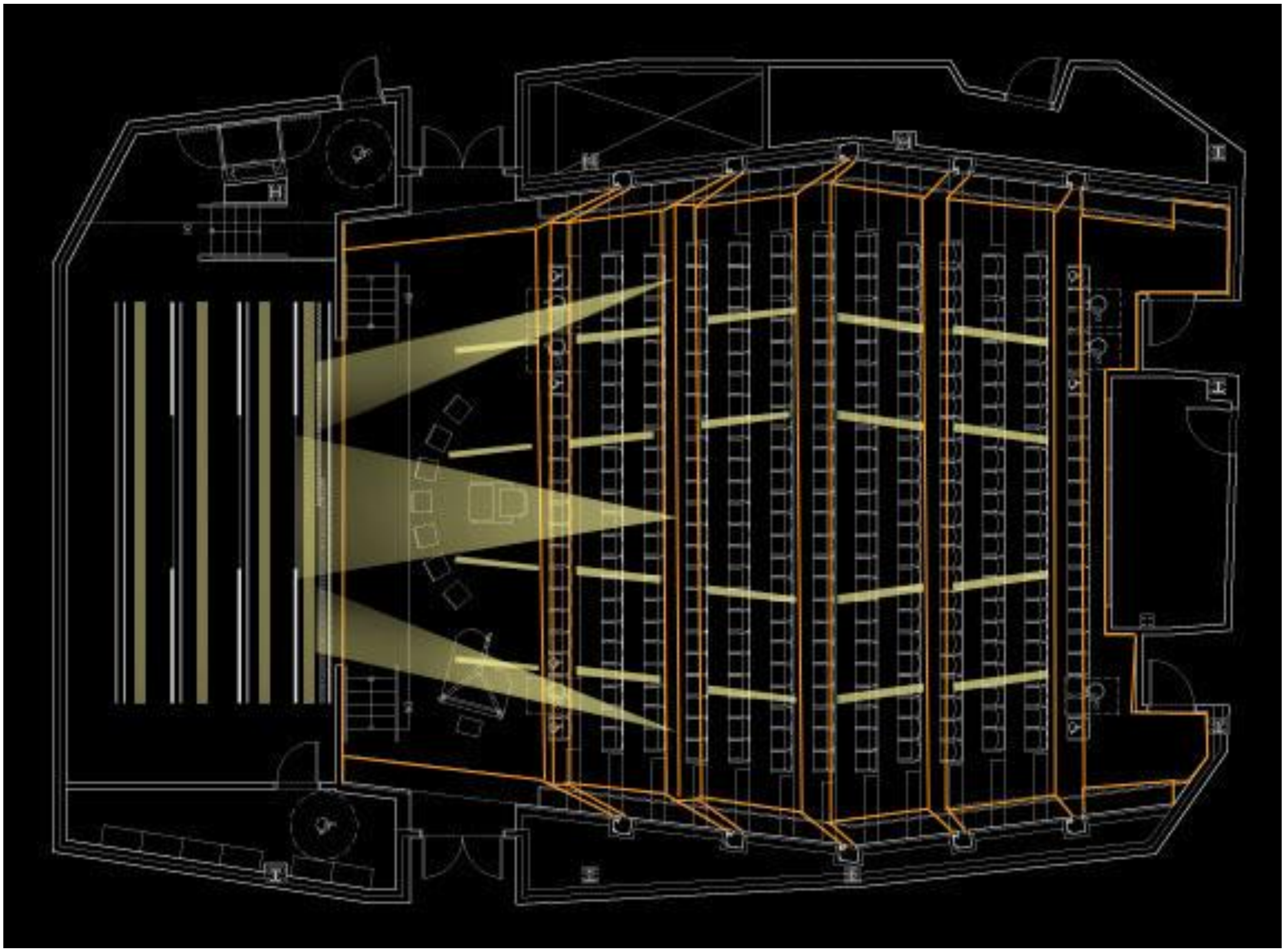
Calculation summary

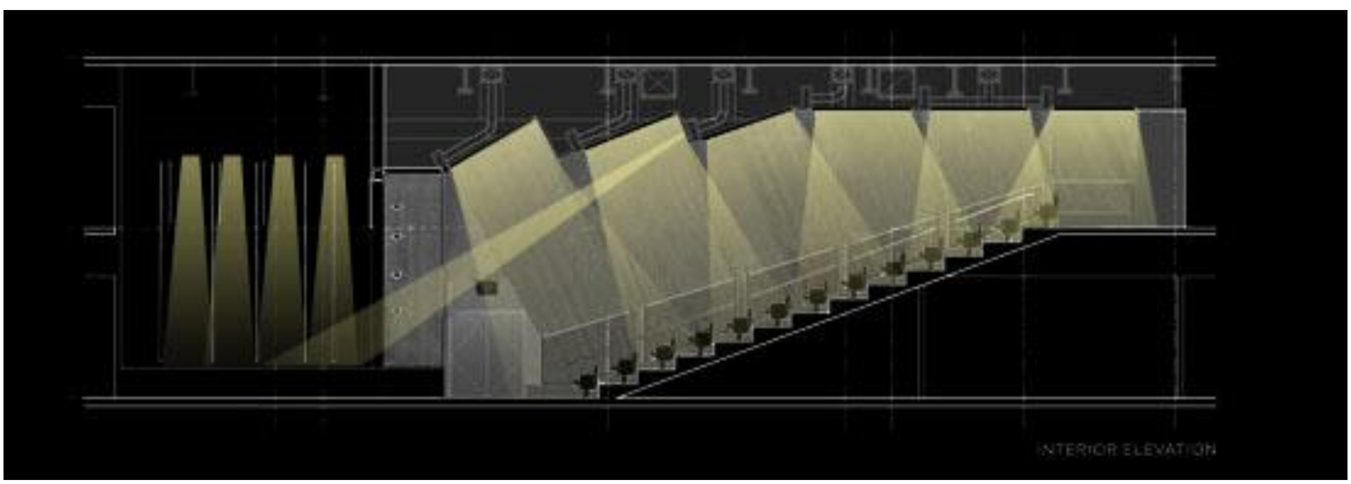
The pseudo diagrams below represent the illuminance distribution in the space under the two lighting scenarios: public and private. The top, the public scenario, has a much more uniform distribution of light throughout the space than does the private scenario. High illuminance levels throughout the space create no particular emphasis at any point, which is desirable for public town meetings or general addresses to the students. The second diagram, the private scenario, has a much less uniform design. The main emphasis is on the stage, with peripheral wall emphasis due to fixtures wall-washing the wood panels

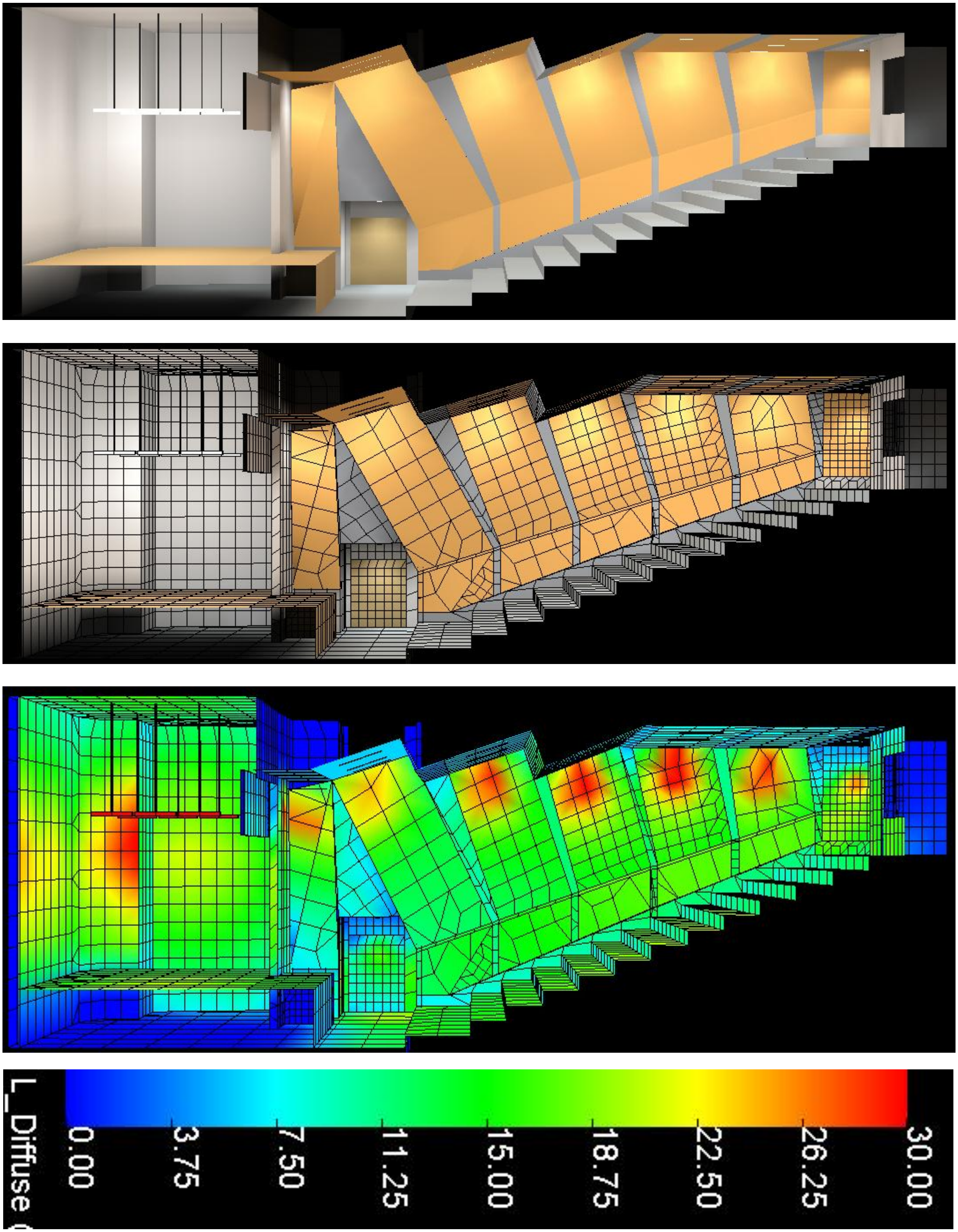


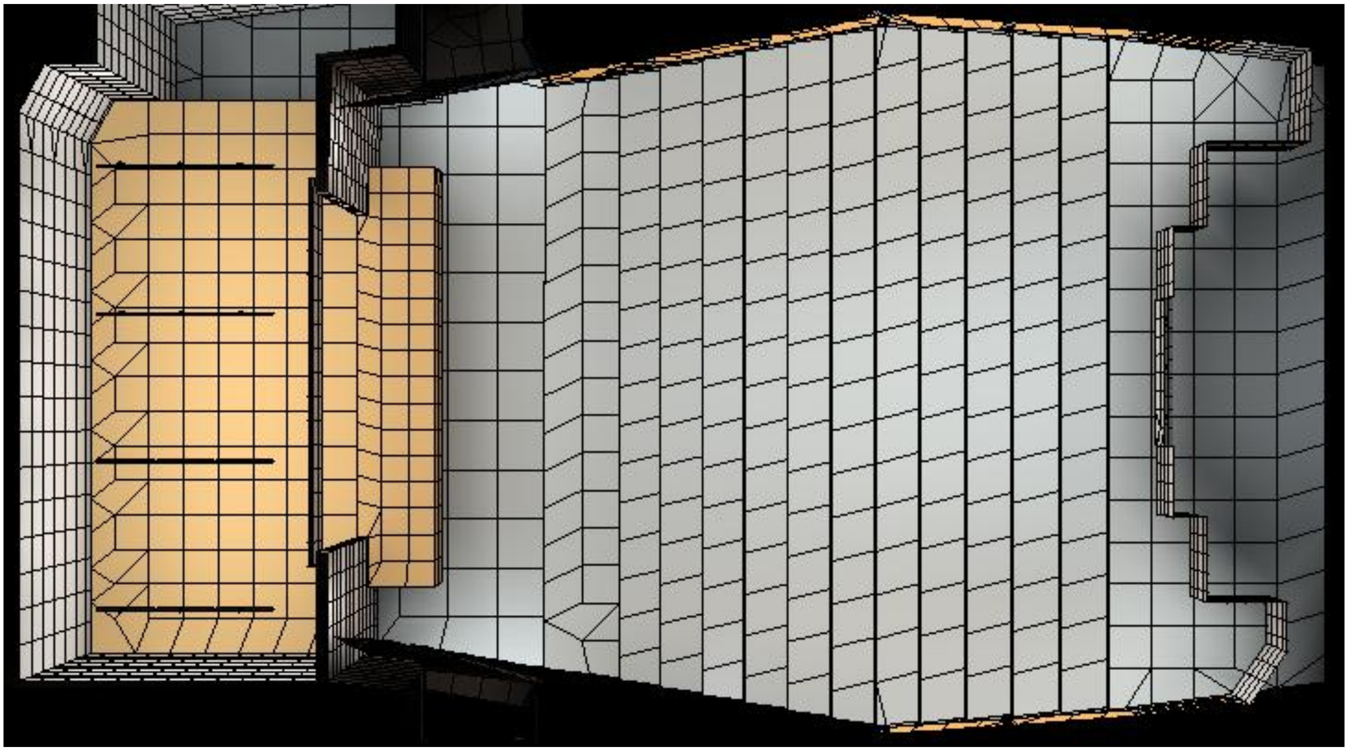
Renderings

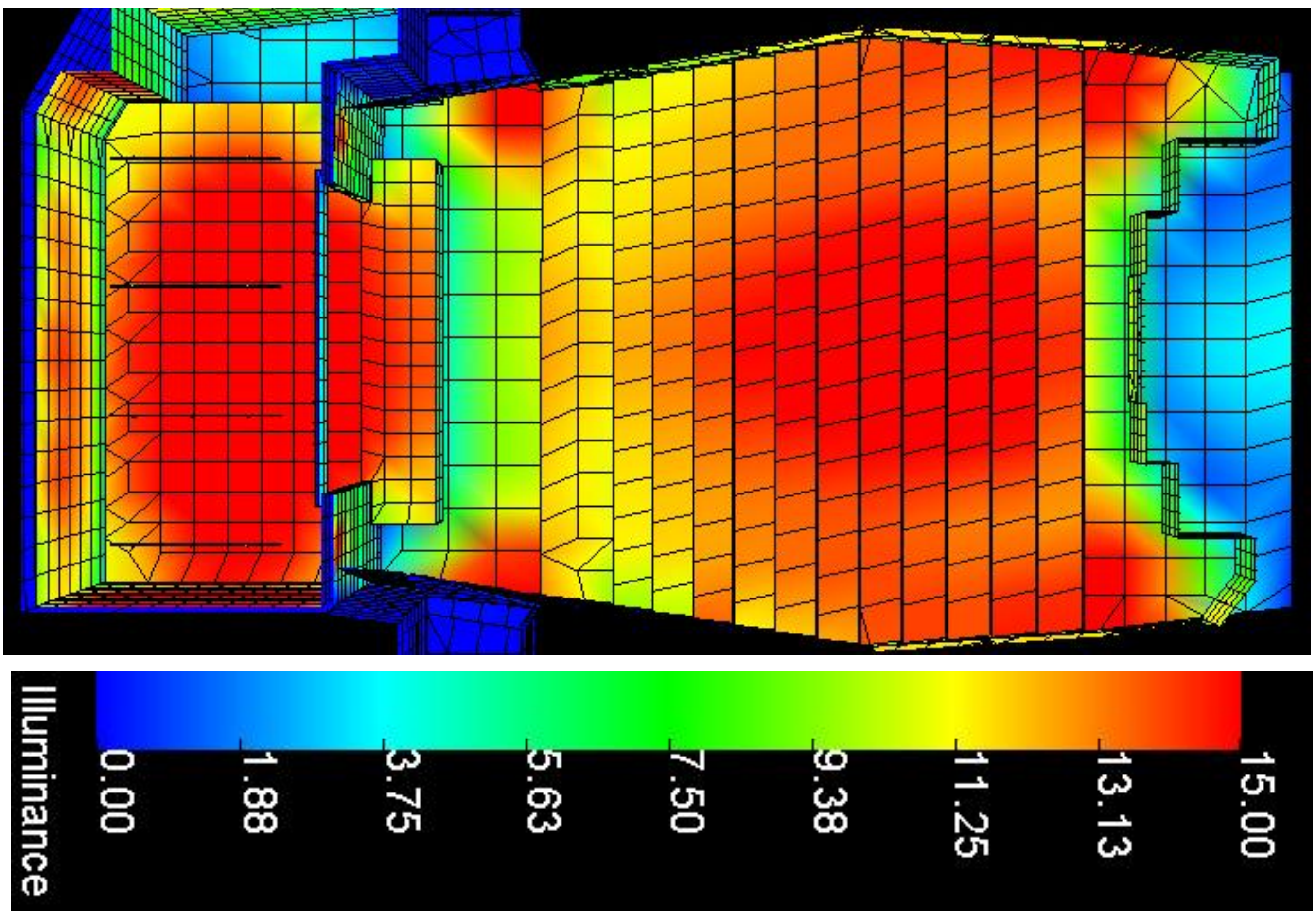
Public



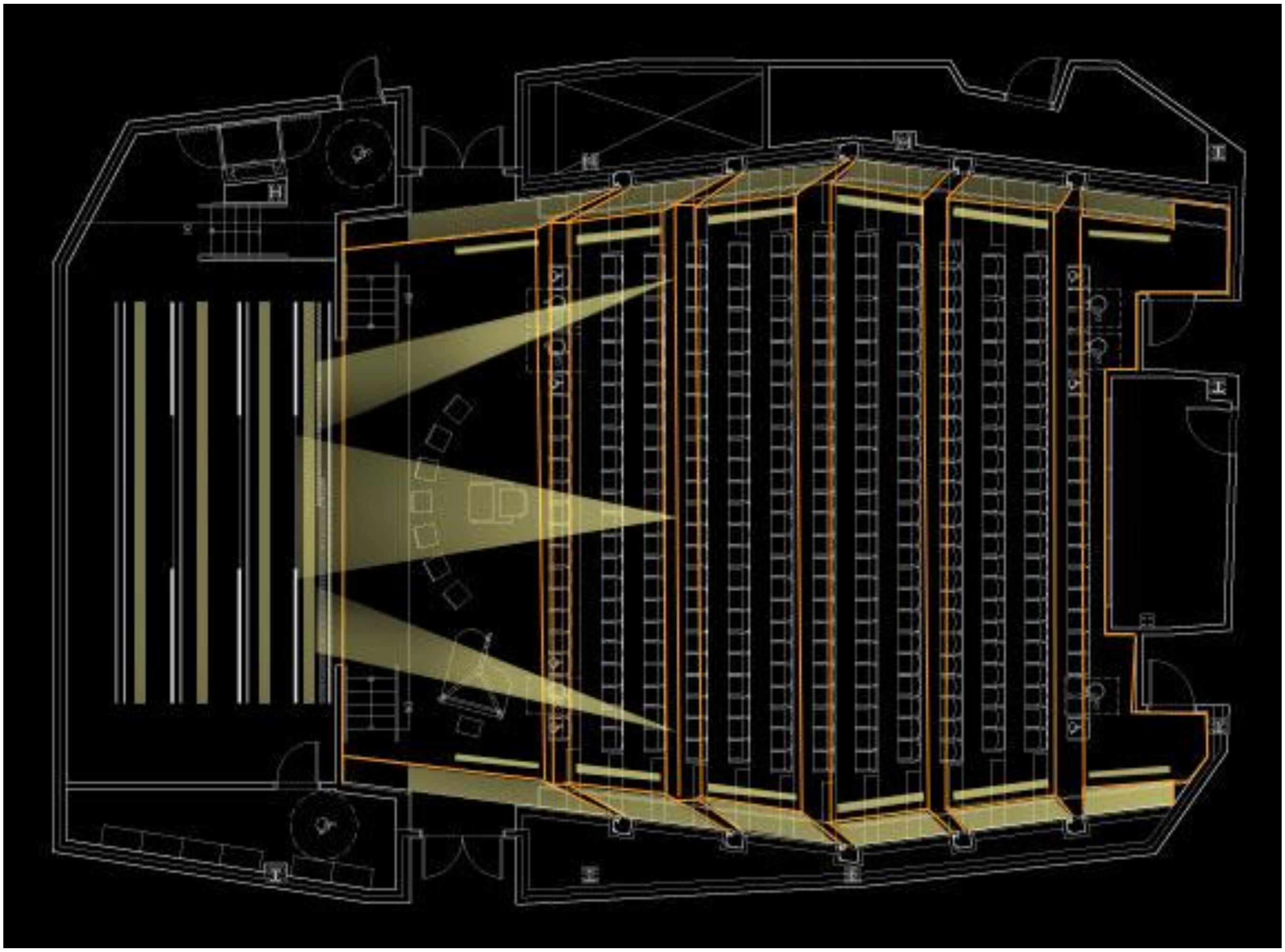


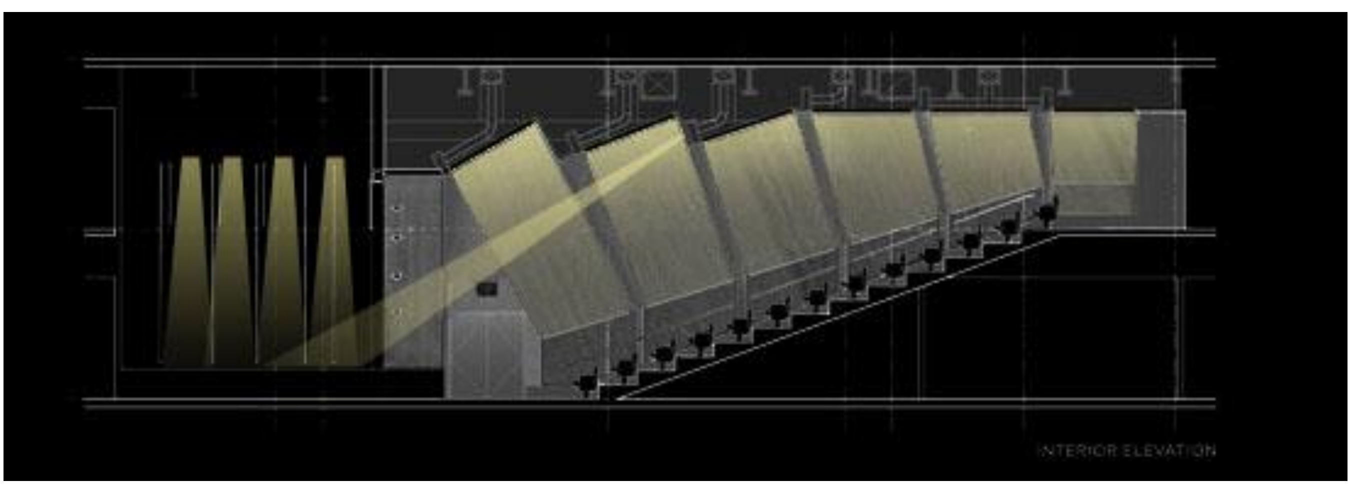

L_Diffuse
0.00
3.75
7.50
11.25
15.00
18.75
22.50
26.25
30.00

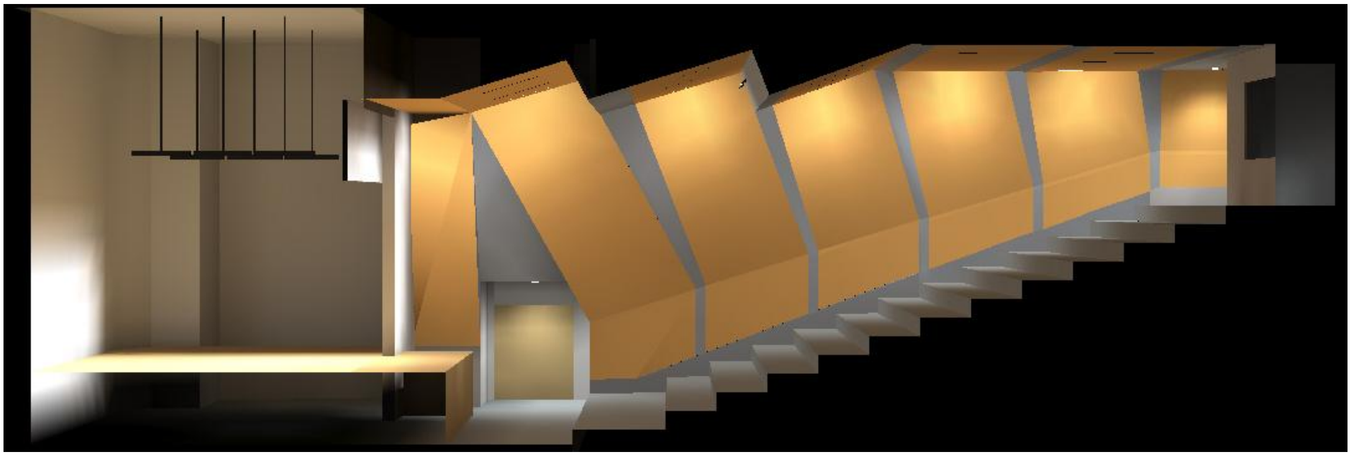


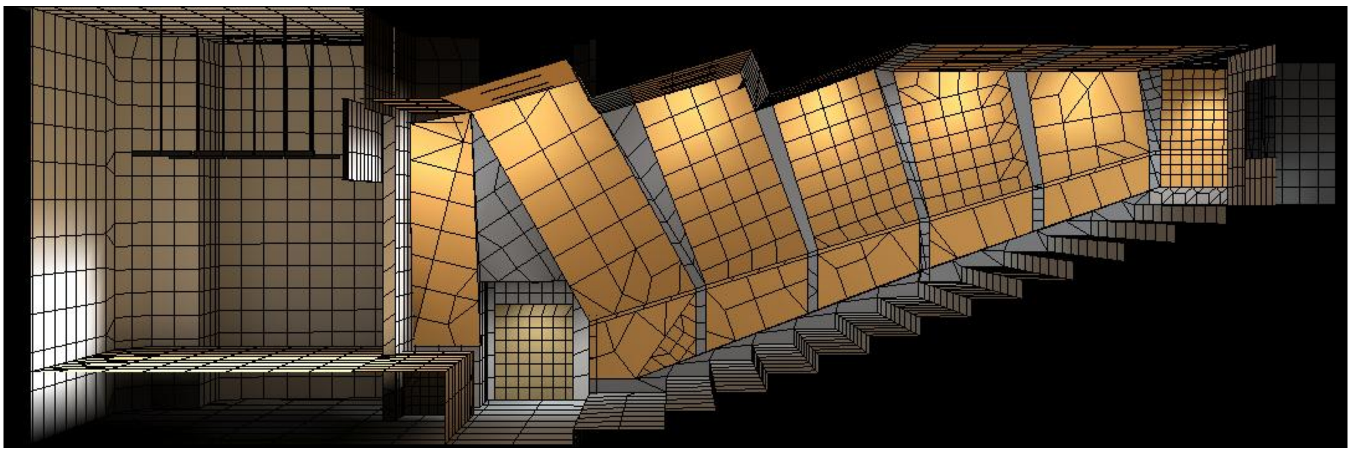

Illuminance
0.00
1.88
3.75
5.63
7.50
9.38
11.25
13.13
15.00

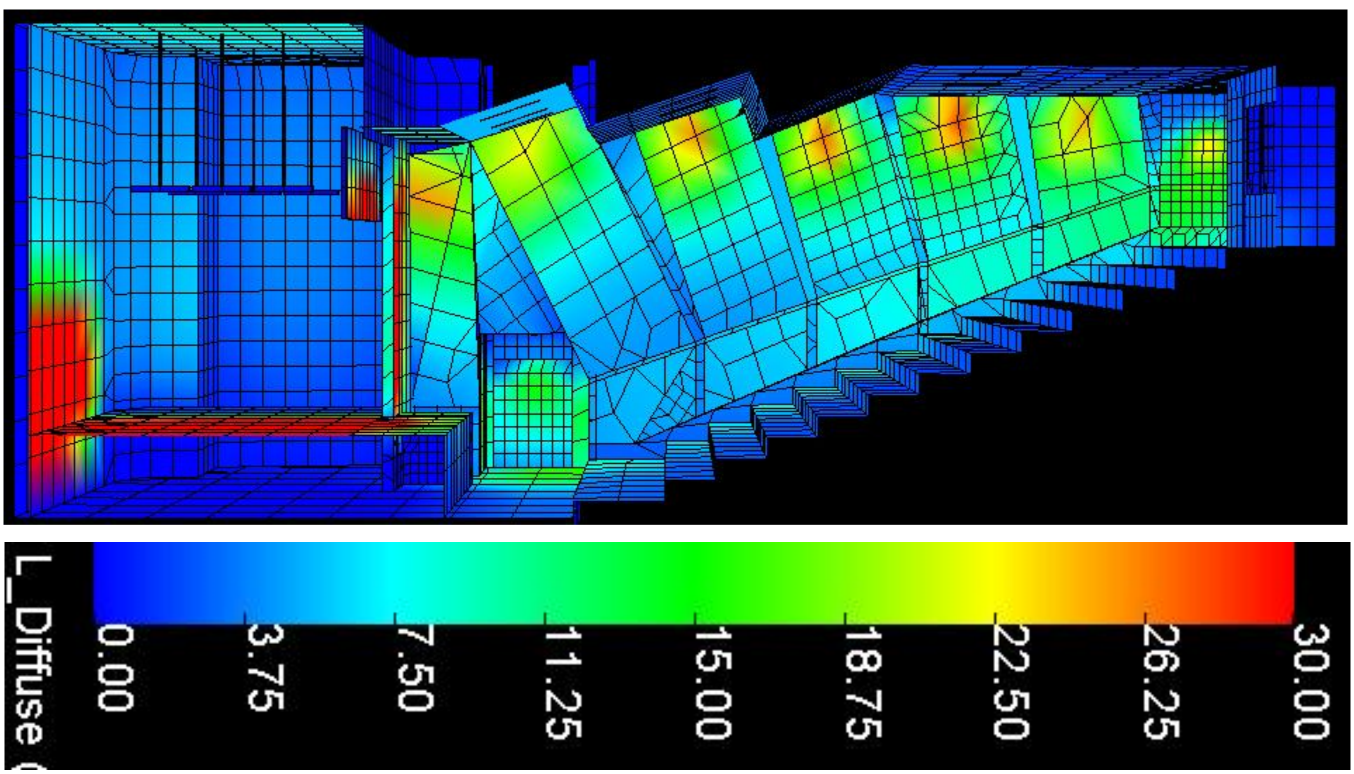
Private

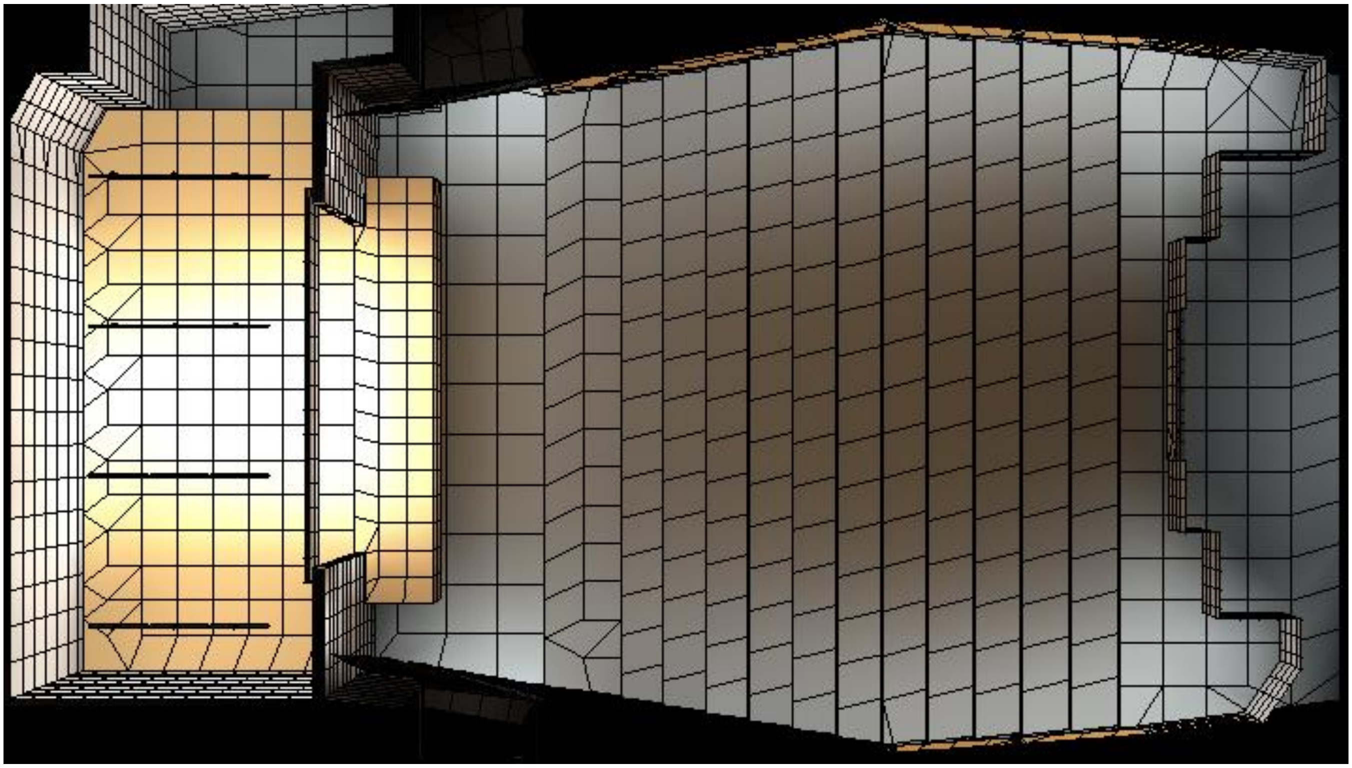


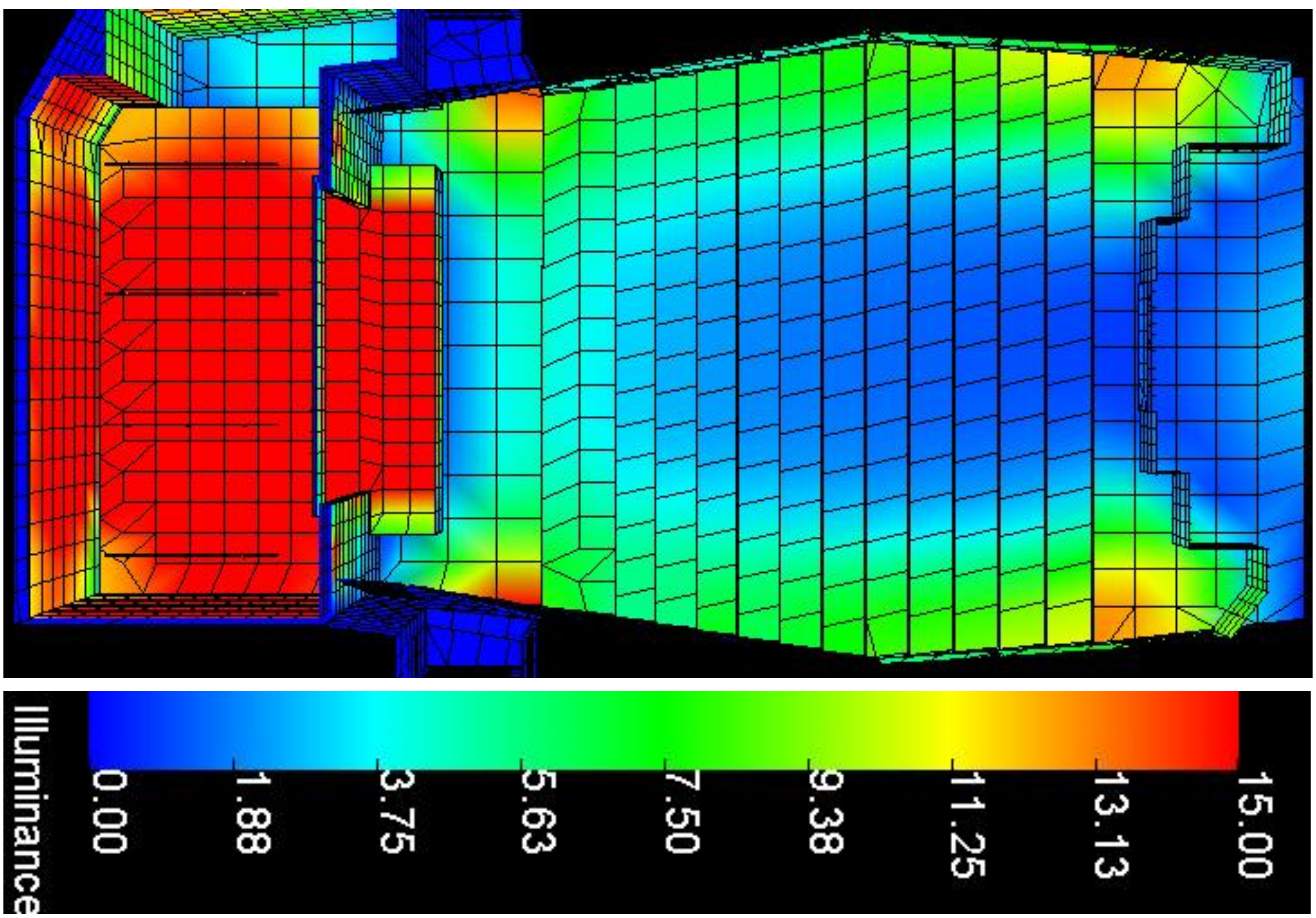




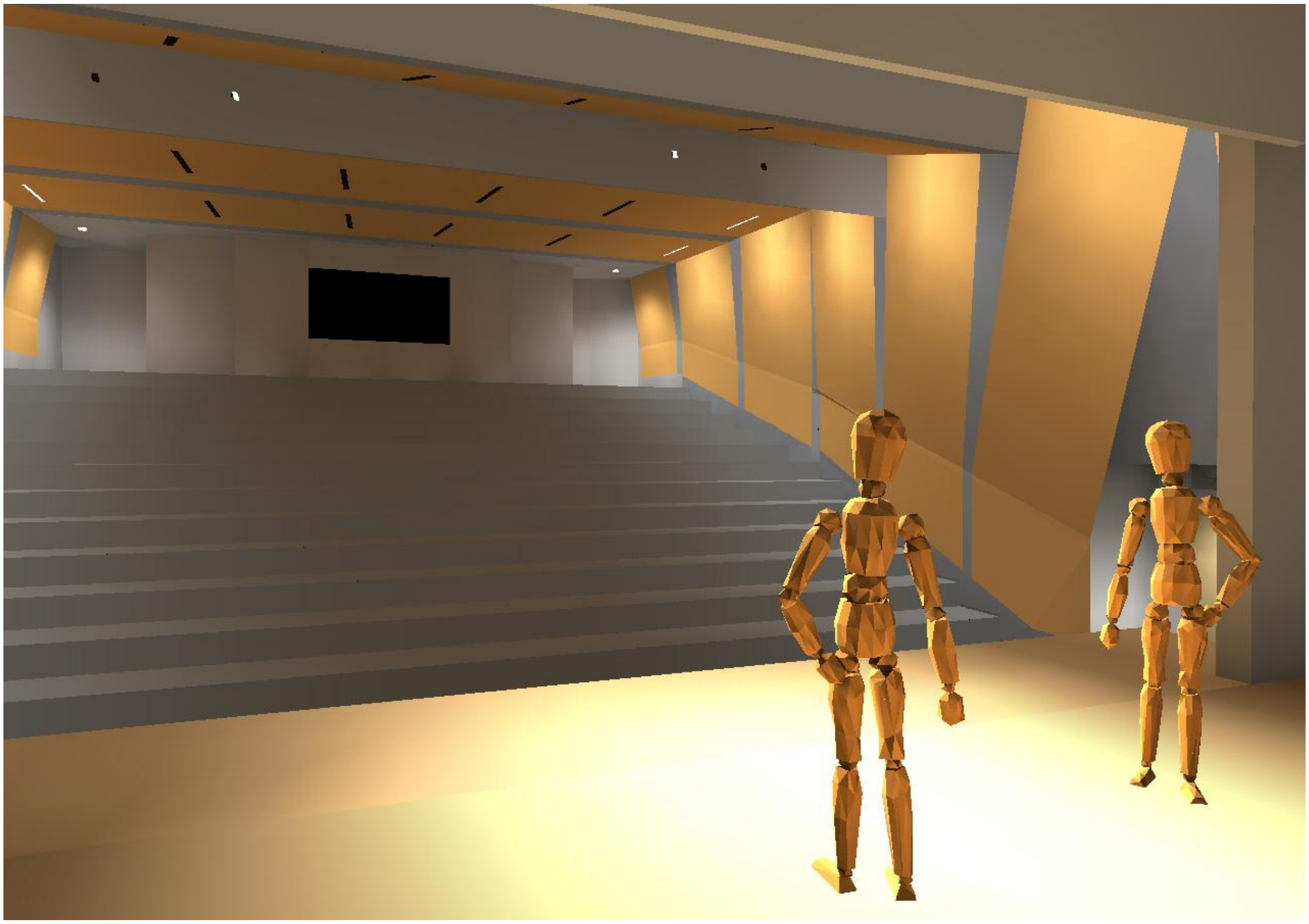



L_Diffuse
0.00
3.75
7.50
11.25
15.00
18.75
22.50
26.25
30.00




Illuminance
0.00
1.88
3.75
5.63
7.50
9.38
11.25
13.13
15.00

To be, or not to be…



a lighting designer?

Evaluation

Summary

The auditorium lighting design effectively creates public and private scenes via flexible lighting controls. In the private scene recessed linear fluorescent wall washers line the perimeter wall creating large peripheral emphasis. The theatrical spot lights aimed at the stage not highlight the actors, but it also creates a focal point; it creates emphasis distant to the seated audience. The public scenario, which has all luminaire turned on, creates high levels of illumination that are more uniform than that of the private scenario. There is no emphasis on any particular area. The lighting successfully achieves these two opposing Flynn impressions without infringing on the architecture.

ASHRAE/IESNA 90.1

The tables below show the power consumption and ASHRAE/IESNA 90.1 code requirements for the Intermediate school cafeteria. The space consumed a total of 1,993 watts which is lower than the calculated allowable 2,907 watts. At this power consumption, the space has a total power density of 0.54 watts/ft^2, which is lower than the 0.79 alloted by ASHRAE. Please note that because the theatrical lighting was not part of my scope of design, it has not been included in either the illuminance (with the exception of the stage spotlight) or the power density.

Auditorium ASHRAE/IESNA 90.1		
Category	Allowable	Actual
Area (sq.ft.)	-	3680
Input Watts (W)	2907.2	1993
Power Density (W/ft)	0.79	**0.54**

AUDITORIUM TOTAL INPUT WATTS				
Type	Lamp	Qty	Input W	Total W
A2	(1) F32T8	20	38	760
B2	(1) F32T8	12	38	456
C2	(1) 32CFTR	4	36	144
D2	(1) F32T8	16	38	608
EX	LED	5	5	25
			Total:	**1993**

3 | Intermediate School Cafeteria

This section, dedicated to the documentation of the lighting design solution for the Intermediate School cafeteria, contains all information pertinent to fully describing the space and lighting design. Included are the design goals and criteria, utilized fixtures and equipment schedules, control descriptions with appropriate diagrams, calculation summary as quantitative evaluation of the design, renderings of appropriate views, and an evaluation comparing the design solution against the design goals set at the outset of the design. This section is outlined as follows:

Description

Area: 2115 ft^2

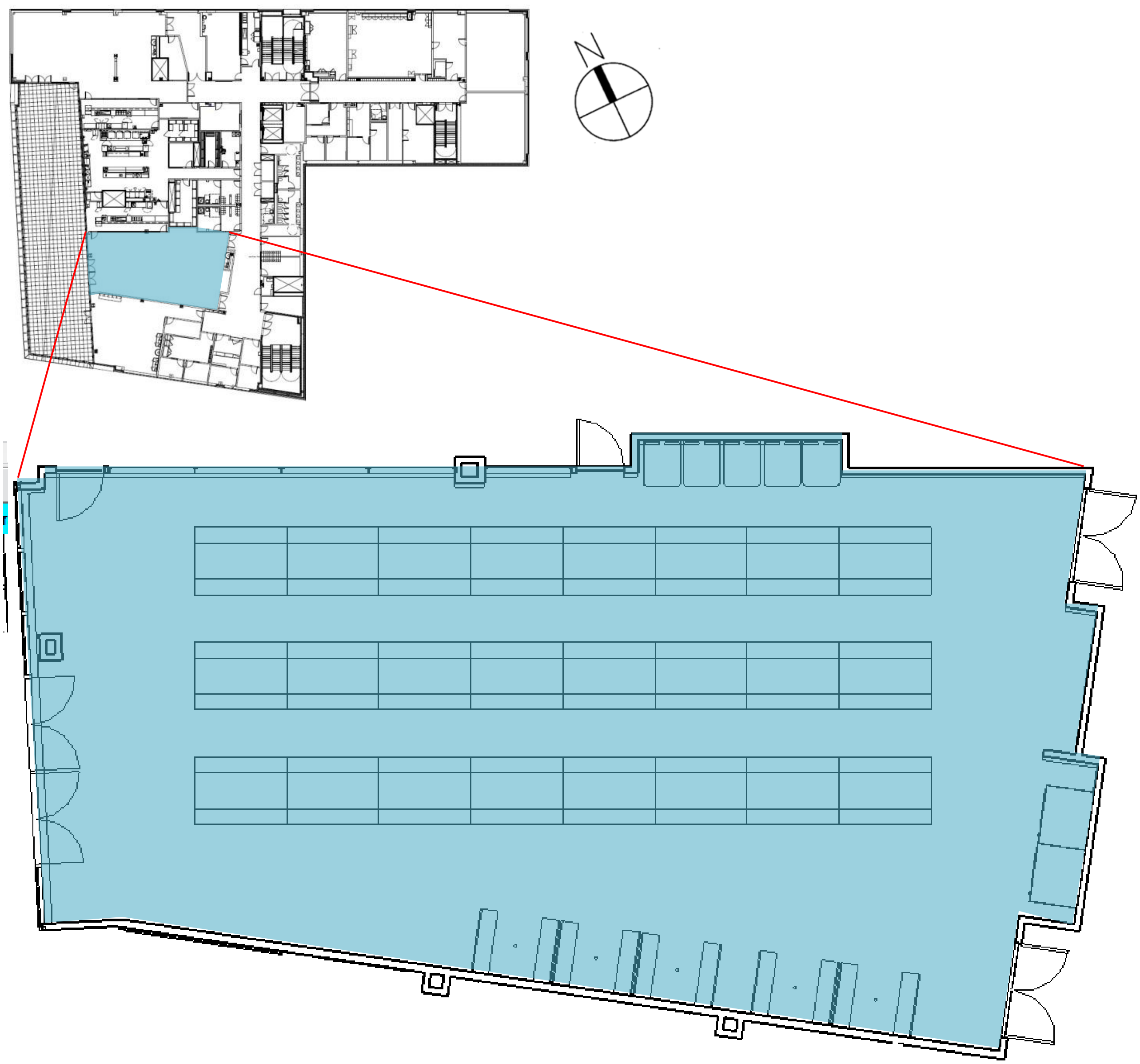
Length: 73 ft.

Width: 40 ft.

Ceiling Height: 10 ft (table eating area), 7 ft (bench eating area)

Location (in building)

The Intermediate School (IS) cafeteria is located on the 5th floor directly (plan) north of the High School (HS) Art Room. There is no direct circulation between these two rooms, but like the High School Art room, the cafeteria has direct access to the exterior roof terrace. The two doors, located on the western side of the North wall, lead to the lunch line, which is linked directly to the kitchen.



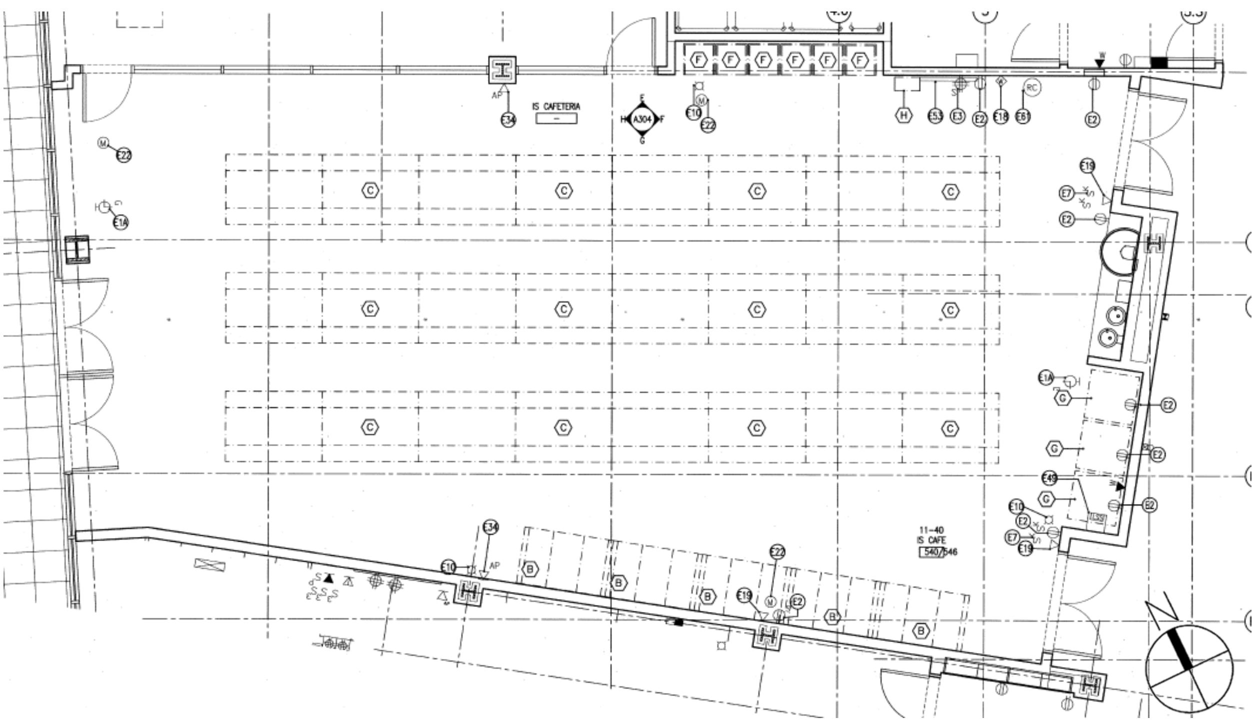
Finishes

The floor of the IS Cafeteria is a pewter vinyl composite tile. The walls, which are a semi-gloss white paint, aid in the distribution of light throughout the space. Also on the walls, are matte white tiles, semi-gloss white tiles, and a tri-color blend of mosaic tiles. These mosaic tiles may be arranged in any configuration desirable, and can be used as a tool to achieve a desired feeling in the space.

IS Cafeteria Materials				
Surface	Material	Description	Style/Color	Reflectance
Floor	VcT	12" x 12" Vinyl Composition tile	112 Pewter	0.30
Walls	SG-P	Semi-Gloss Paint	Simply White OC-117	0.85
Wall Panels	GCT - 1 GCT - 2 GCT - 5	Glazed Ceramic Trim Tile Glazed Ceramic Trim Tile 2"x2" Glazed Ceramic Mosaic Tile	Artic White - Matte Artic White - Semi-Gloss 1:1:1 Three color Blend	0.85 0.85 0.70
Ceiling	GWB	Gypsum Wall Board Painted White	White	0.75

Furnishings

In the main eating area of the cafeteria there are 24 cafeteria tables with benches. The East wall contains 3 vending machines, while the recessed portion of the north wall contains six trash cans. The south wall contains additional seating with booths on the wall.



Tasks/activities

The primary task in this space is eating (more specifically – lunch). Light levels should be adequate enough that eating is not difficult. One additional consideration for this space is security. Lunch rooms in schools may lend themselves to behavioral problems especially in a large, culturally diverse area such as Queens, New York.

Overall design goals

The intermediate school cafeteria is attached indirectly to the HS cafeteria and HS art room via the outdoor roof terrace. This space was chosen to achieve my overall design goal of connectivity of **people + program**, as it was the original design goal of the architect to physically connect the IS and HS cafeterias. My design goals for the space are represented by the pictures below:

| Reflective of Space Usage | Suitable Eating Illuminance | Fun + Creative



Fun and creative: the main occupants of this space will be middle school students, and as such, the design should be fun and interesting to look at. It's very easy for this space to fall victim to a standard, boring lighting design, which is my goal to avoid.

Reflective of space usage: when you walk in the doors to the cafeteria, it should be immediately evident that this space is used for eating purposes.

Provide illuminance suitable for eating: as this space is a cafeteria, the main task in the space is eating. The lighting in the space should provide suitable illuminance for eating purposes.

Design Criteria/Considerations

Illuminance recommendations

Horizontal Illuminance – *Important*

- IES Classification: Common Applications – Food Service – Cafeterias
    - Category N: 75 lux (7.5 fc)
    - Avg/Min: 3:1

Horizontal illuminance in this space is *important* because there needs to be adequate light for the students to eat, and is not a critical task. As long as the luminaires in the room are maintained, there should be no problems achieving adequate illumination levels.

Vertical Illuminance – *Very Important*

- IES Classification: Common Applications – Food Service – Cafeterias
    - Category K: 25 lux (2.5 fc)
    - Avg/Min: 3:1

As the cafeteria could be a source of mischievous behavior, vertical illuminance is essential for face recognition. The adequate illumination for facial recognition of the students is essential for both the school faculty and the security system (cameras).

Design Considerations

Appearance of Space and Luminaires – *Somewhat Important*

The main task in this space is eating, which for the purpose of a middle school cafeteria is not an aesthetically demanding experience. The emphasis tends to be on getting the students in, fed, and out of the space quickly and smoothly. However, the lack of typicality with these types of spaces should not deter from a good lighting design. Although not critical to the space function, the appearance of the space and luminaires should be carefully considered to achieve a quality lighting design solution.

Color Appearance and Color Contrast – *Very Important*

School cafeteria food typically has problems with appearance and quality – the lighting solution should be conscious of this and be designed to optimize color. The chosen light source should have high CRI, with minimal to no color shift over the life of the source. Acceptable light sources might include fluorescent (linear and compact), metal halide, and induction. Unacceptable sources may include high pressure sodium, and some LED's (depending on the quality, trustworthiness, and dependability of the manufacturer).

Daylighting Integration and Controls – *Important*

The west wall of the space—which happens to be the smallest in the room—has floor to ceiling glazing. Although the percent of wall area of glazing in the space is low, and the (only) wall with glazing is facing west, daylight penetration should still be considered in the design. Cost analyses may be performed to determine the feasibility of photosensor dimming, with payback period being the main criteria for determination of system feasibility and practicality.

Direct and Reflected Glare – *Somewhat Important*

Glare itself is an important design consideration and should be avoided whenever possible. However, there is no added importance of glare in this space than normal. That is, there are no critical tasks in this space that require additional attention to glare.

Flicker – *Somewhat Important*

Flicker itself is an important design consideration and should be avoided whenever possible. However, there is no added importance of flicker in this space than normal. That is, there are no critical tasks in this space that require additional attention to flicker.

Light Distribution on Task Plane – *Somewhat Important*

Uniformity on the eating surface is important in that there needs to be sufficient illuminance to eat. This holds true for uniformity as well. Illuminance and uniformity levels should meet the recommended levels. There are no special light distribution criteria to be considered.

Modeling of Faces or Objects – *Important*

Public school cafeterias tend to be areas of high horseplay especially when intended for younger students. With these security concerns, monitoring staff should be able to easily identify a student if need be.

Shadows – *Somewhat Important*

A uniform lighting solution is desired in this space, but high uniformity can make the space feel boring and flat. Surfaces lit non-uniformly create reliefs in the visual field of the eye. However, lighting should not be so non-uniform that shadows are distracting and uncomfortable. Shadows are important to avoid, but not so much that it requires additional attention.

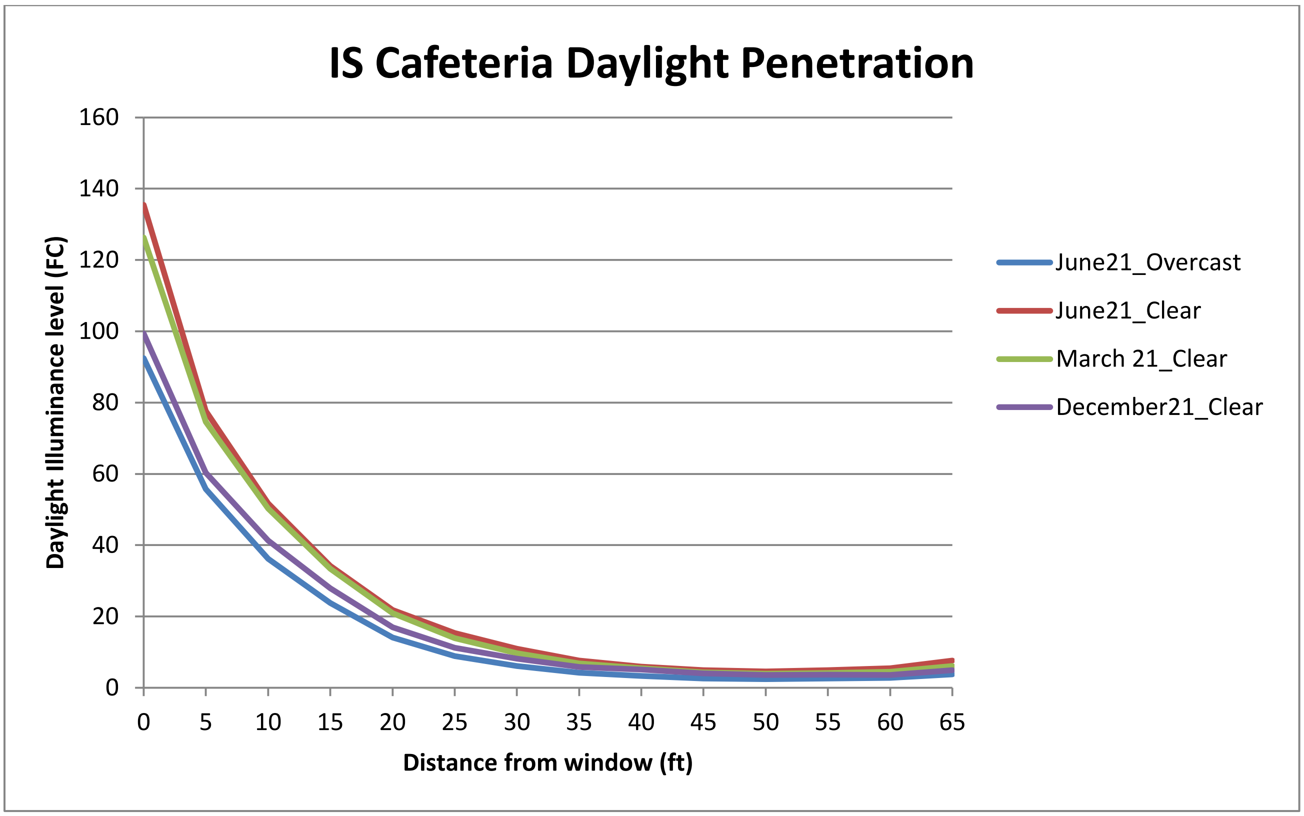
Special Considerations –*Very Important*

Because this is a public school building and this space will primarily contain middle school students, there are inherent security issues that have to be addressed. Lighting control devices such as switches and touchpads must be either out-of-reach of the students, or have restricted access by key or code.

Daylighting

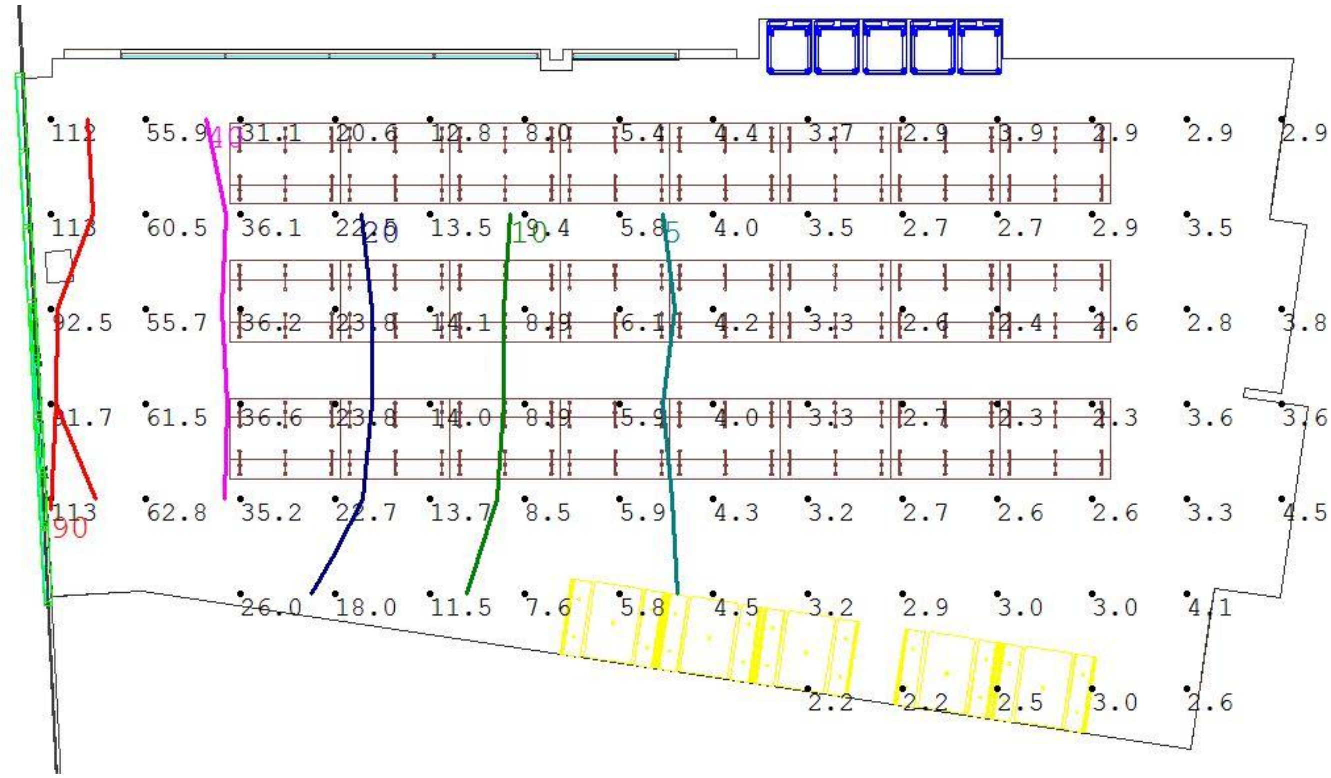
An approximate daylighting analysis was performed on this space to get a general idea of the available daylight illuminance in the space. This space is not the subject of my M.A.E. daylighting breadth. This analysis is an extra effort to have a full understanding of the factors that may affect the lighting design in this space.

Below is a graph of the daylight penetration (Daylight illuminance of the space as a function of distance from the window) for the Intermediate School Cafeteria. This graph includes multiple times of year (Spring, Summer, Winter) and two sky conditions (Clear, Overcast). The shape of the graph is as expected – the daylight illuminance decreases as the distance from the window increases. An interesting find is that the daylight illuminance values fluctuate very little over the different times of year and sky conditions. Although it would be expected that the overcast sky would produce a lower illuminance level overall – and is confirmed in the below graph – we can see that it does not vary significantly. This is most likely due to the orientation of the space, which has the glazing facing predominantly north.



The illuminance results for the space under four daylighting conditions are presented on the following pages. These conditions (all conducted at Noon) are as follows: June 21st with an overcast sky, and June 21st, March 21st, and December 21st with a clear sky. The results on the following page include an isoline diagram showing daylight penetration as well as renderings and luminance pseudo diagrams (with and without meshing).

June 21 – Overcast Sky – Noon

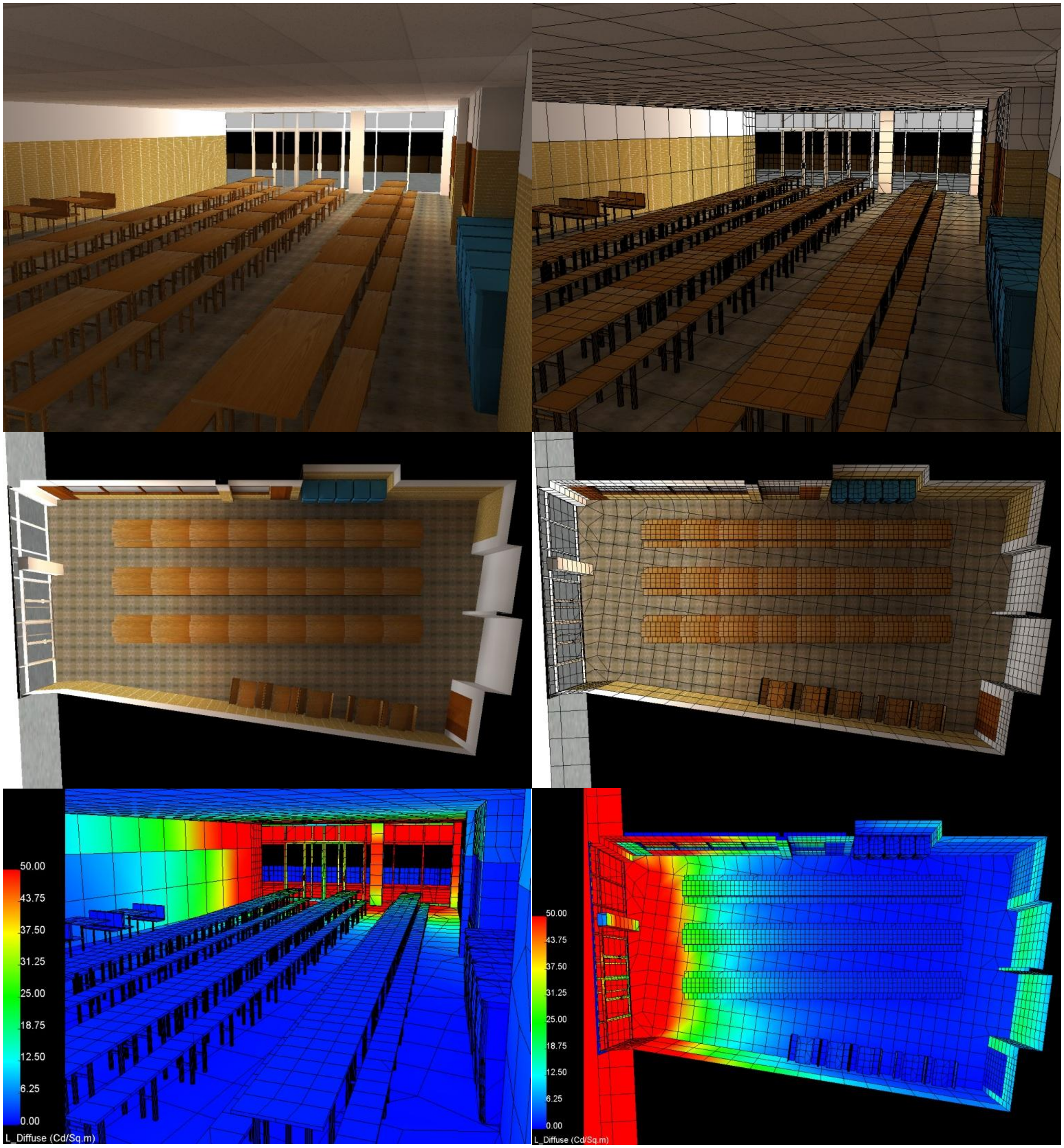


Statistics

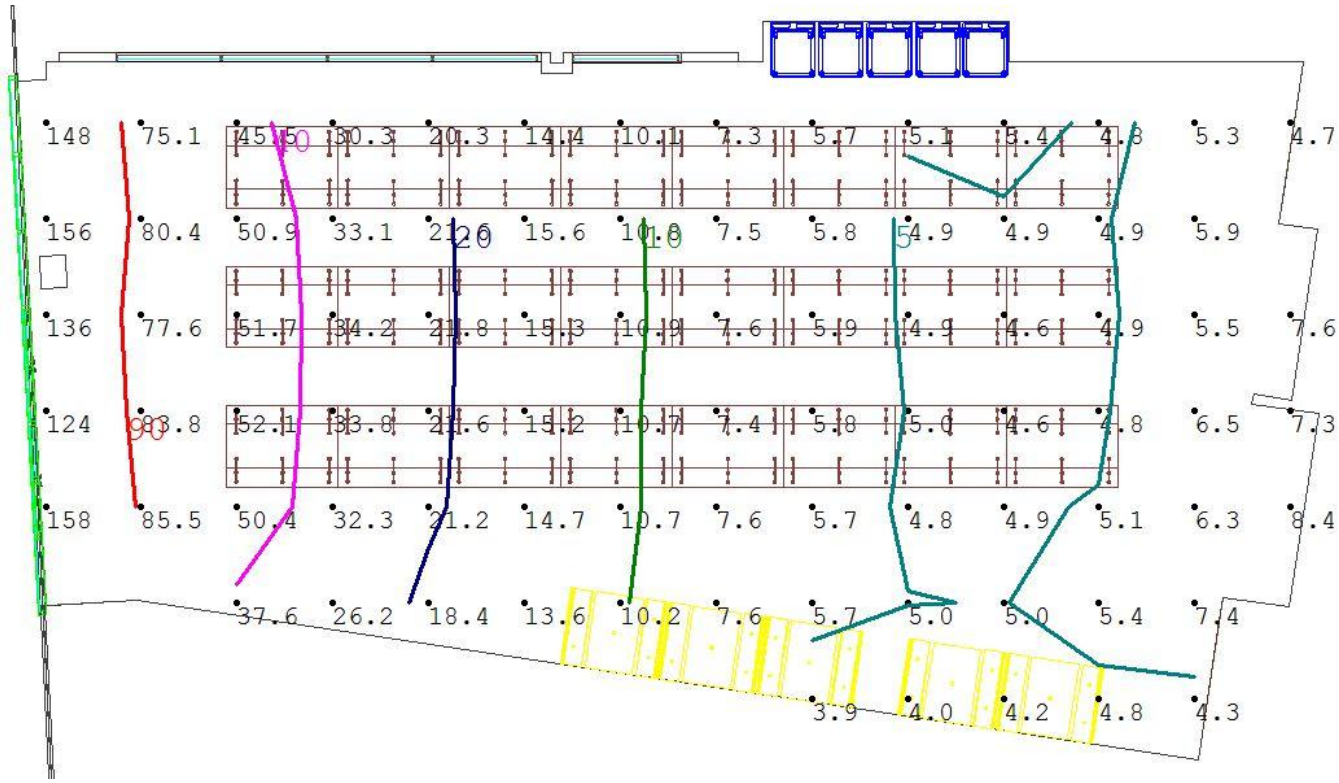
Project 1
Calc Pts

floor
Illuminance (Fc)
Average=17.17 Maximum=113
Minimum=2.2 Avg/Min=7.80 Max/Min=51.45

Value (Fc)	Color	Value (Fc)	Color
90	red	5	teal
40	magenta		dark red
20	navy		purple
10	green		olive


50.00
43.75
37.50
31.25
25.00
18.75
12.50
6.25
0.00
L_Diffuse (Cd/Sq.m)
50.00
43.75
37.50
31.25
25.00
18.75
12.50
6.25
0.00
L_Diffuse (Cd/Sq.m)

June 21 – Clear Sky – Noon

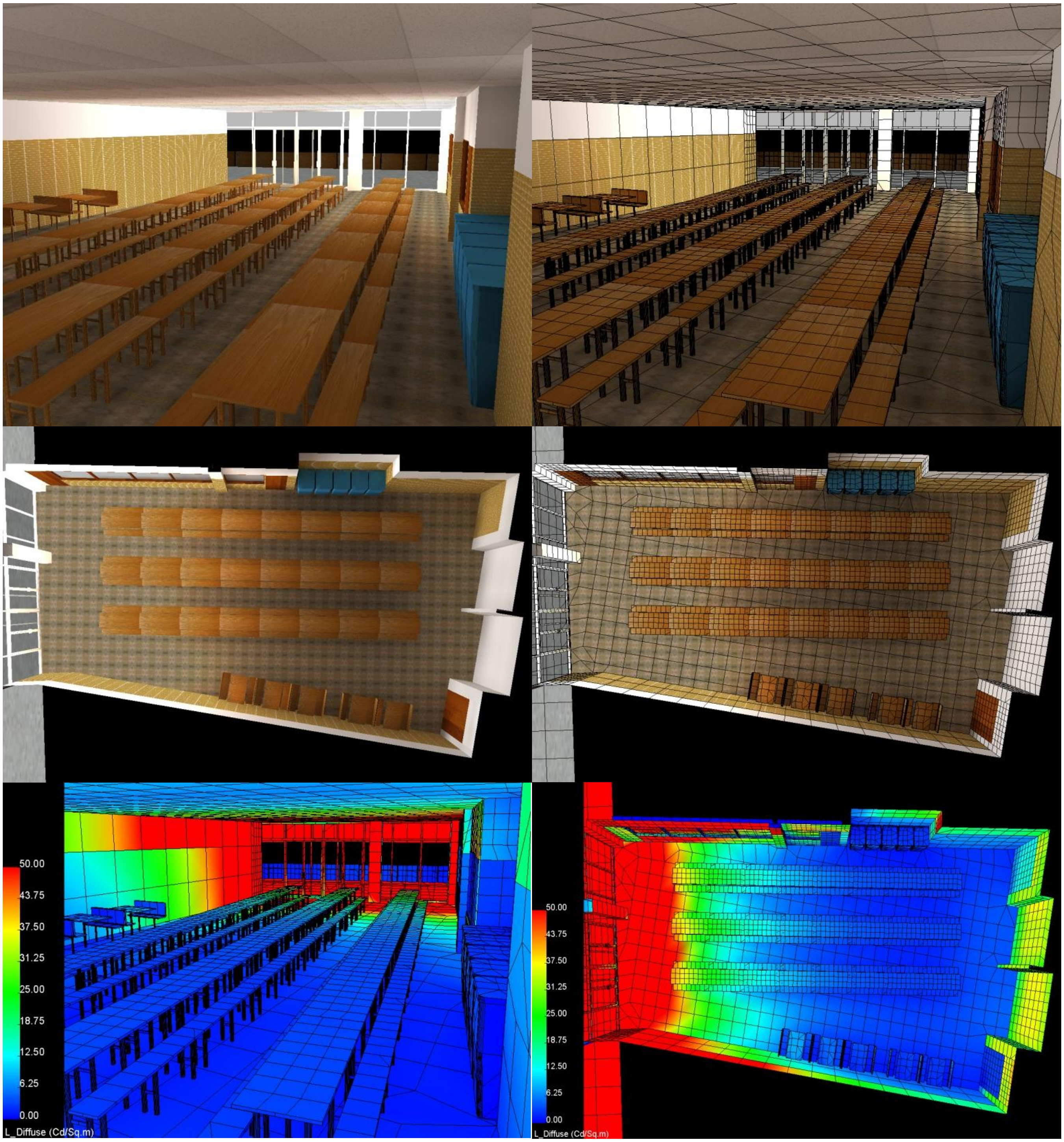


Statistics

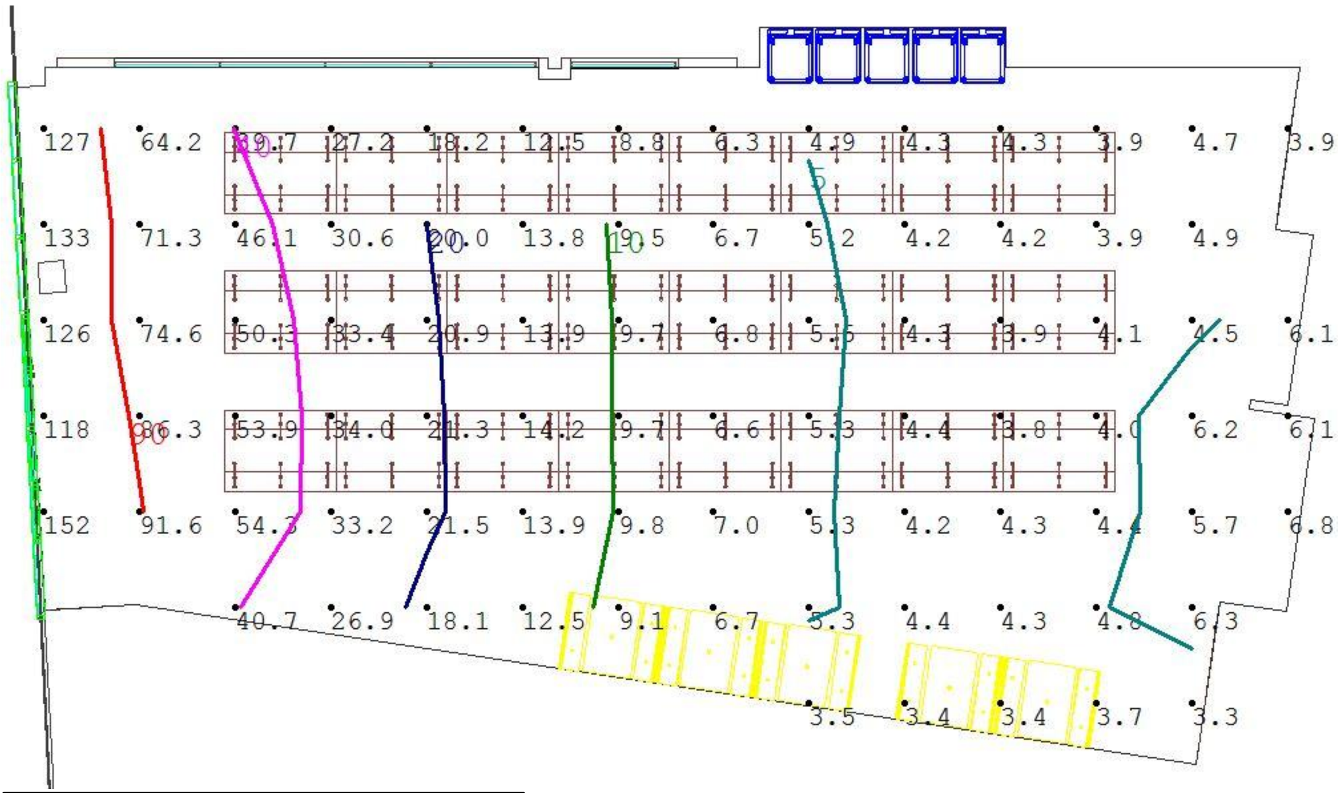
Project 1
Calc Pts

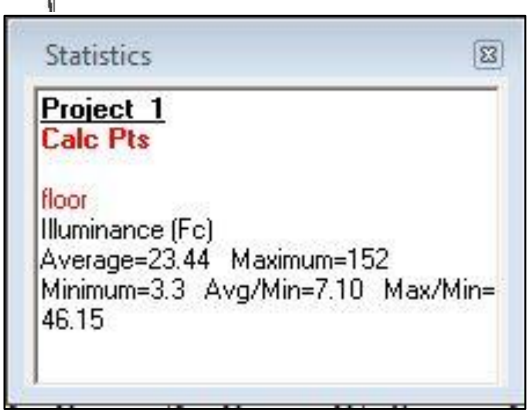
floor
Illuminance (Fc)
Average=25.11 Maximum=158
Minimum=3.9 Avg/Min=6.44
Max/Min=40.64

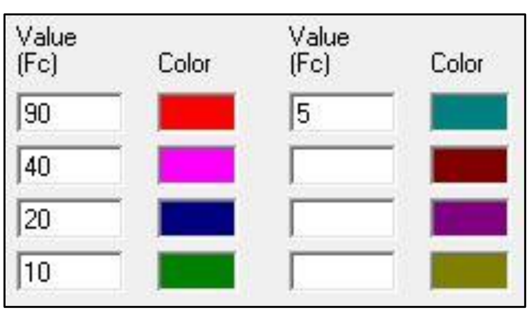
Value (Fc)	Color	Value (Fc)	Color
90	red	5	teal
40	magenta		dark red
20	dark blue		purple
10	green		olive

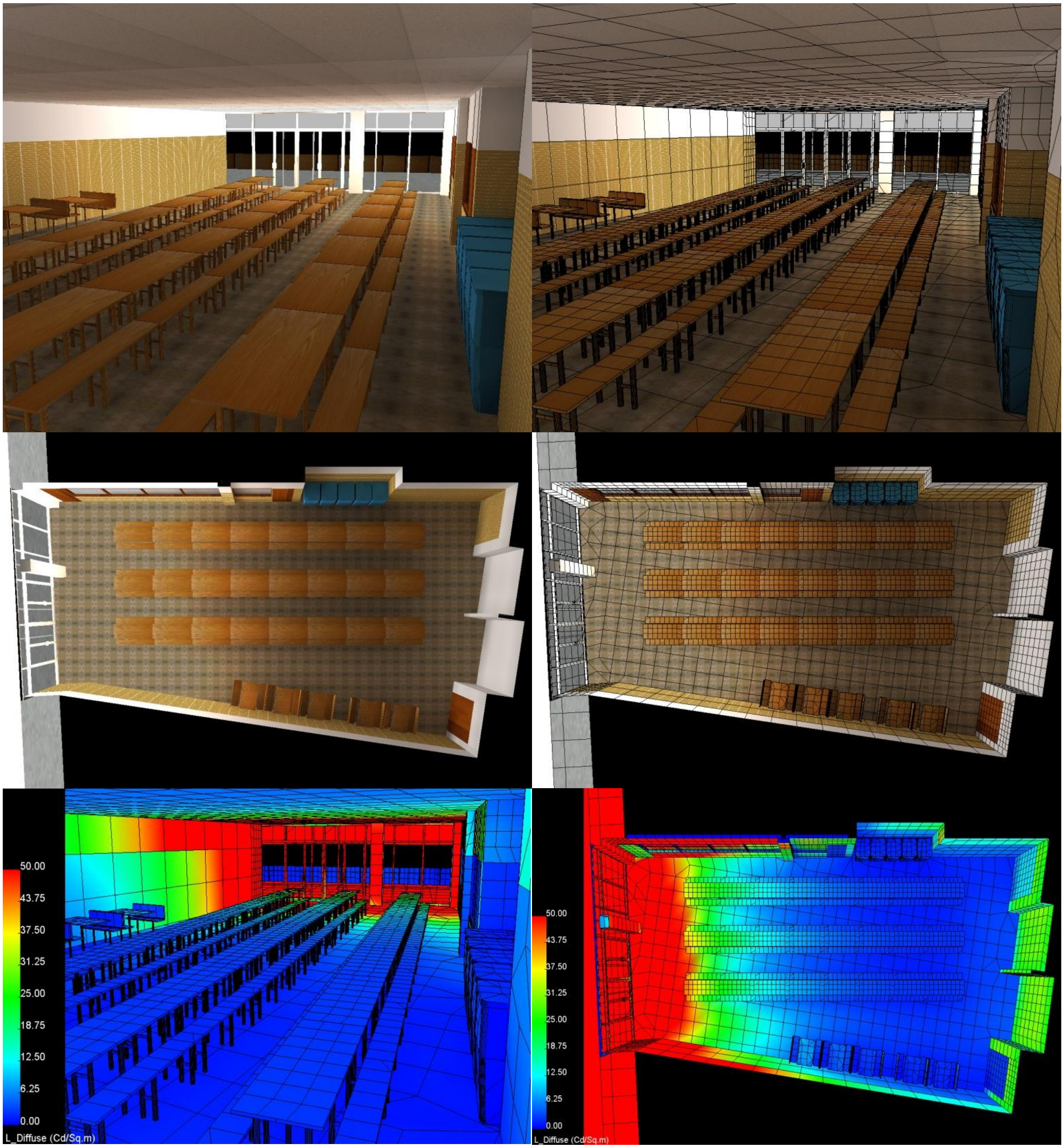

50.00
43.75
37.50
31.25
25.00
18.75
12.50
6.25
0.00
L_Diffuse (Cd/Sq.m)
50.00
43.75
37.50
31.25
25.00
18.75
12.50
6.25
0.00
L_Diffuse (Cd/Sq.m)

March 21 – Clear Sky – Noon

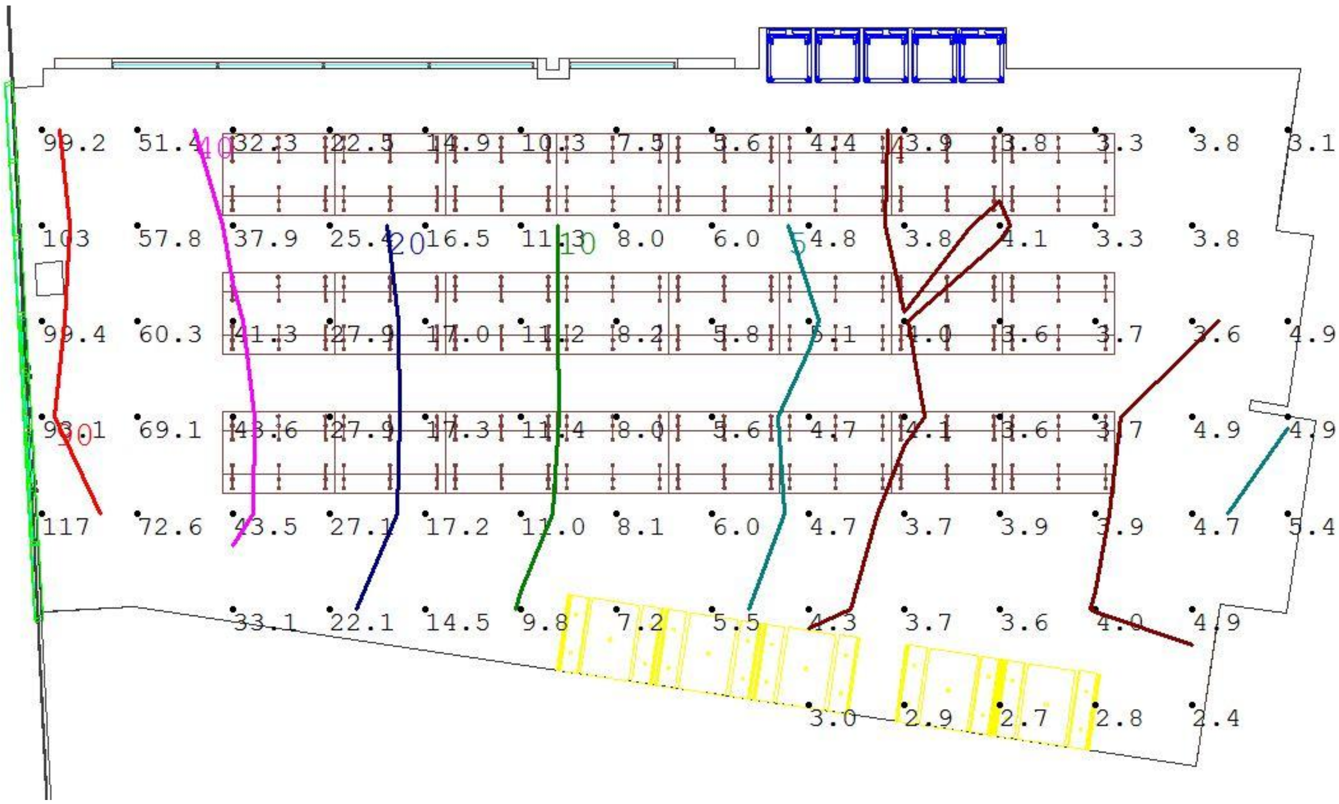


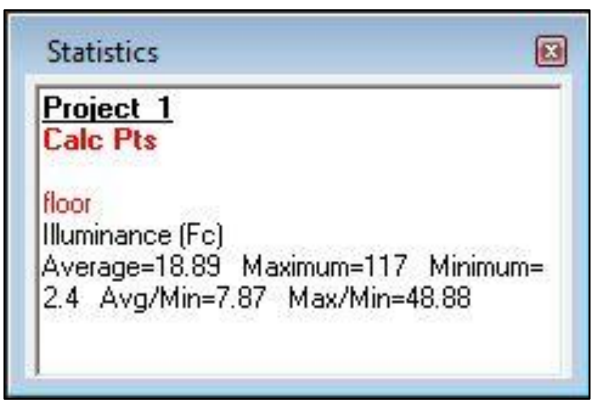





50.00
43.75
37.50
31.25
25.00
18.75
12.50
6.25
0.00
L_Diffuse (Cd/Sq.m)
50.00
43.75
37.50
31.25
25.00
18.75
12.50
6.25
0.00
L_Diffuse (Cd/Sq.m)

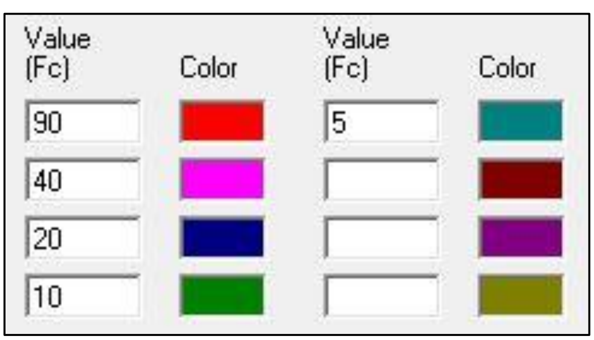
December 21 – Clear Sky – Noon

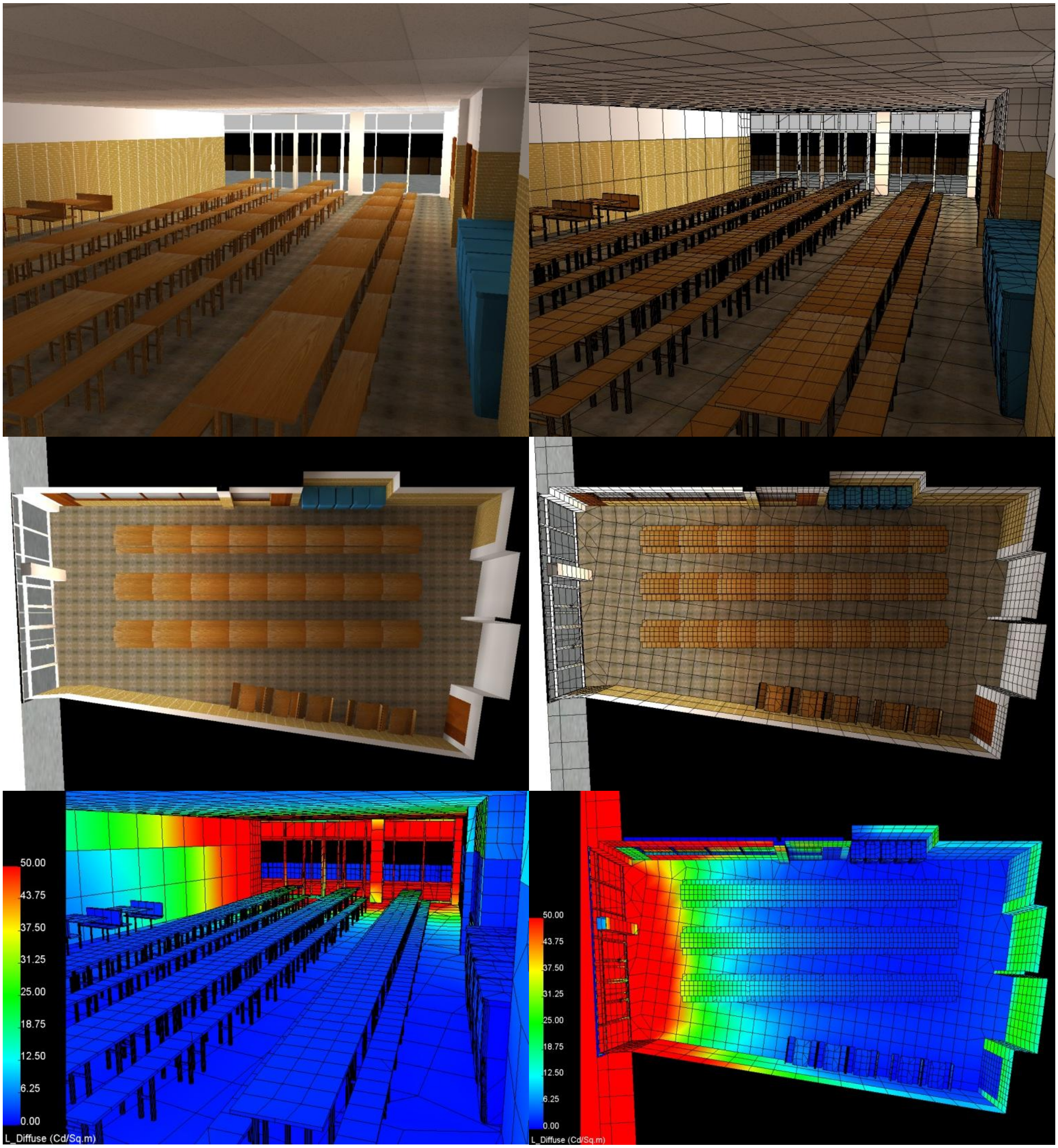



Statistics

Project 1
Calc Pts

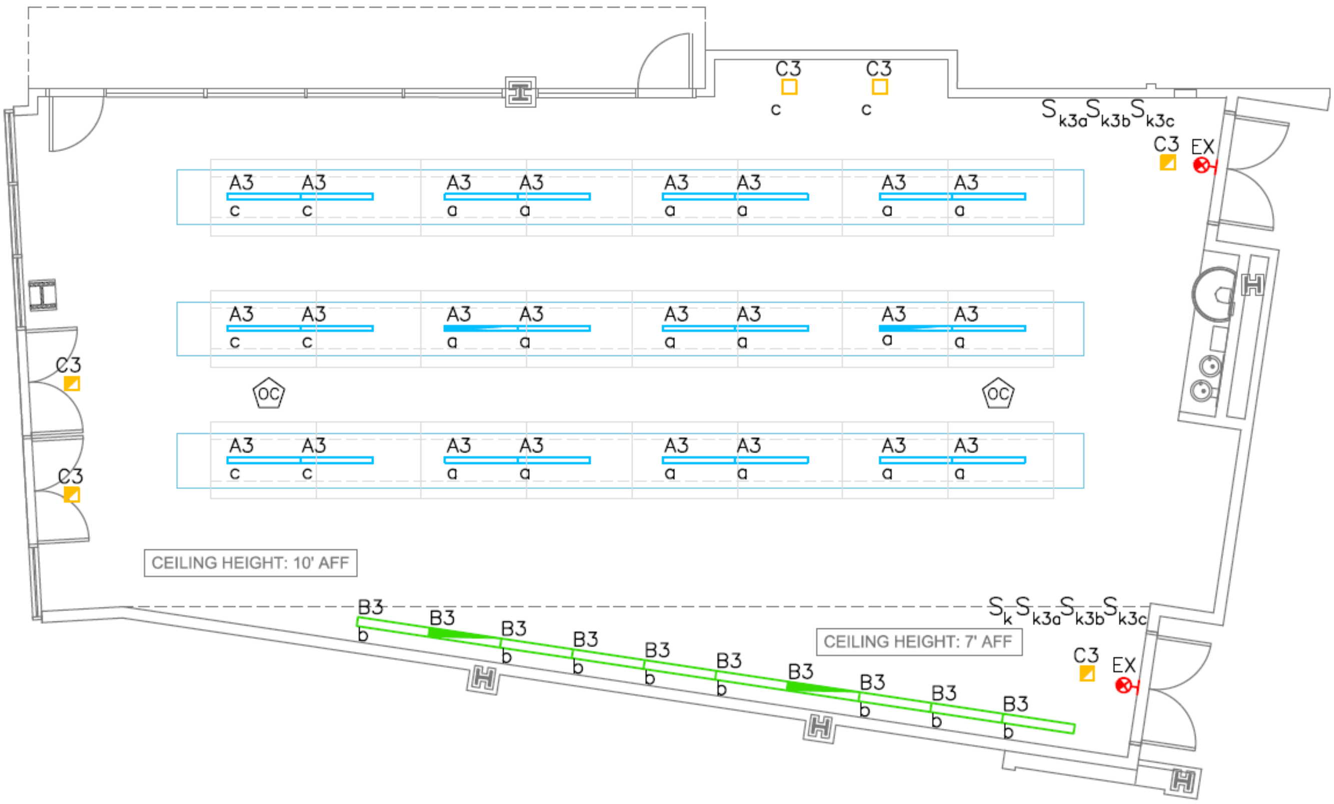
floor
Illuminance (Fc)
Average=18.89 Maximum=117 Minimum=2.4 Avg/Min=7.87 Max/Min=48.88

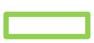



50.00
43.75
37.50
31.25
25.00
18.75
12.50
6.25
0.00
L_Diffuse (Cd/Sq.m)
50.00
43.75
37.50
31.25
25.00
18.75
12.50
6.25
0.00
L_Diffuse (Cd/Sq.m)

Fixtures and equipment

The plan and fixture schedule presented below are intended to give a complete representation of the fixture specifications and placement within the space. Luminaires overhead—represented in **blue**—are recessed, four-foot, linear fluorescent fixtures that illuminate the hanging sculpture. The luminaires along the south wall—represented in **green**—are recessed linear fluorescent wall washers placed to uniformly wash the mosaic wall.



Fixture Schedule				
Type			Description	Manufacturer
A3			Recessed linear fluorescent with flush .07" thick acrylic lens with opal satin finish. 22 ga. steel reflectors with high reflectance white powder coat. Matte White finish	Focal Point
B3			Recessed linear fluorescent wall washer. Housing and flange trim are die-formed, 20 ga. Steel, with gloss white finish. Semi-specular reflector	Peerless
C3			Recess 4.5"x4.5" square LED downlight. Matte white flange and reflector finish.	Lightolier
EX			Wall Mounted, single-sided exit sign. AC only operation with RED lettering on clear panel. Matte white finish on housing. 8" letters, 1" stroke	Mule Lighting

The tables below provide information regarding the energy consumption, assumed light loss factors, and load for the lamp-ballast combinations used for each of the luminaires used in the lighting of the Intermediate Schol Cafeteria. The IS Cafeteria contains a total of 42 lighting fixtures (including the exit signs). The lighting solution in consumes a total of 1,356 Watts (see ASHRAE/IESNA 90.1 under evaluation section). A light loss factor was not included for the exit sign (fixture 'EX') as is does not provide useful illumination to the room, and was not considered in any lighting calculations. It was, however, included in the energy consumption calculation of the space.

IS CAFETERIA VA CALCULATION								
Location	Type	Lamp	Qty	W/Fixture	Total Watts	PF	VA/Fixture	Total VA
IS Café	A3	(1) F32T8	24	38	912	0.9	42	1013
	B3	(1) F32T8	10	38	380	0.9	42	422
	C3	LED	6	9	54	0.7	13	77
	EX	LED	2	5	10	0.7	7	14

LIGHT LOSS FACTORS						
	Lamp Lumens		Light Loss Factors			
Type	Initial	Mean	LLD	LDD	BF	Total
A3	3000	2850	0.95	0.90	1.20	1.0
B3	3000	2850	0.95	0.90	1.20	1.0
C3	500	-	0.80	0.90	-	0.7
EX	-	-	-	-	-	-

Controls

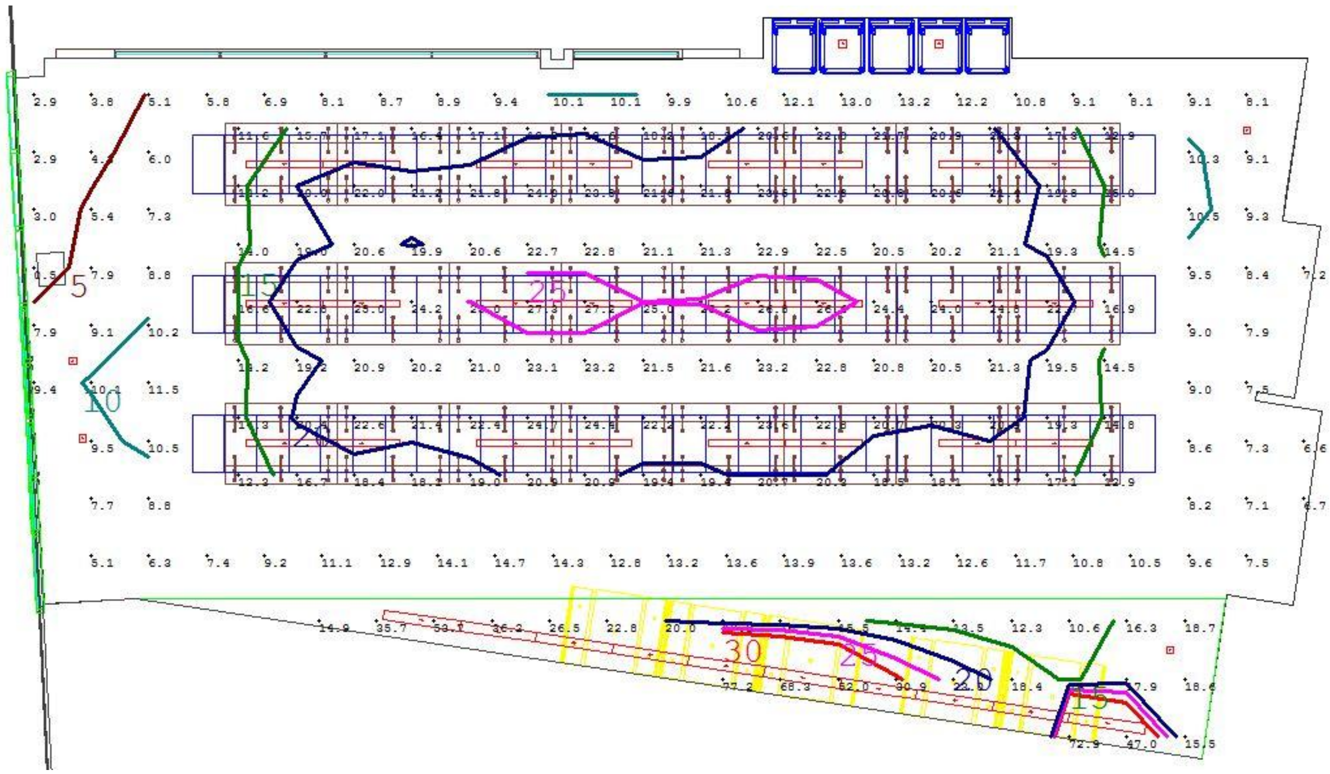
The luminaires in this space are grouped into 3 separate zones, all of which are connected to line-voltage occupancy sensors. Each zone has an override switch located at each of the two entrance doors to the space. All switches in the space are key-locked, meaning that they are only accessible via a physical key given the lunch aids or building maintenance staff.

Zone A controls the recessed linear fluorescent fixates over the main table eating area. These are the fixtures that are recessed into the ceiling above the suspended sculpture, and are controllable so that they may be switch off when daylighting in the space is sufficient.

Zone B controls the recessed linear fluorescents wall-washers along the south wall atop the booth eating area. This zone may be switched if enough illuminance is provided on the eating surface via daylight or the lighting fixtures from zone A. Zone C controls the accent lights over the trash bin area. These may be switched as desired by the staff.

Calculation summary

Electric Light only



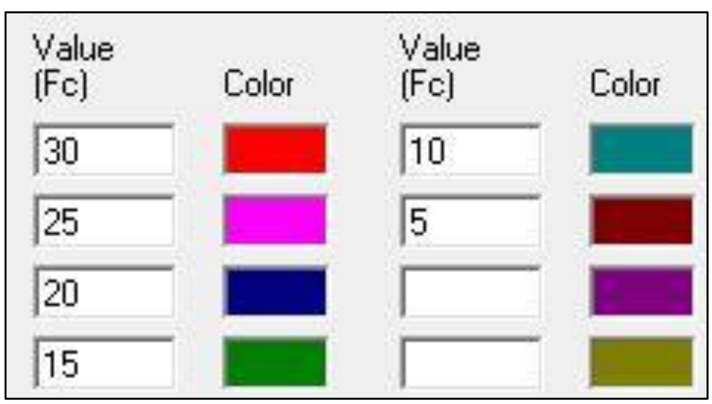
Statistics

Project_1
Calc Pts

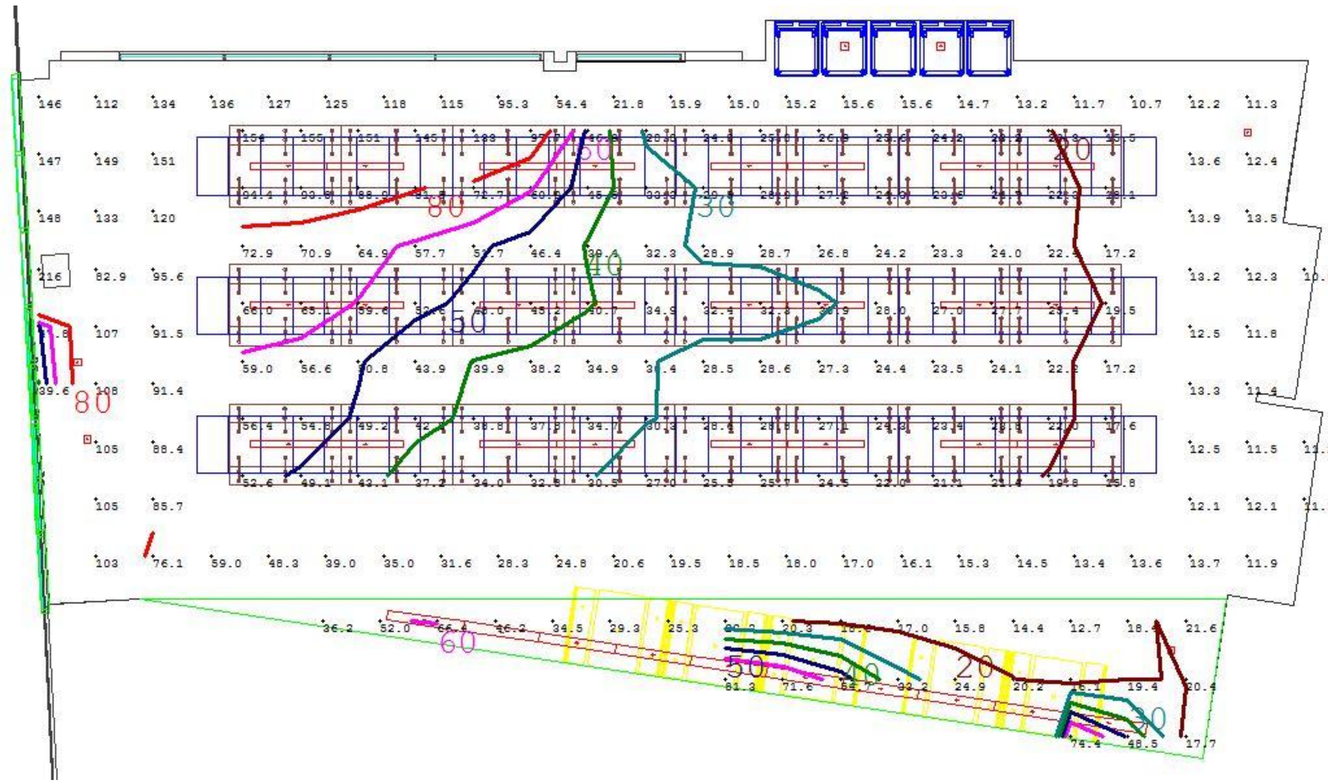
Benches
Illuminance (Fc)
Average=28.91 Maximum=78.2
Minimum=10.6 Avg/Min=2.73
Max/Min=7.38

Floor
Illuminance (Fc)
Average=9.11 Maximum=14.8
Minimum=0.5 Avg/Min=18.22
Max/Min=29.60

Tables
Illuminance (Fc)
Average=20.44 Maximum=27.3
Minimum=11.6 Avg/Min=1.76
Max/Min=2.35



Electric Light and Daylight



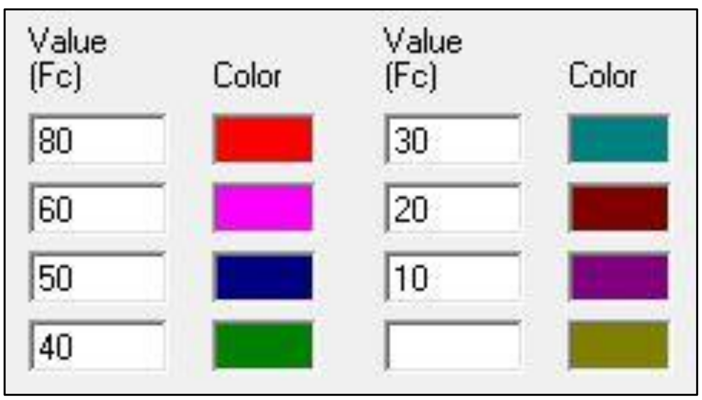
Statistics

Project 1
Calc Pts

Benches
Illuminance (Fc)
Average=33.33 Maximum=81.3
Minimum=12.7 Avg/Min=2.62
Max/Min=6.40

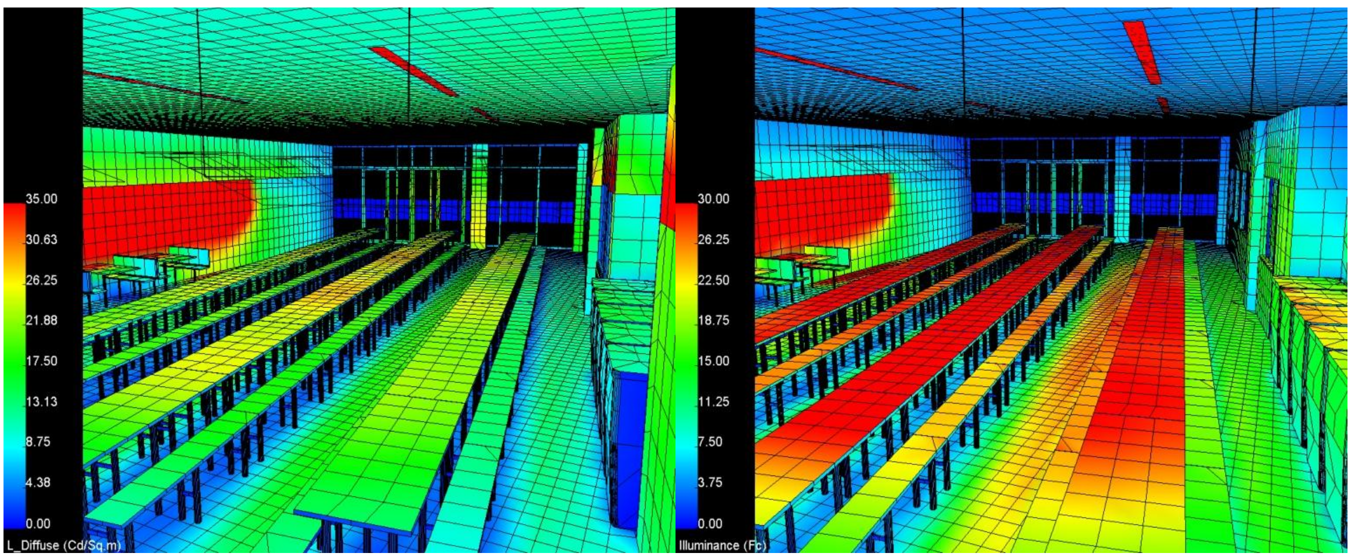
Floor
Illuminance (Fc)
Average=54.34 Maximum=216
Minimum=10.7 Avg/Min=5.08
Max/Min=20.21

Tables
Illuminance (Fc)
Average=42.02 Maximum=155
Minimum=15.5 Avg/Min=2.71
Max/Min=9.99

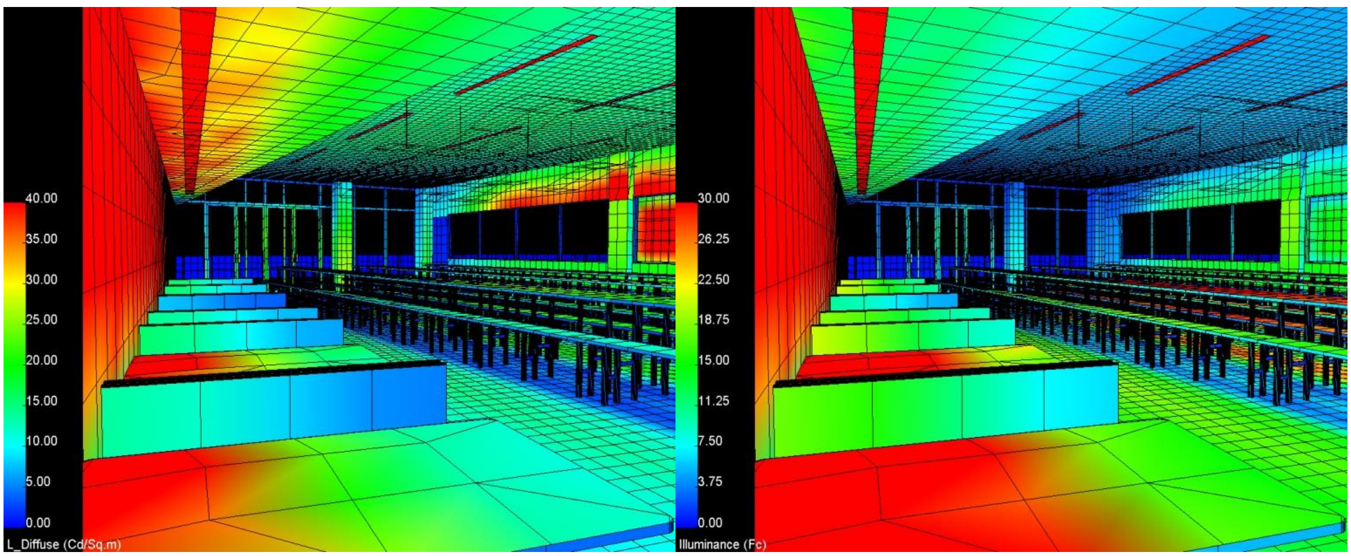


Renderings

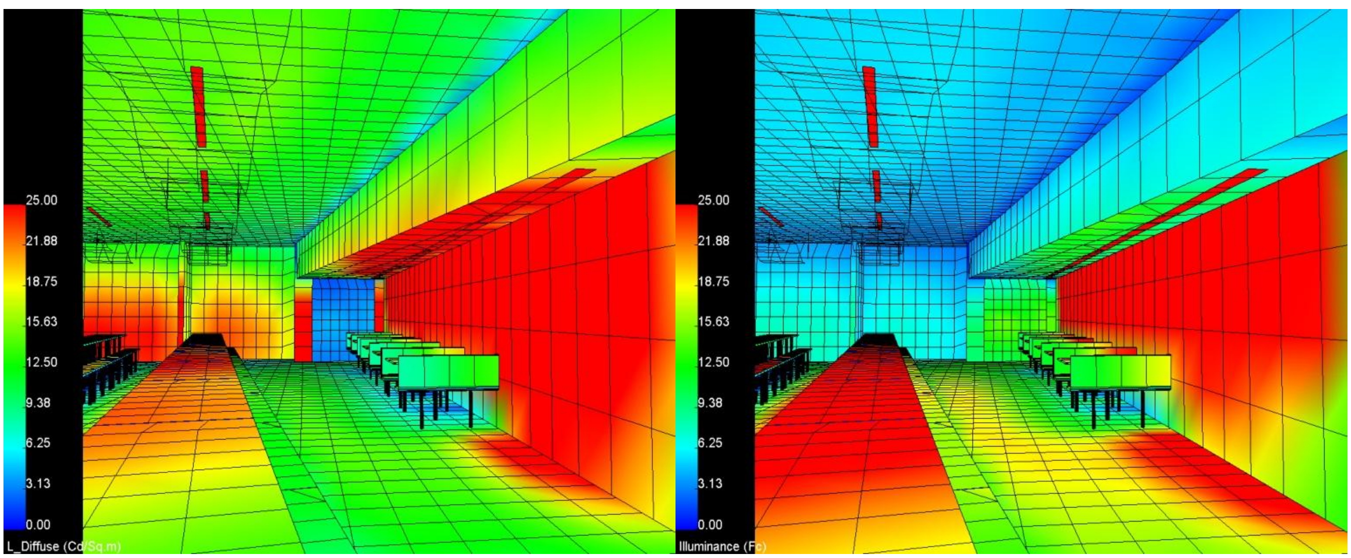
Electric Light Only

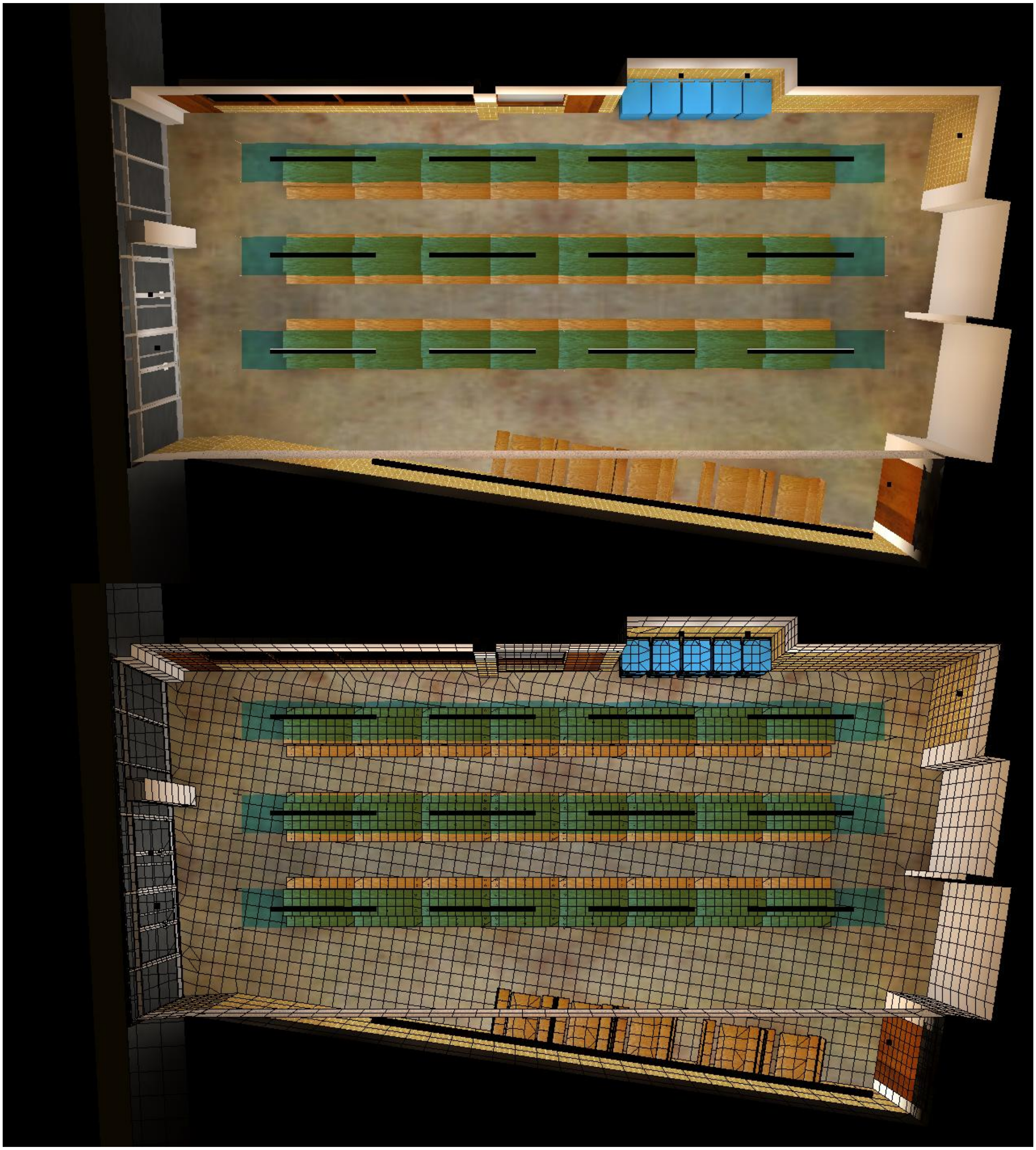


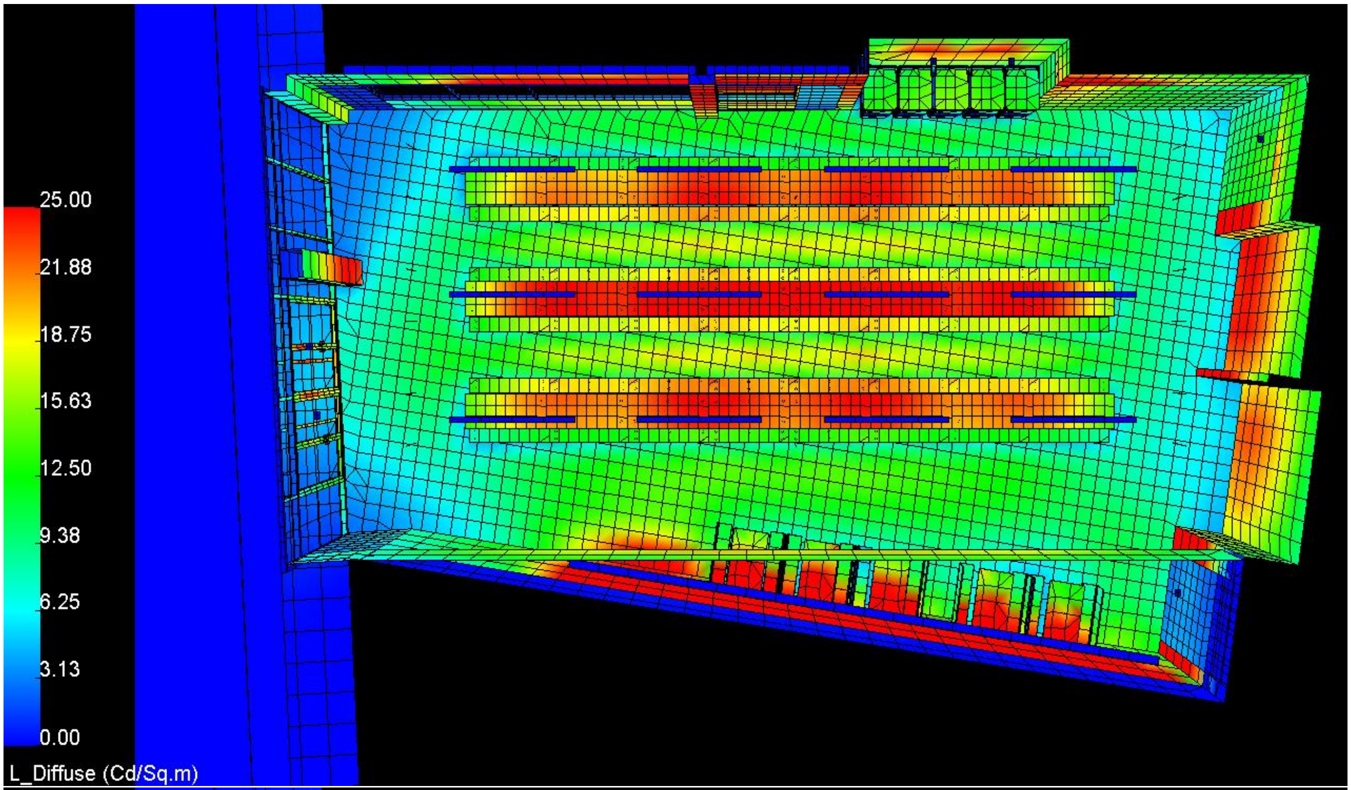
Electric Light Only

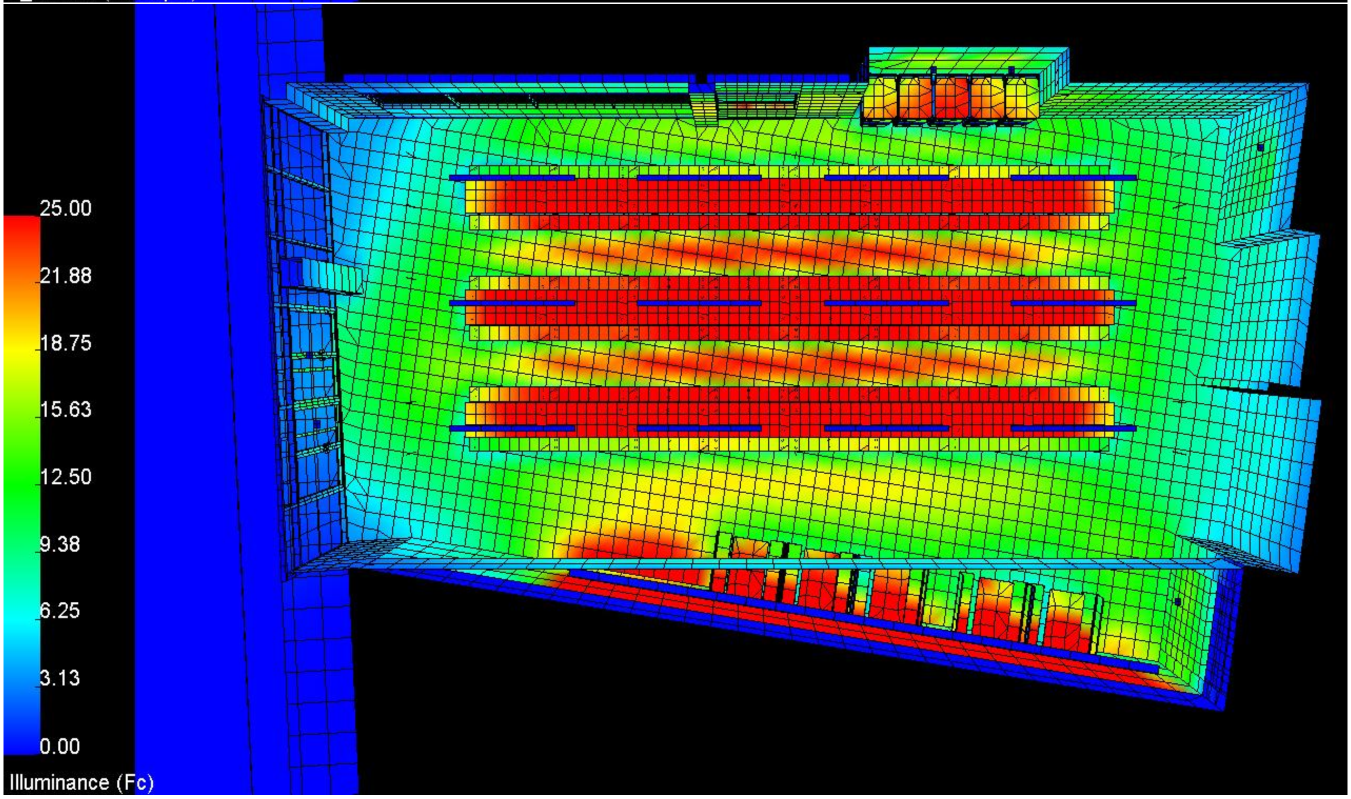


Electric Light Only

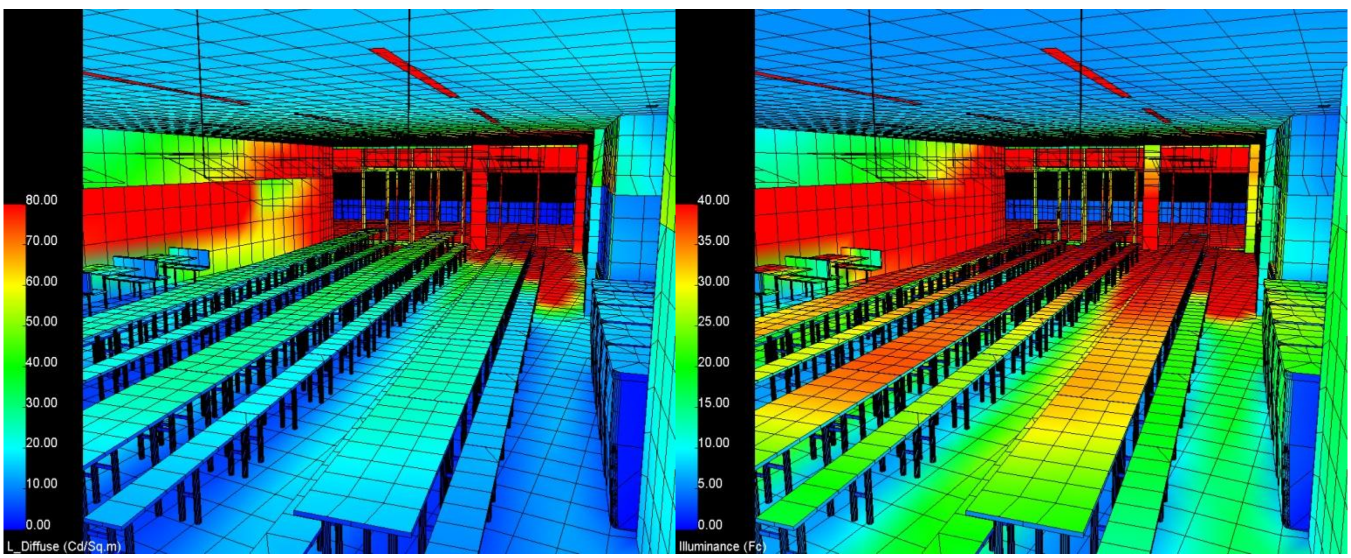




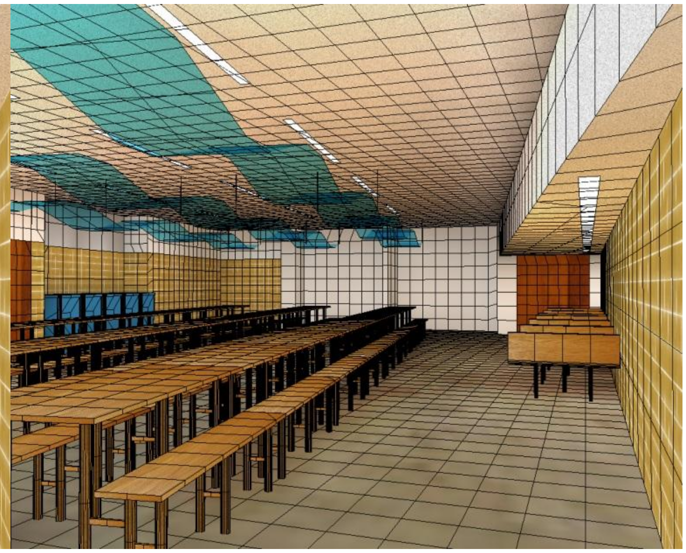

25.00
21.88
18.75
15.63
12.50
9.38
6.25
3.13
0.00
L_Diffuse (Cd/Sq.m)

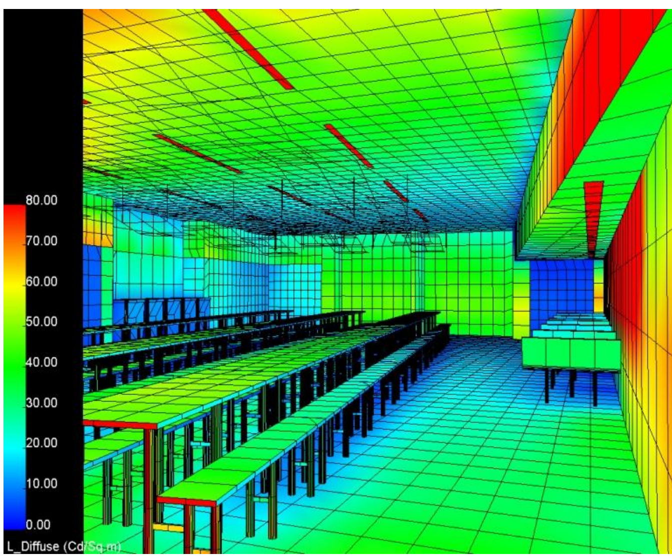

25.00
21.88
18.75
15.63
12.50
9.38
6.25
3.13
0.00
Illuminance (Fc)

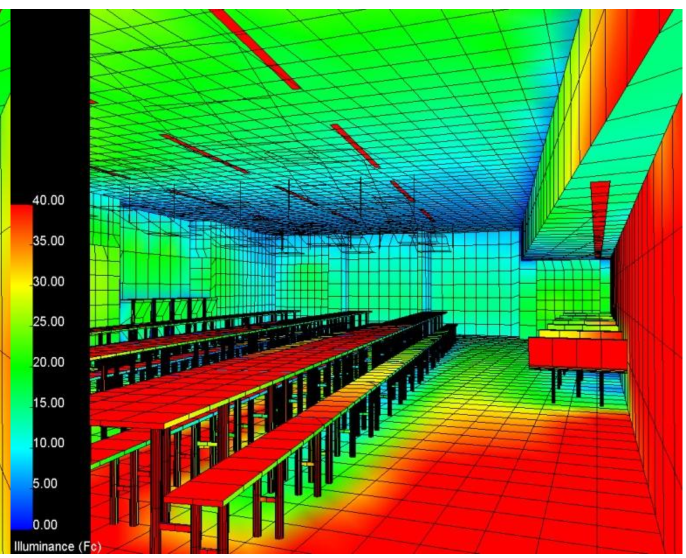
Electric Light and Daylight



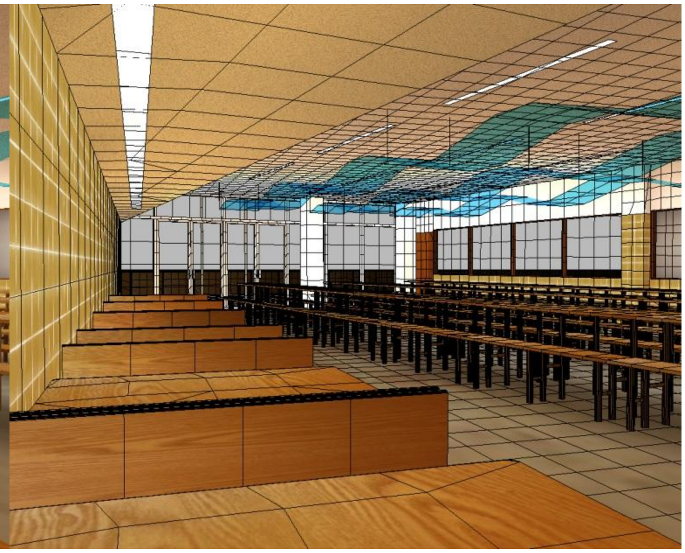
Electric Light and daylight

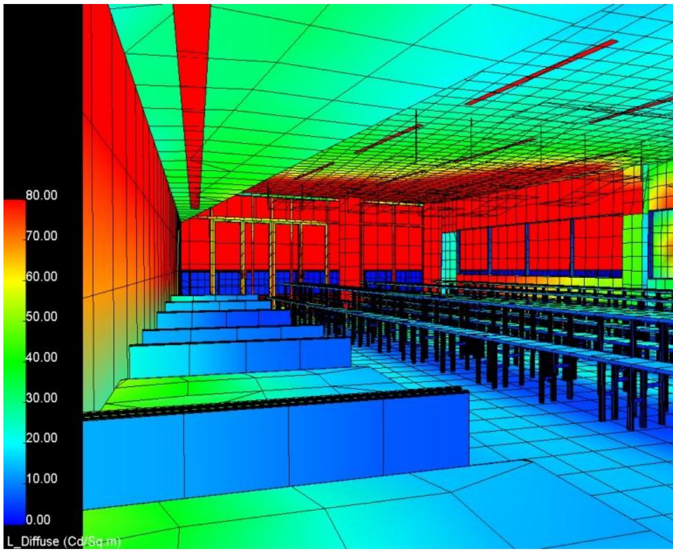


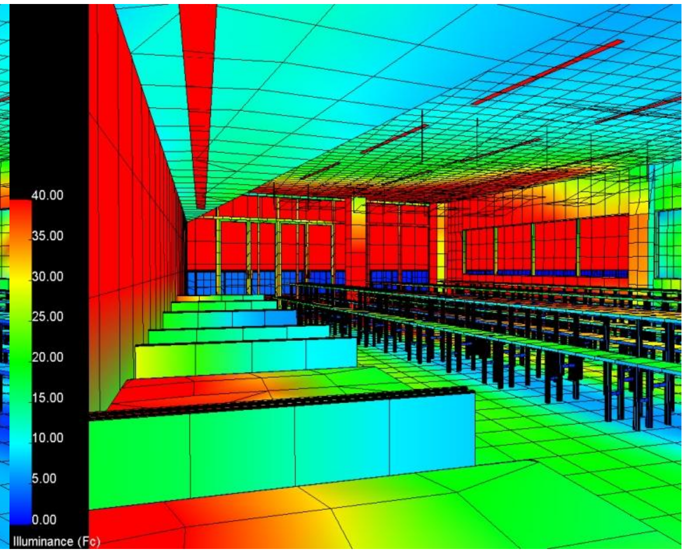


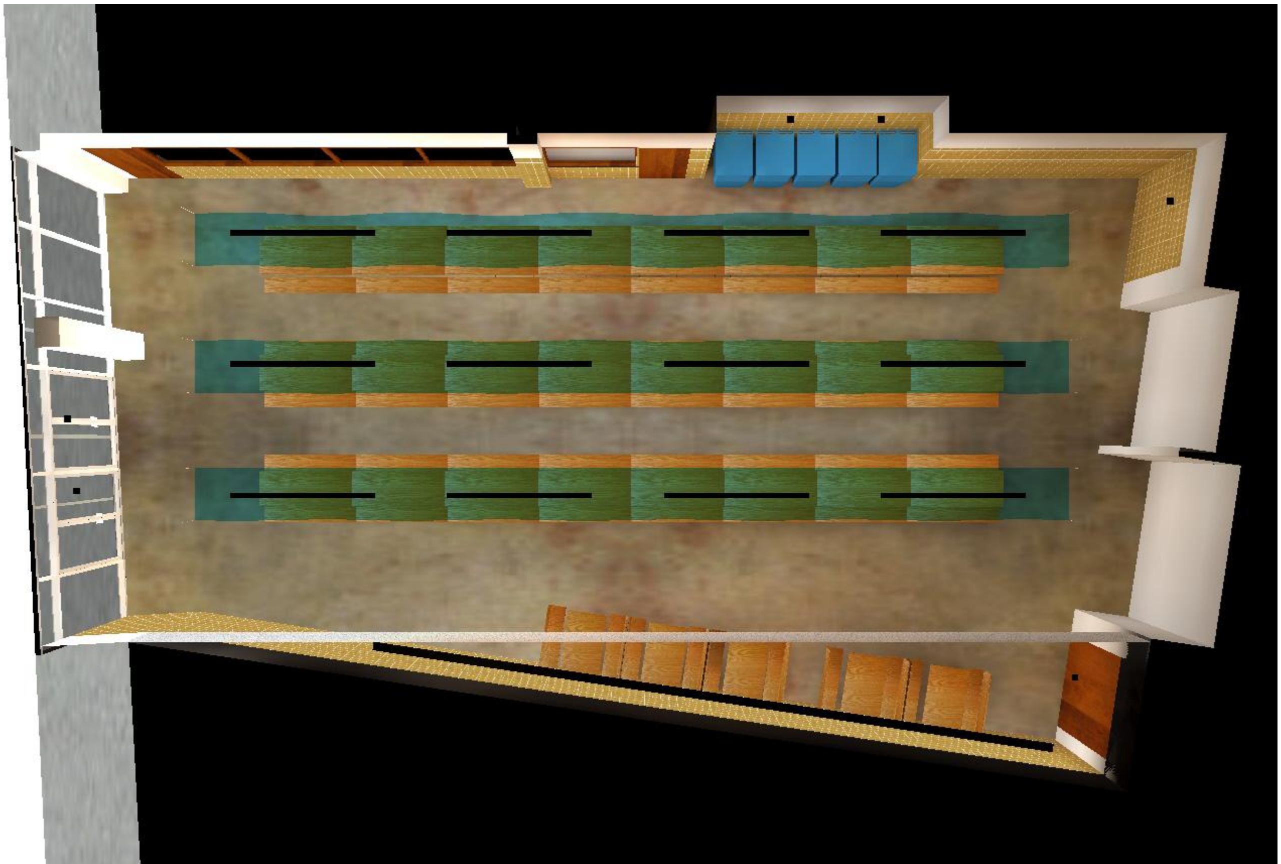


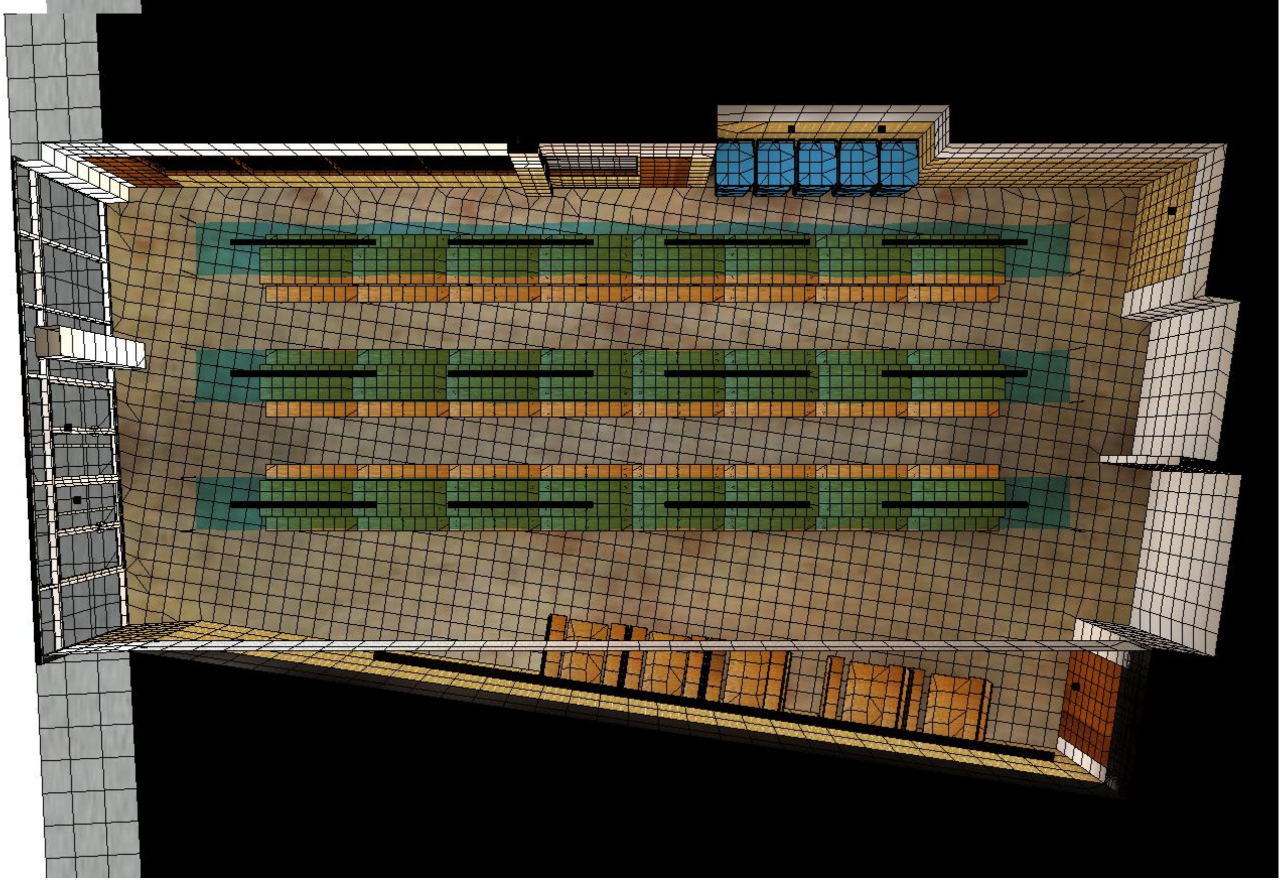
Electric Light and daylight

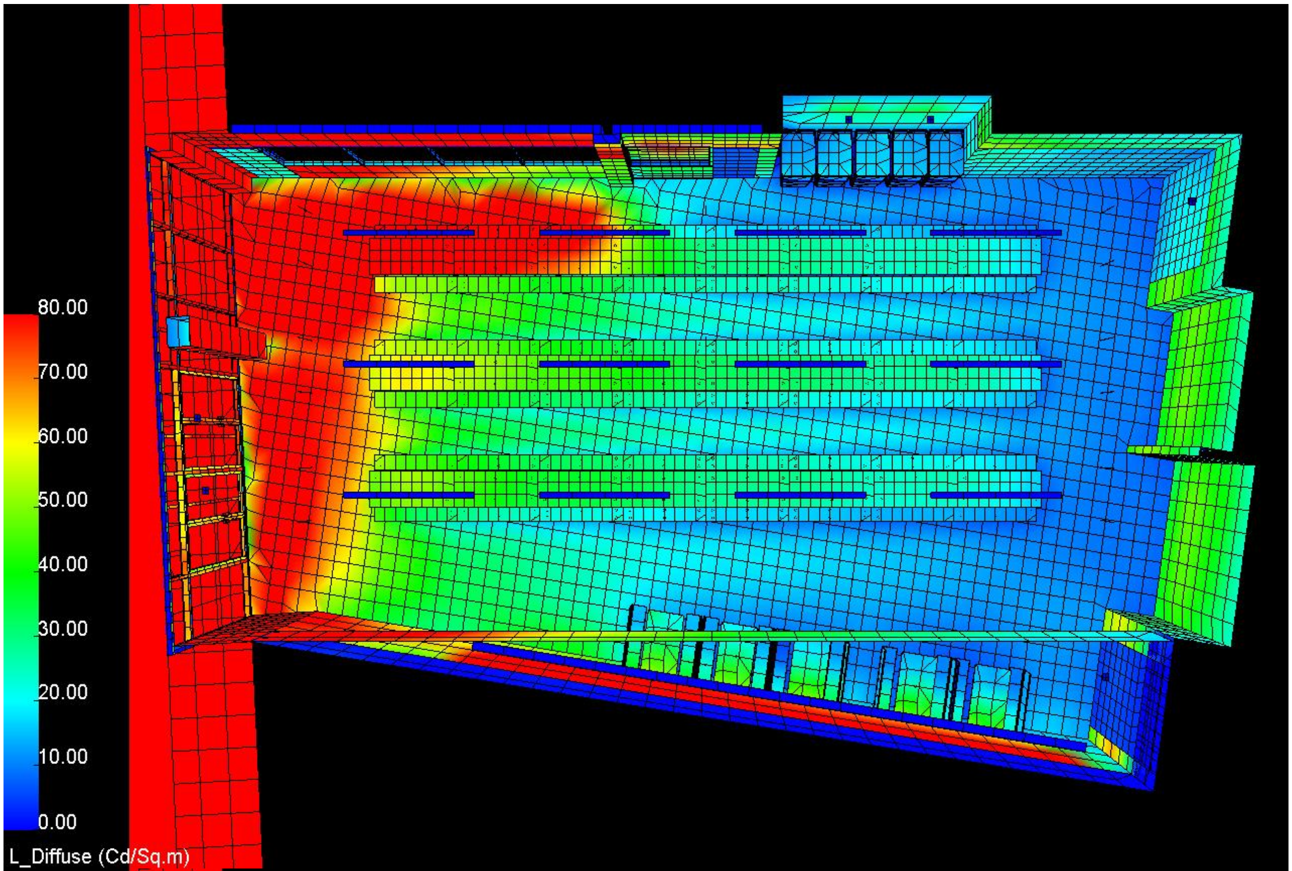


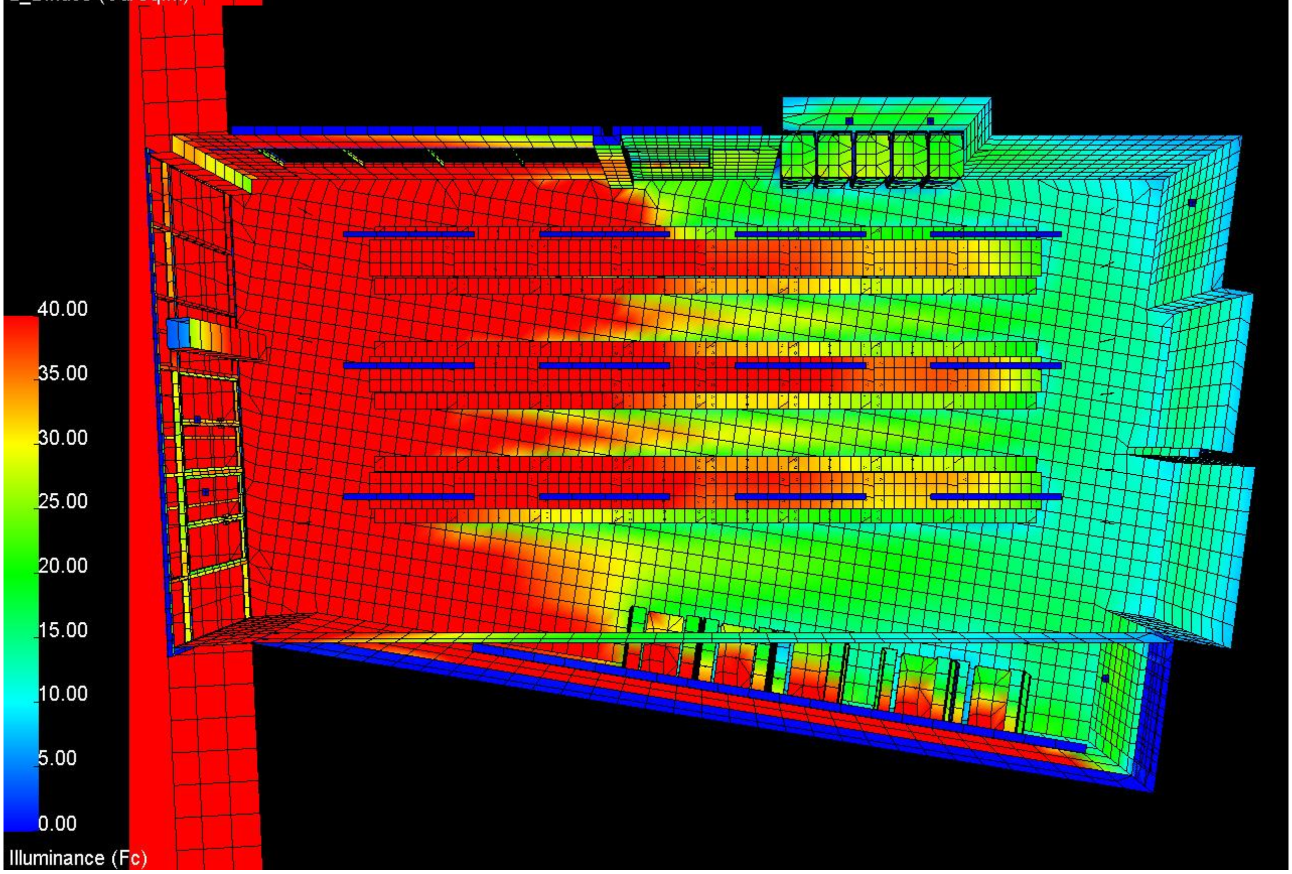









80.00
70.00
60.00
50.00
40.00
30.00
20.00
10.00
0.00
L_Diffuse (Cd/Sq.m)


40.00
35.00
30.00
25.00
20.00
15.00
10.00
5.00
0.00
Illuminance (Fc)

Evaluation

Summary

The design of the Intermediate School Cafeteria creates a more interesting environment than that of a standard middle school cafeteria. The addition of daylight, especially because the façade is predominantly north facing, should create a more natural feeling environment. Because the façade is north-facing, the daylight in the space will be mostly diffuse, which helps with creating a space with no glare. Daylight, being a natural light source, should help with the inherent problem of color rending of cafeteria food. The fixtures in the space, which mimic the flow of the river that is in view out of the window, should make the space fun and interesting for the students. From a purely quantitative point-of-view, both IES illuminance recommendation and ASHRAE power densities were met (See next section). The primary concern may be the quality of light after is has passes through the hanging transparent-blue sculpture hanging from the ceiling. A further study should be conducted to verify the color rending quality of the light passed through the sculpture.

ASHRAE/IESNA 90.1

As shown in the table below, the lighting solution for the Intermediate School Cafeteria consumes a total of 1,356 Watts which amounts to a power density of 0.64 watts/square foot.

IS CAFETERIA TOTAL INPUT WATTS				
Type	Lamp	Qty	Input W	Total W
A	(1) F32T8	24	38	912
B	(1) F32T8	10	38	380
C	LED	6	9	54
EX	LED	2	5	10
			Total:	1356

ASHRAE/IESNA 90.1 2011		
Category	Allowable	Actual
Area (sq.ft.)	-	2115
Input Watts (W)	1375	1356
Power Density (W/sqft)	0.65	**0.64**

4 | High School Art Room

This section, dedicated to the documentation of the lighting design solution for the High School Art Room, contains all information pertinent to fully describing the space and lighting design. Included are the design goals and criteria, utilized fixtures and equipment schedules, control descriptions with appropriate diagrams, calculation summary as quantitative description of the design, renderings of appropriate views, and an evaluation comparing the design solution against the design goals set at the outset of the design. The daylighting analysis for this space is not included in this section. As the High School Art Room was the subject of the MAE daylighting analysis, the analysis and results are outlined in that section. This section is outlined as follows:

Description

- *Space Location*
- *Finishes*
- *Furnishings*
- *Tasks/Activities*

Overall Design Goals

Design Criteria/Considerations

- *Illumination Recommendations*
- *Design Considerations*
- *Daylighting*
  - *See MAE Breadth*

Fixtures and Equipment

Controls

Calculation summary

Renderings

Evaluation

- *Summary*
- *ASHRAE/IESNA 90.1*

Description

Area: 1250 ft^2

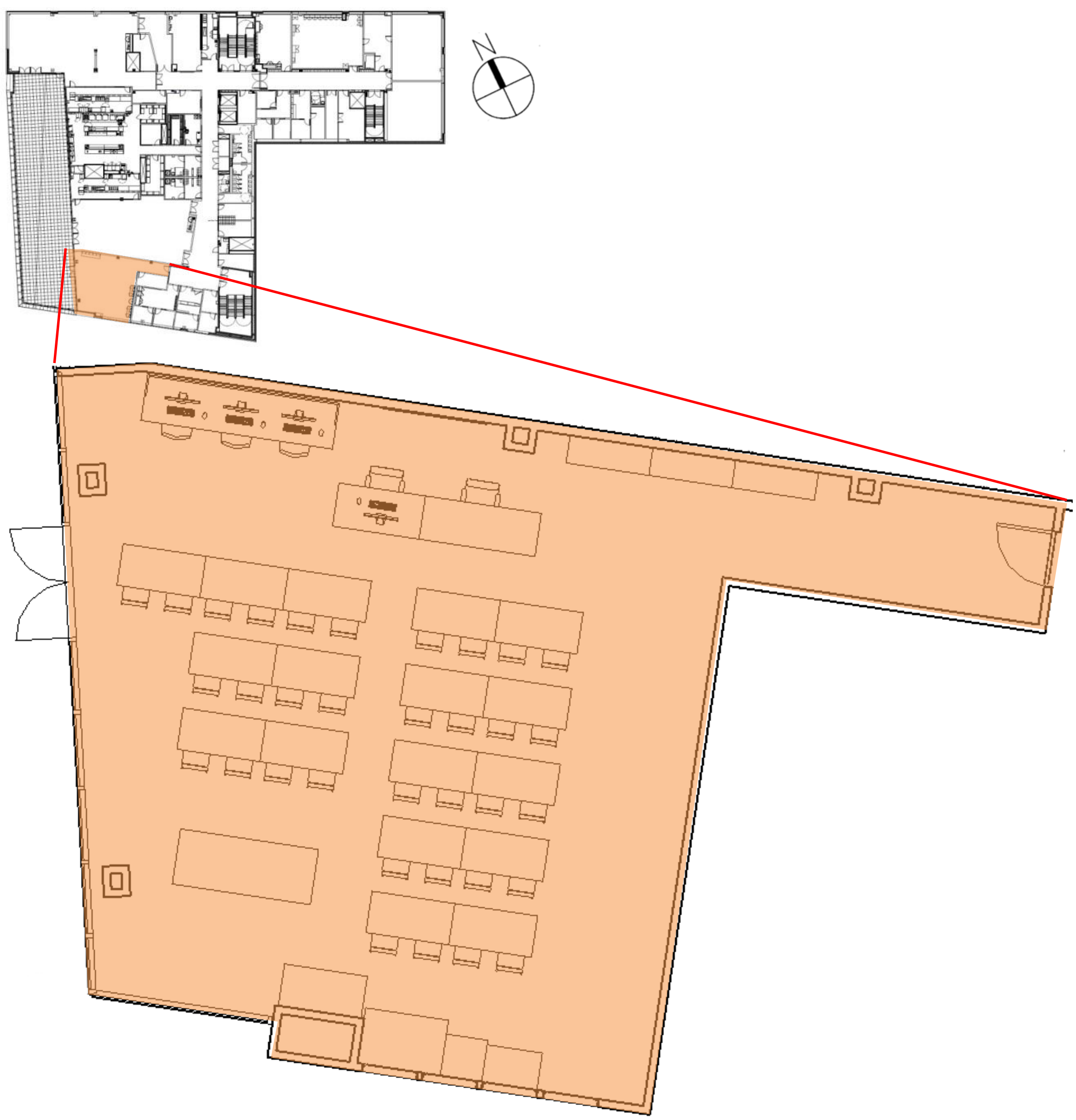
Length: 33 ft.

Width: 54 ft.

Ceiling Height: 10 ft.

Location (in building)

The Intermediate School (IS) cafeteria is located on the 5th floor directly (plan) north of the High School (HS) Art Room. There is no direct circulation between these two rooms, but like the High School Art room, the cafeteria has direct access to the exterior roof terrace. The two doors, located on the western side of the North wall, lead to the lunch line, which is linked directly to the kitchen.



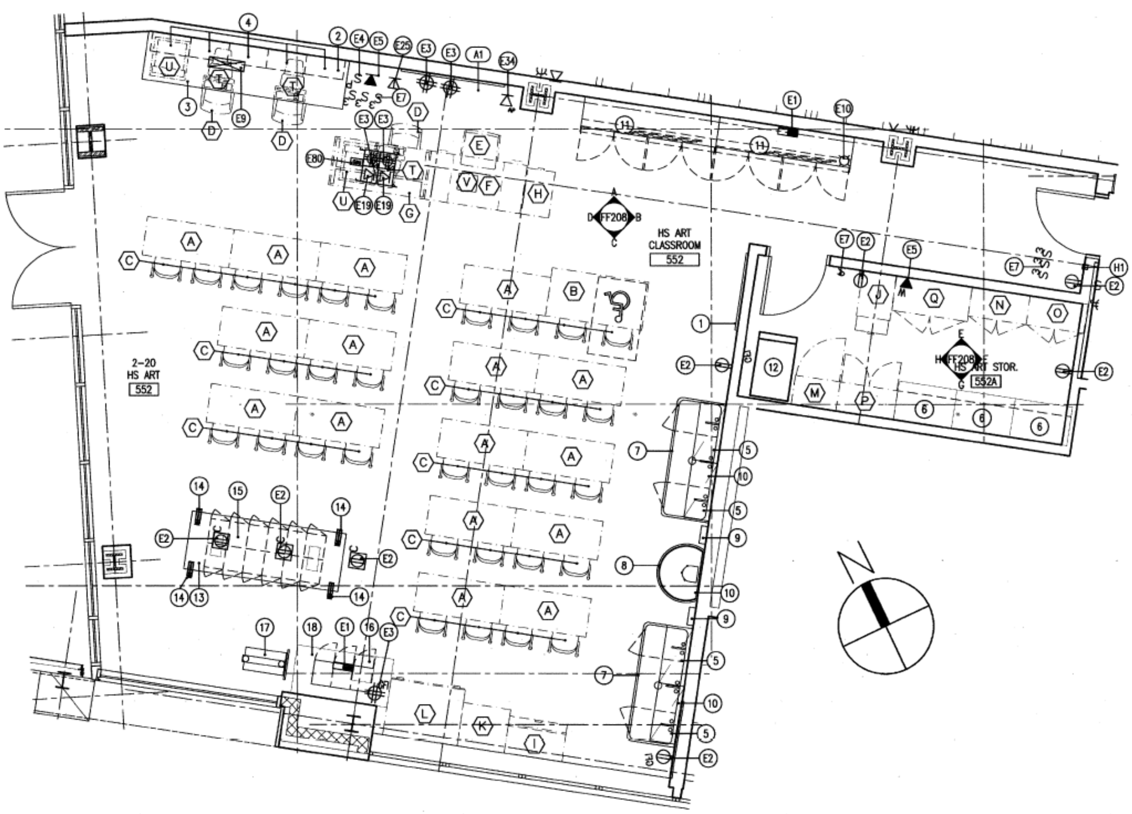
Finishes

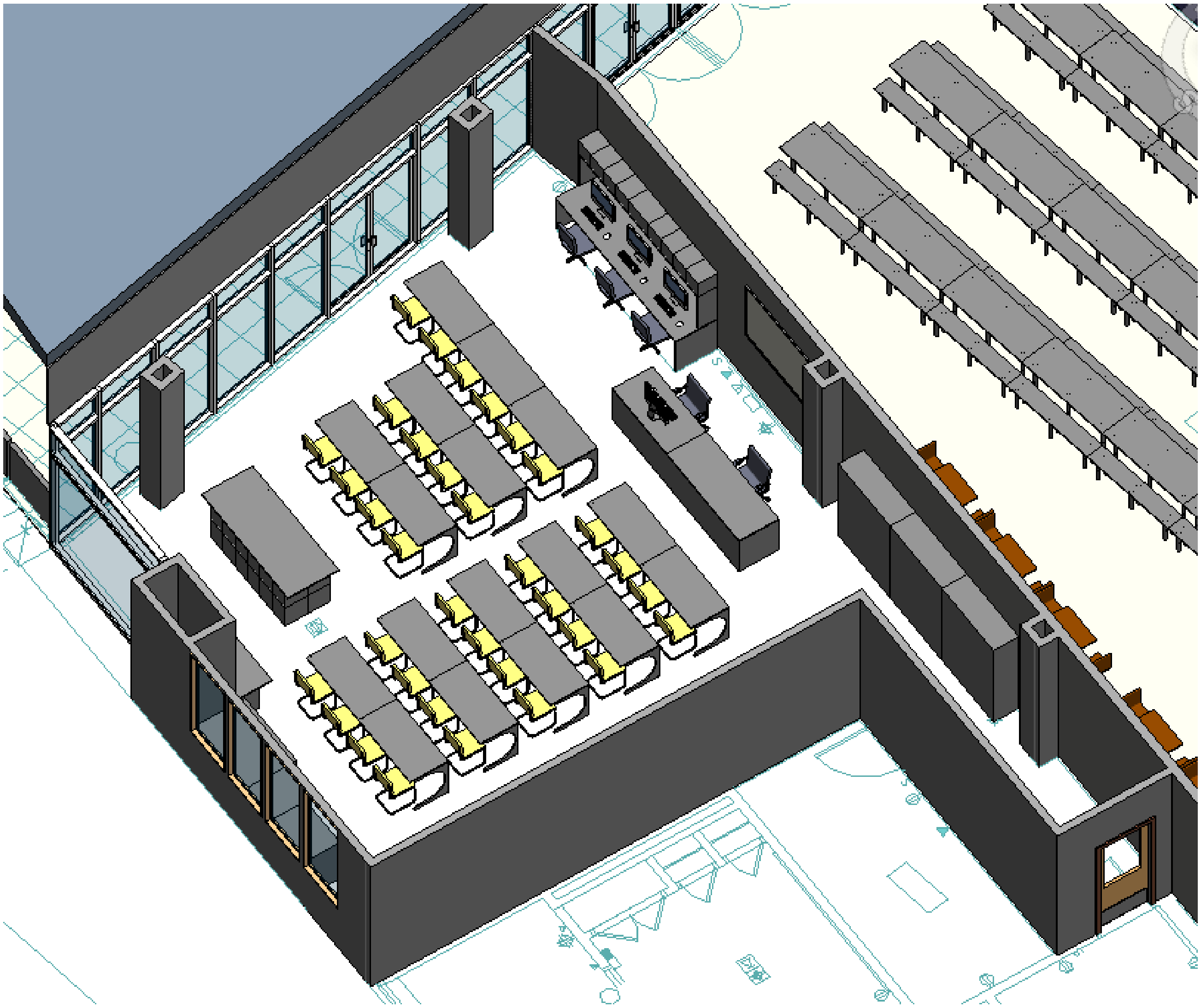
The floor of the High School Art Room is comprised of 12”x12” composite vinyl tile that is pewter in color. The walls, finished with high-reflectance white semi-gloss paint, are ideal for light distribution in the space. The ceiling, which was originally an acoustical drop ceiling, has been removed to expose the systems in the ceiling. See MAE and CM breadth.

Materials				
Surface	Material	Description	Style/Color	Reflectance
Floor	VcT	12" x 12" Vinyl Composition tile	112 Pewter	0.30
Walls	SG-P	Semi-Gloss Paint	Simply White OC-117	0.85
Ceiling	None	No drop ceiling. Open to above	N/A	N/A

Furnishings

The HS Art Room has seating for 34 students (1 handicap). The front wall of the room has a 2-seat computer desk, a large storage cabinet, and a marker-board and tack-board. For cleaning purposes, there are 2 large trough sinks and a wash fountain located on the west wall. Located on the back wall of the room (from left to right), are the following: etching press, jewelry kiln, cabinet/plan file drawer, flat file drawer, and a 3-drawer lateral file cabinet. Also located towards the back of the room in the South-West corner is a large work bench.





Tasks/activities

The primary tasks in this space consist of the creation of (and possibly the critique and appreciation of) art. This room is equipped with a substantial amount of equipment as to facilitate the creation of art in many different forms (painting, drawing, sculpture, etc.).

Although secondary in importance to the actual art creation taking place at the students' desk, formal lectures and "pin-ups" will also be taking place in this room. The marker-board and tack-board on the front wall of the room supports these tasks.

Overall design goals

The High School Art Room is a great space to design as it has limitless possibilities. Its location and orientation within the building and orientation allow for interesting possibilities with daylight. As this is a space that will be used to study and create art, the space itself should be a work of art. The intrinsic artistic nature of the use of this space opens the door to trying things that may not be appropriate in other spaces. This space, if any, should work towards achieving the overall design goal of **lighting + architecture**.

Promote Creativity: The space is an art room. Nothing about the space itself should be bland or boring. An art room itself should be a work of art. It should inspire. It should lead by example, if you will.

Decrease Distraction: The focus should be on creating art. Not glaring or inappropriate lighting.

Utilize Daylight: The location and orientation of the space, as well as the floor to ceiling glazing on two facades, floods the space with lighting. This should be utilized as much as possible.

Lighting as a tool for education: what defines art? If this space is to be used to teach art, why couldn't it be used to educate students about the affects lighting has on people and object?

Design Criteria/Considerations

Illuminance recommendations

Horizontal Illuminance – *Important*

- IES Classification: Education – Classrooms – Art Studios
  - Category R: 250 lux (25.0 fc)
  - Avg/Min: 3:1

Horizontal illuminance in the High School Art Room is important for artwork that will be created on a horizontal work surface (i.e. the students' desks). These types of works include, but art not limited to, the following: pencil/colored pencil/marker/charcoal/pastel drawings and watercolor/acrylic/oil paintings.

Vertical Illuminance – *Important*

- IES Classification: Education – Classrooms – Art Studios
  - Category P: 150 lux (15.0 fc)
  - Avg/Min: 3:1

The vertical levels in the art room are important, but not necessarily for the typical reason of face recognition. Although facial recognition is important, especially for a classroom, clear viewing of artwork is the primary concern here. These illuminance levels are critical to the production of artwork that is not necessarily produced on a two-dimensional surface. These types of work include, but are not limited to, the following: watercolor/acrylic/oil paintings, paper mache/plaster of paris/clay sculpture.

Design Considerations

Appearance of Space and Luminaires – *Very Important*

The lighting in this space is aimed to inspire; to motivate to create great works of art. The space, which should be a work of art itself, requires a creative lighting design. The luminaires should complement the design.

Color Appearance and Color Contrast – *Very Important*

Color rendering and contrast is extremely important especially when it comes to painting and drawing with color. Oil painting, which has very deep saturated colors, requires high color rendering capabilities of luminaires.

Daylighting Integration and Controls – *Very Important*

Besides the fact that daylight integration is one of the main design goals of the lighting design in this space, daylight integration in general is an important factor to consider in any space that has a large percentage of wall area dedicated to glazing. Daylight integration is a requirement of this space. The controls, depending on the results of a daylighting analysis (see MAE breadth) may or may not be required.

Direct Glare – *Very Important*

As this space is aimed at utilizing daylight as much as possible, and in oriented in such a way that direct sun falls on the façade very often, direct glare is of high important and needs to be thoroughly investigated. In addition to being irritating, direct glare from the sun can be distracting and may affect the process of creating great pieces of art.

Flicker – *Somewhat Important*

Flicker itself is an important design consideration and should be avoided whenever possible. However, there is no added importance of flicker in this space than normal. That is, there are no critical tasks in this space that require additional attention to flicker.

Light Distribution on Task Plane – *Important*

The task plane should be uniform enough so as to not distract from the task at hand—which is creating art. However, the task plane should not be overly uniform, as to wash out the detail in paintings and drawings.

Modeling of Faces or Objects – *Somewhat Important*

Modeling of faces is important, but that of objects is extremely important. Sculpture and pottery are two forms of art that require a large physical object. Lighting needs to provide illuminance as to properly model the fine detail required when sculpting.

Reflected Glare – *Very Important*

Glare reflected from surfaces in the space is a very important problem, especially as the ceiling will be removed, exposing the systems in the ceiling. They must be finished with matte white paint to reduce the possibility of reflected glare.

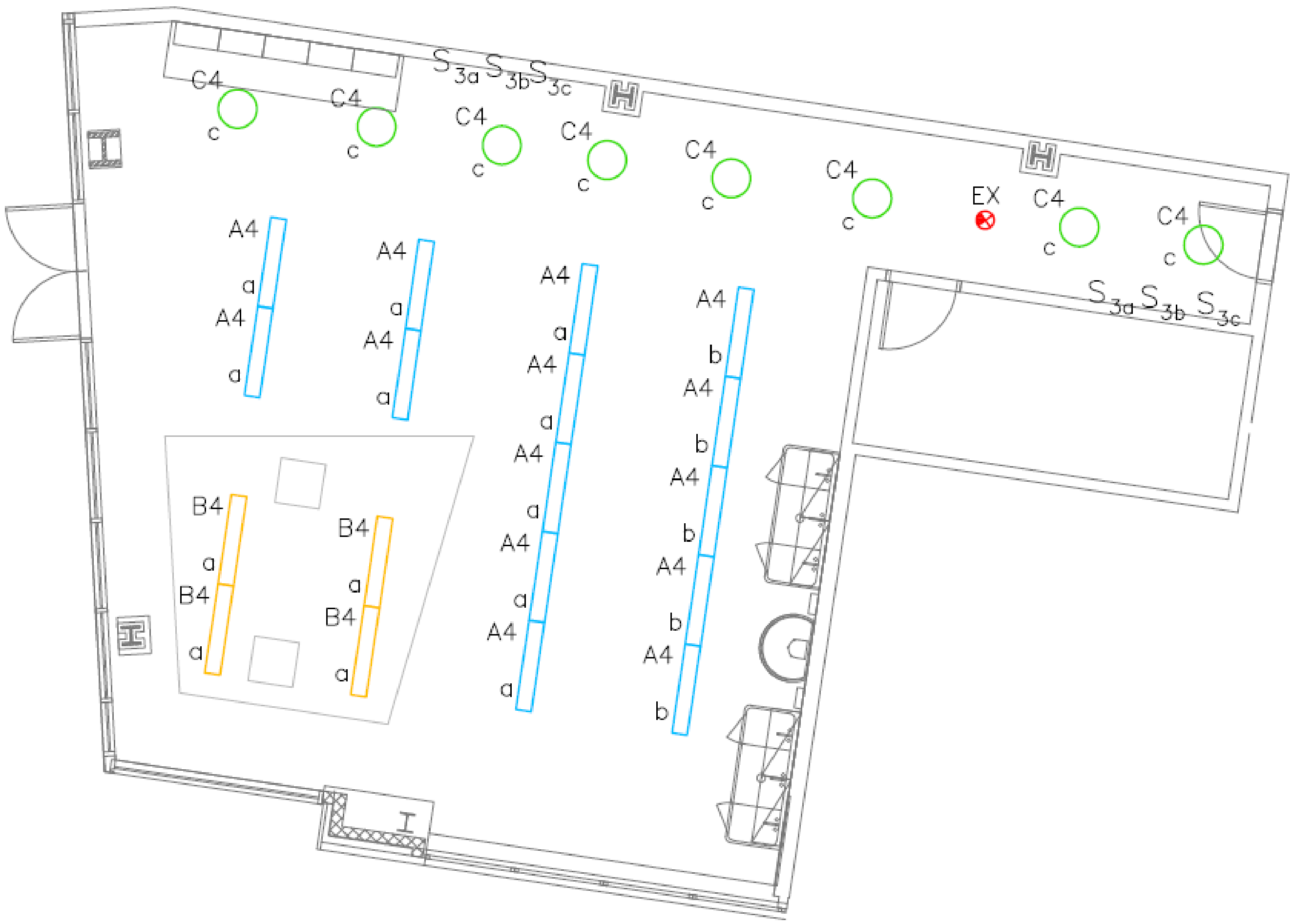
Shadows – *Important*

Shadows, although desirable in some situations, should be avoided in this space—at least for the most part. Direct lighting overhead can cast shadows on the work surface and distract from the task at hand. Wherever possibly, shadows from the general lighting in the space should be avoided. Shadows shall only be introduced into the space where important for artistic demonstration.

Daylighting

See M.A.E Daylighting Breadth

Fixtures and equipment



Fixture Schedule				
Type			Description	Manufacturer
A4			Single-lamp, **Suspended** linear fluorescent semi-indirect pendant with die-formed specular reflector. Reflector 95% reflective. Aluminum semispecular parabolic louver.	Peerless
B4			Single-lamp, **recessed** linear fluorescent semi-indirect pendant with die-formed specular reflector. Reflector 95% reflective. Aluminum semispecular parabolic louver.	Peerless
C4			Suspended, 26W 3500k compact fluorescent, downlight. 14 ga. Single-piece precision-spun aluminum. 14 ga. Anodized aluminum reflector with diffuse satin matte surface.	Focal Point
EX			Ceiling-Mounted, single-sided exit sign. AC only operation with RED lettering on clear panel. Matte white finish on housing. 8" letters, 1" stroke	Mule Lighting

The tables below provide information regarding the energy consumption and assumed light loss factors for each of the luminaires used in the space. The room contains 27 fixtures, consuming a total of 969 Watts. A light loss factor was not included for the exit sign (fixture 'EX') as is does not provide useful illumination to the room, and was not considered in any lighting calculations.

HS ART ROOM VA CALCULATION								
Location	Type	Lamp	Qty	W/Fixture	Total Watts	PF	VA/Fixture	Total VA
HS Art Room	A4	(1) F32T8	14	38	532	0.9	42	591
	B4	(1) F32T8	4	38	152	0.9	42	169
	C4	(1) 32CFTR	8	35	280	0.9	39	311
	EX	LED	1	5	5	0.7	7	7

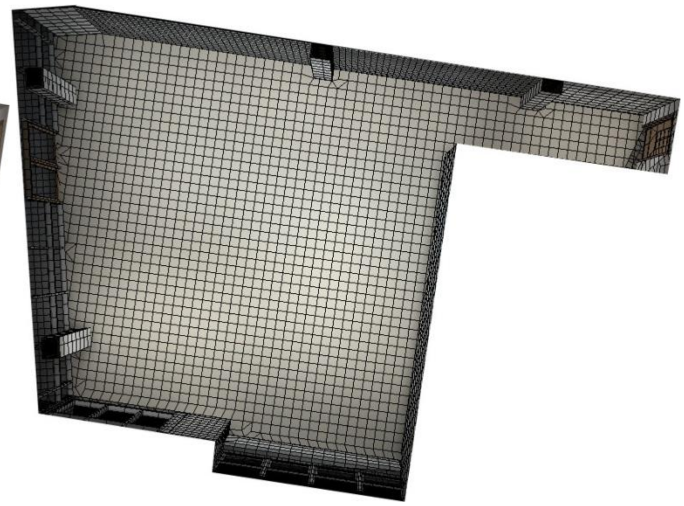
LIGHT LOSS FACTORS						
	Lamp Lumens		Light Loss Factors			
Type	Initial	Mean	LLD	LDD	BF	Total
A4	3000	2850	0.95	0.90	0.88	0.8
B4	3000	2850	0.95	0.90	1.20	1.0
C4	-	-	0.70	0.90	-	0.7
EX	-	-	-	-	-	-

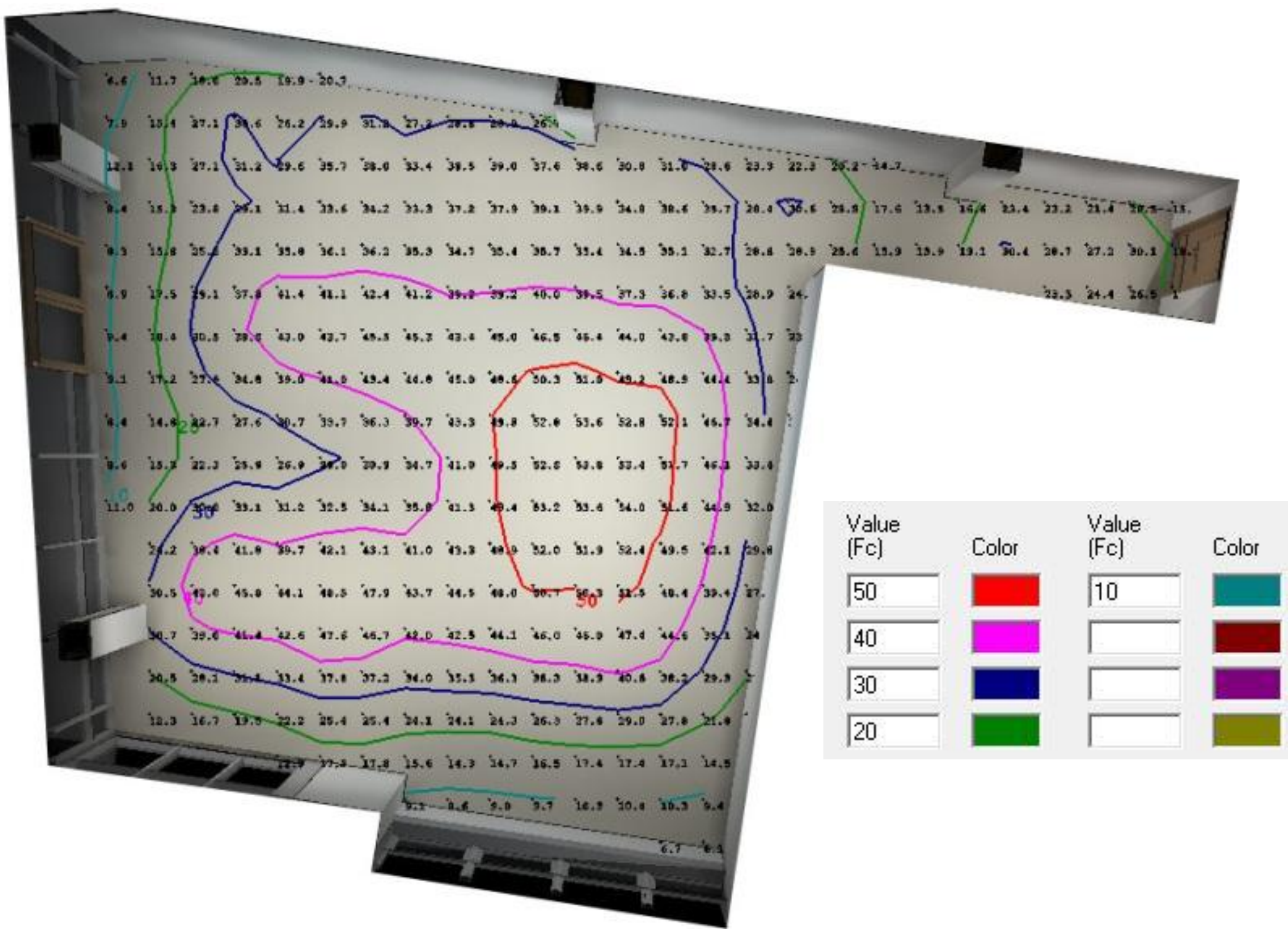
Controls

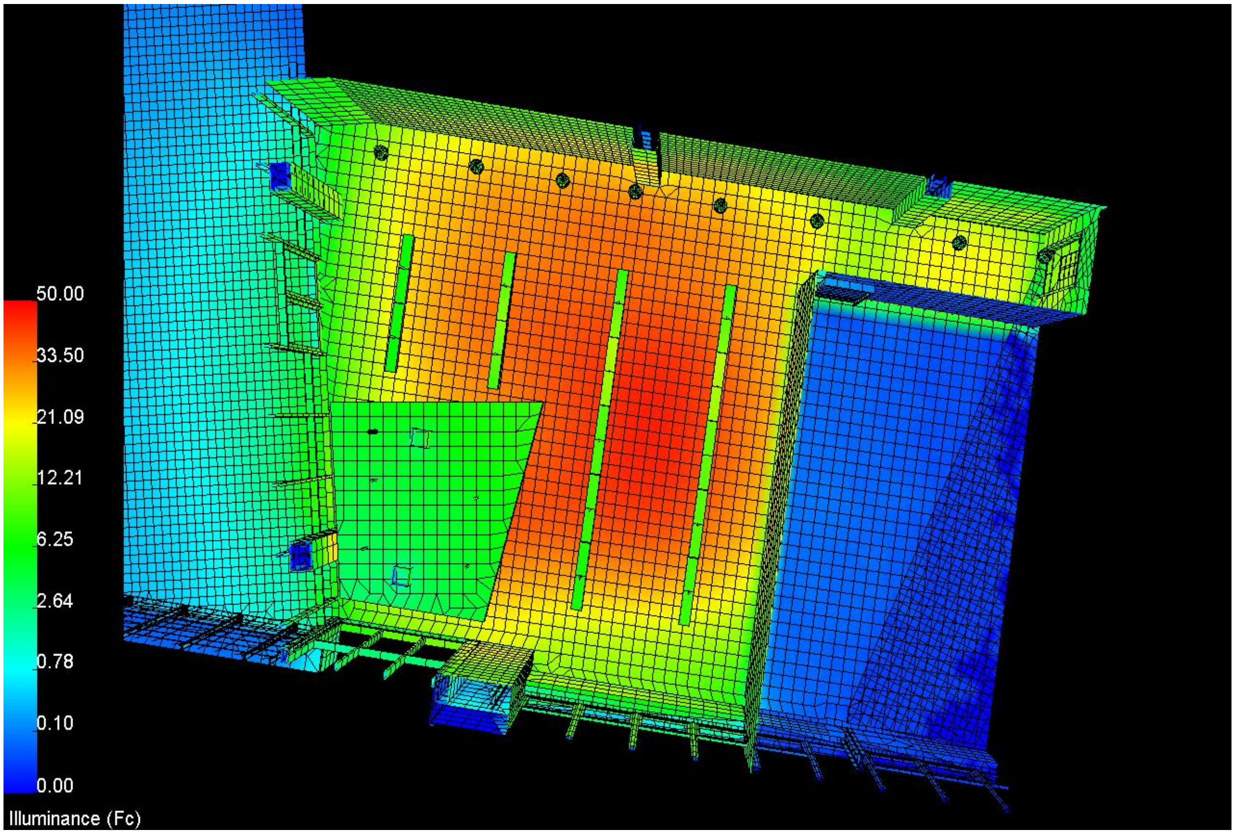
The High School Art Room has a three-zone configuration with switches at two locations; a set at the entrance door to the space, and another to the rear of the teacher's desk by the whiteboard. The suspended compact fluorescent fixtures at the front of the space are on their own zone in the event that daylight provides sufficient illuminance to the rear and middle area of the space, but emphasis is desired in the front of the class; for a lecture, perhaps. The suspended linear fluorescents over the students seating area is broken into two zones. The run of fixtures nearest the east wall are zone separately as this tends to be the area that receives the least daylight and is the location of the sinks and cleaning equipment. There luminaires may be switched on if daylight does not provide sufficient illuminance levels in this area. Luminaires in this space do not have dimming capabilities and are not controlled by photosensors. The daylight and skylights were designed (See MAE Breadth) as to provide sufficient illuminance through most of the occupancy schedule. Therefore, it was deemed redundant to put automatic controls in as the space is design to not need electric light. As such, all lighting is manually operated.

Calculation summary

The figures below show the calculation summary for the High School Art Room. The image in the top row to the left shows the distribution of light in the space. The image to the right shows the space with the calculation mesh. The bottom image shows the calculation points and isolines with corresponding values.



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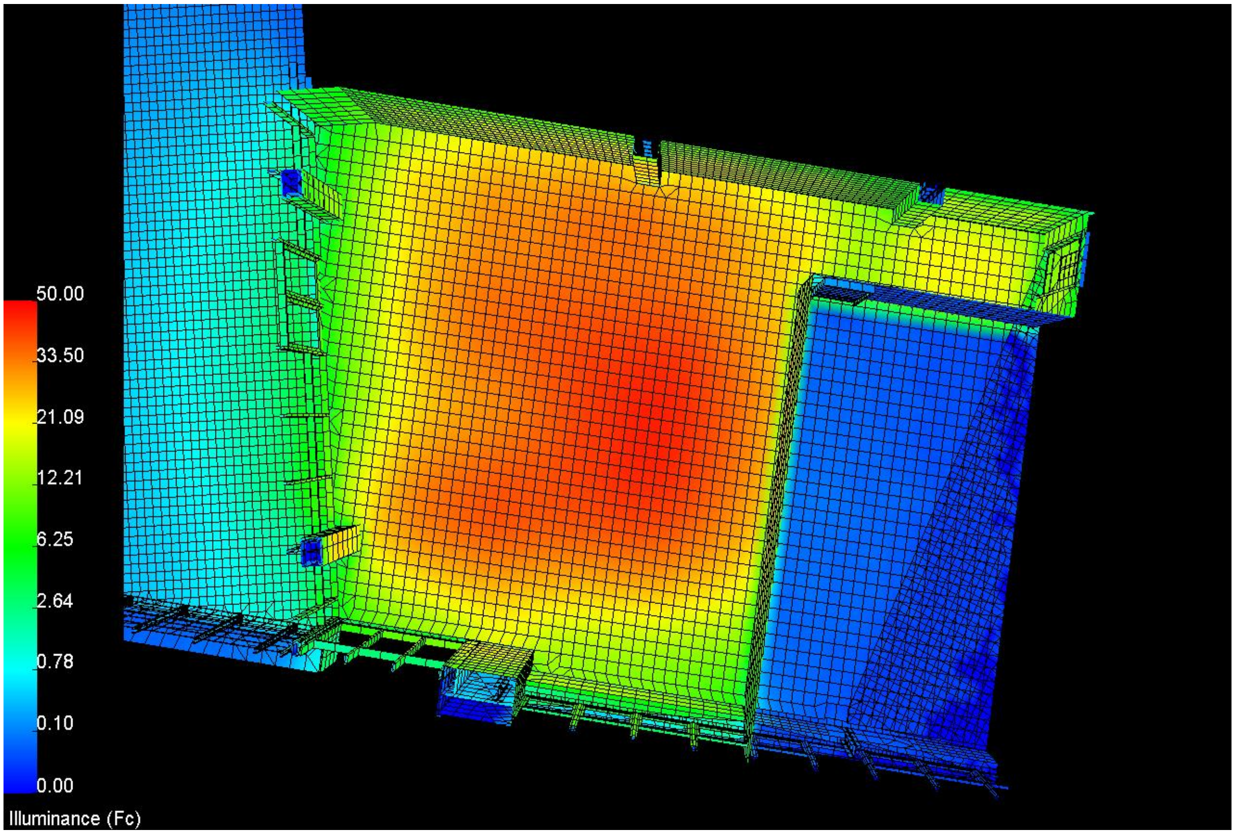
Illuminance (Fc)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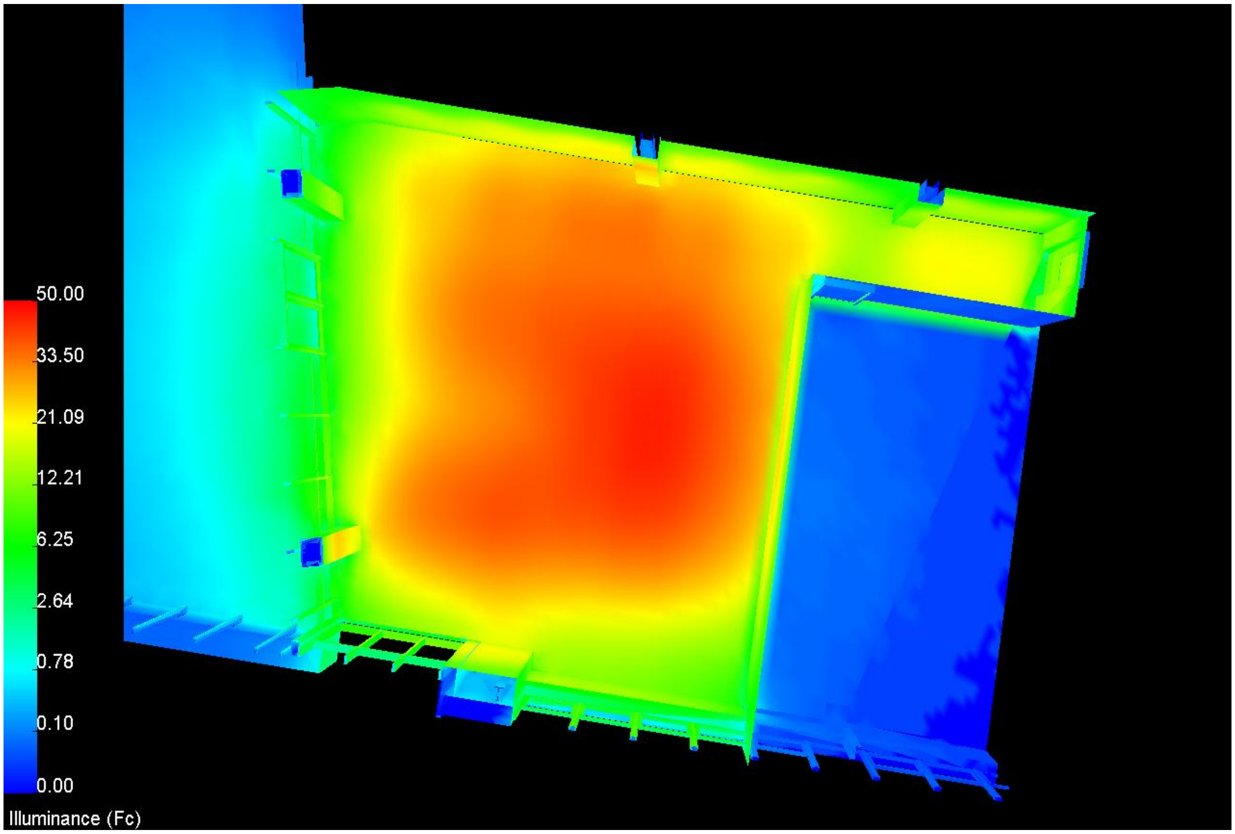
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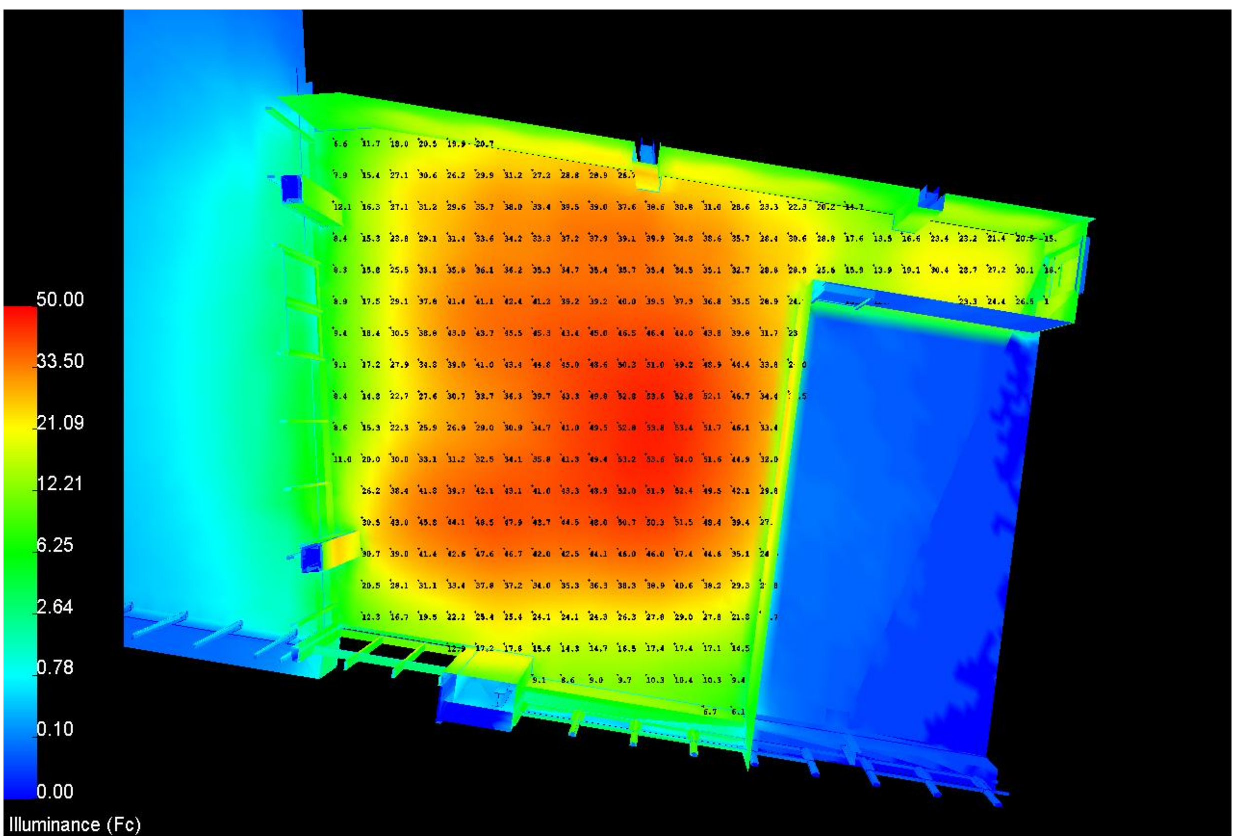
Illuminance (Fc)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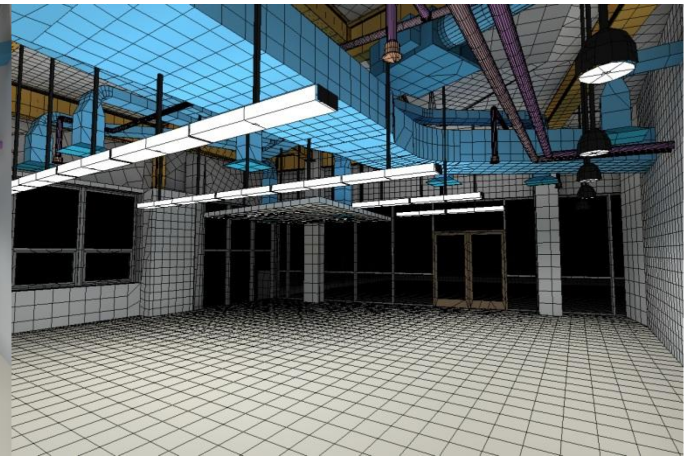
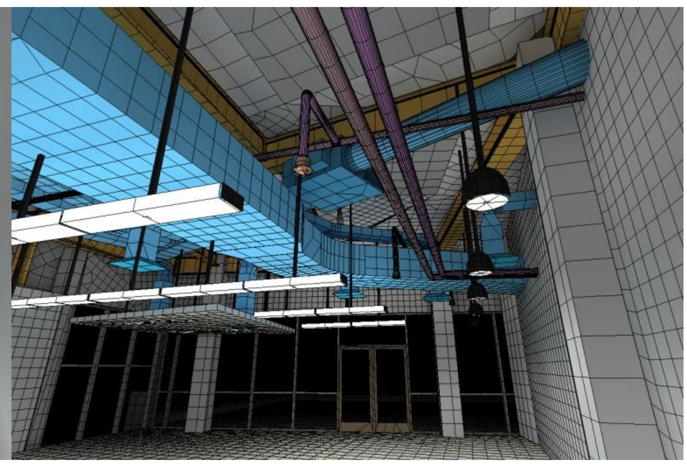
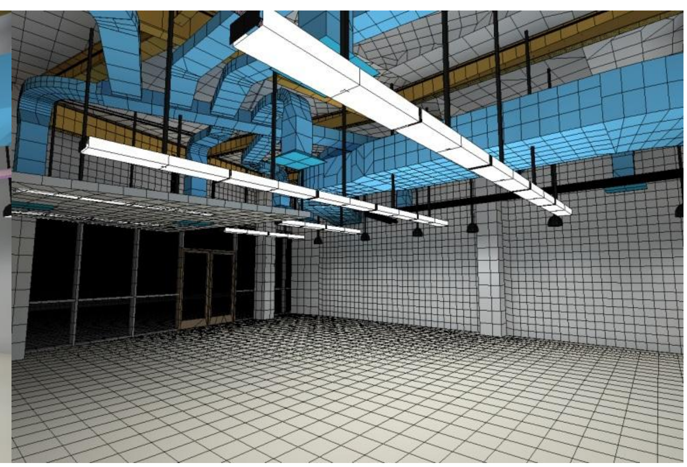
0.00
Illuminance (Fc)

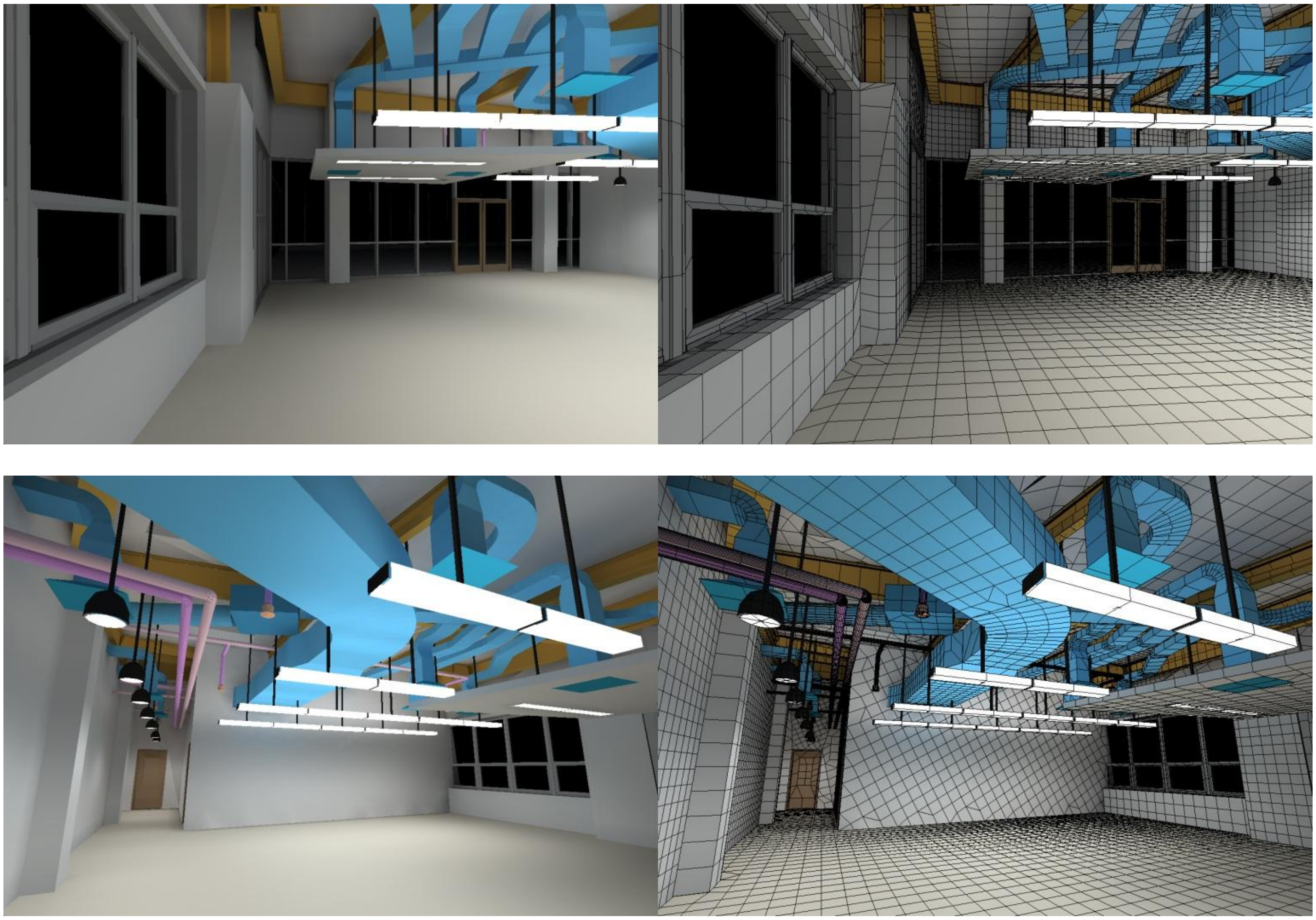
Renderings

This section shows interior renderings of the space that are intended to help give a better understanding of the feeling of the interior environment. These renderings include only electric lighting and no daylight. They are intended to show the space under the times electric light would be utilized, which would most likely be the at night. The image on the left shows the rendering; the image on the right shows the calculation mesh.







Evaluation

Summary

The high school art room design strived to integrate electric lighting, architecture, and daylighting all with the goal of creating a space that is not only efficient in design, but creates the stimulating and creative environment demanded by the tasks evident in an art room. We can conclude that the space achieves a high level of daylight integrate (see MAE breadth) and creates a stimulating and creative environment (shown in the renderings—See CM breadth for further justification). The removal of the standard acoustical ceiling grid creates an interesting environment to be in, and because of the shading system implanted (MAE breadth) glare and distraction is avoided. In general, the overall design goals for this space have been met via daylight integration to both effectively utilize daylight illuminance and also to reduce glare and distraction. The space creates an atmosphere different than the rest of the building. This room is the creative "get-away."

ASHRAE/IESNA 90.1

Looking at the tables below, we see that the High School Art Room consumes a total of 969 Watts, which equates to a space power density of 0.80. This is significantly lower than the allowed 1.24 Watts/ft^2 allowed by ASHRAE 90.1.

HS ART ROOM TOTAL INPUT WATTS				
Type	Lamp	Qty	Input W	Total W
A4	(1) F32T8	14	38	532
B4	(1) F32T8	4	38	152
C4	LED	8	35	280
EX	LED	1	5	5
			Total:	**969**

ASHRAE/IESNA 90.1 2011		
Category	Allowable	Actual
Area (sq.ft.)	-	1208
Input Watts (W)	1498	969
Power Density (W/sqft)	1.24	**0.80**

Electrical

This section is dedicated to the electrical portion of the design work. Included in this section are the electrical requirements for the four lighting spaces, a coordination study and short circuit analysis, and two electrical depth topics. The first depth topic is an analysis of the electrical distribution method of the rooftop mechanical equipment which is aimed at finding a more cost effective method. The second depth topic, is an SKM analysis of the electrical distribution system which aimed to compare the AIC rating of the existing panelboards against the available short-circuit current calculated by SKM. This section of the report is organized according to the following hierarchy:

1 | Four Lighting Spaces

a. Introduction
b. Panelboards
c. Electrical Information
    i. Control Description
    ii. Luminaire Layout and controls
    iii. Existing Panelboard Schedules
    iv. Existing Dimmer Schedules
    v. Panelboard Worksheets
    vi. Revised Panelboard Schedule
    vii. New Dimming and wiring diagram
    viii. Resized Panelboard feeder
    ix. Manufacturer information

2 | Coordination Study / Short Circuit

a. Coordination Study
b. Short Circuit Calculations

3 | Depth Topic 1

3 | Depth Topic 2

1 | Four lighting spaces

a. Introduction

The lighting and electrical redesign will occur for the following four spaces: the Façade, Auditorium, Intermediate School (IS) Café, and High School (HS) Art room. The lighting redesign of these four spaces focuses on achieving the original design goals with as little energy consumption as possible. The goals of the faced are to be minimalistic (unobtrusive to the architecture), have a high visibility from the river, have a vandal-proof installation as it is in an urban area, and last to create a focal point at the entrance of the building as it is very small and hidden.

The auditorium, which is located in the center of the building, acts as the heart and connection point of the third floor (dedicated to the Intermediate School students) and the fourth floor (dedicated to the High School students). The goals of the lighting design in this space is to accent the architecture as a lot of time has gone into beautifully designing this space, but the lighting in this space also needs to be flexible. The space may be used for large class meetings or for performances, talent shows, or musical events – the lighting needs to be suitable for all of these uses.

The Intermediate School Café, which is the main lunchroom for the Intermediate School kids, needs to be reflective of the space usage. Analyzing the age of the students that will be using this space, it is obvious that the lighting should be fun and creative, but provide sufficient illuminance for eating.

The last space in the redesign project, the High School Art Room, is located on the fifth floor, and large potential to utilize daylighting. The space is blanketed on two walls with glazing, and faces mostly north. This means that daylighting can be utilized with minimal worries of glare. Utilizing daylight to the maximum is the main design goal of this space, but the lighting should also promote creativity and individuality, decrease distraction, and – because of my personal interest in education – have the ability to be used as a tool for lighting education.

b. panelboards

PANELBOARDS						
PANEL TAG	VOLTAGE	SYSTEM	FAÇADE	AUDITORIUM	IS CAFÉ	HS ART ROOM
1LP-A	208Y/120V, 3P, 4W	N	X			
1ELP-LS	208Y/120V, 3P, 4W	N/E	X			
5LP-A	208Y/120V, 3P, 4W	N			X	X
5ELP-LS	208Y/120V, 3P, 4W	N/E	X		X	
3LP-DIM 1	208Y/120V, 3P, 4W	N		X		
3LP-DIM 2	208Y/120V, 3P, 4W	N		X		
3ELP-DIM	208Y/120V, 3P, 4W	N/E		X		

c. electrical information

i. Control Description

Façade

The façade lighting for the Hunters Point South Intermediate School and High School is connected into the buildings time clock control system. All lighting comes on at night and comes on in the morning. No manual switching devices have been included for the façade lighting. In addition, the lighting fixtures serving the entrance and exits of the building are connected to the emergency power system, meaning that they are always on.

Auditorium

The auditorium is split into multiple zones, all with dimming capabilities. The fixtures in the space that are deemed emergency fixtures are dimmable as well and are fed from a dimming panel connected to the emergency system. These fixtures may be dimmed as desired—in the event of a power outage the control system will force them back to full output. The stage lighting is split into two zones; 4 of the 16 fixtures dedicated to emergency, the rest dimmable, general illumination stage lighting. The recessed downlights located near the entrance and exits of the space, zoned separately, are connected to the emergency system and are set to be always on at full output. The lighting over the general seating area, is split into four zone, with each row of lighting being its own zone. This gives large flexibility in the lighting in the space, allowing the lighting and illuminance levels to be altered depending on the event.

Intermediate School Cafeteria

The Intermediate School Cafeteria has a three-zone configuration with two switches per zone (one located at each door), all connected to a line-voltage occupancy sensor. All override switches are *key* switches, as to prevent the students from tampering with the lighting. The recessed linear fluorescent over the main eating tables are split into two zones, with the luminaires closest to the exterior glazing controlled separately. This allows those lights to be (manually) turned off when daylight in the space is sufficient. The recessed fluorescent wall washers over the eating benches comprise the third zone. This zone of lights (uniformly) washes the wall, while providing sufficient illuminance for eating at the benches along the wall.

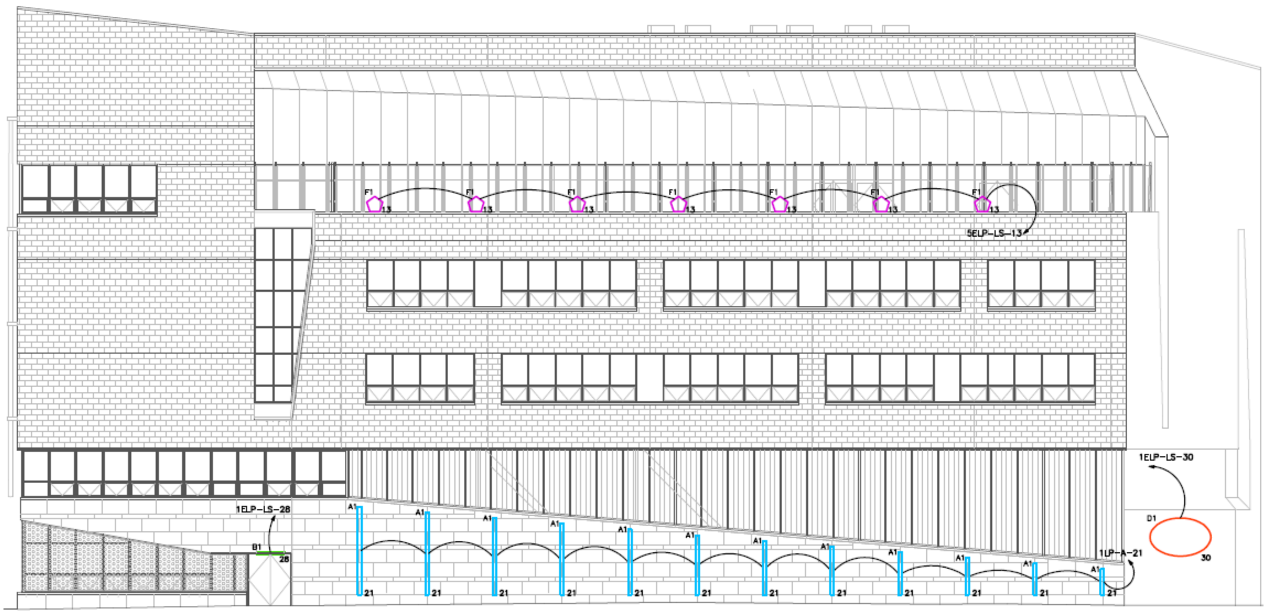
High School Art Room

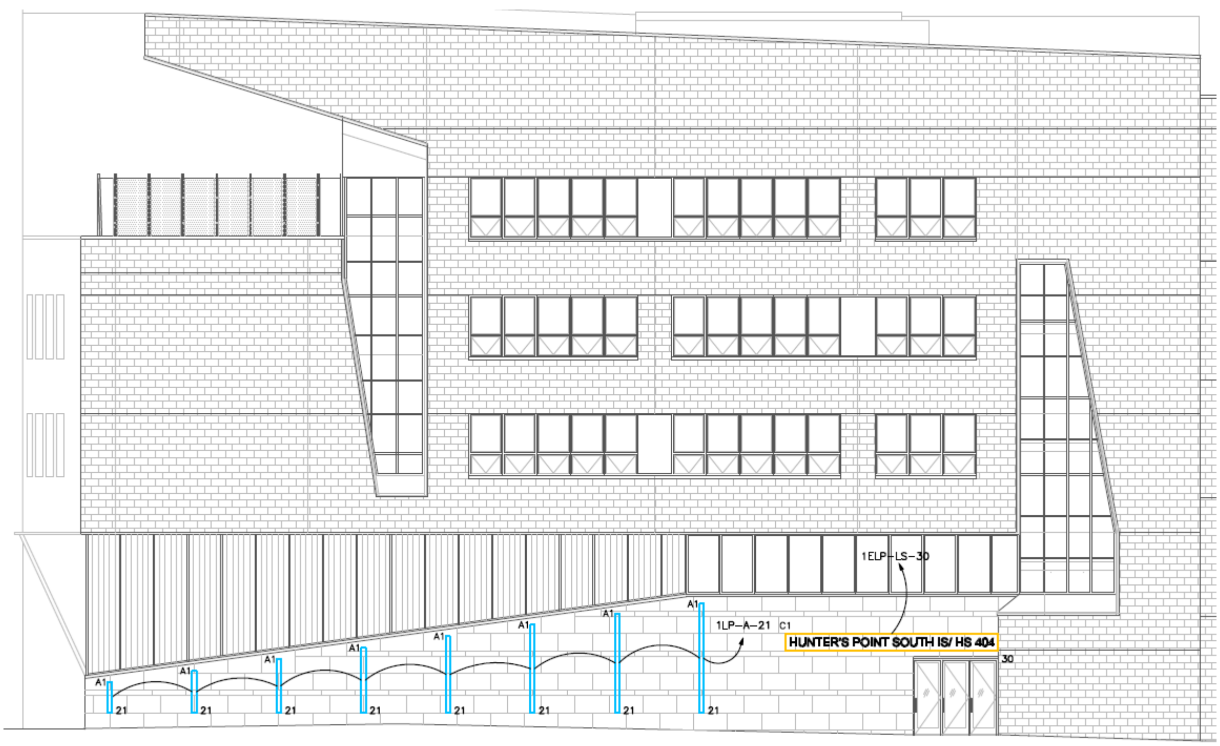
The High School Art Room has a three-zone configuration with switches at two locations; a set at the entrance door to the space, and another to the rear of the teacher's desk by the whiteboard. The suspended compact fluorescent fixtures at the front of the space are on their own zone in the event that daylight provides sufficient illuminance to the rear and middle area of the space, but emphasis is desired in the front of the class; for a lecture, perhaps. The suspended linear fluorescents over the students seating area is broken into two zones. The run of fixtures nearest the east wall are zone separately as this tends to be the area that receives the least daylight and is the location of the sinks and cleaning equipment. There luminaires may be switched on if daylight does not provide sufficient illuminance levels in this area.

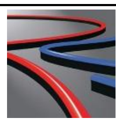
ii. Luminaire Layout and Controls

Façade

The elevations below show the layout of the luminaires for the façade lighting system. Reference the lighting fixture schedule following the elevations for information about the lighting fixtures used on the facade. To view the view the plan to scale, reference the appendices at the end of this report.





Fixture Schedule				
Type			Description	Manufacturer
A1			Recessed linear LED strip. Stainless steel luminaire housing with sealed enclosure - wet listed for exterior. 6500k white LED's. Various fixure lengths, 4W/foot.	HessAmerica
B1			Surface mounted, F32T8 direct linear fluorescent. High impact radial lense (outdoor appropriate) with tamper resistant screws. 4 foot, die-formed, gloss white (YGW) 20-gauge steel housing	Prudential Lighting
C1			Surface mounted, flexible LED strip. Super bright, white (3500K), LED's. 2.4W/ft for LED of white output.	Cooper - RSA Lighting
D1			Acrylic, 0.3 inch, surface-mounted LED lighting panel. Ellipse shaped: long radius 4'6", short radius 2'10". White (3500k) LED's. Reflective opaue white backing to maximize optical brightness	Rosco Architectural
F1			Recessed, in-ground rated, 150W PSMH floodlight. One-piece, die-cast aluminum housing, with white premium polyester powder coat paint for protection. Include top visor.	Cooper Lighting

MATERIAL FINISH KEY

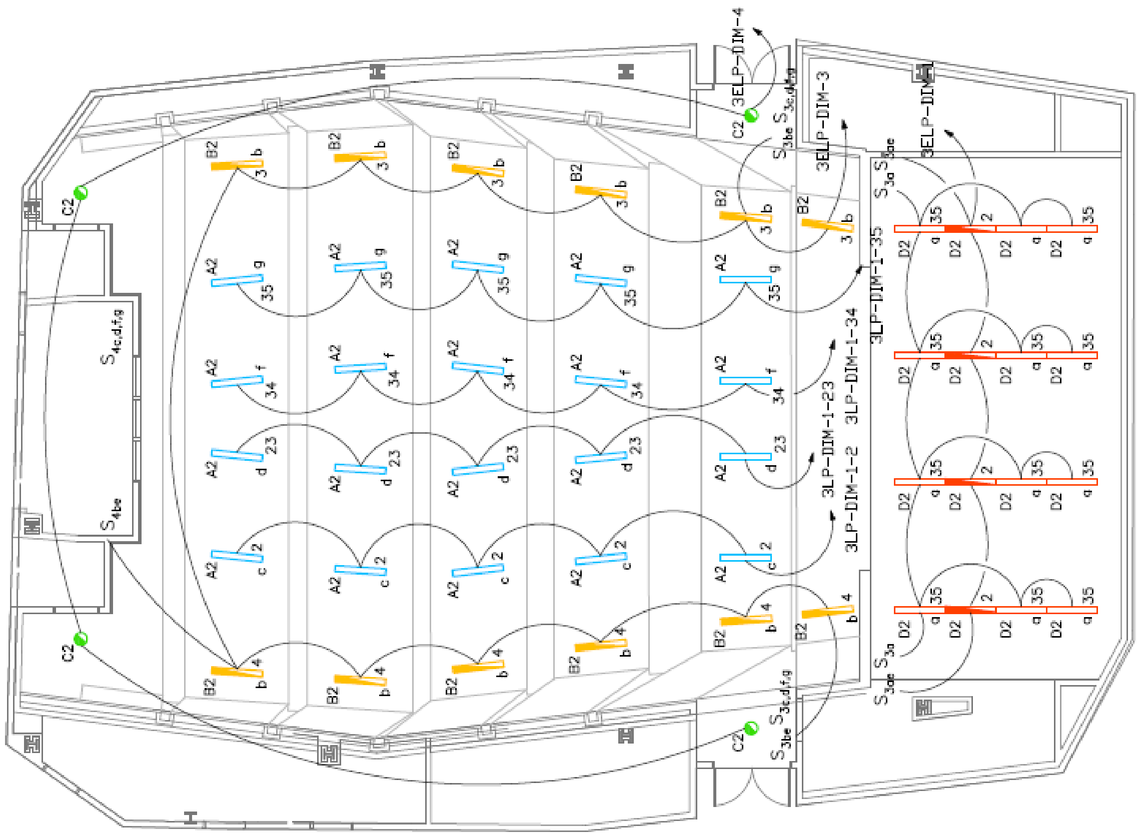
3-5/8" X 3-5/8" X 11-5/8" UTILITY BRICK SET IN ONE-THIRD RUNNING BOND

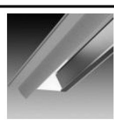
2" THICK EXTERIOR CUT STONE

ALUMINUM COMPOSITE PANEL

Auditorium

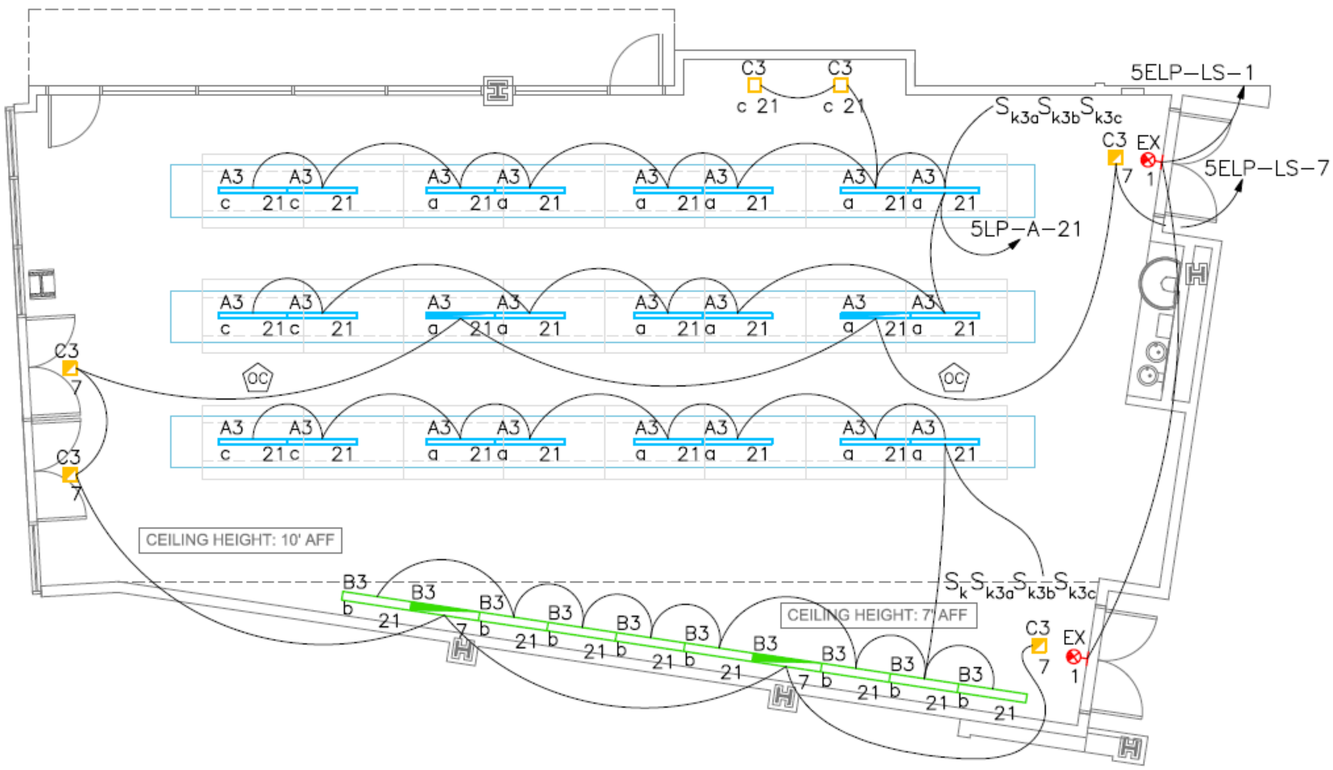
The plan below shows the layout of the luminaires as well as the locations of the switches. Reference the lighting fixture schedule following the plan for information about the lighting fixtures used in the space. To view the plan to scale, reference Appendix D at the end of this report. Following the fixture schedule is the occupancy coverage pattern for the space.



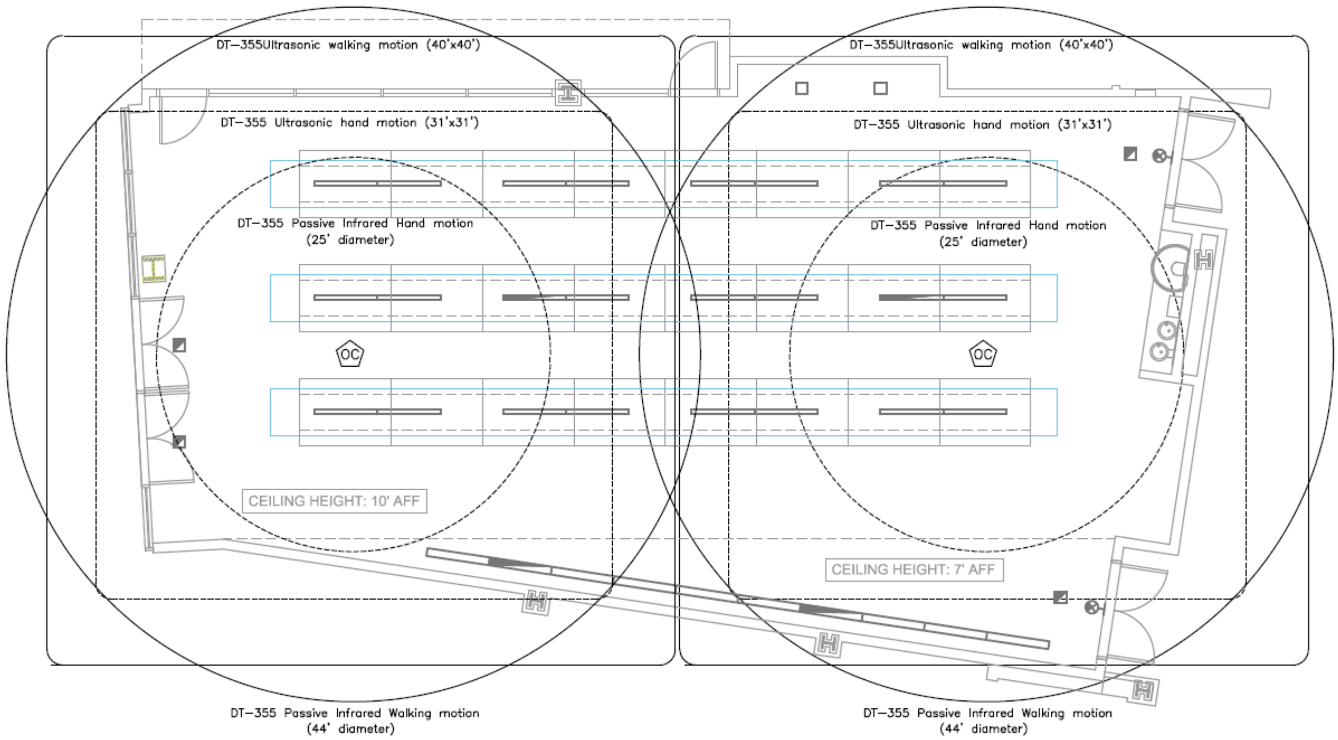
Fixture Schedule				
Type			Description	Manufacturer
A2			Recessed linear fluorescent with flush .07" thick acrylic lens with opal satin finish. 22 ga. steel reflectors with high reflectance white powder coat. Matte White finish	Focal Point
B2			Recessed linear fluorescent **wall-washer** with flush .07" thick acrylic lens with opal satin finish. 22 ga. steel reflectors with high reflectance white powder coat. Matte White finish	Focal Point
C2			Single-lamp, recessed compact fluorescent downlight with 7 3/8" aperture. Matte white finished flange with 16 ga. aluminum, wide distribution refelctor.	Lightolier
D2			Single-lamp, suspended linear T8 linear fluorescent downlight. 4' length bosy of formed and welded die-formed 20-gauge steel. Gloss white (YGW) polyester power paint finish.	Prudential

IS Cafeteria

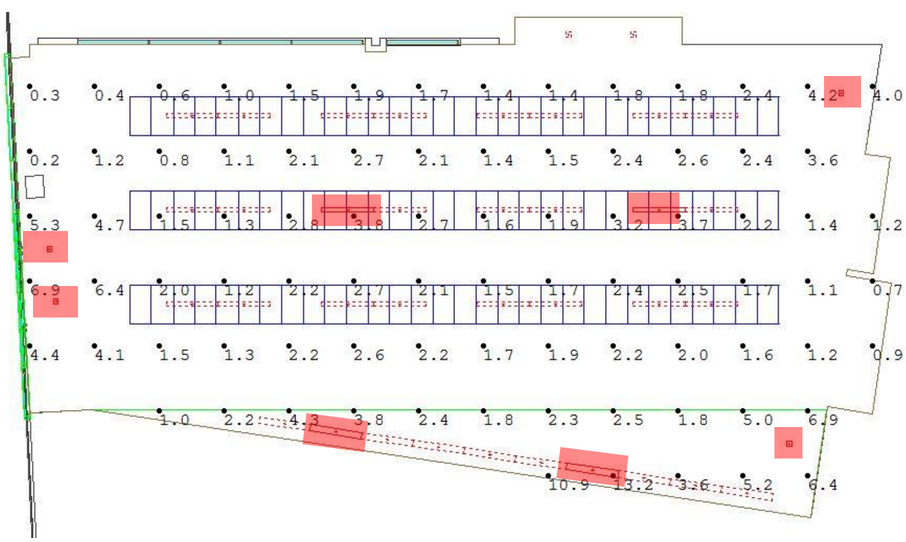
The plan below shows the layout of the luminaires as well as the locations of the switches. Reference the lighting fixture schedule following the plan for information about the lighting fixtures used in the space. To view the plan to scale, reference Appendix D at the end of this report. Following the fixture schedule is the occupancy coverage pattern for the space.

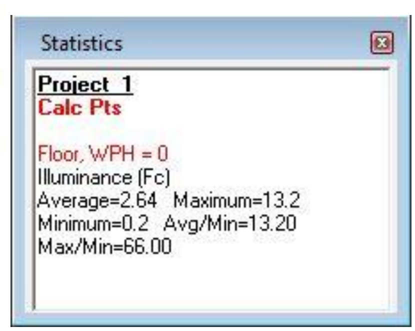


Fixture Schedule				
Type			Description	Manufacturer
A3			Recessed linear fluorescent with flush .07" thick acrylic lens with opal satin finish. 22 ga. steel reflectors with high reflectance white powder coat. Matte White finish	Focal Point
B3			Recessed linear fluorescent wall washer. Housing and flange trim are die-formed, 20 ga. Steel, with gloss white finish. Semi-specular reflector	Peerless
C3			Recess 4.5"x4.5" square LED downlight. Matte white flange and reflector finish.	Lightolier
EX			Wall Mounted, single-sided exit sign. AC only operation with RED lettering on clear panel. Matte white finish on housing. 8" letters, 1" stroke	Mule Lighting

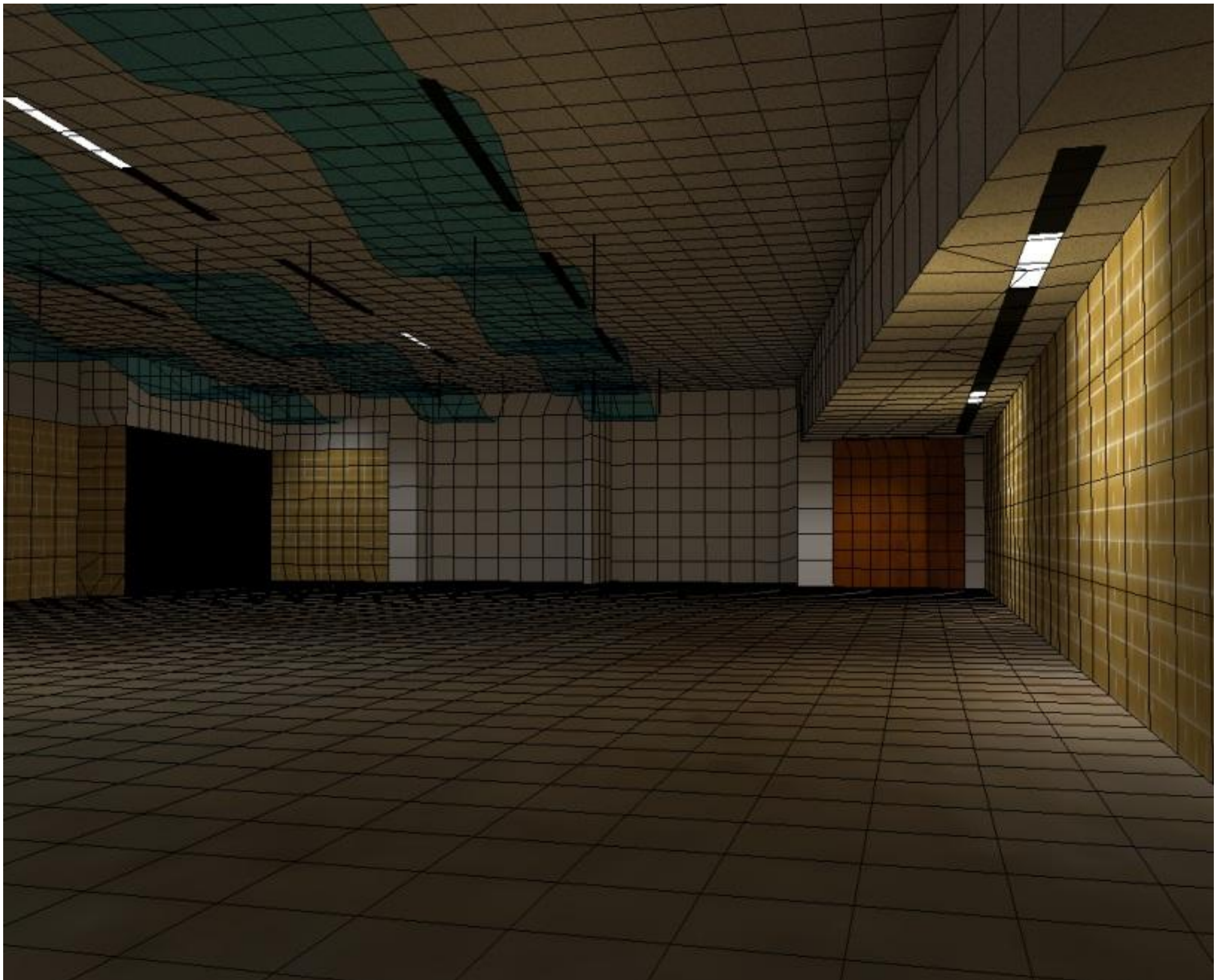


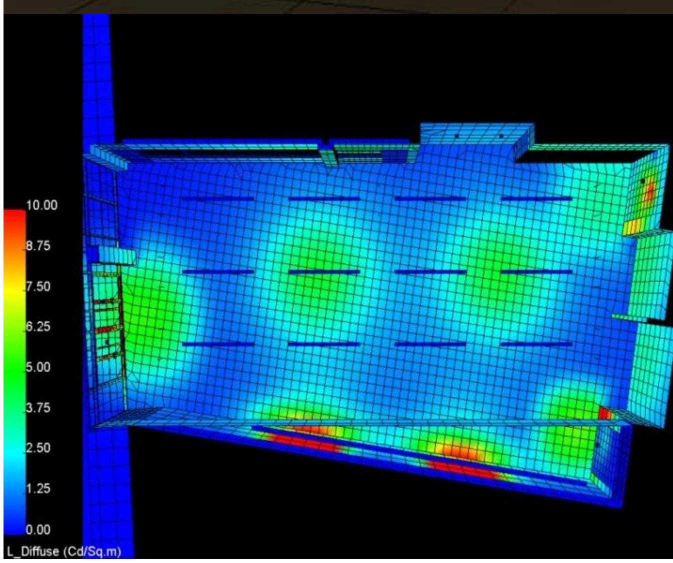
The transparent red boxes on the plan below indicate the emergency lighting fixture in the space. All of these fixtures are on a Normal/Emergency system, and as such, are on all the time. They are not connected to the occupancy sensors in the space, not the wall switches. The emergency lighting performance meets the average and minimum values as required by IBC. It does not, however, meet the uniformity ratio of 40. This is easily fixed by adding an additional luminaire where the values are a bit low, or removing one where the values are a bit high (i.e. the south wall). An interior rendering and pseudo diagrams (illuminance and luminance) of the space during the emergency lighting condition are presented on the next page.

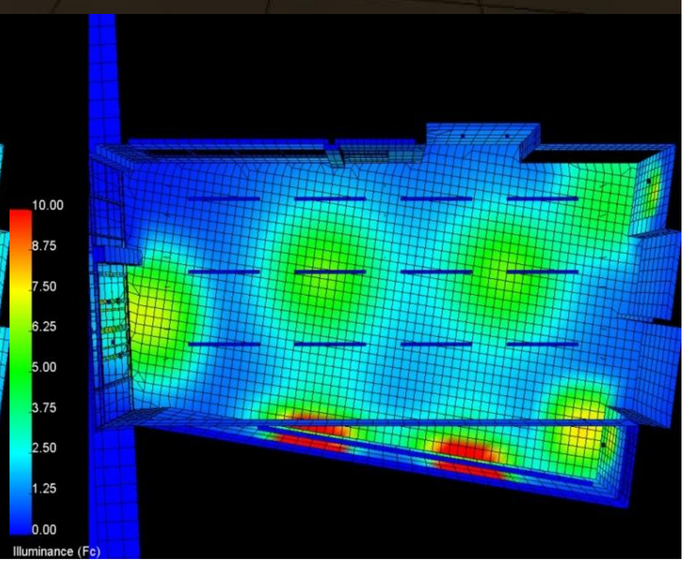




The images below show the interior environment under emergency lighting conditions (furniture removed)

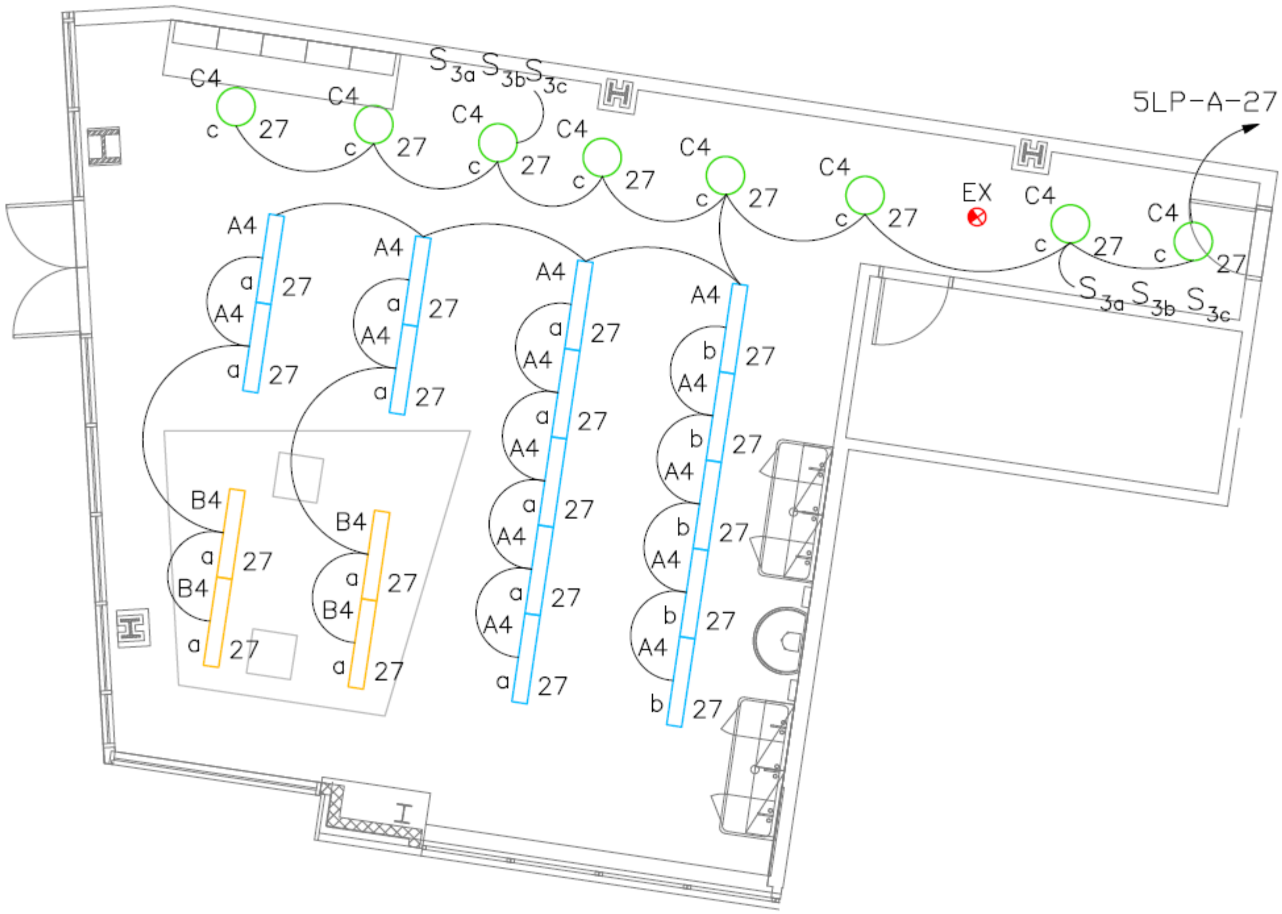






High School Art Room

The plan below shows the layout of the luminaires as well as the locations of the switches for the High School Art Room. Reference the lighting fixture schedule following the plan for information about the lighting fixtures used in the space. To view the view the plan to scale, reference the Appendix D at the end of this report.



Fixture Schedule				
Type			Description	Manufacturer
A4			Single-lamp, **Suspended** linear fluorescent semi-indirect pendant with die-formed specular reflector. Reflector 95% reflective. Aluminum semispecular parabolic louver.	Peerless
B4			Single-lamp, **recessed** linear fluorescent semi-indirect pendant with die-formed specular reflector. Reflector 95% reflective. Aluminum semispecular parabolic louver.	Peerless
C4			Suspended, 26W 3500k compact fluorescent, downlight. 14 ga. Single-piece precision-spun aluminum. 14 ga. Anodized aluminum reflector with diffuse satin matte surface.	Focal Point
EX			Ceiling-Mounted, single-sided exit sign. AC only operation with RED lettering on clear panel. Matte white finish on housing. 8" letters, 1" stroke	Mule Lighting

iii. Existing Panelboard Schedules

Below are the existing panelboards (Normal and Normal/Emergency) that serve the Intermediate School Café. They have been recreated in excel for clarity, and are presented on the next two pages. Circuits serving each space are appropriately colored with each spaces assigned color (see table in section 1b).

JOB:								PANEL CODE–	1(120/208V)	
PANEL:		5LP-A							2(277/480V)	
PANEL CODE:		1							3(265/460V)	
PHASE:		3					LOCATION:	5th Fl Elec Closet		
WIRE:		4					MTD:	Surface		
MAINS AMP:		100		MAIN CB AMP:	100		AIC:	22000		
CIRCUIT		LOAD	LOAD	PHASES			LOAD	LOAD	CIRCUIT	
NO	BKR	DESIGNATION	VA	A	B	C	VA	DESIGNATION	BKR	NO
1	20	RM 505, 511, Ltg	1200	2100			900	Corridor , ltg	20	2
3	20	RM 513, Ltg	700		1100		400	RM 539,541,545, Ltg	20	4
5	20	Spare				400	400	Toilets, Ltg	20	6
7	20	RM 526, Ltg	1100	2000			900	RM 519, ltg	20	8
9	20	RM 519, Ltg	1300		1900		600	RM 523, ltg	20	10
11	20	RM 521,523, Ltg	1300			1900	600	RM 525, ltg	20	12
13	20	RM 525, Ltg	1200	1200				Spare	20	14
15	20	RM 518,522, 524,Ltg	1100		1100			Spare	20	16
17	20	RM 506,508,534, Ltg	800			800		Spare	20	18
19	20	RM 534,536,538, Ltg	800	800				Spare	20	20
21	20	RM 541,546, Ltg	800		1700		900	Roof MER, ltg	20	22
23	20	RM 534, Ltg	400			1000	600	Roof Exterior, ltg	20	24
25	20	Kitchen 534, Ltg	800	1400			600	Roof Exterior, ltg	20	26
27	20	RM 552, Ltg	1300		1900		600	Roof Exterior, ltg	20	28
29	20	RM 547,549,551, Ltg	1000			1000		Spare	20	30
31	20	Spare		0				Spare	20	32
33	20	Spare			0			Spare	20	34
35	20	Spare				0		Spare	20	36
			TOTAL	7500	7700	5100	TOT. KVA	20		
							TOT. AMP	56		
				DEM. DECIMAL		1	DEM.KVA	22		
				SPARE DECIMAL		0.1	DEM.AMP	62		

JOB:								PANEL CODE–	1(120/208V)	
PANEL:		5ELP-LS							2(277/480V)	
PANEL CODE:		1							3(265/460V)	
PHASE:		3					LOCATION:	5th Fl Elec Closet		
WIRE:		4					MTD:	Surface		
MAINS AMP:		100		MAIN CB AMP:	60		AIC:	22000		
CIRCUIT		LOAD	LOAD	PHASES			LOAD	LOAD	CIRCUIT	
NO	BKR	DESIGNATION	VA	A	B	C	VA	DESIGNATION	BKR	NO
1	20	5th fl exit signs	300	900			600	RM 601, 603, 604	20	2
3	20	5th fl Kitchen em ltg	700		700			Spare	20	4
5	20	5th fl HS Cafe em ltg	800			800		Spare	20	6
7	20	5th fl IS Cafe em ltg	500	500				Spare	20	8
9	20	RM 514, 535	300		300			Spare	20	10
11	20	5th fl corridor em ltg	800			800		Spare	20	12
13	20	Terrace ltg	1200	1200				Spare	20	14
15	20	RM 517	400		400			Spare	20	16
17	20	Spare				0		Spare	20	18
			TOTAL	2600	1400	1600	TOT. KVA	6		
							TOT. AMP	16		
				DEM. DECIMAL		1	DEM.KVA	14		
				SPARE DECIMAL		1.5	DEM.AMP	39		

The panelboard below is that which serves normal power to the lighting in the Intermediate School Cafeteria and High School Art Room. All existing lighting for the Intermediate school cafeteria are located on circuit 21 (highlighted in **blue** below), and all lighting fixtures for the High School Art Room are located on circuit 27 (highlighted in **orange**).

PANELBOARD SCHEDULE

Panel:	5LP-A	**BUS:**	100A	**Voltage:**	208/120
Location:	5TH FLR. ELEC. CLOSET	**MCB:**	100A	**Phase:**	3P
Mounting:	SURFACE	**AIC:**	22,000	**Wire:**	4W

CKT NO	**CB**	**LOAD DESCRIPTION**	**Load VA**						**LOAD DESCRIPTION**	**CB**	**CKT NO**
			A		**B**		**C**				
1	20/1	RM 505,511, LTG	1200	900					CORRIDOR, LTG	20/1	2
3	20/1	RM 513, LTG			700	400			RM 539, 541, 545, LTG	20/1	4
5	20/1	SPARE					0	400	TOILETS, LTG	20/1	6
7	20/1	RM 526, LTG	1100	900					RM 519, LTG	20/1	8
9	20/1	RM 519, LTG			1300	600			RM 523, LTG	20/1	10
11	20/1	RM 521,523, LTG					1300	600	RM 535, LTG	20/1	12
13	20/1	RM 525, LTG	1200	*					SPARE	20/1	14
15	20/1	RM 518, 522, 524, LTG			1100	*			SPARE	20/1	16
17	20/1	RM 506, 508, 534, LTG					800	*	SPARE	20/1	18
19	20/1	RM 534, 536, 538, LTG	800	*					SPARE	20/1	20
21	**20/1**	**RM 546, LTG**			**800**	900			ROOF MER, LTG	20/1	22
23	20/1	RM 543, LTG					400	600	ROOF EXTERIOR, LTG	20/1	24
25	20/1	KITCHEN 534, LTG	800	600					ROOF EXTERIOR, LTG	20/1	26
27	**20/1**	**RM 552, LTG**			**1300**	600			ROOF EXTERIOR, LTG	20/1	28
29	20/1	RM 547, 549, 551, LTG					1000	*	SPARE	20/1	30
31	20/1	SPARE	*	*					SPARE	20/1	32
33	20/1	SPARE			*	*			SPARE	20/1	34
35	20/1	SPARE					*	*	SPARE	20/1	36
		VA/PHASE	7500		7700		5100				
		TOTAL [VA]	20300								
		TOTAL [A]	56.39								

The panelboard below is that which serves all emergency fixtures for the 5th floor, which includes both the Intermediate School Cafeteria, and the High School Art Room. Circuit 7 – highlighted in **blue**—contains all emergency lighting fixture in the IS Cafeteria. Circuit 1 – highlighted with a gradient that represents both the Intermediate School Café and the High School Art Room – contains all exit signs for the fifth floor. All exit signs are considered existing to remain, and as such, this circuit will remain unchanged. It is highlighted here for the purposes of showing its consideration. Circuit 13, highlighted in **red**, contains all lighting on the outdoor roof terrace on the fifth floor.

PANELBOARD SCHEDULE

Panel:	5ELP-LS	BUS:	100A	Voltage:	208/120
Location:	5TH FLR. ELEC. CLOSET	MCB:	60A	Phase:	3P
Mounting:	SURFACE	AIC:	22,000	Wire:	4W

CKT NO	CB	LOAD DESCRIPTION	Load VA A		Load VA B		Load VA C		LOAD DESCRIPTION	CB	CKT NO
1	**20/1**	**5TH FL EXIT SIGNS**	**300**	600					RM 601, 603, 604	20/1	2
3	20/1	5TH FL KITCHEN EM LTG			700	*			SPARE	20/1	4
5	20/1	5TH FL HS CAFÉ EM LTG					800	*	SPARE	20/1	6
7	**20/1**	**5TH FL IS CAFÉ EM LTG**	**500**	*					SPARE	20/1	8
9	20/1	RM 514, 535			300	*			SPARE	20/1	10
11	20/1	5TH FL CORRIDOR EM LTG					800	*	SPARE	20/1	12
13	**20/1**	**TERRACE LTG**	**1200**	*					SPARE	20/1	14
15	20/1	RM 517			400	*			SPARE	20/1	16
17	20/1	SPARE					*	*	SPARE	20/1	18
		VA/PHASE	2600		1400		1600				
		TOTAL [VA]	5600								
		TOTAL [A]	15.56								

The following panelboards, 1LP-A and 1ELP-LS, contain all exterior façade lighting. Circuit 21 and 23 of panelboard 1LP-A serves the existing lighting solution which includes step lights recessed into the stone around the perimeter of the building. Circuits 28 and 30 of panelboard 1ELP-LS contain the lighting on the façade of the building near the entrance door and (two) exits of the building.

The first two panelboards shown were snapshotted from my drawings. The second two are reproductions using my own excel panelboard template.

JOB:								PANEL CODE–	1(120/208V)	
PANEL:		1LP–A							2(277/480V)	
PANEL CODE:		1							3(265/460V)	
PHASE:		3					LOCATION:	1st Fl Elec Closet		
WIRE:		4					MTD:	Surface		
MAINS AMP:		100		MAIN CB AMP:		100	AIC:	22000		
CIRCUIT		LOAD	LOAD	PHASES			LOAD	LOAD	CIRCUIT	
NO	BKR	DESIGNATION	VA	A	B	C	VA	DESIGNATION	BKR	NO
1	20	RM 101, 103, Ltg	800	1900			1100	Corridor, Ltg	20	2
3	20	RM 101, 103, Ltg	800		1900		1100	Corridor, Ltg	20	4
5	20	RM 105, Ltg	1200			2300	1100	Stair A	20	6
7	20	RM 102, 134, 106, Ltg	900	2000			1100	Stair B	20	8
9	20	RM 107–109, Ltg	700		1500		800	2nd fl stair C	20	10
11	20	RM 134, 144, Ltg	800			1200	400	Toilets 133	20	12
13	20	RM 145, 141, Ltg	800	800				Spare	20	14
15	20	RM 113–115, Ltg	900		900			Spare	20	16
17	20	RM 121,123,126, Ltg	800			800		Spare	20	18
19	20	RM 118–122, Ltg	900	900				Spare	20	20
21	20	Exterior ltg	900		900			Spare	20	22
23	20	Exterior ltg	900			900		Spare	20	24
25	20	Spare		0				Spare	20	26
27	20	Spare			0			Spare	20	28
29	20	Spare				0		Spare	20	30
			TOTAL	5600	5200	5200	TOT. KVA	16		
							TOT. AMP	44		
				DEM. DECIMAL		1	DEM.KVA	18		
				SPARE DECIMAL		0.1	DEM.AMP	49		

JOB:								PANEL CODE–	1(120/208V)	
PANEL:		1ELP–LS							2(277/480V)	
PANEL CODE:		1							3(265/460V)	
PHASE:		3					LOCATION:	1st Fl Elec Closet		
WIRE:		4					MTD:	Surface		
MAINS AMP:		100		MAIN CB AMP:		100	AIC:	22000		
CIRCUIT		LOAD	LOAD	PHASES			LOAD	LOAD	CIRCUIT	
NO	BKR	DESIGNATION	VA	A	B	C	VA	DESIGNATION	BKR	NO
1	20	1st fl corridor em ltg	1100	1400			300	2nd fl exit signs	20	2
3	20	1st fl corridor em ltg	600		1400		800	2nd fl corridor em ltg	20	4
5	20	1st fl exit signs	300			1300	1000	Library 205	20	6
7	20	1st fl gym em ltg	600	1100			500	RM 230,240	20	8
9	20	RM113,14,17,23,19,33	1100		1300		200	RM 212, 233	20	10
11	20	RM 134, 144	600			1100	500	RM 213	20	12
13	20	Stair A em ltg	1500	1500				Spare	20	14
15	20	Stair B em ltg	1500		1500			Spare	20	16
17	20	Stair C em ltg	800			800		Spare	20	18
19	20	Gym ceiling em ltg	1000	1000				Spare	20	20
21	20	Gym ceiling em ltg	1000		1000			Spare	20	22
23	20	Gym ceiling em ltg	1000			1000		Spare	20	24
25	20	Gym ceiling em ltg	1000	1000				Spare	20	26
27	20	1st fl gym em ltg	600		800		200	Exit door	20	28
29	20	Spare				300	300	Entrace	20	30
			TOTAL	6000	6000	4500	TOT. KVA	17		
							TOT. AMP	46		
				DEM. DECIMAL		1	DEM.KVA	23		
				SPARE DECIMAL		0.4	DEM.AMP	64		

PANELBOARD SCHEDULE					
Panel:	1LP-A	**BUS:**	100A	**Voltage:**	208/120
Location:	1ST FLR ELEC CLOSET	**MCB:**	100A	**Phase:**	3P
Mounting:	SURFACE	**AIC:**	22,000	**Wire:**	4W

CKT NO	**CB**	**LOAD DESCRIPTION**	**Load VA A**		**Load VA B**		**Load VA C**		**LOAD DESCRIPTION**	**CB**	**CKT NO**
1	20/1	RM 101, 103, LTG	800	1100					CORRIDOR, LTG	20/1	2
3	20/1	RM 101, 103, LTG			800	1100			CORRIDOR, LTG	20/1	4
5	20/1	RM 105, LTG					1200	1100	STAIR A	20/1	6
7	20/1	RM 102, 134, 106, LTG	900	1100					STAIR B	20/1	8
9	20/1	RM 107-109 LTG			700	800			2ND FL STAIR C	20/1	10
11	20/1	RM 134, 144, LTG					800	400	TOILETS 133	20/1	12
13	20/1	RM 145, 141, LTG	800	*					SPARE	20/1	14
15	20/1	RM 113-115 LTG			900	*			SPARE	20/1	16
17	20/1	RM 121,123,126, LTG					800	*	SPARE	20/1	18
19	20/1	RM 118-122, LTG	900	*					SPARE	20/1	20
21	**20/1**	**EXTERIOR LTG**			**900**	*			SPARE	20/1	22
23	**20/1**	**EXTERIOR LTG**					**900**	*	SPARE	20/1	24
25	20/1	SPARE	*	*					SPARE	20/1	26
27	20/1	SPARE			*	*			SPARE	20/1	28
29	20/1	SPARE					*	*	SPARE	20/1	30
		VA/PHASE	5600		5200		5200				
		TOTAL [VA]	16000								
		TOTAL [A]	44.44								

PANELBOARD SCHEDULE

Panel:	1ERP-LS	**BUS:**	100A	**Voltage:**	208/120
Location:	1ST FLR ELEC CLOSET	**MCB:**	100A	**Phase:**	3P
Mounting:	SURFACE	**AIC:**	22,000	**Wire:**	4W

CKT NO	**CB**	**LOAD DESCRIPTION**	**Load VA A**		**B**		**C**		**LOAD DESCRIPTION**	**CB**	**CKT NO**
1	20/1	1ST FL CORRDR EM LTG	1100	300					2ND FL EXIT SIGNS	20/1	2
3	20/1	1ST FL CORRDR EM LTG			600	800			2ND FL CORRDR EM LTG	20/1	4
5	20/1	1ST FL EXIT SIGNS					300	1000	LIBRARY 205	20/1	6
7	20/1	1ST FL GYM EM LTG	600	500					RM 230,240	20/1	8
9	20/1	RM 133,14,17,23,19,33			1100	200			RM 212,233	20/1	10
11	20/1	RM 134,144					600	500	RM 213	20/1	12
13	20/1	STAIR A EM LTG	1500	*					SPARE	20/1	14
15	20/1	STAIR B EM LTG			1500	*			SPARE	20/1	16
17	20/1	STAIR C EM LTG					800	*	SPARE	20/1	18
19	20/1	GYM CEILING EM LTG	1000	*					SPARE	20/1	20
21	20/1	GYM CEILING EM LTG			1000	*			SPARE	20/1	22
23	20/1	GYM CEILING EM LTG					1000	*	SPARE	20/1	24
25	20/1	GYM CEILING EM LTG	1000	*					SPARE	20/1	26
27	20/1	1ST FL GYM EM LTG			600	**200**			**EXIT DOOR**	**20/1**	28
29	20/1	SPARE					0	**300**	**ENTRANCE**	**20/1**	30
		VA/PHASE	6000		6000		4500				
		TOTAL [VA]	16500								
		TOTAL [A]	45.83								

iv. Existing dimmer schedules

The existing lighting design for the Façade does not have dimming capabilities.

The existing lighting design for the IS Cafeteria does not have dimming capabilities.

The existing lighting design for the High School Art Room does not have dimming capabilities.

The panels following on the previous pages are that which feed the lighting in the auditorium. These panels, all with dimming capabilities, are connected to a control system that allows lighting to be zoned and dimmed as desired by the lighting consultant. Panel 3ELP-LS is the emergency dimming lighting panel for the space and is the panel that all auditorium emergency lighting is connected to. This panel does not include emergency lighting for other spaces in the building. 3LP-DIM-1 and 3LP-DIM-2 are normal power dimming panels, and power all lighting fixtures in the auditorium that are not deemed emergency. These panels do not include lighting outside of the auditorium space. Panel 3LP-DIM-2 is dedicated entirely to theatrical lighting, which for the sake of complexity and knowledge, has been left existing-to-remain. As such, panel 3LP-DIM-2 has not been altered or changed in any way, and is only shown in this section for the purpose of noting its use in the space. The circuits highlighted on the following panelboards (in green) are that of general purpose lighting only, i.e. non-theatrical lighting fixtures.

PANEL:	3ELP–DIM	DIMMING PANEL		
VOLTAGE	208			
PHASE:	3		Location:	Auditorium
WIRE:	4+G		MTD:	Surface
MAINS AMP:	100	MAIN C.B. None	AIC:	22000

CIRCUIT		CONTROL	FIXTURE		LAMP			WALL	PHASE (W)			Remark
NO	BKR	ZONE	TYPE	QTY	QTY	(W)	TYPE	STATION	A	B	C	
1	20	Note 2	TN	48	1	5	LED	Sd/Skd	240			Step Lits Via Drivers
2	20	On	Exit	5	1	20	LED			100		
3	20	Note 2	TM	12	2	35	Flure	Sa/Ska			840	
4	20	Note 2	TM	8	2	32	Flure	Sb/Skb	512			
5	20	Note 2	TF–1	5	1	50	Flure	Sf/Skf		250		
6	20	Note 2	TL	18	1	35	Flure	Sg/Skg			630	Stage
7	20	Note 2	TN	12	1	5	LED	Se/Ske	60			Step Lits Via Drivers
8	20	ON	TT	2	2	35	Flure	Sc		140		
9	20	Note 2	TN	15	1	5	LED				75	
10	20	Spare							0			
11	20	Spare								0		
12	20	Spare									0	
								KVA / PHASE	812	490	1545	
								AMP / PHASE	2	1	4	
								TOTAL KVA		3		
								TOTAL AMP		8		
								DEM.		1		
								SPARE		4		
								DEM KVA		14		
								DEM AMP		40		

NOTES:
1. REFER TO FIXTURE SPECIFICATION FOR LAMP TYPE.
2. TO BE DETERMINED BT THE LIGHTING CONSULTANT.

JOB:						
PANEL:	3LP-DIM 1	DIMMING PANEL				
VOLTAGE	208					
PHASE:	3				Location:	Auditorium/Stage
WIRE:	4+G				MTD:	Surface
MAINS AMP:	200	MAIN	C.B.	None	AIC:	22000

CIRCUIT		CONTROL	FIXTURE		LAMP			WALL	PHASE (W)			Remark
NO	BKR	ZONE	TYPE	QTY	QTY	(W)	TYPE	STATION	A	B	C	
1	20		TM	8	2	35		Sa/Ska	560			
2	20		TM	4	2	35		Sb/Skb		280		
3	20		TTE	1	1	1500					1500	
4	20		TTE	1	1	1500			1500			
5	20		TTE	1	1	1500				1500		
6	20		TTE	1	1	1500					1500	
7	20		TTE	1	1	1500			1500			
8	20		TTE	1	1	1500				1500		
9	20		TTE	1	1	1500					1500	
10	20		TTE	1	1	1500			1500			
11	20		TTE	1	1	1500				1500		
12	20		TTE	1	1	1500					1500	
13	20		TTE	1	1	1500			1500			
14	20		TTE	1	1	1500				1500		
15	20		TTE	1	1	1500					1500	
16	20		TTE	1	1	1500			1500			
17	20		TTE	1	1	1500				1500		
18	20		TTE	1	1	1500					1500	
19	20		TTH	2	1	750			1500			
20	20		TTH	2	1	750				1500		
21	20		TTH	2	1	750					1500	
22	20		TTH	2	1	750			1500			
23	20		TR	32	1	20	LV	Sc/Skc		640		
24	20		TAA	16	1	50					800	Projection room
25	20		TAA	16	1	50			800			Projection room
26	20		TTD	1	1	1500				1500		Stage floor
27	20		TTD	1	1	1500					1500	Stage floor
28	20		TTD	1	1	1500			1500			Stage floor
29	20		TTD	1	1	1500				1500		Stage floor
30	20		TTD	1	1	1500					1500	Stage floor
31	20		TTD	1	1	1500			1500			Stage floor
32	20		TTD	1	1	1500				1500		Stage floor
33	20		TTD	1	1	1500					1500	Stage floor
34	20		TR	32	1	20	LV	Sc/Skc	640			
35	20		Spare							0		
36	20		Spare								0	
37	20		Spare						0			
38	20		Spare							0		
39	20		Spare								0	
40	20		Spare						0			
41	20		Spare							0		
42	20		Spare								0	
43	20		Spare						0			
44	20		Spare							0		
45	20		Spare								0	
46	20		Spare						0			
47	20		Spare							0		
48	20		Spare								0	
								KVA / PHASE	15500	14420	15800	
								AMP / PHASE	43	40	44	
								TOTAL KVA		46		
								TOTAL AMP		127		
								DEM.		1		

NOTES:

1. REFER TO FIXTURE SPECIFICATION FOR LAMP TYPE.
2. THE CONTROL ZONE TO BE DETERMINED BT THE LIGHTING CONSULTANT.

JOB:					
PANEL:	3LP-DIM 2	DIMMING PANEL			
VOLTAGE	208				
PHASE:	3			Location:	Auditorium/Stage
WIRE:	4+G			MTD:	Surface
MAINS AMP:	200	MAIN C.B.	None	AIC:	22000

CIRCUIT		CONTROL	FIXTURE		LAMP			WALL	PHASE (W)			Remark
NO	BKR	ZONE	TYPE	QTY	QTY	(W)	TYPE	STATION	A	B	C	
1	20		TTA	1	1	1500			1500			Stage
2	20		TTA	1	1	1500				1500		Stage
3	20		TTA	1	1	1500					1500	Stage
4	20		TTA	1	1	1500			1500			Stage
5	20		TTA	1	1	1500				1500		Stage
6	20		TTA	1	1	1500					1500	Stage
7	20		TTA	1	1	1500			1500			Stage
8	20		TTA	1	1	1500				1500		Stage
9	20		TTA	1	1	1500					1500	Stage
10	20		TTA	1	1	1500			1500			Stage
11	20		TTA	1	1	1500				1500		Stage
12	20		TTA	1	1	1500					1500	Stage
13	20		TTA	1	1	1500			1500			Stage
14	20		TTA	1	1	1500				1500		Stage
15	20		TTA	1	1	1500					1500	Stage
16	20		TTA	1	1	1500			1500			Stage
17	20		TTA	1	1	1500				1500		Stage
18	20		TTA	1	1	1500					1500	Stage
19	20		TTA	1	1	1500			1500			Stage
20	20		TTA	1	1	1500				1500		Stage
21	20		TTA	1	1	1500					1500	Stage
22	20		TTA	1	1	1500			1500			Stage
23	20		TTA	1	1	1500				1500		Stage
24	20		TTA	1	1	1500					1500	Stage
25	20		TTA	1	1	1500			1500			Stage
26	20		TTA	1	1	1500				1500		Stage
27	20		TTA	1	1	1500					1500	Stage
28	20		TTA	1	1	1500			1500			Stage
29	20		TTA	1	1	1500				1500		Stage
30	20		TTA	1	1	1500					1500	Stage
31	20		TTA	1	1	1500			1500			Stage
32	20		TTA	1	1	1500				1500		Stage
33	20		TTC	1	3	500					1500	Stage Floor
34	20		TTC	1	3	500			1500			Stage Floor
35	20		TTC	1	3	500				1500		Stage Floor
36	20		TTC	1	3	500					1500	Stage Floor
37	20		TTC	1	3	500			1500			Stage Floor
38	20		TTC	1	3	500				1500		Stage Floor
39	20		TTC	1	3	500					1500	Stage Floor
40	20		TTC	1	3	500			1500			Stage Floor
41	20		Spare							0		
42	20		Spare								0	
43	20		Spare						0			
44	20		Spare							0		
45	20		Spare								0	
46	20		Spare						0			
47	20		Spare							0		
48	20		Spare								0	

	A	B	C
KVA / PHASE	21000	19500	19500
AMP / PHASE	58	54	54
TOTAL KVA		60	
TOTAL AMP		167	
DEM.		0.8	

NOTES:

1. REFER TO FIXTURE SPECIFICATION FOR LAMP TYPE.
2. TO BE DETERMINED BT THE LIGHTING CONSULTANT.

The panels to follow are simply recreations in excel of the existing panelboards. They are shown for clarity as they are more easily readable than those taken from the drawings.

DIMMER PANELBOARD SCHEDULE											
Panel: 3ELP-DIM				BUS: 200A				Voltage: 208/120			
Location: AUDITORIUM				MCB: -				Phase: 3P			
Mounting: SURFACE				AIC: 22,000				Wire: 4W			
CIRCUIT		CONTROL	FIXTURE		LAMP			PHASE (W)			REMARKS
NO	BKR	ZONE	TYPE	QTY	QTY	W	TYPE	A	B	C	
1	**20/1**	**NOTE 1**	**TN**	**48**	**1**	**5**	**LED**	**240**			
2	20/1	ON	EXIT	5	1	20	LED		100		
3	**20/1**	**NOTE 1**	**TM**	**12**	**2**	**35**	**FL**			**840**	
4	**20/1**	**NOTE 1**	**TM**	**8**	**2**	**32**	**FL**	**512**			
5	**20/1**	**NOTE 1**	**TF-1**	**5**	**1**	**50**	**FL**		**250**		
6	**20/1**	**NOTE 1**	**TL**	**18**	**1**	**35**	**FL**			**630**	
7	**20/1**	**NOTE 1**	**TN**	**12**	**1**	**5**	**LED**	**60**			
8	**20/1**	**ON**	**TT**	**2**	**2**	**35**	**FL**		**140**		
9	**20/1**	**NOTE 1**	**TN**	**15**	**1**	**5**	**LED**			**75**	
10	20/1	SPARE						0			
11	20/1	SPARE							0		
12	20/1	SPARE								0	
NOTE 1: TO BE DETERMINED BY LIGHTING CONSULTANT							VA/PHASE	812	490	1545	
							TOTAL [VA]	2847			
							TOTAL [A]	8			

DIMMER PANELBOARD SCHEDULE

Panel: 3LP-DIM-1	BUS: 200A	Voltage: 208/120	
Location: AUDITORIUM/ STAGE	MCB: -	Phase: 3P	
Mounting: SURFACE	AIC: 22,000	Wire: 4W	

CIRCUIT		CONTROL	FIXTURE		LAMP			PHASE (W)			REMARKS
NO	BKR	ZONE	TYPE	QTY	QTY	W	TYPE	A	B	C	
1	**20/1**		**TM**	**8**	**2**	**35**		**560**			
2	**20/1**		**TM**	**4**	**2**	**35**			**280**		
3	20/1		TTE	1	1	1500				1500	
4	20/1		TTE	1	1	1500		1500			
5	20/1		TTE	1	1	1500			1500		
6	20/1		TTE	1	1	1500				1500	
7	20/1		TTE	1	1	1500		1500			
8	20/1		TTE	1	1	1500			1500		
9	20/1		TTE	1	1	1500				1500	
10	20/1		TTE	1	1	1500		1500			
11	20/1		TTE	1	1	1500			1500		
12	20/1		TTE	1	1	1500				1500	
13	20/1		TTE	1	1	1500		1500			
14	20/1		TTE	1	1	1500			1500		
15	20/1		TTE	1	1	1500				1500	
16	20/1		TTE	1	1	1500		1500			
17	20/1		TTE	1	1	1500			1500		
18	20/1		TTE	1	1	1500				1500	
19	20/1		TTH	2	1	750		1500			
20	20/1		TTH	2	1	750			1500		
21	20/1		TTH	2	1	750				1500	
22	20/1		TTH	2	1	750		1500			
23	**20/1**		**TR**	**32**	**1**	**20**			**640**		
24	20/1		TAA	16	1	50				800	

25	20/1		TAA	16	1	50		800			
26	20/1		TTD	1	1	1500			1500		
27	20/1		TTD	1	1	1500				1500	
28	20/1		TTD	1	1	1500		1500			
29	20/1		TTD	1	1	1500			1500		
30	20/1		TTD	1	1	1500				1500	
31	20/1		TTD	1	1	1500		1500			
32	20/1		TTD	1	1	1500			1500		
33	20/1		TTD	1	1	1500				1500	
34	**20/1**		**TR**	**32**	**1**	**20**		**640**			
35	20/1		SPARE						0		
36	20/1		SPARE							0	
37	20/1		SPARE					0			
38	20/1		SPARE						0		
39	20/1		SPARE							0	
40	20/1		SPARE					0			
41	20/1		SPARE						0		
42	20/1		SPARE							0	
43	20/1		SPARE					0			
44	20/1		SPARE						0		
45	20/1		SPARE							0	
46	20/1		SPARE					0			
47	20/1		SPARE						0		
48	20/1		SPARE							0	
							VA/PHASE	15500	14420	15800	
							TOTAL [VA]		45720		
							TOTAL [A]		127		

The panel below, 3LP-DIM-2, is the panel that contains only theatrical fixtures. As such, it is not being redesigned or altered in any way. Note that is contains no green highlights as it contains no normal lighting fixtures.

DIMMER PANELBOARD SCHEDULE

Panel:	3LP-DIM-2	BUS:	200A	Voltage:	208/120
Location:	AUDITORIUM/ STAGE	MCB:	-	Phase:	3P
Mounting:	SURFACE	AIC:	22,000	Wire:	4W

CIRCUIT		CONTROL	FIXTURE		LAMP			PHASE (W)			REMARKS
NO	BKR	ZONE	TYPE	QTY	QTY	W	TYPE	A	B	C	
1	20/1		TTA	1	1	1500		1500			STAGE
2	20/1		TTA	1	1	1500			1500		STAGE
3	20/1		TTA	1	1	1500				1500	STAGE
4	20/1		TTA	1	1	1500		1500			STAGE
5	20/1		TTA	1	1	1500			1500		STAGE
6	20/1		TTA	1	1	1500				1500	STAGE
7	20/1		TTA	1	1	1500		1500			STAGE
8	20/1		TTA	1	1	1500			1500		STAGE
9	20/1		TTA	1	1	1500				1500	STAGE
10	20/1		TTA	1	1	1500		1500			STAGE
11	20/1		TTA	1	1	1500			1500		STAGE
12	20/1		TTA	1	1	1500				1500	STAGE
13	20/1		TTA	1	1	1500		1500			STAGE
14	20/1		TTA	1	1	1500			1500		STAGE
15	20/1		TTA	1	1	1500				1500	STAGE
16	20/1		TTA	1	1	1500		1500			STAGE
17	20/1		TTA	1	1	1500			1500		STAGE
18	20/1		TTA	1	1	1500				1500	STAGE
19	20/1		TTA	1	1	1500		1500			STAGE
20	20/1		TTA	1	1	1500			1500		STAGE
21	20/1		TTA	1	1	1500				1500	STAGE
22	20/1		TTA	1	1	1500		1500			STAGE
23	20/1		TTA	1	1	1500			1500		STAGE
24	20/1		TTA	1	1	1500				1500	STAGE

25	20/1		TTA	1	1	1500		1500			STAGE
26	20/1		TTA	1	1	1500			1500		STAGE
27	20/1		TTA	1	1	1500				1500	STAGE
28	20/1		TTA	1	1	1500		1500			STAGE
29	20/1		TTA	1	1	1500			1500		STAGE
30	20/1		TTA	1	1	1500				1500	STAGE
31	20/1		TTA	1	1	1500		1500			STAGE
32	20/1		TTA	1	1	1500			1500		STAGE
33	20/1		TTC	1	3	500				1500	STAGE FLOOR
34	20/1		TTC	1	3	500		1500			STAGE FLOOR
35	20/1		TTC	1	3	500			1500		STAGE FLOOR
36	20/1		TTC	1	3	500				1500	STAGE FLOOR
37	20/1		TTC	1	3	500		1500			STAGE FLOOR
38	20/1		TTC	1	3	500			1500		STAGE FLOOR
39	20/1		TTC	1	3	500				1500	STAGE FLOOR
40	20/1		TTC	1	3	500		1500			STAGE FLOOR
41	20/1		SPARE						0		
42	20/1		SPARE							0	
43	20/1		SPARE					0			
44	20/1		SPARE						0		
45	20/1		SPARE							0	
46	20/1		SPARE					0			
47	20/1		SPARE						0		
48	20/1		SPARE							0	
							VA/PHASE	21000	19500	19500	
							TOTAL [VA]	60000			
							TOTAL [A]	167			

v. Panelboard Worksheets

1LP-A

PANELBOARD SIZING WORKSHEET										
Panel Tag------------------------->					1LP-A	Panel Location:			1ST FLR ELEC CLOSET	
Nominal Phase to Neutral Voltage------->					120	Phase:			3	
Nominal Phase to Phase Voltage-------->					208	Wires:			4	
Pos	Ph.	Load Type	Cat.	Location	Load	Units	I. PF	Watts	VA	Remarks
1	A	LIGHTING	3	RM 101,103	800	VA	0.90	720	800	
2	A	LIGHTING	3	CORRIDOR	1100	VA	0.90	990	1100	
3	B	LIGHTING	3	RM 101, 103	800	VA	0.90	720	800	
4	B	LIGHTING	3	CORRIDOR	1100	VA	0.90	990	1100	
5	C	LIGHTING	3	RM 105	1200	VA	0.90	1080	1200	
6	C	LIGHTING	3	STAIR A	1100	VA	0.90	990	1100	
7	A	LIGHTING	3	RM 102,134,106	900	VA	0.90	810	900	
8	A	LIGHTING	3	STAIR B	1100	VA	0.90	990	1100	
9	B	LIGHTING	3	RM 107-109	700	VA	0.90	630	700	
10	B	LIGHTING	3	2ND FLR STAIR C	800	VA	0.90	720	800	
11	C	LIGHTING	3	RM 134,144	800	VA	0.90	720	800	
12	C	LIGHTING	3	TOILETS 133	400	VA	0.90	360	400	
13	A	LIGHTING	3	RM 145, 141	800	VA	0.90	720	800	
14	A	SPARE		-	0	VA	0.90	0	0	
15	B	LIGHTING	3	RM 113-115	900	VA	0.90	810	900	
16	B	SPARE		-	0	VA	0.90	0	0	
17	C	LIGHTING	3	RM121,123,126	800	VA	0.90	720	800	
18	C	SPARE		-	0	VA	0.90	0	0	
19	A	LIGHTING	3	RM 118-122	900	VA	0.90	810	900	
20	A	SPARE		-	0	VA	0.90	0	0	
21	B	LTG	3	EXTERIOR	960	VA	0.70	672	960	FAÇADE EXTERIOR
22	B	SPARE		-	0	VA	0.90	0	0	
23	C	SPARE	3	-	0	VA	0.90	0	0	PREVIOUSLY FAÇADE
24	C	SPARE		-	0	VA	0.90	0	0	
25	A	SPARE		-	0	VA	0.90	0	0	
26	A	SPARE		-	0	VA	0.90	0	0	
27	B	SPARE		-	0	VA	0.90	0	0	
28	B	SPARE		-	0	VA	0.90	0	0	
29	C	SPARE		-	0	VA	0.90	0	0	
30	C	SPARE		-	0	VA	0.90	0	0	
PANEL TOTAL								13.5	15.2	Amps= 42.1

PHASE LOADING							kW	kVA	%	Amps
	PHASE TOTAL	A					5.0	5.6	37%	46.7
	PHASE TOTAL	B					4.5	5.3	35%	43.8
	PHASE TOTAL	C					3.9	4.3	28%	35.8
LOAD CATAGORIES			Connected			Demand				Ver. 104
			kW	kVA	DF	kW	kVA	PF		
1	receptacles		0.0	0.0		0.0	0.0			
2	computers		0.0	0.0		0.0	0.0			
3	fluorescent lighting		13.5	15.2	1.00	13.5	15.2	0.89		
4	HID lighting		0.0	0.0		0.0	0.0			
5	incandescent lighting		0.0	0.0		0.0	0.0			
6	HVAC fans		0.0	0.0		0.0	0.0			
7	heating		0.0	0.0		0.0	0.0			
8	kitchen equipment		0.0	0.0		0.0	0.0			
9	unassigned		0.0	0.0		0.0	0.0			
	Total Demand Loads					13.5	15.2			
	Spare Capacity		20%			2.7	3.0			
	Total Design Loads					16.1	18.2	0.89	Amps=	50.5

Default Power Factor =	0.80	
Default Demand Factor =	100	%

PANELBOARD SCHEDULE

VOLTAGE:	208Y/120V,3PH,4W	PANEL TAG:	1LP-A	MIN. C/B AIC:	10K
SIZE/TYPE BUS:	225A	PANEL LOCATION:	1ST FLR ELEC CLOSET	OPTIONS:	PROVIDE FEED THROUGH LUGS
SIZE/TYPE MAIN:	225A/3P C/B	PANEL MOUNTING:	SURFACE		FOR PANELBOARD 1L1B

DESCRIPTION	LOCATION	LOAD (WATTS)	C/B SIZE	POS. NO.	A	B	C	POS. NO.	C/B SIZE	LOAD (WATTS)	LOCATION	DESCRIPTION
LIGHTING	RM 101,103	720	20A/1P	1	*			2	20A/1P	990	CORRIDOR	LIGHTING
LIGHTING	RM 101, 103	720	20A/1P	3		*		4	20A/1P	990	CORRIDOR	LIGHTING
LIGHTING	RM 105	1080	20A/1P	5			*	6	20A/1P	990	STAIR A	LIGHTING
LIGHTING	RM 102,134,106	810	20A/1P	7	*			8	20A/1P	990	STAIR B	LIGHTING
LIGHTING	RM 107-109	630	20A/1P	9		*		10	20A/1P	720	2ND FLR STAIR C	LIGHTING
LIGHTING	RM 134,144	720	20A/1P	11			*	12	20A/1P	360	TOILETS 133	LIGHTING
LIGHTING	RM 145, 141	720	20A/1P	13	*			14	20A/1P	0	-	SPARE
LIGHTING	RM 113-115	810	20A/1P	15		*		16	20A/1P	0	-	SPARE
LIGHTING	RM121,123,126	720	20A/1P	17			*	18	20A/1P	0	-	SPARE
LIGHTING	RM 118-122	810	20A/1P	19	*			20	20A/1P	0	-	SPARE
LTG	EXTERIOR	672	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	0	0	20A/1P	31	*			32	20A/1P	0	0	0
0	0	0	20A/1P	33		*		34	20A/1P	0	0	0
0	0	0	20A/1P	35			*	36	20A/1P	0	0	0
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.	5.04	TOTAL DESIGN LOAD (KW)	16.14
CONNECTED LOAD (KW) - B Ph.	4.54	POWER FACTOR	0.89
CONNECTED LOAD (KW) - C Ph.	3.87	TOTAL DESIGN LOAD (AMPS)	51

1ERP-LS

PANELBOARD SIZING WORKSHEET

Panel Tag------------------------->	1ERP-LS	Panel Location:	5TH FLR ELEC. CLOSET	
Nominal Phase to Neutral Voltage------->	120	Phase:	3	
Nominal Phase to Phase Voltage-------->	208	Wires:	4	

Pos	Ph.	Load Type	Cat.	Location	Load	Units	I. PF	Watts	VA	Remarks
1	A	EM LIGHTING	3	1ST FLR CORRDR	1100	VA	0.90	990	1100	HS Art Room/IS CAFÉ
2	A	EM LIGHTING	3	2ND FLR EXIT SIGNS	300	VA	0.90	270	300	
3	B	EM LIGHTING	3	1ST FLR CORRDR	600	VA	0.90	540	600	
4	B	EM LIGHTING	3	2ND FLR CORRDR	800	VA	0.90	720	800	
5	C	EM LIGHTING	3	1ST FLR EXIT SIGNS	300	VA	0.90	270	300	
6	C	EM LIGHTING	3	LIBRARY 205	1000	VA	0.90	900	1000	
7	A	EM LIGHTING	3	1ST FLR GYM	600	VA	0.90	540	600	
8	A	EM LIGHTING	3	RM 230,240	500	VA	0.90	450	500	
9	B	EM LIGHTING	3	RM133,14,17,23,19,33	1100	VA	0.90	990	1100	
10	B	EM LIGHTING	3	RM 212,233	200	VA	0.90	180	200	
11	C	EM LIGHTING	3	RM 134,144	600	VA	0.90	540	600	
12	C	EM LIGHTING	3	RM 213	500	VA	0.90	450	500	
13	A	EM LIGHTING	3	STAIR A	1500	VA	0.90	1350	1500	
14	A	SPARE		-	0	VA	0.90	0	0	
15	B	EM LIGHTING	3	STAIR B	1500	VA	0.90	1350	1500	
16	B	SPARE		-	0	VA	0.90	0	0	
17	C	EM LIGHTING	3	STAIR C	800	VA	0.90	720	800	
18	C	SPARE		-	0	VA	0.90	0	0	
19	A	EM LIGHTING	3	GYM CEILING	1000	VA	0.90	900	1000	
20	A	SPARE		-	0	VA	0.90	0	0	
21	B	EM LIGHTING	3	GYM CEILING	1000	VA	0.70	700	1000	
22	B	SPARE		-	0	VA	0.90	0	0	
23	C	EM LIGHTING	3	GYM CEILING	1000	VA	0.90	900	1000	
24	C	SPARE		-	0	VA	0.90	0	0	
25	A	EM LIGHTING	3	GYM CEILING	1000	VA	0.90	900	1000	
26	A	SPARE		-	0	VA	0.90	0	0	
27	B	EM LIGHTING	3	1ST FLR GYM	600	VA	0.90	540	600	
28	B	EM LIGHTING	3	EXIT DOOR	42	VA	0.90	38	42	FAÇADE
29	C	SPARE		-	0	VA	0.90	0	0	
30	C	EM LIGHTING	3	ENTRANCE	350	VA	0.90	315	350	FAÇADE
PANEL TOTAL								14.6	16.4	Amps= 45.5

PHASE LOADING						kW	kVA	%	Amps
PHASE TOTAL	A					5.4	6.0	37%	50.0
PHASE TOTAL	B					5.1	5.8	36%	48.7
PHASE TOTAL	C					4.1	4.6	28%	37.9

LOAD CATAGORIES			Connected			Demand				Ver. 104
			kW	kVA	DF	kW	kVA	PF		
1	receptacles		0.0	0.0		0.0	0.0			
2	computers		0.0	0.0		0.0	0.0			
3	fluorescent lighting		14.6	16.4	1.00	14.6	16.4	0.89		
4	HID lighting		0.0	0.0		0.0	0.0			
5	incandescent lighting		0.0	0.0		0.0	0.0			
6	HVAC fans		0.0	0.0		0.0	0.0			
7	heating		0.0	0.0		0.0	0.0			
8	kitchen equipment		0.0	0.0		0.0	0.0			
9	unassigned		0.0	0.0		0.0	0.0			
Total Demand Loads						14.6	16.4			
Spare Capacity			20%			2.9	3.3			
Total Design Loads						17.5	19.7	0.89	Amps=	54.6

Default Power Factor =	0.80	
Default Demand Factor =	100	%

PANELBOARD SCHEDULE

VOLTAGE:	208Y/120V,3PH,4W	PANEL TAG:	1ERP-LS	MIN. C/B AIC:	10K
SIZE/TYPE BUS:	225A	PANEL LOCATION:	5TH FLR ELEC. CLOSET	OPTIONS:	PROVIDE FEED THROUGH LUGS
SIZE/TYPE MAIN:	225A/3P C/B	PANEL MOUNTING:	SURFACE		FOR PANELBOARD 1L1B

DESCRIPTION	LOCATION	LOAD (WATTS)	C/B SIZE	POS. NO.	A	B	C	POS. NO.	C/B SIZE	LOAD (WATTS)	LOCATION	DESCRIPTION
EM LIGHTING	ST FLR CORRD	990	20A/1P	1	*			2	20A/1P	270	D FLR EXIT SIG	EM LIGHTING
EM LIGHTING	ST FLR CORRD	540	20A/1P	3		*		4	20A/1P	720	ND FLR CORRD	EM LIGHTING
EM LIGHTING	T FLR EXIT SIG	270	20A/1P	5			*	6	20A/1P	900	LIBRARY 205	EM LIGHTING
EM LIGHTING	1ST FLR GYM	540	20A/1P	7	*			8	20A/1P	450	RM 230,240	EM LIGHTING
EM LIGHTING	133,14,17,23,1	990	20A/1P	9		*		10	20A/1P	180	RM 212,233	EM LIGHTING
EM LIGHTING	RM 134,144	540	20A/1P	11			*	12	20A/1P	450	RM 213	EM LIGHTING
EM LIGHTING	STAIR A	1350	20A/1P	13	*			14	20A/1P	0	-	SPARE
EM LIGHTING	STAIR B	1350	20A/1P	15		*		16	20A/1P	0	-	SPARE
EM LIGHTING	STAIR C	720	20A/1P	17			*	18	20A/1P	0	-	SPARE
EM LIGHTING	GYM CEILING	900	20A/1P	19	*			20	20A/1P	0	-	SPARE
EM LIGHTING	GYM CEILING	700	20A/1P	21		*		22	20A/1P	0	-	SPARE
EM LIGHTING	GYM CEILING	900	20A/1P	23			*	24	20A/1P	0	-	SPARE
EM LIGHTING	GYM CEILING	900	20A/1P	25	*			26	20A/1P	0	-	SPARE
EM LIGHTING	1ST FLR GYM	540	20A/1P	27		*		28	20A/1P	38	EXIT DOOR	EM LIGHTING
SPARE	-	0	20A/1P	29			*	30	20A/1P	315	ENTRANCE	EM LIGHTING
0	0	0	20A/1P	31	*			32	20A/1P	0	0	0
0	0	0	20A/1P	33		*		34	20A/1P	0	0	0
0	0	0	20A/1P	35			*	36	20A/1P	0	0	0
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.	5.40	TOTAL DESIGN LOAD (KW)	17.46
CONNECTED LOAD (KW) - B Ph.	5.06	POWER FACTOR	0.89
CONNECTED LOAD (KW) - C Ph.	4.10	TOTAL DESIGN LOAD (AMPS)	55

5LP-A

PANELBOARD SIZING WORKSHEET

Panel Tag-------------------------->	5LP-A	Panel Location:	5TH FLR ELEC. CLOSET
Nominal Phase to Neutral Voltage------->	120	Phase:	3
Nominal Phase to Phase Voltage-------->	208	Wires:	4

Pos	Ph.	Load Type	Cat.	Location	Load	Units	I. PF	Watts	VA	Remarks
1	A	LIGHTING	3	RM 505	1200	VA	0.90	1080	1200	
2	A	LIGHTING	3	Corridor	900	VA	0.90	810	900	
3	B	LIGHTING	3	RM 513	700	VA	0.90	630	700	
4	B	LIGHTING	3	RM,539,541,545	400	VA	0.90	360	400	
5	C	LIGHTING	3	-	0	VA	0.90	0	0	
6	C	LIGHTING	3	TOILETS	400	VA	0.90	360	400	
7	A	LIGHTING	3	RM 526	1100	VA	0.90	990	1100	
8	A	LIGHTING	3	RM 519	900	VA	0.90	810	900	
9	B	LIGHTING	3	RM 519	1300	VA	0.90	1170	1300	
10	B	LIGHTING	3	RM 523	600	VA	0.90	540	600	
11	C	LIGHTING	3	RM 521,523	1300	VA	0.90	1170	1300	
12	C	LIGHTING	3	RM 535	600	VA	0.90	540	600	
13	A	LIGHTING	3	RM 525	1200	VA	0.90	1080	1200	
14	A	LIGHTING	3	-	0	VA	0.90	0	0	
15	B	LIGHTING	3	RM 518, 522, 524	1100	VA	0.90	990	1100	
16	B	LIGHTING	3	-	0	VA	0.90	0	0	
17	C	LIGHTING	3	RM 506, 508, 534	800	VA	0.90	720	800	
18	C	LIGHTING	3	-	0	VA	0.90	0	0	
19	A	LIGHTING	3	RM 534,536,538	800	VA	0.90	720	800	
20	A	LIGHTING	3	-	0	VA	0.90	0	0	
21	B	**LIGHTING**	3	RM 546	**1082**	VA	0.70	757	1082	IS Cafeteria
22	B	LIGHTING	3	ROOF MER	900	VA	0.90	810	900	
23	C	LIGHTING	3	RM 543	400	VA	0.90	360	400	
24	C	LIGHTING	3	ROOF EXTERIOR	600	VA	0.90	540	600	
25	A	LIGHTING	3	KITCHEN 534	800	VA	0.90	720	800	
26	A	**LIGHTING**	3	ROOF EXT.	**600**	VA	0.90	540	600	
27	B	LIGHTING	3	RM 552	**1073**	VA	0.90	966	1073	HS Art Room
28	B	LIGHTING	3	ROOF EXT.	600	VA	0.90	540	600	
29	C	LIGHTING	3	RM 547,549,551	1000	VA	0.90	900	1000	
30	C	SPARE		-	0	VA	0.90	0	0	
31	A	SPARE		-	0	VA	0.90	0	0	
32	A	SPARE		-	0	VA	0.90	0	0	
33	B	SPARE		-	0	VA	0.90	0	0	
34	B	SPARE		-	0	VA	0.90	0	0	
35	C	SPARE		-	0	VA	0.90	0	0	
36	C	SPARE		-	0	VA	0.90	0	0	
PANEL TOTAL								18.1	20.4	Amps= 56.5

PHASE LOADING						kW	kVA	%	Amps
PHASE TOTAL	A					6.8	7.5	39%	62.5
PHASE TOTAL	B					5.8	6.7	35%	55.7
PHASE TOTAL	C					4.6	5.1	26%	42.5

LOAD CATAGORIES			Connected			Demand				Ver. 104
			kW	kVA	DF	kW	kVA	PF		
1	receptacles		0.0	0.0		0.0	0.0			
2	computers		0.0	0.0		0.0	0.0			
3	fluorescent lighting		17.1	19.3	1.00	17.1	19.3	0.89		
4	HID lighting		0.0	0.0		0.0	0.0			
5	incandescent lighting		0.0	0.0		0.0	0.0			
6	HVAC fans		0.0	0.0		0.0	0.0			
7	heating		0.0	0.0		0.0	0.0			
8	kitchen equipment		0.0	0.0		0.0	0.0			
9	unassigned		0.0	0.0		0.0	0.0			
Total Demand Loads						17.1	19.3			
Spare Capacity			20%			3.4	3.9			
Total Design Loads						20.6	23.1	0.89	Amps=	64.3

Default Power Factor =	0.80	
Default Demand Factor =	100	%

PANELBOARD SCHEDULE

VOLTAGE:	208Y/120V,3PH,4W	PANEL TAG:	5LP-A	MIN. C/B AIC:	10K
SIZE/TYPE BUS:	225A	PANEL LOCATION:	5TH FLR ELEC. CLOSET	OPTIONS:	PROVIDE FEED THROUGH LUGS
SIZE/TYPE MAIN:	225A/3P C/B	PANEL MOUNTING:	SURFACE		FOR PANELBOARD 1L1B

DESCRIPTION	LOCATION	LOAD (WATTS)	C/B SIZE	POS. NO.	A	B	C	POS. NO.	C/B SIZE	LOAD (WATTS)	LOCATION	DESCRIPTION
LIGHTING	RM 505	1080	20A/1P	1	*			2	20A/1P	810	Corridor	LIGHTING
LIGHTING	RM 513	630	20A/1P	3		*		4	20A/1P	360	RM,539,541,545	LIGHTING
LIGHTING	-	0	20A/1P	5			*	6	20A/1P	360	TOILETS	LIGHTING
LIGHTING	RM 526	990	20A/1P	7	*			8	20A/1P	810	RM 519	LIGHTING
LIGHTING	RM 519	1170	20A/1P	9		*		10	20A/1P	540	RM 523	LIGHTING
LIGHTING	RM 521,523	1170	20A/1P	11			*	12	20A/1P	540	RM 535	LIGHTING
LIGHTING	RM 525	1080	20A/1P	13	*			14	20A/1P	0	-	LIGHTING
LIGHTING	RM 518, 522, 52	990	20A/1P	15		*		16	20A/1P	0	-	LIGHTING
LIGHTING	RM 506, 508, 53	720	20A/1P	17			*	18	20A/1P	0	-	LIGHTING
LIGHTING	RM 534,536,538	720	20A/1P	19	*			20	20A/1P	0	-	LIGHTING
LIGHTING	**RM 546**	**757**	20A/1P	21		*		22	20A/1P	810	ROOF MER	LIGHTING
LIGHTING	RM 543	360	20A/1P	23			*	24	20A/1P	540	ROOF EXTERIOR	LIGHTING
LIGHTING	KITCHEN 534	720	20A/1P	25	*			26	20A/1P	**540**	**ROOF EXT.**	**LIGHTING**
LIGHTING	**RM 552**	**966**	20A/1P	27		*		28	20A/1P	540	ROOF EXT.	LIGHTING
LIGHTING	RM 547,549,551	900	20A/1P	29			*	30	20A/1P	0	-	SPARE
SPARE	-	0	20A/1P	31	*			32	20A/1P	0	-	SPARE
SPARE	-	0	20A/1P	33		*		34	20A/1P	0	-	SPARE
SPARE	-	0	20A/1P	35			*	36	20A/1P	0	-	SPARE
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.	6.75	TOTAL DESIGN LOAD (KW)	21.72
CONNECTED LOAD (KW) - B Ph.	6.76	POWER FACTOR	0.89
CONNECTED LOAD (KW) - C Ph.	4.59	TOTAL DESIGN LOAD (AMPS)	68

5ELP-LS

PANELBOARD SIZING WORKSHEET

Panel Tag-------------------------->	5ELP-LS	Panel Location:	5TH FLR ELEC. CLOSET
Nominal Phase to Neutral Voltage------->	120	Phase:	3
Nominal Phase to Phase Voltage-------->	208	Wires:	4

Pos	Ph.	Load Type	Cat.	Location	Load	Units	I. PF	Watts	VA	Remarks
1	A	**EM LIGHTING**	3	5TH FLR	300	VA	0.90	270	300	HS Art Room/IS CAFÉ
2	A	EM LIGHTING	3	RM 601,603,604	600	VA	0.90	540	600	
3	B	EM LIGHTING	3	5TH FLR KITCHEN	700	VA	0.90	630	700	
4	B	SPARE		-	0	VA	0.90	0	0	
5	C	EM LIGHTING	3	5TH FLR HS CAFÉ	800	VA	0.90	720	800	
6	C	SPARE		-	0	VA	0.90	0	0	
7	A	**EM LIGHTING**	3	5TH FLR IS CAFÉ	360	VA	0.90	324	360	IS CAFÉ
8	A	SPARE		-	0	VA	0.90	0	0	
9	B	EM LIGHTING	3	RM 514,535	300	VA	0.90	270	300	
10	B	SPARE		-	0	VA	0.90	0	0	
11	C	EM LIGHTING	3	5TH FLR CORRDR	800	VA	0.90	720	800	
12	C	SPARE		-	0	VA	0.90	0	0	
13	A	**EM LIGHTING**	3	TERRACE	1458	VA	0.90	1312	1458	TERRACE
14	A	SPARE		-	0	VA	0.90	0	0	
15	B	EM LIGHTING	3	RM 517	400	VA	0.90	360	400	
16	B	SPARE		-	0	VA	0.90	0	0	
17	C	SPARE		-	0	VA	0.90	0	0	
18	C	SPARE		-	0	VA	0.90	0	0	
PANEL TOTAL								5.1	5.7	Amps= 15.9

PHASE LOADING						kW	kVA	%	Amps
PHASE TOTAL	A					2.4	2.7	48%	22.7
PHASE TOTAL	B					1.3	1.4	24%	11.7
PHASE TOTAL	C					1.4	1.6	28%	13.3

LOAD CATAGORIES			Connected			Demand				Ver. 104
			kW	kVA	DF	kW	kVA	PF		
1	receptacles		0.0	0.0		0.0	0.0			
2	computers		0.0	0.0		0.0	0.0			
3	fluorescent lighting		5.1	5.7	1.00	5.1	5.7	0.90		
4	HID lighting		0.0	0.0		0.0	0.0			
5	incandescent lighting		0.0	0.0		0.0	0.0			
6	HVAC fans		0.0	0.0		0.0	0.0			
7	heating		0.0	0.0		0.0	0.0			
8	kitchen equipment		0.0	0.0		0.0	0.0			
9	unassigned		0.0	0.0		0.0	0.0			
Total Demand Loads						5.1	5.7			
Spare Capacity			20%			1.0	1.1			
Total Design Loads						6.2	6.9	0.90	Amps=	19.1

Default Power Factor =	0.80	
Default Demand Factor =	100	%

PANELBOARD SCHEDULE

VOLTAGE:	208Y/120V,3PH,4W	PANEL TAG:	5ELP-LS	MIN. C/B AIC:	10K
SIZE/TYPE BUS:	225A	PANEL LOCATION:	5TH FLR ELEC. CLOSET	OPTIONS:	PROVIDE FEED THROUGH LUGS
SIZE/TYPE MAIN:	225A/3P C/B	PANEL MOUNTING:	SURFACE		FOR PANELBOARD 1L1B

DESCRIPTION	LOCATION	LOAD (WATTS)	C/B SIZE	POS. NO.	A	B	C	POS. NO.	C/B SIZE	LOAD (WATTS)	LOCATION	DESCRIPTION
EM LIGHTING	5TH FLR	270	20A/1P	1	*			2	20A/1P	540	RM 601,603,604	EM LIGHTING
EM LIGHTING	TH FLR KITCHE	630	20A/1P	3		*		4	20A/1P	0	-	SPARE
EM LIGHTING	TH FLR HS CAF	720	20A/1P	5			*	6	20A/1P	0	-	SPARE
EM LIGHTING	TH FLR IS CAF	324	20A/1P	7	*			8	20A/1P	0	-	SPARE
EM LIGHTING	RM 514,535	270	20A/1P	9		*		10	20A/1P	0	-	SPARE
EM LIGHTING	TH FLR CORRD	720	20A/1P	11			*	12	20A/1P	0	-	SPARE
EM LIGHTING	TERRACE	1312	20A/1P	13	*			14	20A/1P	0	-	SPARE
EM LIGHTING	RM 517	360	20A/1P	15		*		16	20A/1P	0	-	SPARE
SPARE	-	0	20A/1P	17			*	18	20A/1P	0	-	SPARE
0	0	0	20A/1P	19	*			20	20A/1P	0	0	0
0	0	0	20A/1P	21		*		22	20A/1P	0	0	0
0	0	0	20A/1P	23			*	24	20A/1P	0	0	0
0	0	0	20A/1P	25	*			26	20A/1P	0	0	0
0	0	0	20A/1P	27		*		28	20A/1P	0	0	0
0	0	0	20A/1P	29			*	30	20A/1P	0	0	0
0	0	0	20A/1P	31	*			32	20A/1P	0	0	0
0	0	0	20A/1P	33		*		34	20A/1P	0	0	0
0	0	0	20A/1P	35			*	36	20A/1P	0	0	0
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.	2.45	TOTAL DESIGN LOAD (KW)	6.18
CONNECTED LOAD (KW) - B Ph.	1.26	POWER FACTOR	0.90
CONNECTED LOAD (KW) - C Ph.	1.44	TOTAL DESIGN LOAD (AMPS)	19

vi. Revised Panelboard Schedules / Dimming Panels

This section shows the changes made to the existing electrical panelboards to accommodate the new lighting design. Each affected circuit is highlighted, in color, according to the space that it feeds. The color of the highlight corresponds to the color assigned to each space under the electrical section "1b. Panelboards." Before each panelboard, the electrical calculation for each circuit is presented. This is to show how the load for each circuit was calculated. The tables below (4 in total, 1 for each space), show information regarding the luminaire which includes: type, lamp, quantity, watts per fixture, total consumed wattage (for all fixtures of that type in the space), power factor, volt-amps per fixture, and total consumed volt-amps (for all fixtures of that type in the space). The values presented in this table those which were used to calculate branch circuit load. See individual panelboards for details.

FAÇADE VA CALCULATION								
Location	Type	Lamp	Qty	W/Fixture	Total Watts	PF	VA/Fixture	Total VA
Façade	A1	LED	168 ft	4 W/ft	672	0.7	5.7 VA/ft	960
	B1	(1) F32T8	1	38	38	0.9	42	42
	C1	LED	50 ft	2.4 W/ft	120	0.7	3.9 VA/ft	171
	D1	LED	24 ft	4.5 W/ft	108	0.7	6.4 W/ft	154
Terrace	F1	(1) PSMH	7	164	1312	0.9	182	1458

AUDITORIUM VA CALCULATION								
Location	Type	Lamp	Qty	W/Fixture	Total Watts	PF	VA/Fixture	Total VA
Auditorium	A2	(1) F32T8	20	38	760	0.9	42	844
	B2	(1) F32T8	12	38	456	0.9	42	507
	C2	(1) 32CFTR	4	36	144	0.9	40	160
	D2	(1) F32T8	16	38	608	0.9	42	676
	EX	LED	2	5	10	0.7	7	14

IS CAFETERIA VA CALCULATION								
Location	Type	Lamp	Qty	W/Fixture	Total Watts	PF	VA/Fixture	Total VA
IS Café	A3	(1) F32T8	24	38	912	0.9	42	1013
	B3	(1) F32T8	10	38	380	0.9	42	422
	C3	LED	6	9	54	0.7	13	77
	EX	LED	2	5	10	0.7	7	14

HS ART ROOM VA CALCULATION								
Location	Type	Lamp	Qty	W/Fixture	Total Watts	PF	VA/Fixture	Total VA
HS Art Room	A4	(1) F32T8	14	38	532	0.9	42	591
	B4	(1) F32T8	4	38	152	0.9	42	169
	C4	(1) 32CFTR	8	35	280	0.9	39	311
	EX	LED	1	5	5	0.7	7	7

PNL 5LP-A, CKT. 21

Total VA = (# Type A Luminaires)*(VA / Luminaire) + (# Type B luminaires)*(VA/luminaires) + (# Type C luminaires)*(VA/Luminaire)

Total VA = (20)(38)+(8)(38)+ (2)(9) = 1082VA

PNL 5LP-A, CKT. 27

Total VA = (# Type A1 Luminaires)*(VA / Luminaire) + (# Type A2 luminaires)*(VA/luminaires) + (# Type B luminaires)*(VA/Luminaire)

Total VA = (14)(42)+(4)(42)+ (8)(39) = 1078VA

PANELBOARD SCHEDULE

Panel:	5LP-A	**BUS:**	100A	**Voltage:**	208/120
Location:	5TH FLR. ELEC. CLOSET	**MCB:**	100A	**Phase:**	3P
Mounting:	SURFACE	**AIC:**	22,000	**Wire:**	4W

CKT NO	**CB**	**LOAD DESCRIPTION**	**Load VA A**		**Load VA B**		**Load VA C**		**LOAD DESCRIPTION**	**CB**	**CKT NO**
1	20/1	RM 505,511, LTG	1200	900					CORRIDOR, LTG	20/1	2
3	20/1	RM 513, LTG			700	400			RM 539, 541, 545, LTG	20/1	4
5	20/1	SPARE					0	400	TOILETS, LTG	20/1	6
7	20/1	RM 526, LTG	1100	900					RM 519, LTG	20/1	8
9	20/1	RM 519, LTG			1300	600			RM 523, LTG	20/1	10
11	20/1	RM 521,523, LTG					1300	600	RM 535, LTG	20/1	12
13	20/1	RM 525, LTG	1200	*					SPARE	20/1	14
15	20/1	RM 518, 522, 524, LTG			1100	*			SPARE	20/1	16
17	20/1	RM 506, 508, 534, LTG					800	*	SPARE	20/1	18
19	20/1	RM 534, 536, 538, LTG	800	*					SPARE	20/1	20
21	**20/1**	**RM 546, LTG**			**1082**	900			ROOF MER, LTG	20/1	22
23	20/1	RM 543, LTG					400	600	ROOF EXTERIOR, LTG	20/1	24
25	20/1	KITCHEN 534, LTG	800	600					ROOF EXTERIOR, LTG	20/1	26
27	**20/1**	**RM 552, LTG**			**1078**	600			ROOF EXTERIOR, LTG	20/1	28
29	20/1	RM 547, 549, 551, LTG					1000	*	SPARE	20/1	30
31	20/1	SPARE	*	*					SPARE	20/1	32
33	20/1	SPARE			*	*			SPARE	20/1	34
35	20/1	SPARE					*	*	SPARE	20/1	36
		VA/PHASE	7500		7760		5100				
		TOTAL [VA]	20360								
		TOTAL [A]	56.56								

PNL 5ELP-LS, CKT. 1

Load and wiring for circuit 1 is existing-to-remain. It is highlighted here to show that is has been considered. Locations and quantity of exit signs will remain unchanged, and as such, the circuit that contains them will remain unchanged. Notice that this circuit is highlighted with a gradient of two colors as it supplies the exit signs for two of my spaces—IS Cafeteria and HS Art Room.

PNL 5ELP-LS, CKT. 7

Total VA = (# Type A Luminaires)*(VA / Luminaire) + (# Type B luminaires)*(VA/luminaires) + (# Type C luminaires)*(VA/Luminaire)

Total VA = (2)(42)+(2)(42)+(4)(13) = 220 VA

PNL 5ELP-LS, CKT. 13

Total VA = (# Type F1 Luminaires)*(VA / Luminaire) = (# Type D1 Luminaires)*[(Watts/Fixture) / PF]

Total VA = (8)*(164 / 0.9) = (8) * (193)

Total VA = 1458 VA

PANELBOARD SCHEDULE

Panel:	5ELP-LS	BUS:	100A	Voltage:	208/120
Location:	5TH FLR. ELEC. CLOSET	MCB:	60A	Phase:	3P
Mounting:	SURFACE	AIC:	22,000	Wire:	4W

CKT NO	CB	LOAD DESCRIPTION	Load VA A		Load VA B		Load VA C		LOAD DESCRIPTION	CB	CKT NO
1	**20/1**	**5TH FL EXIT SIGNS**	**300**	600					RM 601, 603, 604	20/1	2
3	20/1	5TH FL KITCHEN EM LTG			700	*			SPARE	20/1	4
5	20/1	5TH FL HS CAFÉ EM LTG					800	*	SPARE	20/1	6
7	**20/1**	**5TH FL IS CAFÉ EM LTG**	**362**	*					SPARE	20/1	8
9	20/1	RM 514, 535			300	*			SPARE	20/1	10
11	20/1	5TH FL CORRIDOR EM LTG					800	*	SPARE	20/1	12
13	**20/1**	**TERRACE LTG**	**1458**	*					SPARE	20/1	14
15	20/1	RM 517			400	*			SPARE	20/1	16
17	20/1	SPARE					*	*	SPARE	20/1	18
		VA/PHASE	2720		1400		1600				
		TOTAL [VA]	5720								
		TOTAL [A]	15.89								

PNL 1LP-A, CKT. 21

Total VA = (Length of A1 fixture)*(VA / ft)

Total VA = (168 ft)(5.7 VA/ft) = 960 VA

PNL 1LP-A, CKT. 23

This circuit, which was originally occupied by exterior lighting, is no longer being used. It is highlighted to show that is has had the lighting load removed from it, and converted to a spare circuit. A single circuit, circuit 21 in this case, is sufficient enough to contain my exterior lighting design.

PANELBOARD SCHEDULE

Panel:	1LP-A	**BUS:**	100A	**Voltage:**	208/120
Location:	1ST FLR ELEC CLOSET	**MCB:**	100A	**Phase:**	3P
Mounting:	SURFACE	**AIC:**	22,000	**Wire:**	4W

CKT NO	CB	LOAD DESCRIPTION	Load VA						LOAD DESCRIPTION	CB	CKT NO
			A		B		C				
1	20/1	RM 101, 103, LTG	800	1100					CORRIDOR, LTG	20/1	2
3	20/1	RM 101, 103, LTG			800	1100			CORRIDOR, LTG	20/1	4
5	20/1	RM 105, LTG					1200	1100	STAIR A	20/1	6
7	20/1	RM 102, 134, 106, LTG	900	1100					STAIR B	20/1	8
9	20/1	RM 107-109 LTG			700	800			2ND FL STAIR C	20/1	10
11	20/1	RM 134, 144, LTG					800	400	TOILETS 133	20/1	12
13	20/1	RM 145, 141, LTG	800	*					SPARE	20/1	14
15	20/1	RM 113-115 LTG			900	*			SPARE	20/1	16
17	20/1	RM 121,123,126, LTG					800	*	SPARE	20/1	18
19	20/1	RM 118-122, LTG	900	*					SPARE	20/1	20
21	**20/1**	**EXTERIOR LTG**			**960**	*			SPARE	20/1	22
23	**20/1**	**SPARE**					*****	*	SPARE	20/1	24
25	20/1	SPARE	*	*					SPARE	20/1	26
27	20/1	SPARE			*	*			SPARE	20/1	28
29	20/1	SPARE					*	*	SPARE	20/1	30
		VA/PHASE	5600		5260		4300				
		TOTAL [VA]	15160								
		TOTAL [A]	42.11								

PNL 1ERP-LS, CKT. 28

Total VA = (# B1 Fixtures)*(VA / Fixture)

Total VA = (1 fixture)(42 VA/fixture) = 42 VA.

PNL 1ERP-LS, CKT. 30

Total VA = (Length of C1 fixture)*(VA / ft) + (Length of D1 fixture)*(VA / ft) VA / Fixture)

Total VA = (50 ft)(3.9 VA/ft) + (24 ft)*(6.4 VA/ft) = 350 VA

PANELBOARD SCHEDULE

Panel:	1ERP-LS	**BUS:**	100A	**Voltage:**	208/120
Location:	1ST FLR ELEC CLOSET	**MCB:**	100A	**Phase:**	3P
Mounting:	SURFACE	**AIC:**	22,000	**Wire:**	4W

CKT NO	CB	LOAD DESCRIPTION	Load VA A		Load VA B		Load VA C		LOAD DESCRIPTION	CB	CKT NO
1	20/1	1ST FL CORRDR EM LTG	1100	300					2ND FL EXIT SIGNS	20/1	2
3	20/1	1ST FL CORRDR EM LTG			600	800			2ND FL CORRDR EM LTG	20/1	4
5	20/1	1ST FL EXIT SIGNS					300	1000	LIBRARY 205	20/1	6
7	20/1	1ST FL GYM EM LTG	600	500					RM 230,240	20/1	8
9	20/1	RM 133,14,17,23,19,33			1100	200			RM 212,233	20/1	10
11	20/1	RM 134,144					600	500	RM 213	20/1	12
13	20/1	STAIR A EM LTG	1500	*					SPARE	20/1	14
15	20/1	STAIR B EM LTG			1500	*			SPARE	20/1	16
17	20/1	STAIR C EM LTG					800	*	SPARE	20/1	18
19	20/1	GYM CEILING EM LTG	1000	*					SPARE	20/1	20
21	20/1	GYM CEILING EM LTG			1000	*			SPARE	20/1	22
23	20/1	GYM CEILING EM LTG					1000	*	SPARE	20/1	24
25	20/1	GYM CEILING EM LTG	1000	*					SPARE	20/1	26
27	20/1	1ST FL GYM EM LTG			600	**42**			**EXIT DOOR**	**20/1**	28
29	20/1	SPARE					*	**350**	**ENTRANCE**	**20/1**	30
		VA/PHASE	6000		5842		4550				
		TOTAL [VA]	16392								
		TOTAL [A]	45.53								

PNL 3ELP-DIM, CKT. 1

Total VA = (# D2 Fixtures)*(VA / Fixture)

Total VA = (4 fixture)(42 VA/fixture) = 169 VA.

PNL 3ELP-DIM, CKT. 3

Total VA = (# B2 Fixtures)*(VA / Fixture)

Total VA = (12 fixture)(42 VA/fixture) = 504 VA.

PNL 3ELP-DIM, CKT. 4

Total VA = (# C2 Fixtures)*(VA / Fixture)

Total VA = (4 fixture)(40 VA/fixture) = 160 VA.

DIMMER PANELBOARD SCHEDULE

Panel:	3ELP-DIM	BUS:	200A	Voltage:	208/120
Location:	AUDITORIUM	MCB:	-	Phase:	3P
Mounting:	SURFACE	AIC:	22,000	Wire:	4W

CIRCUIT		CONTROL	FIXTURE		LAMP			PHASE (VA)			REMARKS
NO	BKR	ZONE	TYPE	QTY	QTY	W	TYPE	A	B	C	
1	**20/1**	**ae**	**D2**	**4**	**1**	**38**	**FL**	**169**			
2	20/1	ON	EXIT	5	1	5	LED		25		
3	**20/1**	**be**	**B2**	**12**	**1**	**38**	**FL**			**507**	
4	**20/1**	**ON**	**C2**	**4**	**1**	**36**	**FL**	**160**			
5	20/1		SPARE						0		
6	20/1		SPARE							0	
7	20/1		SPARE					0			
8	20/1		SPARE						0		
9	20/1		SPARE							0	
10	20/1		SPARE					0			
11	20/1		SPARE						0		
12	20/1		SPARE							0	
							VA/PHASE	328.89	25	506.67	
							TOTAL [VA]	860.5555556			
							TOTAL [A]	2			

PNL 3LP-DIM-1, CKT. 1
Total VA = (# D2 Fixtures)*(VA / Fixture)
Total VA = (12 fixture)(42 VA/fixture) = 507 VA.

PNL 3LP-DIM-1, CKT. 2
Total VA = (# A2 Fixtures)*(VA / Fixture)
Total VA = (5 fixture)(42 VA/fixture) = 211 VA.

PNL 3LP-DIM-1, CKT. 23
Total VA = (# A2 Fixtures)*(VA / Fixture)
Total VA = (5 fixture)(42 VA/fixture) = 211 VA.

PNL 3LP-DIM-1, CKT. 34
Total VA = (# A2 Fixtures)*(VA / Fixture)
Total VA = (5 fixture)(42 VA/fixture) = 211 VA.

PNL 3LP-DIM-1, CKT. 35
Total VA = (# A2 Fixtures)*(VA / Fixture)
Total VA = (5 fixture)(42 VA/fixture) = 211 VA.

DIMMER PANELBOARD SCHEDULE

Panel:	3LP-DIM-1	BUS:	200A	Voltage:	208/120
Location:	AUDITORIUM/ STAGE	MCB:	-	Phase:	3P
Mounting:	SURFACE	AIC:	22,000	Wire:	4W

CIRCUIT		CONTROL	FIXTURE		LAMP			PHASE (W)			REMARKS
NO	BKR	ZONE	TYPE	QTY	QTY	W	TYPE	A	B	C	
1	**20/1**	**a**	**D2**	**12**	**1**	**38**	**FL**	**507**			
2	**20/1**	**c**	**A2**	**5**	**1**	**38**	**FL**		**211**		
3	20/1		TTE	1	1	1500				1500	
4	20/1		TTE	1	1	1500		1500			
5	20/1		TTE	1	1	1500			1500		
6	20/1		TTE	1	1	1500				1500	
7	20/1		TTE	1	1	1500		1500			
8	20/1		TTE	1	1	1500			1500		
9	20/1		TTE	1	1	1500				1500	
10	20/1		TTE	1	1	1500		1500			
11	20/1		TTE	1	1	1500			1500		
12	20/1		TTE	1	1	1500				1500	
13	20/1		TTE	1	1	1500		1500			
14	20/1		TTE	1	1	1500			1500		
15	20/1		TTE	1	1	1500				1500	
16	20/1		TTE	1	1	1500		1500			

17	20/1		TTE	1	1	1500			1500		
18	20/1		TTE	1	1	1500				1500	
19	20/1		TTH	2	1	750		1500			
20	20/1		TTH	2	1	750			1500		
21	20/1		TTH	2	1	750				1500	
22	20/1		TTH	2	1	750		1500			
23	**20/1**	**d**	**A2**	**5**	**1**	**38**	**FL**		**211**		
24	20/1		TAA	16	1	50				800	
25	20/1		TAA	16	1	50		800			
26	20/1		TTD	1	1	1500			1500		
27	20/1		TTD	1	1	1500				1500	
28	20/1		TTD	1	1	1500		1500			
29	20/1		TTD	1	1	1500			1500		
30	20/1		TTD	1	1	1500				1500	
31	20/1		TTD	1	1	1500		1500			
32	20/1		TTD	1	1	1500			1500		
33	20/1		TTD	1	1	1500				1500	
34	**20/1**	**f**	**A2**	**5**	**1**	**38**	**FL**	**211**			
35	**20/1**	**g**	**A2**	**5**	**1**	**38**	**FL**		**211**		
36	20/1		SPARE							0	
37	20/1		SPARE					0			
38	20/1		SPARE						0		
39	20/1		SPARE							0	
40	20/1		SPARE					0			
41	20/1		SPARE						0		
42	20/1		SPARE							0	
43	20/1		SPARE					0			
44	20/1		SPARE						0		
45	20/1		SPARE							0	
46	20/1		SPARE					0			
47	20/1		SPARE						0		
48	20/1		SPARE							0	
							VA/PHASE	15018	14133	15800	
							TOTAL [VA]	44951.11111			
							TOTAL [A]	124.9			

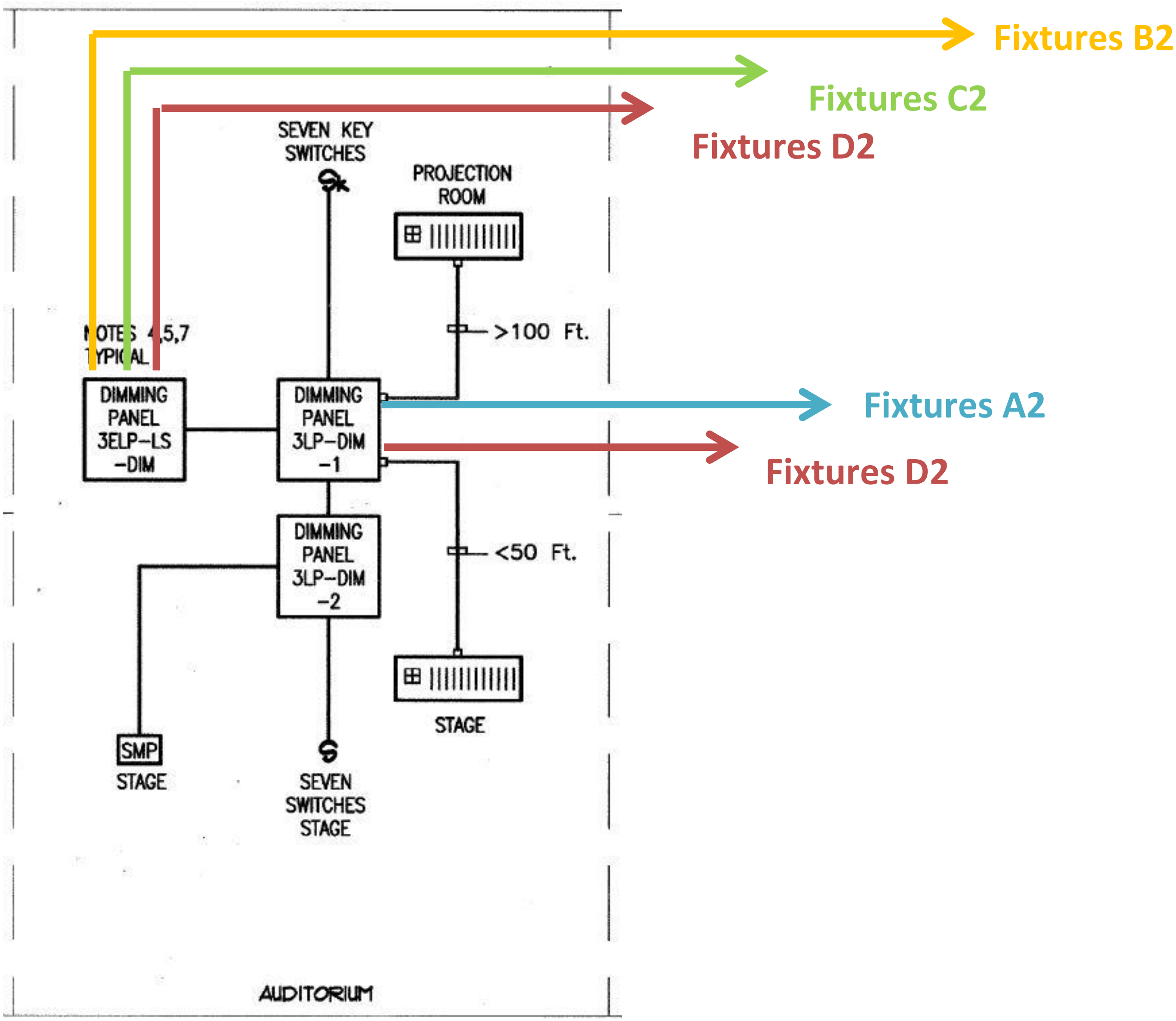
vii. New Dimming wiring diagram

The façade luminaires do not have dimming capabilities.

The Intermediate School Cafeteria luminaires do not have dimming capabilities

The High School Art Room does not have dimming capabilities.

The diagram below shows the dimming wiring diagram for the auditorium. Panels 3LP-DIM-1 and 3LP-DIM-2 are fed from MS2 which is a normal power feed. Panel 3ELP-LS-DIM is fed from 3EDP-LS and is a normal/emergency power feed. The diagram below indicates the fixtures to be fed.



viii. Resize Panelboard Feeder

The table below shows the method with which the spares and spaces were calculated into the feeder sizing. Each spare was taken at 65% of its rating, which came to 13 amps for all of the 20 amp branch circuits. No panelboards had any spaces, so it had no contribution to the overall load.

FEEDER		CONNECTED	SPARES			SPACES		TOTAL
TAG	PNL	LOAD	#	BKR [A]	LOAD [A]	#	LOAD [A]	LOAD
1	1ELP-LS	45.53	8	20	13	0	10	149.53
2	1LP-A	42.11	13	20	13	0	10	211.11
3	3LP-DIM1	124.9	13	20	13	0	10	293.9
4	3ELP-DIM	2	8	20	13	0	10	106
5	5LP-A	56.56	11	20	13	0	10	199.56
6	5ELP-LS	15.89	9	20	13	0	10	132.89

The table below shows the feeder schedule for all of the feeders resized feeders.

FEEDER SCHEDULE														
FEEDER INFO				CONDUIT (PER SET)		CONDUCTORS (PER SET)								
						PHASE CONDUCTORS			NEUTRAL CONDUCTORS			GROUND CONDUCTORS		
TAG	FROM	TO	# SETS	SIZE	TYPE	No.	SIZE	TYPE	No.	SIZE	TYPE	No.	SIZE	TYPE
1	1EDP-LS	1ELP-LS	1	2"	EMT	3	1/0	CU THWN	1	1/0	CU THWN	1	6	CU THWN
2	MS2	1LP-A	1	2 1/2"	EMT	3	4/0	CU THWN	1	4/0	CU THWN	1	4	CU THWN
3	MS2	3LP-DIM1	1	3"	EMT	3	350	CU THWN	1	350	CU THWN	1	4	CU THWN
4	1EDP-LS	3ELP-DIM	1	1 1/2"	EMT	3	2	CU THWN	1	2	CU THWN	1	6	CU THWN
5	MS2	5LP-A	1	2"	EMT	3	3/0	CU THWN	1	3/0	CU THWN	1	6	CU THWN
6	1EDP-LS	5ELP-LS	1	2"	EMT	3	1/0	CU THWN	1	1/0	CU THWN	1	6	CU THWN

The table below is a continuation of the feeder schedule above.

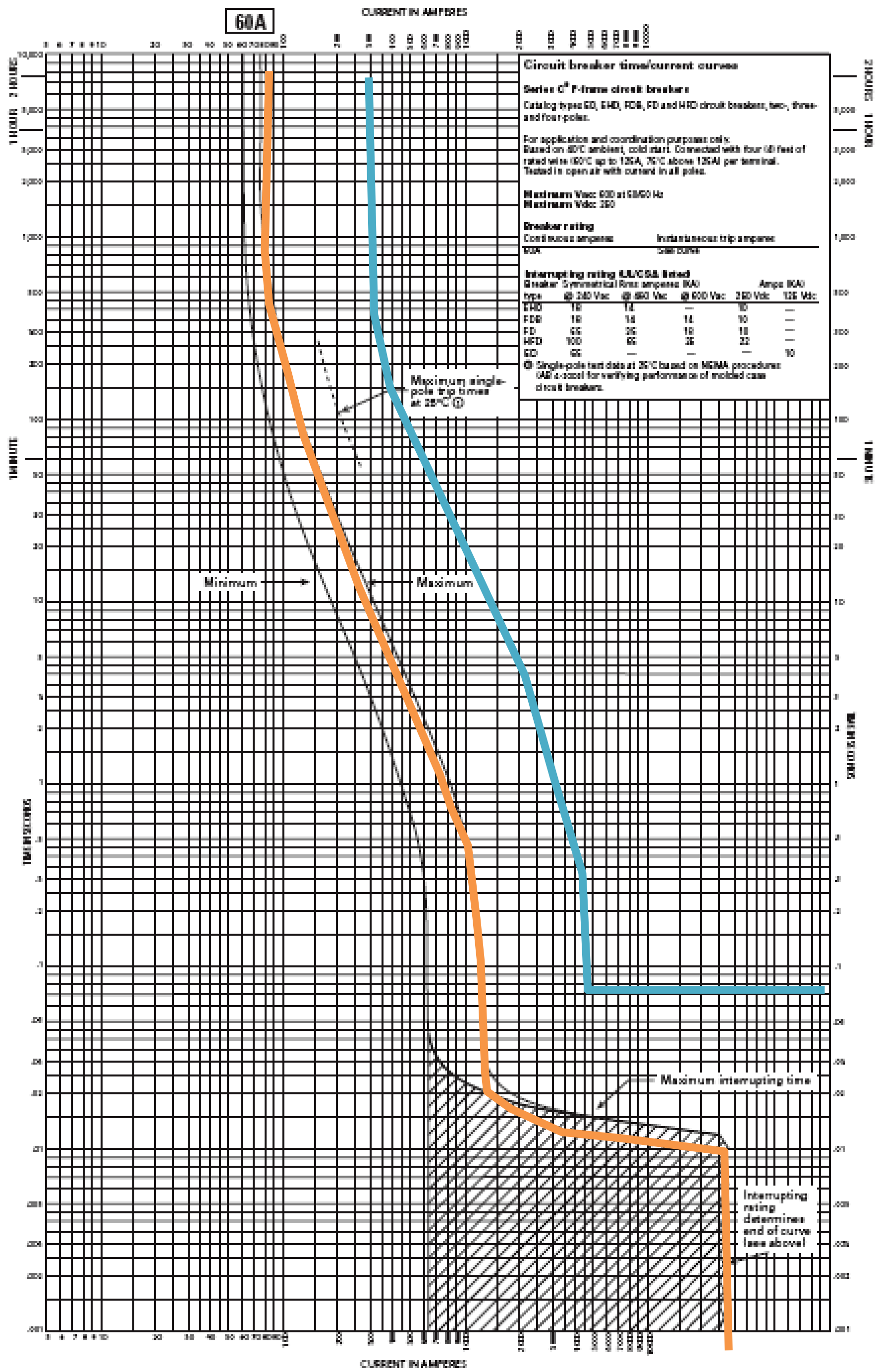
FEEDER SCHEDULE						
FEEDER INFO				SIZE OF OVERCURRENT	FRAME OR SWITCH	
TAG	FROM	TO	# SETS	PROTECTION	SIZE	REMARKS
1	1EDP-LS	1ELP-LS	1	200	225	
2	MS2	1LP-A	1	225	400	
3	MS2	3LP-DIM1	1	300	400	
4	1EDP-LS	3ELP-DIM	1	110	225	
5	MS2	5LP-A	1	200	225	
6	1EDP-LS	5ELP-LS	1	150	225	

ix. Manufacturer Information

Refer to appendix for manufacturer specification sheets.

2 | Coordination Study / Short Circuit

a. coordination study



We see here that the 60A time-current curve, represented in orange, is to the left of the time-current curve of the 100A breaker, represented in blue. This means the 60A breaker will trip first. Breakers are properly coordinated.

b. Short circuit calculations

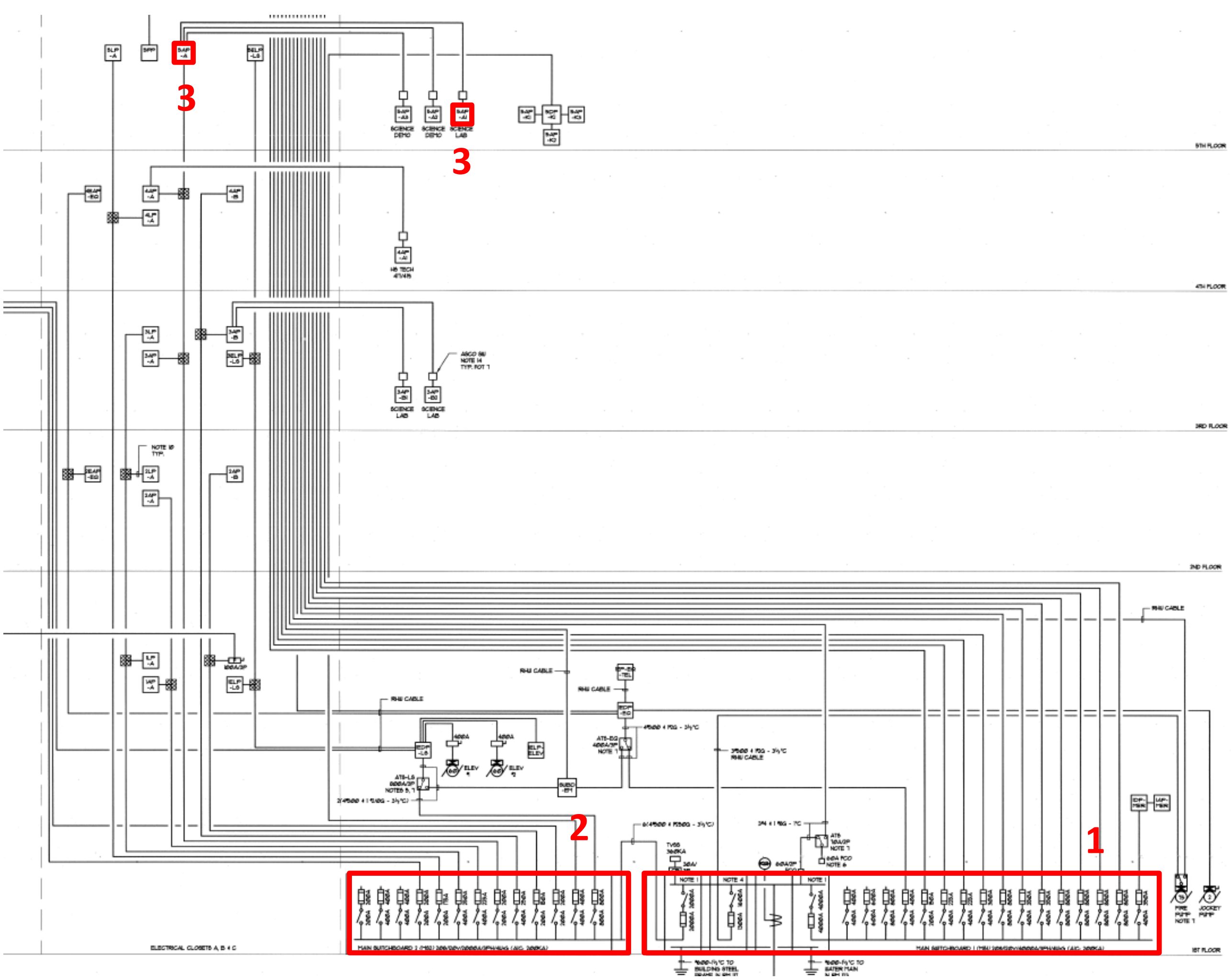
Short-Circuit Calculations

The following calculations are based on the "Point-by Point" method where:

Isc = Isc x M **M= 1/(1+f)** **f = $\frac{1.732 \times L \times I}{C \times E}$** **XFMR: IP(sca)= $\frac{IP(sca) \times Vp \times \%Z}{100{,}000 \times KVA}$** **IS(sca)= $\frac{Vp \times M \times IS(sca)}{Vs}$**

Fault Point	Panel Transformer	Source (Fault Point)	Source I (amps)	Conduit Type	Wire/Bus Size	Wire/Bus Type	'C' value	E (volts)	L (length)	X'FMR KVA	X'FMR Z	f	M	Isc
1	Service	-	42,000											42000
2	MS1	1	42000	M	12 Set(s) of 500 KCML	CU	22185	208	20			0.026	0.97	40925
3	MS2	2	40925	M	6 Set(s) of 500 KCML	CU	22185	208	20			0.051	0.95	38931
4	5AP-A	3	38931	M	1 Set(s) of 3	CU	4760	208	100			6.810	0.13	4985
5	5AP-A1	4	4985	M	1 Set(s) of 3	CU	4760	208	30			0.262	0.79	3951

The previous table shows the short circuit current rating for the path through the electrical system as indicated below.



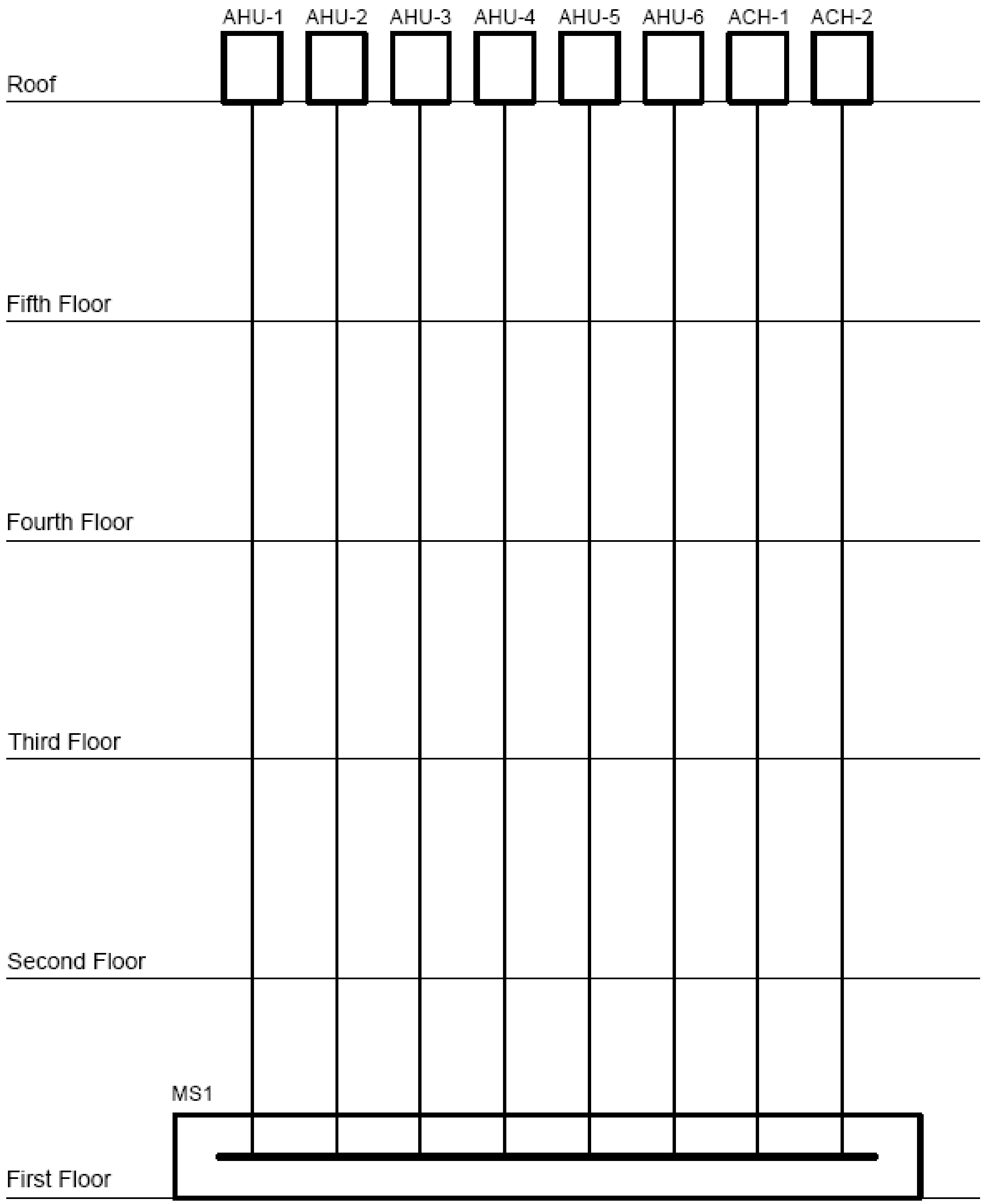
3 | depth topic 1 | Electrical Distribution

This depth topic will analyze the (assumed) cost savings incurred by altering the method with which the rooftop mechanical equipment is served. The existing rooftop mechanical equipment is served, individually, from the main service switchboard, which is located on the first floor. The goal of this depth is to show that money can be saved by running a single feed to the roof (as opposed to the seven that are currently in place) feeding a distribution panel. It is from this distribution panel that each piece of mechanical equipment will be served. Savings are assumed to come from the use of less material (wire and conduit) as well as the (reduced) amount of labor-hours required to install the system. In addition, the single feed running to the roof (from the first floor) will hit a transformer before feeding the rooftop distribution panel. The reason for this is that the entire electrical system is currently operating at 208/120V. Additional savings can be produced by increasing the voltage, and thus, decreasing the size of the wire feeding the mechanical equipment.

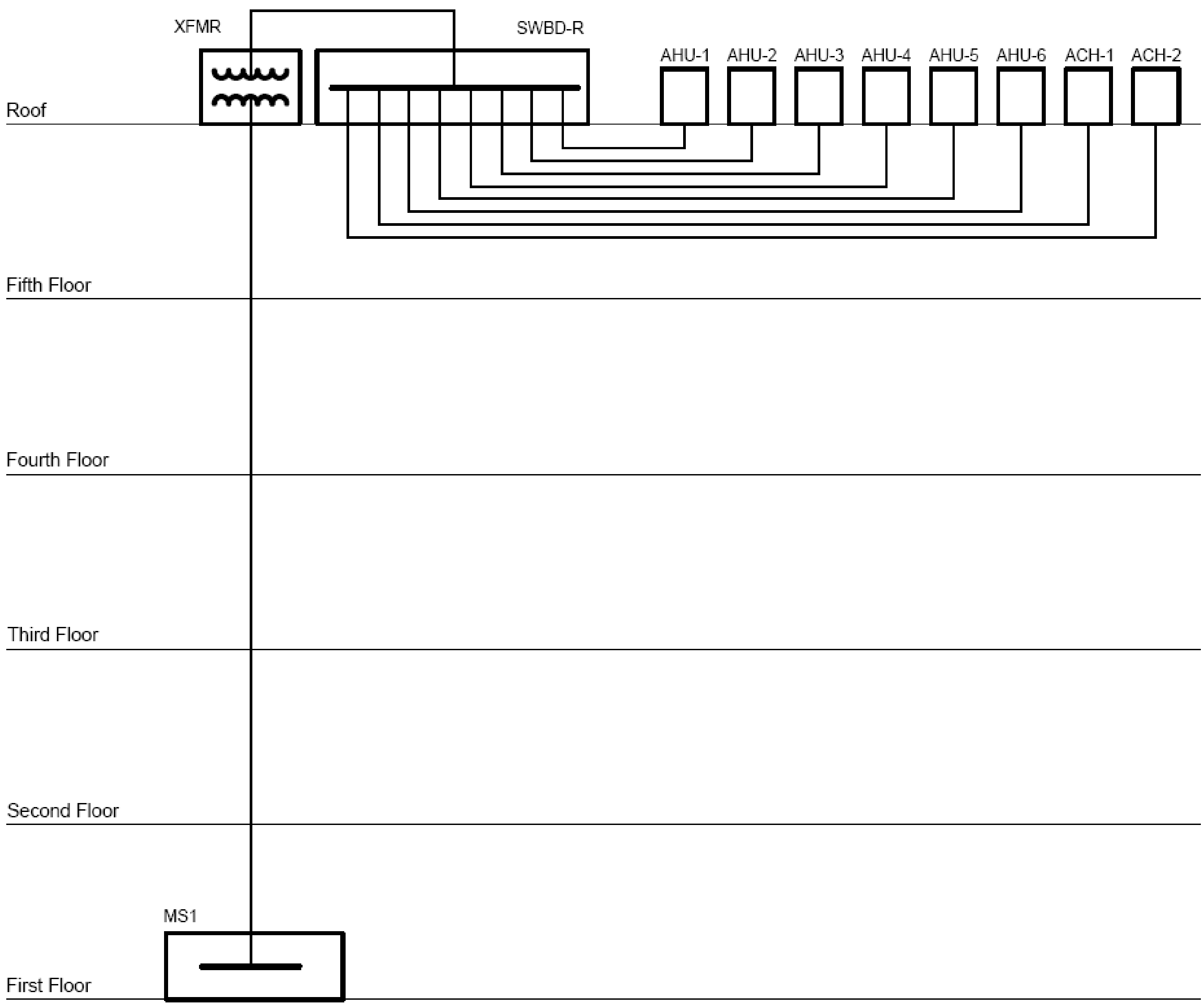
Below is a list of **assumptions** that have been made during this analysis:

- All existing wire is stranded copper, THWN
- All proposed wire is stranded aluminum, THWN
- All electrical cost fate was take from RS Means 2010
- RS Means Conduit prices include 2 terminations, 2 elbows, 11 beam clamps, and 11 couplings per 100 LF
    - It was assumed that these inclusion were sufficient, and none were added in addition
- Pull boxes are NEMA 1, sheet metal, 12”x12”x6”
- Hanger price includes, hanger, bolt, and 12” rod
- Hanger estimates include only standard hangers, no specialty hangers included

Below is a schematic diagram showing the **EXISTING** distribution method:



Below is a schematic diagram showing the **PROPOSED** distribution method:

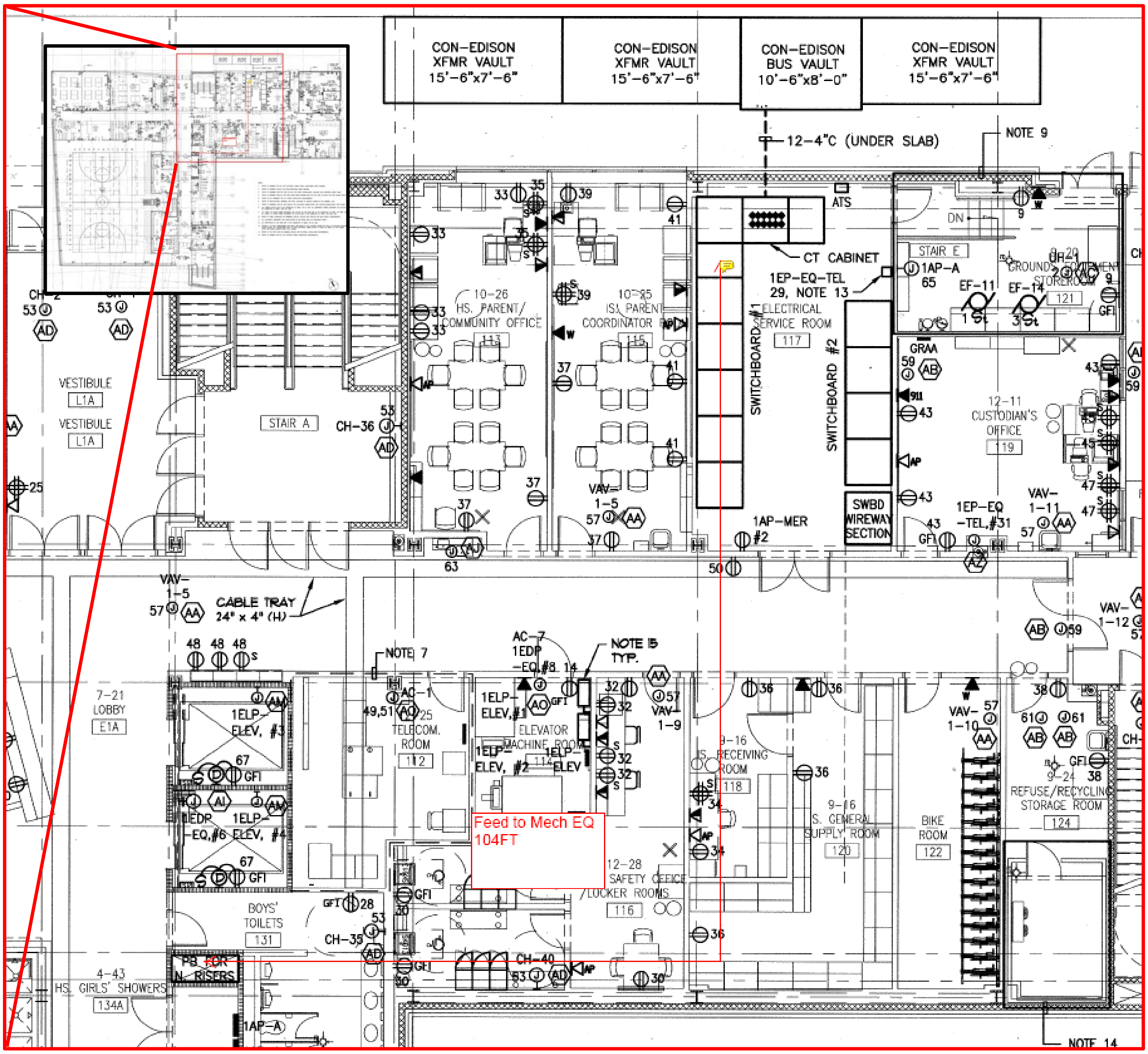


Existing System

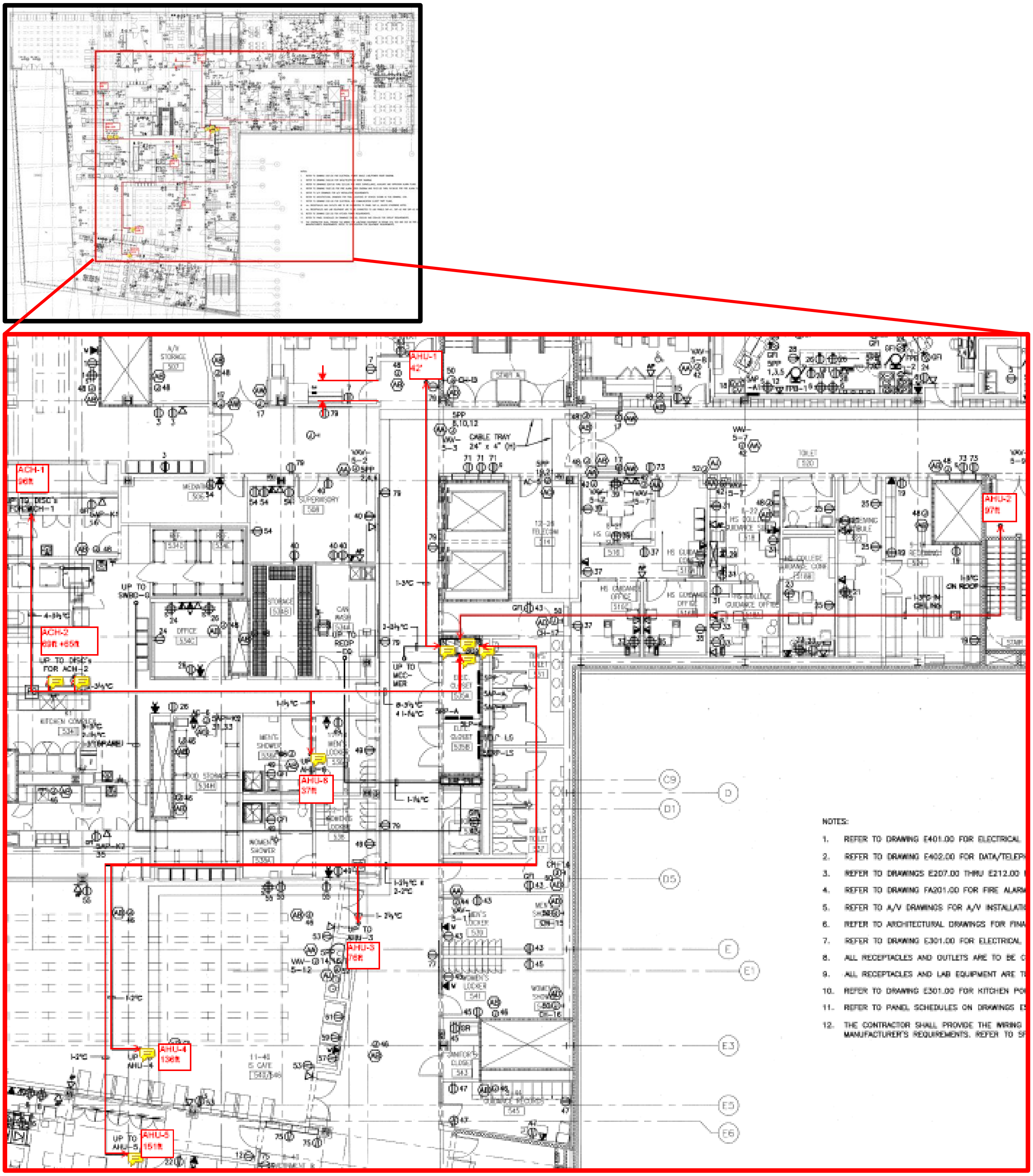
The first step to calculating the total cost of the existing electrical distribution of the rooftop mechanical equipment is to calculate to total run length of the existing wire and conduit. This includes:

1. The horizontal run on the first floor from the main distribution panel MS1 to the conduit riser near the first floor electrical closet
2. The vertical distance travelled up the conduit riser to the fifth floor
3. The horizontal run on the fifth floor to the respective mechanical equipment poke-thru's

The plan below shows the horizontal run from the main distribution panel, MS1, to the electrical riser near the first floor electrical closet. This corresponds to the bullet-point **1.**



The plan below shows the horizontal conduit runs to each piece of mechanical equipment in the ceiling of the 5th floor. The runs start at the 5th floor electric closet and terminate at the poke-thru up to each piece of equipment. The calculated horizontal runs shown in the large plan below corresponds to bullet point **3** from the previous page. The small plan shows the location of the blown up portion relative to the entire floor plan.



The tables below show important information for which the electrical cost estimate was based. This information includes, but is not limited to, the following:

- Total run length, including vertical and horizontal runs
- Required installation equipment, including elbows, couplings, pull boxes, and conduit hangers

QUANTITIES							
EQ	RUN LENGTH			EQUIPMENT			
	HORIZ (FT)	VERT (FT)	TOTAL (FT)	ELBOW	COUPLING	PULL BOX	HANGER
AHU-1	146	80	226	5	10	1	75
AHU-2	201	80	281	6	12	2	94
AHU-3	180	80	260	6	12	1	87
AHU-4	240	80	320	6	12	0	107
AHU-5	255	80	335	6	12	0	112
AHU-6	141	80	221	6	12	1	74
ACH-1/A	200	80	280	5	10	1	93
ACH-1/B	200	80	280	5	10	0	93
ACH-2/A	238	80	318	6	12	1	106
ACH-2/B	238	80	318	6	12	1	106

The table below includes information regarding the feeder and protective device (all fused switches) for each piece of rooftop mechanical equipment. Cost information taken from RS Means 2010 were based on the feeder and protective device information shown below.

FEEDER AND PROCTIVE DEVICE								
EQ	PROTECTIVE DEVICE			FEEDER				
	AF	AT	WIRE/ SET	SETS	WIRE SIZE	COND SIZE	NUETR SIZE	GND SIZE
AHU-1	400	350	3	1	500	3"	-	3
AHU-2	400	350	3	1	500	3"	-	3
AHU-3	400	300	3	1	350	2 1/2	-	3
AHU-4	400	225	3	1	4/0	2	-	4
AHU-5	400	225	3	1	4/0	2	-	4
AHU-6	200	150	3	1	1/0	1 1/2	-	6
ACH-1/A	800	800	4	1	500	3 1/2"	500	2/0
ACH-1/B	800	800	4	1	500	3 1/2"	500	2/0
ACH-2/A	800	800	4	1	500	3 1/2"	500	2/0
ACH-2/B	800	800	4	1	500	3 1/2"	500	2/0

MATERIAL COST CALCULATION												
EQ	FEEDER					MATERIAL PRICE						
	SETS	WIRE SIZE	COND SIZE	NUETR SIZE	GND SIZE	WIRE ($/Ft)	COND ($/Ft)	NUETR ($/Ft)	GND ($/Ft)	PULL BOX ($/EA.)	HANGER ($/EA.)	TOTAL
AHU-1	1	500	3"	-	3	9.6	13.25	0	1.07	37.00	10.15	$10,546.75
AHU-2	1	500	3"	-	3	9.6	13.25	0	1.07	37.00	10.15	$13,141.44
AHU-3	1	350	2 1/2	-	3	6.95	11.15	0	1.07	37.00	9.55	$9,462.87
AHU-4	1	4/0	2	-	4	4.2	4.67	0	0.87	37.00	8.75	$6,736.53
AHU-5	1	4/0	2	-	4	4.2	4.67	0	0.87	37.00	8.75	$7,052.31
AHU-6	1	1/0	1 1/2	-	6	2.11	3.59	0	0.55	37.00	6.50	$2,828.60
ACH-1/A	2	500	3 1/2"	500	2/0	9.6	16.80	9.60	2.65	37.00	12.10	$34,728.67
ACH-1/B	2	500	3 1/2"	500	2/0	9.6	16.80	9.60	2.65	37.00	12.10	$34,654.67
ACH-2/A	2	500	3 1/2"	500	2/0	9.6	16.80	9.60	2.65	37.00	12.10	$39,431.80
ACH-2/B	2	500	3 1/2"	500	2/0	9.6	16.80	9.60	2.65	37.00	12.10	$39,431.80
											TOTAL	**$198,015.43**

The previous table shows the material prices (taken from RS Means 2010 Electrical Cost Data), and calculated price of feeding each piece of equipment.

The formula used to calculate the cost of feeding the equipment is as follows:
Total Cost ($) = (Number of wire sets) * [(3*Wire Cost*Run Length) + (Conduit Cost*Run Length) + (Neutral Cost*Run Length) + (Ground Cost*Run Length) + (Pullbox Cost*QTY) + (Hanger Cost*QTY)]

The total material cost for the rooftop mechanical equipment is **$198,015.43**.

LABOR COST CALCULATION												
EQ	FEEDER					LABOR PRICE						
	SETS	WIRE SIZE	COND SIZE	NUETR SIZE	GND SIZE	WIRE ($/Ft)	COND ($/Ft)	NUETR ($/Ft)	GND ($/Ft)	PULL BOX ($/EA.)	HANGER ($/EA.)	TOTAL
AHU-1	1	500	3"	-	3	2.45	7.85	0	0.79	75.50	6.55	$4,181.54
AHU-2	1	500	3"	-	3	2.45	7.85	0	0.79	75.50	6.55	$5,256.30
AHU-3	1	350	2 1/2	-	3	2.18	6.55	0	0.79	75.50	4.90	$4,107.67
AHU-4	1	4/0	2	-	4	1.78	4.90	0	0.74	75.50	3.92	$3,931.73
AHU-5	1	4/0	2	-	4	1.78	4.90	0	0.74	75.50	3.92	$4,116.03
AHU-6	1	1/0	1 1/2	-	6	1.19	4.36	0	0.61	75.50	3.56	$2,223.99
ACH-1/A	2	500	3 1/2"	500	2/0	2.45	8.70	2.45	1.35	75.50	8.70	$12,891.00
ACH-1/B	2	500	3 1/2"	500	2/0	2.45	8.70	2.45	1.35	75.50	8.70	$12,740.00
ACH-2/A	2	500	3 1/2"	500	2/0	2.45	8.70	2.45	1.35	75.50	8.70	$14,620.00
ACH-2/B	2	500	3 1/2"	500	2/0	2.45	8.70	2.45	1.35	75.50	8.70	$14,620.00
											TOTAL	$78,688.27

The below table shows the labor prices (taken from RS Means 2010 Electrical Cost Data), and the calculated labor cost of feeding each piece of equipment. The total labor cost for the existing rooftop mechanical equipment is **$78,688.27.**

Total Cost = (Material Cost) + (Labor Cost) = $198,015.43+ $78,688.27= **$276,703.70**

The total cost for the **EXISTING** service of the rooftop mechanical equipment is **$276,703.70**.

Proposed System

The goal, obviously aimed at reducing the cost of the system, will feed a single switchboard located on the roof. This will reduce the number of feeds to the roof (from 8 to 1) where savings will be incurred through material and labor. It is then from this switchboard that all mechanical equipment on the roof will be fed.

Steps to calculating the cost of the proposed system:

1. Convert the mechanical equipment load from a voltage of 208/120 to 480/277
2. Determine the feasibility of using a transformer to step up the voltage from 208/120 to 480/277
   a. Calculate the total cost (material + labor) for the feeds from the rooftop switchboard (tag: SWDB-R) to each piece of mechanical equipment.
   b. Do the cost savings incurred from the reduced wire sizes (as a result of raising the voltage) cover the cost of the transformer?
3. Calculate the total cost (material and labor) for the (single) feed from the main switchboard on the first floor, to the rooftop transformer or switchboard (depending on the outcome of step 2).
4. Determine the cost of the rooftop switchboard (material + labor)
5. Add all cost data together to calculate the total cost

Step 1: Calculate load 480/277 volts

The table below shows the calculation of the mechanical equipment loads at a voltage of 480/277 volts. The HP for the motors of the air handling units, taken from the switchboard MS1 that feeds them, was used to calculate the equipment load using **table 430.250** in NFPA70 NEC 2011. For the chillers, the load was given in kVA. Using this, the load, in amps, was found for a voltage of 480/277V. The loads for both voltages are highlighted in **blue** below.

	LOAD				FEEDER (208V)					FEEDER (480V)				
EQ	kVA	HP	A (208V)	A (480V)	SETS	WIRE	COND	NEUTR	GRD	SETS	WIRE	COND	NEUTR	GRD
AHU-1	-	100	273	124	1	500	3	-	2	1	2/0	2	-	4
AHU-2	-	100	273	124	1	500	3	-	2	1	2/0	2	-	4
AHU-3	-	75	211	96	1	300	2 1/2	-	2	1	1	1 1/4	-	6
AHU-4	-	60	169	77	1	4/0	2	-	4	1	2	1 1/4	-	6
AHU-5	-	60	169	77	1	4/0	2	-	4	1	2	1 1/4	-	6
AHU-6	-	40	114	52	1	4	1	-	4	1	4	1	-	8
ACH-1/A	210	-	583	253	2	500	3	500	2/0	1	400	3	400	1
ACH-1/B	220	-	611	265	2	500	3	500	3/0	1	400	3	400	1
ACH-2/A	210	-	583	253	2	500	3	500	2/0	1	400	3	400	1
ACH-2/B	220	-	611	265	2	500	3	500	3/0	1	400	3	400	1

	208/120 V	480/277 V
Total A:	3598	1585
Total kVA:	2990	1317

Step 2: Determine the feasibility of including a transformer

To determine the feasibility of using a transformer, the run length from the switchboard to the mechanical equipment must be calculated. This includes both horizontal and vertical runs. In addition the quantity of additions items, such as elbows, couplings, pullboxes, and hangers needs to be determined. The figure below shows this information for the feed from the rooftop switchboard SWBD-R to each piece of rooftop mechanical equipment.

QUANTITIES								
FEEDER		RUN LENGTH			EQUIPMENT			
FROM	TO	HORIZ (FT)	VERT (FT)	TOTAL (FT)	ELBOW	COUPLING	PULL BOX	HANGER
SWBD-R	AHU-1	48	20	68	3	6	1	23
SWBD-R	AHU-2	125	20	145	3	6	1	48
SWBD-R	AHU-3	75	20	95	3	6	1	32
SWBD-R	AHU-4	72	20	92	3	6	1	31
SWBD-R	AHU-5	100	20	120	3	6	1	40
SWBD-R	AHU-6	28	20	48	3	6	1	16
SWBD-R	ACH-1/A	50	20	70	3	6	1	23
SWBD-R	ACH-1/B	50	20	70	3	6	1	23
SWBD-R	ACH-2/A	60	20	80	3	6	1	27
SWBD-R	ACH-2/B	60	20	80	3	6	1	27

MATERIAL COST CALCULATION: 480/277 V													
RUN		FEEDER (480V)					MATERIAL PRICE						
FROM	TO	NUMBER OF SETS	WIRE SIZE	COND SIZE	NUETR SIZE	GRD SIZE	WIRE ($/Ft)	COND ($/Ft)	NUETR ($/Ft)	GND ($/Ft)	PULL BOX ($/EA.)	HANGER ($/EA.)	TOTAL
SWBD-R	AHU-1	1	2/0	2	-	4	0.775	4.67	0	0.275	37.00	3.07	$600.95
SWBD-R	AHU-2	1	2/0	2	-	4	0.775	4.67	0	0.275	37.00	3.07	$1,239.53
SWBD-R	AHU-3	1	1	1 1/4	-	6	0.545	2.77	0	0.22	37.00	2.33	$550.16
SWBD-R	AHU-4	1	2	1 1/4	-	6	0.375	2.77	0	0.22	37.00	2.33	$487.03
SWBD-R	AHU-5	1	2	1 1/4	-	6	0.375	2.77	0	0.22	37.00	2.33	$624.00
SWBD-R	AHU-6	1	4	1	-	8	0.275	1.70	0	0.22	37.00	2.08	$202.04
SWBD-R	ACH-1/A	1	400	3	400	1	2.14	13.25	2.14	0.545	37.00	3.75	$1,689.35
SWBD-R	ACH-1/B	1	400	3	400	1	2.14	13.25	2.14	0.545	37.00	3.75	$1,689.35
SWBD-R	ACH-2/A	1	400	3	400	1	2.14	13.25	2.14	0.545	37.00	3.75	$1,925.40
SWBD-R	ACH-2/B	1	400	3	400	1	2.14	13.25	2.14	0.545	37.00	3.75	$1,925.40
												TOTAL	$10,933.21

The previous table shows the total **MATERIAL** cost for the feeds to the mechanical equipment from the rooftop switchboard SWBD-R at a voltage of **480/277 volts**. The total cost for these feeds is **$10,933.21**.

LABOR COST CALCULATION: 480/277 V													
RUN		FEEDER					LABOR PRICE						
FROM	TO	NUMBER OF SETS	WIRE SIZE	COND SIZE	NUETR SIZE	GRD SIZE	WIRE ($/Ft)	COND ($/Ft)	NUETR ($/Ft)	GND ($/Ft)	PULL BOX ($/EA.)	HANGER ($/EA.)	TOTAL
SWBD-R	AHU-1	1	2/0	2	-	4	1.09	4.90	0	0.61	37.00	1.47	$667.02
SWBD-R	AHU-2	1	2/0	2	-	4	1.09	4.90	0	0.61	37.00	1.47	$1,380.43
SWBD-R	AHU-3	1	1	1 1/4	-	6	0.87	3.92	0	0.49	37.00	0.98	$734.93
SWBD-R	AHU-4	1	2	1 1/4	-	6	0.74	3.92	0	0.49	37.00	0.98	$677.01
SWBD-R	AHU-5	1	2	1 1/4	-	6	0.74	3.92	0	0.49	37.00	0.98	$871.80
SWBD-R	AHU-6	1	4	1	-	8	0.61	3.41	0	0.49	37.00	3.01	$359.48
SWBD-R	ACH-1/A	1	400	3	400	1	1.70	7.85	1.70	0.87	37.00	2.45	$1,180.57
SWBD-R	ACH-1/B	1	400	3	400	1	1.70	7.85	1.70	0.87	37.00	2.45	$1,180.57
SWBD-R	ACH-2/A	1	400	3	400	1	1.70	7.85	1.70	0.87	37.00	2.45	$1,343.93
SWBD-R	ACH-2/B	1	400	3	400	1	1.70	7.85	1.70	0.87	37.00	2.45	$1,343.93
												TOTAL	$9,739.67

The previous table shows the total **LABOR** cost for the feeds to the mechanical equipment from the rooftop switchboard SWBD-R at a voltage of **480/277 volts**. The total cost for these feeds is **$9,739.67**.

MATERIAL COST CALCULATION: 208/120 V													
RUN		FEEDER					MATERIAL PRICE						
FROM	TO	NUMBER OF SETS	WIRE SIZE	COND SIZE	NUETR SIZE	GRD SIZE	WIRE ($/Ft)	COND ($/Ft)	NUETR ($/Ft)	GND ($/Ft)	PULL BOX ($/EA.)	HANGER ($/EA.)	TOTAL
SWBD-R	AHU-1	1	500	3	-	2	2.36	13.25	0	0.375	37.00	3.75	$1,529.94
SWBD-R	AHU-2	1	500	3	-	2	2.36	13.25	0	0.375	37.00	3.75	$3,220.48
SWBD-R	AHU-3	1	300	2 1/2	-	2	1.8	11.15	0	0.375	37.00	3.51	$1,756.03
SWBD-R	AHU-4	1	4/0	2	-	4	1.07	4.67	0	0.275	37.00	3.07	$881.41
SWBD-R	AHU-5	1	4/0	2	-	4	1.07	4.67	0	0.275	37.00	3.07	$1,138.40
SWBD-R	AHU-6	1	4	1	-	4	0.275	1.70	0	0.275	37.00	2.08	$204.68
SWBD-R	ACH-1/A	2	500	3	500	2/0	2.36	13.25	2.36	0.775	37.00	3.75	$3,534.10
SWBD-R	ACH-1/B	2	500	3	500	3/0	2.36	13.25	2.36	0.960	37.00	3.75	$3,560.00
SWBD-R	ACH-2/A	2	500	3	500	2/0	2.36	13.25	2.36	0.775	37.00	3.75	$4,028.40
SWBD-R	ACH-2/B	2	500	3	500	3/0	2.36	13.25	2.36	0.960	37.00	3.75	$4,058.00
												TOTAL	$23,911.43

The previous table shows the total **MATERIAL** cost for the feeds to the mechanical equipment from the rooftop switchboard SWBD-R at a voltage of **208/120 volts**. The total cost for these feeds is **$23,911.43**.

LABOR COST CALCULATION: 208/120 V													
RUN		FEEDER (208V)					LABOR PRICE						
FROM	TO	NUMBER OF SETS	WIRE SIZE	COND SIZE	NUETR SIZE	GRD SIZE	WIRE ($/Ft)	COND ($/Ft)	NUETR ($/Ft)	GND ($/Ft)	PULL BOX ($/EA.)	HANGER ($/EA.)	TOTAL
SWBD-R	AHU-1	1	500	3	-	2	1.96	7.85	0	0.74	37.00	2.45	$1,076.49
SWBD-R	AHU-2	1	500	3	-	2	1.96	7.85	0	0.74	37.00	2.45	$2,253.57
SWBD-R	AHU-3	1	300	2 1/2	-	2	1.45	6.55	0	0.74	37.00	1.47	$1,189.35
SWBD-R	AHU-4	1	4/0	2	-	4	1.26	4.90	0	0.61	37.00	1.47	$936.30
SWBD-R	AHU-5	1	4/0	2	-	4	1.26	4.90	0	0.61	37.00	1.47	$1,210.00
SWBD-R	AHU-6	1	4	1	-	4	0.61	3.41	0	0.61	37.00	3.01	$365.00
SWBD-R	ACH-1/A	2	500	3	500	2/0	1.96	7.85	1.96	1.09	37.00	2.45	$2,537.53
SWBD-R	ACH-1/B	2	500	3	500	3/0	1.96	7.85	1.96	1.19	37.00	2.45	$2,551.53
SWBD-R	ACH-2/A	2	500	3	500	2/0	1.96	7.85	1.96	1.09	37.00	2.45	$2,889.47
SWBD-R	ACH-2/B	2	500	3	500	3/0	1.96	7.85	1.96	1.19	37.00	2.45	$2,905.47
												TOTAL	$17,914.71

The previous table shows the total **LABOR** cost for the feeds to the mechanical equipment from the rooftop switchboard SWBD-R at a voltage of **208/120 volts**. The total cost for these feeds is **$7,914.71**.

All cost calculations presented in the previous four tables were performed based on the following formula:

Total Cost ($) = (Number of wire sets) * [(3*Wire Cost*Run Length) + (Conduit Cost*Run Length) + (Neutral Cost*Run Length) + (Ground Cost*Run Length) + (Pullbox Cost*QTY) + (Hanger Cost*QTY)]

The table below summarizes the data from the previous four cost calculation tables. As shown, a savings of **$21,153.26** ($41,826.14 – $20,672.88) is produced by serving the mechanical equipment at a voltage of 480/277V as opposed to the original voltage of 208/120V. However, because the total price (material + labor + equipment) for an appropriately sized transformer is **$42,055.00,** using a transformer would ultimately produce a loss of **$20,901.74** ($21,153.26 - $42,055.00).

As such, the use of the transformer has been eliminated. The proposed system will consist of a single feed running to the rooftop switchboard SWBD-R, which will supply the feeds to all of the mechanical equipment. No transformer is included.

	208/120 V	480/277 V
Material	$23,911.43	$10,933.21
Labor	$17,914.71	$9,739.67
Total:	$41,826.14	$20,672.88

Step 3: cost for feed from MS1 to rooftop switchboard SWBD-R

The next step in calculating the total cost of the proposed system is to determine the cost of the feed from the main switchboard MS1 located on the first floor, up to the rooftop switchboard SWBD-R. It is important to note that this is a single feed up to the roof, where the existing system has multiple feeds—one for each piece of mechanical equipment.

To do this, quantity information is needed. The table below shows the total run length, vertical an horizontal, for the feed from MS1 to SWBD-R. The vertical run includes the height through the five floors of electrical raceway space, as well as extra length for terminations and poke-thru distances.

QUANTITIES								
FEEDER		RUN LENGTH			EQUIPMENT			
FROM	TO	HORIZ (FT)	VERT (FT)	TOTAL (FT)	ELBOW	COUPLING	PULL BOX	HANGER
MS1	SWBD-R	60	80	140	5	10	1	47

MATERIAL COST CALCULATION													
RUN		FEEDER (480V)					MATERIAL PRICE						
FROM	TO	NUMBER OF SETS	WIRE SIZE	COND SIZE	NUETR SIZE	GRD SIZE	WIRE ($/Ft)	COND ($/Ft)	NUETR ($/Ft)	GND ($/Ft)	PULL BOX ($/EA.)	HANGER ($/EA.)	TOTAL
MS1	SWBD-R	4	500	3	500	1/0	2.36	13.25	2.36	0.655	37	3.75	$13,921.20

The previous table shows the total **MATERIAL** cost for the feed to the rooftop switchboard SWBD-R from MS1 on the first floor. The total cost for this feed is **$13,921.20**.

LABOR COST CALCULATION													
RUN		FEEDER					LABOR PRICE						
FROM	TO	NUMBER OF SETS	WIRE SIZE	COND SIZE	NUETR SIZE	GRD SIZE	WIRE ($/Ft)	COND ($/Ft)	NUETR ($/Ft)	GND ($/Ft)	PULL BOX ($/EA.)	HANGER ($/EA.)	TOTAL
MS1	SWBD-R	4	500	3	500	1/0	1.96	7.85	1.96	0.98	37.00	2.45	$9,940.53

The previous table shows the total **LABOR** cost for the feed to the rooftop switchboard SWBD-R from MS1 on the first floor. The total cost for this feed is **$9,940.53**.

Step 4: Determine the price of rooftop switchboard SWBD-R

The image below is a tabulation of cost information taken from RS Means 2010 for a 1600A, aluminum bus switchboard. The total cost (material + labor) for the switchboard is **$5,475.00**.

SWBD-R		
INFO	TAG	SWBD-R
	BUS	ALUMINUM
	RATING	1600A
COST	MATERIAL	$4,275.00
	LABOR	$1,200.00
	TOTAL	$5,475.00

Step 5: Calculate the total cost savings

The last step in calculating the total cost of the proposed system is to add the cost of the individual components of the (proposed) system.

The table below shows a tabulated summary of each individual component of the proposed system. The prices for each component are broken into material and labor costs.

PROPOSED SYSTEM PRICE CALCULATION			
PROPOSED	FEED FROM MS1 TO SWBD-R	MATERIAL	$ 13,921.20
		LABOR	$ 9,940.53
	FEED FROM SWBD-R TO EQUIP.	MATERIAL	$ 23,911.43
		LABOR	$ 17,914.71
	1600A SWBD PRICE	MATERIAL	$ 4,275.00
		LABOR	$ 1,200.00
		TOTAL:	**$ 71,162.87**

The total cost can be calculated via the following formula:

Total Cost = (Total Material Cost) + (Total Labor Cost) = $42,107.63 + $29,055.24 = **$71,162.87**

The total cost for the **PROPOSED** service of the rooftop mechanical equipment is **$71,162.87**.

Conclusion

The table below shows a summary comparison for both the existing system as well as the proposed system, split into material and labor prices. The existing system, costing **$276,703.70**, cost significantly more than the proposed system costing **$71,162.87**.

COMPARISON			
EXISTING	FEED FROM MS1 TO EQUIP.	MATERIAL	$ 198,015.43
		LABOR	$ 78,688.27
		TOTAL:	**$ 276,703.70**
PROPOSED	FEED FROM MS1 TO SWBD-R	MATERIAL	$ 13,921.20
		LABOR	$ 9,940.53
	FEED FROM SWBD-R TO EQUIP.	MATERIAL	$ 23,911.43
		LABOR	$ 17,914.71
	1600A SWBD PRICE	MATERIAL	$ 4,275.00
		LABOR	$ 1,200.00
		TOTAL:	**$ 71,162.87**
		SAVINGS:	**$ 205,540.83**

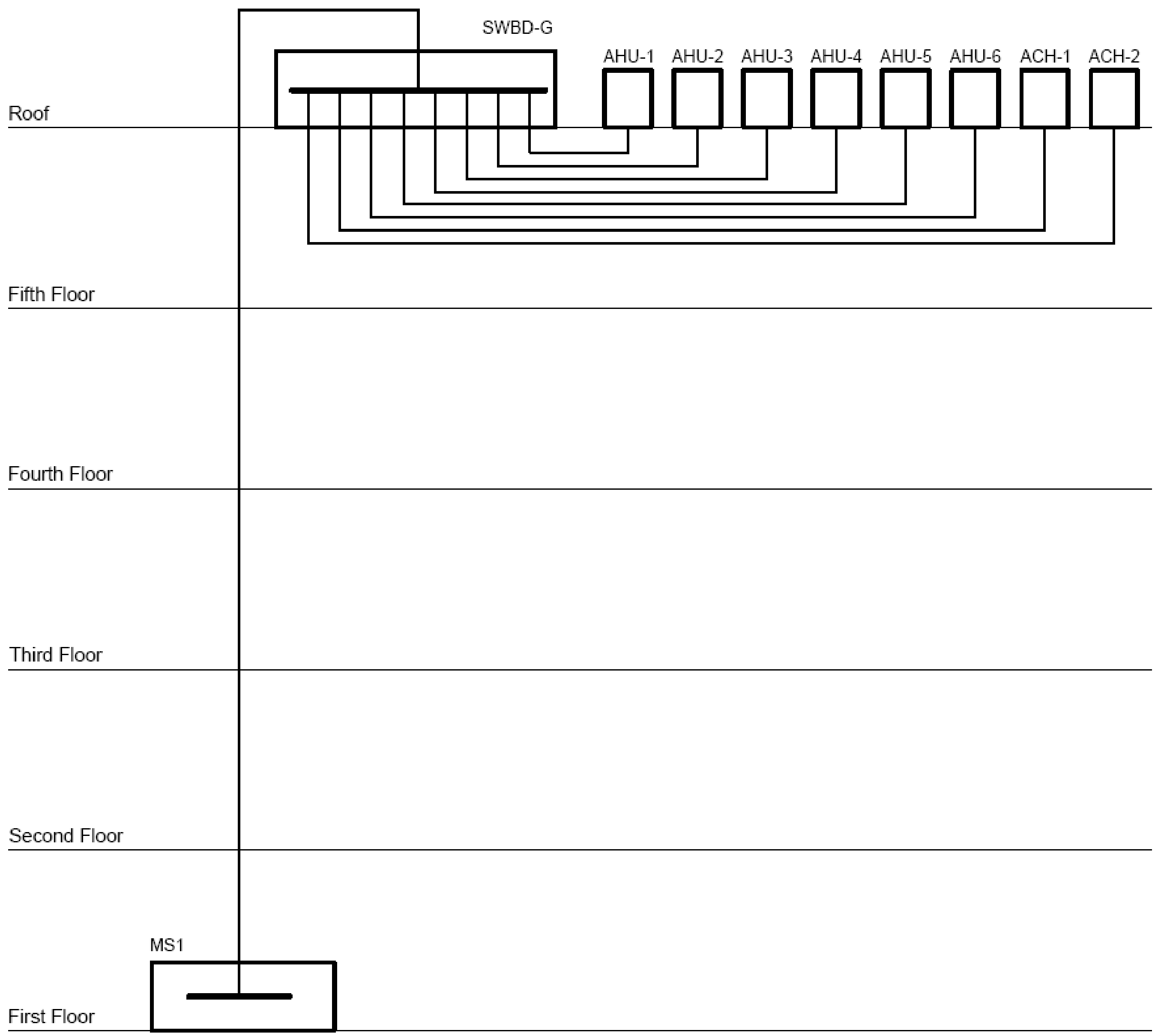
The total cost savings can be calculated using the following formula:

Total Savings ($) = (Total Cost of Existing system) — (Total cost of Proposed System) .

Total Savings ($) = $276,703.70 — $71,162.87

Total Savings ($) = $205,540.83

Because it has been determined during the cost calculations that a rooftop transformer is not practical from a cost standpoint, an updated schematic diagram of the proposed system is needed. The figure below shows the updated schematic riser diagram with the rooftop transformer eliminated.



4 | depth topic 2 | SKM Study

Introduction

This section is dedicated to presenting the results an purpose of the electrical depth topic 2. For electrical depth 2, a short circuit and arc flash analysis was performed on the existing electrical system. Both of these calculations were performed in the software program SKM.

Short Circuit Analysis

A short circuit is a condition that occurs when a connection experiences zero voltage between two nodes that would, under normal conditions, be at different voltages. As per the equation, $I = \frac{V}{R}$, as the resistance approaches zero, the current approaches infinity. The resulting (excessive) electrical current is limited only by the circuits' thévenin equivalent resistance. These high currents can cause overheating, damage to the wire insulation and fire, explosion, and damage to the circuit. The table that follows shows the calculated available short circuit current at each panelboard in the electrical distribution system.

The following table, created from data extracted from the program SKM, shows the available short-circuit current as well as the actual AIC rating (taken from the drawings). The last column, labeled "OK?", compares the actual rating against the SKM available short-circuit current. If the actual rating is higher than the SKM value, the result is "Yes," which says the criteria has been met; if not, the result is "No," meaning the actual AIC rating is too low.

BUS NAME	VOLTAGE (L-L)	AVAILABLE FAULT CURRENT				AIC RATING		
		THREE PHASE	X/R	LINE/ GRD	X/R	SKM	ACTUAL	OK?
1AP-MER	208	2224.4	0.1	0.1	1	2224.4	22000	Yes
1DP-MER	208	35794.1	1.1	0.1	1	35794.1	22000	**No**
1EDP-EQ	208	10851.5	1.1	0.1	1	10851.5	42000	Yes
1EDP-LS	208	22443.6	1.3	0.1	1	22443.6	42000	Yes
2AP-A	208	21370.2	0.4	0.1	1	21370.2	22000	Yes
2AP-B	208	23820.4	0.6	0.1	1	23820.4	22000	**No**
3LP-A	208	20909.5	0.4	0.1	1	20909.5	22000	Yes
3LP-DIM-1	208	23820.4	0.6	0.1	1	23820.4	22000	**No**
3LP-DIM-2	208	13429	0.3	0.1	1	13429	22000	Yes
4AP-B	208	23820.4	0.6	0.1	1	23820.4	22000	**No**
5AP-A	208	14694	0.7	0.1	1	14694	22000	Yes
5AP-A1	208	8475	0.5	0.1	1	8475	22000	Yes
5AP-A2	208	8475	0.5	0.1	1	8475	22000	Yes
5AP-A3	208	8475	0.5	0.1	1	8475	22000	Yes
5AP-K1	208	4786	0.4	0.1	1	4786	22000	Yes
5AP-K2	208	3364.9	0.3	0.1	1	3364.9	22000	Yes
5AP-K3	208	1413.2	0.1	0.1	1	1413.2	22000	Yes
5DP-K1	208	22443.6	1.3	0.1	1	22443.6	22000	**No**
5LP-A	208	21370.2	0.4	0.1	1	21370.2	22000	Yes
MCC-MER	208	13741.8	1.1	0.1	1	13741.8	65000	Yes
MS1	208	181105.1	1	0.1	1	181105.1	200000	Yes
MS1_Service	208	200000	1	0.1	1	200000	200000	Yes
MS2	208	167867.7	1	0.1	1	167867.7	200000	Yes
RAP-MER	208	7466	0.8	0.1	1	7466	42000	Yes
SUP-RAP	208	6835.9	0.8	0.1	1	6835.9	22000	Yes
SWBD-EM	208	7497.2	8.5	7185.7	7.9	7497.2	65000	Yes
SWBD-G	208	8214.1	20	8214.1	20	8214.1	100000	Yes

Arc Flash Analysis

An arc flash is an electrical explosion that has sufficient electrical energy to cause, injury, fire, or substantial damage. These are the result of a low impedance connection to ground or phase in the electrical system. SKM, the software used to conduct the analysis, performs its calculation based on the following steps:

1. Range of the model
2. Apply 3 Phase Fault to each bus in the power system, calculate the Bolted Fault Current at the bus (IB) and the Bolted Fault Current through each protective device (IB br).
3. Calculate the Arcing Fault Current at the bus (Ia) and through each protective device (Ia br).
    - lg (Ia) = K + 0.662 lg (IB) + 0.0966 V + 0.000526 G + 0.5588 V lg (IB) – 0.00304 G lg (IB)
    - Variables defined as following:

lg	log10
Ia	arcing fault current at the bus
K	–0.153 for open configuration and –0.097 for box configuratio
IB	bolted fault current – 3phase sym rms kA at the bus
V	bus voltage in kV
G	bus bar gap between conductors in mm

4. Determine the Trip/Delay time for fuses from the Time Current Coordination Curve (TCC).
    - Conditions as defined as following:

Trip/Delay Time	Condition
Read from clearing curve	Ia < IL
1/2 cycles	IL ≥ Ia ≥ 2 IL
1/4 cycles	Ia > 2 IL

5. Determine the Arcing duration by adding the Trip/Delay time and Breaker Opening time
6. Determine the Equipment Type:

Equipment Type	kV
Panel	≤ 1
Switchgear	≤ 35
Air	> 35

7. Determine the bus bar gap

Classes of Equipment	Gap (mm)
≤ 1kV Switchgear	32
≤ 1kV MCCs and Panelboards	25
1 – 5 kV Switchgear	104
>5 kV Switchgear	152
All Cable	13
1 – 5 kV Open Air	104
> 5 kV Open Air	152

8. Determine the Working Distance (Default the working distance based on the voltage level and equipment type.

Working Distance	Equipment Type	kV
24 inches (610mm)	Switchgear	<= 1
18 inches (455mm)	Panel	< =1
36 inches (910mm)	Switchgear	> 1 & < 35
72 inches (1829mm)	Switchgear	> 35
18 inches (455mm)	all others	

9. Calculate the Incident Energy
   - lg (En) = K1 + K2 + 1.081 lg (Ia) + 0.0011 G

En	is incident energy (J/cm2) normalized for a arcing duration of 0.2s and working distance of 610mm
K1	is –0.792 for open configuration and is –0.555 for box configuration (switchgear, panel, cable)
K2	is 0 for ungrounded and high resistance grounded systems and is –0.113 for grounded systems
G	is the gap between bus bar conductors in mm

10. Calculate the Arc Flash Boundary DB
    - DB = [4.184 Cf En (t/0.2) (610^X / EB)] ^ 1/X

DB	is the arc flash boundary in mm at incident energy of EB
EB	is the limit for a second-degree bare skin burn. EB = 5.0 (J/cm2)

11. Determine the PPE Clothing Category by a simple table look-up from the PPE table Personnel Protection Equipment Table.

12. Determine the Glove Class based on the voltage level. The following Glove Class table comes from ASTM D 120-95.

Glove Class	Voltage
00	500 V
0	1000 V
1	7500 V
2	17,000 V
3	26,500 V
4	36,000 V

Panel Number	Bus Name	Protective Device Name	Bus kV	Bus Bolted Fault (kA)	Bus Arcing Fault (kA)	Prot Dev Bolted Fault (kA)
1	1AP-MER	BKR_1AP-M ER	0.208	2.22	1.51	2.22
2	1DP-MER	BKR_1DP-M ER	0.208	35.79	10.65	35.79
3	1EDP-EQ	FUSE_MS1	0.208	10.85	4.61	10.85
4	1EDP-LS	FUSE_ATS-LS	0.208	22.44	7.67	22.44
5	2AP-A	BKR_2AP-A	0.208	21.37	6.3	21.37
6	2AP-B	BKR_2AP-B	0.208	23.82	8	23.82
7	3LP-A	BKR_3LP-A	0.208	20.91	7.3	20.91
8	3LP-DIM-1	FUSE_3LP-DIM-1	0.208	23.82	8	23.82
9	3LP-DIM-2	FUSE_3LP-DIM-2	0.208	13.43	4.55	13.43
10	4AP-B	BKR_4AP-B	0.208	23.82	6.8	23.82
11	5AP-A	BKR_5AP-A	0.208	14.69	4.84	14.69
12	5AP-A1	BKR_5AP-A	0.208	8.47	3.87	8.47
13	5AP-A2	BKR_5AP-A	0.208	8.47	3.87	8.47
14	5AP-A3	BKR_5AP-A	0.208	8.47	3.87	8.47
15	5AP-K1	BKR_5AP-K 1	0.208	4.79	2.59	4.79
16	5AP-K2	BKR_5AP-K 2	0.208	3.36	2.02	3.36
17	5AP-K3	BKR_5AP-K 3	0.208	1.41	1.1	1.41
18	5DP-K1	FUSE_5DP-K1	0.208	22.44	7.67	22.44
19	5LP-A	BKR_5LP-A	0.208	21.37	7.41	21.37
20	MCC-MER	FUSE_MCC-MER	0.208	13.74	5.44	13.74
21	MS1	FUSE_MS1	0.208	181.11	181.11	181.11
22	MS1_Service	MaxTripTime @2.0s	0.208	200	200	200
23	MS2	FUSE_MS2	0.208	167.87	167.87	167.87
24	RAP-MER	BKR_RAP-M ER	0.208	7.47	3.54	7.47
25	SUP-RAP	BKR_SUP-R AP	0.208	6.84	3.33	6.84
26	SWBD-EM	BKR_SWBD-EM	0.208	7.5	3.02	7.5
27	SWBD-G	MaxTripTime @2.0s	0.208	8.21	3.79	8.21

Panel Number	Bus Name	Protective Device Name	Bus kV	Prot Dev Arcing Fault (kA)	Trip/ Delay Time (sec.)	Breaker Opening Time (sec.)
1	1AP-MER	BKR_1AP-M ER	0.208	1.51	0.065	0
2	1DP-MER	BKR_1DP-M ER	0.208	10.65	0.01	0
3	1EDP-EQ	FUSE_MS1	0.208	4.61	2	0
4	1EDP-LS	FUSE_ATS-LS	0.208	7.67	2	0
5	2AP-A	BKR_2AP-A	0.208	6.3	0.032	0
6	2AP-B	BKR_2AP-B	0.208	8	0.01	0
7	3LP-A	BKR_3LP-A	0.208	7.3	0.01	0
8	3LP-DIM-1	FUSE_3LP-DIM-1	0.208	8	0.01	0
9	3LP-DIM-2	FUSE_3LP-DIM-2	0.208	4.55	0.1	0
10	4AP-B	BKR_4AP-B	0.208	6.8	0.032	0
11	5AP-A	BKR_5AP-A	0.208	4.84	0.024	0
12	5AP-A1	BKR_5AP-A	0.208	3.87	0.09	0
13	5AP-A2	BKR_5AP-A	0.208	3.87	0.09	0
14	5AP-A3	BKR_5AP-A	0.208	3.87	0.09	0
15	5AP-K1	BKR_5AP-K 1	0.208	2.59	0.1	0
16	5AP-K2	BKR_5AP-K 2	0.208	2.02	0.1	0
17	5AP-K3	BKR_5AP-K 3	0.208	1.1	0.1	0
18	5DP-K1	FUSE_5DP-K1	0.208	7.67	0.1	0
19	5LP-A	BKR_5LP-A	0.208	7.41	0.01	0
20	MCC-MER	FUSE_MCC-MER	0.208	5.44	2	0
21	MS1	FUSE_MS1	0.208	181.11	0.008	0
22	MS1_Service	MaxTripTime @2.0s	0.208	200	2	0
23	MS2	FUSE_MS2	0.208	167.87	0.004	0
24	RAP-MER	BKR_RAP-M ER	0.208	3.54	0.09	0
25	SUP-RAP	BKR_SUP-R AP	0.208	3.33	0.1	0
26	SWBD-EM	BKR_SWBD-EM	0.208	3.02	0.309	0
27	SWBD-G	MaxTripTime @2.0s	0.208	3.79	2	0

Panel Number	Bus Name	Protective Device Name	Bus kV	Ground	Equip Type	Gap (mm)
1	1AP-MER	BKR_1AP-M ER	0.208	No	PNL	25
2	1DP-MER	BKR_1DP-M ER	0.208	No	PNL	25
3	1EDP-EQ	FUSE_MS1	0.208	No	PNL	25
4	1EDP-LS	FUSE_ATS-LS	0.208	No	PNL	25
5	2AP-A	BKR_2AP-A	0.208	No	PNL	25
6	2AP-B	BKR_2AP-B	0.208	No	PNL	25
7	3LP-A	BKR_3LP-A	0.208	No	PNL	25
8	3LP-DIM-1	FUSE_3LP-DIM-1	0.208	No	PNL	25
9	3LP-DIM-2	FUSE_3LP-DIM-2	0.208	No	PNL	25
10	4AP-B	BKR_4AP-B	0.208	No	PNL	25
11	5AP-A	BKR_5AP-A	0.208	No	PNL	25
12	5AP-A1	BKR_5AP-A	0.208	No	PNL	25
13	5AP-A2	BKR_5AP-A	0.208	No	PNL	25
14	5AP-A3	BKR_5AP-A	0.208	No	PNL	25
15	5AP-K1	BKR_5AP-K 1	0.208	No	PNL	25
16	5AP-K2	BKR_5AP-K 2	0.208	No	PNL	25
17	5AP-K3	BKR_5AP-K 3	0.208	No	PNL	25
18	5DP-K1	FUSE_5DP-K1	0.208	No	PNL	25
19	5LP-A	BKR_5LP-A	0.208	No	PNL	25
20	MCC-MER	FUSE_MCC-MER	0.208	No	PNL	25
21	MS1	FUSE_MS1	0.208	No	PNL	25
22	MS1_Service	MaxTripTime @2.0s	0.208	No	PNL	25
23	MS2	FUSE_MS2	0.208	No	PNL	25
24	RAP-MER	BKR_RAP-M ER	0.208	No	PNL	25
25	SUP-RAP	BKR_SUP-R AP	0.208	No	PNL	25
26	SWBD-EM	BKR_SWBD-EM	0.208	Yes	PNL	25
27	SWBD-G	MaxTripTime @2.0s	0.208	Yes	PNL	25

Panel Number	Bus Name	Protective Device Name	Bus kV	Arc Flash Boundary (in)	Working Distance (in)	Incident Energy (cal/cm2)
1	1AP-MER	BKR_1AP-M ER	0.208	9	18	0.36
2	1DP-MER	BKR_1DP-M ER	0.208	10	18	0.46
3	1EDP-EQ	FUSE_MS1	0.208	146	18	37
4	1EDP-LS	FUSE_ATS-LS	0.208	205	18	65
5	2AP-A	BKR_2AP-A	0.208	14	18	0.84
6	2AP-B	BKR_2AP-B	0.208	8	18	0.34
7	3LP-A	BKR_3LP-A	0.208	8	18	0.31
8	3LP-DIM-1	FUSE_3LP-DIM-1	0.208	8	18	0.34
9	3LP-DIM-2	FUSE_3LP-DIM-2	0.208	23	18	1.8
10	4AP-B	BKR_4AP-B	0.208	15	18	0.91
11	5AP-A	BKR_5AP-A	0.208	10	18	0.47
12	5AP-A1	BKR_5AP-A	0.208	20	18	1.4
13	5AP-A2	BKR_5AP-A	0.208	20	18	1.4
14	5AP-A3	BKR_5AP-A	0.208	20	18	1.4
15	5AP-K1	BKR_5AP-K 1	0.208	16	18	1
16	5AP-K2	BKR_5AP-K 2	0.208	14	18	0.77
17	5AP-K3	BKR_5AP-K 3	0.208	9	18	0.4
18	5DP-K1	FUSE_5DP-K1	0.208	33	18	3.2
19	5LP-A	BKR_5LP-A	0.208	8	18	0.31
20	MCC-MER	FUSE_MCC-MER	0.208	163	18	45
21	MS1	FUSE_MS1	0.208	14	18	0.77
22	MS1_Service	MaxTripTime @2.0s	0.208	235	18	204
23	MS2	FUSE_MS2	0.208	10	18	0.36
24	RAP-MER	BKR_RAP-M ER	0.208	19	18	1.3
25	SUP-RAP	BKR_SUP-R AP	0.208	19	18	1.3
26	SWBD-EM	BKR_SWBD-EM	0.208	30	18	2.8
27	SWBD-G	MaxTripTime @2.0s	0.208	110	18	23

Panel Number	Bus Name	Protective Device Name	Bus kV	Required Protective FR Clothing Category	Label #
1	1AP-MER	BKR_1AP-M ER	0.208	Category 0	# 0001
2	1DP-MER	BKR_1DP-M ER	0.208	Category 0	# 0002
3	1EDP-EQ	FUSE_MS1	0.208	Category 4 (*N9)	# 0003
4	1EDP-LS	FUSE_ATS-LS	0.208	Dangerous! (*N9)	# 0004
5	2AP-A	BKR_2AP-A	0.208	Category 0 (*N3)	# 0005
6	2AP-B	BKR_2AP-B	0.208	Category 0	# 0006
7	3LP-A	BKR_3LP-A	0.208	Category 0	# 0007
8	3LP-DIM-1	FUSE_3LP-DIM-1	0.208	Category 0	# 0008
9	3LP-DIM-2	FUSE_3LP-DIM-2	0.208	Category 1 (*N3)	# 0009
10	4AP-B	BKR_4AP-B	0.208	Category 0 (*N3)	# 0010
11	5AP-A	BKR_5AP-A	0.208	Category 0 (*N3)	# 0011
12	5AP-A1	BKR_5AP-A	0.208	Category 1	# 0012
13	5AP-A2	BKR_5AP-A	0.208	Category 1	# 0013
14	5AP-A3	BKR_5AP-A	0.208	Category 1	# 0014
15	5AP-K1	BKR_5AP-K 1	0.208	Category 0	# 0015
16	5AP-K2	BKR_5AP-K 2	0.208	Category 0	# 0016
17	5AP-K3	BKR_5AP-K 3	0.208	Category 0	# 0017
18	5DP-K1	FUSE_5DP-K1	0.208	Category 1	# 0018
19	5LP-A	BKR_5LP-A	0.208	Category 0	# 0019
20	MCC-MER	FUSE_MCC-MER	0.208	Dangerous! (*N9)	# 0020
21	MS1	FUSE_MS1	0.208	Category 0 (*N11)	# 0021
22	MS1_Service	MaxTripTime @2.0s	0.208	Dangerous!	# 0022
23	MS2	FUSE_MS2	0.208	Category 0 (*N11)	# 0023
24	RAP-MER	BKR_RAP-M ER	0.208	Category 1	# 0024
25	SUP-RAP	BKR_SUP-R AP	0.208	Category 1	# 0025
26	SWBD-EM	BKR_SWBD-EM	0.208	Category 1 (*N3)	# 0026
27	SWBD-G	MaxTripTime @2.0s	0.208	Category 3 (*N2) (*N9)	# 0027

Load Flow Analysis

BRANCH NAME	FROM NAME	TO NAME	TYPE	VD %	AMPS	KVA	RATING %
WIRE_MS1	MS1_Service	MS1	FDR	0	3667.61	1293.76	87.74
WIRE_MS2	MS1_Service	MS2	FDR	0.12	1620.52	571.64	71.08
WIRE_5DPK1	MS2	5DP-K1	FDR	0.48	206.64	72.8	54.38
WIRE_5APK1	5DP-K1	5AP-K1	FDR	1.71	101.62	35.63	88.36
WIRE_5APK2	5DP-K1	5AP-K2	FDR	2.36	90.62	31.77	106.61
WIRE_5APK3	5DP-K1	5AP-K3	FDR	0.97	14.41	5.05	28.81
CBL-0007	MS2	3LP-DIM-1	FDR	0.42	131.13	46.2	65.56
WIRE_2AP-B	MS2	2AP-B	FDR	0	0	0	0
WIRE_5AP-A1	5AP-A	5AP-A1	FDR	0.16	31.4	11.02	27.3
WIRE_5AP-A2	5AP-A	5AP-A2	FDR	0.1	19.97	7.01	17.36
WIRE_5AP-A3	5AP-A	5AP-A3	FDR	0.12	22.83	8.01	19.85
WIRE_5AP-A	MS2	5AP-A	FDR	0.39	74.19	26.14	32.26
WIRE_4AP-B	MS2	4AP-B	FDR	0.49	154.05	54.27	77.02
WIRE_2AP-A	MS2	2AP-A	FDR	0.66	165.75	58.4	127.5
WIRE_3LP-A	MS2	3LP-A	FDR	0.28	71.17	25.07	54.74
WIRE_5LP-A	MS2	5LP-A	FDR	0.23	56.9	20.05	43.77
WIRE_3LP-DIM-2	MS2	3LP-DIM-2	FDR	1.15	172.33	60.71	132.56
WIRE_1DP-MER	MS1	1DP-MER	FDR	0.51	332.06	117.14	107.12
WIRE_1AP-MER	1DP-MER	1AP-MER	FDR	2.49	58.49	20.52	89.98
WIRE_AHU-1	MS1	BUS-0031	FDR	1.32	284.71	100.43	74.92
WIRE_ACH-1/A	MS1	BUS-0033	FDR	2.14	608.62	214.69	80.08
WIRE_ACH-1/B	MS1	BUS-0035	FDR	2.25	638.31	225.16	83.99
WIRE_AHU-2	MS1	BUS-0037	FDR	1.32	284.71	100.43	74.92
WIRE_AHU-3	MS1	BUS-0039	FDR	1.62	219.13	77.3	57.67
WIRE_AHU-4	MS1	BUS-0040	FDR	2.35	499.56	176.22	131.46
WIRE_AHU_5	MS1	BUS-0041	FDR	2.35	499.56	176.22	131.46
WIRE_AHU-6	MS1	BUS-0042	FDR	1.59	340.02	119.94	89.48
WIRE_MCC-MER	MS1	MCC-MER	FDR	0	0	0	0
WIRE_RAP-MER	MCC-MER	RAP-MER	FDR	0	0	0	0
WIRE_SUP-RAP	RAP-MER	SUP-RAP	FDR	0	0	0	0
WIRE_SWBD-EM	SWBD-G	SWBD-EM	FDR	0	0	0	0
WIRE_LOADBANK	SWBD-G	BUS-0048	FDR	1.3	566.39	202.66	169.07
ATS-EQ	BUS-0054	BUS-0049	FDR	0	0	0	UNKOWN
WIRE_ATS-EQ2	MS1	BUS-0049	FDR	0	0	0	0
WIRE_1EDP-EQ	BUS-0055	1EDP-EQ	FDR	0	0	0	0
WIRE_ATS-EQ	BUS-0054	SWBD-EM	FDR	0	0	0	0
ATS-LS	BUS-0059	BUS-0058	FDR	0	672.83	234.02	UNKOWN
WIRE_1EDP-LS	BUS-0057	1EDP-LS	FDR	1.25	672.83	234.02	88.53
WIRE_ATS-LS	MS2	BUS-0058	FDR	1.25	672.83	237.04	88.53
WIRE_ATS-LS1	SWBD-EM	BUS-0059	FDR	0	0	0	0

Conclusion

The available short circuit current for the panelboards, as expected, decreases as you go further downstream of the service entrance (as well as downstream of the generator). The main discrepancy that arises with my SKM short-circuit calculation is that the available short circuit current at the different panelboards changes drastically with the input for service entrance current. Not knowing what to input, I decided to make the available short circuit current from the utility 200,000 amps. This decision was made because my two main service entrance switchboards, MS1 and MS2, are both rated as 200kAIC. That is, if we make the available utility current 200,000 amps, we can then compare whether or not the rest of the panelboards in the system have adequate AIC ratings as the main service switchboards approach inadequacy (i.e. what the available current would be above 200,000 amps).

Most of AIC rating of the panelboards proved to be sufficient enough in the event that a short-circuit current of 200,000 amps becomes available at the service entrance. Some panelboards, five of them to be exact, did not meet the requirement. The table below shows the SKM calculated available short-circuit current, as well as the actual AIC rating taken from the drawings. The actual value and SKM calculation are so close for panel's 2AP-B, 3LP-DIM-1, 4AP-B, and 5DP-K1, that it is hard to say with confidence that they aren't sufficient. This is because, especially since I am a beginner with the SKM software, that the small difference is due to a mistake in the model. Panel 1DP-MER, roughly 13,000 amps over the required value, would mostly likely be insufficient in the event that 200,000 amps of short-circuit current becomes available at the main distribution panel.

AIC RATING			
BUS NAME	SKM	ACTUAL	OK?
1DP-MER	35794.1	22000	**No**
2AP-B	23820.4	22000	**No**
3LP-DIM-1	23820.4	22000	**No**
4AP-B	23820.4	22000	**No**
5DP-K1	22443.6	22000	**No**

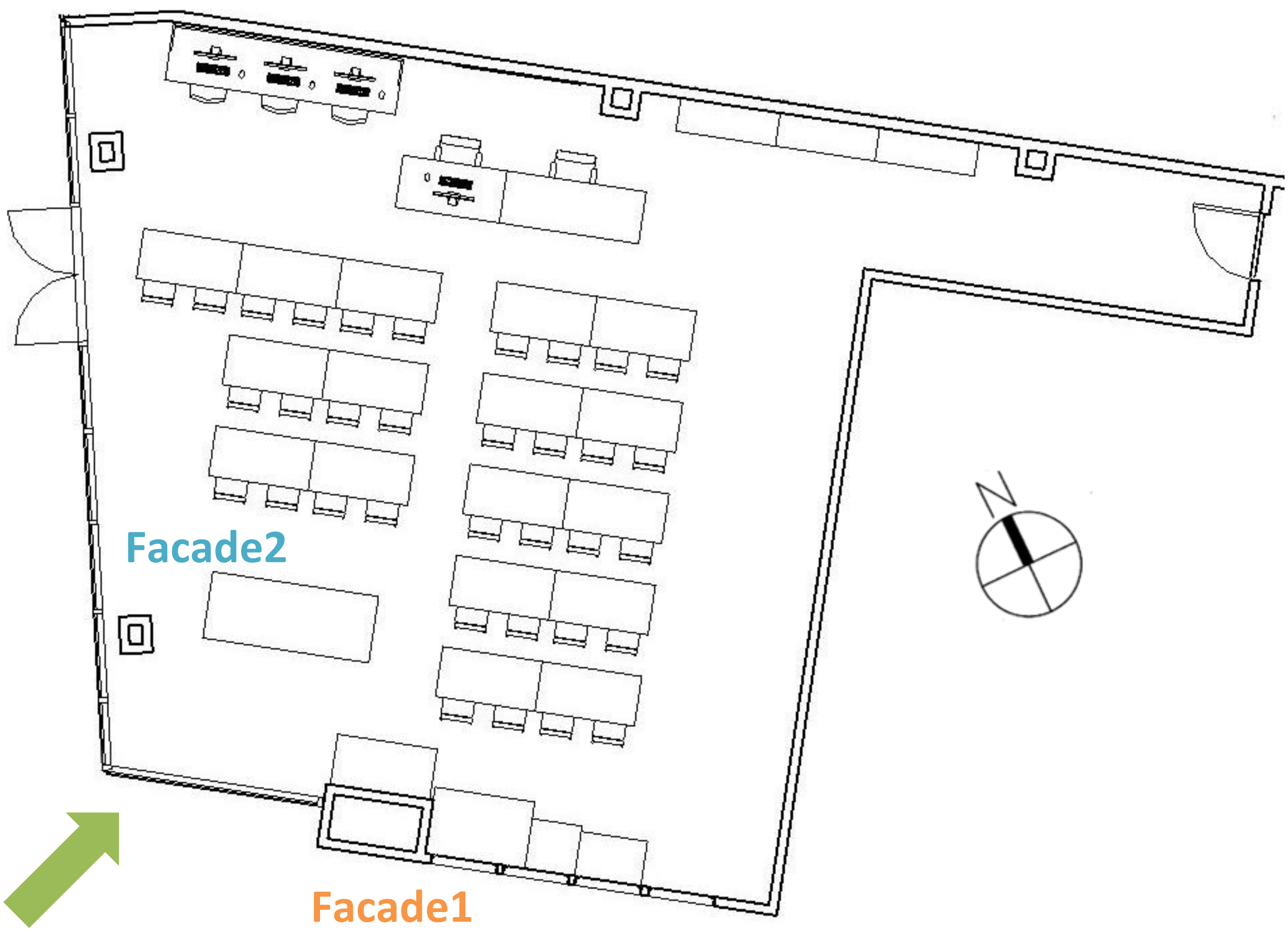
Breadth one (MAE): Daylighting

Introduction

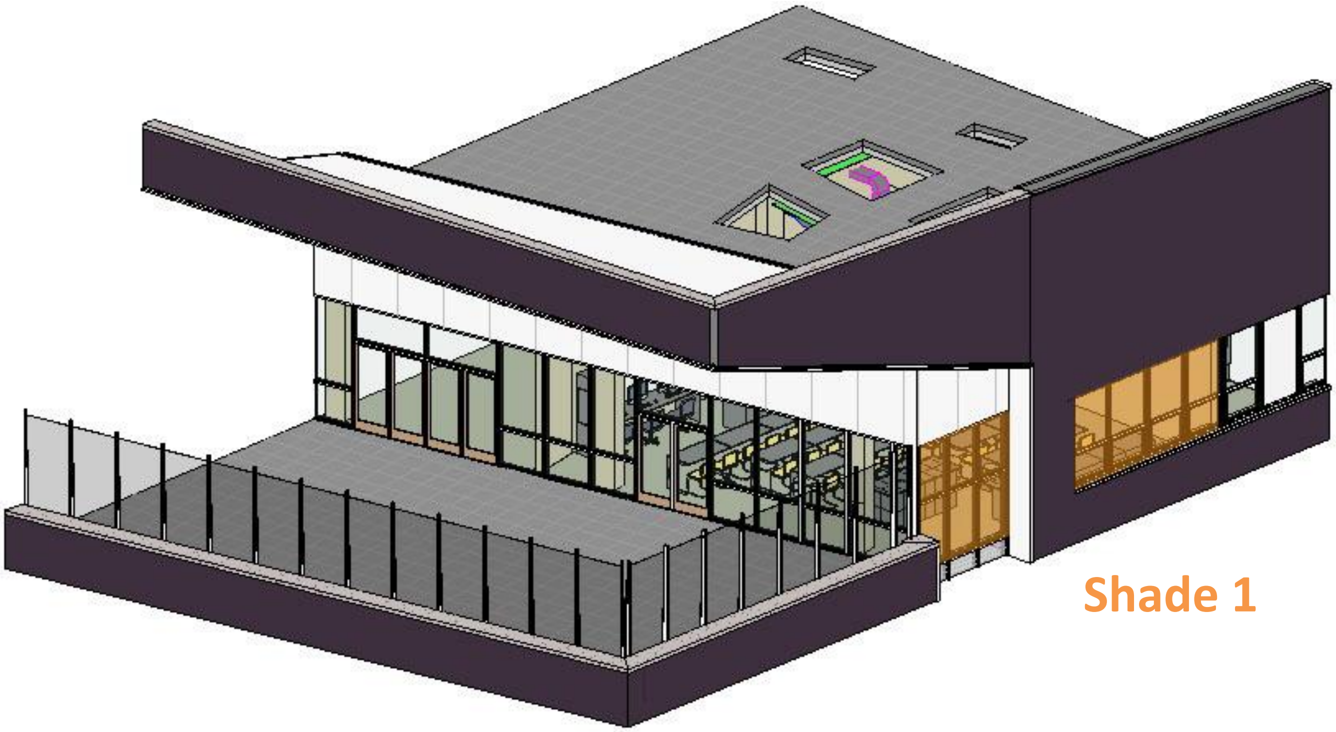
This section is dedicated to describing, in detail, the procedure and results for the MAE daylighting analysis. The High School Art Room, located on the south-west corner of fifth floor, was the basis for the analysis. For the existing space, no daylight penetration or shading devices were considered. As such, the goal of this breadth is to analyze the daylight distribution in the space, design a shading system to prevent direct sunlight penetration into the space, and implement a skylighting layout into the space that supplements the shading system. The steps to performing the MAE daylighting analysis, and the hierarchy of organization of this section of the report, are as follows:

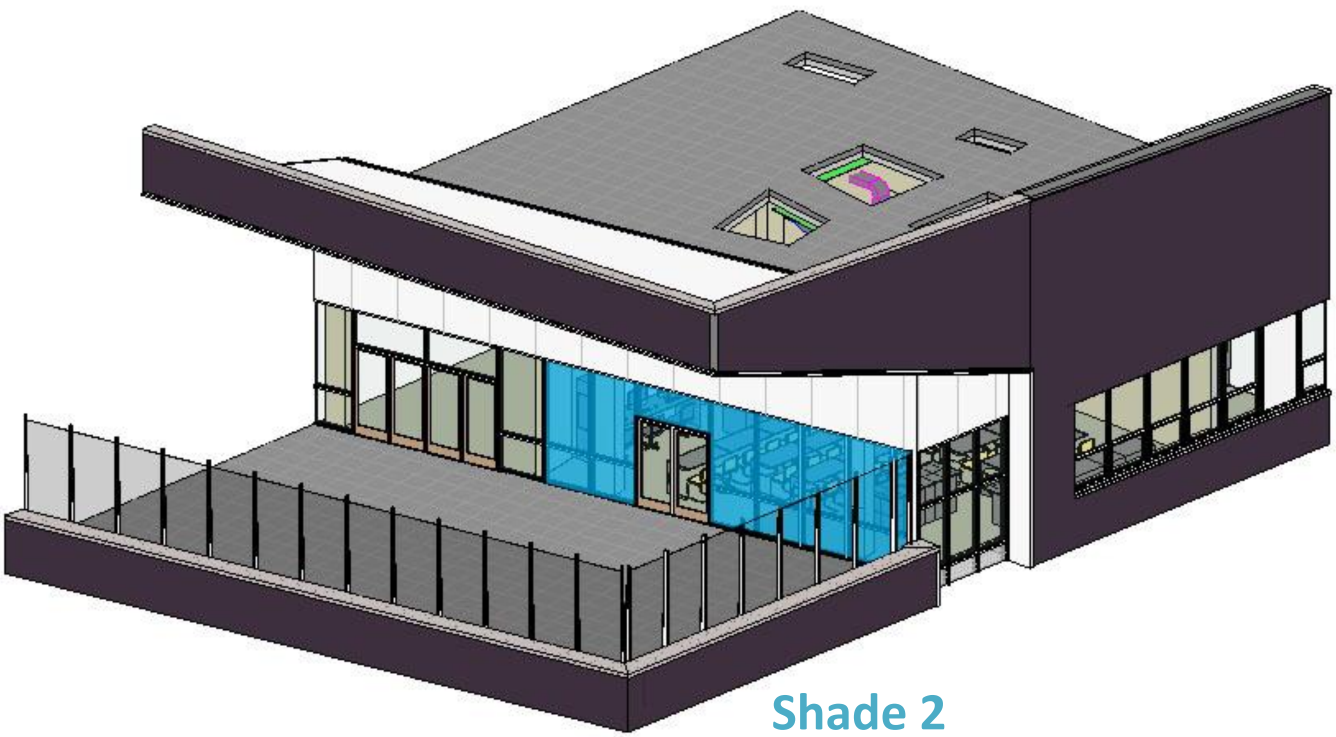
- **Step 1**: Design shading system
- **Step 2**: Design skylight system to supplement shading system
- **Step 3**: Compare daylight distribution in space: shades only vs. skylights and shades
- **Step 4**: Analyze Cost Implications

The layout of the space, as well as the two facades under consideration in this breadth analysis, are show via the plan below. The plan south façade (façade 1) and the plan west façade (façade 2) are those for which shading devices will be designed. The green arrow indicates the elevation view for the figures on the next page.



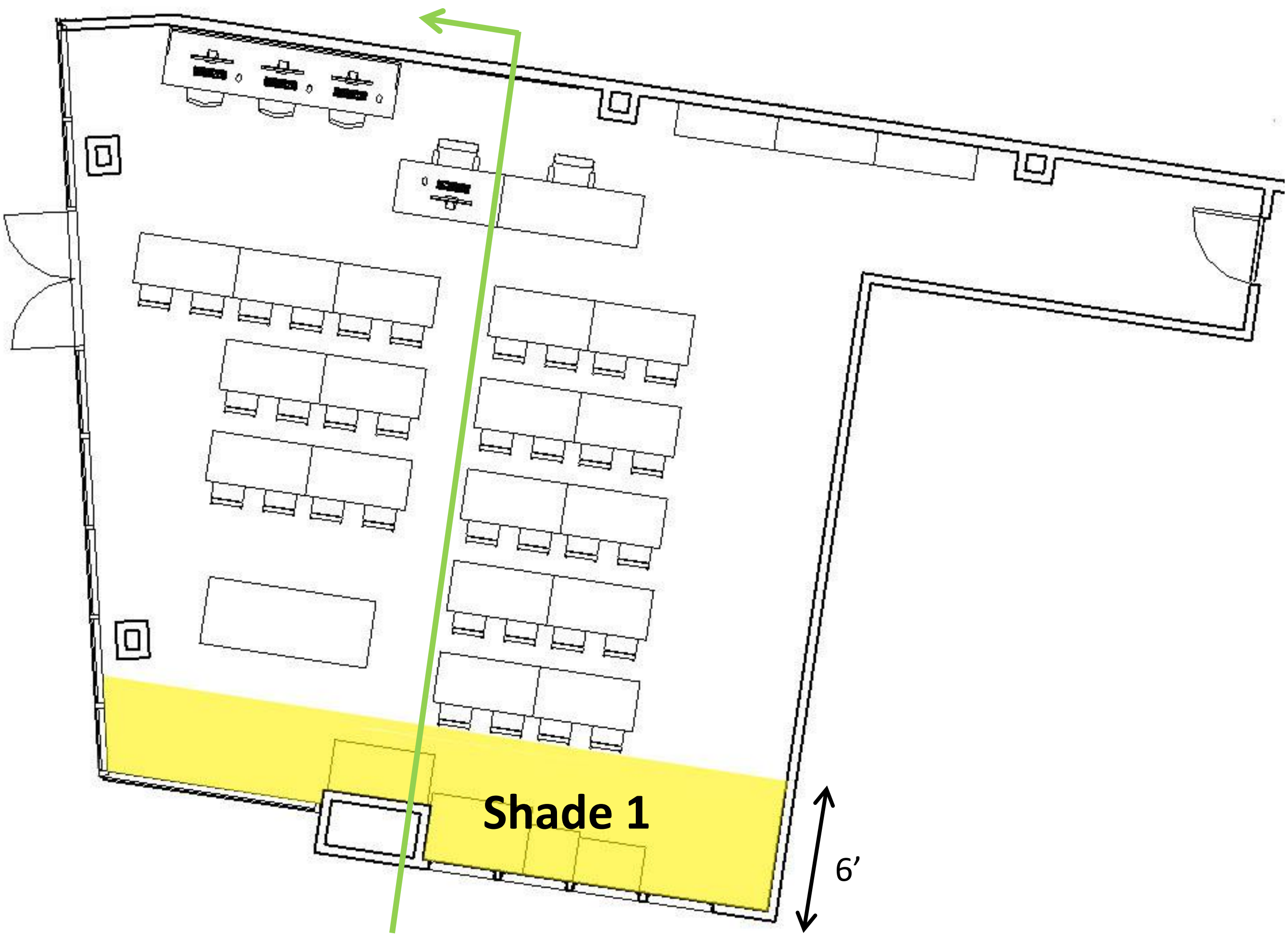
The figures below show, in elevation, the location of **shade 1**and **shade 2**:





Step 1: Design shading system

The first step in designing an effective skylight and shading system is to determine the profile angle at which direct sun would penetrate the space on both facades. The figure below shows a plan of the High School Art Room indicating the location of *shade1* on the plan south façade. The **green** line and arrow through the plan indicates the section plane and viewing direction of the section on the next page.



The section on the next page shows how the profile angle at which the shades come down was calculated. The rear desk in the space is located roughly 6 feet from the windows on *façade 1*. To prevent direct sunlight on those desks, we calculate the profile angle via the following equation:

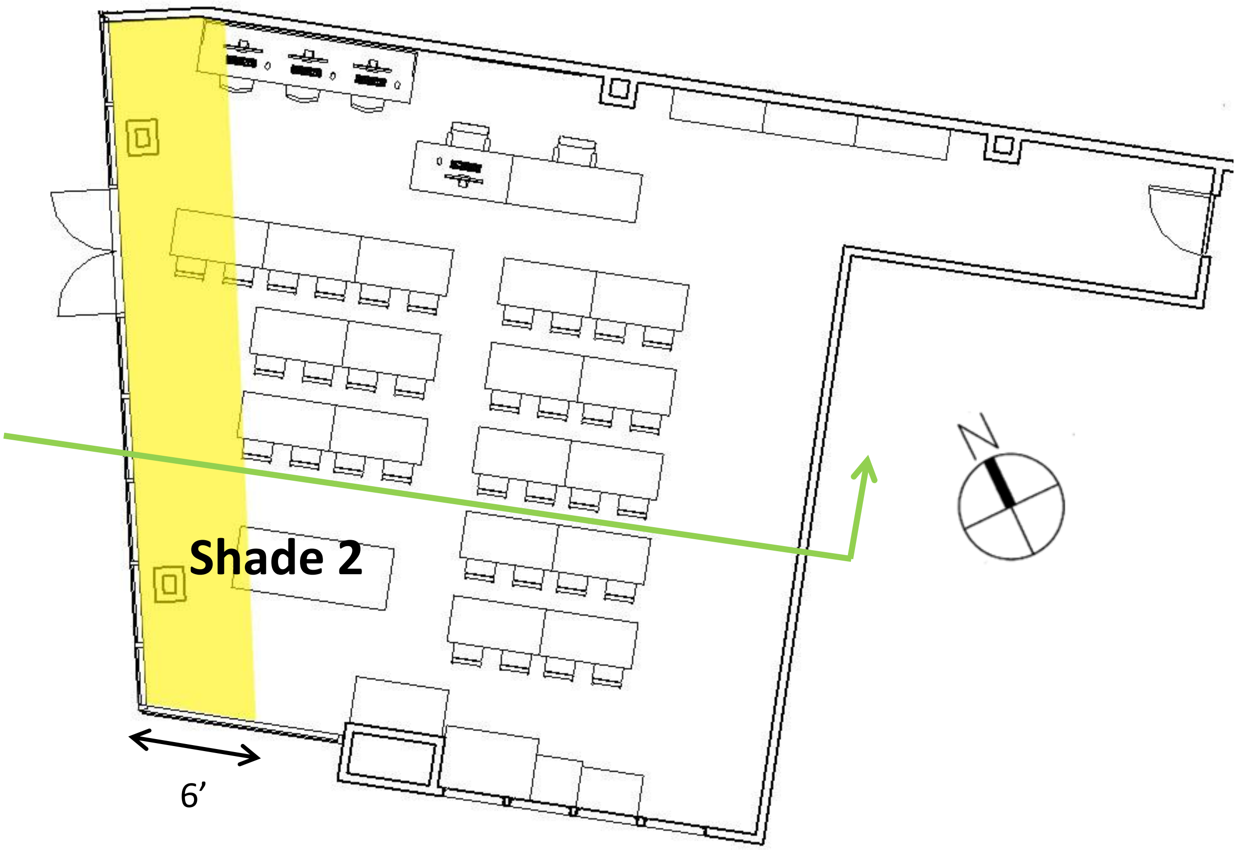
$$\tan(\theta_p) = \frac{(Height\ of\ Window)}{(Distance\ from\ window)}$$

$$(\theta_p)_1 = \tan^{-1}\left(\frac{Height\ of\ Window}{Distance\ from\ window}\right)$$

$$(\theta_p)_1 = \tan^{-1}\left(\frac{9.5'}{6'}\right) = \tan^{-1}(1.583) = 58°$$


9.5’
58°
6’

The figure below shows a plan of the High School Art Room indicating the location of ***shade2*** on the plan west façade. The **green** line and arrow through the plan indicate the section plane and viewing direction of the section on the next page.

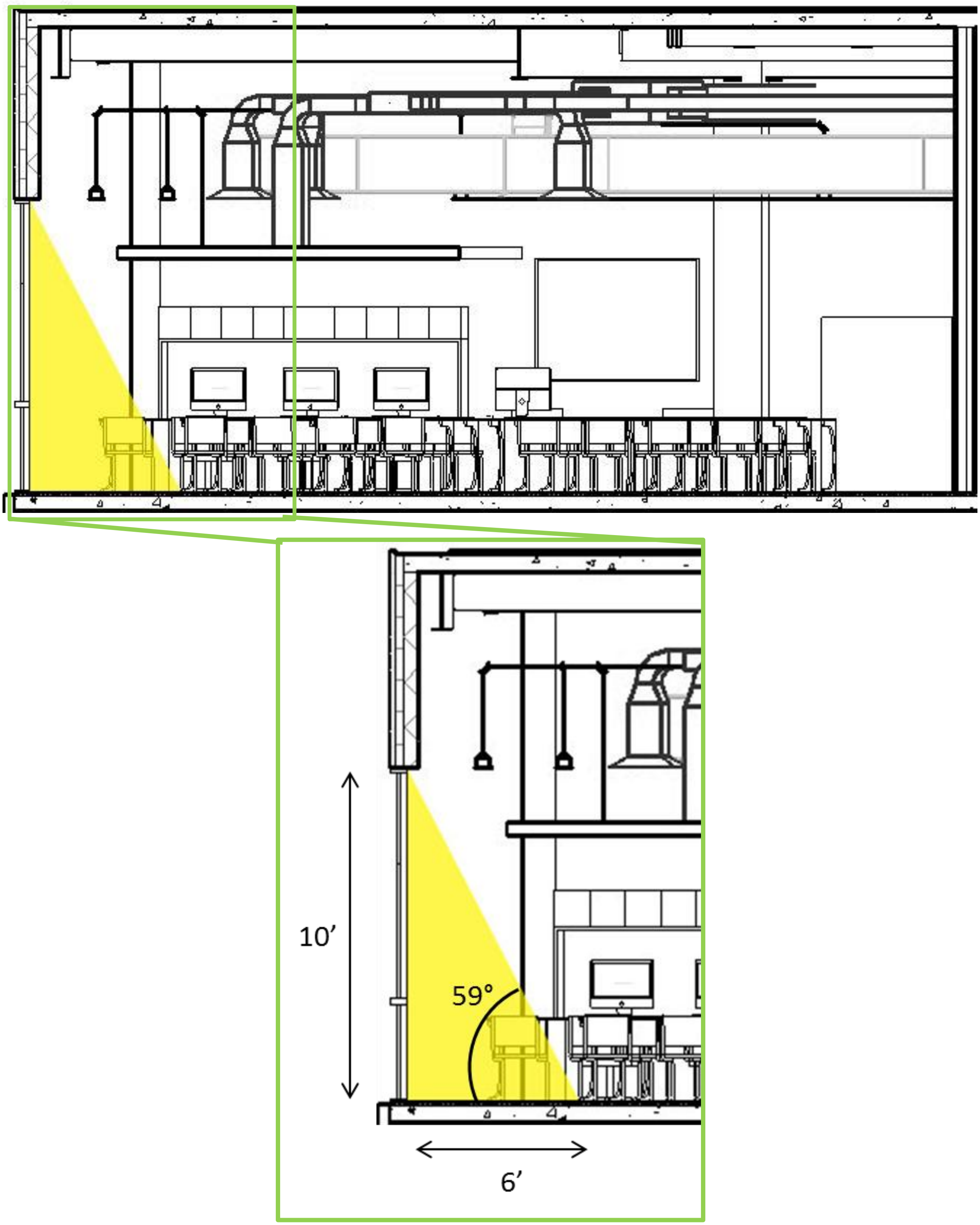


The section on the next page shows how the profile angle at which the shades come down was calculated. The rear desk in the space is located roughly 6 feet from the windows on ***façade 2***. To prevent direct sunlight on those desks, we calculate the profile angle via the following equation:

$$\tan(\theta_p) = \frac{(Height\ of\ Window)}{(Distance\ from\ window)}$$

$$(\theta_p)_2 = \tan^{-1}\left(\frac{Height\ of\ Window}{Distance\ from\ window}\right)$$

$$\boldsymbol{(\theta_p)_2 = \tan^{-1}\left(\frac{10'}{6'}\right) = \tan^{-1}(1.583) = 59°}$$


10’
59°
6’

Now that the profile angles for both facades are known, we need to determine how often the sun falls on each façade below the calculated profile angle. To summarize, the calculated profile angles for ***façade 1*** and ***façade 2*** are as follows:

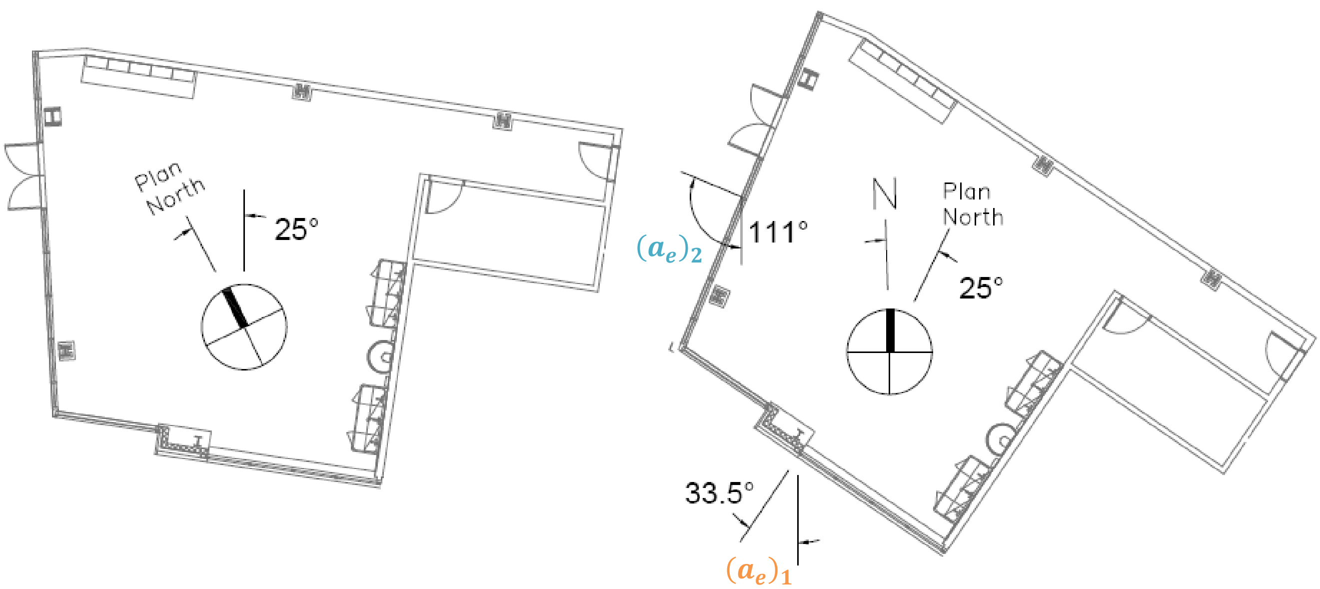
$$(\theta_p)_1 = \mathbf{58°}$$

$$(\theta_p)_2 = \mathbf{59°}$$

To determine how often the sun falls on the façade below the calculated profile angle, the elevation azimuth for each façade needs to be calculated. The plan on the left, in the figure below, represents how the space was presented on the drawings. Plan north is straight up (↑), with true north being represented by the dark bar on the compass (↖). Rotating the plan and the compass so that true north faces up (↑), we reveal the true orientation of the building. From the new plan, the elevation azimuth—which is the angle between south and the normal of the building face—can be calculated. The profile angles were calculated by hand, and verified is AutoCAD 2012. The profile angles calculated for ***façade 1*** and ***façade 2*** are as follows:

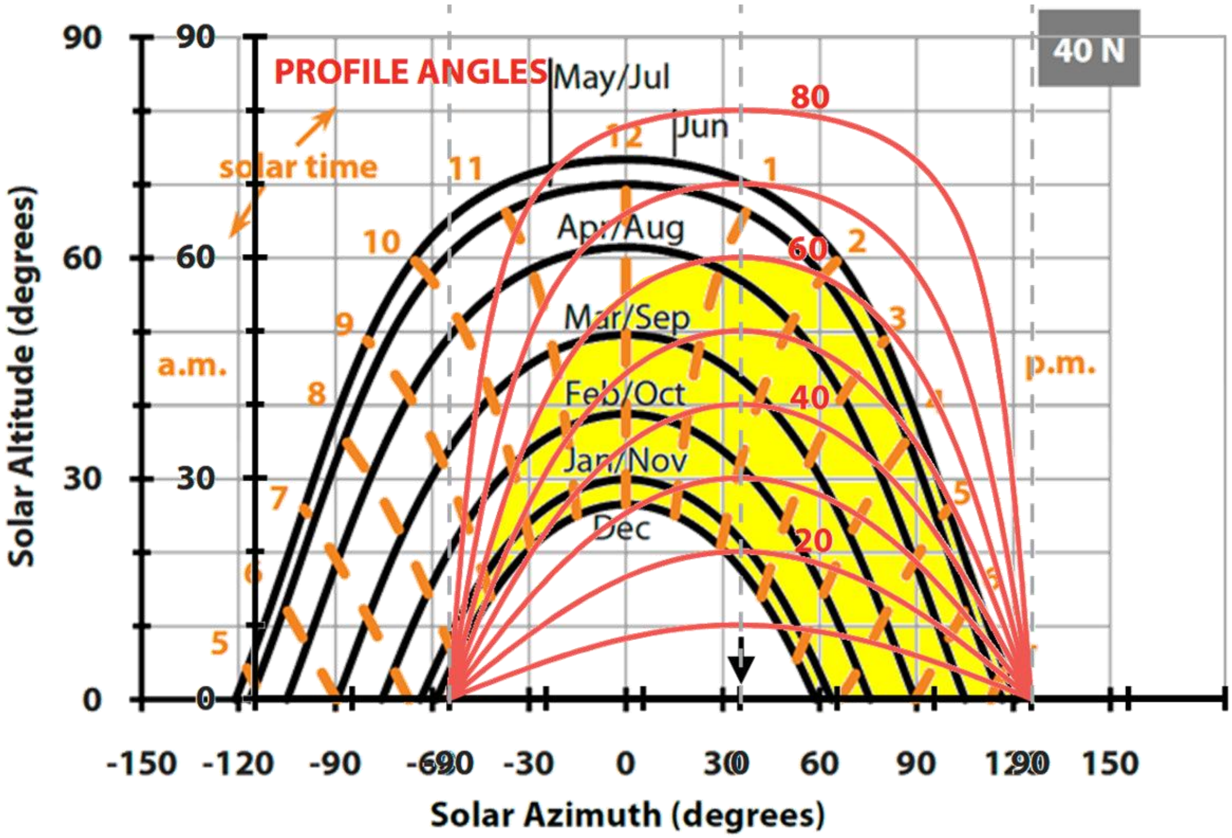
$$(a_e)_1 = \mathbf{33.5°}$$

$$(a_e)_2 = \mathbf{111°}$$

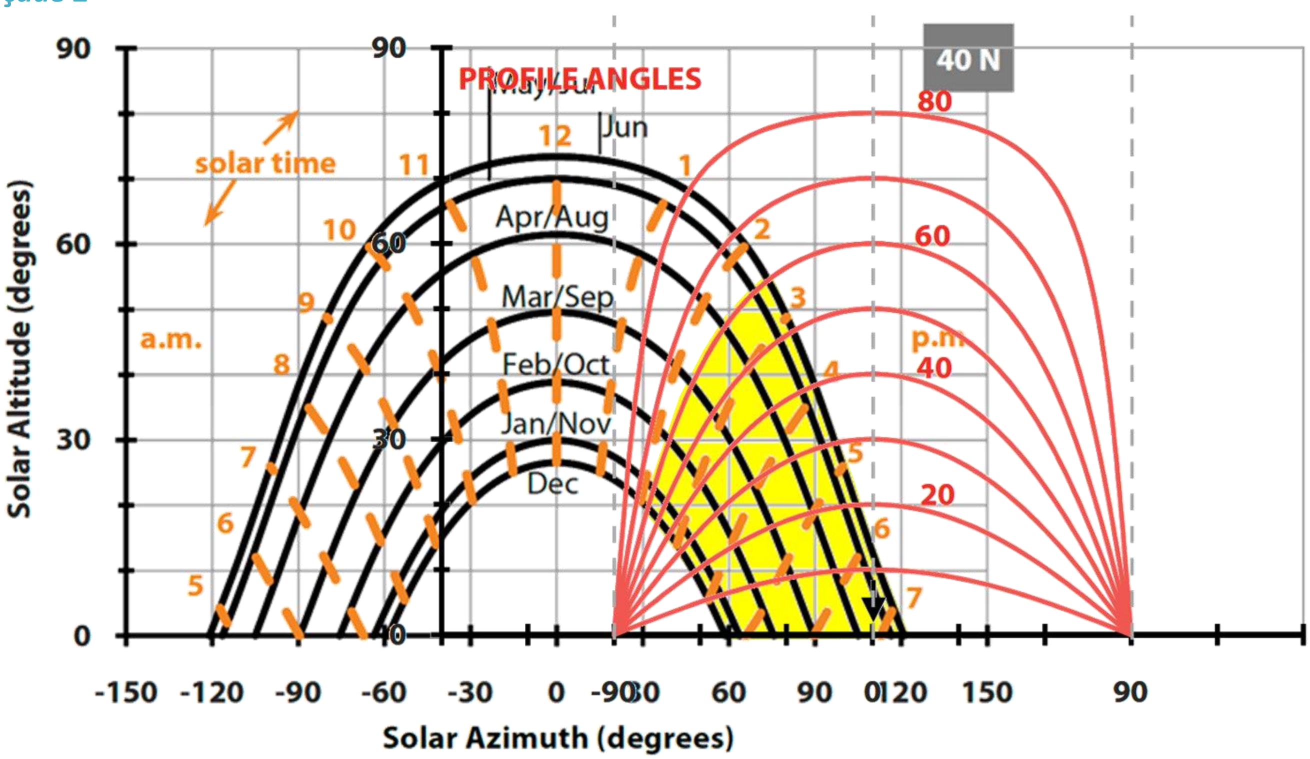


Now that the elevation azimuths for both facades are known, the duration of the year for which the sun falls on each façade below the calculated profile angle, can be shown. If we overlay the graph of solar profile angles (**Figure 14.41** from the 10th Edition IES Handbook) over top of the solar position graph for 40°N latitude (**Figure 7.8** from the 10th Edition IES Handbook), the overlap of the two graphs will show the total portion of the year which the sun falls on the façade below the profile angle. This overlap, for façade 1 and façade 2, are shown on the next page. The first figure, for ***façade 1***, shows the variability across the year with which the sun falls on the façade under 58°. The second figure, for ***façade 2***, shows that the sun falls below a profile angle of 59° all year round after 2pm.

Façade 1



Façade 2



The table below shows the numerical calculation of the total hours each shade comes down, which in turn, can be translated to the total number of occupancy hours the sun falls on each façade below the specified profile angle. This table is inclusive, meaning that, the calculated value for when shade 1 and shade 2 do not include overlap in shade conditions. For example column 5 gives the number of occupancy hours that shade 2 comes down; this number **includes** the hours that shade 2 is down that shade 1 is also down.

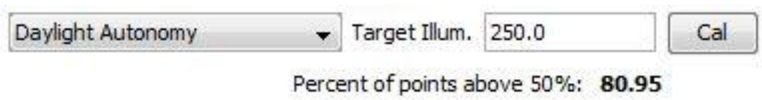
Percent (inclusive) Occupancy hours of shade conditions					
	Total Occupancy Hours	No shades down	shade1 down?	shade2 down?	Both Shades Down
Occupancy hours	2727	1185	1531	556	545
% of occupancy hours	100%	43.45%	56.14%	20.39%	19.99%

The table below is the exclusive version of the table previous. That is, each calculated shade condition ONLY includes the occupancy hours when that specific shade is down. For example, column 5 gives the number of occupancy hours that shade 2 comes down; this number **excludes** the occupancy hours that shade 2 is down that shade 1 is also down.

Percent (exclusive) Occupancy hours of shade conditions					
	Total Occupancy Hours	No shades down	shade1 down?	shade2 down?	Both Shades Down
Occupancy hours	2727	1185	986	11	545
% of occupancy hours	100%	43.45%	36.16%	0.40%	19.99%

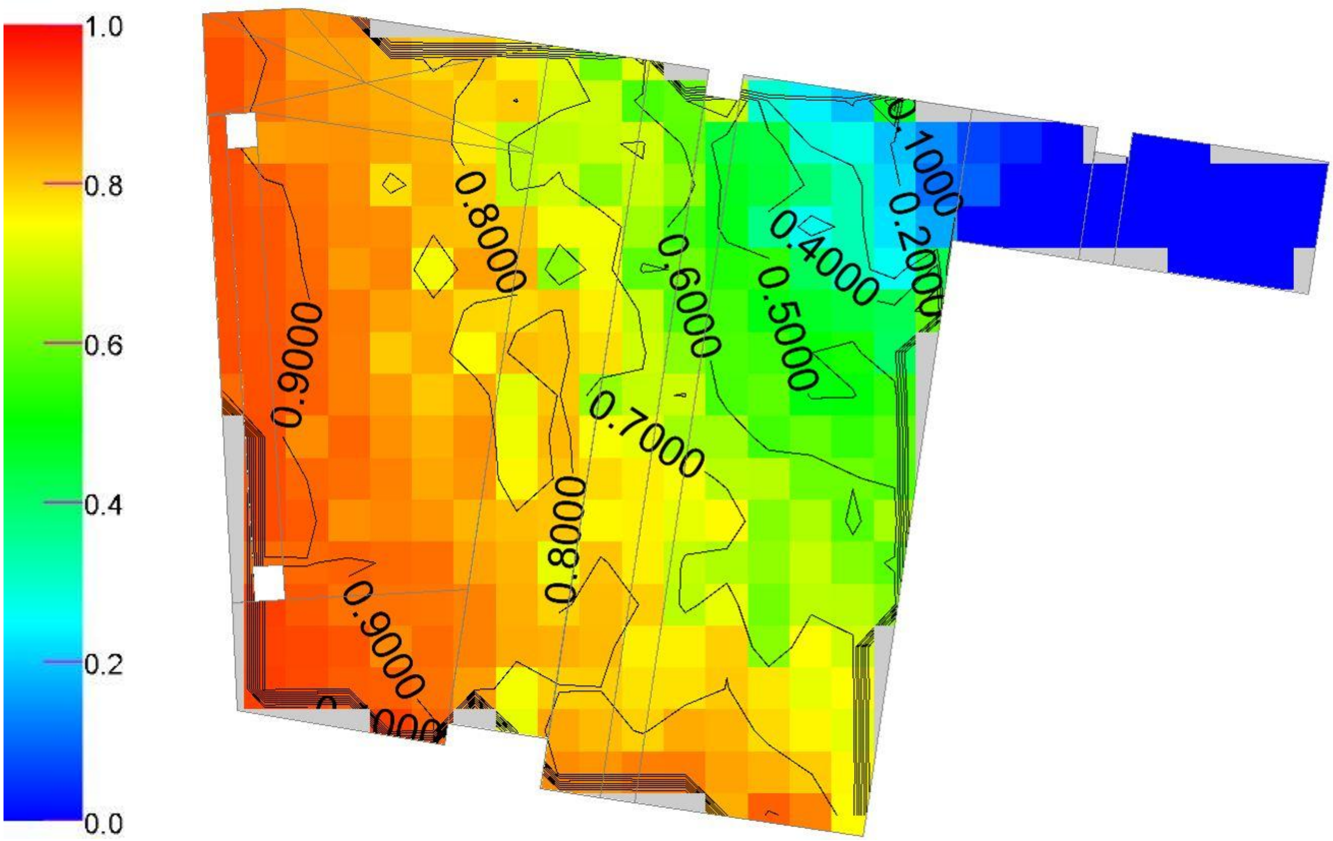
Step 2: Design skylight system to supplement shading system

Once the profile angles are known, DAYSIM can be used to analyze the distribution of daylight in the space across the year. The goal, once the daylight distribution in the space under the shading condition is known, is to design a skylight layout that supplements the shading system. The figure below shows the daylight autonomy and spatial daylight autonomy for the High School Art Room with operable shades according to the profile angles calculated in the previous step. Utilizing operable shades, the space has a ***Spatial Daylight Autonomy** of 80.95* ($SDA_{250lux,50\%} = 80.95$). This means that 80.65% of the points in the room meet the target illuminance of 250 lux 50 percent of occupancy schedule.

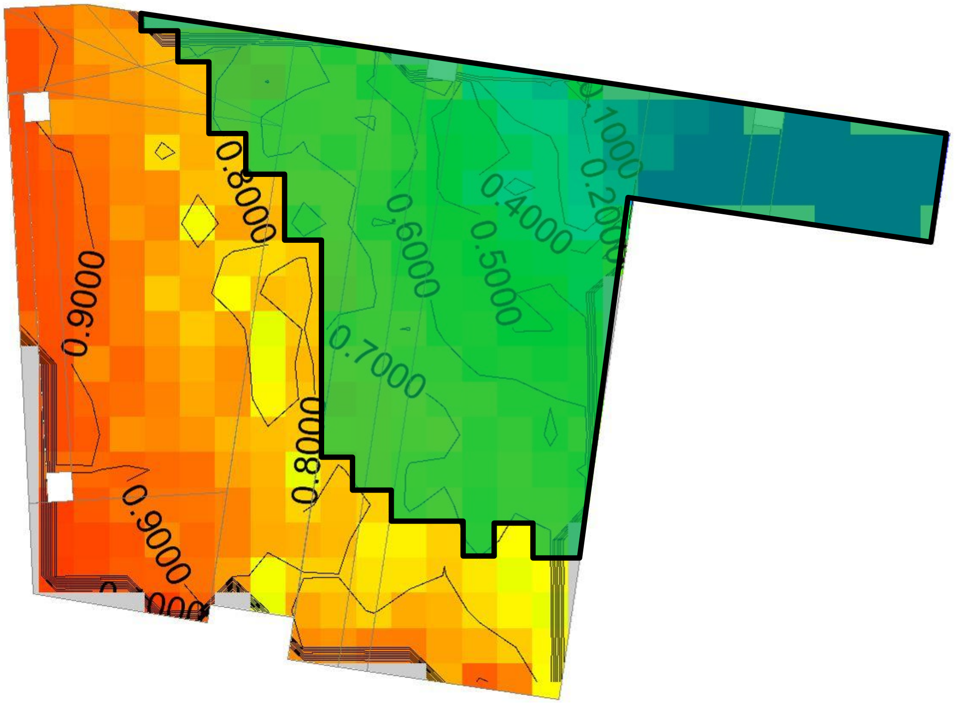


$$(\boldsymbol{SDA_{250lux,50\%} = 80.95})$$

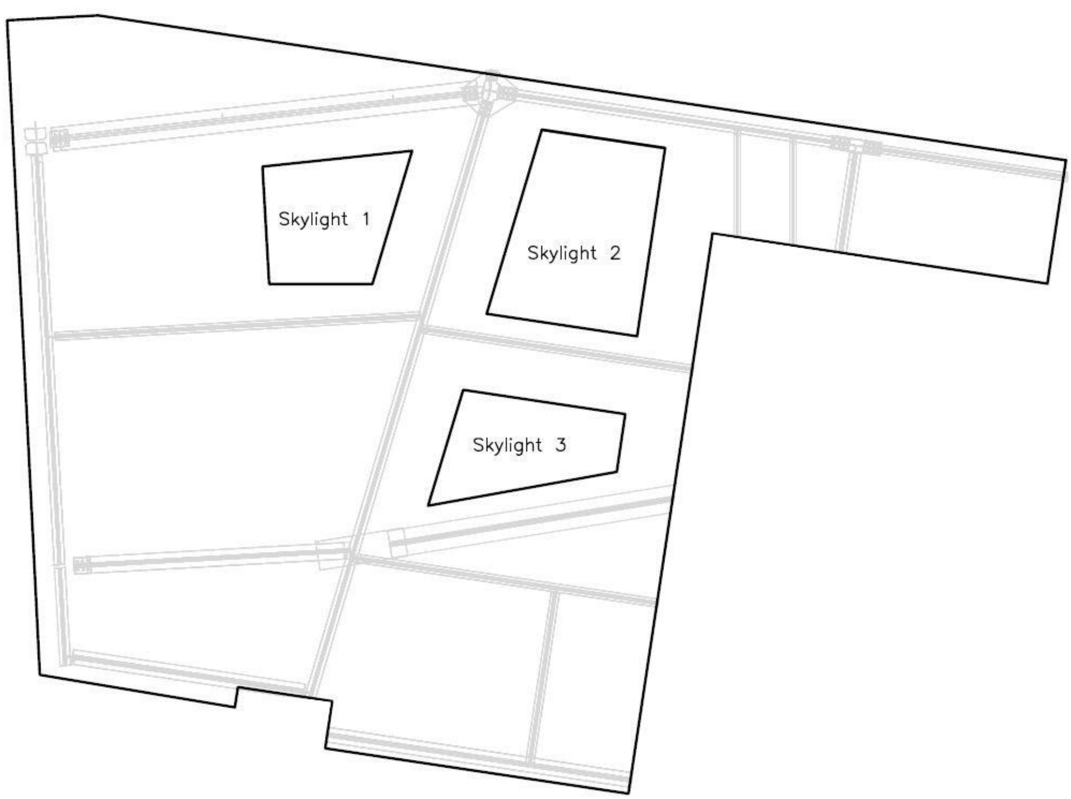
We see from the daylight autonomy plot below the distribution of percentage values of the points that meet the target illuminance across the year. As expected, the points closest to the window meet the target illuminance more times throughout the year than do points further from the window.



The plan below highlights the portion of the space that reaches the target illuminance only a small portion of the year. This area shall be deemed the ***critical zone***. The skylights should be designed so as to provide illuminance to the critical zone to supplement to supplement the shading system.



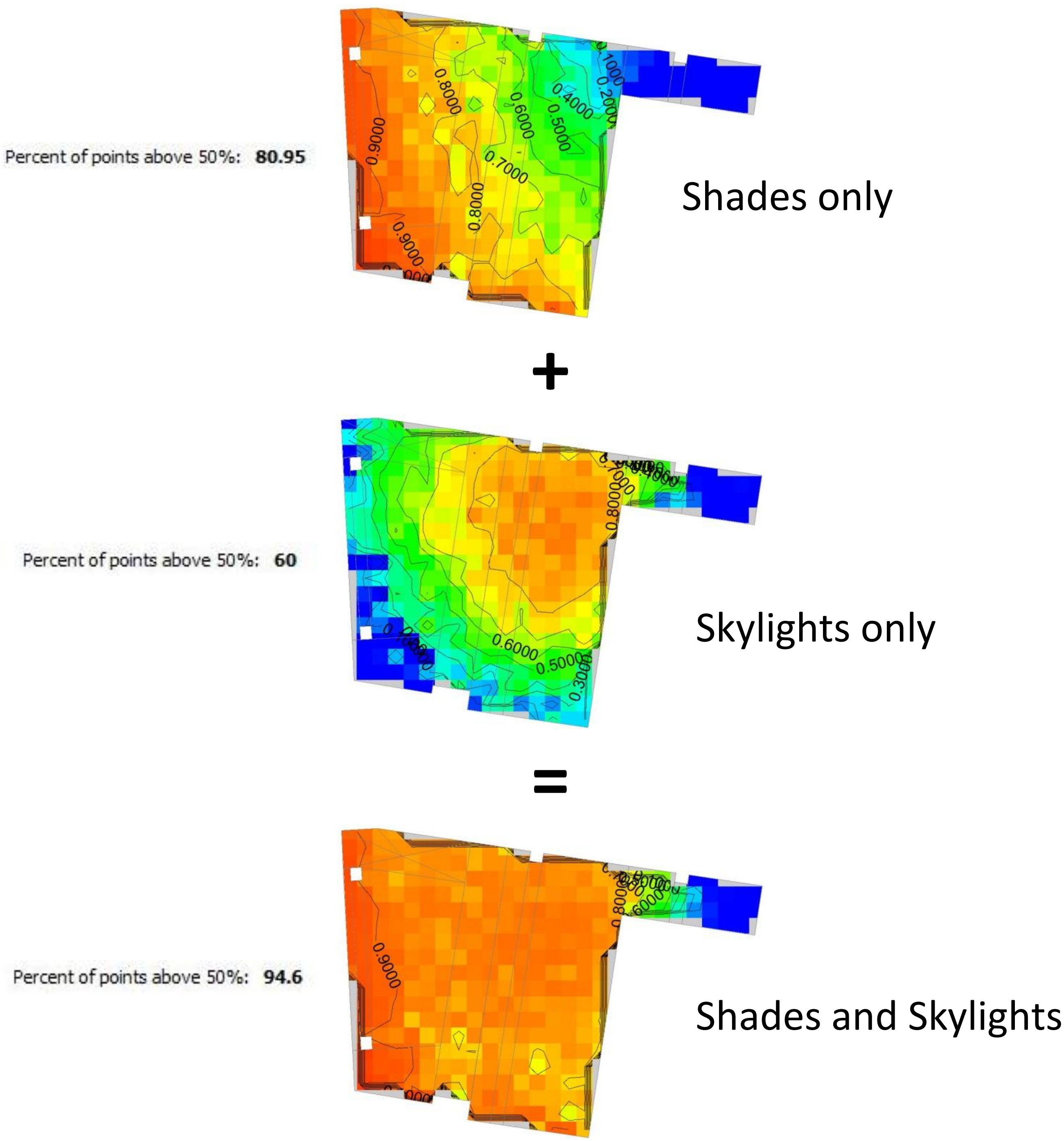
Considering both the need for illuminance in the critical zone, and the layout of the structural system in the space, the following skylighting design is implemented:



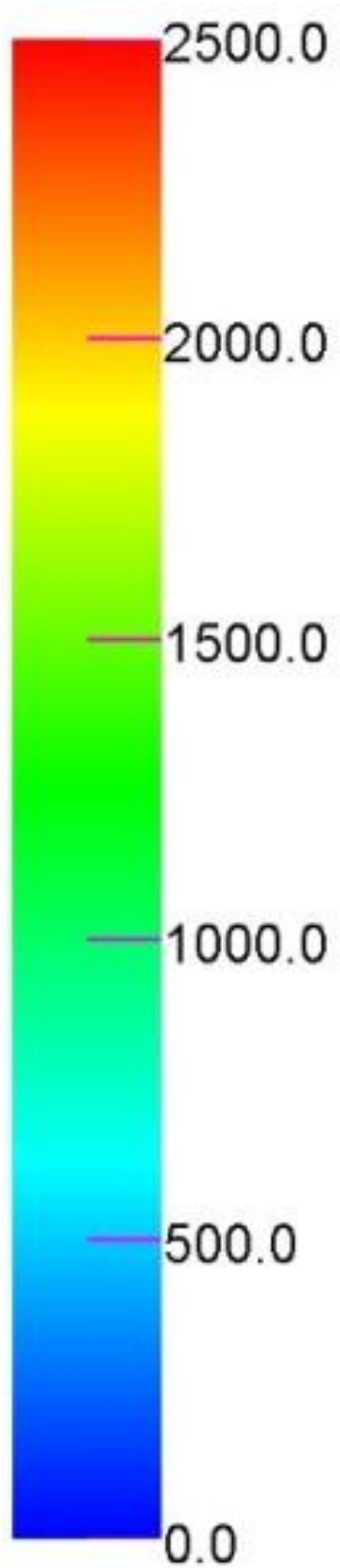
The figures below show, both graphically and mathematically, the calculation of daylight autonomy of the complete system (shades and skylights). Please note that the formula below should not be taken literally—i.e. the daylight autonomy values are not linearly additive due to overlap in percentages. The formula is merely a way to quantitatively represent the addition shown via the images.

$$\left(\boldsymbol{DA}_{\boldsymbol{250lux},\boldsymbol{50\%}}\right)_{\boldsymbol{shades\ and\ skylights}} = \left(\boldsymbol{DA}_{\boldsymbol{250lux},\boldsymbol{50\%}}\right)_{\boldsymbol{shades\ only}} + \left(\boldsymbol{DA}_{\boldsymbol{250lux},\boldsymbol{50\%}}\right)_{\boldsymbol{skylights\ only}}$$

$$\left(\boldsymbol{DA}_{\boldsymbol{250lux},\boldsymbol{50\%}}\right)_{\boldsymbol{shades\ and\ skylights}} =$$



Step 3: Compare daylight distribution in space



Step 3 is more of an analysis rather than a step that needs to be carried out. The previous step has shown the performance of the complete system—which includes both shades and skylights—via the daylighting metric Daylight autonomy. Daylight autonomy alone isn't sufficient information to determine if a system is performing preferably. In addition we shall look to analyze the distribution and penetration of daylight in the space.

This analysis is broken into two separate sections. Each section represents a different time of year, and thus, different sun and sky conditions. Within each section there are two images per row. Each row represents a single hour; the left image represents the space with just the shading system, and the right image shows the space with both the shades and skylights. They are organized this way so that a side-by-side comparison may be made, easily, at each hour of the day. This layout allows for easy comparison and as such, easy determination if the addition of the skylights is effective. The two sections, each representing a different time of year, are as follows:

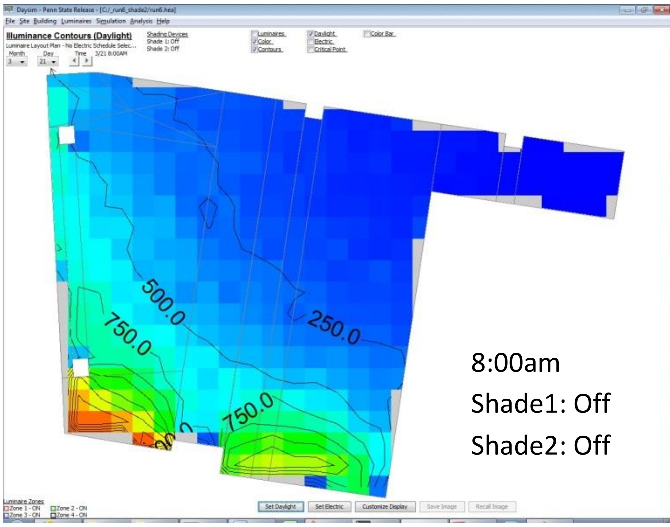
1. **Equinox:** March 21, 2012
2. **Winter Solstice:** December 21, 2012

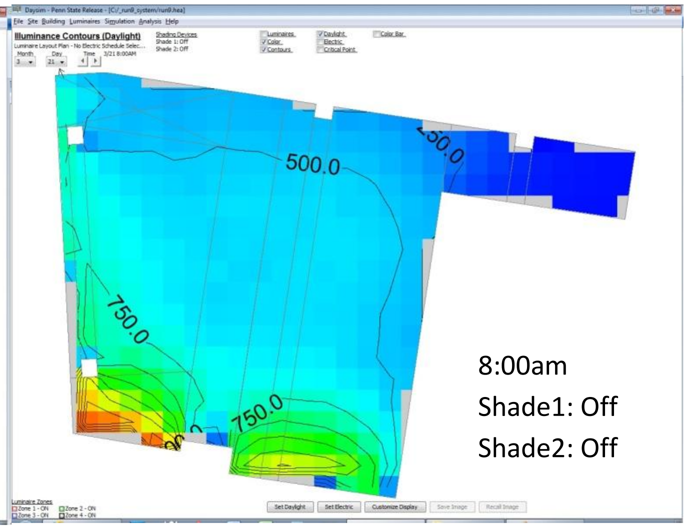
The summer solstice is not presented as it is likely that the high school art room will be unoccupied during the summer.

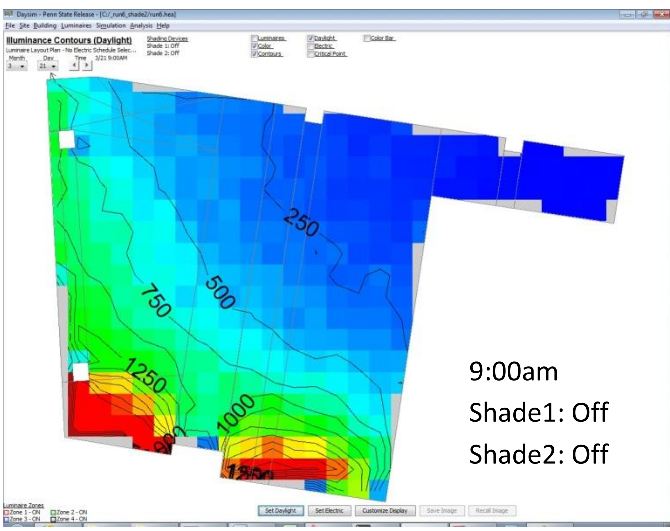
Equinox, March 21: Shades Only vs. Shades and Skylights

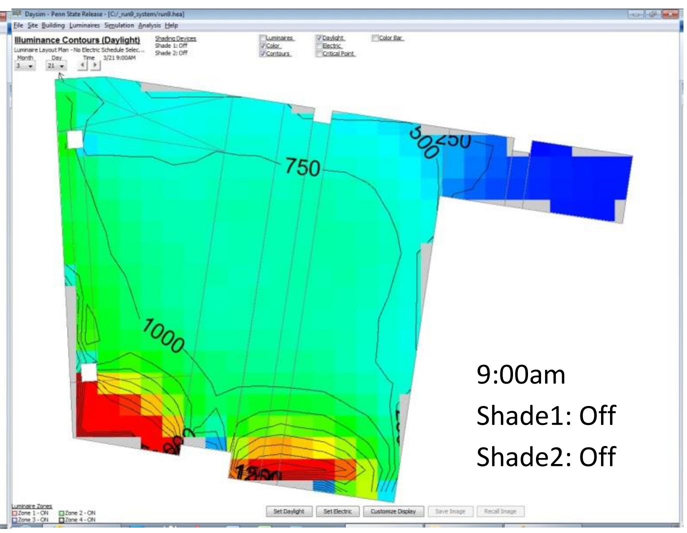
Shades Only

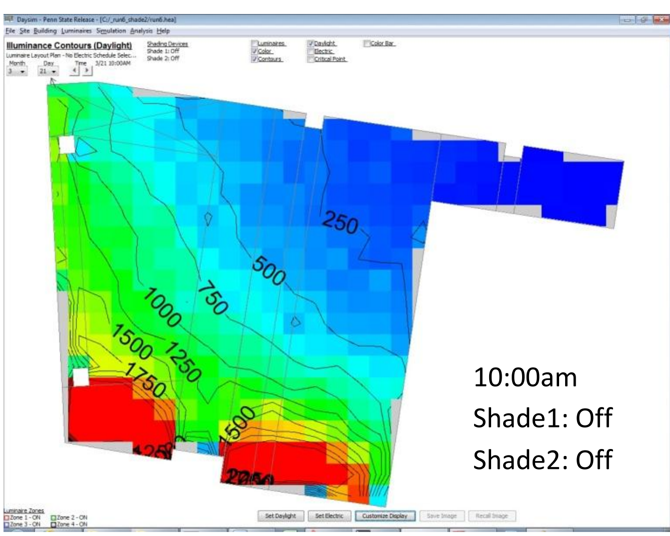
Shades and Skylights

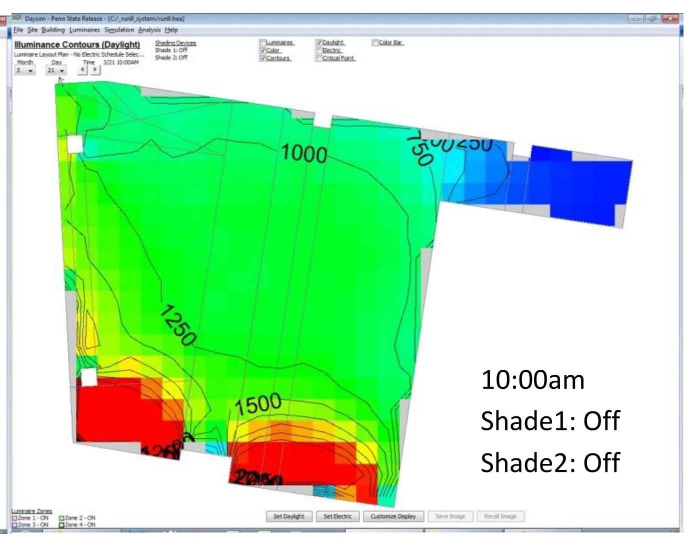






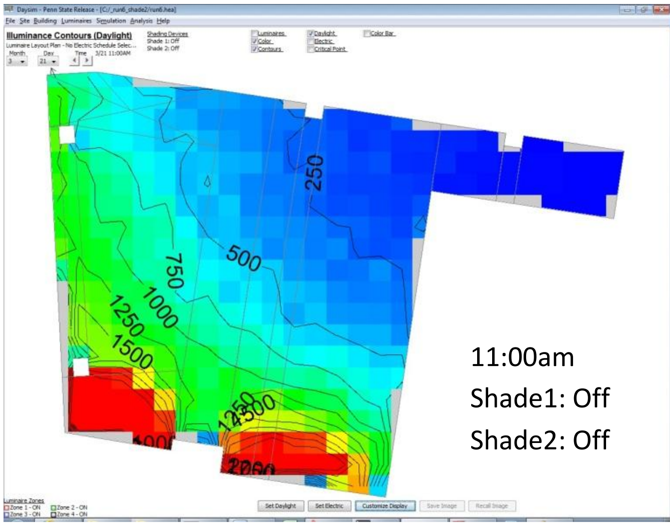


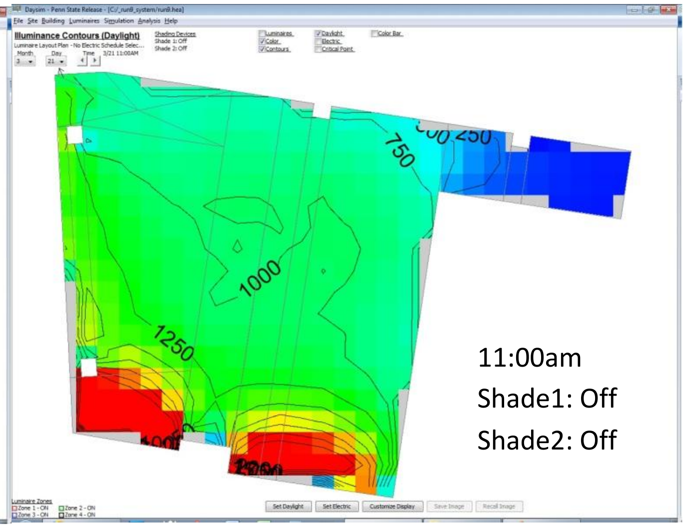


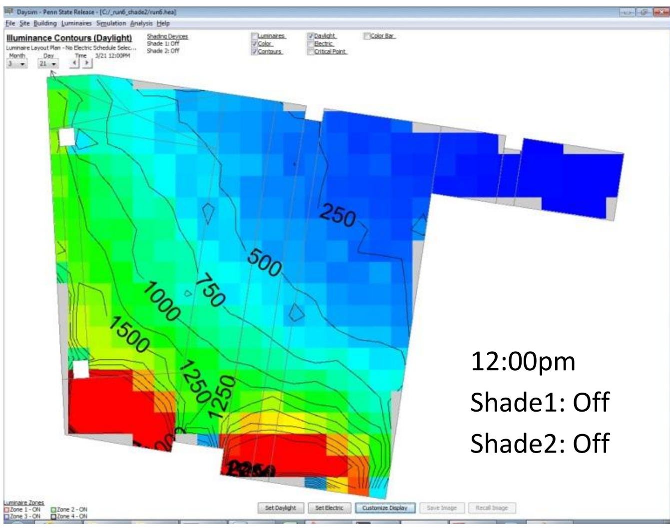


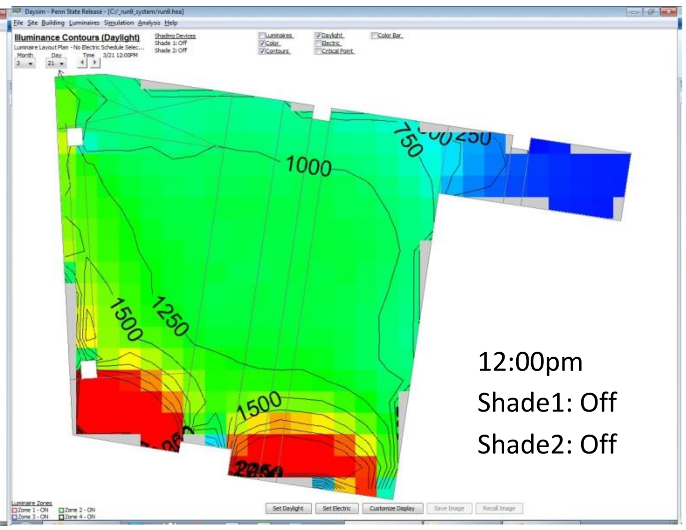
Shades Only

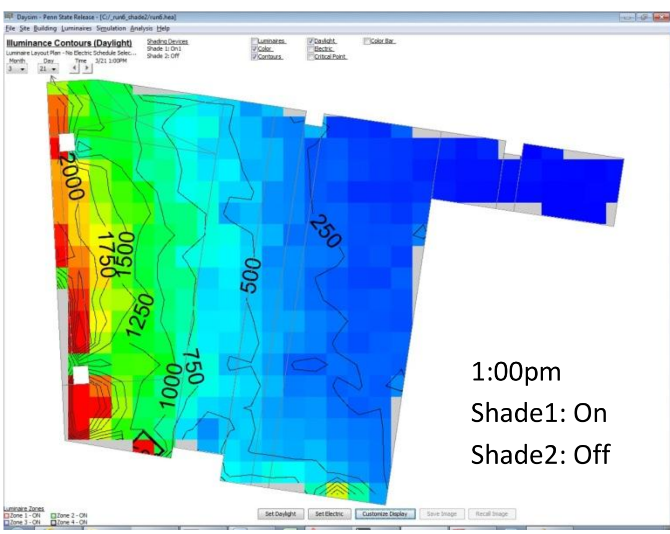
Shades and Skylights

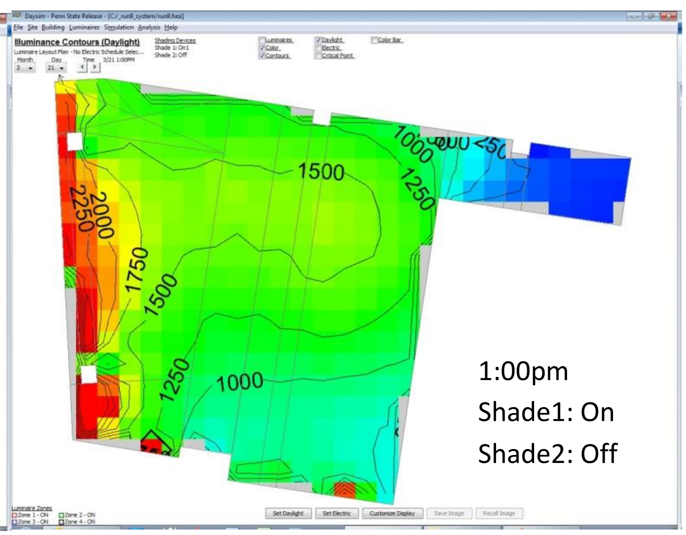




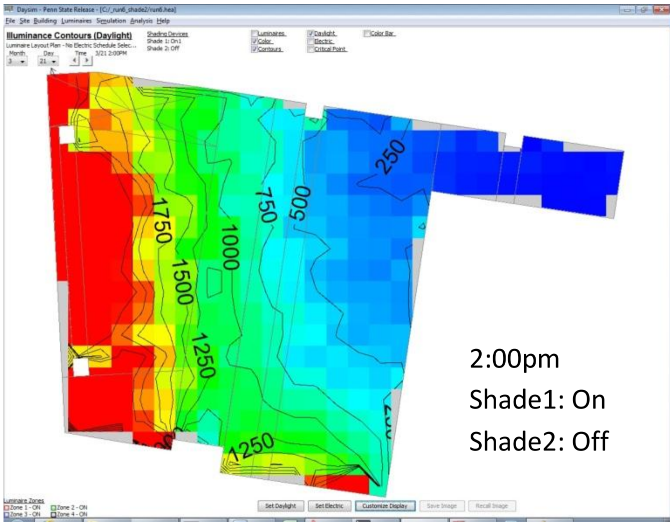


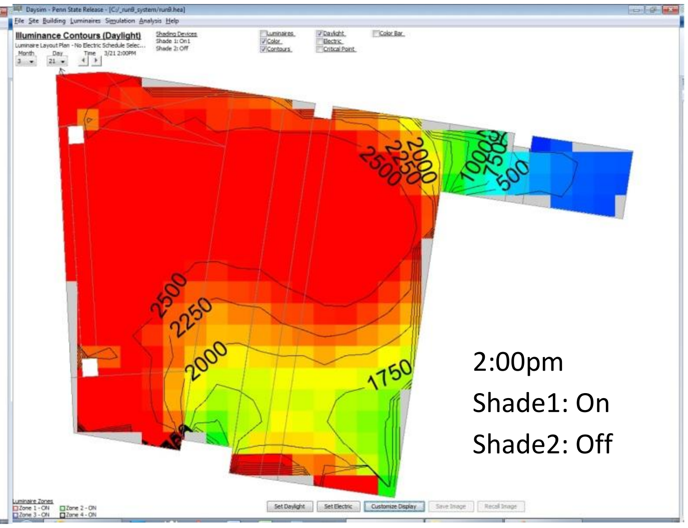


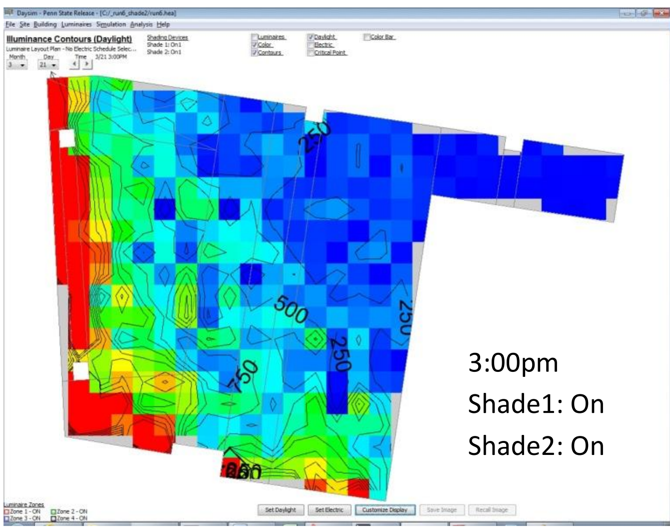


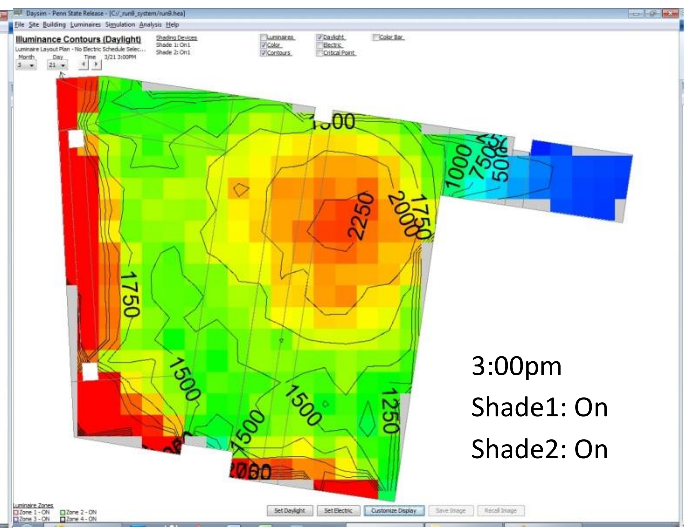


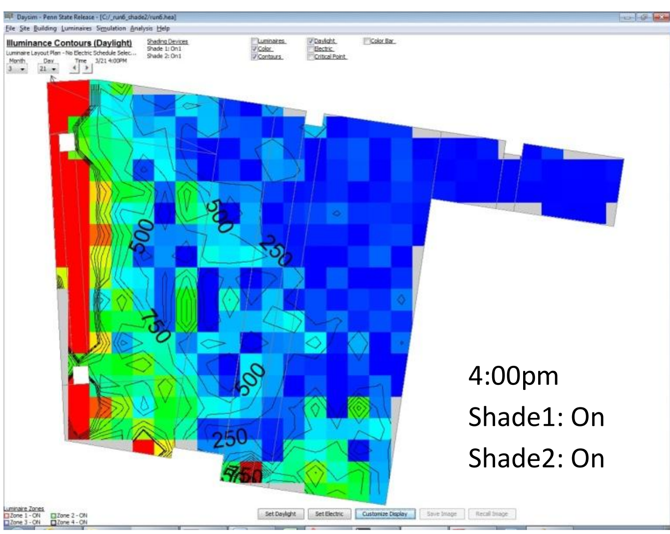
Shades Only	Shades and Skylights

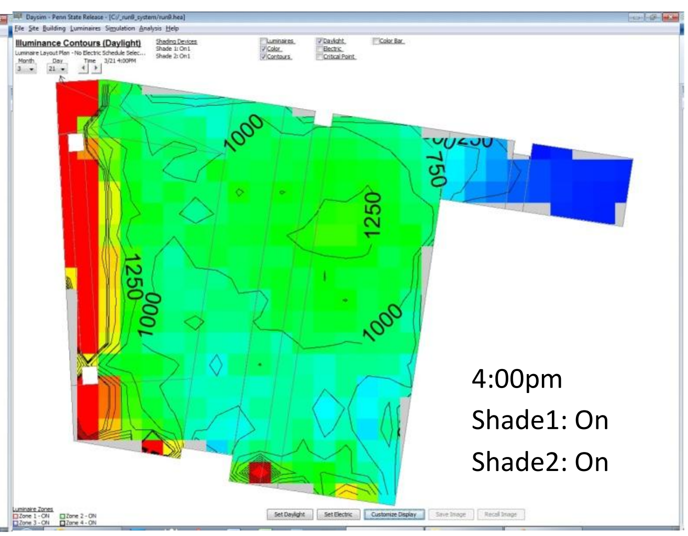






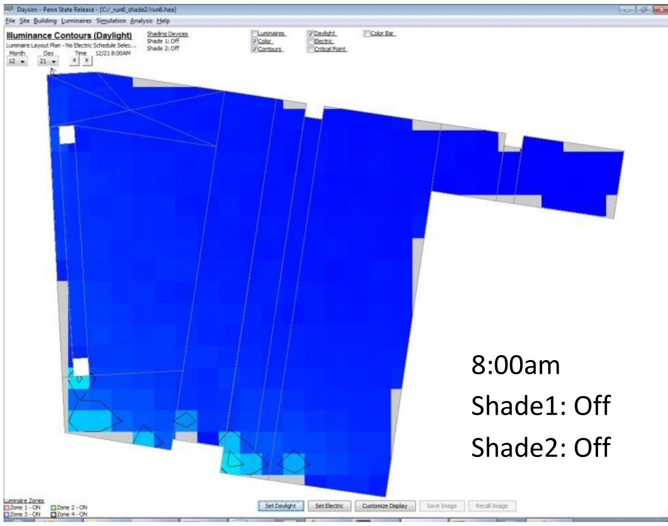


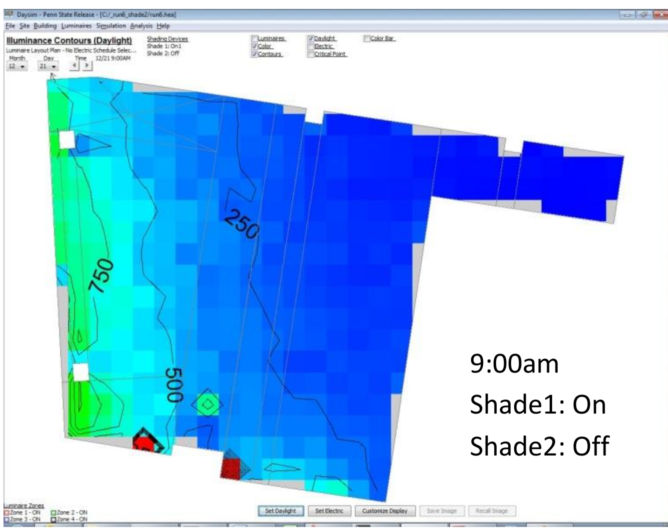


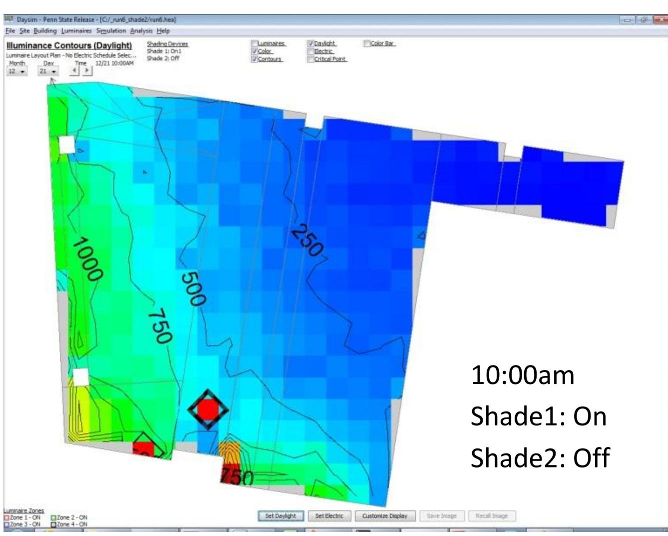


Winter Solstice, December 21: Shades Only vs. Shades and Skylight

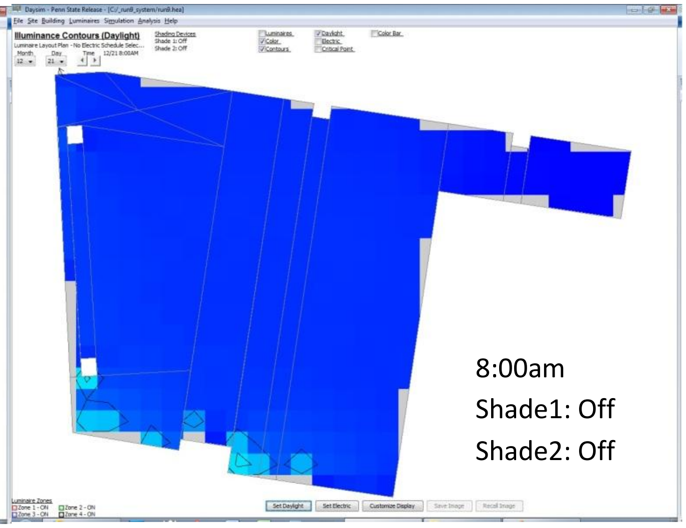
Shades Only

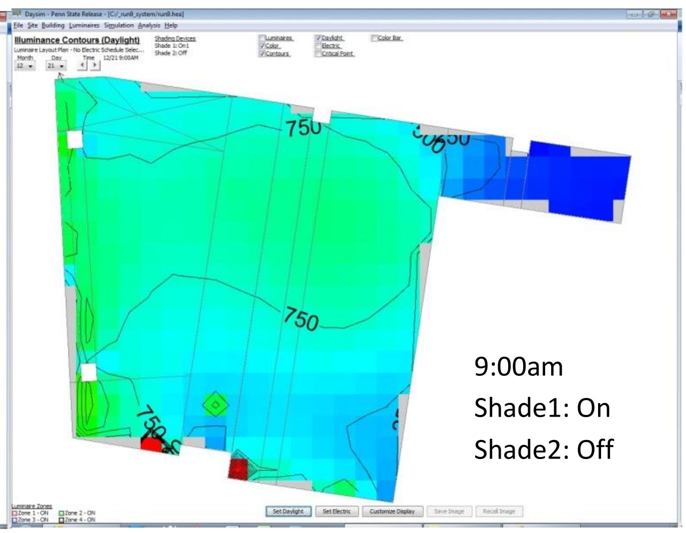


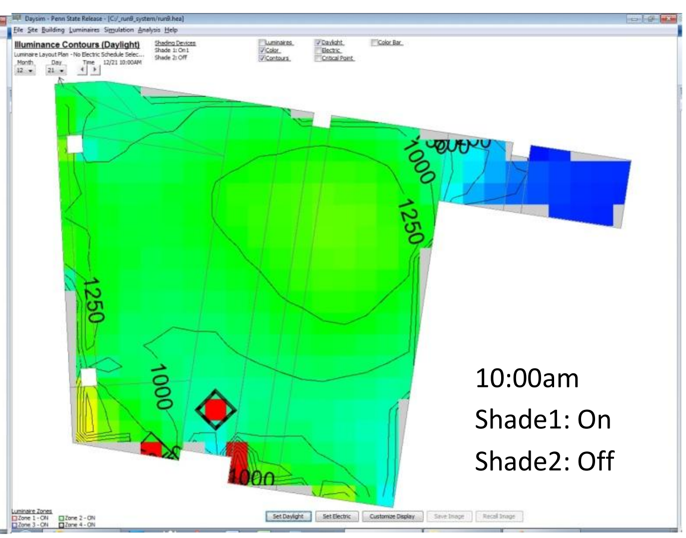




Shades and Skylights

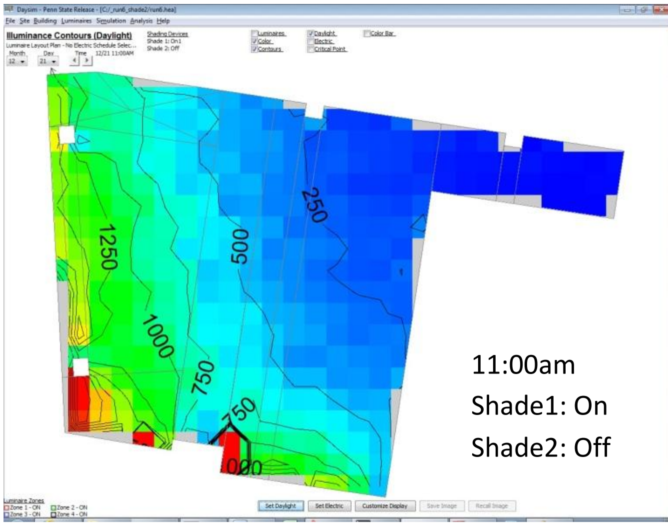


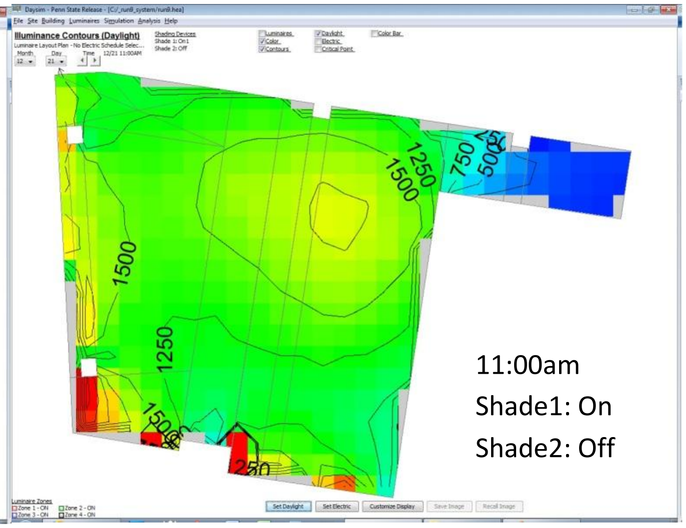


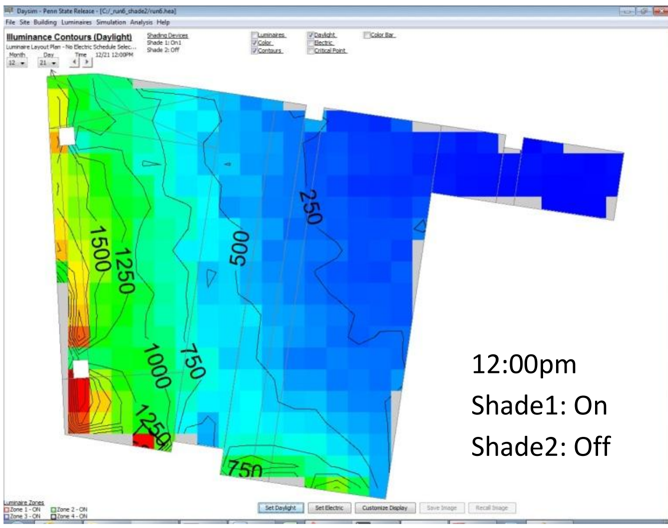


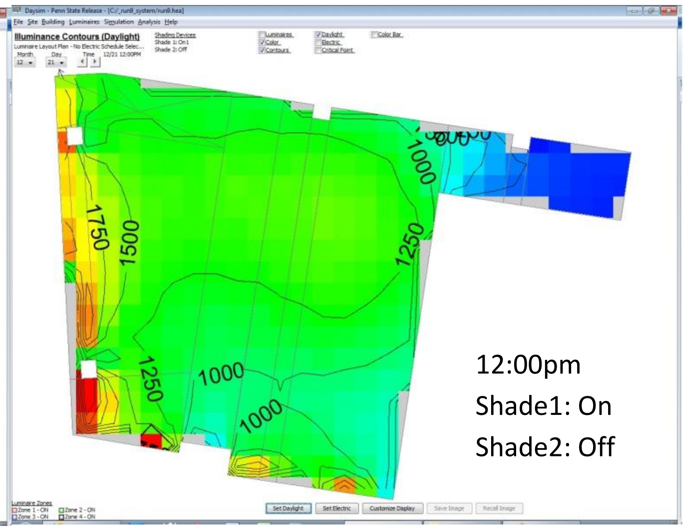
Shades Only

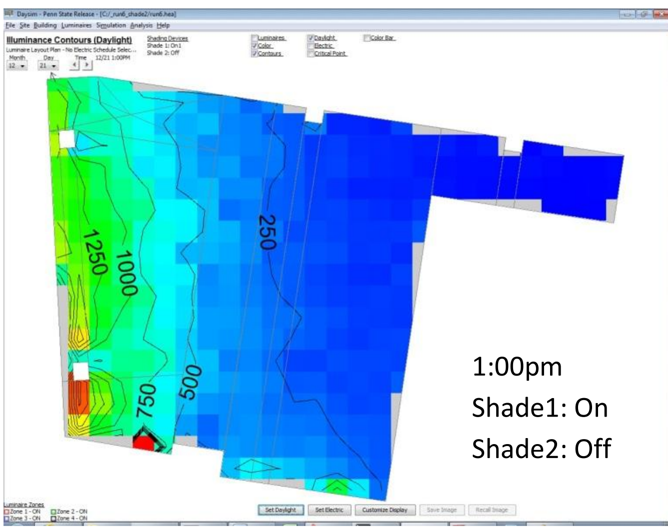
Shades and Skylights

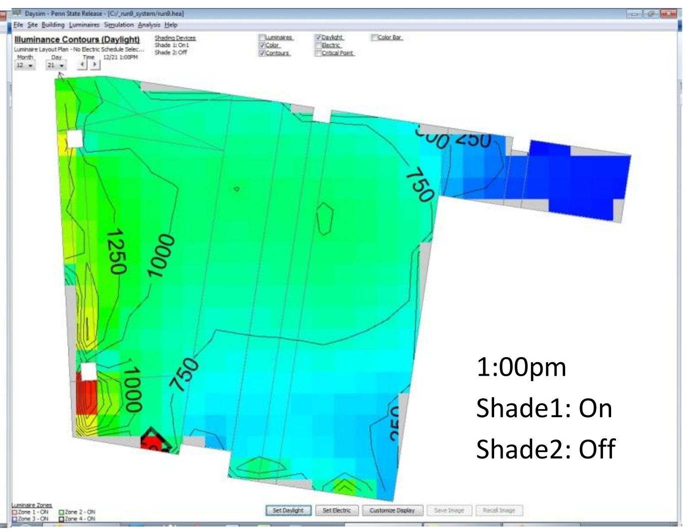




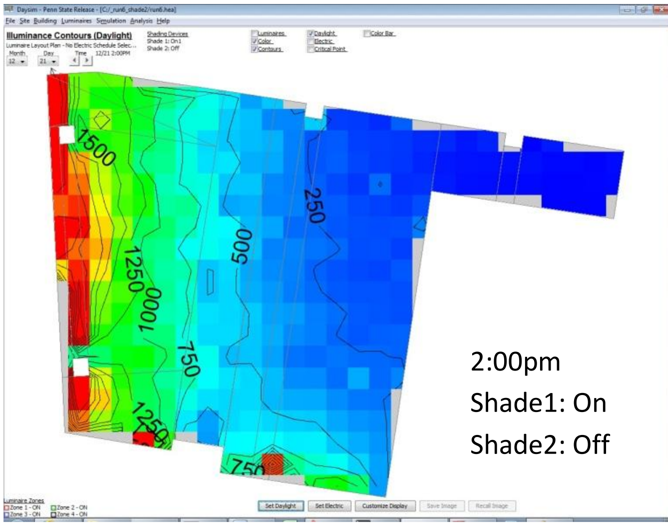


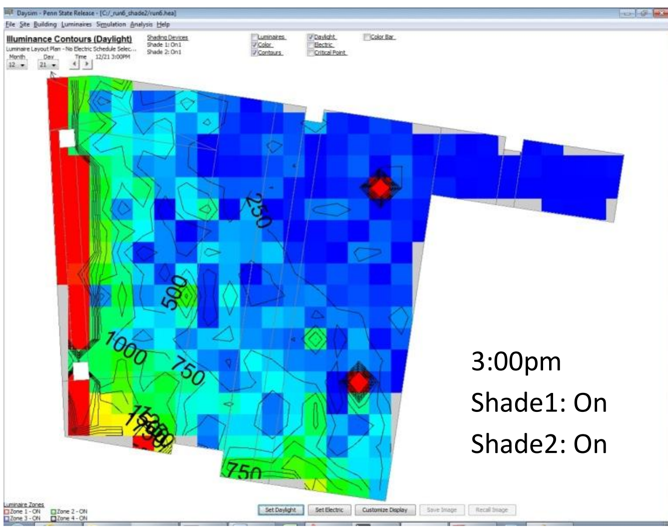


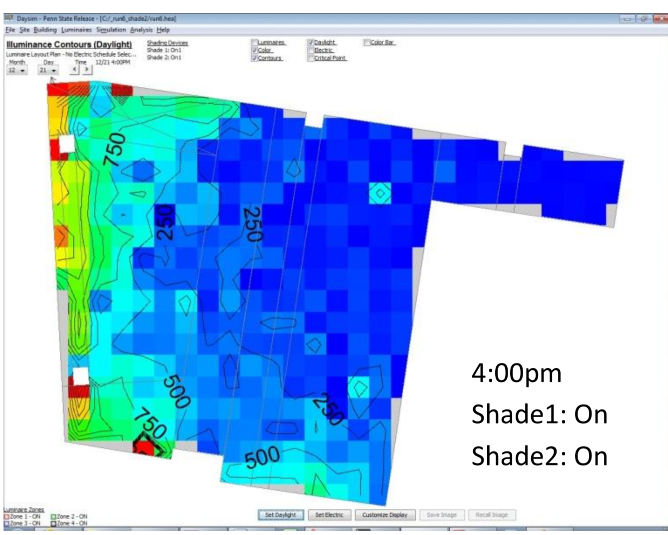




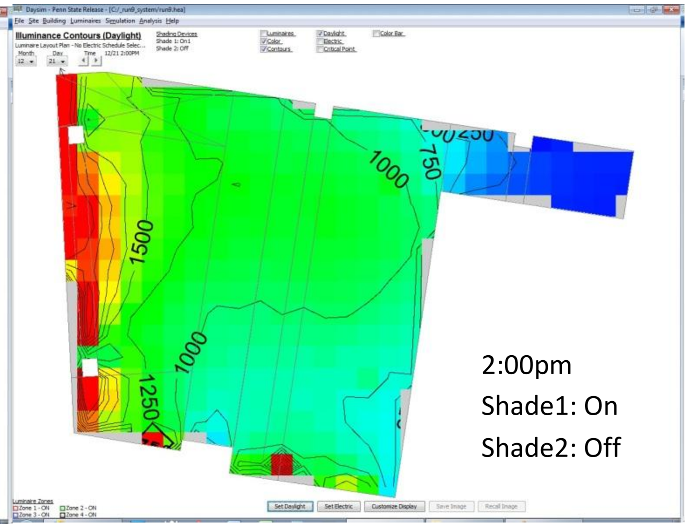
Shades Only

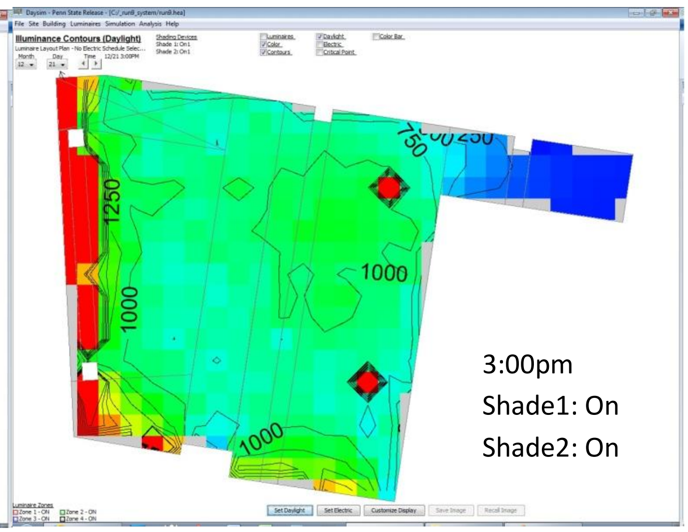


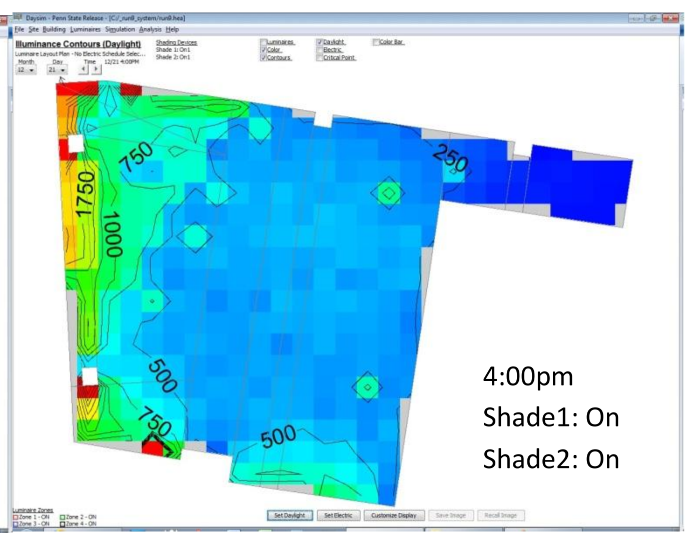




Shades and Skylights







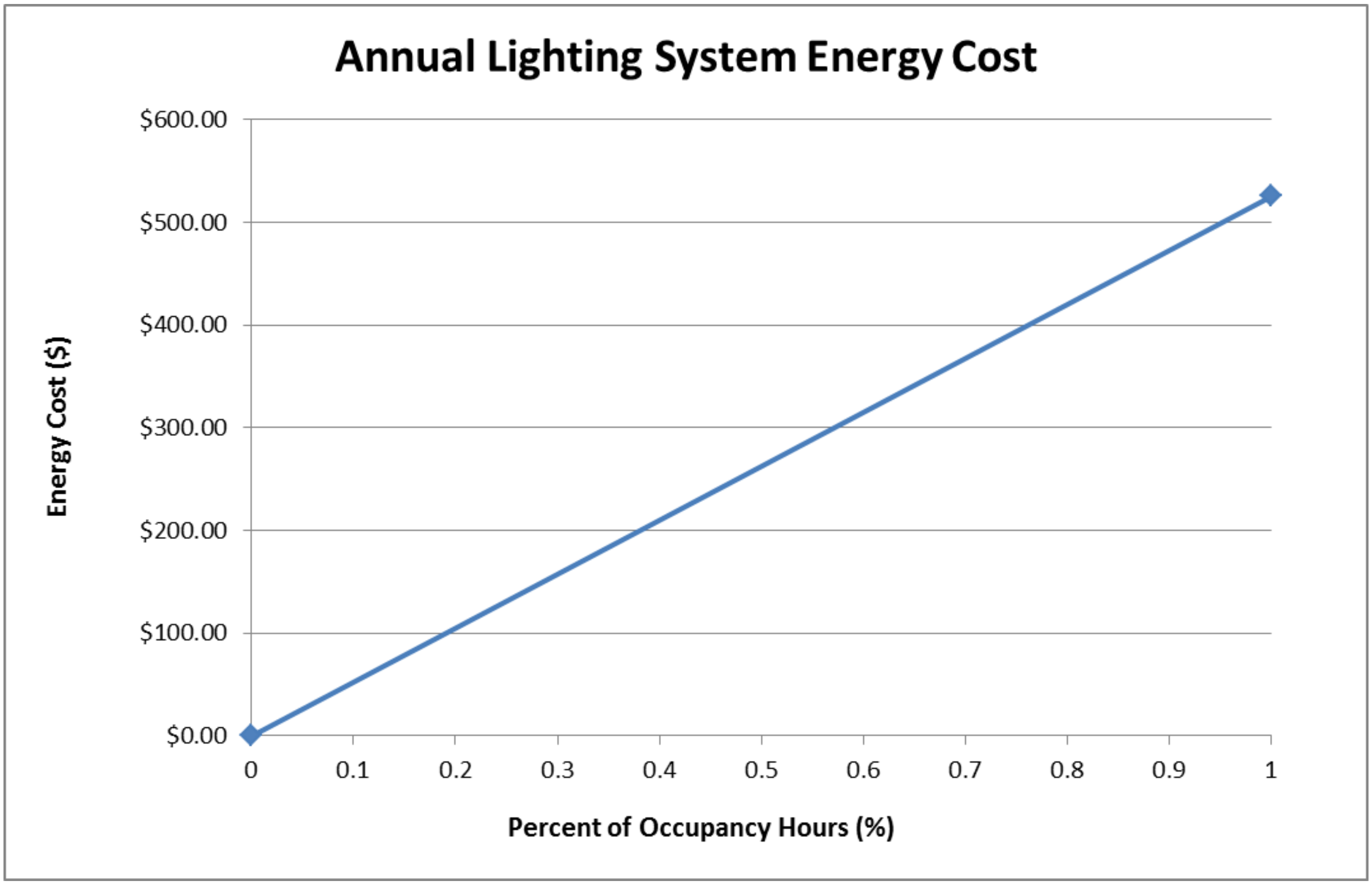
Step 4: Analyze Cost Implications

The table below shows the total cost of the lighting system based on the percentage of occupancy hours that the lighting is switched on. For example:

- **% Occupancy Hours = 1** , Lighting is on 100% of the occupancy schedule, and the lighting system is at full price
- **% Occupancy Hours = 0.5**, Lighting is on 50% of the occupancy schedule, and the annual lighting system saves 50% of the annual price
- **% Occupancy Hours = 0**, Lighting is always turned off, and the annual cost of the lighting system is $0.00

The graph on the next page represents the data from the table below, graphically. The graph alone has little significance until the electrical lighting savings can be compared against the mechanical equipment operating energy costs. This analysis and break-even point are presented in the Mechanical Breadth section.

Lighting Energy Cost by Percent Occupancy hour					
% Occupancy Hours	Input kW	Total Occupancy Hours	$/kWh	Total kWh	$
1	0.964	2727	0.2	2628.828	525.7656
0.95	0.964	2727	0.2	2497.3866	499.47732
0.9	0.964	2727	0.2	2365.9452	473.18904
0.85	0.964	2727	0.2	2234.5038	446.90076
0.8	0.964	2727	0.2	2103.0624	420.61248
0.75	0.964	2727	0.2	1971.621	394.3242
0.7	0.964	2727	0.2	1840.1796	368.03592
0.65	0.964	2727	0.2	1708.7382	341.74764
0.6	0.964	2727	0.2	1577.2968	315.45936
0.55	0.964	2727	0.2	1445.8554	289.17108
0.5	0.964	2727	0.2	1314.414	262.8828
0.45	0.964	2727	0.2	1182.9726	236.59452
0.4	0.964	2727	0.2	1051.5312	210.30624
0.35	0.964	2727	0.2	920.0898	184.01796
0.3	0.964	2727	0.2	788.6484	157.72968
0.25	0.964	2727	0.2	657.207	131.4414
0.2	0.964	2727	0.2	525.7656	105.15312
0.15	0.964	2727	0.2	394.3242	78.86484
0.1	0.964	2727	0.2	262.8828	52.57656
0.05	0.964	2727	0.2	131.4414	26.28828
0	0.964	2727	0.2	0	0



Conclusion

Evaluating all presented information, it is reasonable to say that the skylighting system and layout has been effective. Looking at daylight autonomy we see that the number of points across the year that meet the target illuminance of 250 lux, which is between 80-90% for all points, is very reasonable for a daylit space. Comparing the illuminance distribution of the skylighting and shades combination system against the base case of just shades (Step 3), we see the over parts of the year the skylights are effective and sometimes they are not. However, more times than not, they supplement the shading system in not only reaching the target illuminance of the space, but also creating a more uniform illuminance distribution.

The cost payback, as will be discussed in the price implications section of the mechanical breadth, will show that the electric lighting system needs to be shut off approximately 40% of the occupancy schedule to break even. This is reasonable. The tables at the end of Step 1 show that no shades are down approximately 40% of the occupancy schedule. As the system is designed no electric light during time of open shades, it is likely that the space will produce (at minimum) break-even energy costs.

Breadth two | Mechanical load

Introduction

The previously presented breadth, the MAE daylighting analysis of the High School Art Room, poses a slight problem that needs to be addressed. The skylights that were installed to provide useful daylight will also produce additional, undesirable, load on the heating and cooling systems. In the winter, heat loss through the skylights must be replaced by the heating system, which for the High School Art Room, is comprised of fin tube radiators lining the perimeter of the space. In the summer, heat gain through the skylights must be combatted by the cooling system, which for this building, is by overhead ductwork and diffusers. This breadth topic will present the findings of analyses that were aimed to answer the following two questions:

1. **Heating:** Are the fin tube radiators large enough to replenish the heat lost through the skylights?
2. **Cooling:** Is the existing cooling system (ductwork) capable of cooling the addition heat introduced into the space by the skylights?

The image below shows the ceiling plan of the High School Art Room with the skylights shown. The table shown with the plan gives the area of each skylight, as well as the percentage of the roof it occupies.

Roof Area		
Surface	Area [ft^2]	% of roof
Roof	1260	100
Skylight 1	40.4	3.2
Skylight 2	67.6	5.4
Skylight 3	38.89	3.1
Total:	147	11.66

Heating | Fin Tube Radiator

The HS Art Room is heated with a fin tube radiator system which lines the two exterior perimeter walls. In addition to the fin tube radiators, a unit heater located near the door provides additional heating. The goal is thus to determine if the fin tubes and unit heater are sufficiently sized to handle the additional (heating) load resulting from the introduction of the skylight system. The following steps to determine this are as follows:

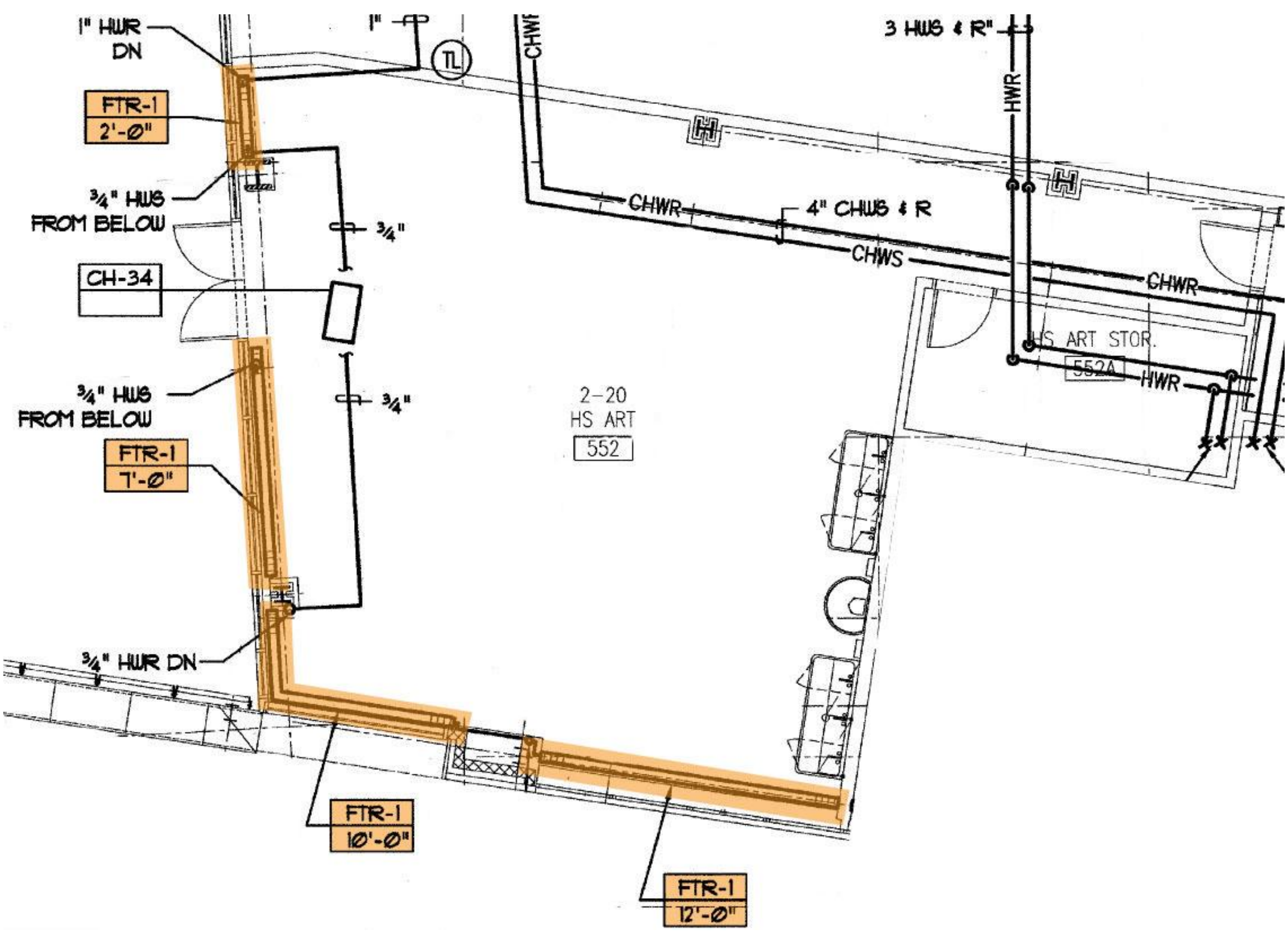
- Step 1: Calculate total space heating **capacity**
- Step 2: Determine air supply **induced heating load**
- Step 3: Calculate skylight **heat loss**.
- Step 4: Determine if existing fin tubes are **sufficient** for new load

Step 1: Calculate total space heating capacity

Total space heating capacity = Fin tube heater capacity + Cabinet Unit heater capacity

To find the capacity of the fin tube heater we first have to find the total length of the fin tubes in the room. Adding the length of the fin tubes counter-clockwise on the plan below we have:

Total Fin tube length = 2'-0" + 7'-0" + 10'-0" + 12'-0" = **31'-0"**



With the total length of the fin tubes known, we can calculate the total heating capacity of the fin tubes. The table below shows that the fin tube of type FTR-1 (that which serves this particular space) produces **690 BTU/ft**. Thus, the total heating capacity of the fin tube radiators in this space is:

Total fin tube heating capacity = (31 feet) * (690 BTU/feet) = **21, 390 BTU's**

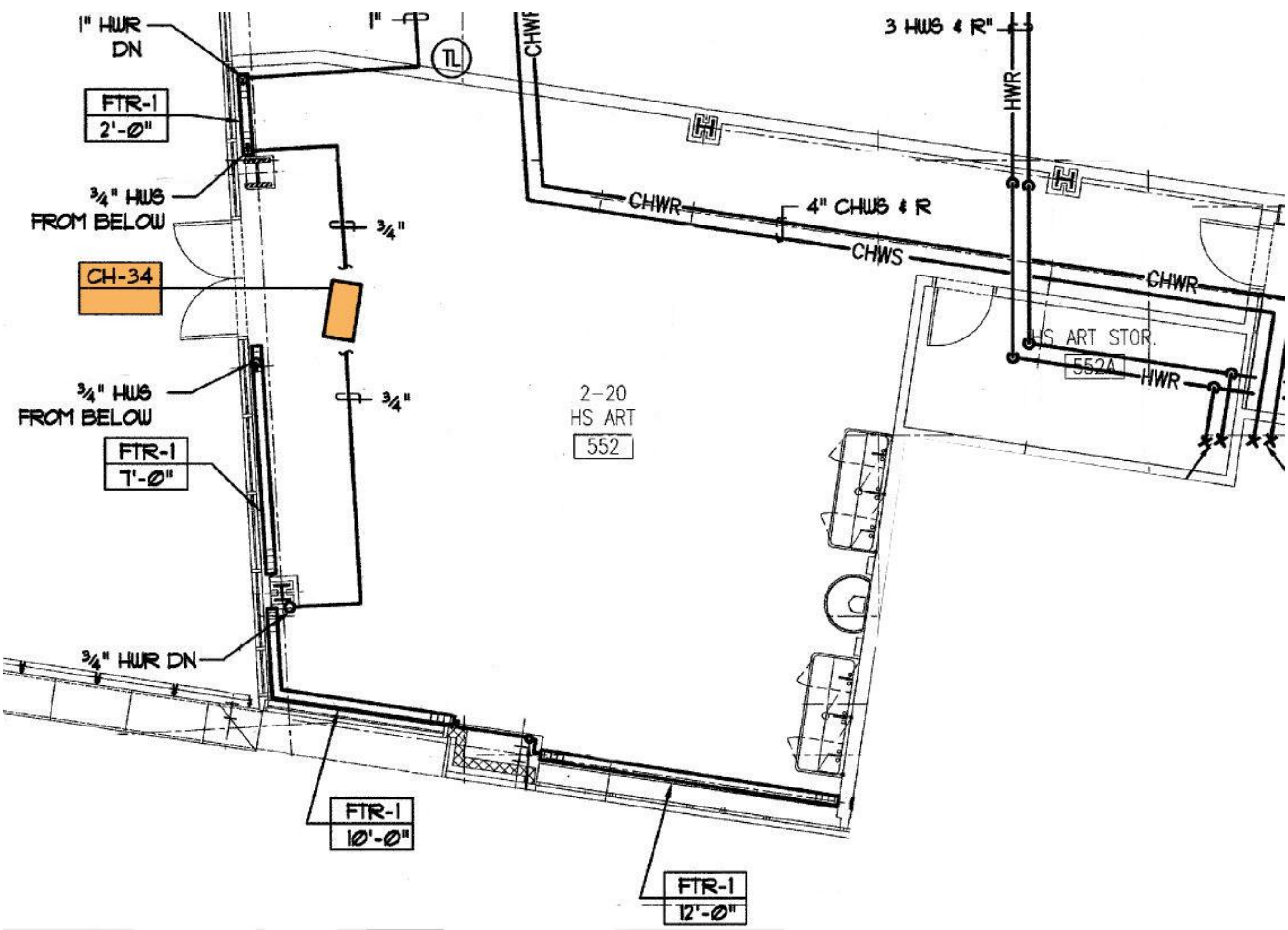
FIN TUBE RADIATION SCHEDULE

SYMBOL: FTR-1 = TYPE; 4'-0" = LENGTH OF ELEMENT

"VULCAN AS STANDARD, EXCEPT NOTED"

TYPE	MANUFACTURER	MODEL	ELEMENT						AVERAGE TEMP. °F	EAT °F	BTUH PER LIN. FT.	DAMPER	ENCLOSURE MTG. HT. -IN.	
			MATERIAL	FIN THICKNESS	NO OF FINS PER FT.	FIN SIZE IN.	PIPE SIZE IN.	NO OF ROWS					FLOOR TO BOTTOM	BOTTOM TO TOP
FTR-1	VULCAN	DS SLOPE TOP	COPPER-ALUMINUM	0.020"	48	4¼x4¼	1¼	2-12" CC	130	72	690	NO	SEE NOTE No. 1	24
FTR-2	VULCAN	DS SLOPE TOP	COPPER-ALUMINUM	0.020"	48	4¼x4¼	1¼	1	130	72	520	NO	|	24
FTR-3	RUNTAL	RC-10	COLD ROLLED STEEL	-	-	-	-	-	130	72	386	-	-	-

The second step in finding the total heating capacity of the system in the HS Art Room is to find the heating capacity of the unit heater CH-34 located in the space. The plan below shows the location of the unit heater near the door. The placement of the heater near the door helps prevent drafts in the space.



The schedule below shows the total heating capacity of the space unit heater, which is **7.9 MBH**.

CABINET & UNIT HEATER SCHEDULE											
GENERAL		UNIT DATA							MOTOR DATA		
UNIT NO.	SERVICE & LOCATION	MODEL NO	TYPE	CAP. MBH EACH @ HIGH SPEED	CFM EACH	ROOM TEMP. °F	NO. OF COILS	HW GPM EACH	HP EACH	RPM (AT HIGH)	VOLTAGE PHASE HZ
CH-1 & 2	NORTH MAIN ENT. VESTIBULE (1ST FL.)	RC-1200-04	CEILING RECESSED	22.0	430/380	72	2 ROW	2.3	1/8	1550	115/1/60
CH-3 & 4	SOUTH MAIN ENT. VESTIBULE (1ST FL.)	RC-1200-04	CEILING RECESSED	14.3	430/380	72	STAND.	1.5	1/8	1550	115/1/60
CH-5	WEST ENT. (1ST FL.)	RC-1200-02	CEILING RECESSED	7.9	230/170	72	STAND.	0.83	1/8	1550	115/1/60
CH-6	NORTH SERVICE ENT. (1ST FL.)	RC-1200-02	CEILING RECESSED	7.9	230/170	72	STAND.	0.83	1/8	1550	115/1/60
CH-7	EAST ENT. (1ST FL.)	F-1000-02	FREE STANDING	7.9	230/170	72	STAND.	0.83	1/8	1550	115/1/60
CH-8	OVERHNG ON 2ND FLOOR	RC-1210-03	CEILING FULLY RECESSED	9.0	335/260	72	STAND.	0.96	1/8	1550	115/1/60
CH-9 & CH-9 A	I/S CAFE EXIT TO TERRACE (5TH FL.)	RC-1200-03	CEILING FULLY RECESSED	16.7	335/260	72	2 ROW	1.8	1/8	1550	115/1/60
CH-10 & CH-10 A	H/S CAFE EXIT TO TERRACE (5TH FL.)	RC-1200-03	CEILING FULLY RECESSED	16.7	335/260	72	2 ROW	1.8	1/8	1550	115/1/60
CH-11	STAIR A VESTIBULE (ROOF)	F-1000-03	FREE STANDING	19.4	335/260	72	STAND.	2.1	1/8	1550	115/1/60
CH-12 & 36	STAIR B (5TH FLOOR & 1ST FL.)	RW-1120-02	WALL RECESSED	7.9	230/170	72	STAND.	0.83	1/8	1550	115/1/60
CH-13	STAIR A (5TH FLOOR)	F-1000-02	FREE STANDING	7.9	230/170	72	STAND.	0.83	1/8	1550	115/1/60
CH-14,17,19,20,22 23,26,27,31 & 35	BOY'S & GIRL'S TOILET (1ST TO 5TH FL.)	RW-1120-02	WALL RECESSED	7.9	230/170	72	STAND.	0.83	1/8	1550	115/1/60
CH-15 & 16	MEN'S &WOMENS SHOWER (5TH FL.)	RW-1120-02	WALL RECESSED	7.9	230/170	72	STAND.	0.83	1/8	1550	115/1/60
CH-18	HS STAFF LOCK (4TH FL.)	RC-1200-02	CEILING RECESSED	7.9	230/170	72	STAND.	0.83	1/8	1550	115/1/60
CH-21	HS STAFF LOCK (3RD FL.)	RC-1200-02	CEILING RECESSED	7.9	230/170	72	STAND.	0.83	1/8	1550	115/1/60
CH-24 & 25	HS STAFF LOCK (2ND FL.)	RF-131	WALL SEMI RECESSED	5.5	110 MAX.	72	STAND.	1.0	1/10	VARI	115/1/60
CH-28	VISITOR LOCK (1ST FLOOR)	RC-1200-02	CEILING RECESSED	7.9	230/170	72	STAND.	0.83	1/8	1550	115/1/60
CH-29 & 33	SHOWERS (1ST FL.)	RC-1200-02	CEILING RECESSED	7.9	230/170	72	STAND.	0.83	1/8	1550	115/1/60
CH-30 & 32	LOCKER ROOM (1ST FL.)	RC-1200-02	CEILING RECESSED	7.9	230/170	72	STAND.	0.83	1/8	1550	115/1/60
CH-34	HS ART (5th. FL.)	RC-1200-02	CEILING FULLY RECESSED	7.9	230/170	72	STAND.	0.83	1/8	1550	115/1/60
CH-36 & 38	STAIR A & B (1ST FL.)	RW-1120-03	WALL RECESSED	9.0	335/260	72	STAND.	0.96	1/8	1550	115/1/60
CH-37	STAIR C (1ST FL.)	RC-1200-02	CEILING RECESSED	7.9	230/170	72	STAND.	0.83	1/8	1550	115/1/60
CH-39	IS BOY'S LOCKER RM. (1ST FL.)	RC-1200-02	CEILING RECESSED	7.9	230/170	72	STAND.	0.83	1/8	1550	115/1/60
CH-40	SCHOOL SAFETY OFFICE (1st FL.)	RF-131	WALL SEMI RECESSED	5.5	110 MAX	72	STAND.	1.0	1/10	VARI	115/1/60
UH-1	GROUND EQUIPMENT STORE ROOM #21	HV-108A	HORIZONTAL UNIT HEATER	5.0	245	72	-	0.53	9 WATTS	1550	115/1/60

Now that the heating capacity for the fin tube radiators and space unit heater are known, we can calculate the total heating capacity of the space. Thus, we have:

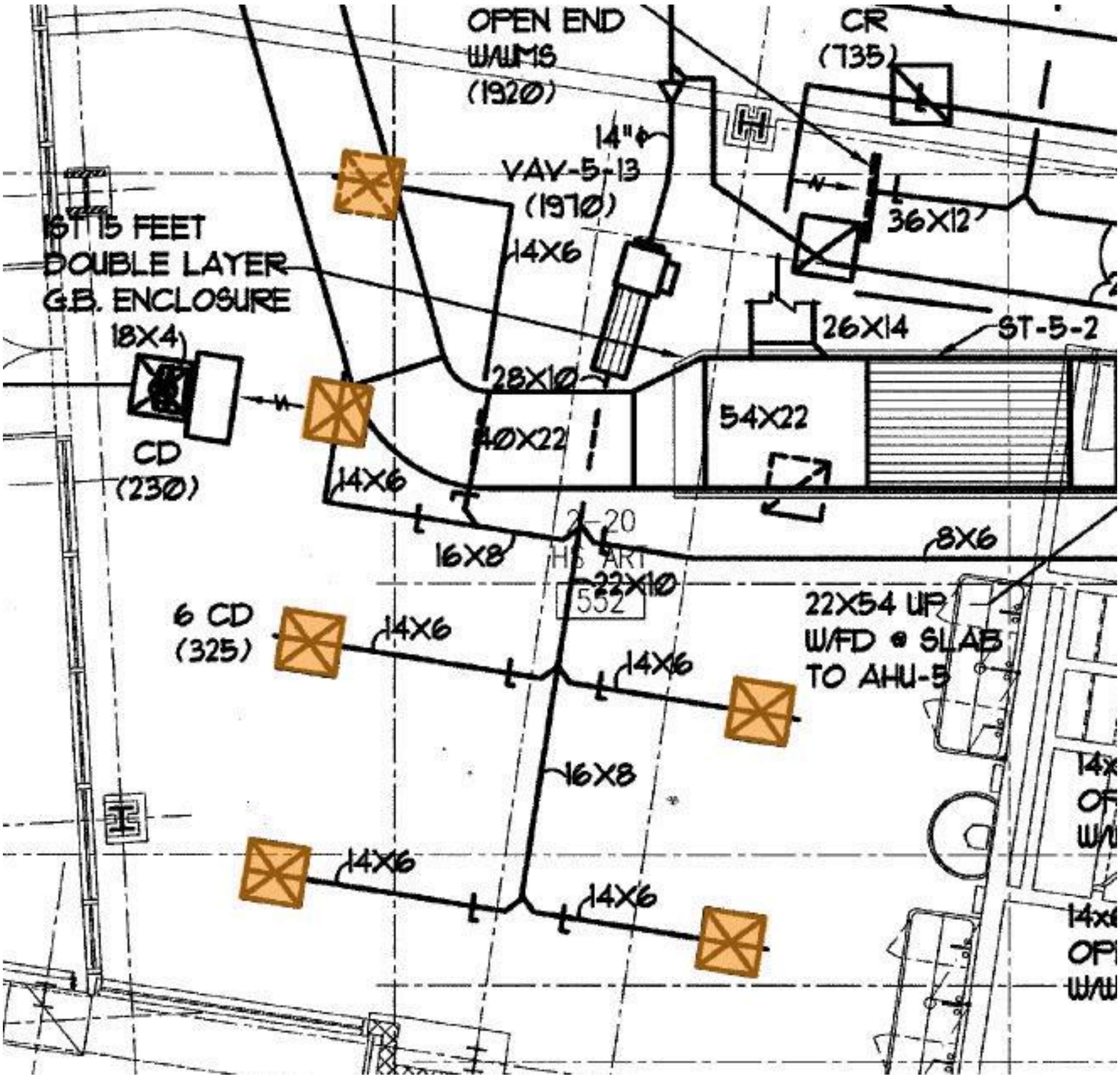
Total space heating capacity = Fin tube heater capacity + Cabinet Unit heater capacity

Total space heating capacity = (21,290 BTU/hr) + (7.9 MBH)*($1000\,\frac{BTU/hr}{MBH}$) = **29,290 BTUs/hr.**

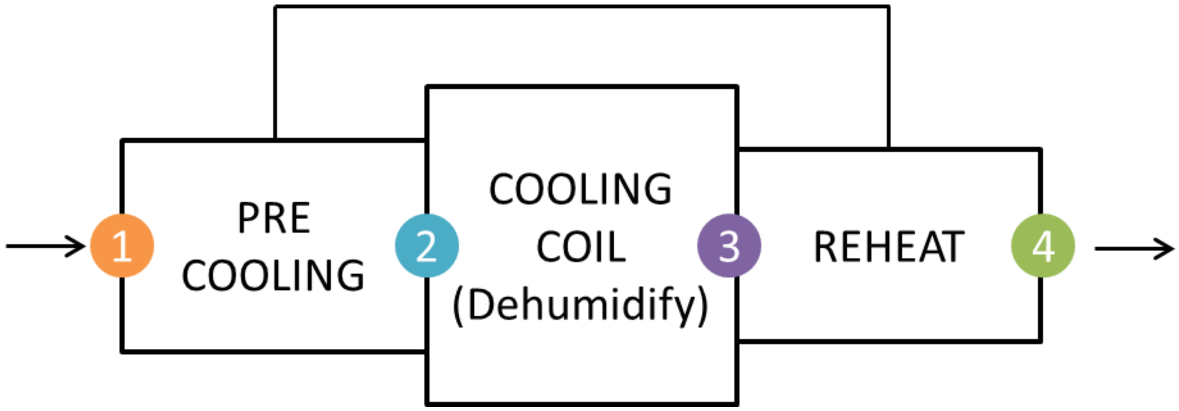
Step 2: Air supply induced heating load

Now that we know the load capacity of the mechanical heating system for the High School Art Room, we have to calculate the total heating load required for the space. In the winter months, the supply air from the ductwork system is at a temperature below that of the desire room set-point temperature. As a result, ironically, the cooling system introduces an additional load on the heating system. To calculate this load, we first need to calculate the total air flow the system is providing. The six supply diffusers are highlighted in orange on the mechanical plan below. Each of these provides 325 CFM to the space. Thus, we have:

Total air flow to space = (325 CFM/Diffuser) * (6 Diffusers) = **1950 CFM_{supply}**



The next step is to determine the change in temperature. We know from good mechanical design practice that the winder set point temperature is 72 degrees. The mystery in finding the change in temperature is finding the temperature the air is supplied at. The mechanical system in this building utilized a wrap-around heat pump, schematic heat pump diagram show below.



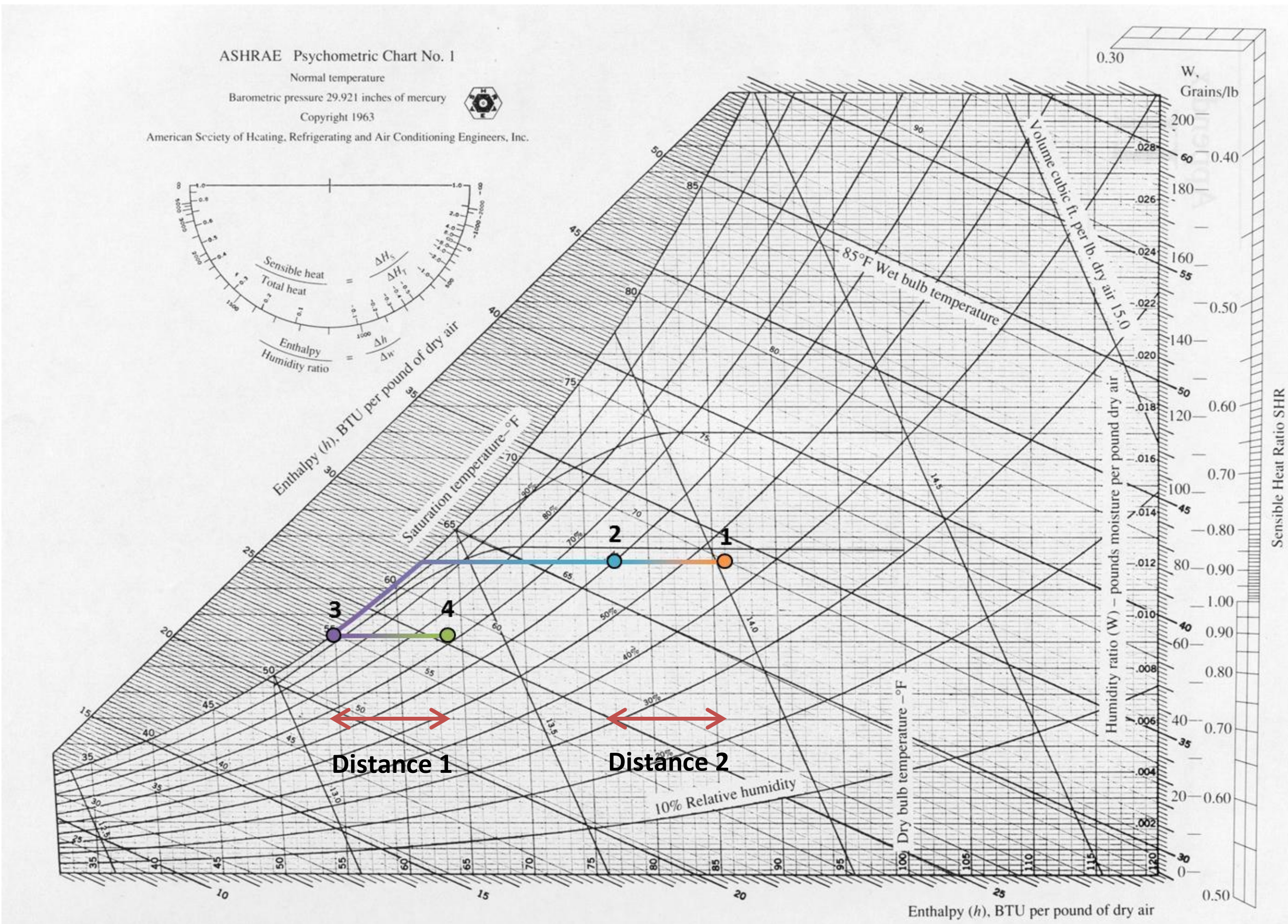
The wrap-around heat pumps works are follows:

At point 1: the air enters pre-cooling section of the heat pipe at a high temperature.
At point 2: the air leaves the pre-cooling coil, and goes through the cooling coil for dehumidification
At point 3: the air enters the reheat cool where it is heated with the pre-cooling exhaust heat
At point 4: the air leaves the reheat coil and is ready to be delivered to the space

The table below shows the wet bulb and dry bulb temperature for the air at each point in this process. Matching up the colors, it can be seen that the air to be delivered to the space is **64.1°**. This is the air delivery temperature that is needed to calculate the change in temperature for our load calculation.

GENERAL							WRAP AROUND HEAT PIPES						
UNIT NO.	SERVICE	MODEL NO.	LOCATION	TOTAL UNIT CFM SUPPLY / RETURN	MIN OUTSIDE AIR CFM / MIN. EXH. AIR CFM	MAX OUTSIDE AIR CFM / MAX. EXH. AIR CFM	FACE AREA	VELOCITY FPM	TEMPERATURE HP ENT °F	TEMPERATURE CC ENT °F	TEMPERATURE CC LVG °F	TEMPERATURE HP LVG °F
AHU-1	CLASSROOMS, OFFICES, CORRIDORS AND NON-PUBLIC	WF-RBHRE60	ROOF	30,000 / 27,000	14,945 / 11,945	30,000 / 27,000	59.5	504	86.5 / 70.2	77.9 / 67.6	55.1 / 55.0	63.7 / 58.4
AHU-2	CLASSROOMS, OFFICES, CORRIDORS AND NON-PUBLIC	WF-RBHRE62	ROOF	31,700 / 27,100	19,445 / 14,845	31,700 / 27,100	62.3	509	87.7 / 70.9	78.7 / 68.2	54.9 / 54.8	63.9 / 58.3
AHU-3	CLASSROOMS, OFFICES, CORRIDORS AND NON-PUBLIC	WF-RBHRE54	ROOF	27,000 / 24,300	13,210 / 10,510	27,000 / 24,300	56.7	476	86.5 / 70.2	77.6 / 67.5	55.2 / 54.8	64.1 / 58.3
AHU-4	GYMNASIUM	WF-RBHRE46	ROOF	20,860 / 18,560	13,360 / 11,060	20,860 / 18,560	51.0	409	83.9 / 71.3	74.1 / 68.4	52.0 / 51.9	61.8 / 55.9
AHU-5	CAFE/KITCHEN	WF-RBHRE32	ROOF	18,700 / 12,500	11,840 / 5,640	18,700 / 12,500	36.8	508	87.5 / 70.9	78.7 / 68.2	55.1 / 54.9	64.0 / 58.4
AHU-6	AUDITORIUM	WF-RBHRE19	ROOF	9,600 / 9,200	6,325 / 5,925	9,600 / 9,200	19.1	504	84.0 / 70.5	75.7 / 68.0	53.8 / 53.7	62.1 / 57.0

The diagram below shows the location of each during the wrap-around heat pump cycle on a psychometric chart. The air is first cooled in the pre-cooling phase. It is then cooled to the dew point line with the cooling coil where the air is dehumidified. Once the air leaves the cooling coil, it is heated to the desired air delivery temperature of **64.1°** with the waste heat from the pre-cooling coil. Notice that distance 1 and distance two are approximately the same length as the air is being reheated with the same amount of heat as was originally extracted.



APPENDIX II.1 Psychrometric Chart.
Based on ASHRAE Psychrometric Chart No. 1. Reprinted with permission from ASHRAE Inc.
Sensible heat ratio (SHR), humidity ratio scale in grains/lb, and two cooling and dehumidifying curves were added by author.

With all unknowns found, we can calculate the total heat load introduced by the cooling system:

$$Q = 1.08 * CFM * \ \Delta T \ (T_{setpoint} - T_{supply})$$
$$Q = 1.08 * (1950) * (72° - 64.1°)$$
$$Q = 1.08 * (1950) * (7.9°)$$

$$\boldsymbol{Q = 16,637.4\ BTU/hr}$$

Step 3: Calculate skylight heating load

In addition to the cooling system, the skylights add a load on the heating system. During the winter, heat that escapes through the skylights has to be replenished by the fin tube radiators. The mechanical load calculation program TRACE700 was used to calculate the total heating load introduced in the space. Highlighted in the figures below are the total heating load in the space as a result of heat loss through the roof, exterior wall, and façade for the base case of no skylights (on the **left**), and the skylight case (on the **right**). The negative sign in front of the values designates the load as a heating load.

HEATING COIL PEAK

Mo/Hr: Heating Design
OADB: 15

	Space Peak Space Sens Btu/h	Coil Peak Tot Sens Btu/h	Percent Of Total (%)
Envelope Loads			
Skylite Solar	0	0	0.00
Skylite Cond	0	0	0.00
Roof Cond	0	-3,470	5.03
Glass Solar	0	0	0.00
Glass/Door Cond	-39	-39	0.06
Wall Cond	-567	-1,523	2.21
Partition/Door	0	0	0.00
Floor	0	0	0.00
Adjacent Floor	0	0	0.00
Infiltration	-2,938	-2,938	4.26
Sub Total ==>	-3,544	-7,971	11.56
Internal Loads			
Lights	0	0	0.00
People	0	0	0.00
Misc	0	0	0.00
Sub Total ==>	0	0	0.00
Ceiling Load	-764	0	0.00
Ventilation Load	0	0	0.00
Adj Air Trans Heat	0	0	0
Ov/Undr Sizing	0	0	0.00
Exhaust Heat		689	-1.00
OA Preheat Diff.		-58,584	84.96
RA Preheat Diff.		0	0.00
Additional Reheat		-6,061	8.79
System Plenum Heat		2,975	-4.31
Underflr Sup Ht Pkup		0	0.00
Supply Air Leakage		0	0.00
Grand Total ==>	-4,308	-68,953	100.00

HEATING COIL PEAK

Mo/Hr: Heating Design
OADB: 15

	Space Peak Space Sens Btu/h	Coil Peak Tot Sens Btu/h	Percent Of Total (%)
Envelope Loads			
Skylite Solar	0	0	0.00
Skylite Cond	0	-4,031	5.63
Roof Cond	0	-3,066	4.28
Glass Solar	0	0	0.00
Glass/Door Cond	-39	-39	0.06
Wall Cond	-567	-1,523	2.13
Partition/Door	0	0	0.00
Floor	0	0	0.00
Adjacent Floor	0	0	0.00
Infiltration	-2,938	-2,938	4.10
Sub Total ==>	-3,544	-11,598	16.20
Internal Loads			
Lights	0	0	0.00
People	0	0	0.00
Misc	0	0	0.00
Sub Total ==>	0	0	0.00
Ceiling Load	-764	0	0.00
Ventilation Load	0	0	0.00
Adj Air Trans Heat	0	0	0
Ov/Undr Sizing	0	0	0.00
Exhaust Heat		945	-1.32
OA Preheat Diff.		-58,584	81.83
RA Preheat Diff.		0	0.00
Additional Reheat		-8,698	12.15
System Plenum Heat		6,345	-8.86
Underflr Sup Ht Pkup		0	0.00
Supply Air Leakage		0	0.00
Grand Total ==>	-4,308	-71,589	100.00

To calculate the load introduced by the skylights, the following formula is applied:

Skylight heating load = (Skylight scenario heating load) – (Base case heating load)
Skylight heating load = (11,598 BTUs/hr) – (7,971 BTUs/hr)

Skylight heating load = 3,627 BTUs/hr

Step 4: Determine if existing fin tubes are sufficient for new load

Now that all load calculations have been performed a comparison can be made. The load capacity comparison calculations are as follows:

Base Case:

- Total load = (16,637.40 + 7,971.00) = 24,608.40 BTUs/hr
- % Under capacity = **[**(29,290.00 – 24,608.40) / (29,290.00)**] = 16.0 %**

Skylight Case:

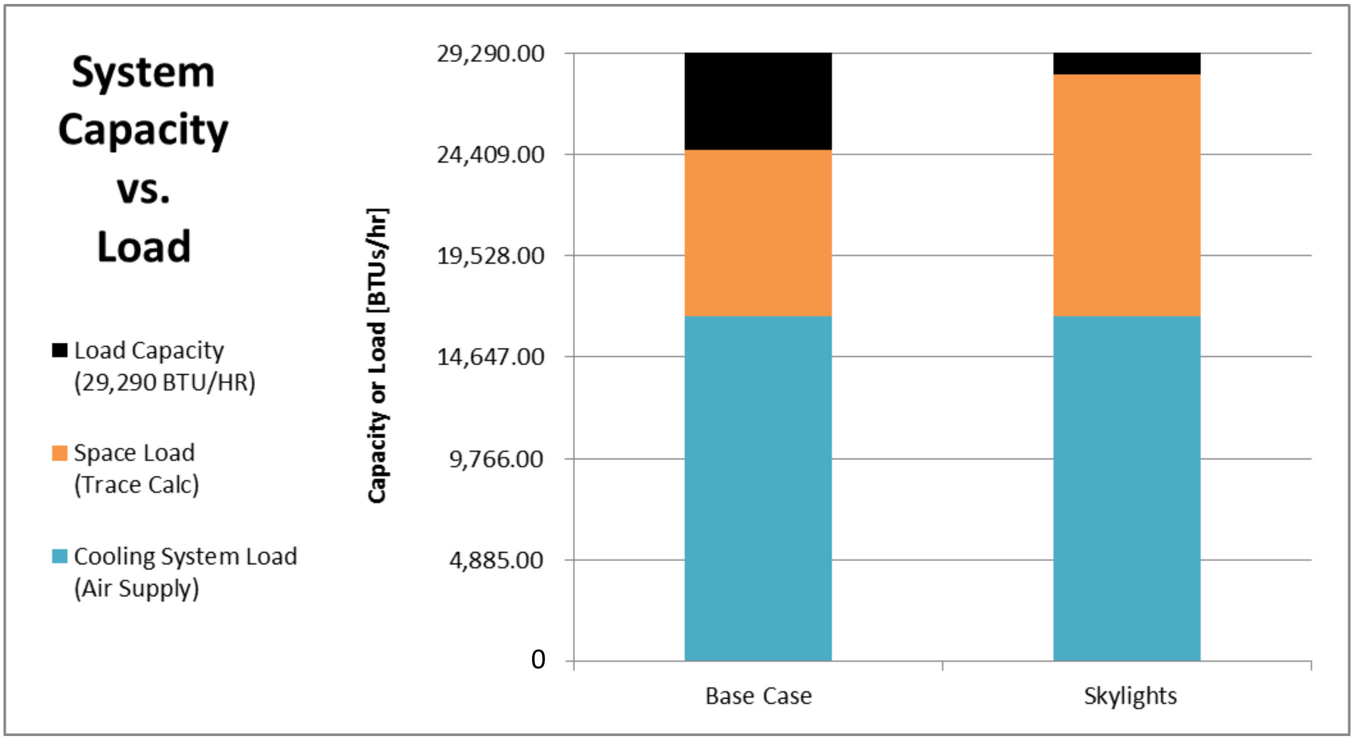
- Total load = (16,637.40 + 11,598.00.00) = 28,235.40 BTUs/hr
- % Under capacity = **[**(29,290.00 – 24,608.40) / (29,290.00)**] = 3.6 %**

The table below shows the total load for each space compared to the capacity of the system, which is 29,290.00. The load capacity calculations are as follows:

Scenario Comparison		
	Base	Skylights
Sytem Capacity	29,290.00	29,290.00
Space Load	16,637.40	16,637.40
Cooling System	7,971.00	11,598.00
% under Capacity	16.0%	**3.6%**

The graph below shows a graphical representation of the system capacity of the comparison in the table to the left. The height of the bars is equal to the total load capacity of the heating system, and as such, the **black** bar represents how system capacity is available in excess of the heating load.

In conclusion, as the total heating load in the skylighting scenario is still **3.6%** below the capacity of the system, **NO ADDITION FIN TUBE RADIATORS NEED TO BE ADDED INTO THE SPACE.**



Cooling | Mechanical Duct work

The HS Art Room is cooled via the overhead duct system. With the addition of the skylights, additional load will be put onto the mechanical cooling system. The goal is thus to determine if the existing ductwork are sufficiently sized to handle the additional (cooling) load resulting from the introduction of the skylight system. The following steps to determine this are as follows:

- Step 1: Calculate total space heating **capacity**
- Step 2: Determine the **occupant** total sensible load
- Step 3: Determine the total **equipment** cooling load
- Step 4: Calculate total **heat gain** through room surfaces
- Step 5: **Calculate CFM** needed and compare

Step 1: Calculate total space heating capacity

The space has a total of 6 diffusers each supplying 325 CFM. Refer to Step 2 under Heating | Fin Tube Radiator for diffuser locations. The total air supply to the space is calculated as follows:

Total air flow to space = (325 CFM/Diffuser) * (6 Diffusers) = **1950 CFM**$_{\mathbf{supply}}$

Step 2: Determine the occupant total sensible

$$Q_{sensible} = (36\ People) * \left(\frac{250\ {}^{BTU}/_{hr}}{Person}\right)$$

$$\boldsymbol{Q_{sensible} = 9{,}000\ {}^{BTU}/_{hr}}$$

Step 3: Determine the total equipment cooling load

$$Q_{Equipment} = \left(Q_{Lighting} + Q_{misc.\ equipment}\right) * (Room\ Area)$$

$$Q_{Equipment} = \left(1.24\ \frac{W}{ft^2} + 1.0\ \frac{W}{ft^2}\right) * (1260\ ft^2)$$

$$Q_{Equipment} = 2822.4\ Watts$$

$$Q_{Equipment} = (2822.4\ Watts) * \left(\frac{3.412\ {}^{BTU}/_{hr}}{1\ Watt}\right)$$

$$\boldsymbol{Q_{Equipment} = 9630\ {}^{BTU}/_{hr}}$$

Step 4: Calculate total heat gain through room surfaces

Not that the total load from the occupants and the space are known, the total heat gain through the surfaces in the room can be calculated. To calculate the conductive heat gain through the room surfaces, the following equation is used:

$$\frac{\boldsymbol{Q}}{\boldsymbol{t}} = \frac{kA(T_{hot} - T_{cold})}{d}$$

The table below shows the application of this conductive heat transfer equation to all surfaces for which heat gain will occur. It is assumed that interior walls that are shared with another interior space will have no net heat transfer as both spaces will have (approximately) the same room temperature. As such, the only room surfaces considered are those that are shared with the exterior. These surfaces are as follows: the roof, exterior walls, skylights, and façade (glazing).

Total gain loss through room surfaces							
Surface	u [BTU/hr*Ft^2*F]	d [Ft]	k [BTU/hr*Ft*F]	A [Ft^2]	Thot [°F]	Tcold [°F]	q [BTU/hr]
Roof	0.05	1.5	0.075	1113	89.5	75	806.925
Wall	0.056	1.5	0.084	173.8	89.5	75	141.1256
Skylight	0.495	0.08333	0.04124835	147	89.5	75	1055.093
Façade	0.3	0.2	0.06	415	89.5	75	1805.25
						Total:	3808.393

From the calculation in the previous table, using the conductive heat transfer equation, the total heat gain through the room surfaces is computed. This heat transfer totals **3,808.39 BTUs/hr**.

Step 5: Calculate CFM needed and compare

$$Q_{net} = \sum Q = \sum Q_{supply} - \sum Q_{load}$$

$$Q_{net} = (q_{capacity}) - (q_{occupant} + q_{misc\ equipment} + q_{cond\ room\ surfaces})$$

$$Q_{net} = (22{,}955)\ {}^{BTU}/_{hr} - (13{,}000 + 9630 + 3{,}808)\ {}^{BTU}/_{hr} = \boldsymbol{-3{,}483\ {}^{BTUs}/_{hr}}$$

Q_{net}, as visible in the previous calculation, is **-3,483 BTUs/hr.** The fact that it is negative means that the capacity of the cooling system is not sufficient to handle the load of the space with the skylight included. As the system is not capable of cooling the full load in the space, the ductwork needs to be upsized. The next step is to determine the additional CFM needed to meet the load requirements of the space.

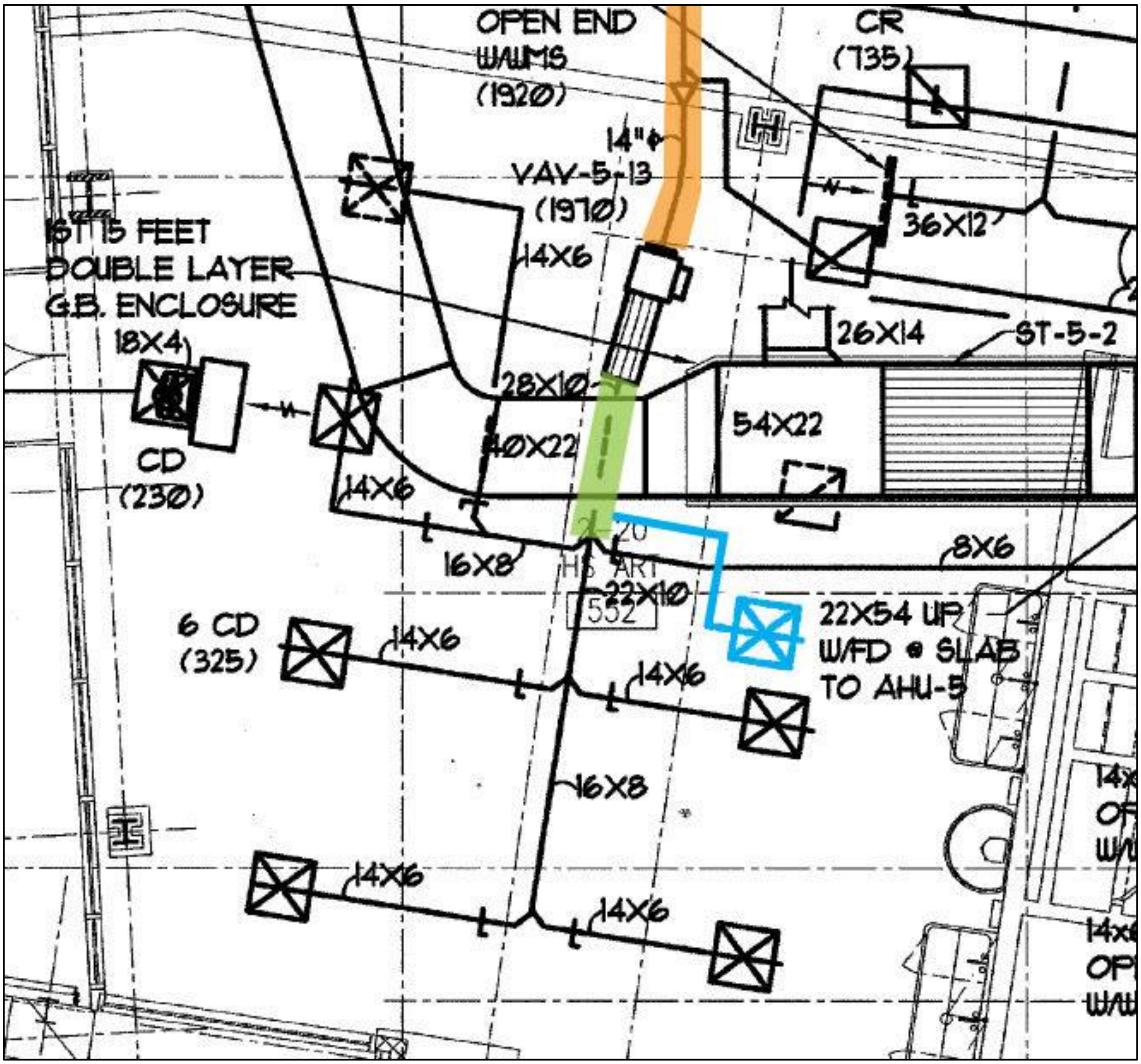
$$Q = 1.08 * CFM * \Delta T$$

$$CFM = \frac{Q}{1.08 * (T_{set\ point} - T_{supply})}$$

$$CFM = \frac{3{,}483\ {}^{BTUs}/_{hr}}{1.08 * (75 - 64.1)\text{°F}} = \boldsymbol{296\ CFM}$$

Sizing Comparison		
Color	Existing	Resized
	14" ϕ	16" ϕ
	28"x10"	30"x10"
	N/A	10"x10"

The table to the left and the plan below are intended to graphically represent the ductwork and piping that has been affected by the additional load introduced in the space. Because of the extra CFM needed, an additional diffuser has been added to the space, as shown in **blue**. The duct is connected to the main supply duct (shown in **green**) as to avoid resizing all other ductwork downstream. The main supply pipe, the 14" diameter pipe shown in **orange,** has to be upsized to account for the additional CFM needed in the space. From 14 inches in diameter, it is upsized to 16 inches. Although the changes are minor in comparison to the magnitude of the original duct sizes, they are changes that must be made to meet the load. All sizes were calculated using a ductulator.



Conclusion

Adequacy calculations for both the heating and cooling systems have been presented. It has been shown that the existing heating system, which utilizes fin tube radiators, is sufficiently sized to handle the additional load introduce by the skylighting system. With the additional load from the skylights, the system is still oversized by **3.6%** with a remaining (available) capacity of **1,055 BTUs/hr**. No upsizing of the fin tube radiators is needed, and thus there are no (heating system) material cost implications with the introduction of the skylights. However, there will be cost increases in energy use as the system will be combatting a higher load than previously, which is inherent with any load increase.

The cooling system on the other hand, has been shown to be inadequate to handle the additional load associated with the introduction of the skylights. The cooling system, which is predominantly the overhead ductwork, provides too few CFM to the space. As such, appropriate resizing has been done. The tables below show the cost implications of the mechanical ductwork resizing. The existing ductwork is estimated to have cost **$104.05**. The new ductwork, which includes the change from 14" diameter circular ductwork to 16" diameter and change from 28x10 duct to 30x10, is estimated to cost **$125.55**. The new system, due to an increase in supple CFM needed, requires an addition 10"x10" diffuser. The cost of a 10"x10" duct with appropriate supply duct is estimated to cost **$224.00**.

The total cost of increasing the ductwork is as follows:

$$Total\ cost\ (\$) = New\ System\ Cost\ (\$) - Existing\ System\ Cost\ (\$)$$
$$Total\ cost\ (\$) = (\$126.55 + \$224.00)\ - (\$104.05)$$
$$\boldsymbol{Total\ cost}\ (\$) = \mathbf{\$246.50}$$

Mechanical Ductwork resizing cost				
Category	Existing		New	
Baseline Duct Size	14"ϕ	28x10	16"ϕ	30x10
Total [lf]	15	10	15	10
Weight [lb/lf]		9.18		9.65
Total Weight [lb]		91.8		96.5
RS Means		0100		0100
Material ($/Lb)		3.58		3.58
Round Material [$/LF]	4.55		6.05	
Total Material /LF or LB	4.55	3.58	6.05	3.58
Total Cost	68.25	35.8	90.75	35.8
Total:	104.05		126.55	
Cost Difference:	**$22.50**			

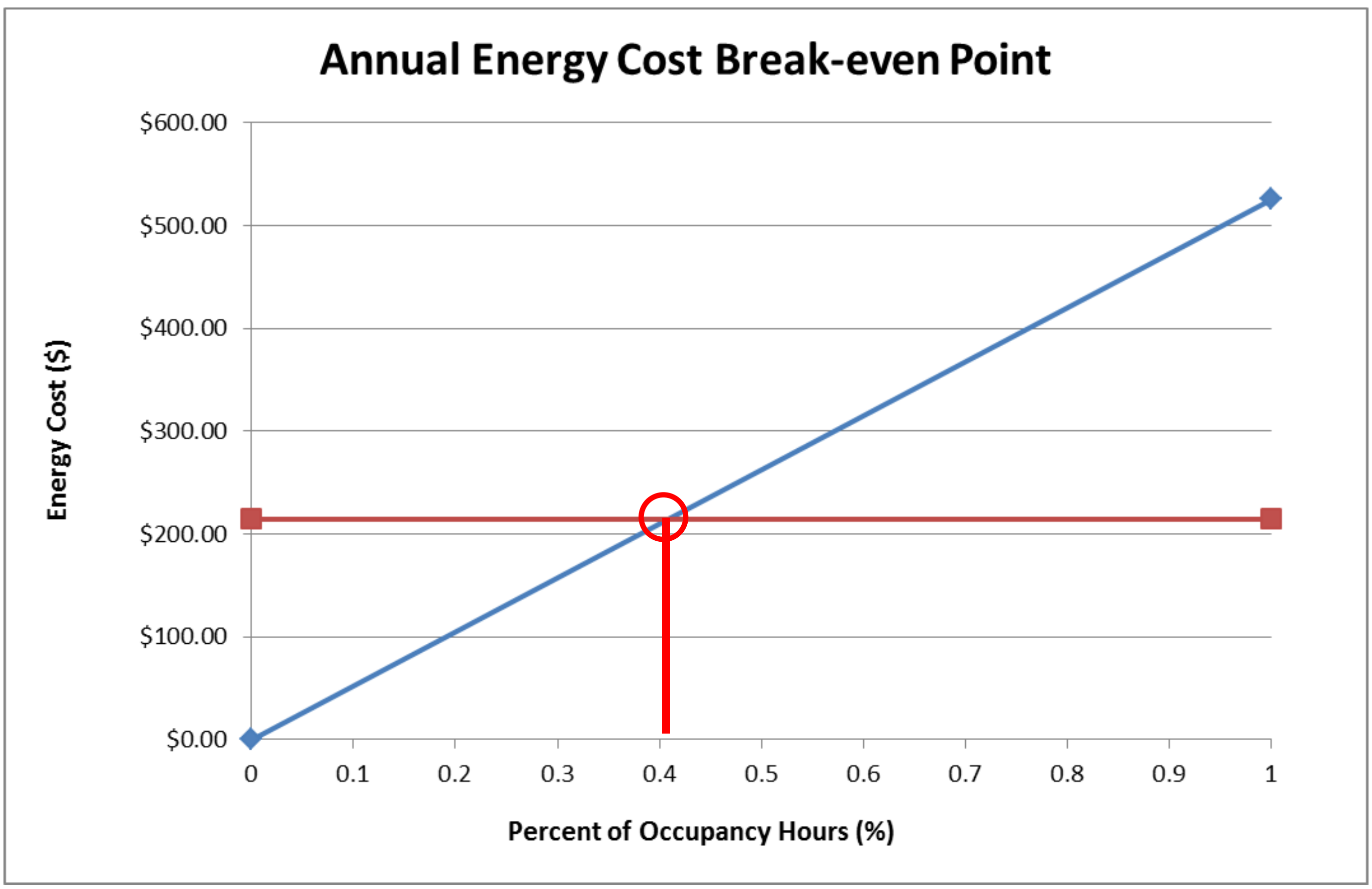
10"x10" Diffuser	
Material	$ 162.00
Labor	$ 30.00
Overhead	$ 32.00
Total:	**$ 224.00**

Note: All cost data was taken from RS Means 2010.

In addition to material cost implication of upsizing the ductwork, there is going to be operating energy cost implications due to the introduction of the skylights. During the summer, when the cooling system is in effect, heat gain through the skylights is going to increase the load on the system. In the winter, when the heating system is in effect, solar heat gain through the skylights will reduce the load on the heating system. The table below presents the cost associated with each of these scenarios. The total net operating energy cost of the skylight system is **-$214.32**.

Cost of heating and Cooling due to Skylighting load								
Load Type	% Occupancy Hours	Occupancy Hours	BTU/hr	W	kW	kWh	$/kWh	$
Cooling	0.4	2727	-5400	-1578.95	-1.58	-1722	0.2	-344.46
Heating	0.6	2727	4533.75	1325.658	1.33	2169	0.2	130.14
							Savings:	-214.32

Plotting a line of total cost implications of the skylights on the lighting system energy cost plot (presented in the MAE breadth section) we see that if the lighting system is switched off approximately 40% of the occupancy hours, the lighting system will save as much energy costs as the mechanical energy costs. This is the break-even point. For every occupancy hour over this that the lighting is switched off, net energy savings are incurred.



Breadth three | BIM

Introduction

The previous two depths, which were based upon the introduction of skylights into the High School Art Room, assume that the skylights introduced into the space are free from obstruction. Although this is a rational assumption for the simplification of analysis, it is the ideal case and is likely without consideration of the systems in the ceiling space. The main goal of this depth is thus to analyze the existing coordination of the systems in the ceiling space of the High School Art Room, and to redesign the ceiling space to accommodate the skylighting system.

Most of the deliverables for a coordination analysis would typically include renderings, sections, and conflict reports demonstrating that no conflicts or crashes exist within the ceiling space redesign. However, the coordination analysis will also consider the effects of the ceiling space layout on the skylight layout. This consideration will facilitate two calculations:

1. What percentage are the skylights covered for the original design as opposed to the new design?
2. What change in illuminance does the change in skylight coverage area amount to?

The systems included in the coordination analysis are as follows:

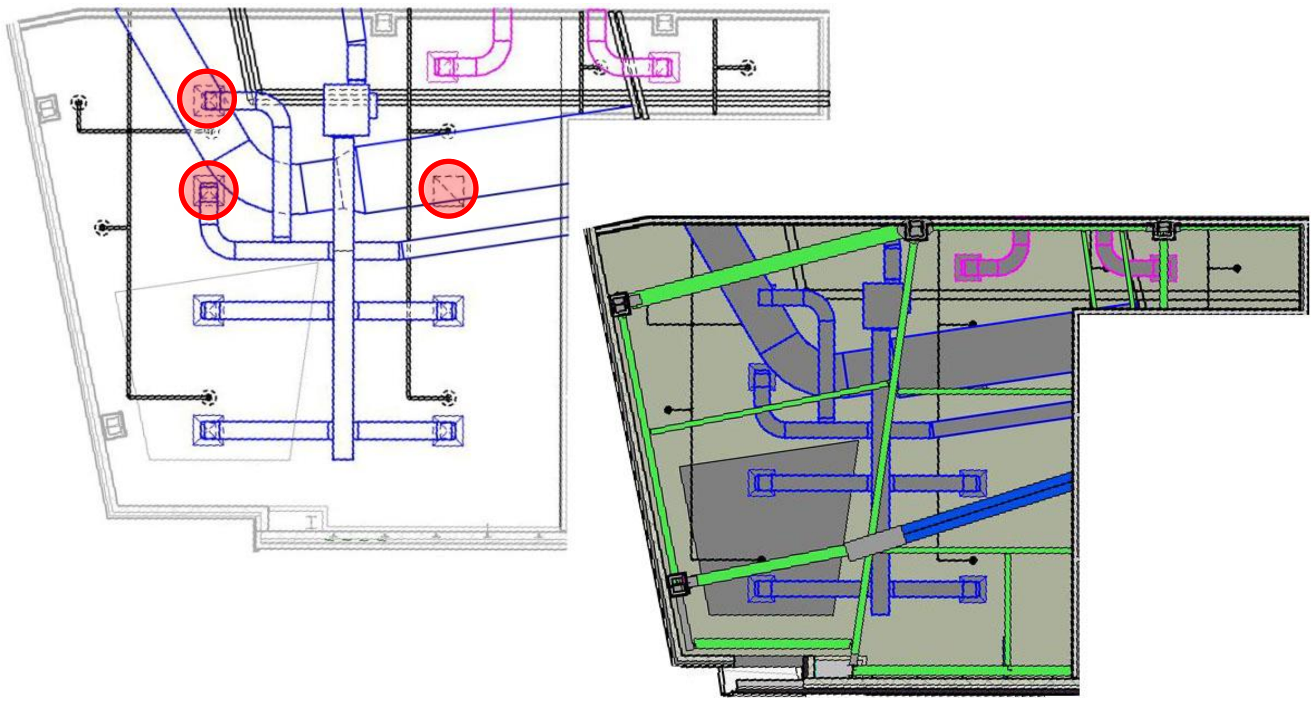
- Mechanical System (including supply and return duct)
- Sprinkler System (including supply piping and sprinkler heads)
- Plumbing (Include Hot and Cold water supply and return)
- Lighting (Suspended linear fluorescent and suspended CFL pendants)
- **Wire and conduit were NOT modeled**

The content of this breath is thus organized as follows:

- **Step 1**: Model existing ceiling layout
- **Step 2**: Redesign ceiling layout to accommodate skylights
- **Step 3**: Compare two scenarios, performing appropriate calculations
- **Step 4**: Prove ceiling space is organized and conflict-free
    - Sections / 3d Interior Views
    - Renderings

Step 1: Model existing ceiling layout

The first step in this breadth is modeling the existing High School Art Room ceiling space to analyze the conflicts and clashes. The existing ceiling space layout, which was taken from the drawings provided to me by SKANSKA, were only represented in 2D. It was the goal of this step to take the 2D plans, and create a 3D BIM model to analyze the clashes of the system that may have not been caught originally in the 2D plans. A 3D BIM model of the space was created in REVIT MEP 2012, and the existing systems modeled. The two figures below represent the existing mechanical system. The left image represents the plan layout of the ceiling space, where the right image shows a section cut of the 3D model. The image on the right shows the layout of the ceiling space system below the structural members. The plan layout on the left does not show the structural system.

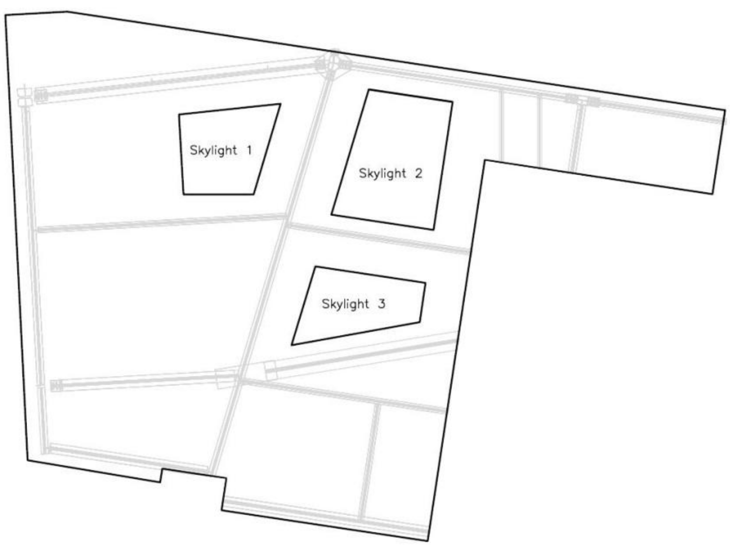


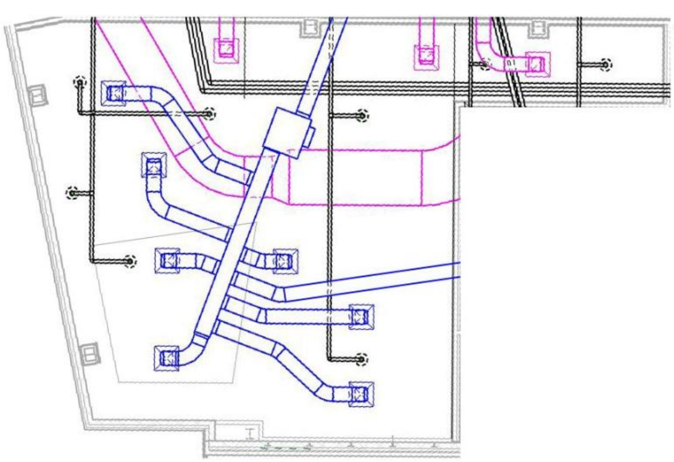
Although best effort was given to model the existing system without conflicts, it proved difficult to do so. The previous plan layout of the ceiling space highlights (in **red**) the area which conflicts could not be avoided—staying true to the existing design that is. A few diffusers conflicted with the air return duct, and a return grille, located directly under the return duct, was unable to be fed directly to the return due to lack of space above it.

Step 2: Redesign ceiling layout to accommodate skylights

After analyzing the existing layout, the system must next be coordinated as to minimally affect the skylighting layout. The first image below shows the skylight layout of the room as proposed in the MAE breadth section. The second image (on the right of the first row) shows how the skylights sit in relation to the systems in the ceiling. As you can see, the supply and return ducts have been rotated and moved so they do not obstruct the skylights. A direct comparison will be made in the next step.

The left image in the second row represents the plan layout of the redesigned ceiling space, where the right image shows a section cut of the 3D model. The image on the right shows the layout of the ceiling space system below the structural members. The plan layout on the left does not show the structural system.





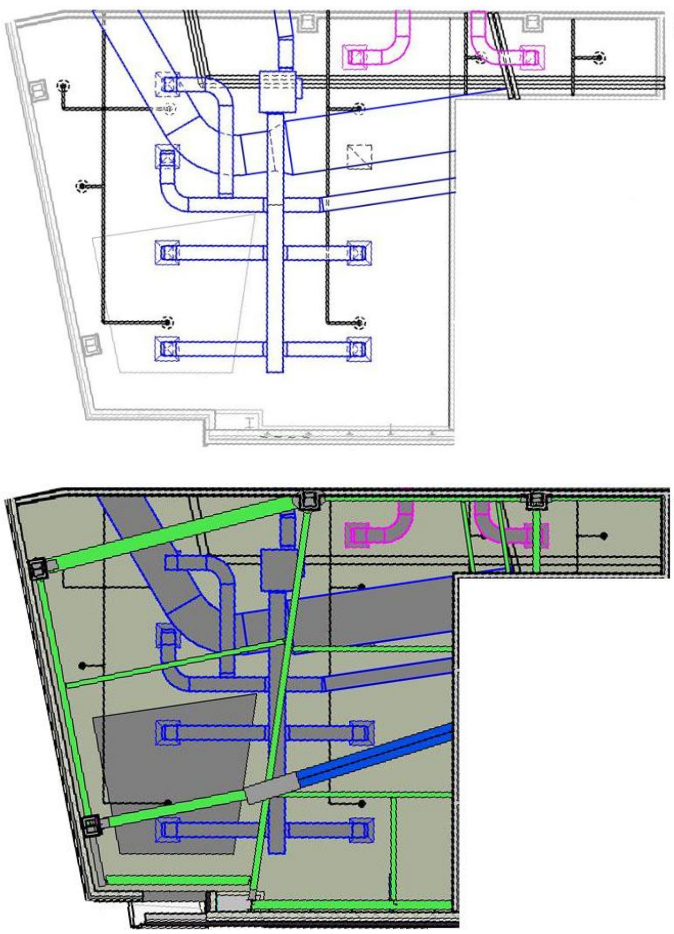
Step 3: Compare two scenarios

Now that the existing system has be redesigned and coordinated as best possible, it is time to analyze them side-by-side. Additionally, two calculations will be performed so that a quantitative comparison may be made between the two. These two calculations are:

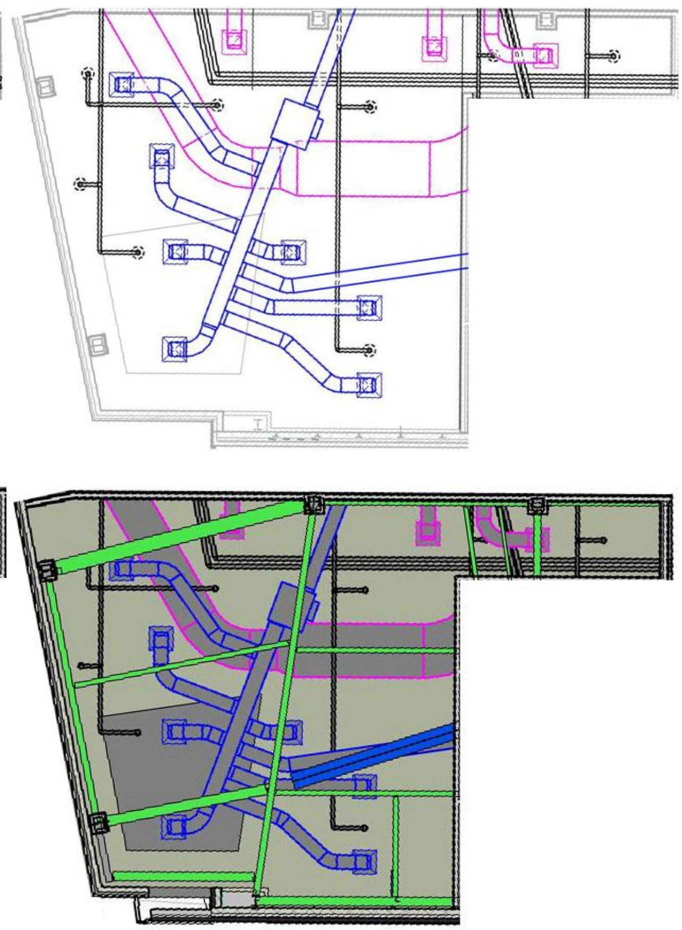
1. What percentage are the skylights covered for the original design as opposed to the new design?
2. What change in illuminance does the change in skylight coverage area amount to?

The images below show a visual comparison of the existing layout versus the proposed layout. The images in the left column represent the existing design as taken from the buildings' drawings. The images to right are for that of the redesigned system. The top images represent the plan layout of the ceiling space, where the top images shows a section cut of the 3D model. The bottom images show the layout of the ceiling space system below the structural members. The plan layouts on top do not show the structural system.

EXISTING ceiling space layout

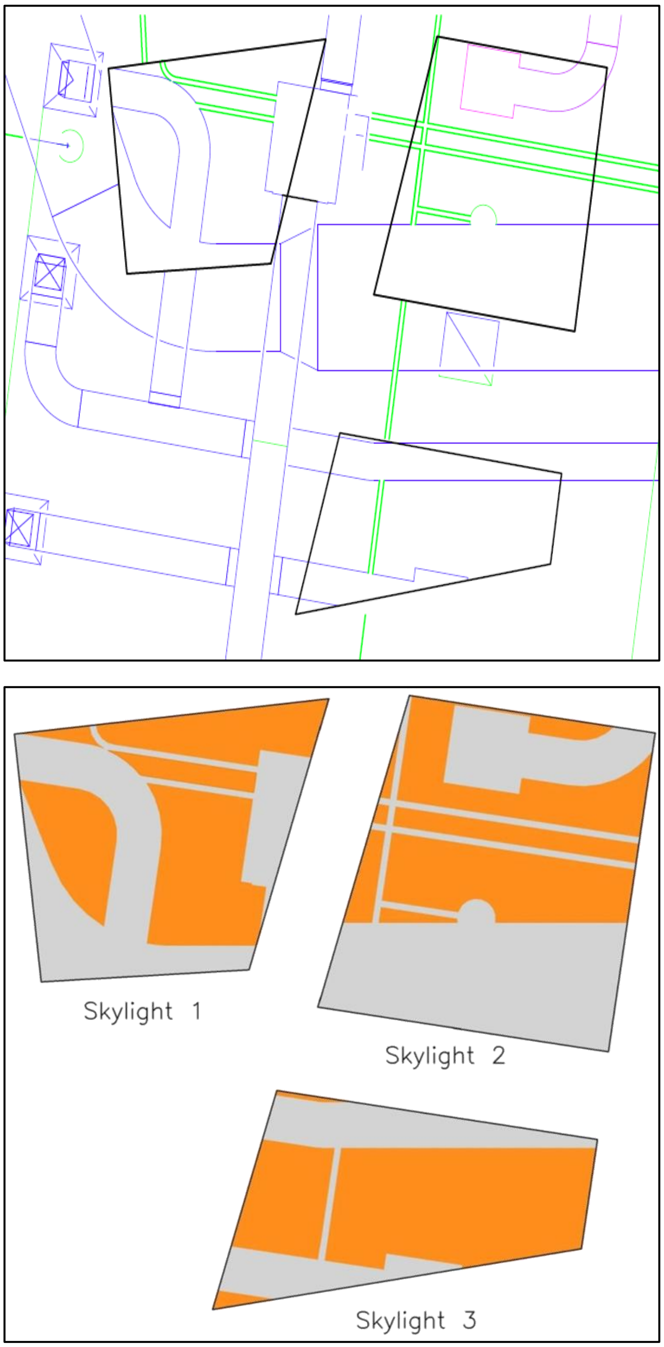


PROPOSED ceiling space layout



Overlaying the skylight layout on the layout of the ceiling space equipment, a side-by-side comparison can be made of how covered the skylights are. The figured on the left represent the existing ceiling layout, whereas the figures to the right show the proposed, or redesigned system. The top images show the overlap of the skylights and MEP equipment in wireframe view. This enables a quick determination of the equipment that runs through the skylight. The bottom images show the coverage areas of the skylights, via two colors. **Orange** shows the portion of the skylight that is unobstructed. **Grey** represents the area that is occupied by some portion of equipment.

EXISTING ceiling space layout



PROPOSED ceiling space layout

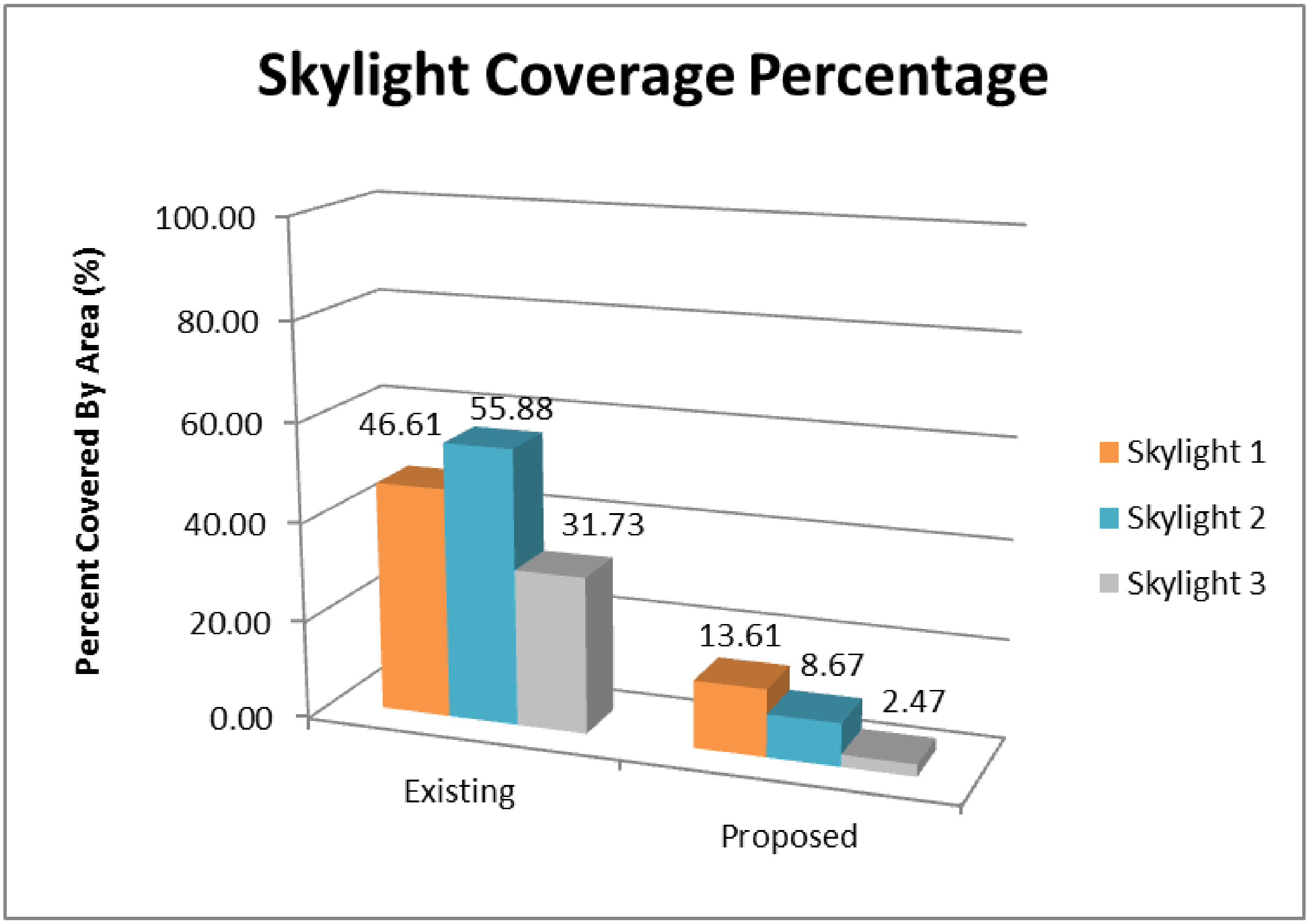
Using the previous figures, the total percentage of area that is covered can be calculated. The figures below show the tabular calculation for each individual skylight, under both the existing and redesigned conditions. The skylights with the existing ceiling coordination design are obstructed **46.47%** (by area). Under the new design, the skylight obstruction area was reduced to **9.10%**.

The total reduction in area coverage = (Existing Design coverage) – (Proposed Design Coverage)
The total reduction in area coverage = (46.47%) – (9.10%) = **37.57%**

Covered Skylight Area: Existing Design						
	Existing Design					
	Skylight 1		Skylight 2		Skylight 3	
Area	Open	Covered	Open	Covered	Open	Covered
	0.489	-	9.57	-	0.205	-
	6.258	-	0.267	-	5.92	-
	1.697	-	0.169	-	19.21	-
	10.08	-	3.24	-	0.381	-
	5.42	-	1.38	-	-	11.95
	-	20.9	10.6	-	-	-
	-	-	0.527	-	-	-
	-	-	-	7.8	-	-
	-	-	-	24.82	-	-
Total Area:	23.944	20.9	25.753	32.62	25.716	11.95
% Covered	46.61		55.88		31.73	
% Covered	**46.47%**					

Covered Skylight Area: Proposed Design						
	Proposed Design					
	Skylight 1		Skylight 2		Skylight 3	
Area	Open	Covered	Open	Covered	Open	Covered
	6.83	0.99	0.254	-	11.22	-
	3.34	1.15	17.29	-	21.61	-
	37.23	4.95	0.169	-	-	0.83
	-	0.38	3.24	-	-	-
	-	-	3.45	-	-	-
	-	-	26.17	-	-	-
	-	-	-	4.8	-	-
	-	-	-	-	-	-
	-	-	-	-	-	-
Total Area:	47.4	7.47	50.573	4.8	32.83	0.83
% Covered	13.61		8.67		2.47	
% Covered	**9.10%**					

The graph below shows a visual representation of the coverage area percentages presented in the tables on the previous page. Comparing the existing and proposed scenario, you can see the reduction in area per skylight.



As calculated on the previous page, approximately 36% of the skylight area has been opened up with the redesign of the systems in the ceiling space. The next useful calculation will be to translate the skylight coverage area to illuminance values. The table below does just this. With the existing system, an average illuminance of **14.55 FC** was achieved in the space. With the new system, an average illuminance of **20.31 FC** was achieved. This equates to an approximate increase in illuminance of **40%**.

Illuminace Comparison			
Category	Existing	Proposed	% Better
Average	14.55	20.31	39.6%
Avg/Min	29.1	11.28	61.2%
Max/Min	77.8	30.17	61.2%

This calculation was performed under an overcast sky, at noon, on March 21st, 2012.

Step 4: Prove ceiling space is organized and conflict-free

This section is dedicated to showing views and section cuts of the space as to provide evidence of a clash-free design. This section is split into two sections: the first includes sections and 3d cuts of the space; the second consists entirely of interior renderings of the space.

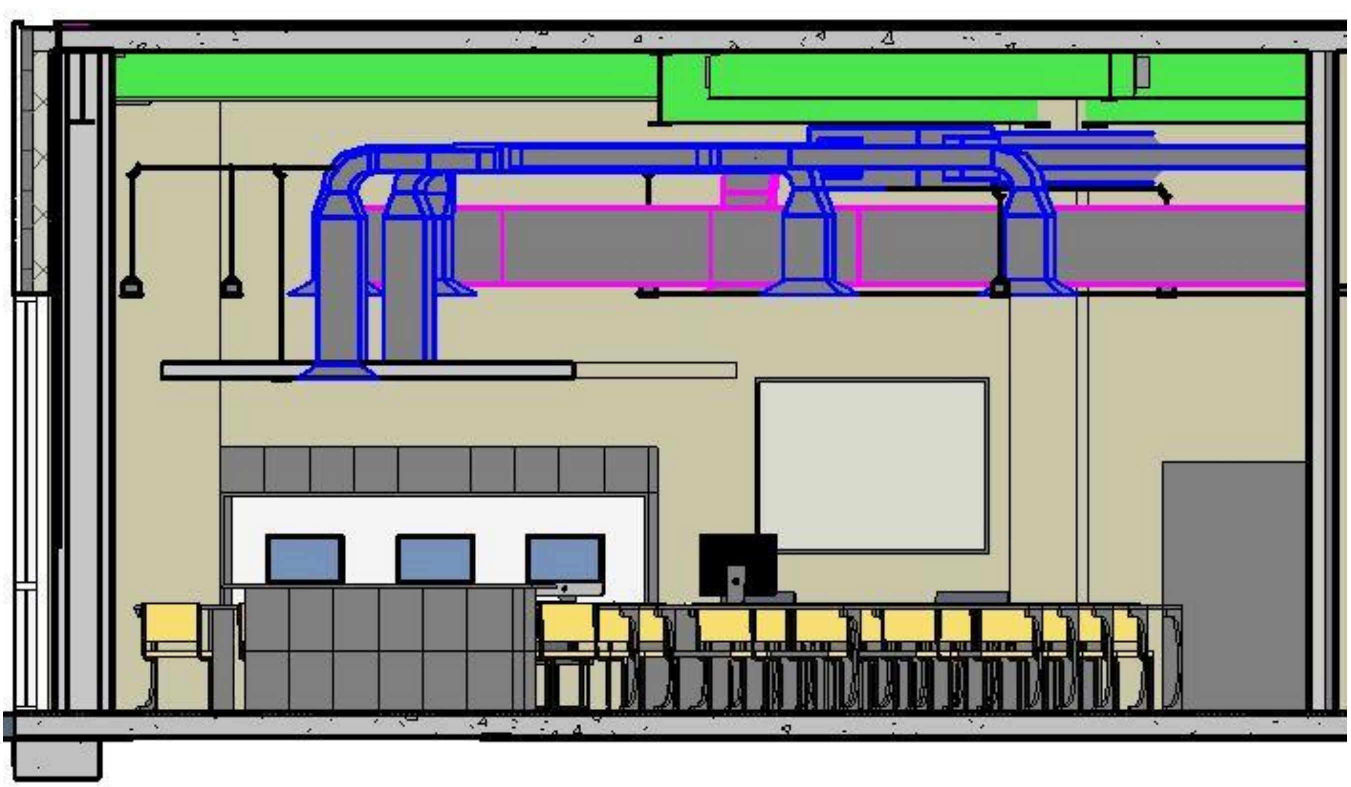
Sections

This portion of step 4 is dedicated to showing section cuts (both 2d and 3d) of the space to help provide a better understanding of the configuration of the systems in the ceiling space of the High School Art room. The plan below shows the layout of the art room, with 4 separate (colored) lines across it. These colored lines represent the section plane for the four sections on the following pages. The arrow represents the viewing direction. The colors are assigned to the following sections:

- **Section 1:** GREEN
- **Section 2:** ORANGE
- **Section 3:** PURPLE
- **Section 4:** BLUE

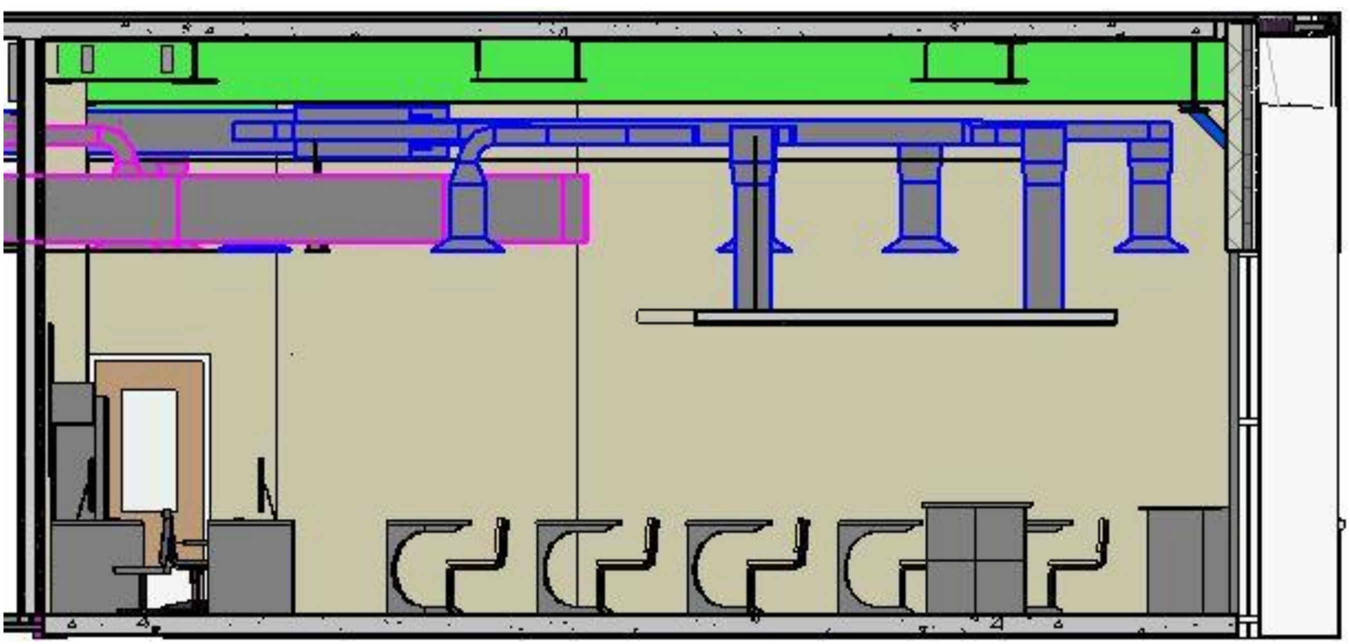
Section 1:

Section 2:

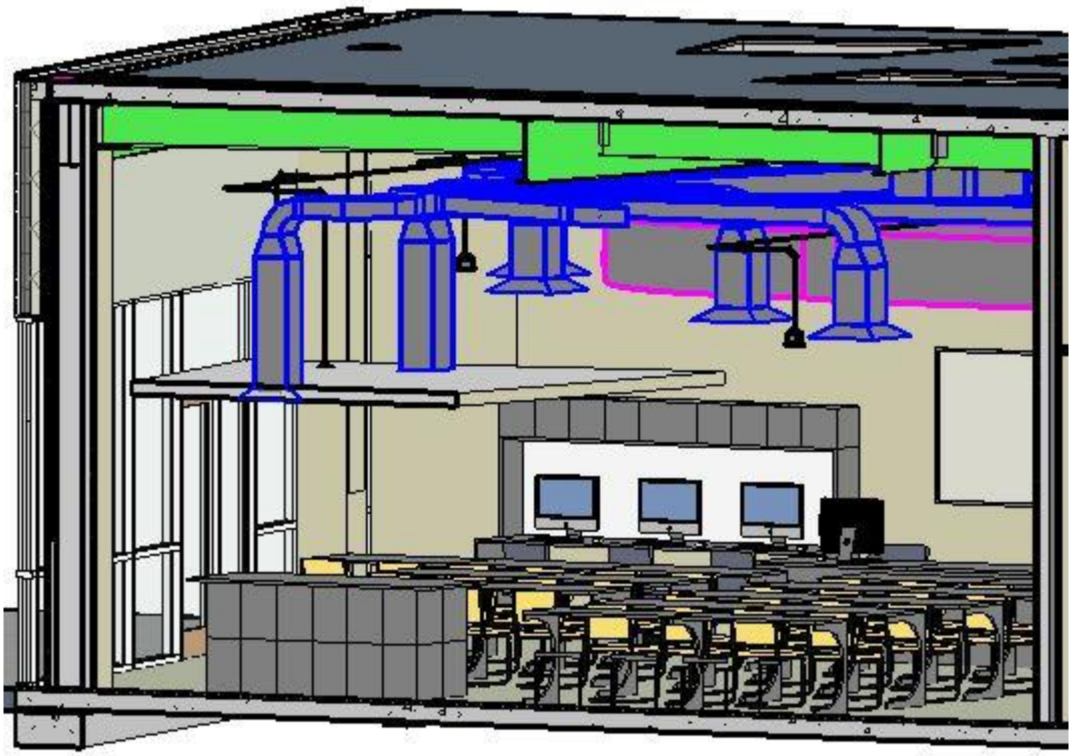


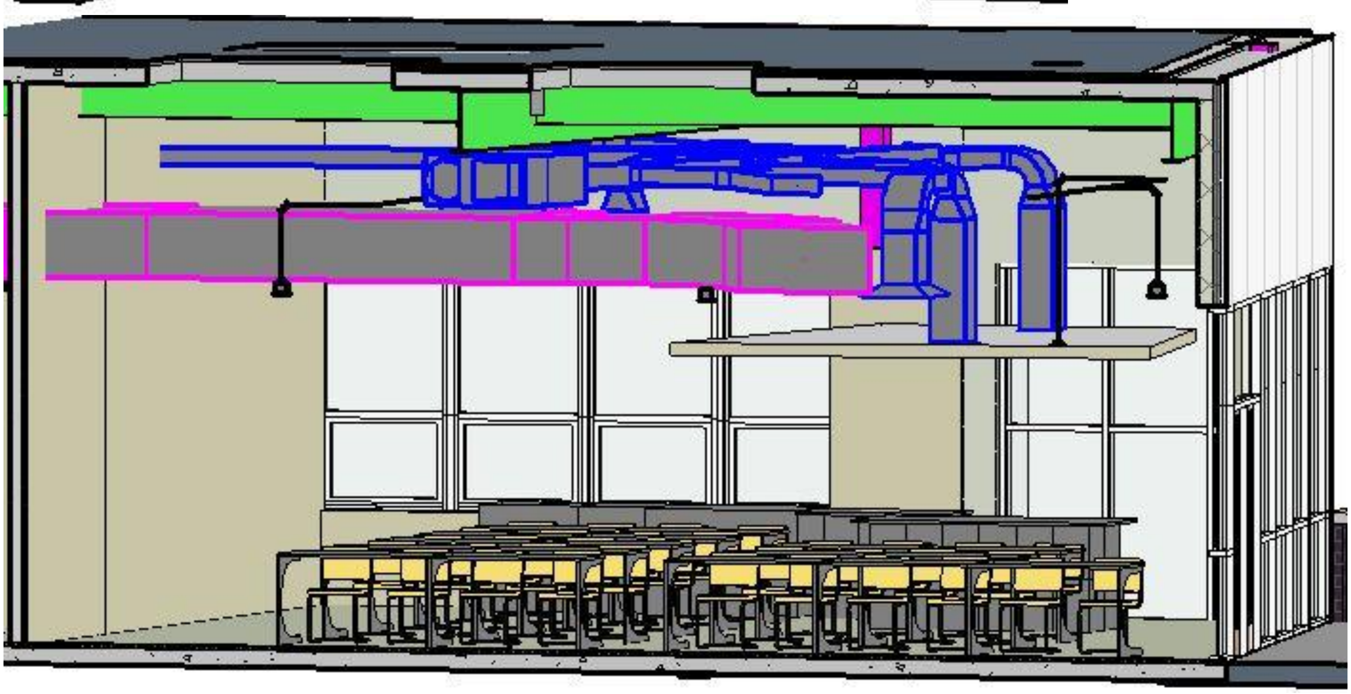
Section 3:

Section 4:

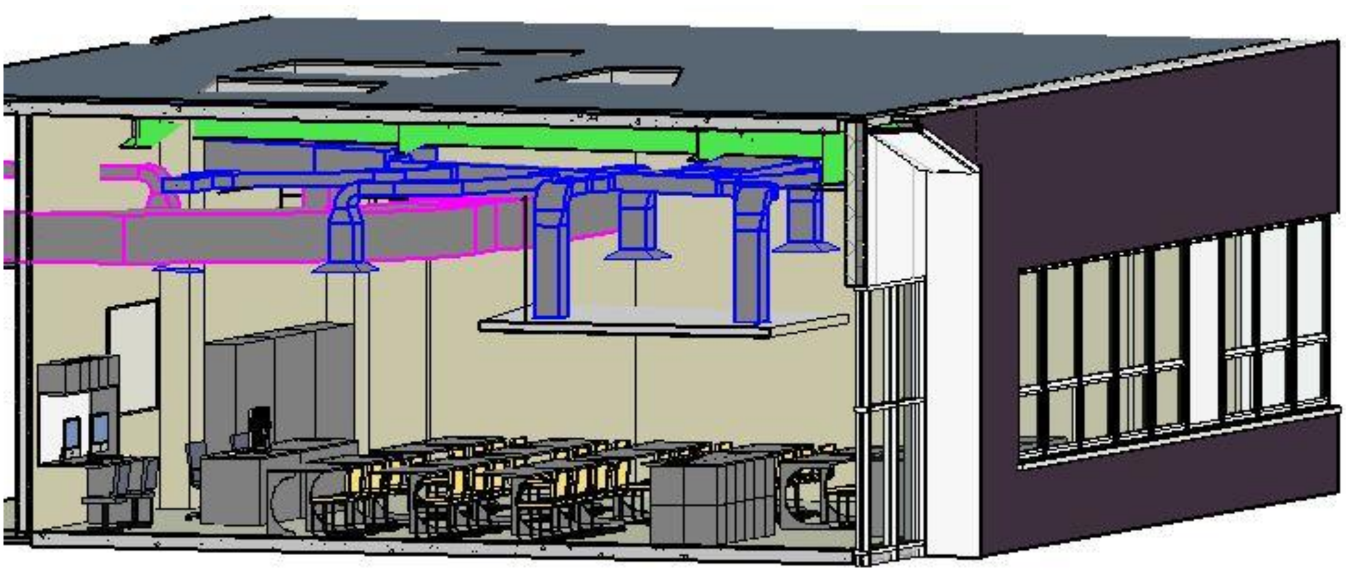


The two figures below show 3D section cuts to help better understand the coordination of the ceiling space in the High School Art Room.



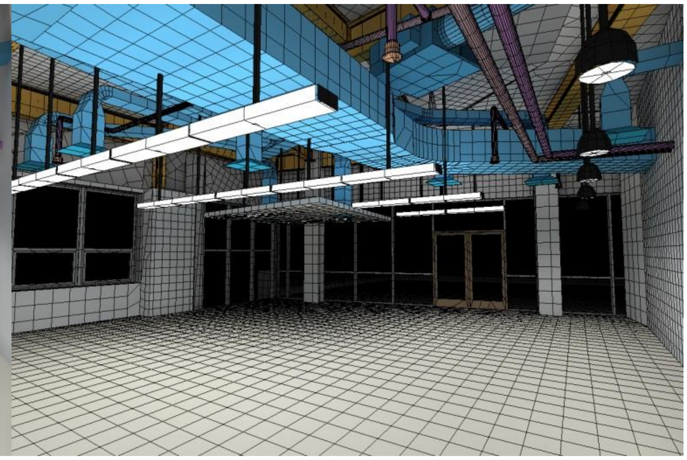


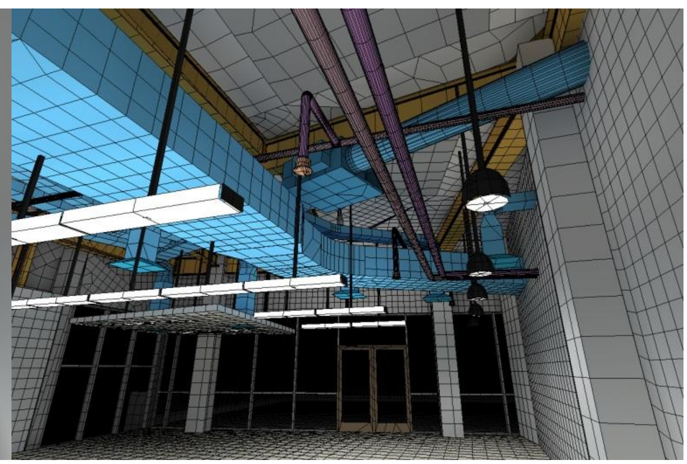
The two images below are intended to help give a better understanding of the coordination of the system in the ceiling space of the High School Art Room. The figure at the bottom is a section cut at the floor plane looking at the ceiling.

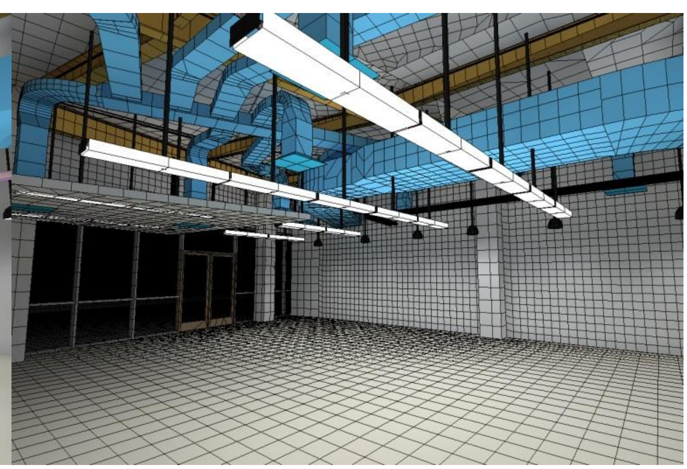


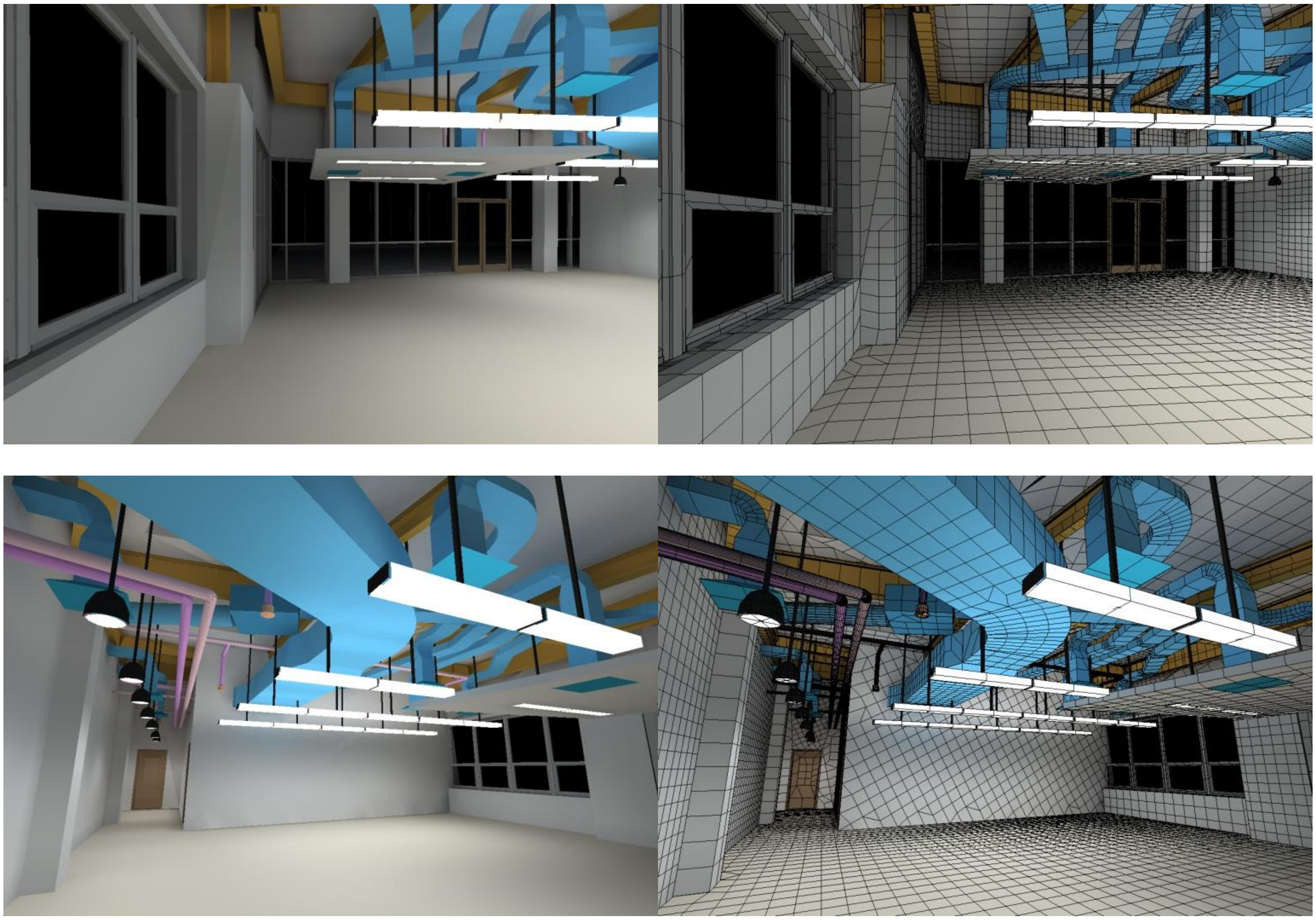
Renderings

This section shows interior renderings of the space that are intended to help give a better understanding of the coordination of the systems in the space. These renderings include only electric lighting and no daylight. They are intended to show the space under the times electric light would be utilized, which would most likely be the at night. The image on the left shows the rendering; the image on the right shows the calculation mesh.



Conclusion

Based upon the material presented in this section, it is a fair assumption to say that the redesign and coordination of the MEP systems in the ceiling space of the High School Art Room has been effective. The systems have been coordinated such that a reduction in skylight obstruction of 38% has been achieved. In addition, the reduction of skylight obstruction has resulted in an increase of 40% in workplane (average) illuminance.

Conclusion

Summary

The work presented in this report will help better increase the overall design aesthetic and community feel of the Hunters Point School. The building design overall will contribute to its connection with the neighborhood, and hopefully become a large part of the community. The building may serve as a wayfinding device and landmark for those traveling along the river. Becoming part of the neighborhood, the design goal of connection the **building + community** will be achieved.

The designs of the spaces, especially that of the auditorium, will hopefully encourage student from both programs, the intermediate school program and the high school program, to interact with one another. The goal in choosing the auditorium to design was because it is a literal connection point between the two floors that house these separate programs. Encouraging the students to interact in the space via plays, musicals, talent shows, and other events will achieve the overall design goal of connecting **people + programs**.

All designs were mindful of the architecture, especially that of the auditorium. However, it is the high school art room that truly integrates lighting and architecture. The removal of the drop-ceiling, exposing the MEP systems in the ceiling space, and adding skylights in the roof all truly merge lighting and architecture. Combining both lighting and architecture, in harmony, to create a pleasant, beautiful indoor built enviorment achieves the overall design goal of connecting **lighting + architecture**.

In general, this building will become a more interesting, occupant friendly building. The façade will invite people. The auditorium will intrigue them. The high school art room will fascinate and inspire them. The intermediate school cafeteria will provide them nourishment in an interested and beautifully lit space.

References

Software

2. AGI32
3. AutoCAD 2010
4. 3DStidioMAX
5. TRACE700
6. REVIT MEP 2012
7. Adobe Photoshop CS5
8. DAYSIM 3.0

Textbooks

Houser, Mistrick, and Stefy. The IESNA Lighting Handbook: Reference & Application. 10th ed. New York, NY: Illuminating Engineering Society of North America, 2011.

The IES Lighting Handbook was used as an aid in design, daylight calculations and studies, illuminance recommendations, and for answers to general lighting questions.

National Electric Code 2011, Quincy, MA: National Fire Protection Association, Inc. 2011

The NFPA National Electric Code was used for all phase-wire, ground-wire, neutral-wire, and conduit sizing. In addition, the code was used to find full load amps of 3-phase squirrel-cage motors.

ASHRAE Standard 90.1-2010. Atlanta, GA: American Society of Heating, Refrigerating and Air Condition Engineers, Inc. 2010

ASHRAE Standard 90.1 was used for power density values for all lighting spaces. Power densities, in combination with calculated areas, were used to calculate the max wattage of lighting that could be used in each space.

ASHRAE Standard 55-2007. Thermal Environmental Conditions for Human Occupancy. Atlanta, GA: American Society of Heating Refrigeration and Air Conditioning Engineers, Inc.

ASHRAE Standard 55 was used to locate human loads on the heating and cooling systems. These values were used in the TRACE model that was utilized in my mechanical breadth

RS Means Electrical Cost Data 2010. 33th Annual Edition. Kingston, Massachusetts: RS Means Co., 2010. Print.

RS Means electrical cost data was used for **ALL** electrical cost information used in this report. The primary use of this book was in electrical depth 1 in which a cost comparison was made between two electrical distribution methods.

Acknowledgements

I would like to personally thank the following people for both their help not only throughout thesis, but also throughout my college career.

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Dr. Kevin Houser
Dr. Richard Mistrick
Professor Ted Dannerth
Professor Sean Good
Professor Robert Holland
Professor Kevin Parfitt

Of these people, I would like to send a personal token of gratitude to Dr. Mistrick and Dr. Houser. I cannot begin to explain how honored I am to have had the privilege and opportunity to study under you.

I would like to thank SKANSKA for providing my thesis project. A big thank you goes out to Sharvil Patel at SKANSKA for all of his help during this whole process.

Lastly, I have to send the biggest thanks of all to my mother. I would not have succeeded thus far without her. She is the main reason I am who I am, and the sole reason for my achievements and success. I dedicate this thesis and my past 5 years of college to her.

Thank you mom, I love you.