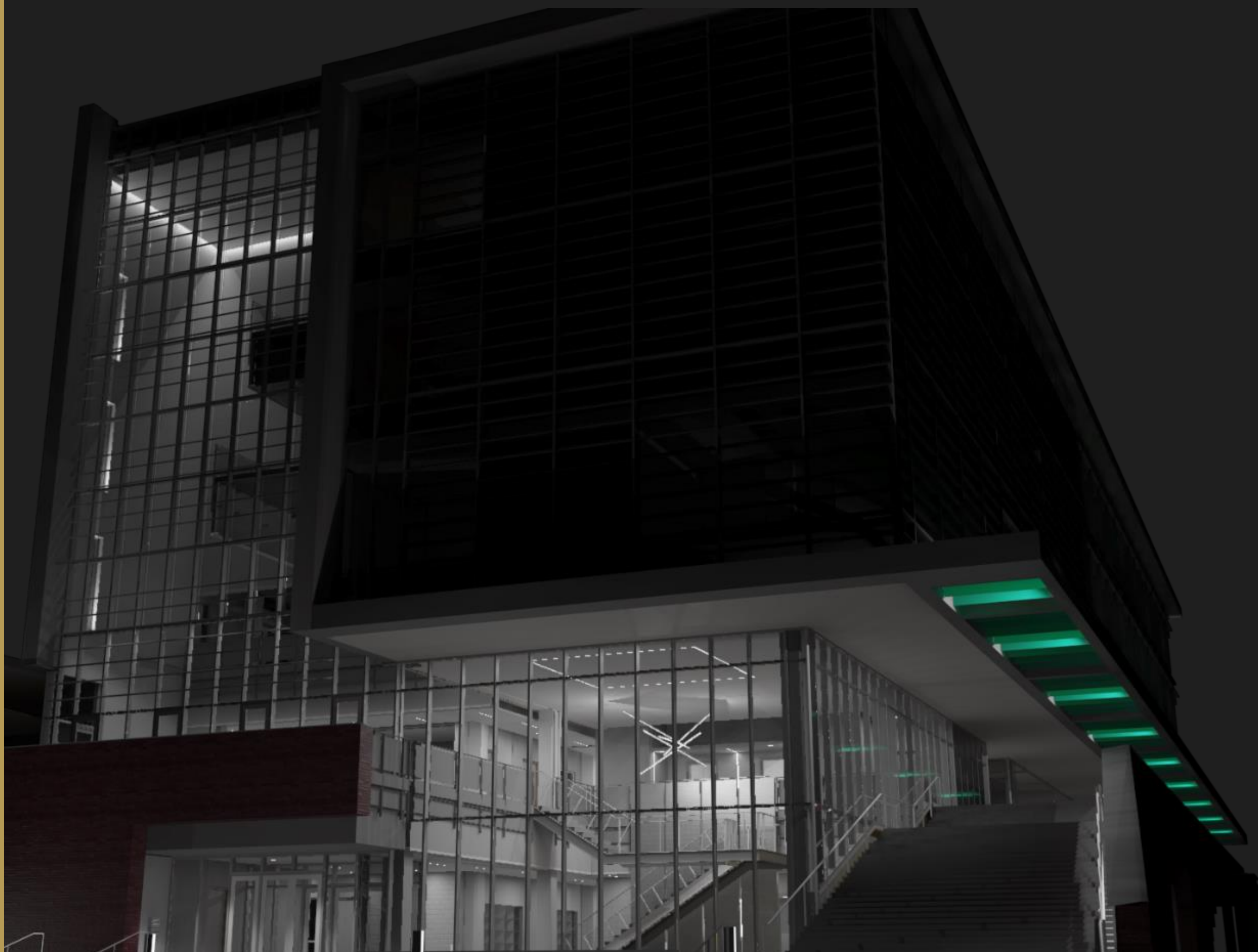

OAKLAND UNIVERSITY ENGINEERING CENTER

ROCHESTER, MI

SENIOR THESIS FINAL REPORT

JOHN CONLEY | LIGHTING + ELECTRICAL
SHAWN GOOD | FACULTY ADVISOR

04.08.2015

OAKLAND UNIVERSITY

engineering center
rochester, michigan

john conley | lighting + electrical

general building statistics |

occupant | Oakland University, School of Engineering and Computer Science

occupancy or function types | 2 Buildings separated by firewall; Building A is MBC TYPE IIB, NFPA TYPE II(000) and Building B is MBC TYPE IB, NFPA TYPE II(222)

size | 136,653 GSF

levels | 5 all above grade

dates of construction | January 2013 – September 2014

estimated cost | $57 Million Construction Cost

project delivery method | Design-bid-build

architects + engineers | SmithGroupJJR

construction manager | Walbridge Aldinger Company

Figure 1 South Lobby perspective | SmithGroupJJR

Figure 2 Lecture Hall perspective | SmithGroupJJR

architecture |

The new Engineering Center is a state-of-the-art facility for research and education within the School of Engineering and Computer Science and consolidates four departments under one roof. This building is designed to foster curiosity, research enthusiasm and student collaboration.

lighting + electrical |

The lighting and electrical systems consist of:

- Low voltage LED and FL fixtures with clean aesthetic
- Primary service 13.2KV down to 480/277V 3PH, 4W from a substation transformer.
- Step-down transformers per floor 480Y/277V down to 208Y/120V 3PH, 4W
- Rooftop natural gas generator which provides 480V power to the emergency panels

mechanical |

The main mechanical systems are located on the penthouse level and include two centrifugal chillers both with a nominal capacity of 290 tons, two turbogenerators, and the main air handling unit supplying 5200 CFM to the building.

structural |

The structural system of the building consists of:

- Concrete footings and slabs
- Steel decking
- A framework of steel beams and columns
- Reinforced CMUs on the lower level perimeter

EXECUTIVE SUMMARY |

The following report is the culmination of a semester of work to research the building, study redesign possibilities, and develop final designs and recommendations. The report focuses on the lighting and electrical aspects of the building as the senior thesis depth topics. Additionally, a daylighting study was performed as an MAE special topic based on work done in graduate courses. And finally, two breadth topics were studied to display the wide base of knowledge that the Penn State Architectural Engineering has provided.

The existing lighting for four select spaces in the new Engineering Center at Oakland University was redesigned. The lighting redesign is focused on a central concept of furthering the engineering industries through the studies undergone at Oakland University which ultimately pave the way for progress. The lighting design also attempts to accent the very geometric forms of the Engineering center and provide spaces that are visually appealing and conducive to collaboration.

From these redesigns, the effects on the electrical system were analyzed and branch circuits were altered to show the differences in connected loads. The electrical system was not drastically altered and no changes would have to be made to the main electrical equipment.

The two breadth topics, as well as the daylighting analysis are centered around the addition of three Kalwall pre-engineered Skyroof products to the project labs space on the first level. The main purpose for these skylights was to increase the daylighting in the project labs space to further the lighting concept and save energy through photosensor dimming of the electric lighting. The addition of these skylights also decreased the structural dead load providing the possibility to downsize the members directly affected by this decrease. Hand calculations were done to show this possible change in structure. Likewise, the mechanical heating and cooling loads were affected by the addition of the skylights and analyzed. A simple payback period was calculated based on an official quote of the Kalwall system and final recommendations are given.

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BUILDING OVERVIEW |

General Building Data

Building name | Engineering Center

Location and Site | Oakland University, Rochester, Michigan

Building Occupant Name | Oakland University, School of Engineering and Computer Science

Occupancy or function types | 2 Buildings separated by firewall; Building A is MBC TYPE IIB, NFPA TYPE II(000) and Building B is MBC TYPE IB, NFPA TYPE II(222)

Size | 136,653 SF (Gross)

Number of stories above grade / total levels | 5 / 5

Primary project team |

Owner	Oakland University (http://www.oakland.edu/)
Architect	SmithGroup JJR (http://www.smithgroupjjr.com/)
Lighting Designer	
MEP Engineer	
Structural Engineer	
Civil Engineer	Johnson & Anderson (http://ja-engr.com/)
Audiovisual, Telecommunications, Security, Acoustics	Convergent Technologies (http://www.cti-usa.net/)
Construction Manager	Walbridge Aldinger Company (http://www.walbridge.com/)

Dates of construction | January 2013 – September 2014

Actual cost information | $57 Million Construction Cost

Project delivery method | Design-bid-build

Architecture

Southeast Perspective | Courtesy of SmithGroupJJR

Southwest Perspective | Courtesy of SmithGroupJJR

Design | This new Engineering Center for Oakland University's campus is a much needed addition to the campus in terms of faculty office, classroom and research lab space for the campus' ever growing school of engineering and computer science. As the new heart of Oakland University's School of Engineering and Computer Science, this building needs to provide the appropriate spaces for the improvement of teaching, learning and research. The building's program of spaces includes, 1000 seats of classroom space, 200 seat lecture hall, SECS (School of Engineering and Computer Sciences) office spaces, departmental office spaces, faculty office spaces, student office spaces, class laboratories, research laboratories, clean rooms and study spaces including a café. This building, for those involved at Oakland University, is a symbol of future growth of the university and the School of Engineering and Computer Science (SECS), interdisciplinary collaboration and an incubator of ideas in research and learning.

The design aesthetics of the building are intended to be very raw and geometric in nature. That being said, there were attempts, architecturally, to tie the building into the campus fabric through the use of the brick on the lower levels to reflect the older buildings on the campus and the modern feeling panels and curtain walls to reflect the more recent projects completed on the campus. The building sits on a hill and creates a nice transition from the upper level near the campus library to the lower parking area as well as helping to create more of a quad feeling in the upper area and a nice stair feature for transition through the campus. The new Engineering Center is to be a tangible symbol of the future for Oakland University and the School of Engineering and Computer Science.

National Model Codes | The main codes used by the architects and engineers while designing include: The Michigan Building Code 2009 (MBC 2009) which is an amended version of IBC 2009; the Michigan Fire Prevention Code MFPC which adopts NFPA 1; Michigan 2008 Electrical Code incorporating National Electrical Code 2008 (NEC); the Michigan Plumbing Code 2009 (MPC) which is an amended version of the International Plumbing Code 2009; the Michigan Mechanical Code 2009 (MMC) which is an amended version of the International Mechanical Code 2009; 2003 ICC/ANSI A117.1 2010 ADA Standards for accessibility and usability.

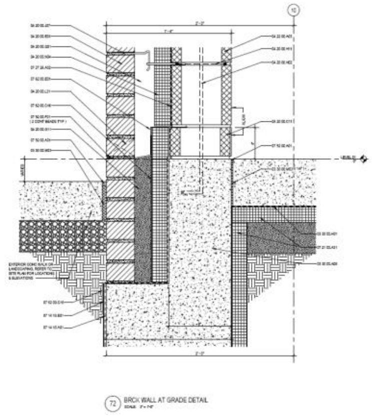
Zoning | For zoning purposes, Oakland University is located in both the Auburn Hills zone and the Rochester Hills zone. The Engineering Center will be situated within the Auburn Hills zoning ordinance under a special purposes designation. According to Article X, Section 1000 Special Land Uses Permitted, colleges, universities or other institutions of higher learning have to comply with three stipulations: First being that to be considered in this special purpose designation the site must be greater than 40 acres. The second, is that the ingress and egress from the site must be onto a major or secondary thoroughfare. And third, no building can be closer than 75 feet from any property line unless it is for one family residential purposes.

Historic Requirements | There are no historic requirements to adhere to in the design of this new engineering building for Oakland University's campus.

Building Enclosure

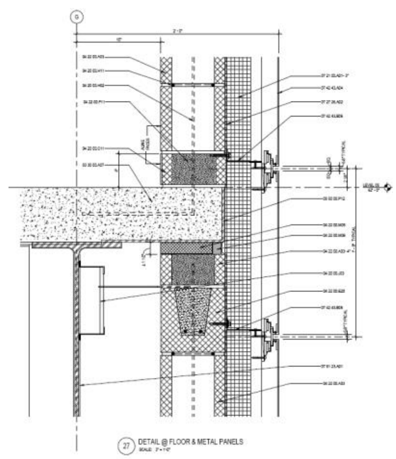
Building Facades |

Brick Walls | The exterior brick facades, found on the lower two floors of the building, are typically made up of a veneer face brick tied back into a CMU wall with dovetail wire anchors, an air space, fluid-applied vapor-retarding membrane, then the concrete wall separating the exterior from the interior wall structures.



Courtesy of SmithGroupJJR

Panel Walls | The metal panel walls, found in the upper floors of the Engineering Center, include a zinc faced composite wall panel connected to the structure with adjustable framing angles which allows for room for an air space and XPS-1 extruded-polyestrene board insulation followed by the concrete masonry unit wall assembly.

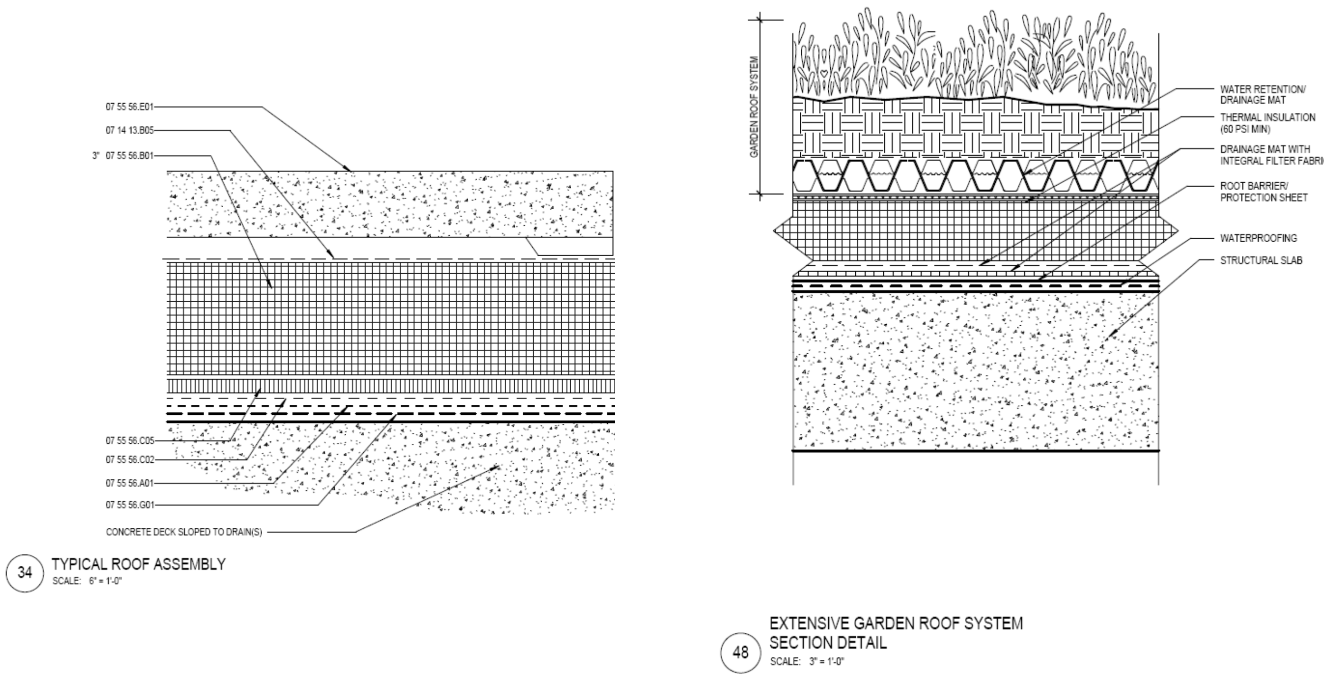


Panel Façade Section | Courtesy of SmithGroupJJR

Curtain Walls | The curtain wall system utilizes two sided structural sealant glazed curtain wall with 1" insulating glass with ½" argon airspace and a visible transmittance of 79% as well as vertical mullion mounted sunshade system which is horizontal louver based and angled down at 20 degrees.

Atrium Section showing exterior glazing and shading louvers | Courtesy of SmithGroupJJR

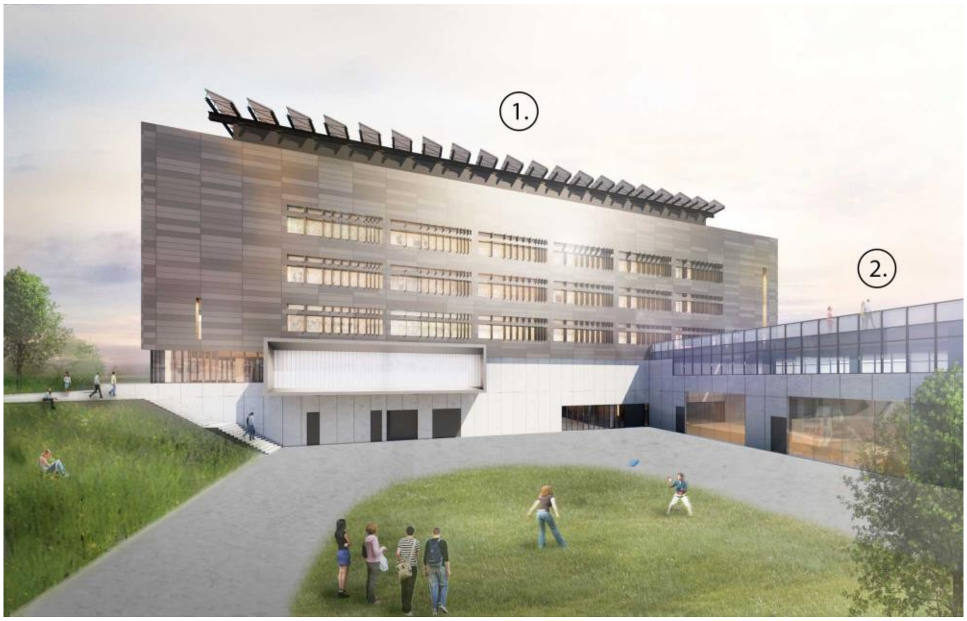
Roofing |



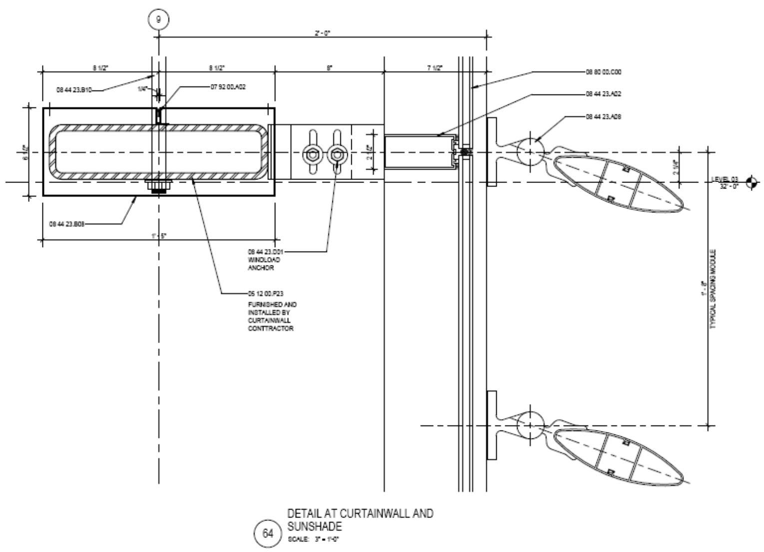
A section of a typical roof (left) as well as the garden roof (right) | Courtesy of SmithGroupJJR

A typical roof section, shown above on the left, contains, from the structure to the exterior, surface conditioner, fluid-applied protected membrane roofing, protection course, drainage panel, three inches of semi-rigid insulation, a filter fabric and another later of concrete which is a precast concrete roof paver. For the garden roof assembly we have, waterproofing, root barrier protection sheet, drainage mat with integral filter fabric, thermal insulation (60 psi minimum) and a water retention drainage mat all below the actual garden roof system.

Sustainability Features



West Perspective with two sustainability features | Courtesy of SmithGroupJJR



Curtain wall and sunshade section detail | Courtesy of SmithGroupJJR

Of the sustainability features included in the design of this building, the ones that are most apparent are the photovoltaic panels on the main roof (1 above), the garden roof on the lower roof (2 above), and the sun shading features on the South curtain wall façade. The photovoltaics, create energy for the building's use, provides a testing ground for the energy research that the school foresees in their future and compliments the overall aesthetic of the building giving it an interesting and raw quality. The lower roof garden will aid with the heating and cooling of the lab spaces below and also provide the students and faculty a nice environment to walk around. The sunshades on the curtain wall façade on the South side of the building will provide shading to the interior and let in a smaller portion of the total daylight into the atrium space and also add another layer to the curtain wall aesthetic. The designers and construction managers along with Oakland University are targeting a LEED Gold Certification upon completion of the project and have outlined a plan so as to obtain this.

Construction

Walbridge Aldinger Company was the construction manager at risk for this project. They started work on the construction in January of 2013 and finished up construction in late August of 2014 opening the Engineering Center for use in the fall 2014 semester. As part of the construction of this new facility for the School of Engineering and Computer Sciences, they also renovated 15,000 square feet of space in other buildings that the SECS previously occupied on campus.

Electrical

Utility power, at 13.2 kV, enters the building on the ground level into a designated substation room. The substation room contains two transformers taking the voltage down to 480Y/277V power, which travels through feeders to the electrical rooms on each level and multiple 480/277V panels in the substation room. There are designated electrical rooms on every floor including the penthouse level. Within each electrical room are step-down transformers from 480Y/277V power to 208Y/120V which supplies the power to branch panelboards powering the receptacles, mechanical equipment, and some lighting.

The emergency power is supplied by a 225A natural gas generator in the penthouse provides the power to the fire pump controller from a 480Y/277V panel. Two turbogenerators are also located in the penthouse and provide the power to the other necessary amenities for life safety including emergency lighting, elevators, stair pressure fans, lab and atrium exhaust fans, sump pumps, atrium coiling doors, and the other loads on the legally required panels.

Lighting

The lighting design for the Engineering Center is energy efficient, functional, fairly minimalistic, and pleasingly accents the architecture of the spaces. Each space was evaluated both quantitatively and qualitatively to provide the building with a solution that works with the architecture and provides quality lighting. The building primarily uses LED and linear fluorescent fixtures. The spaces with one or two main tasks are simpler in design and contain a minimal number of fixture types. Those that are more public and more complex, in terms of task, have more complex and visually appealing lighting schemes with points of interest and layers of lighting.

A very important aspect of the lighting scheme is the use of controls. The larger classrooms are all equipped with Lutron lighting controllers to provide zonal control and scene control of the spaces as well as interface with projector and projector screen control. Daylight dimming photocell sensors are used throughout the building for lighting dimming purposes to save energy by supplementing daylight for electric light. Combination occupancy/daylight/HVAC sensors are also used to turn on lights and HVAC systems when occupied as well as dimming as daylight increases.

Mechanical

The air handling system for the Engineering Center comprises of one 5200 CFM capacity air handling unit in the penthouse of the building, a 30000 CFM make-up air unit on the roof, and a 30000 CFM heat recovery unit also on the roof. These units provide the required air exchanges to all of the interior spaces through volume control boxes.

Cooling for the building uses two cooling towers, CT-1 and CT-2, rated 750 GPM each and an 8” main cooling loop servicing the building fan coil units and chilled beams. If the system is in a heating mode, heat exchangers connected to the system provide cooling as well.

General building heating is provided by a low temp heat recovery boiler that recovers heat from the exhaust of the turbine generators. The high temp heat recovery system also recovers the exhaust from the turbine generators and provides some heat to the building and some to the campus high temperature loop.

A building management system, or BMS, controls the mechanical systems in the building through a central control.

Structural

The structure of the Engineering Center consists of a concrete foundation, steel framing structure, and composite decking for the floors and roof. Foundations include 3000 PSF continuous footings, 35 PCF retaining walls, and 55 PCF basement walls. Structural beams are placed to account for building dead and live loads as per code in a manner that does not detract from the building aesthetic. The column sizes vary in size from W8x28 to W14x176 and are spliced for the longer column lengths. The composite slab typically consists of 2” depth 16 or 18GA steel decking, 4.5” deep normal weight concrete at 4000-PSI strength, and steel reinforcing.

The most interesting structural challenge on this project was the cantilevered stair structure in the southern lobby space. Here the engineers used an exposed beam structure to support the middle of the stair without detracting from the effect.

Fire Protection

Fire protection is important for both the safety of the occupants as well as the building. The building is fully equipped, in accordance with NFPA requirements, with smoke detectors, fire alarms and sirens, strobe lights, a sprinkler system, exit signs, fire-proofing, fire walls, and lab and atrium exhaust fans. On the first level there is a designated fire pump room with a 480V, 3PH, 3W, 100HP fire pump and a 480V, 3PH, 3W, 2HP jockey pump as well as a fire pump controller with wye-delta starter and integral automatic transfer switch. The systems necessary for life safety and code are all included on the emergency power.

Transportation

There are three elevators servicing the building and transporting occupants to all levels of the Engineering Center. Elevator #1 is 30HP and is controlled in room 100A. Elevator #2 is 30HP and is controlled in room 100B and elevator #3 is 45HP and is controlled in room 153A; elevators #2 and #3 are included in the emergency power scheme.

Another transportation related device in the Engineering Center is a wheelchair lift located in the 200-seat lecture hall and provides disabled individuals access to the bottom tier of the lecture hall.

Telecommunications

The Engineering Center uses many different telecommunications systems to be the most state-of-the-art a facility as possible. CATV and CCTV cables service the building’s video surveillance and television systems. Each of the classroom spaces house projectors, projector screens, central control systems, video cameras, and audio speaker systems. Certain rooms and the building entrances require card reader access so as to keep the facilities safe. This facility is certainly equipped for the future for the School of Engineering and Computer Sciences.

LIGHTING DEPTH |

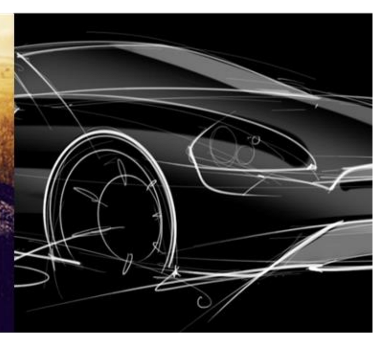
Overview

The lighting depth section of this report will explore the design development of four selected spaces in the new Engineering Center at Oakland University. The schematic design for these spaces were completed in the Fall 2014 semester culminating a presentation to the faculty advisor and another presentation at the Lutron facility in Coopersburg, PA to lighting design professionals. The comments that were received during both presentations were considered and further design on each of the spaces was conducted to refine and improve.

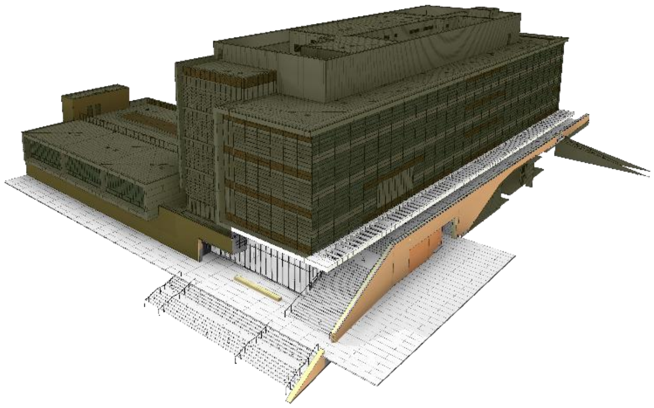
The spaces that were studied include: the exterior walkway that travels up the eastern side of the building from the southern entrance to the entrance on the north side of the building, the large transition area of the southern lobby and atrium spaces including the corridors that run into them, the 200-seat lecture hall auditorium, and the project labs large workspace in the western wing of the building.

Concept | Paving the Road to Progress

The design of these spaces is unified by a design concept that embodies the essence of the building and the goals of the occupants. Oakland University's engineering program has a close interaction with the automotive industry in southeastern Michigan. The work that they are doing in the engineering programs there is important as they hold the ability to ensure a more promising future in the automotive industry. They are "paving the road to progress" with the research and studies they undergo at school, building on the successes of the past in southeastern Michigan, and starting a new generation of engineers for the future of the automotive industry. The concept "paving the road to progress" focuses on automobile related ideas and the importance of collaboration, research, and innovation in the work that will be conducted in the new Engineering Center to further enhance the industry. This idea of a path, and a continuation from past to present embodies the idea that everyone has a part in this overall progress and that all of these individual paths intersect in points of studying the past and collaborating towards a common goal.



Outdoor Space | Covered Walkway + Stair



Space Locator

Description of Space

The exterior walkway stretches from the southern side of the building to the north and elevates from the first level of the building to the second. This is a major transition area for the building, with three entrances off of this walkway, and for the campus, with intersections with other paths and the connection to the parking lot in the south. The materiality of the exterior here is consistent with the rest of the building with brick exterior walls, concrete stairs and ground, and a metal panel overhang with green tinted architectural fins.

Concept

Figure 1 Exterior Schematic Design Sketch

With the heavy traffic potential and the importance of this main walkway for the building and the campus, the idea of an intersection of is going to be used to emphasize the lighting design. An intersection is a crossing of paths by definition, and as the students and faculty traverse the campus and share knowledge, these paths are crossed. The pathways will be clearly marked and the entrances to building are the intersections of the pathways and will be given importance through higher illuminances.

Design Criteria

The following is a list of important design criteria, both quantitative and qualitative, to reinforce design concepts and desires for the final lighting design.

Illuminance Criteria | According to the IES Lighting Handbook
LZ2 According to Table 26.4
Table 26.2 Building Entries
Covered Entry High Activity = 20 lux E_h, 10 lux E_v (25-65 age range)
Stairs High Activity = 6 lux E_h, 2 lux E_v

Safety | Since this is an exterior space on campus, it was very important to consider how this space would ultimately feel in terms of safety and to provide a space that welcomes rather intimidates.

Color Rendering | The color temperatures desired were in the 4000 K range with high color rendering indexes to reinforce the safety factor and to ensure that the rendering of faces would be adequate.

Lighting Power Density | According to ASHRAE 90.1 – 9.4.2-1 Zone 3,
Large Walkways = 0.16 W/ft^2
Stairways = 1 W/ft^2
Main Entries = 30 W/(linear ft of doorway)

Lighting Layers

Due to comments from the Lutron presentation, the design was simplified from the initial schematic design which was deemed to be too literal with the concept. The linear in grade fixtures and step lights that created the center of the roadway were taken out of the design. A schematic sketch is shown on the previous page.

The final lighting design contains five main layers of light to achieve the design goals outlined above. The architectural element of the brick handrail on the right hand side of the walkway has a linear LED detail to accent the wall and to provide a clean line of travel from north to south along the building. The recessed downlight fixtures are used at each of the covered entryways to provide a higher illuminance to the entry as the literal intersections of the paths creating a hierarchy of light for the pedestrians. The architectural fins are highlighted with a wall mounted fixture in-between the fins which also provides a repeated pool of light on the walkway to brighten the path and create the sense of safety that is intended. Bollard fixtures at the top of the southernmost stair and along the path in front of the building create another pathway line and levels of lighting that allow for proper vision while traversing the steps. And finally, two linear in grade fixtures are used near the north entry to highlight the architectural feature there which contains the nameplate for the building. These layers of light can be seen in the renders below.

Fixture Schedule

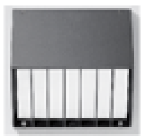
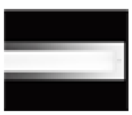
Exterior Fixture Schedule				
Type	**Symbol**	**Image**	**Description**	**Manufacturer**
L1			Handrail detail encapsulated LED strip light, IP67 plug in connectors at both ends, 4000K, 85 CRI, 3-Step MacAdam binning	LED Linear
L2			Recessed 6" round LED downlights, tempered clear glass enclosure, anodized aluminum reflector, Outdoor rating IP65, 4000K, 85CRI	Bega
L3			8" square wall mounted assymmetric LED, die-cast aluminum housing, semi-specular anodized aluminum internal reflector, weather tight IP65 rating, 4000K, 85 CRI	Bega
L4			30" tall two sided bollard with 21-5/8" illuminated height per side, 1/4" thick aluminum extruded housing with electrostatically applied powder coat finish, 1/4" polycarbonate lens, UL/CUL Wed Location rated, 4000K	A-Light
L5			20-7/8" x 3-1/2" linear LED ingrade symmetrical floodlight, extruded stainless steel with 1/4" tempered matte safety glass cover, IP67 rating, 4000K, 80 CRI	Bega

Figure 2 Exterior Fixture Schedule with symbol colors matching those in the plans on the following pages

Controls

According with ASHRAE 90.1 9.4.1.4, the exterior lighting must be controlled by a time clock system with photosensors to turn the exterior lights on or off depending on the time of day to provide light when sufficient daylight is not present. The lighting must also be able to retain programming. This will save on energy as well as provide insurance of safety.

Lighting Plans

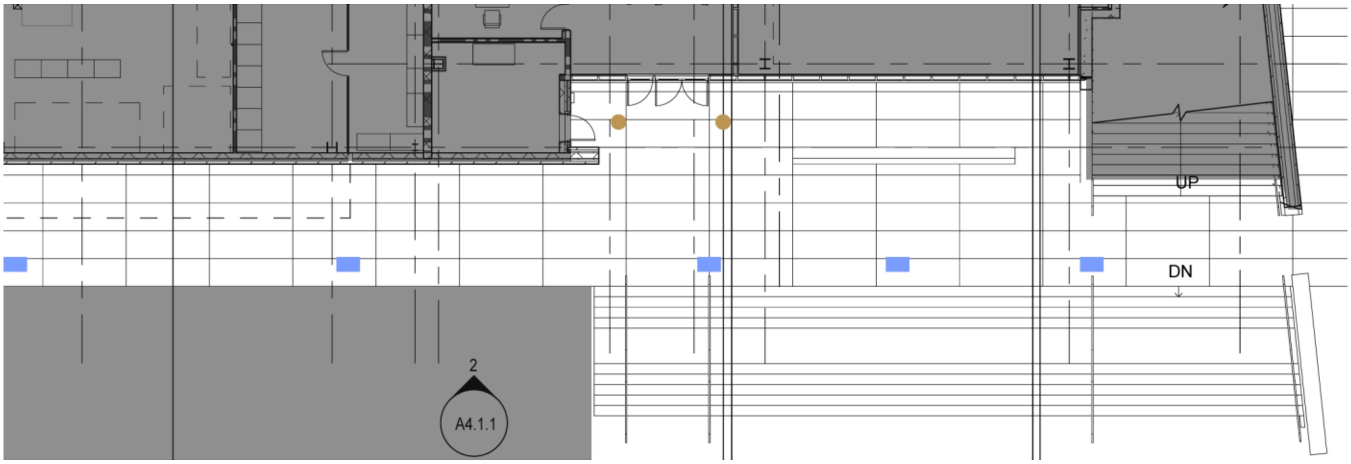


Figure 3 Exterior Level 1 showing South Stair and Entrance

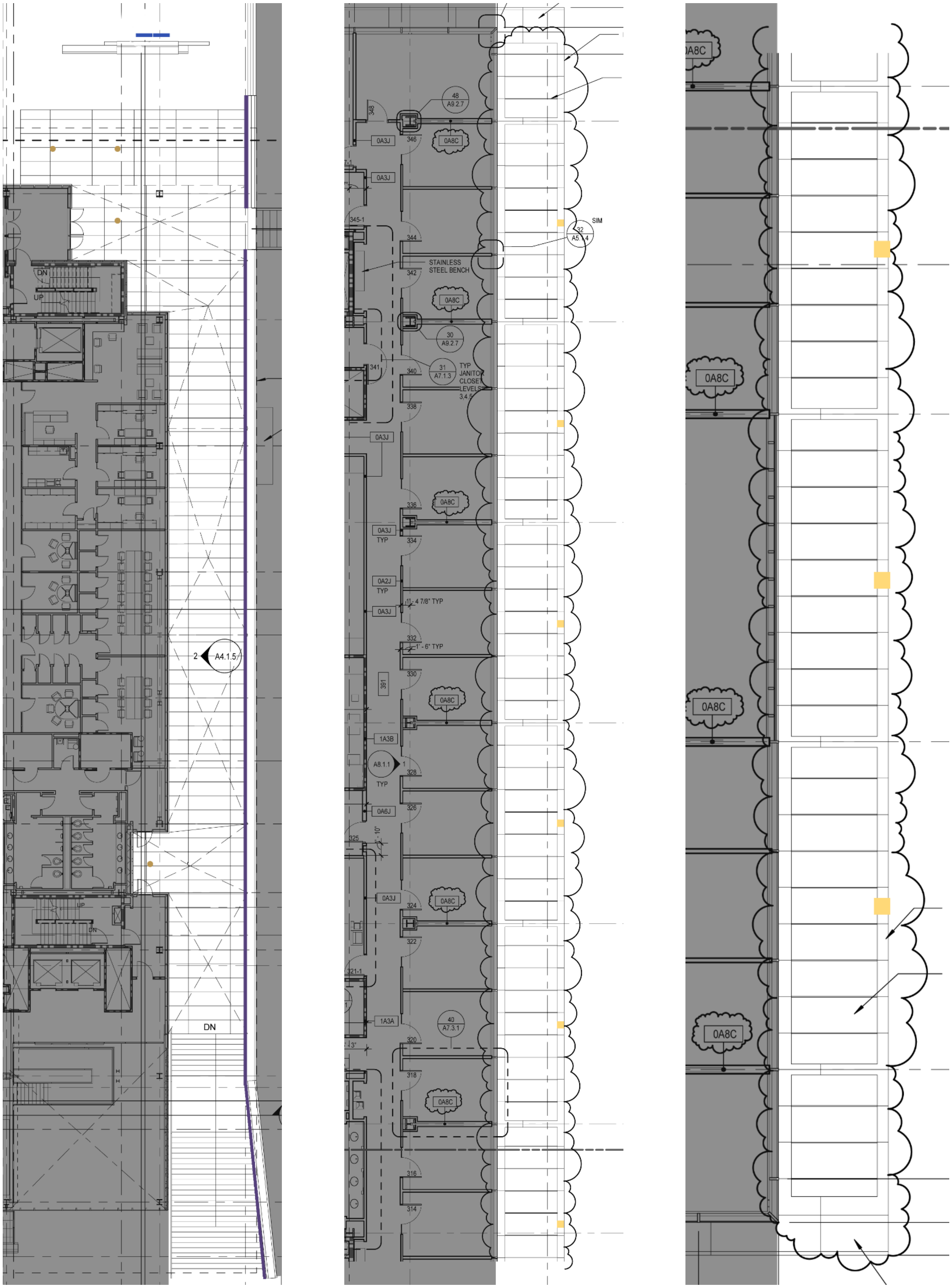


Figure 4 (Left to Right) Level 2 Lighting Plan of walkway, Level 3 Architectural Fins Northern portion, Level 3 Architectural Fins Southern Portion

Renders

The following lighting plans and sections have colored symbols to indicate the fixtures used and their locations in the space. The fixture schedule above indicates what fixture each symbol stand for. The circuiting for these fixtures can be found in the electrical depth.

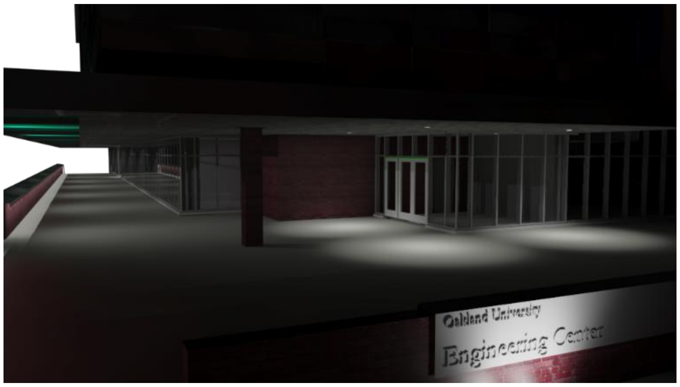


Figure 5 North Entry

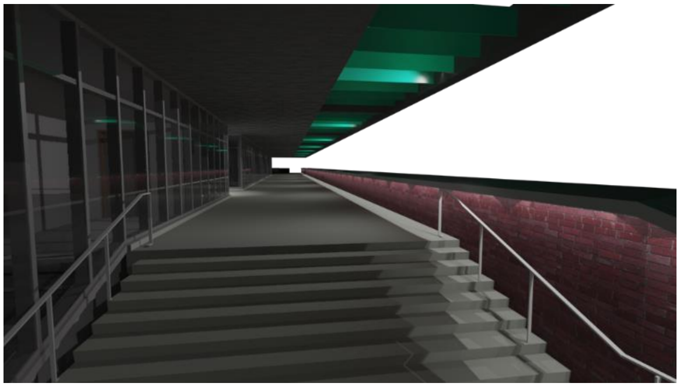


Figure 6 Covered Walkway

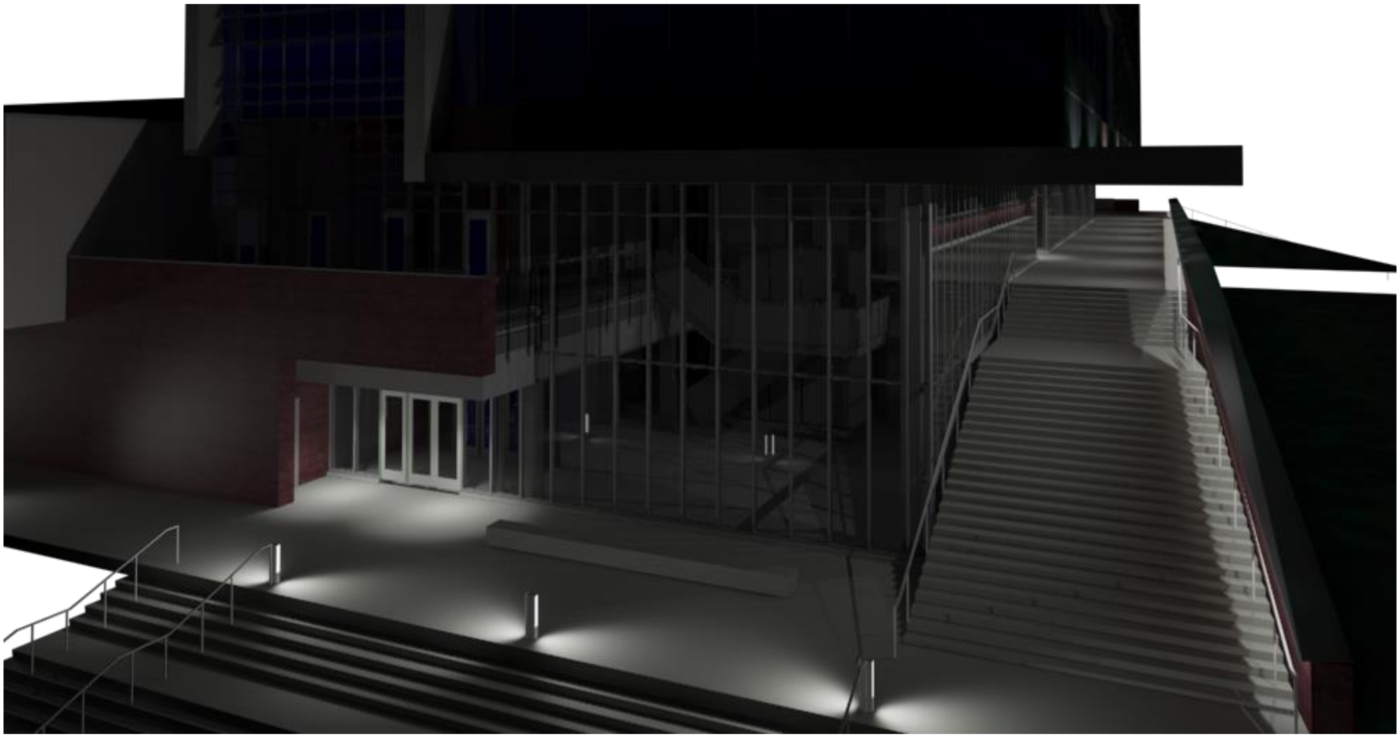


Figure 7 Southern View

Pseudocolors (Light Levels)

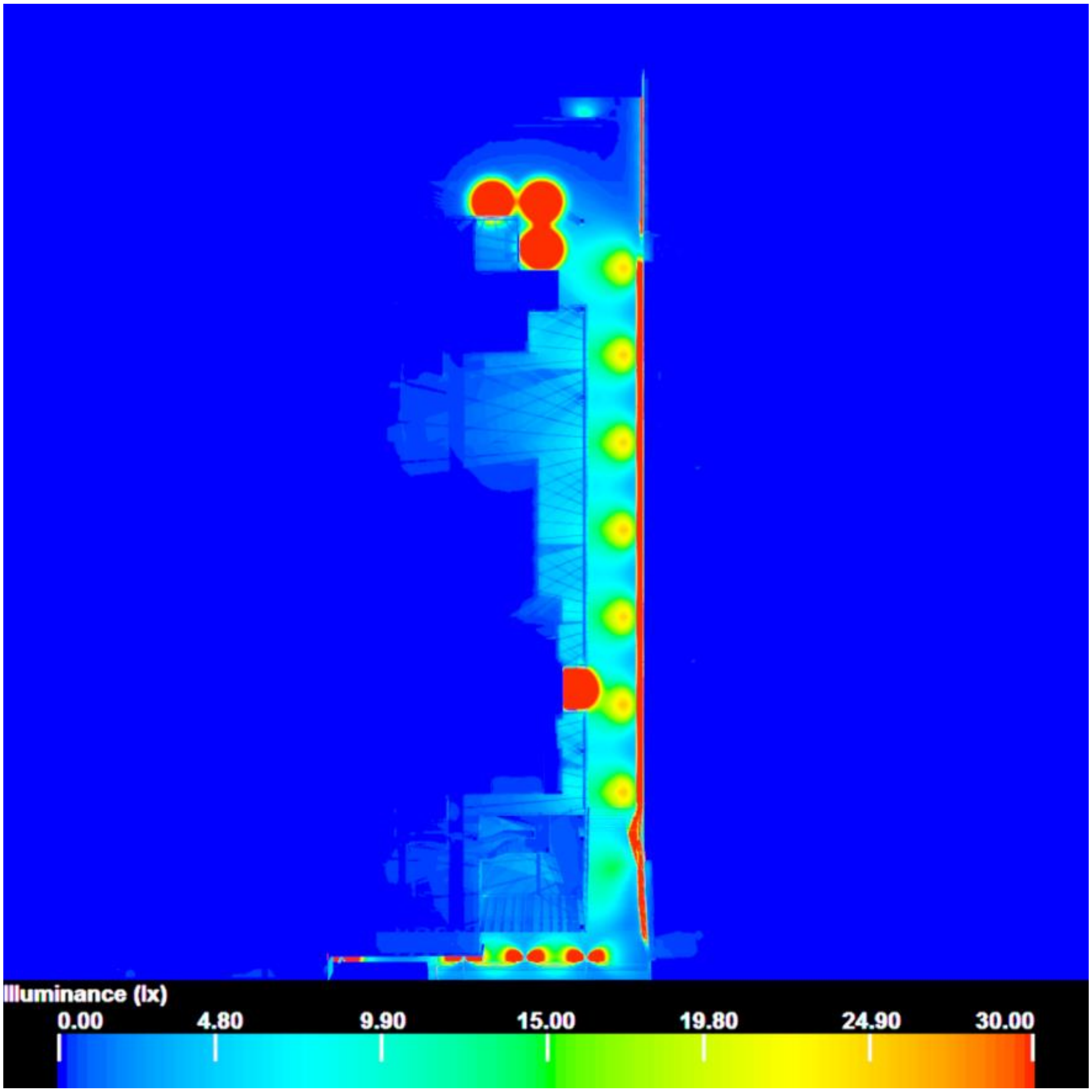


Figure 8 Pseudocolor Render from the top

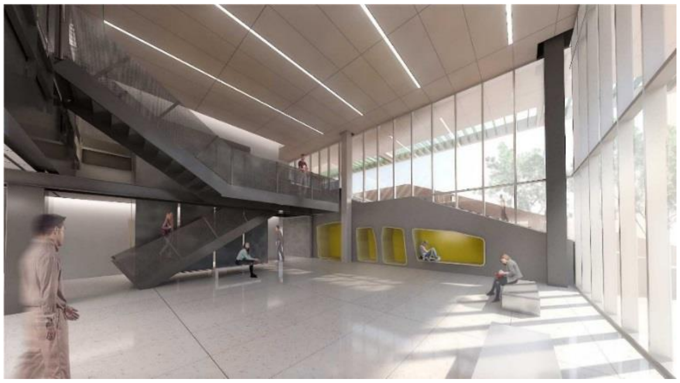
Lighting Power Density

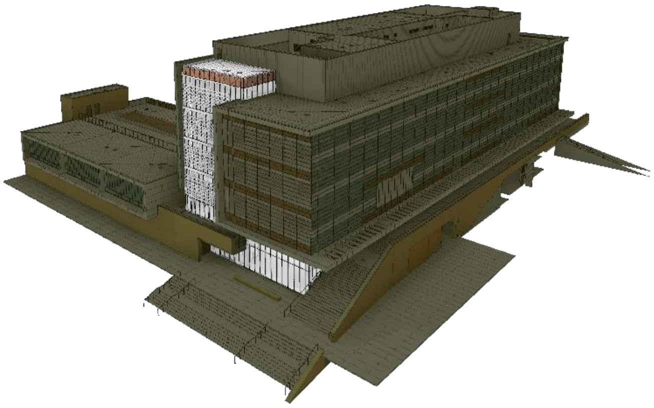
Exterior Lighting Power Density				
Space	**Watts Allowed**	**Area or Length**	**Total Watts Allowed**	**Watts Used**
Large Walkways				
Covered Walkway	0.16 W/ft²	5328 ft²	852.48 W	588.8 W
South Entry Walkway		6978 ft²	1116.48 W	120 W
Stairways				
Lower Stair	1 W/ft²	1307 ft²	1307 W	-
Walkway Stair		1099 ft²	1099 W	145.6 W
Main Entries				
South Entry	30 W/linear ft of doorway	10 ft	300 W	46 W
North Entry		10 ft	300 W	69 W
Walkway Entry		7.33 ft	220 W	23 W

Space Evaluation + Summary

The final lighting design for the exterior space creates literal lines of travel from north to south along the walkway and east to west across the south of the building and dramatically highlights the entryways with a hierarchy of light. The illuminances achieved on the pathways and stairs average around 10 lux with spots of higher illuminance which acceptably exceeds the criteria. The illuminances at the entries also exceed target illuminances but create an easier transition to the higher interior lighting. The lighting power densities from the lighting design are well below what is allowed by ASHRAE 90.1 which also reinforces the validity of the design and the hopes to create a well-lit and safe exterior space. The lighting design criteria here are found to be met and the lighting design follows the overall lighting concept by lighting the roads to progress which lead to the intersections with the building in which the students who enter find the knowledge to improve the industry.

Transition Space | South Lobby + Atrium





Space Locator

Description of Space

The lobby and atrium spaces off of the southern entrance are heavily trafficked areas within the building providing a transition space through which most people will see when traveling to specific parts of the building. Because of the high level of use and visibility in the building, this space needs to provide a visual statement as well as provide ease of way finding and places for occupants to feel comfortable in.

The space has a nice and rustic palate of materiality including terrazzo flooring, exposed CMU and gypsum walls, perforated metal handrails, and acoustic ceiling tile and metal mesh ceilings.

The main tasks of the space are general transition of pedestrians, congregation to study and sit near the café on the second level, and reading/studying in the study niches in the southern lobby.

Concept

Figure 9 Schematic Lighting for Lobby

The combined space of the southern lobby and atrium with the prominent connecting staircase is the largest and most important transition space in the whole of the Engineering Center. With such a high level of activity, and so many different ways to travel through the space, the idea of a highway with off-ramps drove the design concept. There are areas of high traffic, the highways, where the light will be more direct and intense to provide a feeling of tension to direct the traffic in specific ways. Then there are areas of congregation, or off-ramps, with more decorative and perimeter lighting to denote areas of relaxation where the light is less intense.

Design Criteria

The following is a list of important design criteria, both quantitative and qualitative, to reinforce design concepts and desires for the final lighting design.

Illuminance Criteria | According to the IES Lighting Handbook
Lobbies | Circulation | Building Entries
Day = 100 lux E_h, 50 lux E_v, 3:1 Avg:Min
Night = 50 lux E_h, 20 lux E_v, 3:1 Avg:Min
Lounges | Pleasure Reading = 200 lux E_h, 100 lux E_v, 1.5:1 Avg:Min
Stairs | High Activity = 100 lux E_h, 50 lux E_v, 2:1 Avg:Min
Dining Areas | Coffee Shops = 100 lux E_h, 30 lux E_v, 3:1 Avg:Min

Way Finding | Lines of light to denote main traveling routes and aid in finding the desired means to reaching locations within the building

Psychological Impression | In these spaces, the John Flynn psychological impressions of tension and relaxation are employed to denote areas of transition and areas of study and collaboration

Color Rendering | The color temperatures desired were in the 4000 K range with high color rendering indexes to provide a consistent design

Lighting Power Density | According to ASHRAE 90.1
Lobby | All other Lobbies = 0.90 W/ft^2
Lobby | Elevator Lobbies = 0.64 W/ft^2
Corridor | All other Corridors = 0.66 W/ft^2
Atriums = 0.4 + 0.02 * total height = 1.82 W/ft^2

Lighting Layers

A few changes were made to the lighting design since the schematic design presentations due to limitations from the quantitative criteria, limitations with the fixtures to achieve the desired look, and misunderstandings regarding the architecture. The circular recessed lights were taken out of the design near the elevator lobbies due to available ceiling area in which to mount the fixtures and an overhang that would block much of the light from illuminating the ground in front of the elevators. The circular recessed light in the main lobby space was replaced with a square due to the very angular and geometric architecture of the building to better enhance the overall aesthetic. Due to the task of reading in the study niches it was determined that mounting LED tape to the perimeter was not going to be sufficient. And finally, in the lobby, due to LED driver limitations, maintenance issues, and possible safety issues, the tube pendants in the atrium space were taken out and replaced with window details to create the sense of verticality. A schematic design sketch of the lobby space can be seen on the previous page.

The lobby has multiple layers of lighting to create visual interest in the space. To provide ease of way finding and areas of tension for the purpose of movement, scattered lines of recessed linear luminaires provide downlighting to the corridors on the first and second levels adjacent to the lobby and atrium spaces. To bring attention to the staircase, a decorative cluster of linear LED pendant fixtures hovers above the stair as a statement piece which also exemplifies the importance of the stair as an intersection of paths between two levels of transition. To bring attention to the architecture of the study niches on the western side of the lobby, linear LED details in the wooden finishes of the niches provide adequate reading light to the workplanes for relaxing places to study and congregate. The elevator lobbies on both the first and second floors incorporate recessed linear wall to ceiling fixtures to indicate the vertical transition of the elevators and create a waiting space that is not fully tense as the hallways are, and not fully relaxing with perimeter lighting. And finally, to indicate the spaces of respite within all of the busyness of the space, recessed linear lights in a square provide perimeter lighting for main area of the lobby for congregation purposes.
The stairway goes up to the second floor café seating area and four story atrium space. This space lends itself to being a great place for social interaction outside of the classroom. To create an area of relaxation, perimeter lighting will be provided from mullion mounted lighting over the seating area and cove lighting on the third floor. In an attempt to draw the eye upwards, and metaphorically towards a common future for the engineering and computer science goals of the school, linear lights uplight the window recesses along the western wall of the atrium. As your eye travels up the atrium, they reach the top where more cove lights create a floating ceiling effect as this sort of exciting and promising future within site. These layers of light can be seen in the renders below.

Fixture Schedule

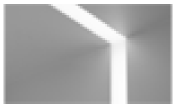
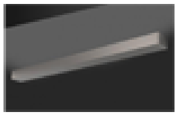
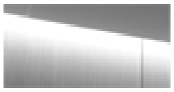
Lobby + Atrium Fixture Schedule				
Type	**Symbol**	**Image**	**Description**	**Manufacturer**
L2			Recessed 6" round LED downlights, tempered clear glass enclosure, anodized aluminum reflector, Outdoor rating IP65, 4000K, 85CRI	Bega
L6			4' x 2.64" Recessed linear LED downlight, flush mount, extruded aluminum housing, white powder coat steel reflector, frosted acrylic lens, replaceable LED modules and drivers from below, 4000 K, 80 CRI	Focal Point
L7			Linear surface mounted LED, 11-5/16" length segments, anodized aluminum extrusion with injection molded end caps, clear high strength acrylic lens, 3500K, 85 CRI	USAI
L8			8' linear LED pendant, aluminum extrusion with a matte anodized finish, frosted white acrylic lens diffuser, suspended with adjustable aircraft cable with push button glider, 4000K, 90 CRI	Delray Lighting Inc.
L9			Same product as L6 with a modified wall to ceiling housing and flex whip connector	Focal Point
L10			7' x 2.25" x 3.375" Mullion mounted assymmetric LED fixture, aluminum extruded housing, precision milled endcaps, 4000K	A-Light
L11			1' x 1.5" x 2.1" linear LED wall grazing fixture, narrow 10 x 60 degree beam angle, 4000K, 84 CRI	Philips Color Kinetics
L12			Cove lighting LED fixture with a 4" opening from ceiling grid and total 7.3" depth above ceiling, extruded aluminum housing with polyester poweder coat, frosted lens, 3500K	Focal Point

Figure 10 Lobby + Atrium Fixture Schedule with symbol colors matching those in the plans on the following pages

Controls

To provide dimmer lighting during the nighttime, all fixtures will be on dimmer circuits to allow for dimming. Manual control of these fixtures will be provided in convenient locations for those allowed to control the lighting without access to the general public. Lighting in the atrium will utilize daylighting controls due to the amount of natural light that enters the space during the day.

Lighting Plans + Sections

The following lighting plans and sections have colored symbols to indicate the fixtures used and their locations in the space. The fixture schedule above indicates what fixture each symbol stand for. The circuiting for these fixtures can be found in the electrical depth.

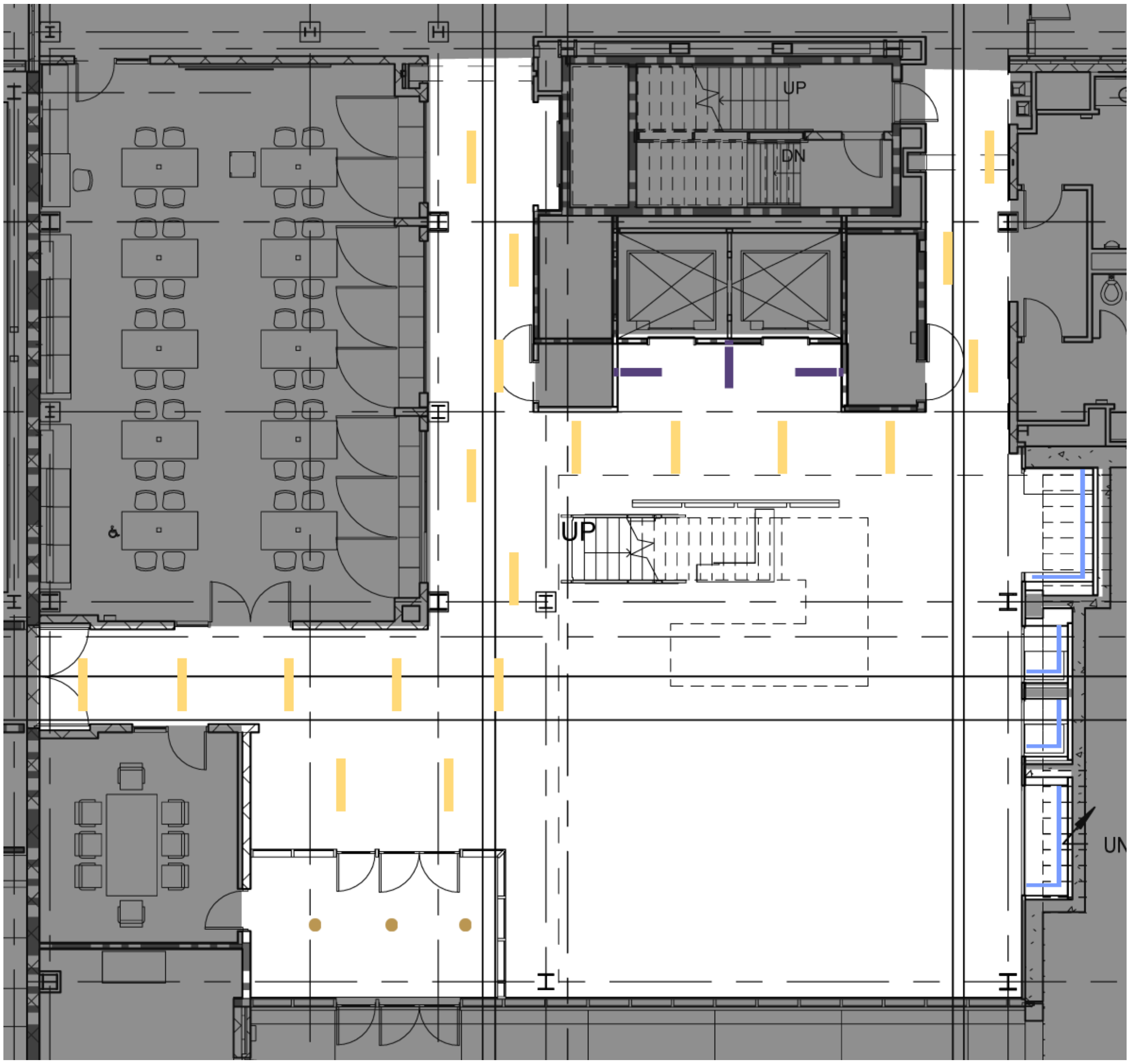


Figure 11 First Floor lobby and Corridor Lighting Plan

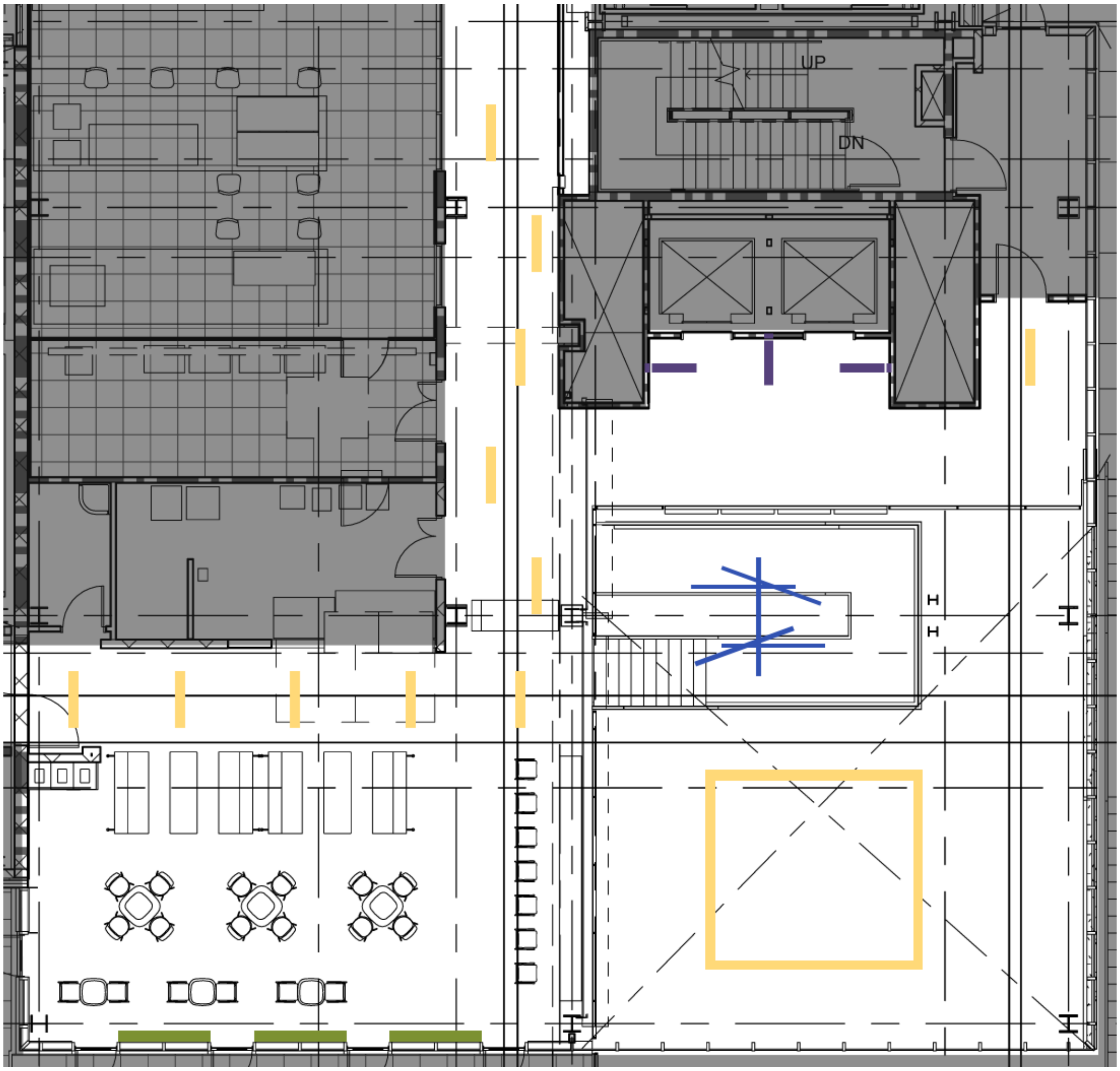


Figure 12 Level Two Lobby and Atrium Lighting Plan

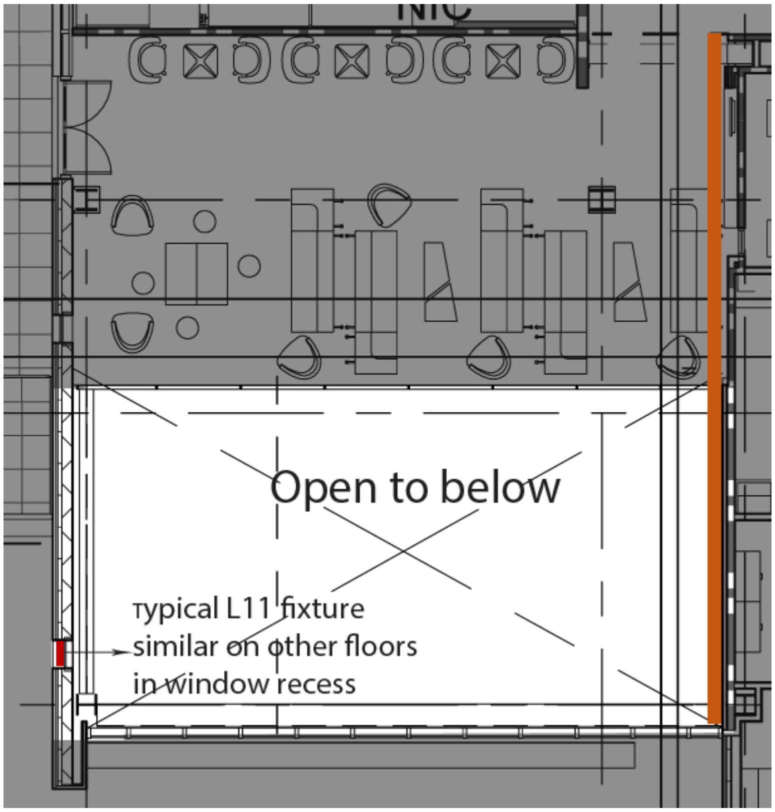


Figure 13 Level Three Atrium Lighting Plan

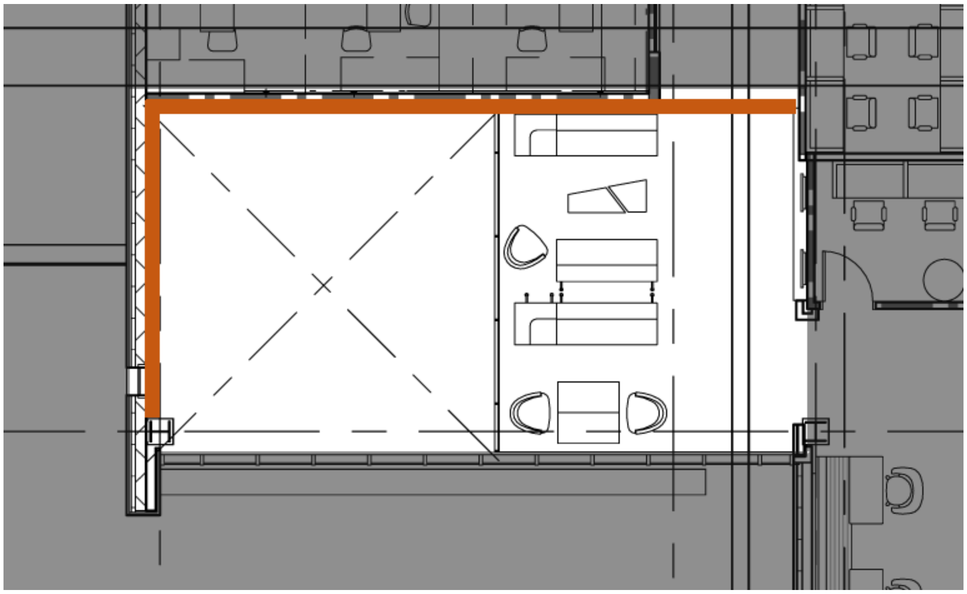


Figure 14 Level Five Atrium Lighting Plan

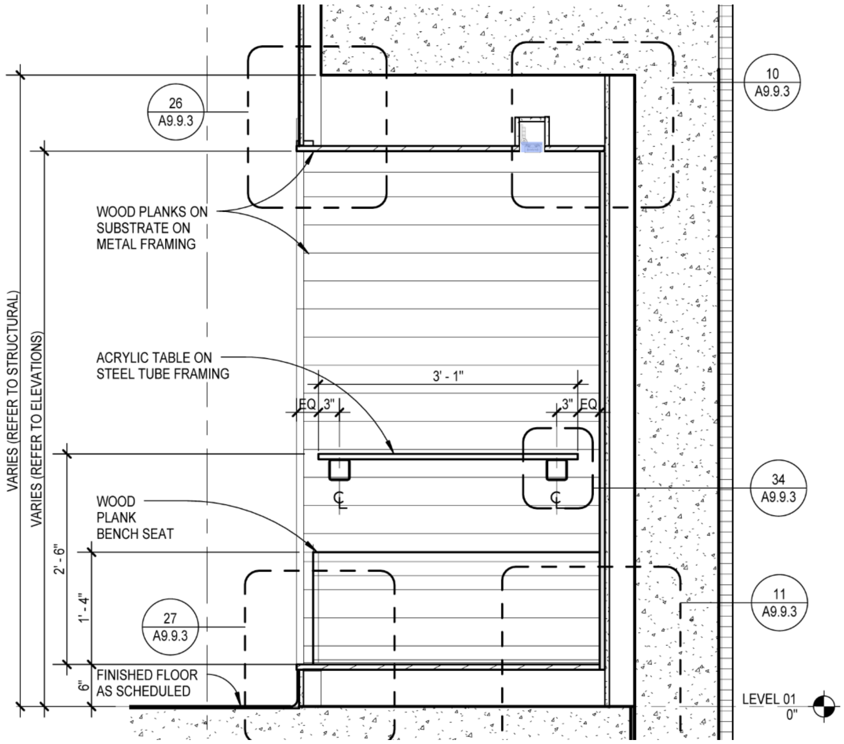


Figure 15 Lobby Study Niche Lighting Detail with L7 Fixture

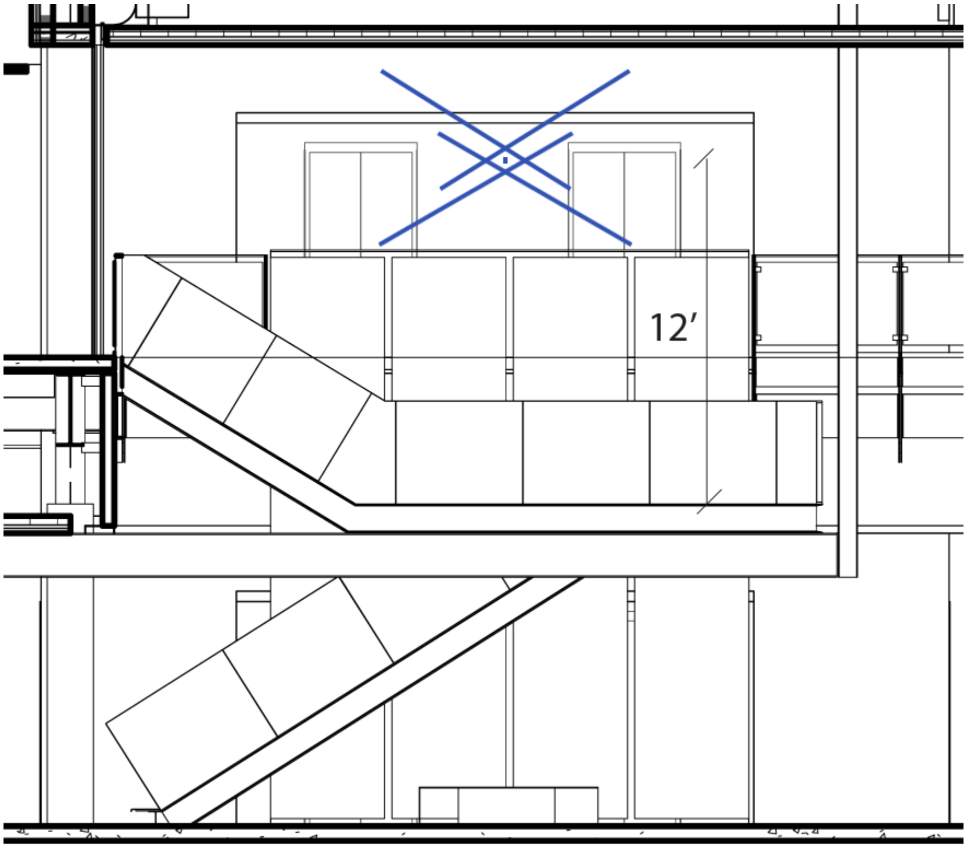


Figure 16 Elevation Showing Stair Pendant Fixtures

Renders

Figure 17 Lobby Section Render

Figure 18 Vestibule and Corridor Render

Figure 19 1st Floor Corridor Render

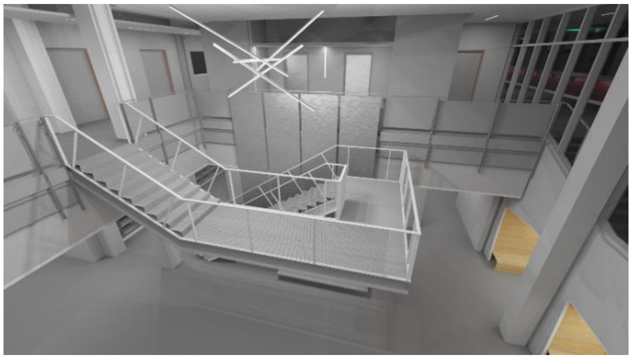


Figure 20 Stair Pendant Render

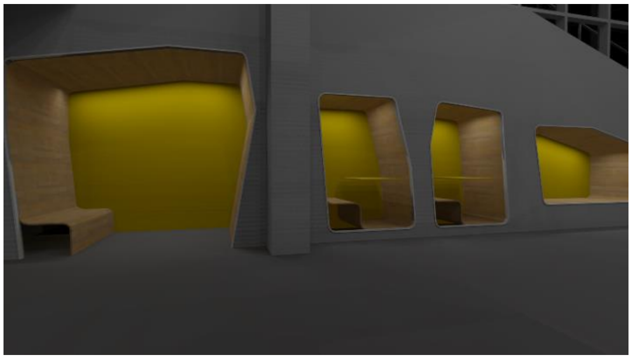


Figure 21 Study Niches Render

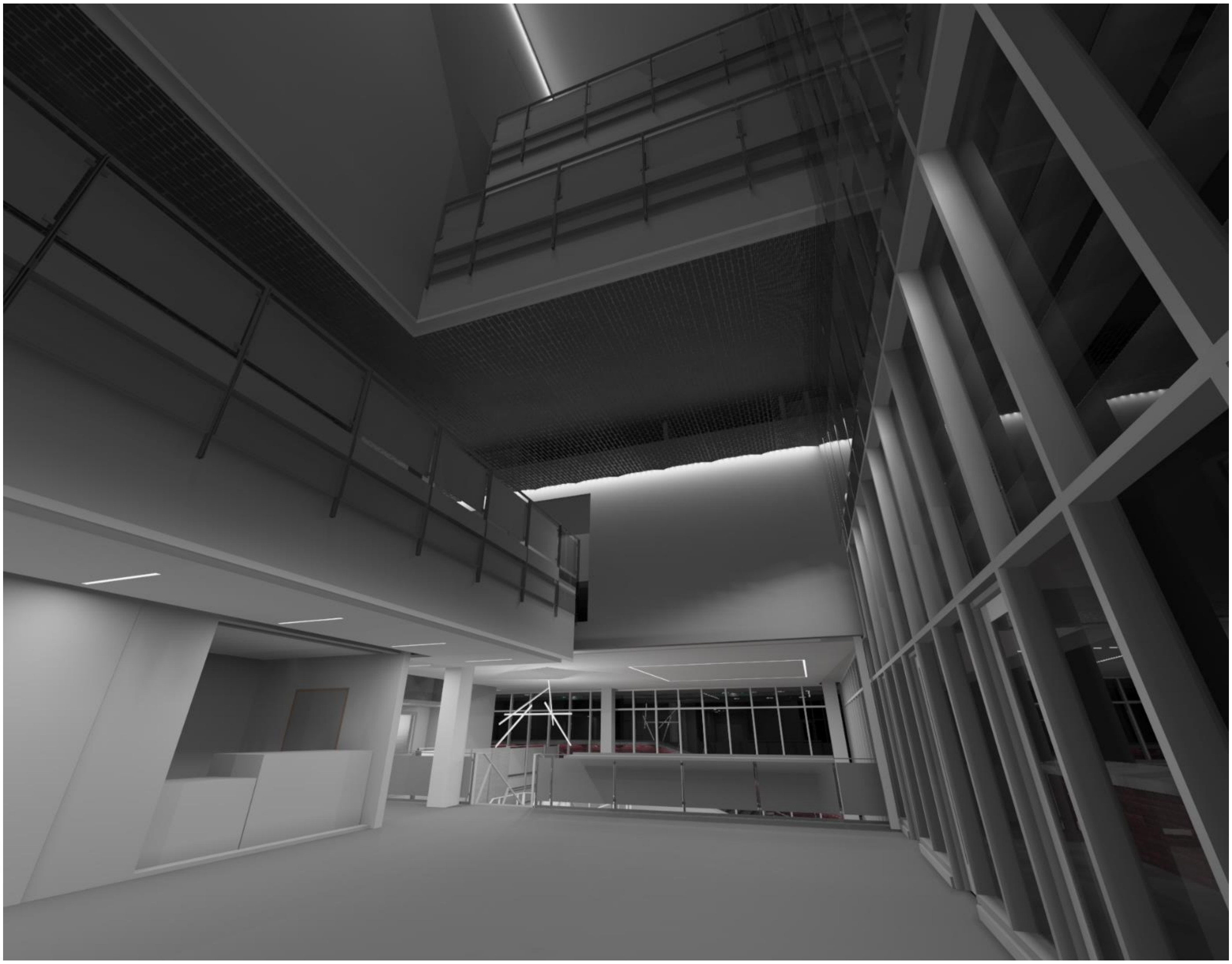


Figure 22 Atrium Perspective Render

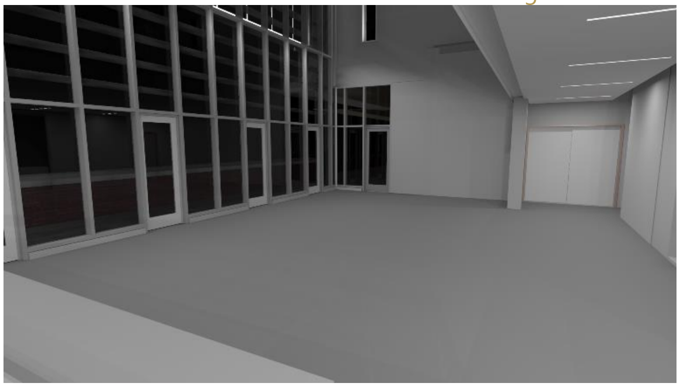


Figure 23 Atrium Level Two Render

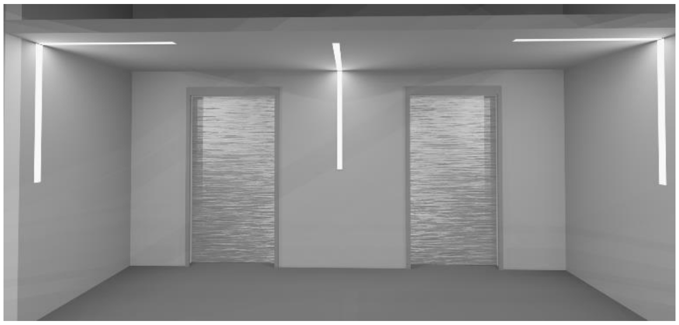


Figure 24 Level Two Elevator Lobby Render

Pseudocolors (Light Levels)

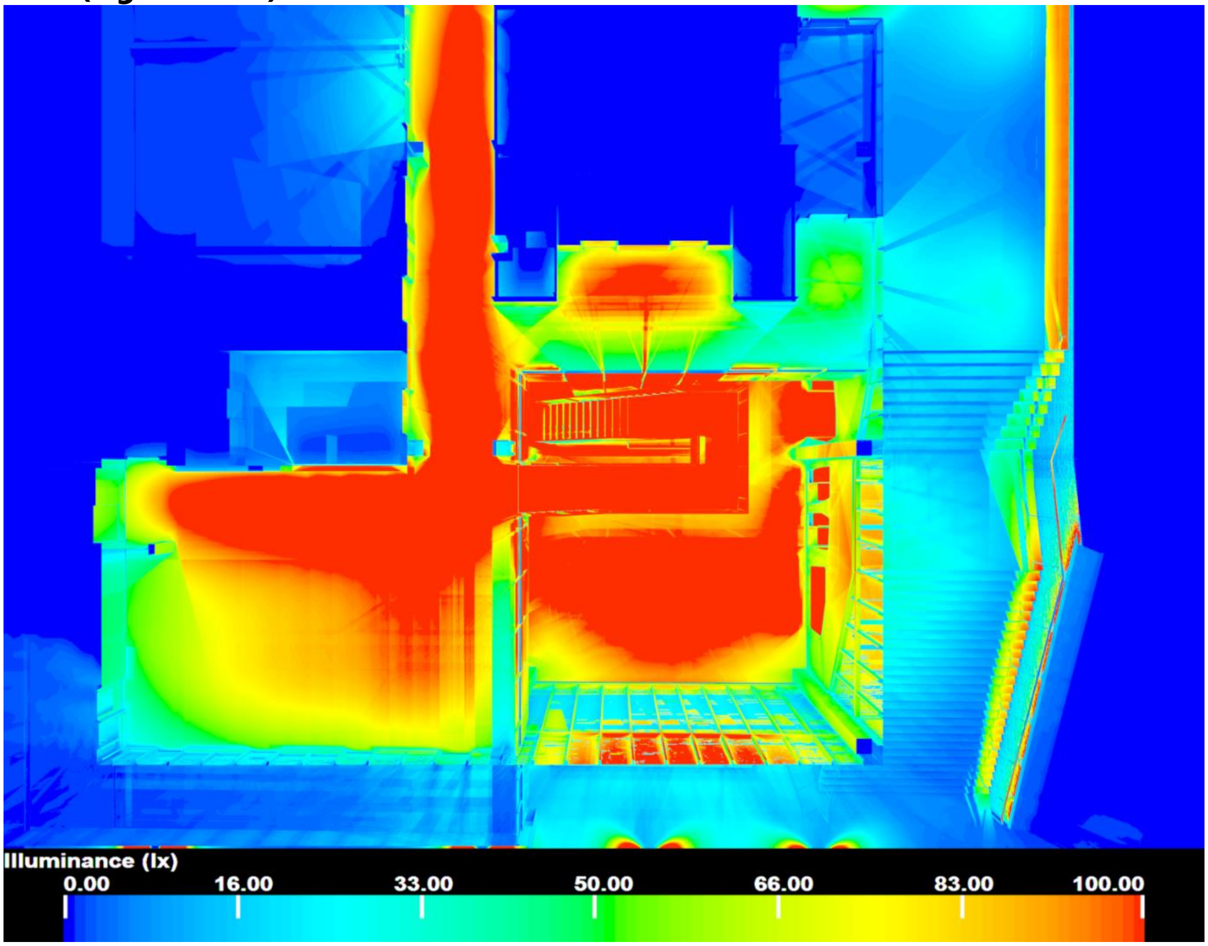


Figure 25 Top Section Pseudocolor showing Atrium Level 2 and Lobby Level 1

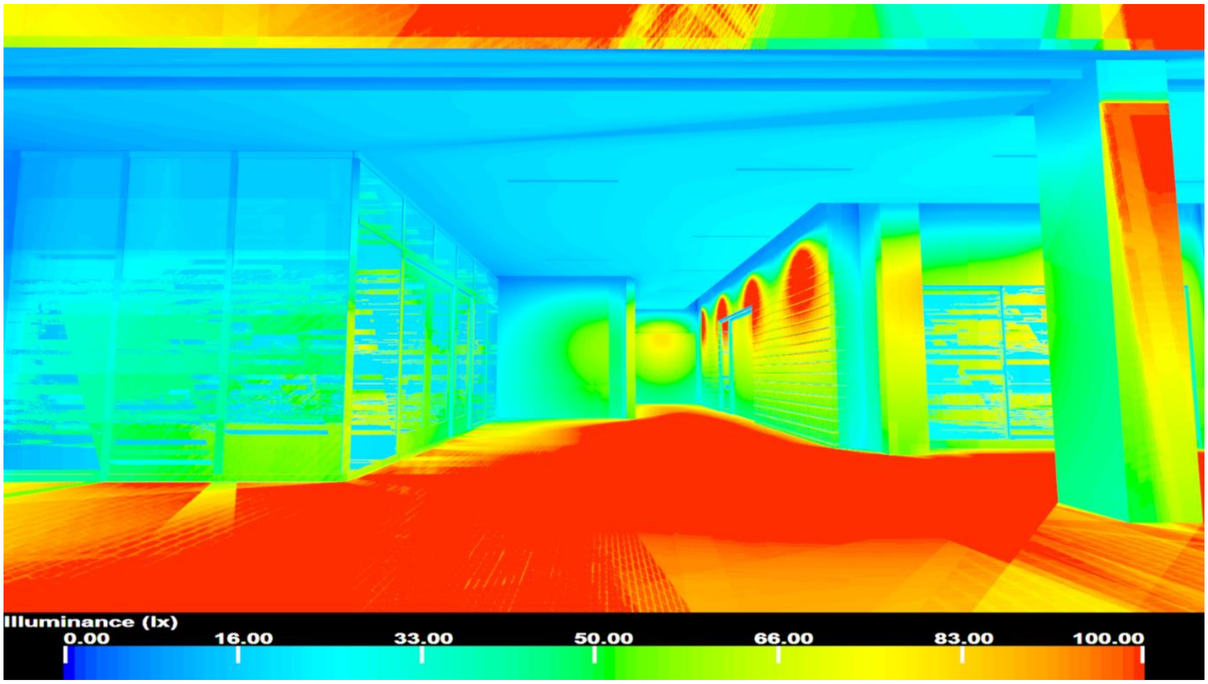


Figure 26 Vestibule to Lobby Pseudocolor

Lighting Power Density

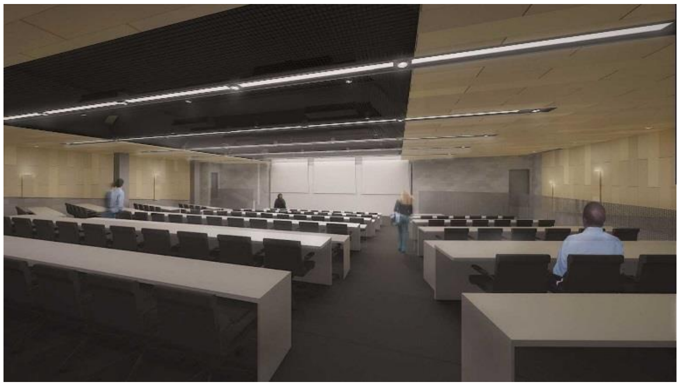
Lobby Lighting Power Density					
Type	**Quantity**	**Input Watts**	**Lobby Watts**	**Corridor Watts**	**Elev. Lobby Watts**
L2	3	19.5	58.5		
L6	35	21	336	399	
L7	38 FT	6.3 W/FT	239.4		
L8	10	24	240		
L9	12	8			96
		Total Watts	874	399	96
		Total Area	1933	1564	176
		Calculated LPD	0.45	0.26	0.55
		ASHRAE 90.1 LPD Allowed	0.90	0.66	0.64
		Difference	0.45	0.40	0.09

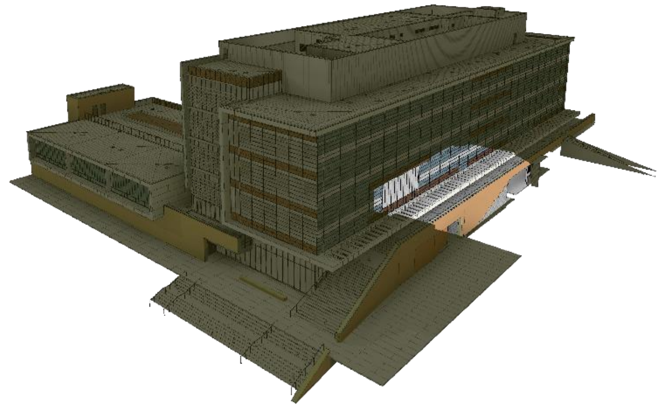
Atrium Lighting Power Density				
Type	**Quantity**	**Input Watts**	**Total Atrium Watts**	**Total Corridor Watts**
L6	11	21		231
L10	3	30	90	
L11	3	12.5	37.5	
L12	24	22.9	549.6	549.6
		Total Watts	677.1	780.6
		Total Area	886	1800
		Calculated LPD	0.76	0.43
		ASHRAE 90.1 LPD Allowed	1.82	0.66
		Difference	1.06	0.23

Space Evaluation + Summary

By dividing the intents of the space into transient areas of movement and areas for congregation, the lighting design has a connectedness but also a clear shift which helps to aid in the design intents for this space. The final lighting design is in accordance with the lighting design criteria, creates an affective transition space through the building, and acts as a nice architecture improving statement from the exterior. The transition space meets the illuminance criteria of 100 lux in the lobby, corridors, and the stairway and fades off in the café seating area to bring more attention to the verticality and because the space will mostly be used during the daytime. The lobby lighting is 50% more efficient than the maximum allowed loads according to ASHRAE 90.1. Likewise, the atrium was 58% more efficient due to minimal design, the elevator lobby 15%, the first floor corridors 61%, and the second floor corridors 34%. The final design seems to be successful even after having gone through a reality check filter to make it more reasonable than the schematic design.

Special Purpose Space | Lecture Hall





Auditorium Space Locator

Description of Space

The 200-seat lecture hall auditorium, located on the first level, is the largest space in the building for the instruction of students and is thus very important to the program of the building. This space will be used for classes, presentations, guest lectures, and any multitude of other uses to the school of engineering and computer science. Because of this multiuse aspect of the space, the lighting design, scene control, and AV schemes are very important and will need to be coordinated. The lighting design needs to have multiple layers of functionality as well as providing appropriate lighting levels for reading, writing, presentations and safe travel through the space.

The space materials are quite interesting comprising of carpet tile flooring, wooden panel side walls and side ceilings, a metal mesh ceiling in the center of the space, and exposed CMU walls in the front and backs of the room.

Some significant features of the space are the three motorized projectors, the slightly tiered aspect to the seating, the wheelchair ramp along the right-hand side of the space, and the personal wheelchair lift in the front left of the space. A plan and section of the space are shown below.

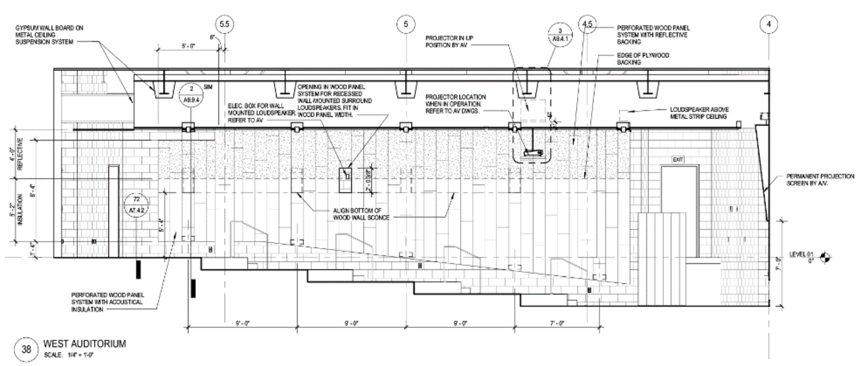


Figure 27 Auditorium Section Looking West

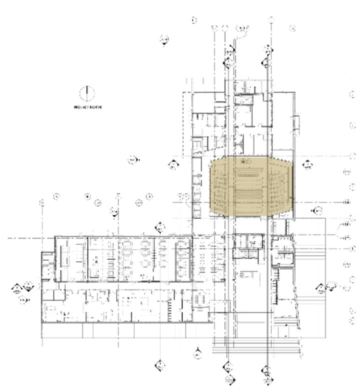


Figure 28 Auditorium 1st Floor

Concept

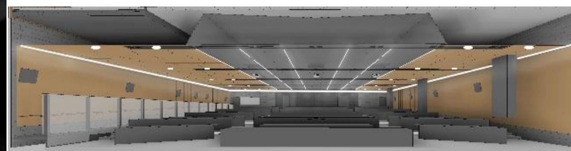
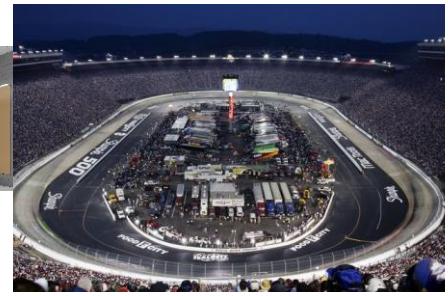


Figure 29 Auditorium Schematic Sketch



When coming up with an appropriate concept for the auditorium space, three schematic concepts were created for the schematic presentations last semester. There was not one concept that stood out from the rest however comments were made to steer the lighting design away from a literal interpretation of the concept. The schematic concepts all centered on the presenter and this idea of displaying and sharing of knowledge to reach a common future for the industry.

By taking these initial concepts and analyzing the feelings of the space that are desired, a new concept was formulated. The space really is a testament to the present and an arena to display and share achievements. For these reasons, the new concept is “embracing the present”. This concept fits with the building overall concept and lives within it as a snapshot in the continuum from past to future. This idea of embracing the future shapes the lighting design for the auditorium space.

Design Criteria

The following is a list of important design criteria, both quantitative and qualitative, to reinforce design concepts and desires for the final lighting design.

Illuminance Criteria | According to the IES Lighting Handbook
Educational Facilities | Auditoria
- Lecture Hall | Audience | AV and Notes = 50 lux E_h, 15 lux E_v, 2:1 Avg:Min
- Lecture Hall | Audience | AV and No Notes = 10 lux E_h, 6 lux E_v 2:1 Avg:Min
- Lecture Hall | Speaker/Panel | AV = 30 lux E_h, 18 lux E_v (<3 times audience)
- Lecture Hall | Speaker/Panel | No AV = 500 lux E_h, 200 lux E_v, 3:1 Avg:Min
- Circulation | AV = 2 lux E_h, 10 lux E_v, 5:1/3:1 Avg:Min
- Circulation | All but AV = 10 lux E_h, 30 lux E_v, 10:1/3:1 Avg:Min
- Reading + Writing = 300 lux E_h

Versatility | Multiple layers of light to allow for zone control and scene selections

Color Rendering | The color temperatures desired were in the 4000 K range with high color rendering indexes to provide a consistent design

Lighting Power Density | According to ASHRAE 90.1
Classroom | Lecture Hall = 1.24 W/ft^2

Design Development

As stated in the concept portion of this section, the original three schematic designs were combined and discarded for a new concept and final design. As per the design criteria, a versatile and multi-function design is desired which meets the necessary quantitative criteria. For the final design, five layers, or zones, of lighting fixtures are used to be as versatile as possible.

The main general illuminance is provided by large surface mounted luminaires which have a rounded square shape and embody the idea of an embrace as per the concept.

The second layer also embodies the idea of the embrace. It is a series of cove mounted fixtures which line the side walls and a portion of the front wall to bring attention to the presenter and to provide illuminance to the circulation areas on the perimeter.

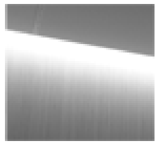
The third layer provides the illuminance for the presenter area and consists of 5 square downlight fixtures. Using a similar fixture with a wider beam spread and lower lumen output, a filler general illuminance is provided to the audience area for certain lighting applications of the space.

The final layer is a series of linear surface mounted LED strip lights to provide low light levels and a dappled look to the center of the room by shining down through the metal mesh ceiling. These lines of light are also intended to draw the audience's eyes towards the front of the room.

Appropriate control schemes will be in place to allow for infinite possibilities for using these five layers for different situations. Three possible lighting schemes are shown in the renders below.

Fixture Schedule

Auditorium Fixture Schedule

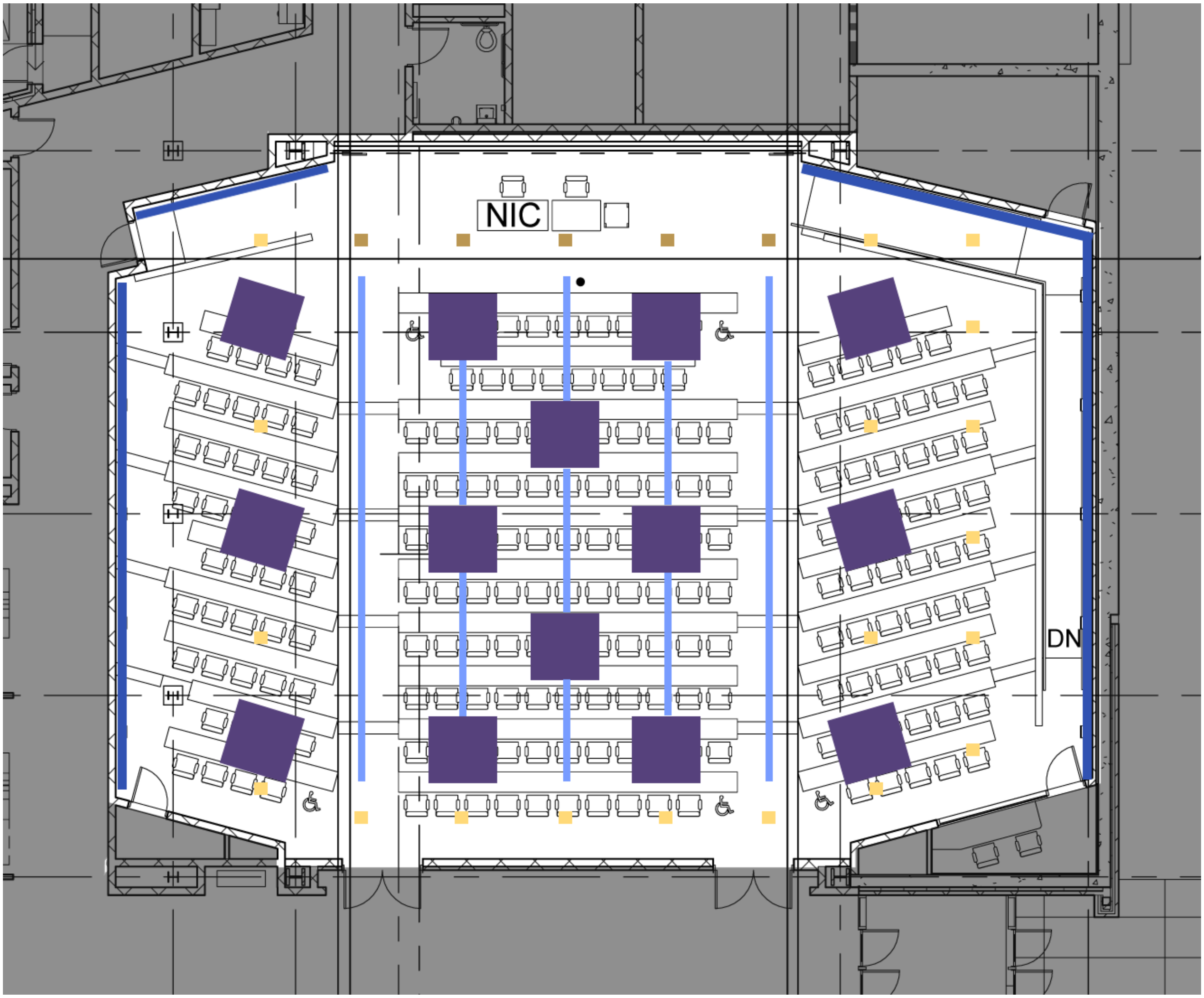
Type	Symbol	Image	Description	Manufacturer
L7			Linear surface mounted LED, 11-5/16" length segments, anodized aluminum extrusion with injection molded end caps, clear high strength acrylic lens, 3500K, 85 CRI	USAI
L12			Cove lighting LED fixture with a 4" opening from ceiling grid and total 7.3" depth above ceiling, extruded aluminum housing with polyester poweder coat, frosted lens, 3500K	Focal Point
L13			66.7" x 66.7" x 3.1" Ceiling mounted direct LED fixture, polished aluminum housing finish, integrated acrylic cover, fabric covering as a light and acoustic diffuser, 4000K	Sattler
L14A			4" Square recessed LED downlight, self-flanged semi-specular reflector, highly transmissive lens, 20 degree beam angle, 3500K	Gotham
L14B			4" Square recessed LED downlight, self-flanged semi-specular reflector, highly transmissive lens, 60 degree beam angle, 3500K	Gotham

Controls

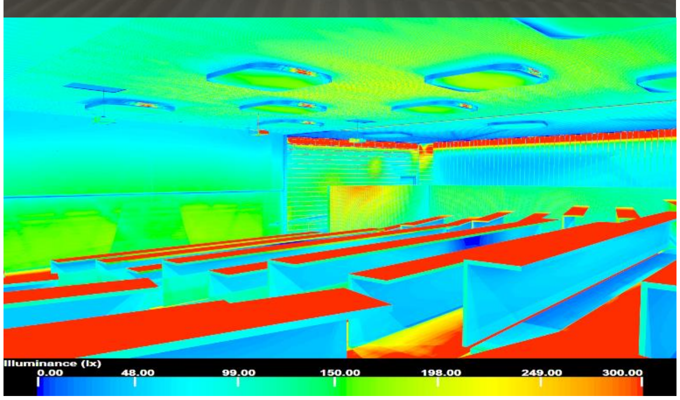
Using Lutron's GRAFIK Eye software, and researching their products, it was determined that a GRAFIK Eye QS system would be used with at least one wall mounted button control in the back and one in the front. The QS system can be used to control the five zones of light by determining their dimming levels and coming up with set lighting schemes for the space and can be wirelessly addressed by the wall mounted button controls. There will be two wall mounted infrared occupancy sensors, one in the front of the room and one in the back. In the back, an all-on and all-off button control will be available in case the occupancy sensors are not working correctly. The front button control will allow the presenter to control the lights to any scene that they desire. Information on these Lutron products are shown in Appendix IV. For the study of this space, 3 lighting schemes were devised.

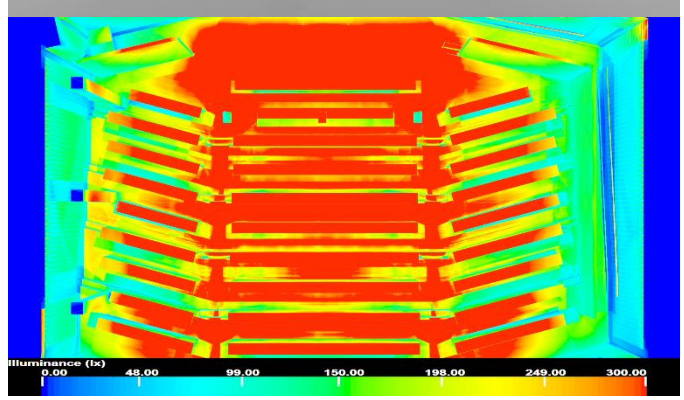
All-On Testing Mode = all lights at 100%
Presenter = L7, L12, L14B at 50%, L13 off, and L14A at 100%
AV mode = L7, L12, L14B at 50%, L13 and L14A off

Lighting Plans

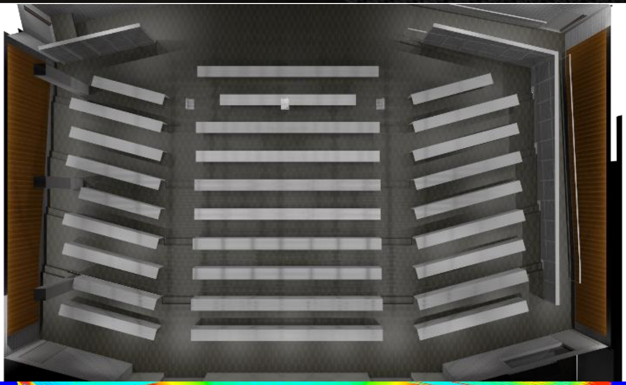


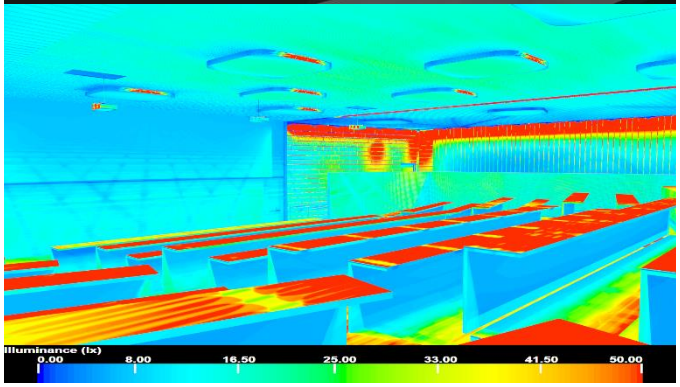
Renders + Pseudocolors | All-On Testing Mode

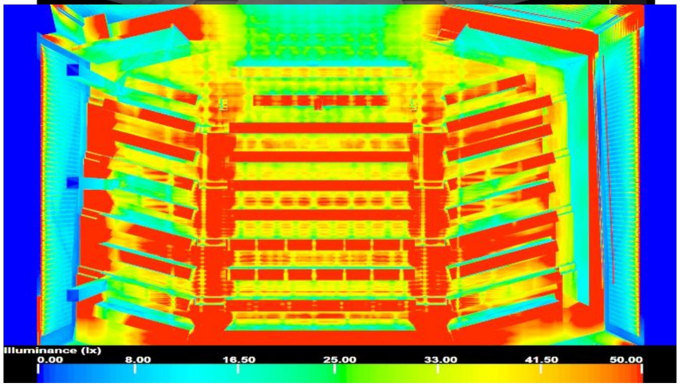




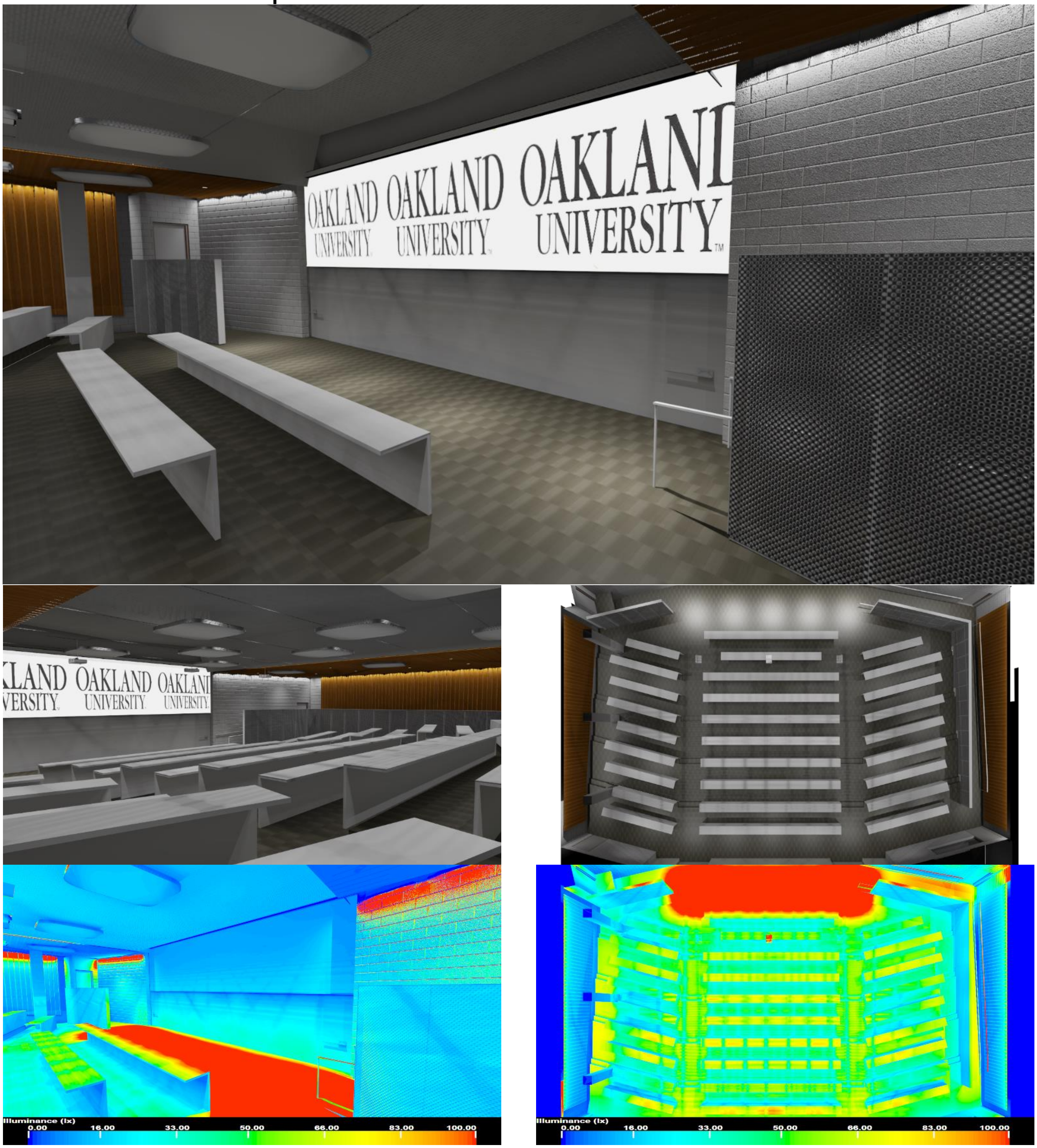
Renders + Pseudocolors | AV Mode







Renders + Pseudocolors | Presenter Mode



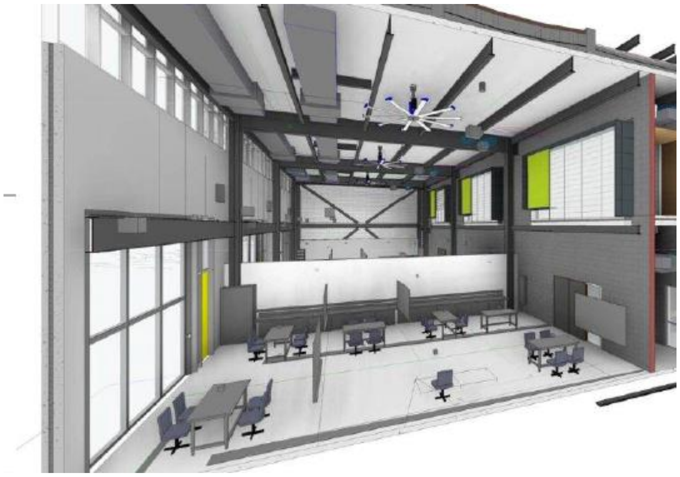
Lighting Power Density

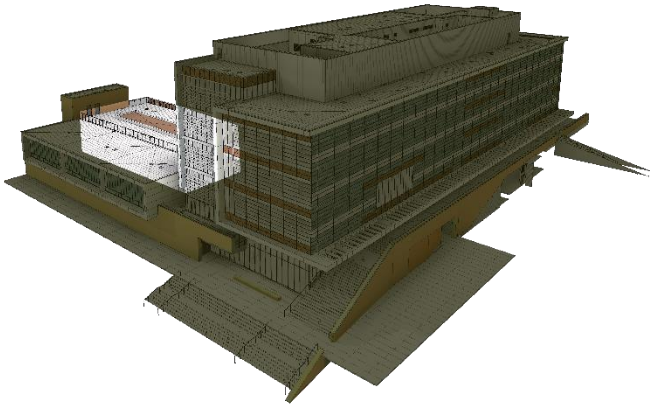
Auditorium Lighting Power Density			
Type	**Quantity**	**Input Watts**	**Total Watts**
L7	159 ft	6.3	55.65
L12	31	22.9	709.9
L13	14	87	1218
L14A	5	42	210
L14B	19	8	152
		Total Watts	2345.55
		Total Area	4408
		Calculated LPD	0.532112069
		ASHRAE 90.1 LPD Allowed	1.24
		Difference	0.71

Space Evaluation + Summary

The design for the auditorium successfully embraces the present and provides a lighting situation that is affective and versatile. The lighting levels for the all on testing mode are around 300 lux on the desk surfaces as well as the presenting area providing a nice bright test taking atmosphere. The other two schemes provide about 50 lux on the desks which is the desired level. The circulation levels are kept slightly higher than those recommended in the IES handbook at between 40 and 50 lux depending on the scheme because it was decided that higher illuminances would be more acceptable than lower illuminances and that way the lighting for the space is more uniform. The presenting area was kept slightly under that recommended for the presenter mode but slightly higher for the AV mode. This compromise was determined to be acceptable and the design allows for a reconfiguration of the scene levels. The lighting power density for the space is 40% more efficient than the ASHRAE allowable wattage.

Large Workspace | Project Labs





Project Labs Locator

Description

The project labs space is the largest workspace in the building and will be used for the production of formula cars as well as a multitude of other products in the school of engineering. This is where the ideas of the students and the knowledge they have obtained are put together to create and to show off and test their ideas which is why this space deserves to be a place that is comfortable to work in as well as functional. The design will have layers of stylized light to make the space visually appealing and layers of high level lighting for the visually intensive tasks of using machinery. The materiality is fairly plain with concrete flooring, exposed ceiling, exposed CMU walls, and exposed steel beams throughout.

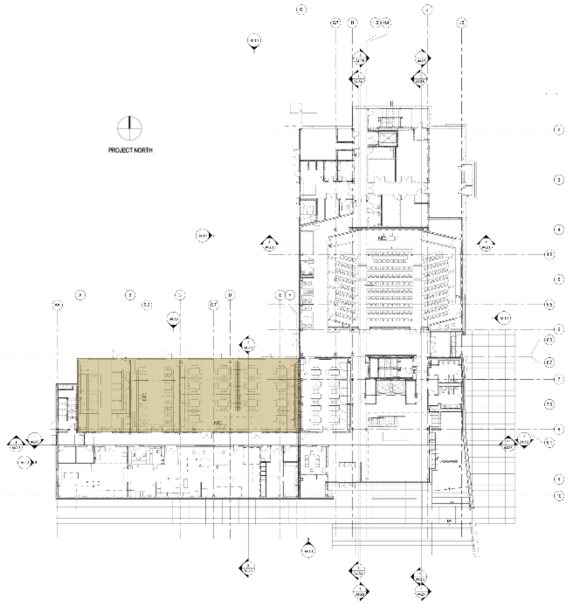


Figure 30 Project Labs 1st Floor

Concept

Figure 31 Schematic Design Sketch

The project labs space, as a hands-on learning experience for the students, was seen as a sort of an outlet to allow the students to break out of their normal schooling and push the boundaries with the application of knowledge. Here, the past is set aside and the projects look only to the future. This space needs to have a stylized and industrial feel to the space to make it both realistic and yet also visually stimulating.

Design Criteria

The following is a list of important design criteria, both quantitative and qualitative, to reinforce design concepts and desires for the final lighting design.

Illuminance Criteria | According to the IES Lighting Handbook
Educational Facilities | Classrooms
Shops | Assembly = 500 lux E_h, 250 lux E_v (<25 years old)

Stylized Industrial Feeling | According with the concept, a higher end feeling to this fairly industrial space is desired

Color Rendering | The color temperatures desired were in the 4000 K range with high color rendering indexes to provide a consistent design as well as a good quality of light for the type of work that is to be done in the project labs

Lighting Power Density | According to ASHRAE 90.1
Many space types seemed to match the project labs space which is in fact three different rooms. Laboratory in or as a classroom = 1.43 W/ft^2, Workshop = 1.59 W/ft^2, Vehicular Maintenance Area = 0.67 W/ft^2, and Manufacturing Facility (25-50 ft floor to ceiling) = 1.23 W/ft^2. The average of these four lighting power densities is 1.23 W/ft^2 and also matches that of the manufacturing facility and thus this one was used

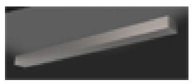
Design Development

During the schematic design phase last semester, many perimeter lighting layers were envisioned which would uplight the ceiling and provide ground plane illuminance at the entrances along with an industrial pendant array for the visual tasks. Due to the open ceiling plan, and large amount of mechanical equipment and structural beams in the space, many of the perimeter lights were abandoned in the design development phase of design. The number of pendant fixtures was minimized from the original design.

The pendant array are grouped into 4 main zones for the 2 smaller spaces and then the larger space on the east side having 2 zones. This was done for dimming capabilities as well as occupancy sensing. There are two layers of stylized light in the final design above and below the second floor overlooks into the space. The luminaires below the overlooks are surface mounted and illuminate the entryways from the first floor corridor. The luminaires above are linear bottom mounted asymmetric LED fixtures that provide some uplighting to the ceiling and mechanical equipment as well as emphasizing the overlook architecture.

A very important aspect to the project labs lighting scheme was added during the design development phase with the addition of the Kalwall Skyroof skylights. These skylights allow the LED pendants to dim much of the day and provide a nice diffuse layer of sunlight to the space and emphasizes the idea of “breaking out of normal schooling” and “pushing the boundaries”. This topic is further discussed in the MAE daylighting section of this report.

Fixture Schedule

Project Labs Fixture Schedule				
Type	**Symbol**	**Image**	**Description**	**Manufacturer**
L15			3.15' x 9.18" x 4.63" Industrial high-bay LED pendant, 6' cable length, heavy duty extruded anodized aluminum construction, protective optical lumen maintenance tray, 4000K, 73 CRI	Big Ass Lights
L16			11' x 3.5" x 2.5" Bottom mounted assymmetric LED fixture, aluminum extruded housing, 4000K	A-Light
L17			11' x 2-3/8" x 3-9/16" Surface mounted Linear LED fixture, extruded aluminum housing with aluminum endcaps, polyester powder coating, extruded impact resistant acrylic lens, 4000K, 80 CRI	Selux

Controls

The main control aspects of the space include, vacancy sensors, multiple zones for switching of each of the three main spaces, and photosensor dimming of the pendant fixtures due to the addition of the skylights. The controls will be easily accessible from either side of the project labs.

Lighting Plans + Sections

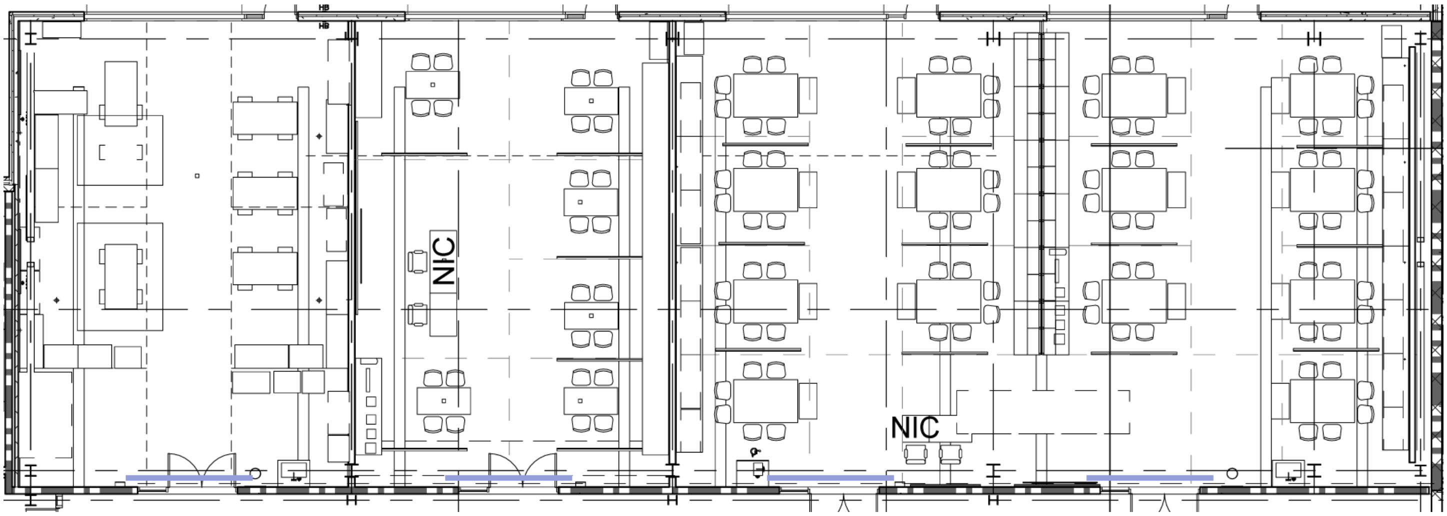


Figure 32 First Floor Lighting Plan

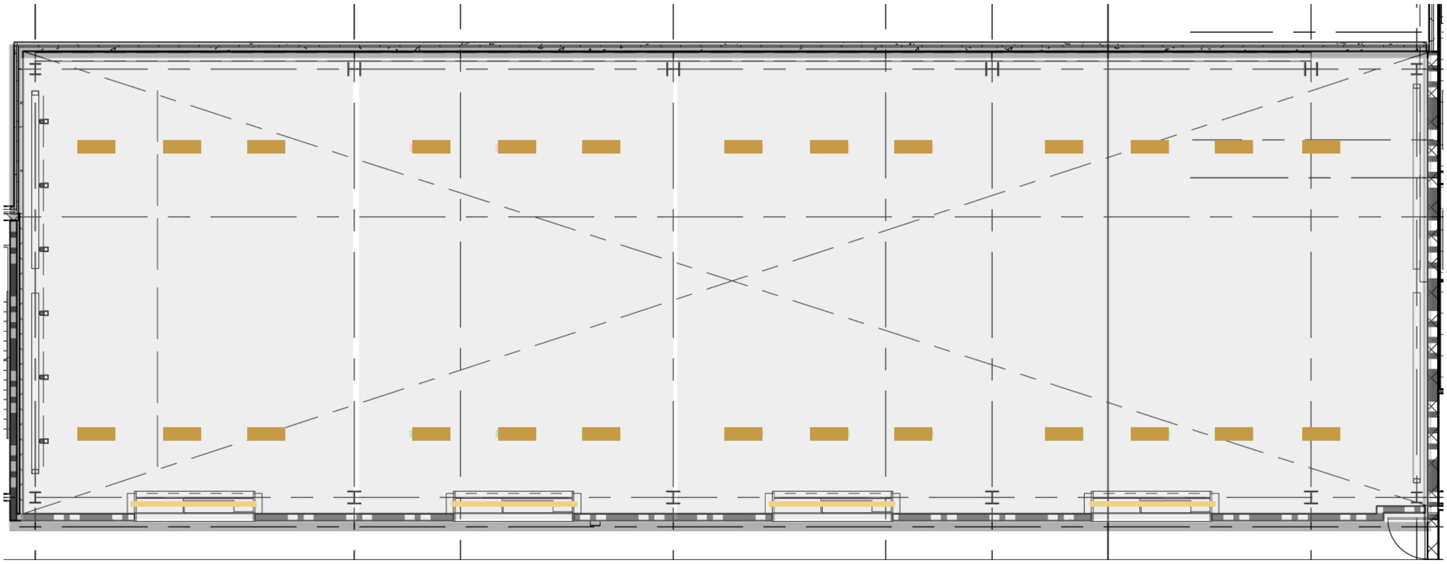


Figure 33 Second Floor Lighting Plan

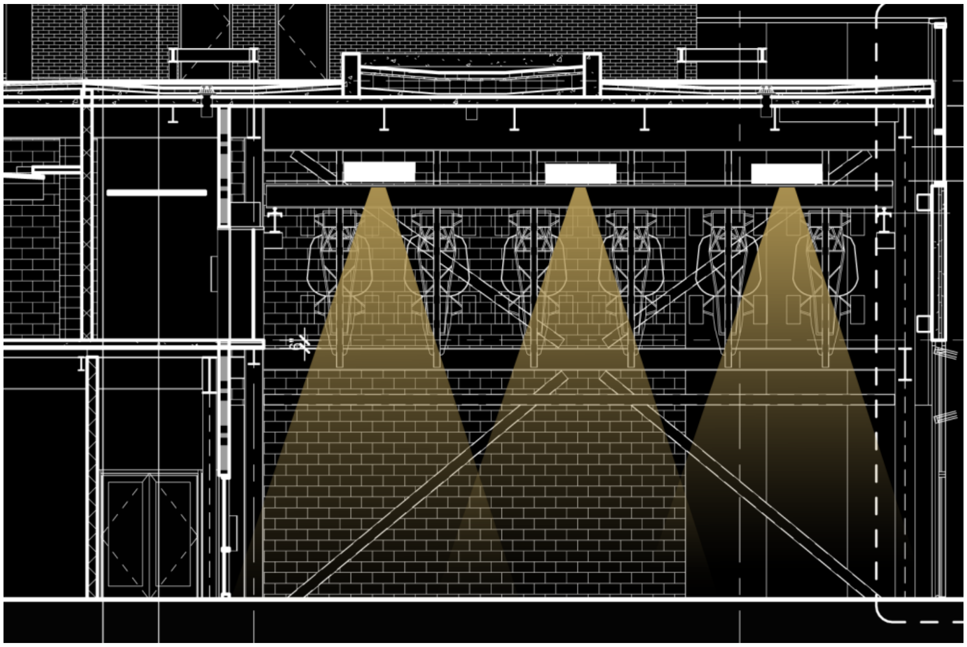


Figure 34 Original Lighting Section

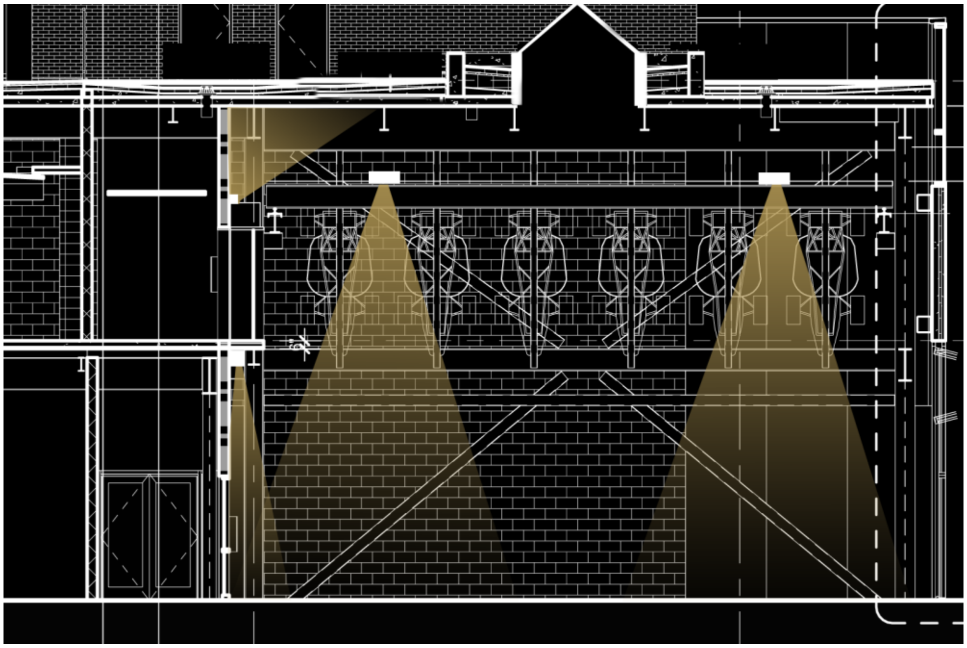


Figure 35 New Lighting Section with Skylight

Renders

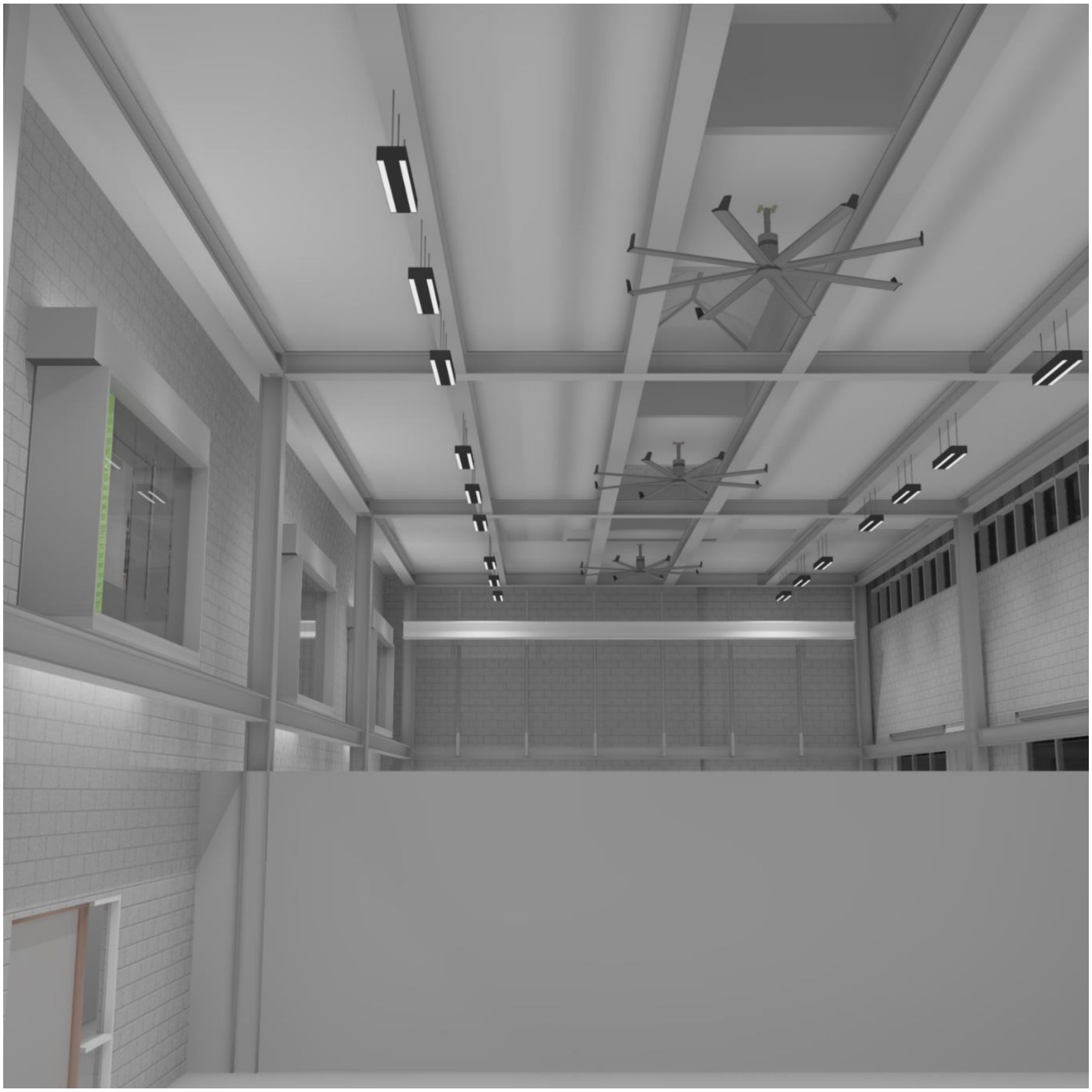


Figure 36 Perspective Rendering

Figure 37 Section Render Looking East

Figure 38 Perspective Render Looking Southwest

Pseudocolors (Light Levels)

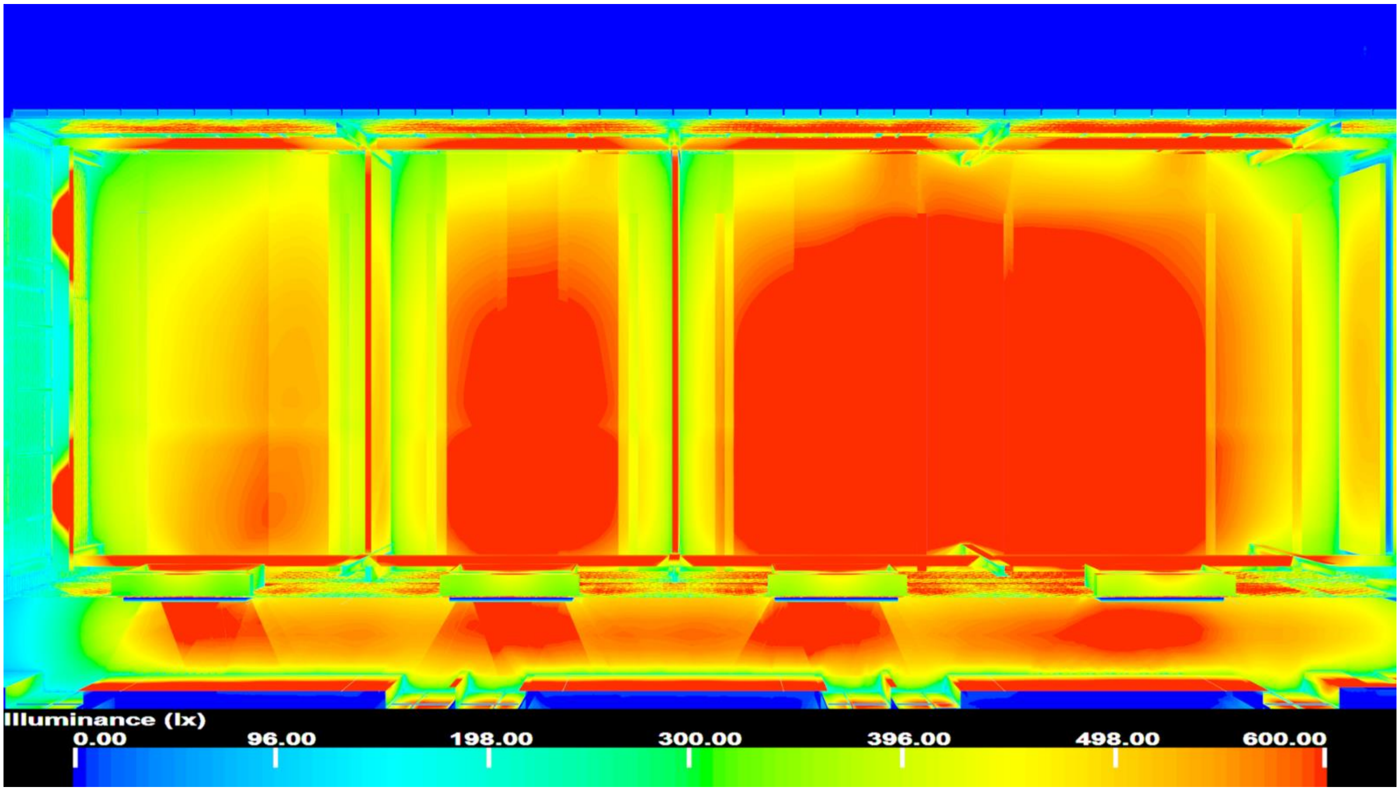


Figure 39 Top Section Pseudocolor

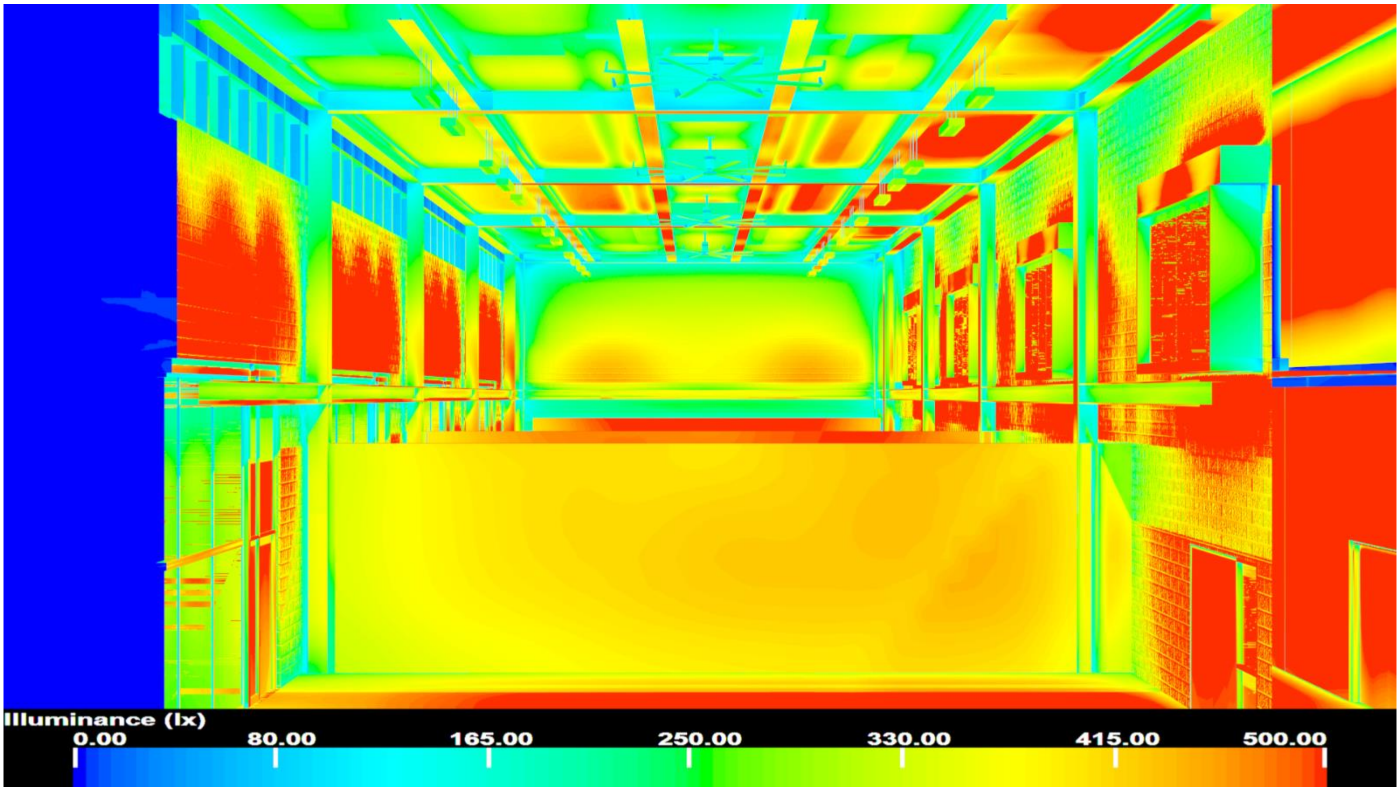


Figure 40 Project Lab Section Looking East

Lighting Power Density

Project Labs Lighting Power Density			
Type	**Quantity**	**Input Watts**	**Total Watts**
L15	26	194	5044
L16	44 FT	10	440
L17	44 FT	8.4	369.6
		Total Watts	5853.6
		Total Area	5704
		Calculated LPD	1.03
		ASHRAE 90.1 LPD Allowed	1.23
		Difference	0.20

Space Evaluation + Summary

Overall, the three layers of light in conjunction with the addition of the skylights seem to emphasize the concepts of breaking from tradition and pushing the boundaries. The lighting emphasizes both the industrial feeling of a workshop and the stylized feel with the perimeter lighting and the stylish LED pendant luminaires used. The quantitative design criteria also seem to be met fairly well. The average ground plane illuminance ranges between 400 and 600 lux which is fine for the space which should be around 500 lux on the workplane. The lighting power density for the space was calculated to be 1.03 and is 17% more efficient than the ASHRAE 90.1 allowed lighting power density. The space seems to meet the criteria set forth and is a successful space.

General Lighting Notes

This short section outlines a few lighting design general notes for the process used in coming up with the final lighting designs. These notes can be applied to each space.

3ds Max Studio

3ds Max was used to perform all interior lighting calculations and renders. Revit models were provided by the architect, SmithGroupJJR. These models were exported as .dwf files from Revit and imported into 3ds Max. The models were cleaned up of extra geometries and then the layers were assigned appropriate general materials and or specific materials if they could be made and were important to the design. From here, there was a long iterative process of determining appropriate lights to place into the model to achieve the desired effects that were thought of during the schematic phase to ultimately achieve the lighting levels desired.

To check the lighting levels, radiosity solutions were calculated with adaptive subdivision. In 3ds Max, this radiosity solution stores the luminance values in each of the surfaces and allows for a convenient way to explore the model to determine any problems. From the radiosity solution, renders could then be made through the Scanline rendering settings of 3ds Max. For the normal renders, a logarithmic lighting solution was used. For the pseudocolors, a linear illuminance solution was used.

3ds Max Studio has been validated by many as a decent lighting tool and the methods used were a variation of what was learned at a previous internship. The materiality and complexity of the models made this process fairly time consuming and the final solutions do not reflect how exactly how the lighting would most likely appear. The renders were done to the best of my knowledge of the program and of the use of materials however and they are good enough for the purposes of getting my points across.

Light Loss Factors

Due in part to using strictly LED fixtures for each space and due to the fact that the technology is getting increasingly better in terms of lamp life, a light loss factor of 0.7 was used for each fixture. Using lamp dirt depreciation as well for some fixtures was considered, but due to the 0.7 being fairly conservative already this was determined to be sufficient enough. During the past internship, 0.7 LLF was almost always utilized.

ELECTRICAL DEPTH |

Overview

The new Engineering Center, being located on the Oakland University campus, receives its utility power from the University at a discounted cost compared to the surrounding area of Rochester, Michigan. This utility power enters the building at the ground level into a secondary unit substation, room 160, which contains two 15 kV fused load interrupter break switches (PS-A2 + PS-B2) for the two primary service transformers. All of the electrical rooms are fed from feeders located in this room. A penthouse generator is used in the event that emergency power is needed. Most of the panels in this building use 480Y/277V 3PH, 4W power from the two main transformers through distribution panels however, some panels using 208Y/120V power require step-down transformers in the designated electrical rooms on each floor. There are 63 wall-mounted branch panel boards located in the eight designated electrical rooms throughout the building. Of these, only nine panels were affected by the lighting redesign.

The electrical depth consists mainly of a branch circuit analysis of the lighting panels that have been impacted by the lighting redesign of the four main spaces that are covered in the lighting depth portion of this report. The lighting panels are all very conservatively designed to meet NEC requirements and to allow for changes during the life of this building. Because of this, none of the panels have been resized as the load added to the panels in most cases does not impact the connected load very much.

The second portion of this depth includes a point-by-point short circuit analysis from the substation main transformer to one of the impacted lighting branch circuit panel boards. This analysis showed what was assumed about the oversizing of the panels with all points along the fault analysis having less load than the equipment's Ampere Interrupting Capacity (AIC) rating.

Branch Circuit Calculation

Firstly, the affected branch circuit panels were determined and the loads were noted and each fixture on these panels were used to calculate the load that would be subtracted from the appropriate circuits.

Modified Panelboards						
Panel	**Voltage**	**Normal/Emergency**	**Exterior**	**Lobby + Atrium**	**Auditorium**	**Project Labs**
L11A	480Y/275	Normal			X	
H11	480Y/277	Normal			X	
H13	480Y/278	Normal	X			
H13LS	480Y/279	N/E	X	X	X	
H21	480Y/280	Normal	X			
H23	480Y/281	Normal		X		X
H23LS	480Y/282	N/E	X			X
H31	480Y/283	Normal		X		
H51	480Y/284	Normal		X		

Table 1 Modified Panel boards to Analyze

Original Design Loads						
Area	**Type**	**Quantity**	**Wattage**	**Voltage**	**VA**	**Circuit**
Project Labs	**F7**	27	364 W	277 V	9828 VA	H23-8
Project Labs	**F7**	8	364 W	277 V	2912 VA	H23LS-5
Lobby 1	**L7**	10	14 W	277 V	140 VA	H13-1
Exterior	**L7**	1	14 W	277 V	14 VA	H13-1
Exterior 1	**L11**	22	6 W	277 V	132 VA	H13-3
Exterior 2	**L11**	12	6 W	277 V	72 VA	H21-5
Auditorium	**L13**	10	4.5 W	277 V	45 VA	H11-1
Lobby 1	**L14**	24 FT	6 W/FT	277 V	144 VA	H13-1
Auditorium	**L15**	27	5 W	120 V	135 VA	L11A-34
Lobby 2	**SF1**	90 FT	7.5 W/FT	277 V	675 VA	H23-1
Hallway 2	**SF5**	7	36 W	277 V	252 VA	H23LS-5
Atrium 5	**SH4**	6	75 W	277 V	450 VA	H51-7
Exterior 2	**SL1**	3	20 W	277 V	60 VA	H23LS-5
Exterior 2	**SL2**	22	10 W	277 V	220 VA	H23LS-1
Lobby 2	**SL4**	41 FT	9 W/FT	277 V	369 VA	H23-5
Atrium 3	**SL4**	46 FT	9 W/FT	277 V	414 VA	H31-8
Exterior 1	**SL5**	34	11 W	277 V	374 VA	H13LS-5
Lobby 1	**SL10**	10	21 W	277 V	210 VA	H13-1,H13LS-3
Auditorium	**SL10A**	5	21 W	277 V	105 VA	H11-1
Exterior 1	**SL10B**	2	20 W	277 V	40 VA	H13-1
Exterior 2	**SL10B**	7	20 W	277 V	140 VA	H21-1,H23LS-1
Auditorium	**SL11**	10	3 W	120 V	30 VA	L11A-34
Auditorium	**SL13**	28	18 W	120 V	504 VA	H11-1
Auditorium	**SL13B**	7	40 W	120 V	280 VA	L11A-34
Atrium 3	**SL13C**	10	28 W	277 V	280 VA	H31-7
Lobby 2	**SL22**	120 FT	9 W/FT	277 V	1080 VA	H23-5
Auditorium	**SL26**	12	2.2 W	120 V	26 VA	L11A-34
Auditorium	**SL27**	8	20 W	120 V	160 VA	L11A-34
Lobby 1	**SL28**	23	36 W	277 V	828 VA	H13-1,H13LS-3
Lobby 2	**SL28**	11	36 W	277 V	396 VA	H23-1,H23LS-5
Auditorium	**SL29**	30	63 W	277 V	1890 VA	H11-1

Table 2 Original Loads and Circuits Affected

For the branch circuits affected by the lighting redesign, the loads from all of the installed fixtures from the four main spaces were added to appropriate circuits according to proximity to the electrical rooms and the lighting fixtures that they are replacing. Installed lighting with the lighting redesign Refer to lighting depth section for luminaire type descriptions or Appendix I for the full lighting fixture schedule.

To find the volt-amp loads for each of the fixtures, a 0.9 power factor was used as a conservative value as per EnergyStar and DoE recommendations. And, for the maximum continuous load, in VA, a continuous load factor of 125% was used to determine the maximum VA to put on each circuit as per the NEC.

Maximum Continuous Load VA per circuit for 480Y/277V Panels = 277V * 20A * 0.8 = 4432 VA

Maximum Continuous Load VA per circuit for 208Y/120V Panels = 120V * 20A * 0.8 = 1920 VA

		US						
		DoE	EnergyStar	California	Europe	China	Korea	Japan
Residential	Efficiency	50lm/W	50lm/W	N/A	N/A	N/A	N/A	N/A
	PF	>0.7	>0.7	N/A	>0.7	N/A	>0.85	N/A
	THD	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Commercial	Efficiency	55lm/W	55lm/W	55lm/W	N/A	N/A	N/A	N/A
	PF	>0.9	>0.9	>0.9	>0.9	>0.9	>0.9	>0.9
	THD	<20%	<20%	<20%	<20%	<30%	<30%	<30%

Figure 41 Power Factor for LED Lighting

Then, for each luminaire type in the lighting redesign, the VA contribution was calculated and the appropriate circuit was chosen as shown in the figures below.

Exterior Lighting Load Calculation

Type	Quantity	Wattage	Voltage	PF	VA	Circuits
L1	91 m	4.8 W/m	24 V	0.9	485 VA	(19m) H13-3, (72m) H21-5
L2	6	23 W	277 V	0.9	153 VA	(2) H13LS-3, (4) H21-1
L3	9	32 W	277 V	0.9	320 VA	H23LS-1
L4	6	40 W	277 V	0.9	267 VA	H13-3
L5	2	27 W	277 V	0.9	60 VA	H23
				Total:	1285 VA	

Lobby Level One Lighting Load Calculation

Type	Quantity	Wattage	Voltage	PF	VA	Circuits
L2	3	23 W	277 V	0.9	77 VA	H13-1
L6	19	21 W	277 V	0.9	443 VA	H13-12
L7	38 FT	6.3 W/FT	277 V	0.9	266 VA	H13-1
L9	6	8 W	277 V	0.9	53 VA	H13LS-3
				Total:	839 VA	

Lobby + Atrium Level Two Lighting Load Calculation						
Type	**Quantity**	**Wattage**	**Voltage**	**PF**	**VA**	**Circuits**
L6	27	21 W	277 V	0.9	630 VA	H23-5
L8	5	48 W	277 V	0.9	267 VA	H23-1
L9	6	8 W	277 V	0.9	53 VA	H23LS-5
L10	18 FT	5 W/FT	277 V	0.9	100 VA	H23-1
L11	3 FT	12.5 W/FT	277 V	0.9	42 VA	H23-1
				Total:	1092 VA	

Atrium Level Three Lighting Load Calculation						
Type	**Quantity**	**Wattage**	**Voltage**	**PF**	**VA**	**Circuits**
L12	10	22.9 W	277 V	0.9	254 VA	H31-8

Atrium Level Five Lighting Load Calculation						
Type	**Quantity**	**Wattage**	**Voltage**	**PF**	**VA**	**Circuits**
L12	14	22.9 W	277 V	0.9	356 VA	H51-7

Auditorium Lighting Load Calculation						
Type	**Quantity**	**Wattage**	**Voltage**	**PF**	**VA**	**Circuits**
L7	159 FT	6.3 W/FT	24 V	0.9	1113 VA	L11A-34
L12	31	22.9 W	277 V	0.9	789 VA	H11-1
L13	14	87 W	277 V	0.9	1353 VA	H11-1
L14A	5	42 W	277 V	0.9	233 VA	H11-1
L14B	19	8 W	277 V	0.9	169 VA	H11-1
				Total:	3657 VA	

Project Labs Lighting Load Calculation						
Type	**Quantity**	**Wattage**	**Voltage**	**PF**	**VA**	**Circuits**
L15	26	194 W	277 V	0.9	5604 VA	(14) H23-8, (12) H23-10-6
L16	44 FT	10 W/FT	277 V	0.9	489 VA	H23-11
L17	44 FT	8.4 W/FT	277 V	0.9	411 VA	H23-11
				Total:	6504 VA	

These loads were then added to the selected circuits and the original loads were subtracted to determine the final loads on these circuits which then updated the panel boards. All of the updated and original panels are shown on the following pages with the affected circuits highlighted.

VA Normal Load Changes					
Circuit	**Area**	**VA**	**VA Taken Out**	**VA Replaced**	**New Total**
H11-1	Auditorium	2005 VA	2005 VA	2544 VA	2544 VA
H13-1	South Entry + Lobby 1	1732 VA	1022 VA	343 VA	1053 VA
H13-3	Handrail + Exterior 1	322 VA	322 VA	368 VA	368 VA
H13-12	Lobby 1	0 VA	0 VA	443 VA	443 VA
H13LS-3	Lobby 1	757 VA	354 VA	104 VA	507 VA
H21-1	North Entry	1395 VA	140 VA	162 VA	1417 VA
H21-5	Handrail	173 VA	72 VA	384 VA	485 VA
H23-1	Lobby 2	1059 VA	675 VA	408 VA	792 VA
H23-5	Lobby 2	1237 VA	1237 VA	630 VA	630 VA
H23-6	Project Labs	0 VA	0 VA	2587 VA	2587 VA
H23-8	Project Labs	3420 VA	3420 VA	3018 VA	3018 VA
H23-11	Project Labs	0 VA	0 VA	900 VA	900 VA
H23LS-1	Exterior 2	92 VA	92 VA	320 VA	320 VA
H23LS-5	Lobby 2	3455 VA	258 VA	53 VA	3250 VA
H31-7	Atrium 3	2461 VA	280 VA	0 VA	2181 VA
H31-8	Atrium 3	386 VA	386 VA	254 VA	254 VA
H51-7	Atrium 5	3428 VA	450 VA	356 VA	3334 VA
L11A-34	Auditorium	501 VA	501 VA	1113 VA	1113 VA
	Totals:	22.4 KVA	11.2 KVA	14.0 KVA	25.2 KVA

Table 3 Circuit VA Load Changes

Panelboard: H11 Updated

Location:	ELEC 154	**Volts:**	480Y/277	**A.I.C. Rating:**	14000
Supply From:	LDP-H11	**Phases:**	3	**Mains Type:**	MCB
Mounting:	Surface	**Wires:**	4	**Bus Rating:**	100 A
Enclosure:	Type 1			**MCB Rating:**	100 A

CKT	Circuit Description	Trip	Poles	A		B		C		Poles	Trip	Circuit Description	CKT
1	Lighting 200 Seat Classroom 116	20 A	1	2544	3078					1	20 A	Lighting Fire Pump/Domestic Water 152	2
3	Lighting Corridor 193	20 A	1			408 VA	384 VA			1	20 A	Lighting	4
5	Lighting	20 A	1					428 VA	352 VA	1	20 A	Lighting Room 731	6
7	Lighting	20 A	1	360 VA	0 VA					1	20 A	Spare	8
9	Spare	20 A	1			0 VA	0 VA			1	20 A	Spare	10
11	Spare	20 A	1					0 VA	0 VA	1	20 A	Spare	12
13	Spare	20 A	1	0 VA	0 VA					1	20 A	Spare	14
15	Spare	20 A	1			0 VA	0 VA			1	20 A	Spare	16
17	Spare	20 A	1					0 VA	0 VA	1	20 A	Spare	18
19	Spare	--	--	0 VA	0 VA					--	--	Spare	20
21	Spare	--	--			0 VA	0 VA			--	--	Spare	22
23	Spare	--	--					0 VA	0 VA	--	--	Spare	24
25	Spare	--	--	0 VA	0 VA					--	--	Spare	26
27	Spare	--	--			0 VA	0 VA			--	--	Spare	28
29	Spare	--	--					0 VA	0 VA	--	--	Spare	30
			Total Load:	5982 VA		792 VA		780 VA					
			Total Amps:	22 A		3 A		3 A					

Load Classification	Connected Load	Demand Factor	Estimated Demand	Panel Totals	
Lighting	7554 VA	80%	6043 VA		
				Total Conn. Load:	7554 VA
				Total Est. Demand:	6043 VA
				Total Conn.:	9 A
				Total Est. Demand:	7 A

Panelboard: H13 Updated

Location:	ELEC 173	**Volts:**	480Y/277	**A.I.C. Rating:**	14,000
Supply From:	LDP-H11	**Phases:**	3	**Mains Type:**	MCB
Mounting:	Surface	**Wires:**	4	**Bus Rating:**	100 A
Enclosure:	Type 1			**MCB Rating:**	100 A

CKT	Circuit Description	Trip	Poles	A		B		C		Poles	Trip	Circuit Description	CKT
1	Lighting PRE-FUNCTION 196	20 A	1	1053	1629					1	20 A	Lighting SOPHOMORE DESIGN LAB 170	2
3	Lighting	20 A	1			368 VA	2724			1	20 A	Lighting PROJECT LAB STORAGE 177	4
5	Lighting	20 A	1					81 VA	270 VA	1	20 A	Lighting CORRIDOR-1 197-1	6
7	Lighting	20 A	1	804 VA	780 VA					1	20 A	Lighting	8
9	Lighting	20 A	2			2138	0 VA			1	20 A		10
11								2138	443 VA	1	20 A	Lighting Lobby Linear Downlights	12
13	Spare	20 A	1	0 VA	0 VA					1	20 A	Spare	14
15	Spare	20 A	1			0 VA	0 VA			1	20 A	Spare	16
17	Spare	20 A	1					0 VA	0 VA	1	20 A	Spare	18
19	Space	--	1	0 VA	0 VA					1	20 A	Spare	20
21	Space	--	1			0 VA	0 VA			1	--	Space	22
23	Space	--	1					0 VA	0 VA	1	--	Space	24
25	Space	--	1	0 VA	0 VA					1	--	Space	26
27	Space	--	1			0 VA	0 VA			1	--	Space	28
29	Space	--	1					0 VA	0 VA	1	--	Space	30
			Total Load:	4266 VA		5230 VA		2932 VA					
			Total Amps:	15 A		19 A		11 A					

Load Classification	Connected Load	Demand Factor	Estimated Demand	Panel Totals	
Lighting	12428 VA	80.00%	9942 VA		
				Total Conn. Load:	12428 VA
				Total Est. Demand:	9942 VA
				Total Conn.:	15 A
				Total Est. Demand:	12 A

Panelboard: H13LS Updated

Location:	ELEC 173	**Volts:**	480Y/277	**A.I.C. Rating:**	14,000
Supply From:	DP-LS	**Phases:**	3	**Mains Type:**	MCB
Mounting:	Surface	**Wires:**	4	**Bus Rating:**	100 A
Enclosure:	Type 1			**MCB Rating:**	60 A

CKT	Circuit Description	Trip	Poles	A		B		C		Poles	Trip	Circuit Description	CKT
1	Lighting ELEVATOR CONTROL ROOM 150	20 A	1	2210	295 VA					1	20 A	Lighting CORRIDOR 193	2
3	Lighting PRE-FUNCTION 196	20 A	1			507 VA	962 VA			1	20 A	Lighting ELEC 173	4
5	Lighting	20 A	1					689 VA	485 VA	1	20 A	Lighting CORRIDOR-1 197-1	6
7	Lighting Room 731	20 A	1	192 VA	64 VA					1	20 A	Lighting ELEV. 153A	8
9	Spare	20 A	1			0 VA	96 VA			1	20 A	Lighting ELEV. 100A	10
11	Spare	20 A	1					0 VA	0 VA	1	20 A	Spare	12
13	Spare	20 A	1	0 VA	0 VA					1	20 A	Spare	14
15	Spare	20 A	1			0 VA	0 VA			1	20 A	Spare	16
17	Spare	20 A	1					0 VA	0 VA	1	20 A	Spare	18
19	Space	--	--	0 VA	0 VA					--	--	Spare	20
21	Space	--	--			0 VA	0 VA			--	--	Space	22
23	Space	--	--					0 VA	0 VA	--	--	Space	24
25	Space	--	--	0 VA	0 VA					--	--	Space	26
27	Space	--	--			0 VA	0 VA			--	--	Space	28
29	Space	--	--					0 VA	0 VA	--	--	Space	30
			Total Load:	2761 VA		1565 VA		1174 VA					
			Total Amps:	10 A		6 A		4 A					

Load Classification	Connected Load	Demand Factor	Estimated Demand	Panel Totals	
Lighting	5500 VA	80.00%	4400 VA		
				Total Conn. Load:	5500 VA
				Total Est. Demand:	4400 VA
				Total Conn.:	7 A
				Total Est. Demand:	5 A

Panelboard: H21 Updated

Location:	ELEC 265C	**Volts:**	480Y/277	**A.I.C. Rating:**	14,000
Supply From:	LDP-H11	**Phases:**	3	**Mains Type:**	MCB
Mounting:	Surface	**Wires:**	4	**Bus Rating:**	100 A
Enclosure:	Type 1			**MCB Rating:**	100 A

CKT	Circuit Description	Trip	Poles	A		B		C		Poles	Trip	Circuit Description	CKT
1	Lighting	20 A	1	1417	262 VA					1	20 A	Lighting Room 247	2
3	Lighting Room 203, 293B, _293C, 179F, _293B	20 A	1			1191	3420			1	20 A	Lighting WAITING 255	4
5	Lighting	20 A	1					485 VA	2547	1	20 A	Lighting 100 SEAT CLASSROOM _704	6
7	Spare	20 A	1	0 VA	0 VA					1	20 A	Spare	8
9	Spare	20 A	1			0 VA	0 VA			1	20 A	Spare	10
11	Spare	20 A	1					0 VA	0 VA	1	20 A	Spare	12
13	Spare	20 A	1	0 VA	0 VA					1	20 A	Spare	14
15	Spare	20 A	1			0 VA	0 VA			1	20 A	Spare	16
17	Spare	20 A	1					0 VA	0 VA	1	20 A	Spare	18
19	Space	--	--	0 VA	0 VA					1	20 A	Spare	20
21	Space	--	--			0 VA	0 VA			--	--	Space	22
23	Space	--	--					0 VA	0 VA	--	--	Space	24
25	Space	--	--	0 VA	0 VA					--	--	Space	26
27	Space	--	--			0 VA	0 VA			--	--	Space	28
29	Space	--	--					0 VA	0 VA	--	--	Space	30
			Total Load:	1679 VA		4611 VA		3032 VA					
			Total Amps:	6 A		17 A		11 A					

Load Classification	Connected Load	Demand Factor	Estimated Demand	Panel Totals	
Lighting	9322 VA	80.00%	7458 VA		
				Total Conn. Load:	9322 VA
				Total Est. Demand:	7458 VA
				Total Conn.:	11 A
				Total Est. Demand:	9 A

Panelboard: H23 Updated

Location: ELEC 273
Supply From: LDP-H11
Mounting: Surface
Enclosure: Type 1

Volts: 480Y/277
Phases: 3
Wires: 4

A.I.C. Rating: 14,000
Mains Type: MCB
Bus Rating: 100 A
MCB Rating: 100 A

CKT	Circuit Description	Trip	Poles	A		B		C		Poles	Trip	Circuit Description	CKT
1	Lighting	20 A	1	792	1026					1	20 A	Lighting Room 179F, 297, 202, 212	2
3	Lighting	20 A	1			4509	26 VA			1	20 A	Lighting MENS 265E	4
5	Lighting STAIR _261X	20 A	1					630	2587	1	20 A	Lighting Project Labs	6
7	Lighting	20 A	1	2697	3018					1	20 A	Lighting	8
9	Spare	20 A	1			0 VA	0 VA			1	20 A	Spare	10
11	Lighting Project Labs	20 A	1					900 VA	0 VA	1	20 A	Spare	12
13	Spare	20 A	1	0 VA	0 VA					1	20 A	Spare	14
15	Spare	20 A	1			0 VA	0 VA			1	20 A	Spare	16
17	Spare	20 A	1					0 VA	0 VA	1	20 A	Spare	18
19	Space	--	--	0 VA	0 VA					1	20 A	Spare	20
21	Space	--	--			0 VA	0 VA			--	--	Space	22
23	Space	--	--					0 VA	0 VA	--	--	Space	24
25	Space	--	--	0 VA	0 VA					--	--	Space	26
27	Space	--	--			0 VA	0 VA			--	--	Space	28
29	Space	--	--					0 VA	0 VA	--	--	Space	30
			Total Load:	7533 VA		4535 VA		4116 VA					
			Total Amps:	27 A		16 A		15 A					

Load Classification	Connected Load	Demand Factor	Estimated Demand	Panel Totals	
Lighting	16184 VA	80.00%	12947 VA		
				Total Conn. Load:	16184 VA
				Total Est. Demand:	12947 VA
				Total Conn.:	19 A
				Total Est. Demand:	16 A

Panelboard: H23LS Updated

Location:	ELEC 273	**Volts:**	480Y/277	**A.I.C. Rating:**	14,000
Supply From:	DP-LS	**Phases:**	3	**Mains Type:**	MCB
Mounting:	Surface	**Wires:**	4	**Bus Rating:**	100 A
Enclosure:	Type 1			**MCB Rating:**	60 A

CKT	Circuit Description	Trip	Poles	A		B		C		Poles	Trip	Circuit Description	CKT
1	Lighting	20 A	1	320 VA	702 VA					1	20 A	Lighting CORRIDOR 193	2
3	Lighting WAITING 255	20 A	1			719 VA	0 VA			1	20 A	Lighting ELEC 173	4
5	Lighting Room 267, 212, _261X, 179F, 102-2, 297	20 A	1					3250	0 VA	1	20 A	Lighting CORRIDOR-1 197-1	6
7	Spare	20 A	1	0 VA	0 VA					1	20 A	Lighting ELEV. 153A	8
9	Spare	20 A	1			0 VA	0 VA			1	20 A	Lighting ELEV. 100A	10
11	Spare	20 A	1					0 VA	0 VA	1	20 A	Spare	12
13	Spare	20 A	1	0 VA	0 VA					1	20 A	Spare	14
15	Spare	20 A	1			0 VA	0 VA			--	--	Space	16
17	Space	--	--					0 VA	0 VA	--	--	Space	18
19	Space	--	--	0 VA	0 VA					--	--	Space	20
21	Space	--	--			0 VA	0 VA			--	--	Space	22
23	Space	--	--					0 VA	0 VA	--	--	Space	24
25	Space	--	--	0 VA	0 VA					--	--	Space	26
27	Space	--	--			0 VA	0 VA			--	--	Space	28
29	Space	--	--					0 VA	0 VA	--	--	Space	30
			Total Load:	1022 VA		719 VA		3250 VA					
			Total Amps:	4 A		3 A		12 A					

Load Classification	Connected Load	Demand Factor	Estimated Demand	Panel Totals	
Lighting	4991 VA	80.00%	3993 VA		
				Total Conn. Load:	4991 VA
				Total Est. Demand:	3993 VA
				Total Conn.:	6 A
				Total Est. Demand:	5 A

Panelboard: H31 Updated

Location:	ELEC 365C	**Volts:**	480Y/277	**A.I.C. Rating:**	14,000
Supply From:	LDP-H11	**Phases:**	3	**Mains Type:**	MCB
Mounting:	Surface	**Wires:**	4	**Bus Rating:**	100 A
Enclosure:	Type 1			**MCB Rating:**	100 A

CKT	Circuit Description	Trip	Poles	A		B		C		Poles	Trip	Circuit Description	CKT
1	Lighting SEMINAR 347	20 A	1	2474	3609					1	20 A	Lighting GRAD OFFICE 354	2
3	Lighting LAB MANAGER/ ELECTRONICS SHOP	20 A	1			2872	994 VA			1	20 A	Lighting	4
5	Lighting ROOFTOP LAB 390	20 A	1					23 VA	950 VA	1	20 A	Lighting CORRIDOR 391	6
7	Lighting CORRIDOR 390	20 A	1	2181	254 VA					1	20 A	Lighting Room 271	8
9	Spare	20 A	1			0 VA	0 VA			1	20 A	Spare	10
11	Spare	20 A	1					0 VA	0 VA	1	20 A	Spare	12
13	Spare	20 A	1	0 VA	0 VA					1	20 A	Spare	14
15	Spare	20 A	1			0 VA	0 VA			1	20 A	Spare	16
17	Spare	20 A	1					0 VA	0 VA	1	20 A	Spare	18
19	Space	--	--	0 VA	0 VA					1	20 A	Spare	20
21	Space	--	--			0 VA	0 VA			--	--	Space	22
23	Space	--	--					0 VA	0 VA	--	--	Space	24
25	Space	--	--	0 VA	0 VA					--	--	Space	26
27	Space	--	--			0 VA	0 VA			--	--	Space	28
29	Space	--	--					0 VA	0 VA	--	--	Space	30
			Total Load:	8518 VA		3866 VA		973 VA					
			Total Amps:	31 A		14 A		4 A					

Load Classification	Connected Load	Demand Factor	Estimated Demand	Panel Totals	
Lighting	13357 VA	80.00%	10686 VA		
				Total Conn. Load:	13357 VA
				Total Est. Demand:	10686 VA
				Total Conn.:	16 A
				Total Est. Demand:	13 A

Panelboard: H51 Updated

Location:	ELEC 565C	**Volts:**	480Y/277	**A.I.C. Rating:**	14,000
Supply From:	LDP-H11	**Phases:**	3	**Mains Type:**	MCB
Mounting:	Surface	**Wires:**	4	**Bus Rating:**	100 A
Enclosure:	Type 1			**MCB Rating:**	100 A

CKT	Circuit Description	Trip	Poles	A		B		C		Poles	Trip	Circuit Description	CKT
1	Lighting GROUP PROJECT/ STUDY 547	20 A	1	3168	3285					1	20 A	Lighting COMPUTING LAB 550	2
3	Lighting INFORMAL LEARNING 563	20 A	1			2963	2260			1	20 A	Lighting GROUP PROJECT/ STUDY 575	4
5	Lighting CORRIDOR590	20 A	1					1000	1449	1	20 A	Lighting CORRIDOR-2 593-2	6
7	Lighting Room 655,653	20 A	1	3334	0 VA					1	20 A	Spare	8
9	Spare	20 A	1			0 VA	0 VA			1	20 A	Spare	10
11	Spare	20 A	1					0 VA	0 VA	1	20 A	Spare	12
13	Spare	20 A	1	0 VA	0 VA					1	20 A	Spare	14
15	Spare	20 A	1			0 VA	0 VA			1	20 A	Spare	16
17	Spare	20 A	1					0 VA	0 VA	1	20 A	Spare	18
19	Space	--	--	0 VA	0 VA					--	--	Spare	20
21	Space	--	--			0 VA	0 VA			--	--	Space	22
23	Space	--	--					0 VA	0 VA	--	--	Space	24
25	Space	--	--	0 VA	0 VA					--	--	Space	26
27	Space	--	--			0 VA	0 VA			--	--	Space	28
29	Space	--	--					0 VA	0 VA	--	--	Space	30
			Total Load:	9787 VA		5223 VA		2449 VA					
			Total Amps:	35 A		19 A		9 A					

Load Classification	Connected Load	Demand Factor	Estimated Demand	Panel Totals	
Lighting	17459 VA	80.00%	13967 VA		
				Total Conn. Load:	17459 VA
				Total Est. Demand:	13967 VA
				Total Conn.:	21 A
				Total Est. Demand:	17 A

Panelboard: L11A Updated

Location:	ELEC 154	**Volts:**	208Y/120	**A.I.C. Rating:**	10,000
Supply From:		**Phases:**	3	**Mains Type:**	MCB
Mounting:	Surface	**Wires:**	4	**Bus Rating:**	225 A
Enclosure:	Type 1			**MCB Rating:**	100 A

CKT	Circuit Description	Trip	Poles	A		B		C		Poles	Trip	Circuit Description	CKT
1	Power FIRE PUMP/DOMESTIC WATER 152	20 A	1	110	75					1	20 A	Power ELEC 154	2
3	Power SUBSTATION _732	20 A	1			145 VA	110 VA			1	20 A	Power	4
5	EF-11	20 A	1					828 VA	110 VA	1	20 A	Power SUBSTATION 160	6
7	Receptacle Space _728	20 A	1	360 VA	1080					1	20 A	Receptacle HAZARD. WASTE 156B	8
9	Receptacle OFFICE 156H	20 A	1			900 VA	180 VA			1	20 A	Receptacle VENDING 164	10
11	Receptacle FAMILY TOILET 166	20 A	1					900 VA	720 VA	1	20 A	Receptacle GROUP PROJECT/STUDY 168C	12
13	Receptacle CORRIDOR 195	20 A	1	900 VA	720 VA					1	20 A	Receptacle	14
15	Receptacle JC 155	20 A	1			540 VA	720 VA			1	20 A	Receptacle SUBSTATION 160	16
17	Receptacle STORAGE CAGES 163	20 A	1					900 VA	180 VA	1	20 A	Receptacle SUBSTATION 160	18
19	Spare	20 A	1	0 VA	200 VA					1	20 A	LCP	20
21	Power FAMILY TOILET 166	20 A	1			1500	1500			1	20 A	Power M TOILET 171	22
23	Power W TOILET 169	20 A	1					1500	1200	1	20 A	Receptacle VENDING 164	24
25	Receptacle VENDING 164	20 A	1	1200	1200					1	20 A	Receptacle VENDING 164	26
27	Receptacle VENDING 164	20 A	1			1200	1200			1	20 A	Receptacle VENDING 164	28
29	EF-10	20 A	1					828 VA	368 VA	1	20 A	Power CORRIDOR 195	30
31	Power SHIPPING/ RECEIVING LOADING 156	20 A	1	828 VA	0 VA					1	20 A	Spare	32
33						0 VA	1113			1	20 A	Lighting 200 SEAT CLASSROOM 116	34
35	Spare	20 A	1					0 VA	0 VA	1	20 A	Spare	36
37	Spare	20 A	1	0 VA	0 VA					1	20 A	Spare	38
39	Spare	20 A	1			0 VA	0 VA			1	20 A	Spare	40
41	Spare	20 A	1					0 VA	0 VA	1	20 A	Spare	42
			Total Load:	6673 VA		9108 VA		7534 VA					
			Total Amps:	56 A		76 A		63 A					

Load Classification	Connected Load	Demand Factor	Estimated Demand	Panel Totals	
Lighting	1113 VA	80.00%	890 VA		
Power	6446 VA	30.00%	1934 VA	**Total Conn. Load:**	23315 VA
Receptacle	14100 VA	85.46%	12050 VA	**Total Est. Demand:**	15867.66 VA
Mechanical Equipment	1656 VA	60.00%	994 VA	**Total Conn.:**	65 A
				Total Est. Demand:	44 A

Panelboard: H11(Unchanged)

Location: ELEC 154 **Volts:** 480Y/277 **A.I.C. Rating:** 14000
Supply From: LDP-H11 **Phases:** 3 **Mains Type:** MCB
Mounting: Surface **Wires:** 4 **Bus Rating:** 100 A
Enclosure: Type 1 **MCB Rating:** 100 A

CKT	Circuit Description	Trip	Poles	A		B		C		Poles	Trip	Circuit Description	CKT
1	Lighting 200 Seat Classroom 116	20 A	1	2005	3078					1	20 A	Lighting Fire Pump/Domestic Water 152	2
3	Lighting Corridor 193	20 A	1			408 VA	384 VA			1	20 A	Lighting	4
5	Lighting	20 A	1					428 VA	352 VA	1	20 A	Lighting Room 731	6
7	Lighting	20 A	1	360 VA	0 VA					1	20 A	Spare	8
9	Spare	20 A	1			0 VA	0 VA			1	20 A	Spare	10
11	Spare	20 A	1					0 VA	0 VA	1	20 A	Spare	12
13	Spare	20 A	1	0 VA	0 VA					1	20 A	Spare	14
15	Spare	20 A	1			0 VA	0 VA			1	20 A	Spare	16
17	Spare	20 A	1					0 VA	0 VA	1	20 A	Spare	18
19	Spare	--	--	0 VA	0 VA					--	--	Spare	20
21	Spare	--	--			0 VA	0 VA			--	--	Spare	22
23	Spare	--	--					0 VA	0 VA	--	--	Spare	24
25	Spare	--	--	0 VA	0 VA					--	--	Spare	26
27	Spare	--	--			0 VA	0 VA			--	--	Spare	28
29	Spare	--	--					0 VA	0 VA	--	--	Spare	30
			Total Load:	5443 VA		792 VA		780 VA					
			Total Amps:	20 A		3 A		3 A					

Load Classification	Connected Load	Demand Factor	Estimated Demand	Panel Totals	
Lighting	7015 VA	80%	5612 VA		
				Total Conn. Load:	7015 VA
				Total Est. Demand:	5612 VA
				Total Conn.:	8 A
				Total Est. Demand:	7 A

Panelboard: H13 (Unchanged)

Location: ELEC 173 **Volts:** 480Y/277 **A.I.C. Rating:** 14,000
Supply From: LDP-H11 **Phases:** 3 **Mains Type:** MCB
Mounting: Surface **Wires:** 4 **Bus Rating:** 100 A
Enclosure: Type 1 **MCB Rating:** 100 A

CKT	Circuit Description	Trip	Poles	A		B		C		Poles	Trip	Circuit Description	CKT
1	Lighting PRE-FUNCTION 196	20 A	1	1732	1629					1	20 A	Lighting SOPHOMORE DESIGN LAB 170	2
3	Lighting	20 A	1			322 VA	2724			1	20 A	Lighting PROJECT LAB STORAGE 177	4
5	Lighting	20 A	1					81 VA	270 VA	1	20 A	Lighting CORRIDOR-1 197-1	6
7	Lighting	20 A	1	804 VA	780 VA					1	20 A	Lighting	8
9	Lighting	20 A	2			2138	0 VA			1	20 A		10
11								2138	0 VA	1	20 A	Spare	12
13	Spare	20 A	1	0 VA	0 VA					1	20 A	Spare	14
15	Spare	20 A	1			0 VA	0 VA			1	20 A	Spare	16
17	Spare	20 A	1					0 VA	0 VA	1	20 A	Spare	18
19	Space	--	1	0 VA	0 VA					1	20 A	Spare	20
21	Space	--	1			0 VA	0 VA			1	--	Space	22
23	Space	--	1					0 VA	0 VA	1	--	Space	24
25	Space	--	1	0 VA	0 VA					1	--	Space	26
27	Space	--	1			0 VA	0 VA			1	--	Space	28
29	Space	--	1					0 VA	0 VA	1	--	Space	30
			Total Load:	4945 VA		5184 VA		2489 VA					
			Total Amps:	18 A		19 A		9 A					

Load Classification	Connected Load	Demand Factor	Estimated Demand	Panel Totals	
Lighting	12618 VA	80.00%	10094 VA		
				Total Conn. Load:	12618 VA
				Total Est. Demand:	10094 VA
				Total Conn.:	15 A
				Total Est. Demand:	12 A

Panelboard: H13LS (Unchanged)

Location: ELEC 173 **Volts:** 480Y/277 **A.I.C. Rating:** 14,000
Supply From: DP-LS **Phases:** 3 **Mains Type:** MCB
Mounting: Surface **Wires:** 4 **Bus Rating:** 100 A
Enclosure: Type 1 **MCB Rating:** 60 A

CKT	Circuit Description	Trip	Poles	A		B		C		Poles	Trip	Circuit Description	CKT
1	Lighting ELEVATOR CONTROL ROOM 150	20 A	1	2210	295 VA					1	20 A	Lighting CORRIDOR 193	2
3	Lighting PRE-FUNCTION 196	20 A	1			757 VA	962 VA			1	20 A	Lighting ELEC 173	4
5	Lighting	20 A	1					689 VA	485 VA	1	20 A	Lighting CORRIDOR-1 197-1	6
7	Lighting Room 731	20 A	1	192 VA	64 VA					1	20 A	Lighting ELEV. 153A	8
9	Spare	20 A	1			0 VA	96 VA			1	20 A	Lighting ELEV. 100A	10
11	Spare	20 A	1					0 VA	0 VA	1	20 A	Spare	12
13	Spare	20 A	1	0 VA	0 VA					1	20 A	Spare	14
15	Spare	20 A	1			0 VA	0 VA			1	20 A	Spare	16
17	Spare	20 A	1					0 VA	0 VA	1	20 A	Spare	18
19	Space	--	--	0 VA	0 VA					--	--	Spare	20
21	Space	--	--			0 VA	0 VA			--	--	Space	22
23	Space	--	--					0 VA	0 VA	--	--	Space	24
25	Space	--	--	0 VA	0 VA					--	--	Space	26
27	Space	--	--			0 VA	0 VA			--	--	Space	28
29	Space	--	--					0 VA	0 VA	--	--	Space	30
			Total Load:	2761 VA		1815 VA		1174 VA					
			Total Amps:	10 A		7 A		4 A					

Load Classification	Connected Load	Demand Factor	Estimated Demand	Panel Totals	
Lighting	5750 VA	80.00%	4600 VA		
				Total Conn. Load:	5750 VA
				Total Est. Demand:	4600 VA
				Total Conn.:	7 A
				Total Est. Demand:	6 A

Panelboard: H21 (Unchanged)

Location: ELEC 265C **Volts:** 480Y/277 **A.I.C. Rating:** 14,000
Supply From: LDP-H11 **Phases:** 3 **Mains Type:** MCB
Mounting: Surface **Wires:** 4 **Bus Rating:** 100 A
Enclosure: Type 1 **MCB Rating:** 100 A

CKT	Circuit Description	Trip	Poles	A		B		C		Poles	Trip	Circuit Description	CKT
1	Lighting	20 A	1	1395	262 VA					1	20 A	Lighting Room 247	2
3	Lighting Room 203, 293B, _293C, 179F, _293B	20 A	1			1191	3420			1	20 A	Lighting WAITING 255	4
5	Lighting	20 A	1					173 VA	2547	1	20 A	Lighting 100 SEAT CLASSROOM _704	6
7	Spare	20 A	1	0 VA	0 VA					1	20 A	Spare	8
9	Spare	20 A	1			0 VA	0 VA			1	20 A	Spare	10
11	Spare	20 A	1					0 VA	0 VA	1	20 A	Spare	12
13	Spare	20 A	1	0 VA	0 VA					1	20 A	Spare	14
15	Spare	20 A	1			0 VA	0 VA			1	20 A	Spare	16
17	Spare	20 A	1					0 VA	0 VA	1	20 A	Spare	18
19	Space	--	--	0 VA	0 VA					1	20 A	Spare	20
21	Space	--	--			0 VA	0 VA			--	--	Space	22
23	Space	--	--					0 VA	0 VA	--	--	Space	24
25	Space	--	--	0 VA	0 VA					--	--	Space	26
27	Space	--	--			0 VA	0 VA			--	--	Space	28
29	Space	--	--					0 VA	0 VA	--	--	Space	30
			Total Load:	1657 VA		4611 VA		2720 VA					
			Total Amps:	6 A		17 A		10 A					

Load Classification	Connected Load	Demand Factor	Estimated Demand	Panel Totals	
Lighting	8988 VA	80.00%	7190 VA		
				Total Conn. Load:	8988 VA
				Total Est. Demand:	7190 VA
				Total Conn.:	11 A
				Total Est. Demand:	9 A

Panelboard: H23 (Unchanged)

Location:	ELEC 273	**Volts:**	480Y/277	**A.I.C. Rating:**	14,000
Supply From:	LDP-H11	**Phases:**	3	**Mains Type:**	MCB
Mounting:	Surface	**Wires:**	4	**Bus Rating:**	100 A
Enclosure:	Type 1			**MCB Rating:**	100 A

CKT	Circuit Description	Trip	Poles	A		B		C		Poles	Trip	Circuit Description	CKT
1	Lighting	20 A	1	1059	1026					1	20 A	Lighting Room 179F, 297, 202, 212	2
3	Lighting	20 A	1			4509	26 VA			1	20 A	Lighting MENS 265E	4
5	Lighting STAIR _261X	20 A	1					1237		1	20 A		6
7	Lighting	20 A	1	2697	3420					1	20 A	Lighting	8
9	Spare	20 A	1			0 VA	0 VA			1	20 A	Spare	10
11	Spare	20 A	1					0 VA	0 VA	1	20 A	Spare	12
13	Spare	20 A	1	0 VA	0 VA					1	20 A	Spare	14
15	Spare	20 A	1			0 VA	0 VA			1	20 A	Spare	16
17	Spare	20 A	1					0 VA	0 VA	1	20 A	Spare	18
19	Space	--	--	0 VA	0 VA					1	20 A	Spare	20
21	Space	--	--			0 VA	0 VA			--	--	Space	22
23	Space	--	--					0 VA	0 VA	--	--	Space	24
25	Space	--	--	0 VA	0 VA					--	--	Space	26
27	Space	--	--			0 VA	0 VA			--	--	Space	28
29	Space	--	--					0 VA	0 VA	--	--	Space	30
			Total Load:	8202 VA		4535 VA		1237 VA					
			Total Amps:	30 A		16 A		4 A					

Load Classification	Connected Load	Demand Factor	Estimated Demand	Panel Totals	
Lighting	13974 VA	80.00%	11179 VA		
				Total Conn. Load:	13974 VA
				Total Est. Demand:	11179 VA
				Total Conn.:	17 A
				Total Est. Demand:	13 A

Panelboard: H23LS (Unchanged)

Location: ELEC 273 **Volts:** 480Y/277 **A.I.C. Rating:** 14,000
Supply From: DP-LS **Phases:** 3 **Mains Type:** MCB
Mounting: Surface **Wires:** 4 **Bus Rating:** 100 A
Enclosure: Type 1 **MCB Rating:** 60 A

CKT	Circuit Description	Trip	Poles	A		B		C		Poles	Trip	Circuit Description	CKT
1	Lighting	20 A	1	92 VA	702 VA					1	20 A	Lighting CORRIDOR 193	2
3	Lighting WAITING 255	20 A	1			719 VA	0 VA			1	20 A	Lighting ELEC 173	4
5	Lighting Room 267, 212, _261X, 179F, 102-2, 297	20 A	1					3455	0 VA	1	20 A	Lighting CORRIDOR-1 197-1	6
7	Spare	20 A	1	0 VA	0 VA					1	20 A	Lighting ELEV. 153A	8
9	Spare	20 A	1			0 VA	0 VA			1	20 A	Lighting ELEV. 100A	10
11	Spare	20 A	1					0 VA	0 VA	1	20 A	Spare	12
13	Spare	20 A	1	0 VA	0 VA					1	20 A	Spare	14
15	Spare	20 A	1			0 VA	0 VA			--	--	Space	16
17	Space	--	--					0 VA	0 VA	--	--	Space	18
19	Space	--	--	0 VA	0 VA					--	--	Space	20
21	Space	--	--			0 VA	0 VA			--	--	Space	22
23	Space	--	--					0 VA	0 VA	--	--	Space	24
25	Space	--	--	0 VA	0 VA					--	--	Space	26
27	Space	--	--			0 VA	0 VA			--	--	Space	28
29	Space	--	--					0 VA	0 VA	--	--	Space	30
			Total Load:	794 VA		719 VA		3455 VA					
			Total Amps:	3 A		3 A		12 A					

Load Classification	Connected Load	Demand Factor	Estimated Demand	Panel Totals	
Lighting	4968 VA	80.00%	3974 VA		
				Total Conn. Load:	4968 VA
				Total Est. Demand:	3974 VA
				Total Conn.:	6 A
				Total Est. Demand:	5 A

Panelboard: H31 (Unchanged)

Location: ELEC 365C **Volts:** 480Y/277 **A.I.C. Rating:** 14,000
Supply From: LDP-H11 **Phases:** 3 **Mains Type:** MCB
Mounting: Surface **Wires:** 4 **Bus Rating:** 100 A
Enclosure: Type 1 **MCB Rating:** 100 A

CKT	Circuit Description	Trip	Poles	A		B		C		Poles	Trip	Circuit Description	CKT
1	Lighting SEMINAR 347	20 A	1	2474	3609					1	20 A	Lighting GRAD OFFICE 354	2
3	Lighting LAB MANAGER/ ELECTRONICS SHOP	20 A	1			2872	994 VA			1	20 A	Lighting	4
5	Lighting ROOFTOP LAB 390	20 A	1					23 VA	950 VA	1	20 A	Lighting CORRIDOR 391	6
7	Lighting CORRIDOR 390	20 A	1	2461	386 VA					1	20 A	Lighting Room 271	8
9	Spare	20 A	1			0 VA	0 VA			1	20 A	Spare	10
11	Spare	20 A	1					0 VA	0 VA	1	20 A	Spare	12
13	Spare	20 A	1	0 VA	0 VA					1	20 A	Spare	14
15	Spare	20 A	1			0 VA	0 VA			1	20 A	Spare	16
17	Spare	20 A	1					0 VA	0 VA	1	20 A	Spare	18
19	Space	--	--	0 VA	0 VA					1	20 A	Spare	20
21	Space	--	--			0 VA	0 VA			--	--	Space	22
23	Space	--	--					0 VA	0 VA	--	--	Space	24
25	Space	--	--	0 VA	0 VA					--	--	Space	26
27	Space	--	--			0 VA	0 VA			--	--	Space	28
29	Space	--	--					0 VA	0 VA	--	--	Space	30
			Total Load:	8930 VA		3866 VA		973 VA					
			Total Amps:	32 A		14 A		4 A					

Load Classification	Connected Load	Demand Factor	Estimated Demand	Panel Totals	
Lighting	13769 VA	80.00%	11015 VA		
				Total Conn. Load:	13769 VA
				Total Est. Demand:	11015 VA
				Total Conn.:	17 A
				Total Est. Demand:	13 A

Panelboard: H51 (Unchanged)

Location:	ELEC 565C	**Volts:**	480Y/277	**A.I.C. Rating:**	14,000
Supply From:	LDP-H11	**Phases:**	3	**Mains Type:**	MCB
Mounting:	Surface	**Wires:**	4	**Bus Rating:**	100 A
Enclosure:	Type 1			**MCB Rating:**	100 A

CKT	Circuit Description	Trip	Poles	A		B		C		Poles	Trip	Circuit Description	CKT
1	Lighting GROUP PROJECT/ STUDY 547	20 A	1	3168	3285					1	20 A	Lighting COMPUTING LAB 550	2
3	Lighting INFORMAL LEARNING 563	20 A	1			2963	2260			1	20 A	Lighting GROUP PROJECT/ STUDY 575	4
5	Lighting CORRIDOR590	20 A	1					1000	1449	1	20 A	Lighting CORRIDOR-2 593-2	6
7	Lighting Room 655,653	20 A	1	3428	0 VA					1	20 A	Spare	8
9	Spare	20 A	1			0 VA	0 VA			1	20 A	Spare	10
11	Spare	20 A	1					0 VA	0 VA	1	20 A	Spare	12
13	Spare	20 A	1	0 VA	0 VA					1	20 A	Spare	14
15	Spare	20 A	1			0 VA	0 VA			1	20 A	Spare	16
17	Spare	20 A	1					0 VA	0 VA	1	20 A	Spare	18
19	Space	--	--	0 VA	0 VA					--	--	Spare	20
21	Space	--	--			0 VA	0 VA			--	--	Space	22
23	Space	--	--					0 VA	0 VA	--	--	Space	24
25	Space	--	--	0 VA	0 VA					--	--	Space	26
27	Space	--	--			0 VA	0 VA			--	--	Space	28
29	Space	--	--					0 VA	0 VA	--	--	Space	30
			Total Load:	9881 VA		5223 VA		2449 VA					
			Total Amps:	36 A		19 A		9 A					

Load Classification	Connected Load	Demand Factor	Estimated Demand	Panel Totals	
Lighting	17553 VA	80.00%	14042 VA		
				Total Conn. Load:	17553 VA
				Total Est. Demand:	14042 VA
				Total Conn.:	21 A
				Total Est. Demand:	17 A

Panelboard: L11A (Unchanged)

Location:	ELEC 154	**Volts:**	208Y/120	**A.I.C. Rating:**	10,000
Supply From:		**Phases:**	3	**Mains Type:**	MCB
Mounting:	Surface	**Wires:**	4	**Bus Rating:**	225 A
Enclosure:	Type 1			**MCB Rating:**	100 A

CKT	Circuit Description	Trip	Poles	A		B		C		Poles	Trip	Circuit Description	CKT
1	Power FIRE PUMP/DOMESTIC WATER 152	20 A	1	110	75					1	20 A	Power ELEC 154	2
3	Power SUBSTATION _732	20 A	1			145 VA	110 VA			1	20 A	Power	4
5	EF-11	20 A	1					828 VA	110 VA	1	20 A	Power SUBSTATION 160	6
7	Receptacle Space _728	20 A	1	360 VA	1080					1	20 A	Receptacle HAZARD. WASTE 156B	8
9	Receptacle OFFICE 156H	20 A	1			900 VA	180 VA			1	20 A	Receptacle VENDING 164	10
11	Receptacle FAMILY TOILET 166	20 A	1					900 VA	720 VA	1	20 A	Receptacle GROUP PROJECT/STUDY 168C	12
13	Receptacle CORRIDOR 195	20 A	1	900 VA	720 VA					1	20 A	Receptacle	14
15	Receptacle JC 155	20 A	1			540 VA	720 VA			1	20 A	Receptacle SUBSTATION 160	16
17	Receptacle STORAGE CAGES 163	20 A	1					900 VA	180 VA	1	20 A	Receptacle SUBSTATION 160	18
19	Spare	20 A	1	0 VA	200 VA					1	20 A	LCP	20
21	Power FAMILY TOILET 166	20 A	1			1500	1500			1	20 A	Power M TOILET 171	22
23	Power W TOILET 169	20 A	1					1500	1200	1	20 A	Receptacle VENDING 164	24
25	Receptacle VENDING 164	20 A	1	1200	1200					1	20 A	Receptacle VENDING 164	26
27	Receptacle VENDING 164	20 A	1			1200	1200			1	20 A	Receptacle VENDING 164	28
29	EF-10	20 A	1					828 VA	368 VA	1	20 A	Power CORRIDOR 195	30
31	Power SHIPPING/ RECEIVING LOADING 156	20 A	1	828 VA	0 VA					1	20 A	Spare	32
33						0 VA	501 VA			1	20 A	Lighting 200 SEAT CLASSROOM 116	34
35	Spare	20 A	1					0 VA	0 VA	1	20 A	Spare	36
37	Spare	20 A	1	0 VA	0 VA					1	20 A	Spare	38
39	Spare	20 A	1			0 VA	0 VA			1	20 A	Spare	40
41	Spare	20 A	1					0 VA	0 VA	1	20 A	Spare	42
			Total Load:	6673 VA		8496 VA		7534 VA					
			Total Amps:	56 A		71 A		63 A					

Load Classification	Connected Load	Demand Factor	Estimated Demand	Panel Totals	
Lighting	501 VA	80.00%	401 VA		
Power	6446 VA	30.00%	1934 VA	**Total Conn. Load:**	22703 VA
Receptacle	14100 VA	85.46%	12050 VA	**Total Est. Demand:**	15378.06 VA
Mechanical Equipment	1656 VA	60.00%	994 VA	**Total Conn.:**	63 A
				Total Est. Demand:	43 A

Short Circuit Analysis

A short circuit analysis was performed in accordance with the National Electrical Code and with guidance from the Cooper Bussmann Short Circuit Current Calculations

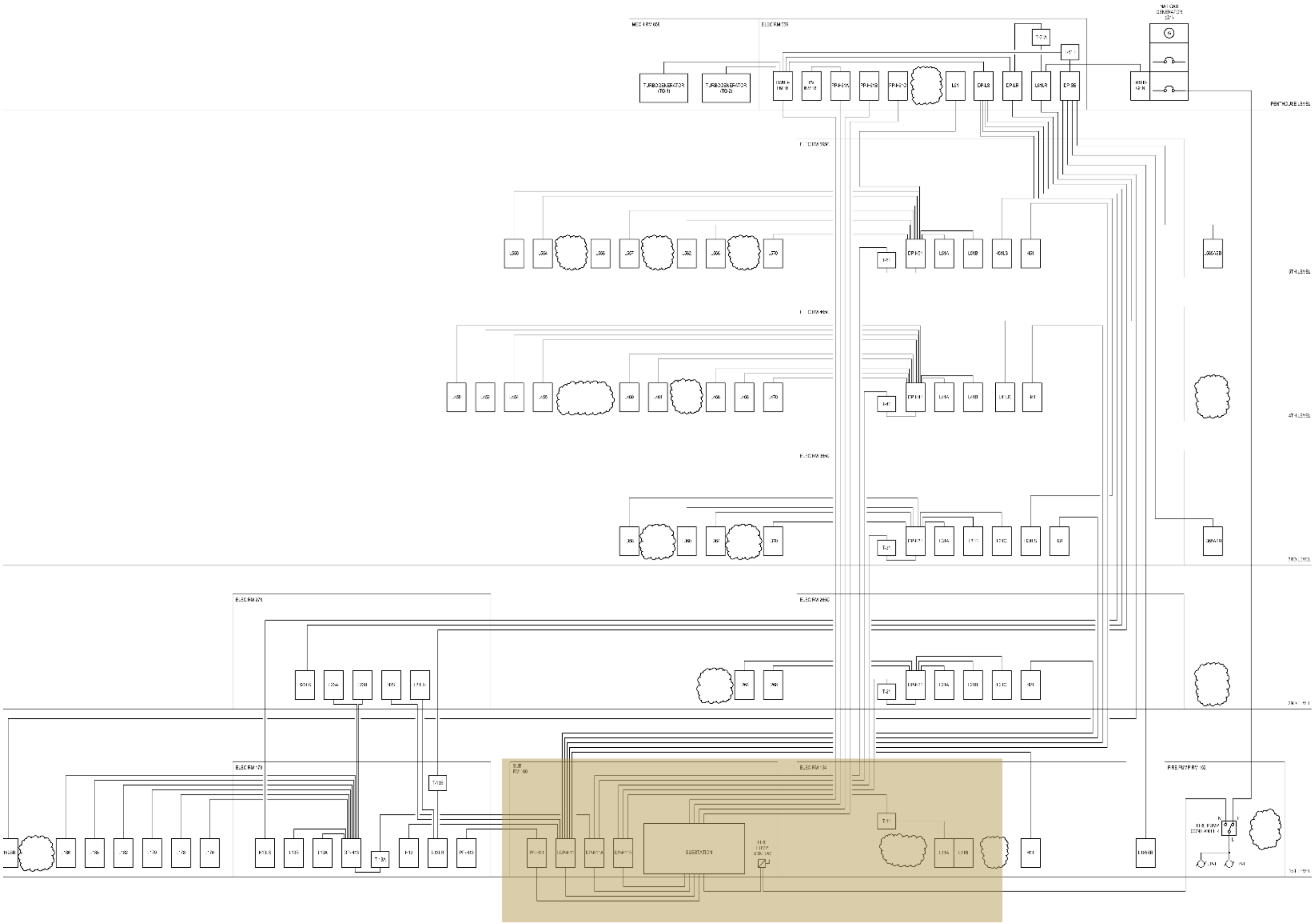


Figure 42 One Line Diagram of the Building

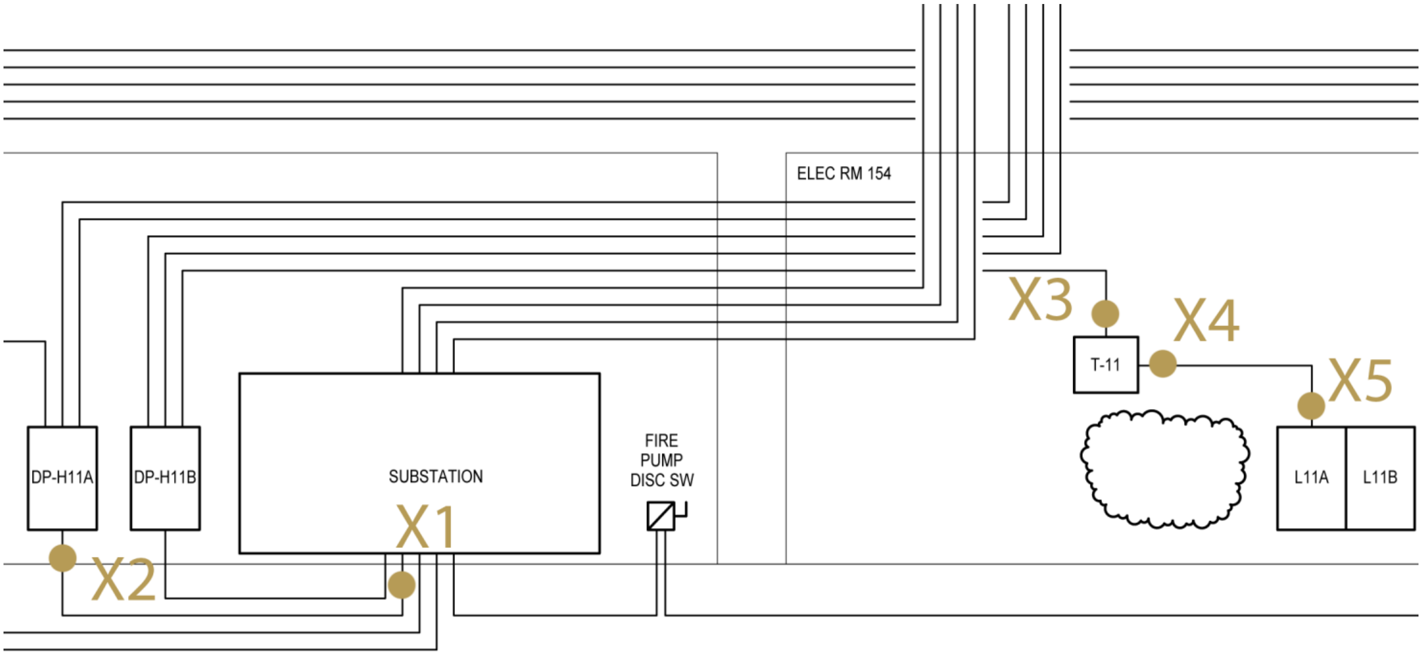


Figure 43 Enlarged One-Line Showing Fault Locations

FAULT X1

Available Utility Infinite Assumption

1500 KVA Transformer, 13.2kV - 480Y/277V, 3Φ, 3.5%Z

Step 1. $3\emptyset\ Transformer\ I_{FLA} = \frac{kVA \times 1000}{E_{LL} \times 1.732} = \frac{1500 \times 1000}{480 \times 1.732} = 1804.27$

Step 2. $Multiplier = \frac{100}{3.5} = 28.57$

Step 3. $I_{S.C.} = 1804.27 \times 28.57 = 51{,}551A$

Step 4. $f\ factor = \frac{1.732 \times L \times I_{3\emptyset}}{C \times n \times E_{LL}} = \frac{1.732 \times 0 \times 1804.27}{28752 \times 2 \times 480} = 0$

Step 5. $M = \frac{1}{1+f} = 1$

Step 6. $I_{s.c.symRMS} = I_{s.c.} \times M = 51{,}551\ A$

Step 6A. No motor short circuit contribution.

FAULT X2

This fault is just before the distribution panel, DP-H11A, located in the substation room 160 with the primary transformers. This fault is approximately 18.25 feet from the first fault.

Step 4. $f\ factor = \frac{1.732 \times L \times I_{3\emptyset}}{C \times n \times E_{LL}} = \frac{1.732 \times 18.25 \times 51551}{28752 \times 2 \times 480} = 0.0590$

Step 5. $M = \frac{1}{1+f} = \frac{1}{1+0.059034} = 0.944$

Step 6. $I_{s.c.symRMS} = I_{s.c.} \times M = 51551 \times 0.944 = 48{,}677\ A$

Step 6A. No motor short circuit contribution.

FAULT X3

Fault 3 is directly before the low voltage transformer T11 in the electrical room 154. Faults 2 and 3 are approximately 53.75 feet apart.

Step 4. $f\ factor = \frac{1.732 \times L \times I_{3\emptyset}}{C \times n \times E_{LL}} = \frac{1.732 \times 53.75 \times 48677}{3830 \times 1 \times 480} = 2.465$

Step 5. $M = \frac{1}{1+f} = 0.289$

Step 6. $I_{s.c.symRMS} = I_{s.c.} \times M = 48677 \times 0.289 = 14{,}048\ A$

Step 6A. No motor short circuit contribution.

FAULT X4

This fault lies directly after the transformer T11 and uses slightly adjusted equations.

Step A. $f\ factor = \frac{I_{S.C.primary} \times V_{primary} \times 1.732 \times (\%Z)}{100{,}000 \times KVA_{transformer}} = \frac{14{,}048 \times 480 \times 1.732 \times 1.0}{100{,}000 \times 45} = 2.595$

Step B. $M = \frac{1}{1+f} = \frac{1}{1+2.595} = 0.278$

Step C. $I_{s.c.secondary} = \left(\frac{V_{primary}}{V_{secondary}}\right) \times I_{s.c.primary} \times M = 9{,}017\ A$

Step 6A. No motor short circuit contribution.

FAULT X5

The final fault is directly before the branch circuit panel L11A, which is also located in electrical room 154 about 3.25 feet from the transformer T11.

Step 4. $f\ factor = \frac{1.732 \times L \times I_{3\emptyset}}{C \times n \times E_{LL}} = \frac{1.732 \times 3.25 \times 9017}{617 \times 1 \times 208} = 0.395$

Step 5. $M = \frac{1}{1+f} = \frac{1}{1+0.395} = 0.717$

Step 6. $I_{s.c.symRMS} = I_{s.c.} \times M = 9017 \times 0.717 = 6{,}461\ A$

Step 6A. No motor short circuit contribution.

Below is a table summarizing the above calculations and also showing the conductors that were chosen when going through the calculations which were used to fine the 'C' values. In order to determine whether or not the calculations were done correctly, Cooper Bussmann's online short circuit calculation software, FC^2, was used. The results from the website with normal impedance came out the same as these results and can be found in Appendix V. When the max impedance of -10% was used, the values were still fine in terms of the equipment AIC ratings which shows that the equipment was conservatively oversized.

Short Circuit Calculation (Cooper Bussmann Method, see References)

Fault Point	Panel/XFMR	E_{LL} (V)	XFMR (%Z)	I_{FLA}	M	$I_{S.C.}$	L (ft)	Conductors + Busways n	Conductors + Busways Size	Conductor Material	'C' Value	f	M	$I_{s.c.symRMS}$	AIC Rating
1	1500 kVA TR-B2	480	3.50	1804.27	28.57	51551	0	2	600 kcmil	Copper	28752	0	1	51551 A	100000
2	DP-H11A	480	-	-	-	51551	18.25	2	600 kcmil	Copper	28752	0.059034	0.944256	48677 A	65000
3	T11 Before	480	-	-	-	48677	53.75	1	#4 AWG	Copper	3830	2.464963	0.288603	14048 A	65000
4	T11 After	208	1.00	0.000125	100.00	14048	-	1	#12 AWG	Copper	617	2.595387	0.278134	9017 A	65000
5	L11A	208	-	-	-	9017	3.25	1	#12 AWG	Copper	617	0.395495	0.716592	6461 A	10000

Figure 44 Short Circuit Calculation Summary

Conclusions

Though the analyses of the electrical systems were merely surface level and reactionary, they showed that the lighting changes were minimal. The electrical system would not need to have any resizing and the branch circuits are all still conservatively designed. If there were more time, a downsizing of the branch panels and distribution panels could have been done, but not advised due to future changes in building use and additions that could be in store as the University grows and the School of Engineering and Computer Science engrains itself into the new building.

MAE DAYLIGHTING |

Overview

The daylighting in the project labs space has been improved to provide the space with an improved appearance during the daytime and a more energy efficient space by photosensor dimming of the electric lighting. Firstly, an analysis of the existing conditions showed that the space was not receiving very much sunlight as the only glazing was on the northern side of the space. As a fairly large space, and one that requires higher illuminances, it seemed a logical space to try to improve the daylighting and harness natural light to provide task plane illuminance. Since the space is only open to the north for side lighting and there is a roof deck directly above the space, top lighting is the most logical means to improvement. For this daylighting analysis, many different skylight systems were researched to try to find the best way to integrate into the existing architecture, structural grid, and mechanical equipment layout in the space. In order to accomplish the best integration and to maximally enhance the design of the building, Kalwall Skyroof systems were chosen as the basis for this study.

Introduction to Kalwall

The technology behind the Kalwall panel system is a great architectural material due to its structural strength, diffuse visual light transmittance capabilities, and incredible insulation properties far exceeding most glazing systems. The Kalwall panel is a structural composite sandwich panel formed of translucent fiberglass sheets bonded to a grid core of interlocking I-beams that are thermally broken. Kalwall products are custom made to fit the design needs and have a multitude of design choices. The custom Skyroof skylights are also lightweight at less than 3 lbs./ft^2 and structurally sound. For these reasons, the Skyroof product line was chosen for this study.

Integration

The layout for the skylights and the specific product were chosen in order to minimally affect the architecture, structure, and mechanical systems and maximize the daylighting capabilities. The structural members are approximately 8 feet on center going east to west across the project labs space and there are four large fans hanging in the center of the room 30 feet apart from each other with a blade diameter of 10 feet. For this reason, it was decided that the most integrative way to implement the skylights was to use three of the self-supporting ridge Skyroof product with plan dimensions of 8 feet by 20 feet as shown in the image below. Kalwall representatives confirmed that these dimensions can be used for this product. The self-supporting ridge product is also visually appealing for the pedestrian-accessible rooftop and structurally sound adding to the benefits of using this system.

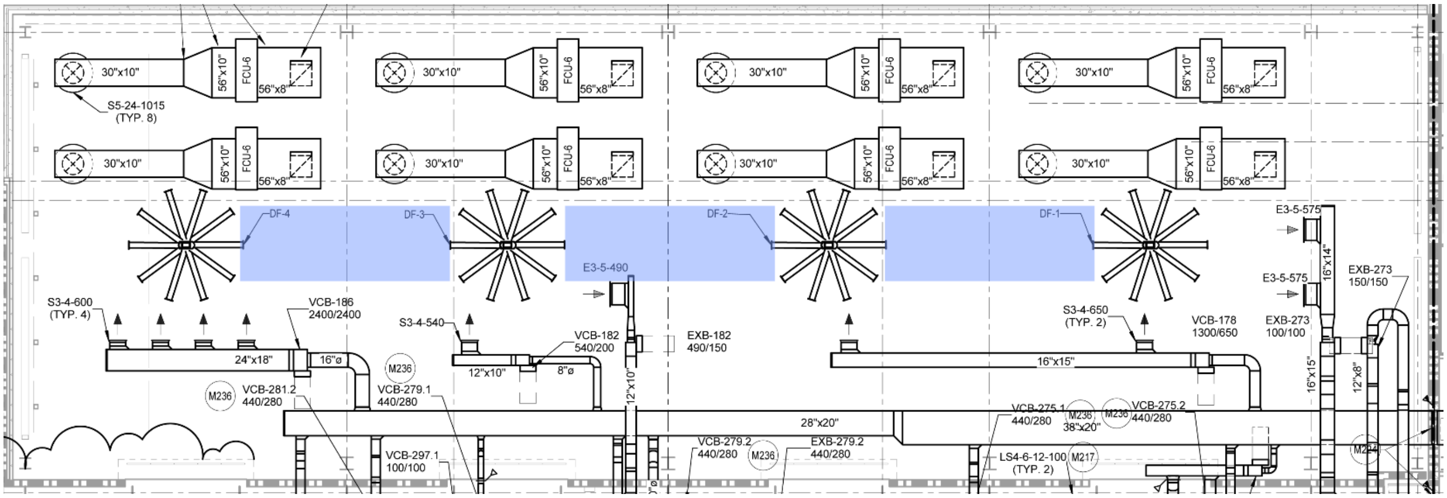


Figure 45 Skylight Integration

Self-Supporting Ridge Roof with Hip Ends

Plan Dimensions – 8′ x 20′

Angle of Inclination - 27°

Panel Type – 2-3/4″ panels, Crystal outside / White inside, with VLT of 20%

KALWALL®

high performance translucent building systems

LIGHT TRANSMISSION & SOLAR HEAT GAIN COEFFICIENT FOR 2 ¾" (70mm) PANELS

(For 4" (100mm) Light Transmission & Solar Heat Gain Coefficent values, see Page 9.10)

FACE SHEET COMBINATION note 1,5		% LIGHT TRANSMISSION note 2					WALL SYSTEM SOLAR HEAT GAIN COEFFICIENT AT 0° note 3				
EXTERIOR COLOR	INTERIOR COLOR	0.53 "U" note 4	0.29/0.23 "U"	0.22/0.14 "U"	0.18/0.10 "U"	0.05 "U"	0.53 "U"	0.29/0.23 "U"	0.22/0.14 "U"	0.18/0.10 "U"	0.05 "U"
Greenish Blue	White	25	14	5	3	14	0.50	0.23	0.14	0.10	0.19
Aqua	White	29	17	6	4	15	0.45	0.24	0.14	0.10	0.21
Rose	White	30	18	6	4	16	0.46	0.24	0.15	0.10	0.21
Ice Blue	White	35	20	8	6	21	0.54	0.28	0.17	0.12	0.26
Greenish Blue	Crystal	37	20	7	4	NA	0.53	0.26	0.16	0.11	NA
Aqua	Crystal	43	23	7	4	NA	0.55	0.27	0.16	0.11	NA
Rose	Crystal	48	24	8	5	NA	0.57	0.28	0.17	0.12	NA
Ice Blue	Crystal	53	27	10	6	NA	0.68	0.32	0.19	0.13	NA
White	Crystal	30	18	12	8	NA	0.46	0.24	0.14	0.10	NA
White	White	20	15	8	5	14	0.38	**0.23**	**0.15**	**0.11**	**0.18**
Crystal	White	35	20	12	8	20	0.52	**0.28**	**0.17**	**0.13**	**0.25**
Crystal	Crystal	50	30	15	10	NA	0.65	**0.33**	**0.18**	**0.13**	NA
Crystal SWC	White	29	16	9	6	16	0.47	0.25	0.15	0.10	0.23
Crystal SWC	Crystal	44	22	11	8	NA	0.58	0.29	0.17	0.12	NA

Figure 46 Kalwall Panel Choices

Daysim

For the analysis, DaysimPS was used to determine the light levels achieved, annual daylighting metrics, dimming capabilities, and cost savings from dimming. A simplified model of the project labs space was created in AutoCAD, with and without the skylight geometries added in, and converted to .rad files with dxf2rad.exe. The material file was created with generalized reflectances given to all of the opaque geometries, a 63% VLT glass as per SmithGroupJJR drawings, and the Kalwall trans-material was specified as per Christoph Reinhart's paper entitled "Development and validation of a Radiance model for a translucent panel" shown in the image below. For the Daysim runs, an assumed occupancy schedule was created, a location specific weather file was used, and the luminaires specified in the lighting depth were added.

```
# RADIANCE "trans" model of a translucent panel assuming
# only direct normal hemispherical transmittance is available
# Rd = Cr = Cg = Cb = 0.21 = diffuse reflectance
# Rs = A4 =0.08 = specular reflectance
# Sr = 0.0 = surface roughness
# Td = 0.24 = direct normal diffuse hemispherical transmittance
# Ts = 0 = transmitted specularity (ideal diffuser)
# A7 = Ts/(Td+Ts) = 0
# A6 = (Td+Ts)/(Rd+Td+Ts) = 0.5333
# A5 = Sr = 0
# A1 = A2 =A3 = Rd/((1-Rs)*(1-A6)) = 0.48913
# St = A6*A7*(1-A1)*A4 = 0
# resulting Radiance material:
void trans PANEL
0
0
7 0.48913 0.48913 0.48913 0.08 0  0.5333 0
# A1      A2      A3      A4   A5 A6     A7
```

Figure 47 Kalwall Radiance Material

```
Mat.rad - Notepad
File  Edit  Format  View  Help
#####################################################
# Daysim Material File
# JOHN CONLEY
# Oakland University - Engineering Center
#####################################################

void plastic l_surrounds 0 0 5 0.3000 0.3000 0.3000 0.0000 0.0000

void plastic l_walls 0 0 5 0.5000 0.5000 0.5000 0.0000 0.0000

void plastic l_ceiling 0 0 5 0.8000 0.8000 0.8000 0.0000 0.0000

void plastic l_floor 0 0 5 0.3 0.3 0.3 0.0000 0.0000

void plastic l_mullions 0 0 5 0.5000 0.5000 0.5000 0.0000 0.0000

void plastic l_metalpnl 0 0 5 0.5000 0.5000 0.5000 0.0000 0.0000

void glass l_glass 0 0 3 0.697575 0.697575 0.697575

void plastic l_roofwall 0 0 5 0.5000 0.5000 0.5000 0.0000 0.0000

#20% transmitance kalwall crystal-white

void trans l_kalwall1 0 0 7 0.445652174 0.445652174 0.445652174 0.08 0 0.487804878 0
```

Figure 48 Material .rad file

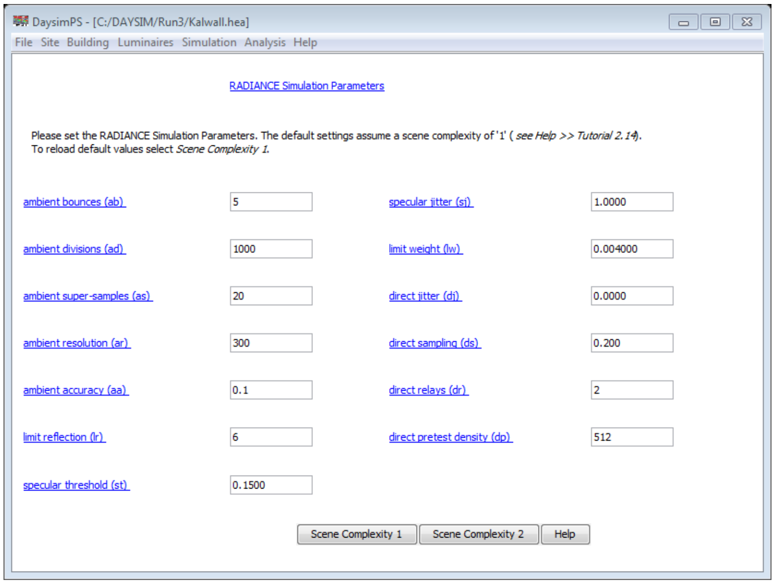


Figure 49 Daysim Simulation Settings

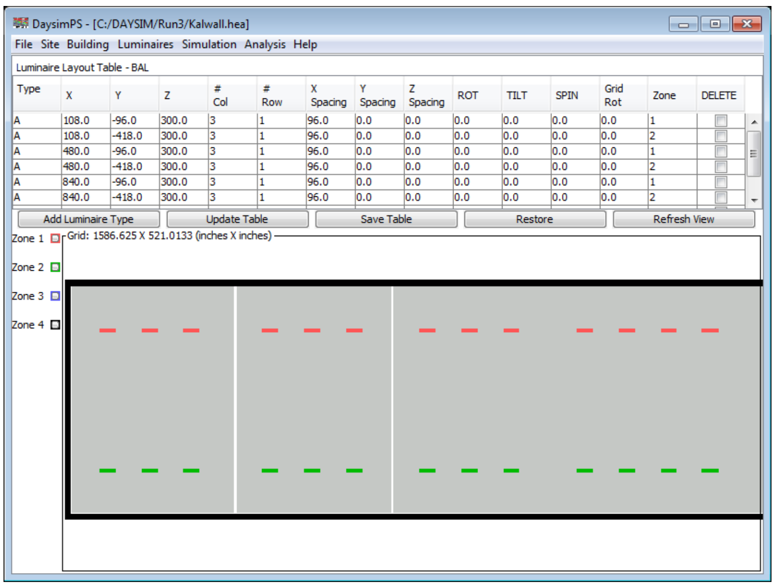


Figure 50 Luminaire Layout and Schedule (2 Zones)

Comparisons

The following section is a series of comparisons between the project labs space with and without the skylights added. In all aspects, it appears that with the added skylights, the daylighting condition in the space will be greatly enhanced by reaching further into the space and providing higher levels of daylight for more of the year. It can also be noted that with the addition of the skylights, the illuminance levels greatly increase on the north side of the space due to skylight and window contributions. Since this is the north side of the building, it is not beneficial to look into shading systems to lessen the lighting level. However, the situation lends itself very nicely to photosensor control of the dimming of zone 1 of the electric lighting.

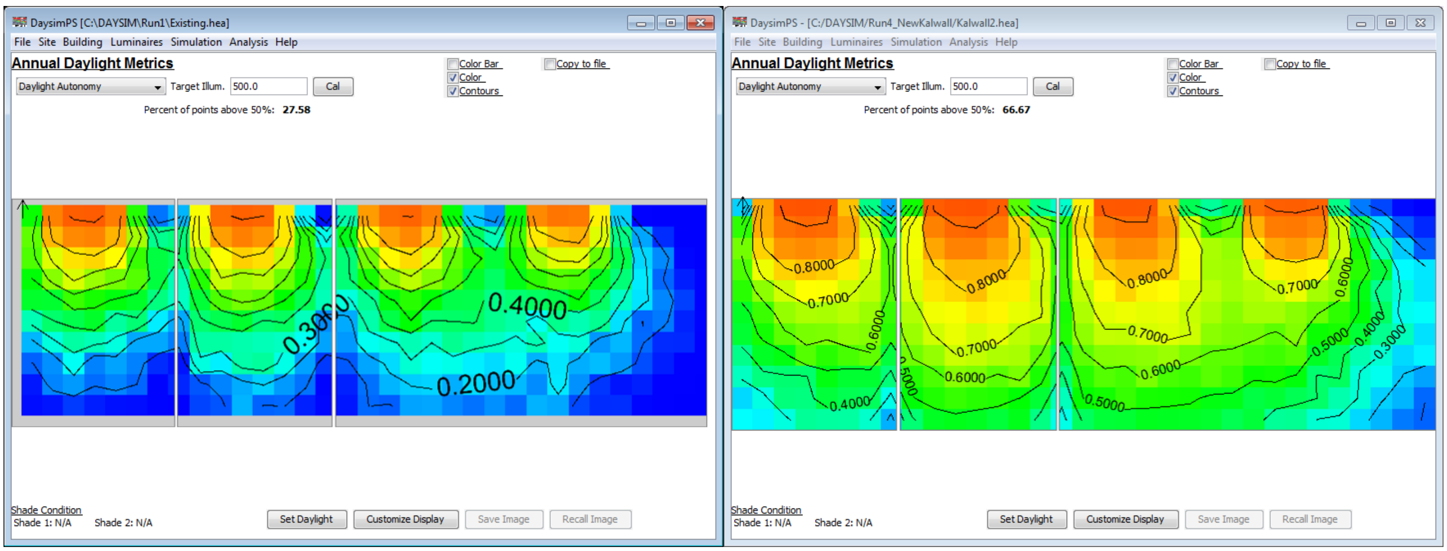


Figure 51 Daylight Autonomy Comparison (27.58 without, 66.67 with skylights)

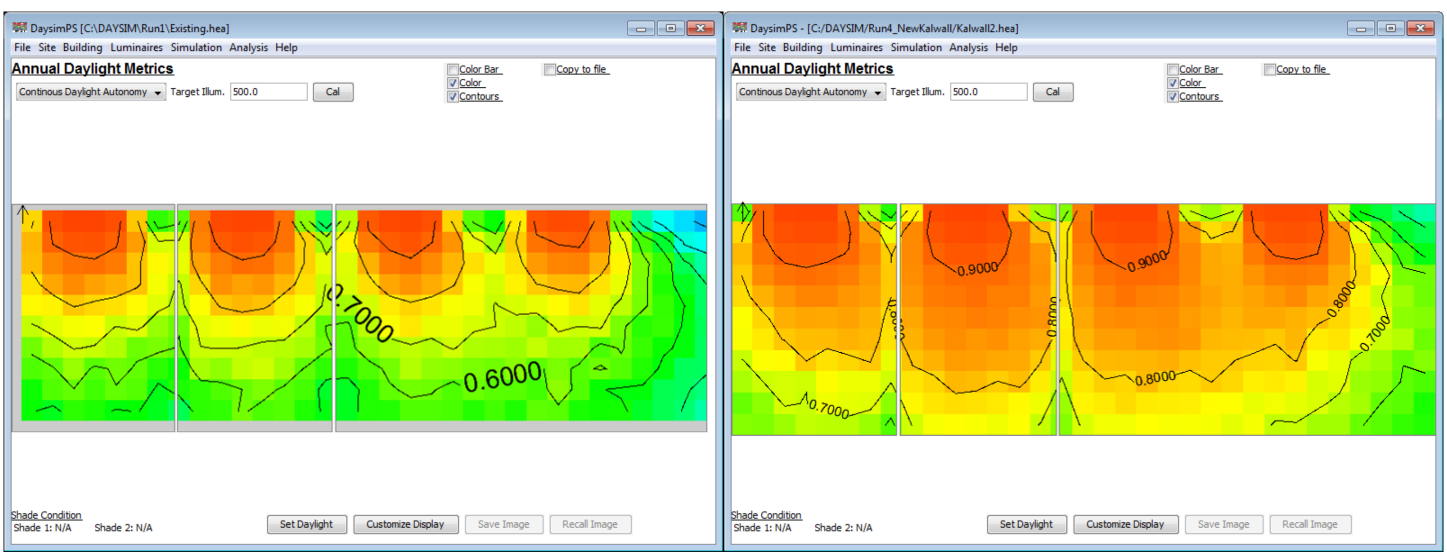


Figure 52 Continuous Daylight Autonomy Comparison

Equinox | June, 21 (Dates are for this year; times are approximately every hour from 8 to 5)

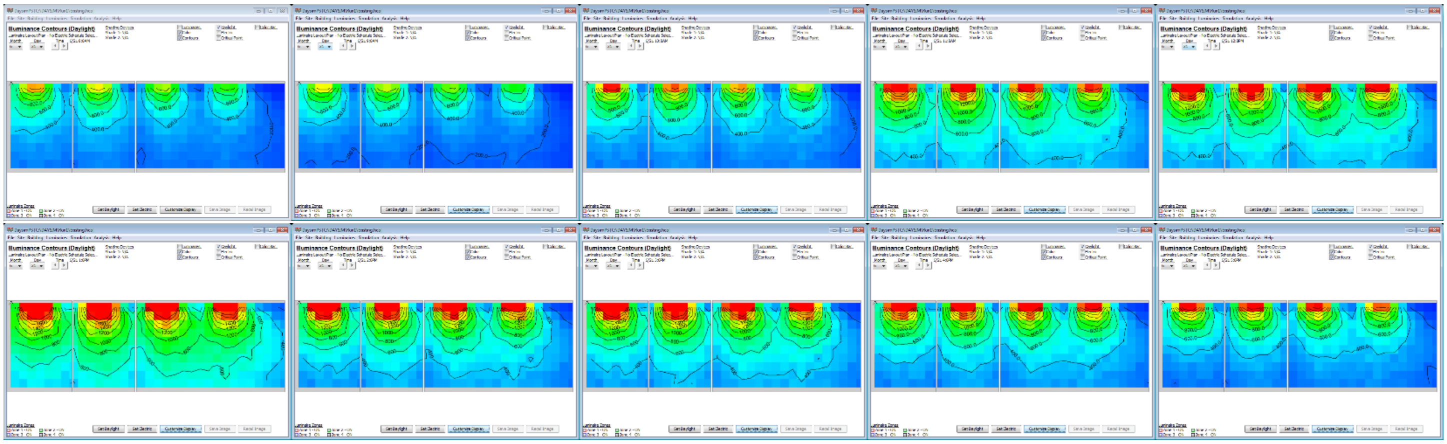


Figure 53 June 21st Without Skylights

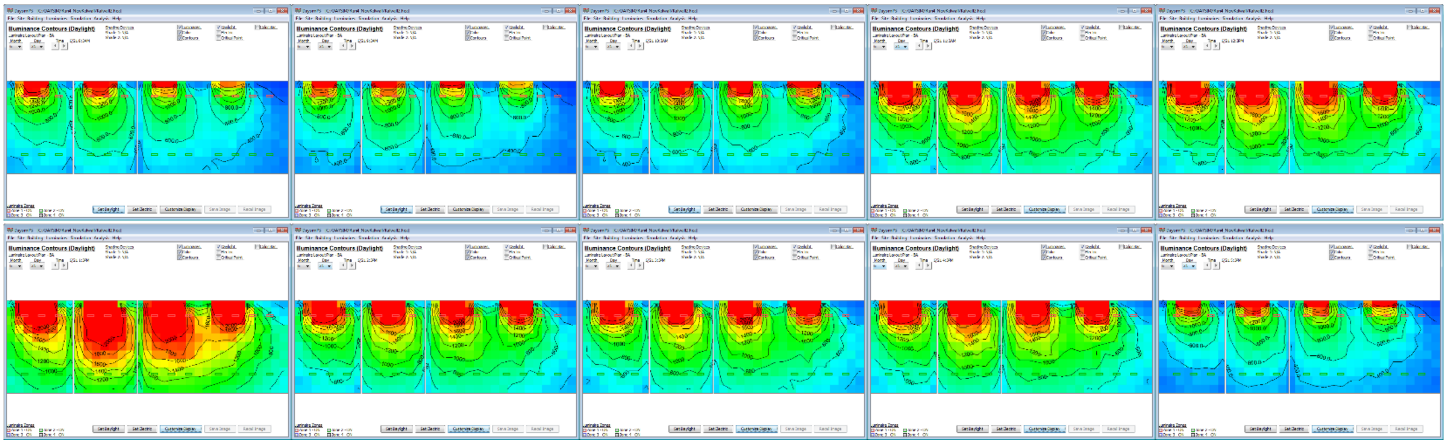


Figure 54 June21st with Skylights

Solstice | September, 23

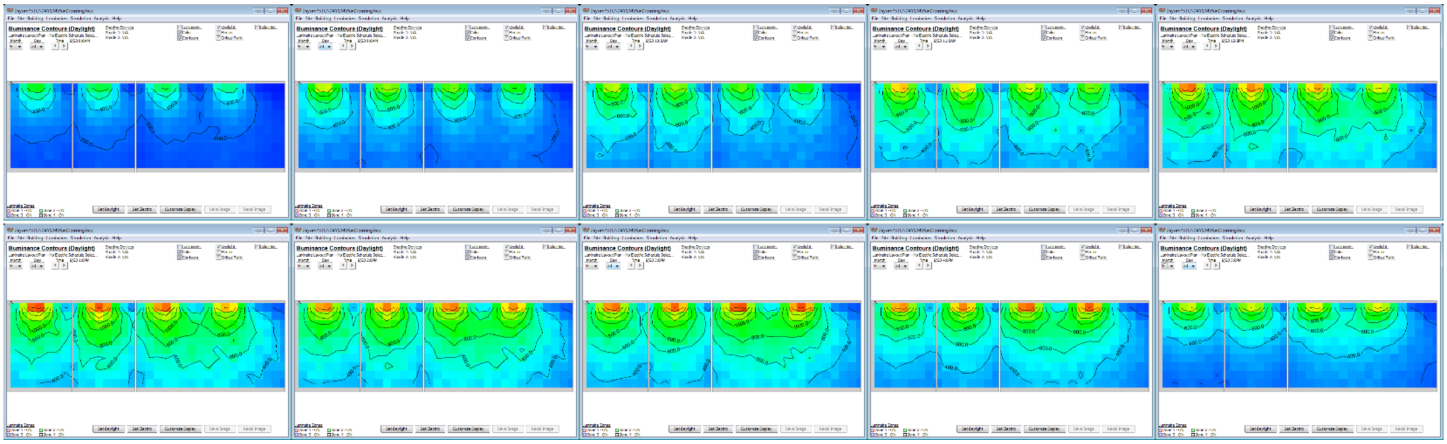


Figure 55 September 23rd Without Skylights

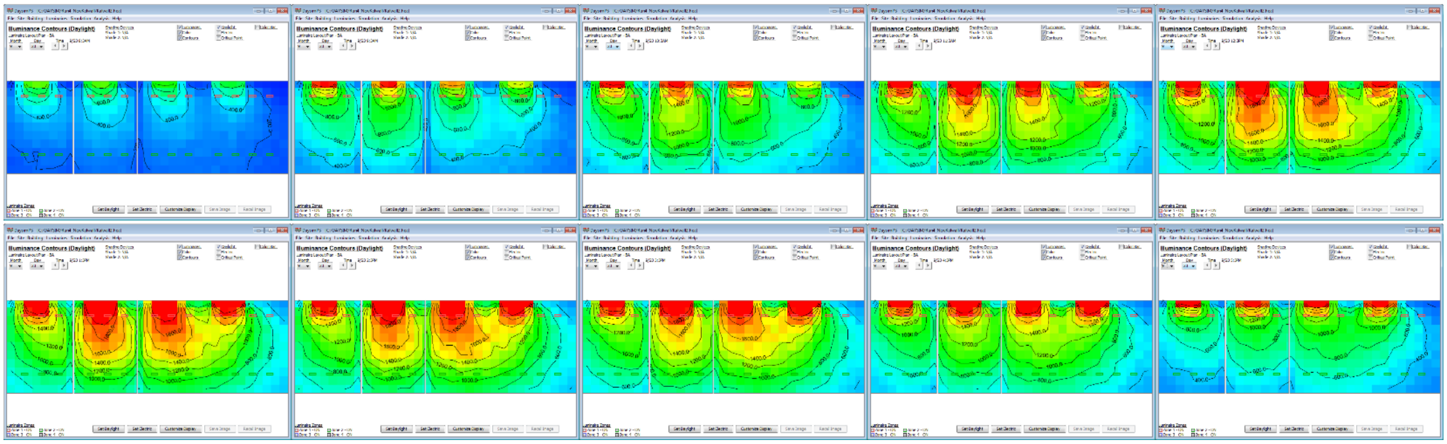


Figure 56 September 23rd with Skylights

Equinox | December, 22

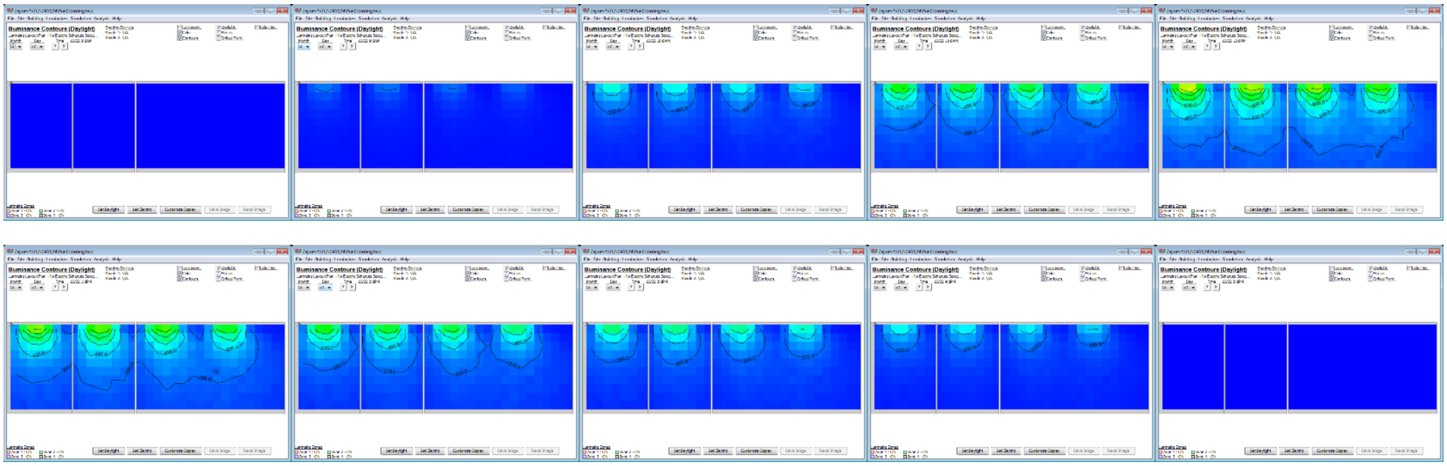


Figure 57 December 22nd Without Skylights

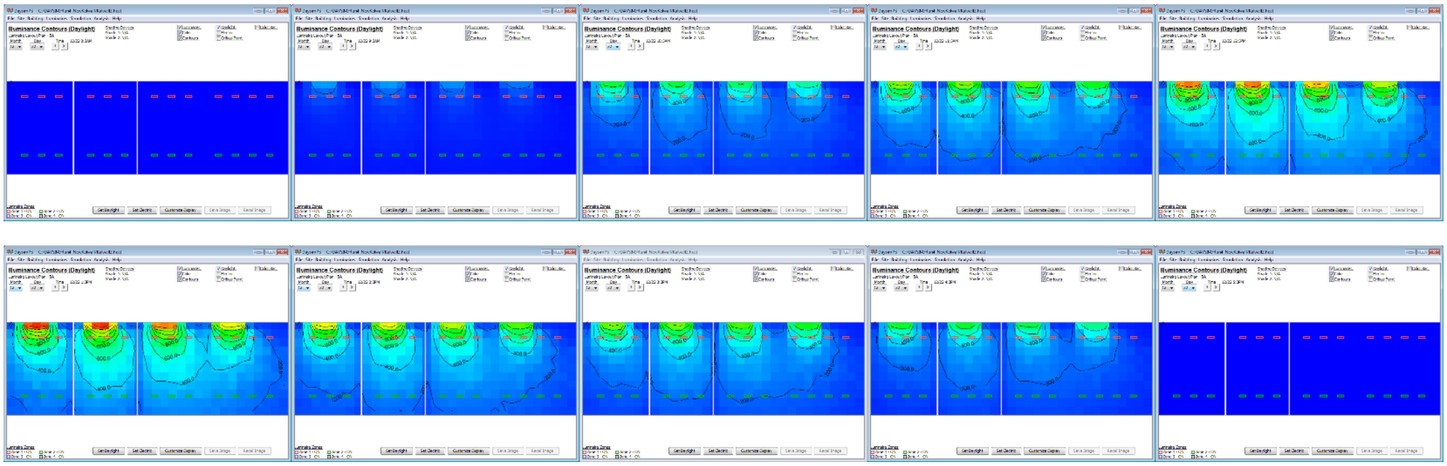


Figure 58 December 22nd with Skylights

Analysis

Dimming of zone 1 is explored by noting the lighting levels of the standalone electric lights and finding a suitable critical point and photosensor algorithm through manipulation of the critical point tool and the photosensor location. Since the Big Ass Lights used in the project labs space have built in photosensors, the photosensor was placed at the level of the luminaires facing downward and used in conjunction with a closed loop proportional algorithm.

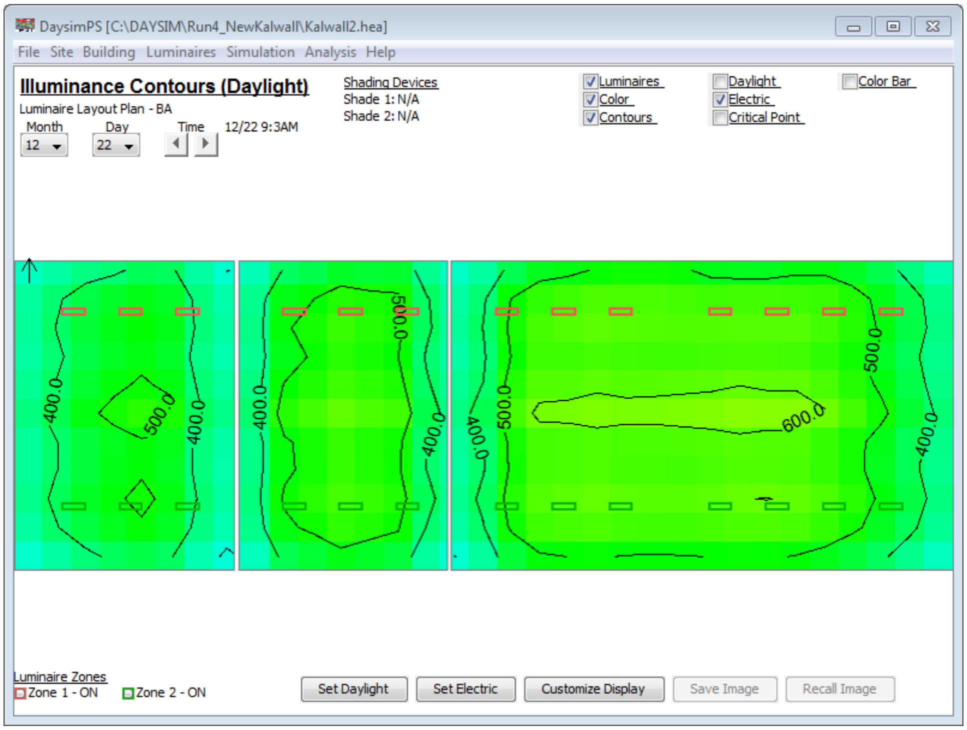
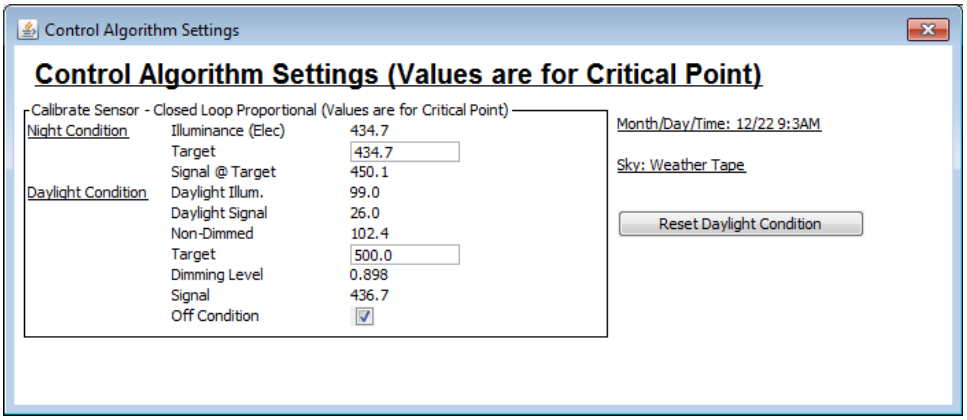


Figure 59 Electric Lighting Levels



Control Algorithm Settings

Control Algorithm Settings (Values are for Critical Point)

Calibrate Sensor - Closed Loop Proportional (Values are for Critical Point)

Night Condition	Illuminance (Elec)	434.7
	Target	434.7
	Signal @ Target	450.1
Daylight Condition	Daylight Illum.	99.0
	Daylight Signal	26.0
	Non-Dimmed	102.4
	Target	500.0
	Dimming Level	0.898
	Signal	436.7
	Off Condition	☑

Month/Day/Time: 12/22 9:3AM

Sky: Weather Tape

Reset Daylight Condition

Figure 60 Photosensor Control Algorithm

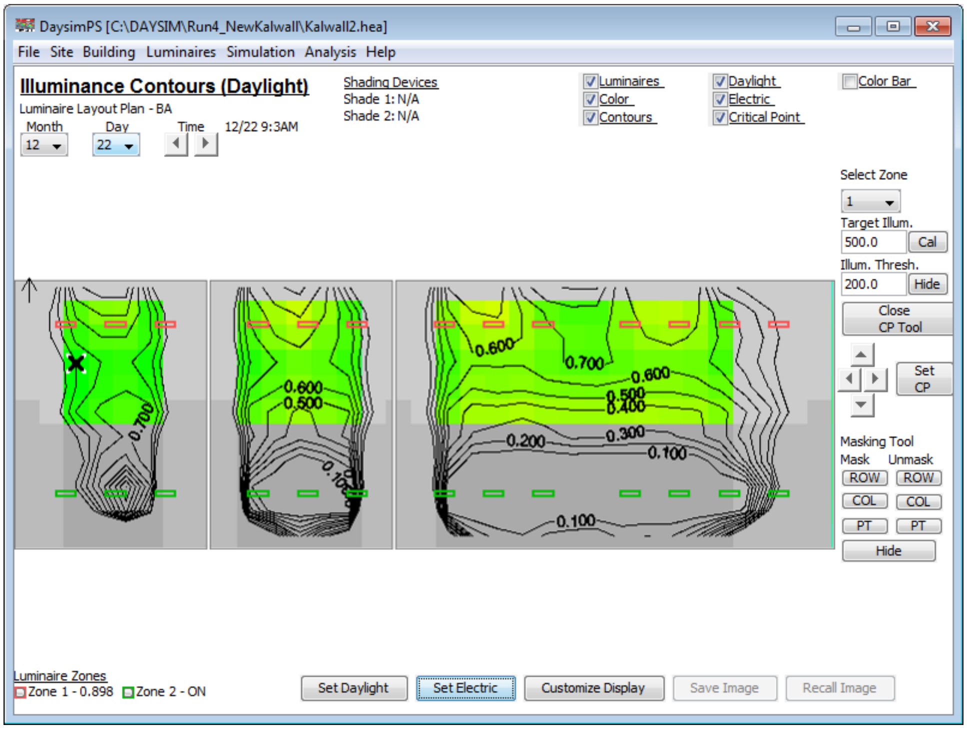


Figure 61 Critical Point Selection

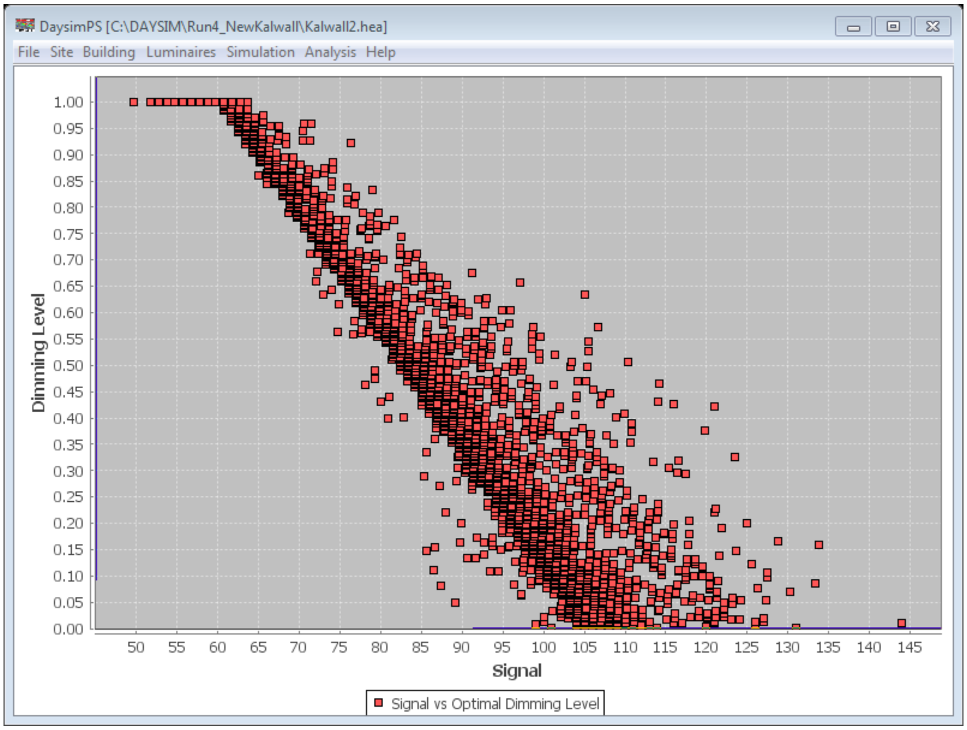


Figure 62 Signal vs. Dimming Level Plot

Savings

Energy Tables (KWh)

Controlled Zone | Grand Total

	January	February	March	April	May	June	July	August	September	October	November	December	Total
Base	327.9	289.52	319.32	306.53	327.9	306.53	319.32	327.9	297.95	327.9	315.11	310.74	3776.65
Optimal	181.33	149.76	161.95	153.86	164.11	153.39	159.72	164.39	150.11	170.5	174.93	186.99	1971.08
Algorithm	179.36	149.45	161.91	153.89	164.11	153.41	159.76	164.38	150.05	169.7	172.63	182.99	1961.7
Savings	148.53	140.06	157.4	152.63	163.78	153.11	159.55	163.52	147.89	158.2	142.48	127.75	1814.95

After a seemingly good critical point was chosen with an acceptable signal vs. dimming plot, the data from the energy table function of Daysim could be looked at. The savings per year amount to around 1814.95 kWh. This number however is less than optimal. At an electricity cost of $0.054/kWh, annual savings due to the dimming of Zone 1 in Daysim would amount to approximately $98. These savings were then compared to SkyCalc savings which are based on a less precise model of the situation. SkyCalc overestimated the savings by 350 kWh/yr, which is pretty impressive due to the simplicity of the information that is used as input for the SkyCalc program. Since Daysim results are probably slightly more correct, these savings will be used to analyze the payback period of the Kalwall skylights which can be found in the Mechanical Breadth section of this report.

Skylighting System Description		**Site Description**		
Skylight unit size (ft^2)	160.0	Climate Location	Pontiac.wea3	
Number of Skylights	3	Climate Zone	CZ5 (cool, 5,400 < HDD65°F <= 7,200)	
Total Skylight Area (ft^2)	480	Building Type	University 9 mo	
Skylight to Floor Ratio (SFR)	8.4%	Building Area	5,704	(ft^2)
Effective Aperture	0.9%			
Floor Area per Skylight	1,901	**Elecric Lighting System Description**		
Skylight U-value	0.230	Lighting Type	Industrial fluorescent	
Skylight SHGC	25%	Lighting Control	Dimming min 5% light	
Skylight T_{vis}	20%	Light Level Setpoint	50	fc
Well Efficiency (WF)	78%	Lighting Density	1.03	W/ft^2
Dirt and Screen Factor	70%	Connected Load	5.9	kW
Overall Skylight System Tvis	11%	Fraction Controlled	50%	
Skylight CU	66%			

Savings from Design Skylighting System			
Savings		**Annual Energy Savings (kWh/yr)**	**Annual Cost Savings ($/yr)**
Lighting		2,165	$116

Figure 63 SkyCalc Output

Conclusions

Daylighting is an important part of any architectural space to render the world in a bright and comfortable light. With the implementation of these Kalwall skylights, the architectural aesthetic of the space is increased as well as providing an informed and integrated solution that will provide savings in the building electricity costs as well. This solution brings together multiple aspects into one integrated product.

Figure 64 Visualization of the Roof Top with Skylights

STRUCTURAL BREADTH |

Overview

Due to the addition of large skylights into the project labs space, which is discussed in more depth in the daylighting section of this report, there is a large decrease in dead weight of the roof. Due to the layout of the structural system as well as the mechanical equipment and fan layouts in the space, the skylights were placed to span between bays in the center of the room. The structural system was analyzed and hand calculations were performed to determine if a resizing of the structural members directly affected by the skylights would be cost beneficial. From these calculations, a small decrease in some of these beams could save the project some money in initial costs but may be disregarded due to an attempt save money with bulk purchase of same-size members.

The figure below shows the main structural members for the 5 bays of the project labs space with the green roof highlighted in green.

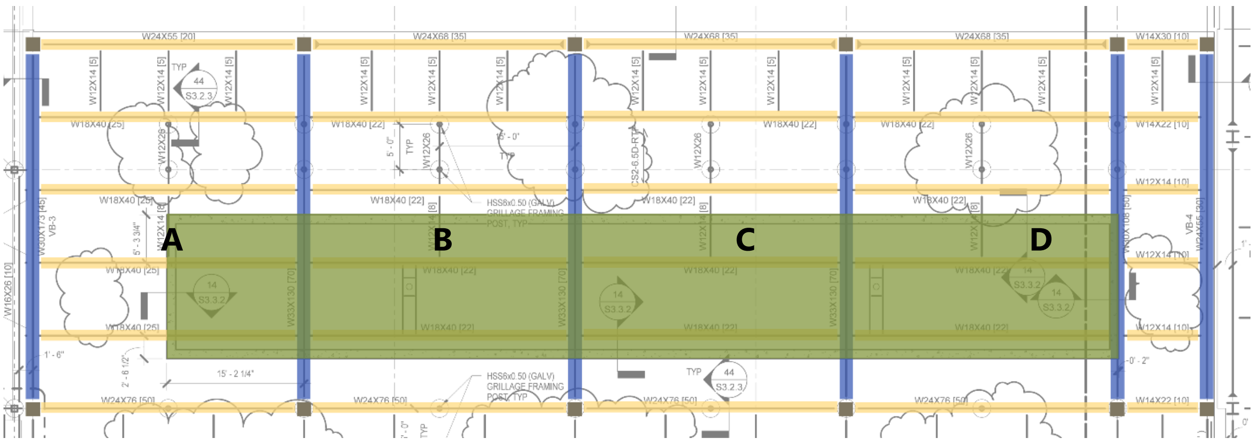


Figure 65 Original Layout with Green Roof Shown

The green roof shift and the addition of the Kalwall SkyRoof is shown in the figure below.

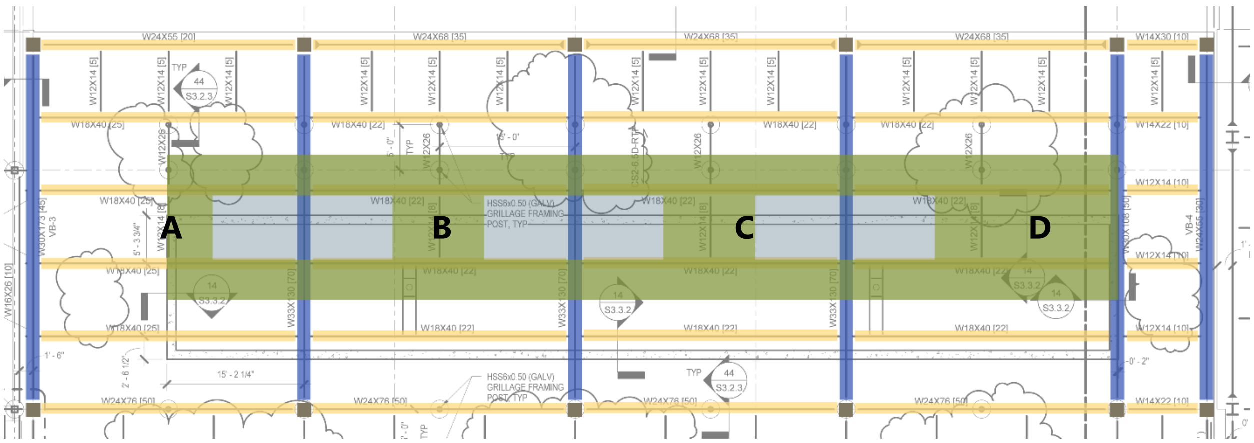


Figure 66 Green Roof Moved and Skylights Added

Loads

To start with, the major loads on the roof were calculated and or researched through ASCE 7-10 and SmithGroupJJR's structural and architectural plans.

Live Load = 100 psf

From the 2010 ASCE 7 Design Loading Code for "Roofs used for roof gardens"

Snow Load = 19.25 psf

Ground Snow Load P_g = 25 psf from Figure 7-1 of ASCE 7-10

Exposure coefficient C_e = 1.1 from Figure 7-2 of ASCE 7-10 and Terrain Category from Section 26.7 for a Sheltered roof of Terrain Category C. *This designation was provided by SmithGroupJJR and checked

Thermal Factor C_t = 1.0 from Figure 7-3 of ASCE 7-10

Importance Factor I_s = 1.0 for normal buildings

$$\boldsymbol{P_f = 0.7C_eC_tI_sP_g = 0.7(1.1)(1.0)(1.0)(25) = 19.25\ psf}$$

The superimposed dead load for a roof, as provided in the SmithGroupJJR plans, is given as 110 psf. This number is providing for some extra safety in the design and thus a calculation was performed, with some approximation, to check the validity of this number.

Greenroof = 35 psf (saturated maximum from SmithGroupJJR specifications)

Roof concrete pavers = 51 psf (calculated based on area and makeup of the roof flooring)

Kalwall SkyRoof System = 3 psf

Misc. Dead Load (Duct, Lights, Plumbing, Sprinklers) = 10 psf

Rigid Insulation = 2 psf

Total SDL = 35+51+3+10+2 = 101 psf

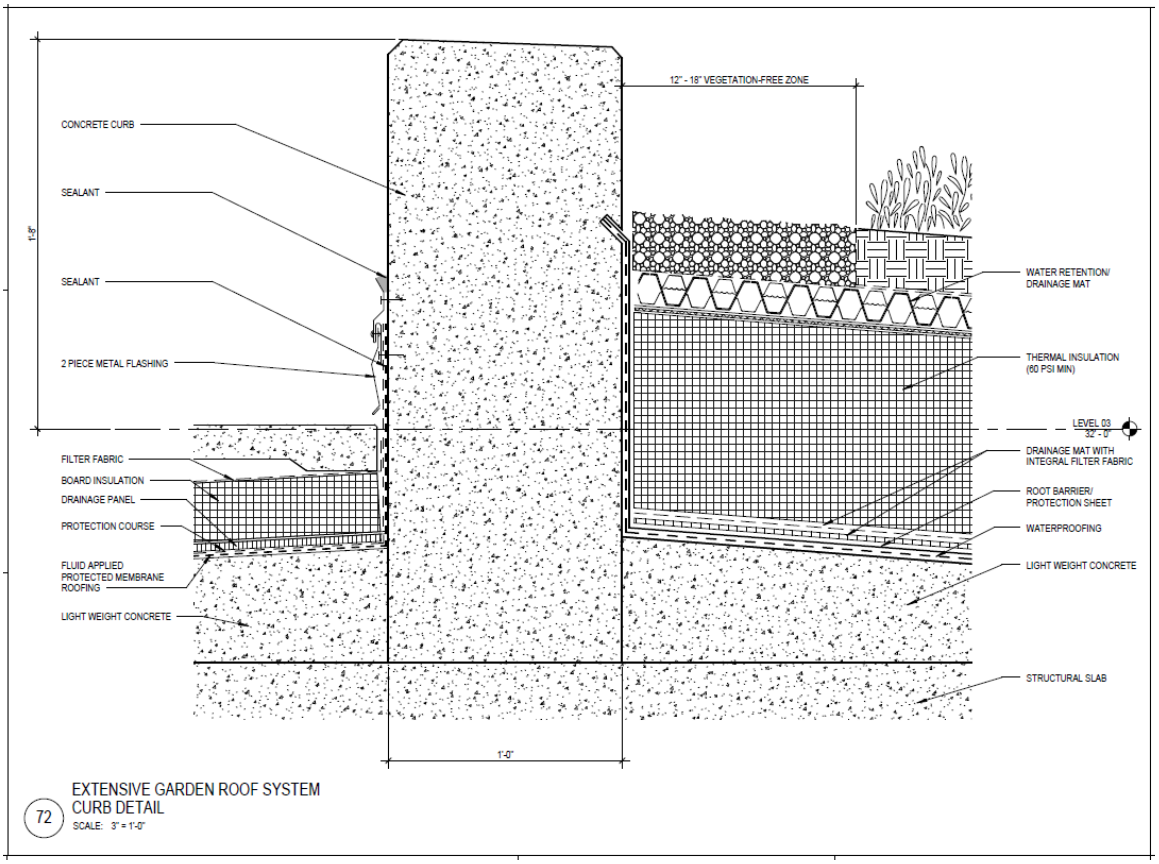


Figure 67 Green Roof Section Detail

Since the calculated value is very close to the 110 psf which is used by SmithGroupJJR, 110 psf will be used. Since the Kalwall skylight system is so light, it will not have much of an impact on the structural member sizes. The following calculations will test the validity of the current beam sizes and determine if there is a possibility of downsizing the beams to save some money structurally with the addition of the skylights. The reason that the current structure is more robust is due to a sliding crane in the SAE lab which has a substructure below the primary beams and girders and has been omitted in this analysis of the structural system as it does not directly affect the sizing of the beams that are being analyzed.

Deck Calculations

The structural plans state that the top of steel is at an elevation of 30'-5 ½" and that the top of concrete elevation is 31'-0". The plans also dictate that a 2" composite floor deck should be used, installed in 3 span lengths only, and with normal weight concrete. Thus, a 2VLI20 Vulcraft deck will be used with a 6 ½" total slab depth. This decking has a SDI maximum unshored clear span of 9'-0" which is greater than the needed 8'-3.8" span necessary in this situation. The superimposed live load for this will then be 264 PSF for an 8'-0" clear span. To check the validity of this deck the following needs to be true, $W_{LL} + W_{misc\ DL} \leq Superimposed\ Live\ Load$. W_{LL} is equal to 100 psf and $W_{misc\ DL}$ is equal to 110 psf, so $210\ psf \leq 264\ psf$ and this composite roof deck will work. This deck will have a dead weight of 69 psf which will be used to specify the beams.

Beam Calculations

The following calculations will look at the beams that are directly affected by the decrease in weight due to the skylight addition and determine if a decrease in beam size is warranted. The dead load for the beam calculations will include a typical beam self-weight allowance of 5 psf, the specified deck weight of 69 psf, and the superimposed dead load used above of 110 psf which includes the roof paver system, greenroof, miscellaneous loads. Live loads for roofs cannot be reduced thus, the live load used will be 100 psf for the roof and 40 psf for the skylight areas. Loading combination 3 will be used in this case because this is a roof calculation with dead loads and a roof live load.

$$\boldsymbol{W_u = 1.2 * (Dead\ Load) + 1.6 * (Live\ or\ Snow\ Load)}$$

The live load is much larger than the snow load, so the live load will be used. For beams along the two lines shown below, the tributary area, shaded in grey, will include partially the typical roof load and partially the new skylight roof load. The only bay that does not have a partial skylight load is bay E, but a calculation for this bay has also been conducted.

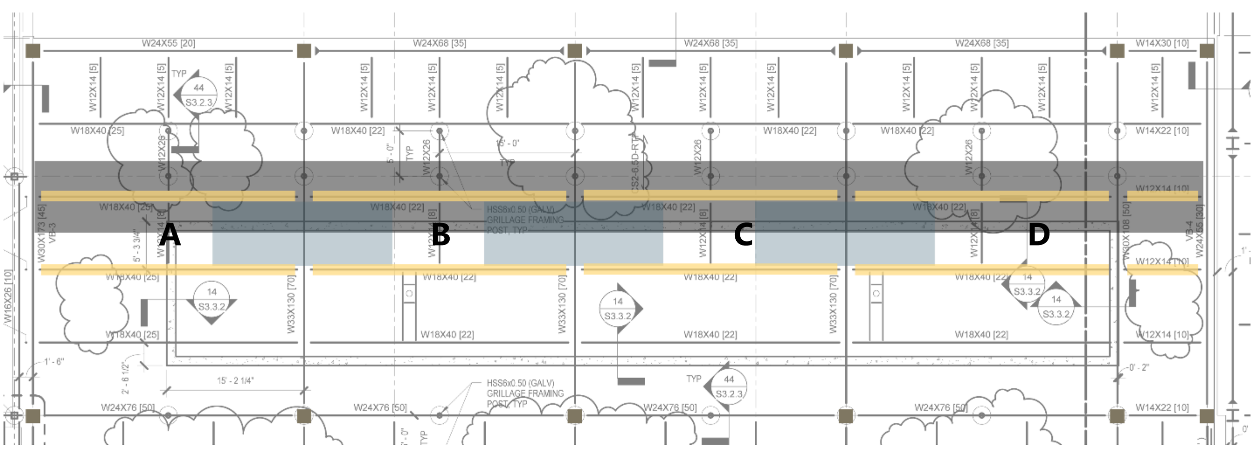


Figure 68 Altered Layout with Beam Tributary Areas Highlighted

For the tributary area with normal roofing conditions the factored load is as follows.

$$\boldsymbol{W_u = 1.2 * (110 + 5 + 69) + 1.6 * (100) = 381\ psf}$$

For the tributary area containing the skylighting system the factored load is as follows.

$$\boldsymbol{W_u = 1.2 * (3) + 1.6 * (40) = 67.6\ psf}$$

For bays A & D the skylight covers approximately ¼ of the tributary area.

$$\boldsymbol{w_u(bays\ A\ \&D) = W_u * \left(\frac{spacing}{1000}\right) = \left(\left(381 * \frac{3}{4}\right) + \left(67.6 * \frac{1}{4}\right)\right) * (8'3.8")/1000\ =\ 2.52\ klf}$$

$$\boldsymbol{V_u = (w_u * l)/2 = (2.52\ klf * 30')/2 = 37.7\ kips}$$

$$\boldsymbol{M_u = (w_u * l^2)/8 = (2.52\ klf * 30'^2)/2 = 283\ kip - ft}$$

The middle bays will assume ½ skylight tributary area.

$$\boldsymbol{w_u(bays\ B\ \&\ C) = W_u * \left(\frac{spacing}{1000}\right) = 0.5 * (381 + 67.6) * (8'3.8")/1000 =\ 1.86\ klf}$$

$$\boldsymbol{V_u = (w_u * l)/2 = (1.86\ klf * 30')/2 = 27.97\ kips}$$

$$\boldsymbol{M_u = (w_u * l^2)/8 = (1.86\ klf * 30'^2)/2 = 210\ kip - ft}$$

For bay E the tributary area is all roof .

$$\boldsymbol{w_u(bay\ E) = W_u * \left(\frac{spacing}{1000}\right) = 381 * ((8'3.8")/2)/1000 =\ 1.58\ klf}$$

$$\boldsymbol{V_u = (w_u * l)/2 = (1.58\ klf * 30')/2 = 7.87\ kips}$$

$$\boldsymbol{M_u = (w_u * l^2)/8 = (1.58\ klf * 30'^2)/2 = 19.6\ kip - ft}$$

Table 3-2 of th AISC Steel Construction Manual, 14th ed. was used to determine the most economical beam size for the strength criteria calculated. For bays A and D, W18x40 was chosen which is the same size that is already installed. For bays B and C, which have more influence by the lighter skylights, W18x35 beams were chosen. For bay E, it was determined that these beams may be oversized at W12x14 when W8x10 beams seem to work with the loading that is present. These sizes were checked against the moment, shear, floor deflection of members due to the accessibility of the roof and the large live load, and against the roof deflection of members. The summary of each of the calculations is shown below and the full calculation process for bays B and C is also outlined.

Bays A and D (0.75 roof, 0.25 skylight)			Bays B and C (0.5 roof, 0.5 skylight)			Bay E (all roof)		
wu	2.52	klf	**wu**	1.86	klf	**wu**	1.58	klf
Vu	37.74	kips	**Vu**	27.97	kips	**Vu**	7.87	kips
Mu	283.03	ft-kip	**Mu**	209.77	ft-kip	**Mu**	19.55	ft-kip
(size) W	18	40	**(size) W**	18	35	**(size) W**	8	10
Vn	169	kips	**Vn**	159	kips	**Vn**	40.2	kips
Mn	294	ft-kip	**Mn**	249	ft-kip	**Mn**	32.9	ft-kip
I	612	in^4	**I**	510	in^4	**I**	30.8	in^4
E	29000	ksi	**E**	29000	ksi	**E**	29000	ksi
wLL	10.22	klf	**wLL**	8.42	klf	**wLL**	12.02405	klf
Defl.	0.010495	in	**Defl.**	0.010372	in	**Defl.**	0.002954	in
L/360	1	in	**L/360**	1	in	**L/360**	0.33125	in
wTL	26.90	klf	**wTL**	19.65932	klf	**wTL**	34.1483	klf
Defl.	0.03	in	**Defl.**	0.024225	in	**Defl.**	0.008389	in
L/240	1.50	in	**L/240**	1.5	in	**L/240**	0.496875	in
Self Wt.	41.58	plf	**Self Wt.**	41.58	plf	**Self Wt.**	41.58	plf

Table 4 Summary of Structural Calculations

Bays B and C are loaded with approximately half roof load and half skylight load in the beam tributary areas. With the max moment and shear calculated above, the beam W18x35 was chosen as the most economical size for strength calculated.

$$V_u = 27.97\ kips\ < 159\ kips = \varphi V_n\ From\ AISC\ Table\ 3-2$$

$$M_u = 210\ ft-kips\ < 249\ ft-kips = \varphi M_n\ From\ AISC\ Table\ 3-2$$

Then, the deflections need to be checked; with I = 510 in^4 and E = 29,000 ksi. The distributed live load for the tributary area is calculated then, the deflection is checked against the L/360 value for the floor member deflection calc. The distributed total load for the tributary area is calculated then, the deflection is checked against the L/240 value for the roof member deflection calc.

$$w_{LL} = \frac{\frac{LL}{2}}{(tributary\ length)} = \frac{1}{2} * \frac{(100\ psf + 40\ psf)}{8' - 3.8"} = 8.42\ klf$$

$$\Delta_{LL} = \frac{5 * w_{LL} * L^4}{384 * E * I} = \frac{5 * 8.42klf * 30'^4}{384 * 29,000ksi * 510in^4} * \frac{1728 \frac{in^3}{ft^3}}{1000 \frac{lb}{kip}} = 0.0104\ in$$

$$\frac{L}{360} = \frac{30'}{360} * 12 \frac{in}{ft} = 1\ in$$

$$\Delta_{LL} < \frac{L}{360}\ so, live\ load\ floor\ deflection\ is\ acceptable$$

$$w_{TL} = \frac{\frac{TL}{2}}{(tributary\ length)} = \frac{1}{2} * \frac{(110 + 69 + 5 + 100\ psf + 3 + 40\ psf)}{8' - 3.8"} = 19.66\ klf$$

$$\Delta_{LL} = \frac{5 * w_{LL} * L^4}{384 * E * I} = \frac{5 * 19.66klf * 30'^4}{384 * 29{,}000ksi * 510in^4} * \frac{1728\frac{in^3}{ft^3}}{1000\frac{lb}{kip}} = 0.0242\ in$$

$$\frac{L}{240} = \frac{30'}{240} * 12\frac{in}{ft} = 1.5\ in$$

$$\Delta_{TL} < \frac{L}{240}\ so, total\ load\ roof\ deflection\ is\ also\ acceptable$$

As a final check, the self-weight assumption needs to be checked against the actual weight of the beam. Self-weight was assumed to be 5 psf as a safe bet. The beam in this case is only 35 plf so the assumption was safe.

$$5psf * (8' - 3.8") = 41.58\ plf > 35\ plf\ for\ this\ beam\ so\ this\ is\ acceptable$$

Conclusions

The calculations that were done proved that the structural members that are already in place are adequately sized if not conservatively designed. It was also determined that some of the members that would be directly affected by the decrease in load due to the skylight installation could be downsized slightly. This would provide a decrease in tonnage of steel members by about 0.34 tons from the resizing of the members that were calculated above. This change in tonnage would amount to some savings, but for the sake of consistency in the project labs structural design and some level of conservancy it is not advised to make these changes.

MECHANICAL BREADTH |

Overview

Modifications to the project labs space have been made with the addition of the three Kalwall Skyroof products as described in the daylighting section of this report. In order to validate the choice to implement these skylights it was crucial to investigate other effects beyond the daylighting, including the change in the mechanical loads on the space due to the difference in the boundary materials. For this breadth, the excel-based energy analysis program, SkyCalc, was used. This program is provided for free use by Heschong Mahone Group.

Through this program it was noted that due to the incredible insulation properties of the Kalwall system, implementing these skylights would actually allow for savings in heating. Kalwall gives a much better U-value than more traditional skylight options, especially when the panels are thermally broken. However, since these panels will let more solar heat gain into the space it also means that there will be some cooling energy losses. It was also discovered that adding even more square footage of skylight would only increase the overall annual savings. Due to the existing mechanical and structural layouts as well as the cost of the Kalwall system, it was determined not to pursue an increase in the area of skylights used.

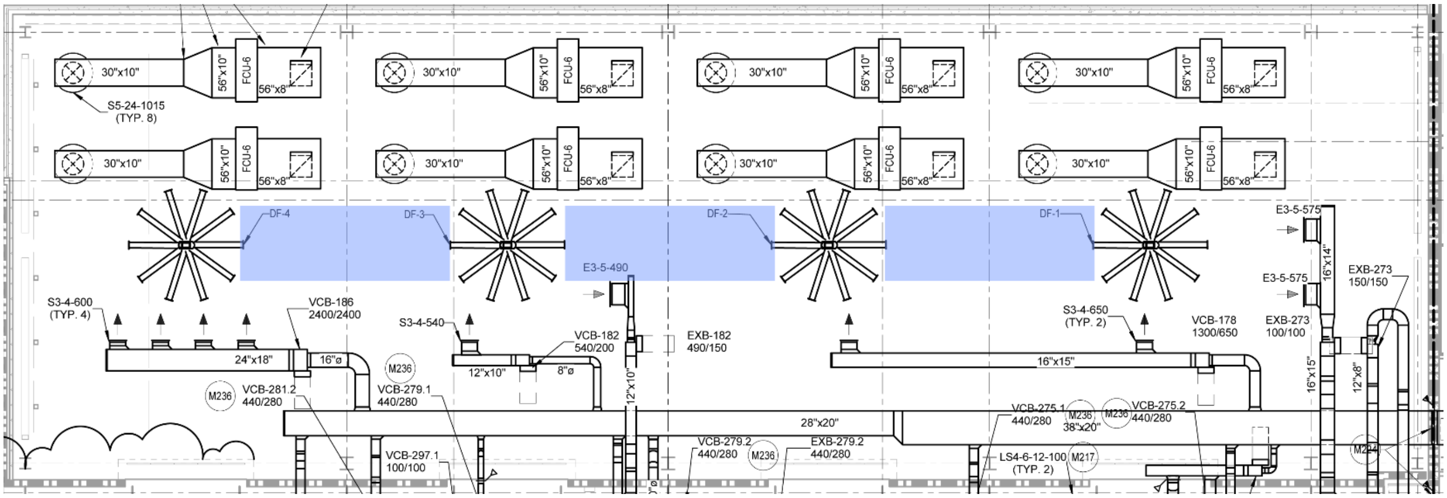
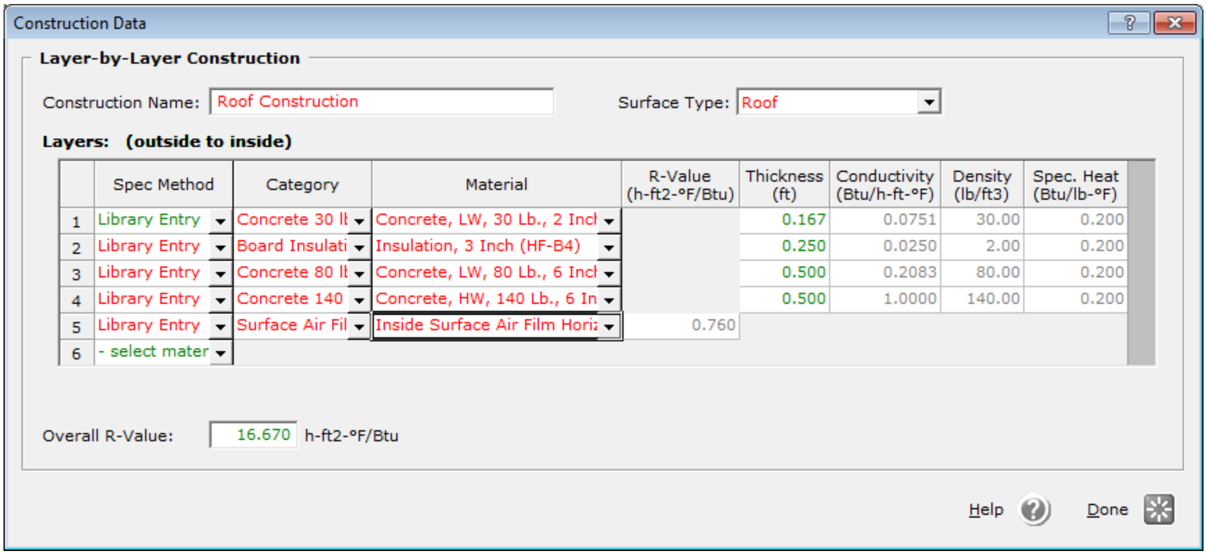


Figure 69 Existing Mechanical Equipment

Basic Roof U-Value Calculation

eQUEST software was used to determine a rough U-value for the construction of the roof including the concrete tiled flooring, the insulation, lightweight concrete, and structural reinforced concrete. This can be seen in the figure below followed by another figure showing the roof in section. With an overall R-Value of 16.670, the approximate U-Value would be 0.06.



Construction Data

Layer-by-Layer Construction

Construction Name: Roof Construction Surface Type: Roof

Layers: (outside to inside)

	Spec Method	Category	Material	R-Value (h-ft2-°F/Btu)	Thickness (ft)	Conductivity (Btu/h-ft-°F)	Density (lb/ft3)	Spec. Heat (Btu/lb-°F)
1	Library Entry	Concrete 30 lb	Concrete, LW, 30 Lb., 2 Inch		0.167	0.0751	30.00	0.200
2	Library Entry	Board Insulati	Insulation, 3 Inch (HF-B4)		0.250	0.0250	2.00	0.200
3	Library Entry	Concrete 80 lb	Concrete, LW, 80 Lb., 6 Inch		0.500	0.2083	80.00	0.200
4	Library Entry	Concrete 140	Concrete, HW, 140 Lb., 6 In		0.500	1.0000	140.00	0.200
5	Library Entry	Surface Air Fil	Inside Surface Air Film Horiz	0.760				
6	- select mater							

Overall R-Value: 16.670 h-ft2-°F/Btu

Help Done

Figure 70 eQUEST Roof Construction

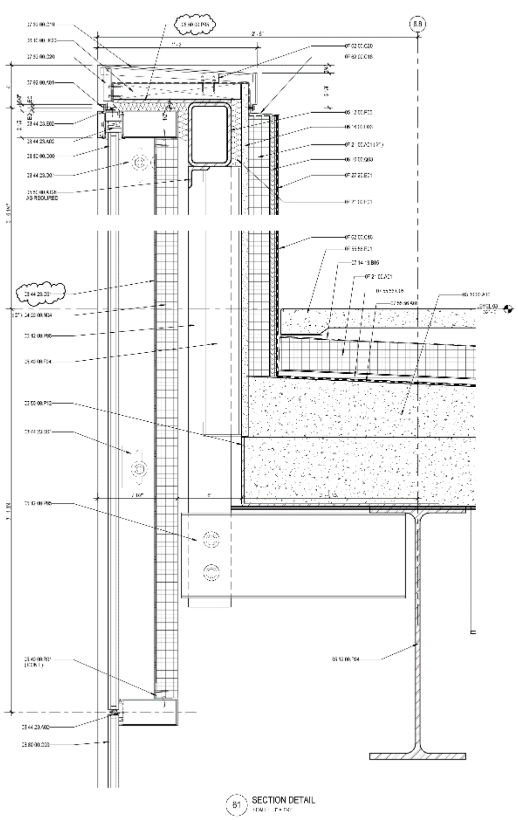


Figure 71 Roof Construction Section

Some Kalwall Technical Data

The panels chosen are the 2-3/4" panels with Crystal exterior and White interior and a visual light transmission of 20%. For the pre-engineered Skyroof product chosen, the panels with added Lumira aerogel are not available to use, which would have increased the insulation properties immensely. Because of this, the U-Value is 0.23 instead of 0.05 which was originally going to be used.

FACE SHEET COMBINATIONS		% LIGHT TRANSMISSION 2¾" (70 mm) thick panels note 1					SOLAR HEAT GAIN COEFFICIENT @0° ∠ note 3				
EXTERIOR COLOR	INTERIOR COLOR	0.53 "U"	0.29 /0.23 "U" note 2	0.22 /0.14 "U" note 2	0.18 /0.10 "U" note 2	0.05 "U" note 2	0.53 "U"	0.29 /0.23 "U" note 2	0.22 /0.14 "U" note 2	0.18 /0.10 "U" note 2	0.05 "U" note 2
Greenish Blue	White	25	14	5	3	12	0.50	0.23	0.14	0.10	0.19
Aqua	White	29	17	6	4	13	0.45	0.24	0.14	0.10	0.21
Rose	White	30	18	6	4	14	0.46	0.24	0.15	0.10	0.21
Ice Blue	White	35	20	8	6	18	0.54	0.28	0.17	0.12	0.26
White	White	20	15	8	5	14	0.38	0.23	0.15	0.11	0.18
Crystal	White	35	20	12	8	20	0.52	0.28	0.17	0.13	0.25
Crystal	Crystal	50	30	15	10	NA	0.65	0.33	0.18	0.13	NA

Figure 72 Kalwall Product Table; Crystal/White Chosen

U Value = 0.23 Btu/hr/ft^2/°F

SHGC = 0.28

SC = 1.15 * SHGC = 1.15 * 0.28 = 0.322

For the input into SkyCalc, the exact dimensions and shape of the skylights could not be used. However, the approximation was made to be as close to the real situation as possible. The dimensions of the skylights in plan are eight feet by twenty feet and in elevation they are ridged to about two feet in height with hipped ends. This shape was approximated in the program with the same plan dimensions and height but using a domed shape with a well.

SkyCalc: Skylight Design Assistant - Optional Inputs	
Company Name:	John Conley
Project Description:	Oakland University Engineering Center

Skylights	Default	User Revisions	Design Input
Skylight shape	Flat	Dome	Dome
Height of dome (Rise) (ft)	2	2	2
Visible transmittance	8%	20%	20%
Solar heat gain coefficient	6%	28%	28%
Curb type	Wood	Integral frame	Integral frame
Frame type	Metal w/ thermal brk	Metal w/ thermal brk	Metal w/ thermal brk
Unit U-value (Btu/h•°F•ft^2)	0.607	0.230	0.230
Dirt light loss factor	70%		70%
Screen or safety grate factor	100%		100%
Light well reflectance	70%		70%
Well factor (WF)	78%		78%
Bottom of light well:			
Width (ft)	8.00	8.00	8.00
Length (ft)	20.00	20.00	20.00
Diffuser on bottom of well?	No	Yes, No	No

Figure 73 SkyCalc Skylights Input

Additional Information for SkyCalc Input

Electricity Cost

On-Peak = $0.0567 per KWh

Off-Peak = $0.0537 per KWh

Natural Gas Rate

Average Annual Gas Cost = $6.10 per MMBtu = $0.61 per Therm

Transportation cost to Oakland University = $0.75 per MMBtu = $0.075 per Therm

Total = $0.685 per Therm

Heating and Air Conditioning Systems

Air Conditioning = Evaporative Cooling

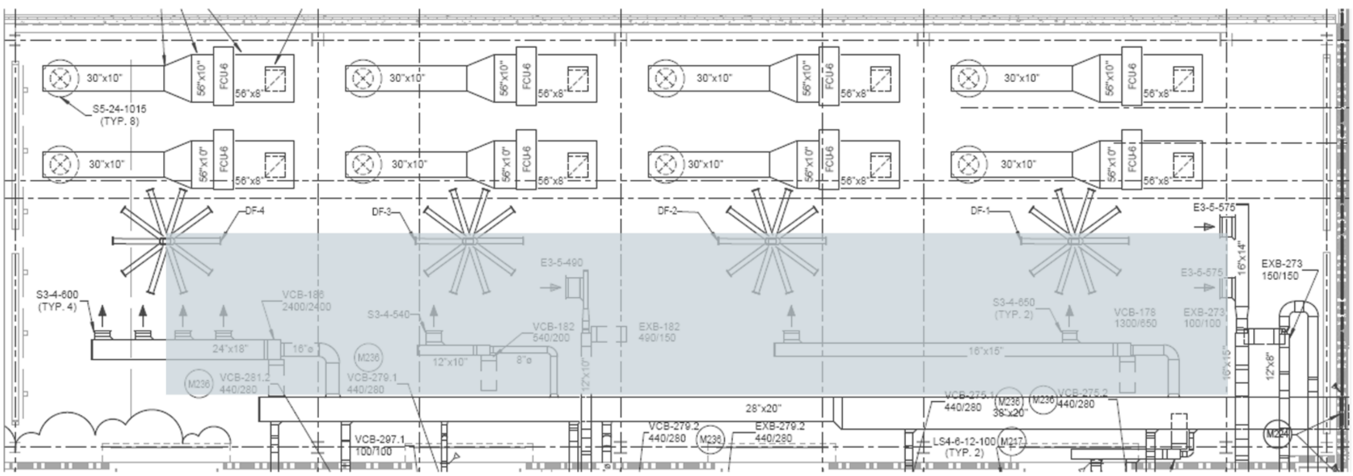
Heating System = Gas/Oil Boiler

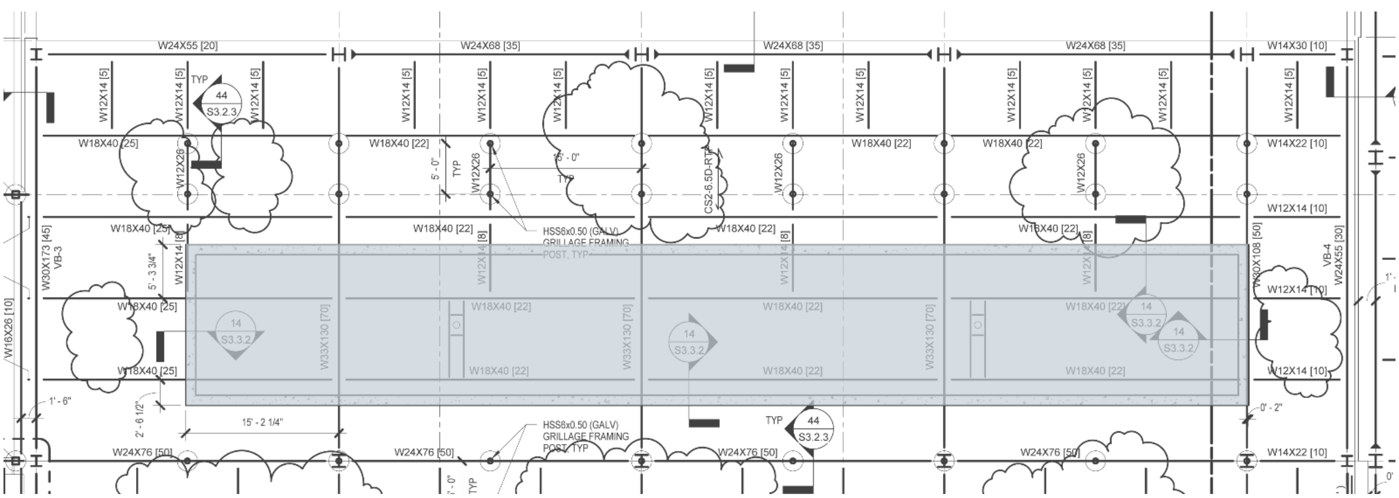
SkyCalc Analysis

Before the decision was made to limit the changes in mechanical equipment layout, a case in which one large skylight was used to span most of the length of the project labs was analyzed. This case proved to be much better for the overall savings in the space. This case was however determined to be too disruptive of the other existing systems in the space including mechanical equipment and structural beams. A more integrative solution was then devised which would still give energy savings as well as daylighting improvement.

Large Skylight Trial

The original plan was to use a single 14.5 ft by 103 ft sized Skyroof which would essentially sit in the area which is now occupied by the extensive greenroof, which is shown in the images below.





As you can see, this solution would require an extensive rerouting of mechanical equipment and a fairly in depth redesign of the structure to allow for a clean opening into the space below the skylights. But, for the purpose of analyzing all options, this solution was analyzed in SkyCalc. The results are as follows.

SkyCalc: Skylight Design Assistant - Tabular Results

Company Name:	John Conley
Project Description:	Oakland University Engineering Center

Electric Lighting Usage	**kWh/yr**		
Ltg. Energy without Skylights	20,163	Lighting Fraction Saved	
Lighting Energy w/ Skylights	20,163	Full daylighting (h/yr)	1,474

Update Results

Savings from Design Skylighting System

Savings		**Annual Energy Savings (kWh/yr)**	**Annual Cost Savings ($/yr)**
Lighting			
Cooling		-139	-$7
Heating		11,809	$276
Total		**11,670**	**$269**

Skylighting System Description

Skylight unit size (ft^2)	1,467.8
Number of Skylights	1
Total Skylight Area (ft^2)	1,468
Skylight to Floor Ratio (SFR)	25.7%
Effective Aperture	2.8%
Floor Area per Skylight	5,704
Skylight U-value	0.230
Skylight SHGC	28%
Skylight T_{vis}	20%
Well Efficiency (WF)	78%
Dirt and Screen Factor	70%
Overall Skylight System Tvis	11%
Skylight CU	66%

Site Description

Climate Location	Pontiac.wea3	
Climate Zone	CZ5 (cool, 5,400 < HDD65°F <= 7,200)	
Building Type	University 9 mo	
Building Area	5,704	(ft^2)

Elecric Lighting System Description

Lighting Type	Industrial fluorescent	
Lighting Control	No Daylight Control	
Light Level Setpoint	50	fc
Lighting Density	1.03	W/ft^2
Connected Load	5.9	kW
Fraction Controlled	50%	

3 Smaller Skylight Units

After weighing the different factors at play and analyzing the daylighting with the large Skyroof, it was decided to use three smaller skylights which fit more nicely within the existing mechanical equipment and structure. These skylights were deemed to be good enough after studying the daylighting in DAYSIM and the structure through hand calculations and were then input into SkyCalc. The results of which are below. The results show that there will still be savings in heating and losses in cooling which was seen with the large skylight. The savings are about 60% less than the large skylight case, but the initial cost would be much greater and this would have to be taken into consideration. A simple payback period is calculated below.

SkyCalc: Skylight Design Assistant - Tabular Results

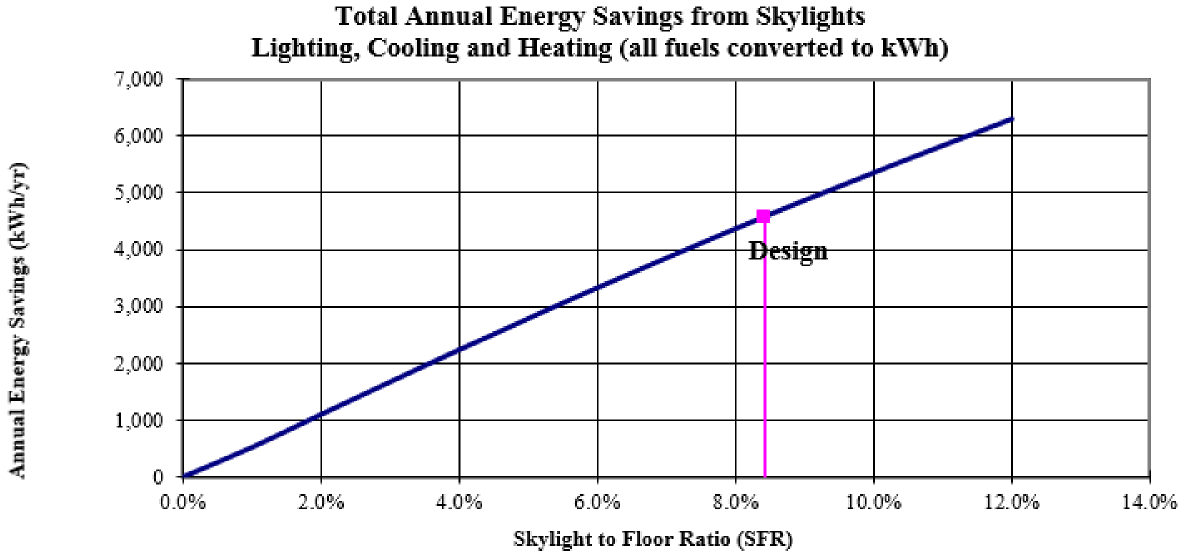
Company Name: John Conley
Project Description: Oakland University Engineering Center

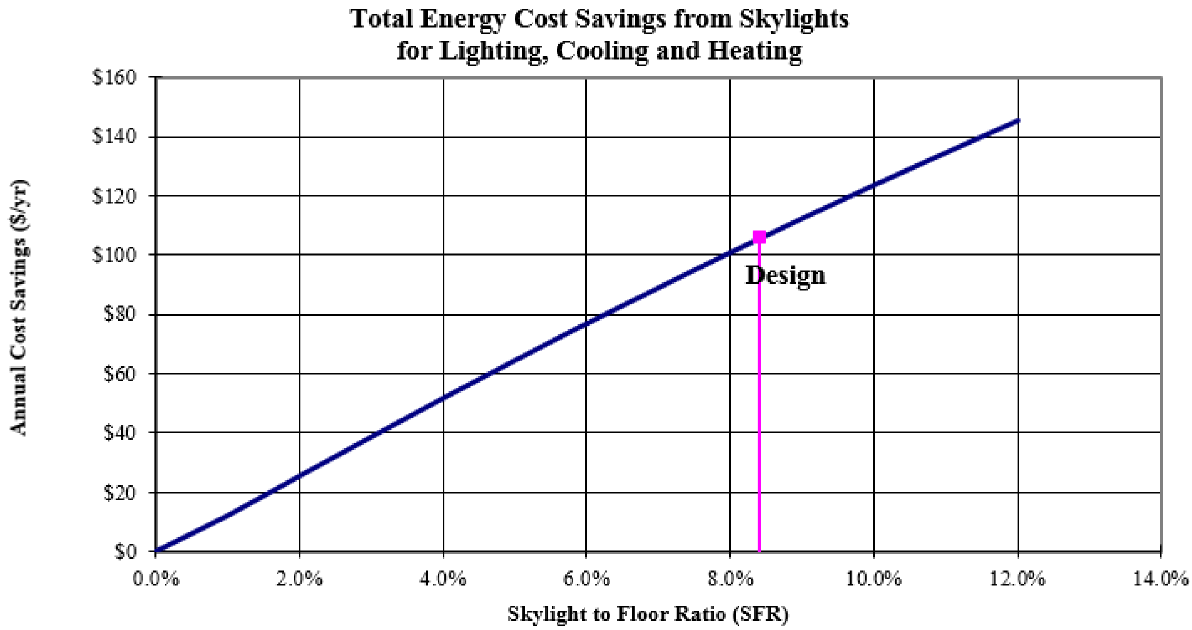
Electric Lighting Usage	kWh/yr		
Ltg. Energy without Skylights	20,163	Lighting Fraction Saved	
Lighting Energy w/ Skylights	20,163	Full daylighting (h/yr)	112

Update Results

Savings from Design Skylighting System

Savings		Annual Energy Savings (kWh/yr)	Annual Cost Savings ($/yr)
Lighting			
Cooling		-49	-$3
Heating		4,632	$108
Total		**4,582**	**$106**





Skylighting System Description		Site Description		
Skylight unit size (ft^2)	160.0	Climate Location	Pontiac.wea3	
Number of Skylights	3	Climate Zone	CZ5 (cool, 5,400 < HDD65°F <= 7,200)	
Total Skylight Area (ft^2)	480	Building Type	University 9 mo	
Skylight to Floor Ratio (SFR)	8.4%	Building Area	5,704	(ft^2)
Effective Aperture	0.9%			
Floor Area per Skylight	1,901	**Elecric Lighting System Description**		
Skylight U-value	0.230	Lighting Type	Industrial fluorescent	
Skylight SHGC	28%	Lighting Control	No Daylight Control	
Skylight T_{vis}	20%	Light Level Setpoint	50	fc
Well Efficiency (WF)	78%	Lighting Density	1.03	W/ft^2
Dirt and Screen Factor	70%	Connected Load	5.9	kW
Overall Skylight System Tvis	11%	Fraction Controlled	50%	
Skylight CU	66%			

Payback Period Calculation

In many projects, what seems good from a design standpoint can often be discarded when the cost is accounted into the analysis. For the simple payback period calculation, the following factors were incorporated:

Initial Kalwall Product Cost (See Appendix VI)

Initial Project Cost Reductions of the Greenroof and Structural Members

Annual Lighting, Cooling, and Heating Savings

Kalwall was contacted and an official quote was given for the size and specified panels. This initial cost was much larger than expected, at $30,700.00. For a panel with a U value of 0.14 instead of 0.23, the cost would be $31,585.00. The 0.14 U value option is not going to be considered due to the reduction in visual light transmittance.

For the initial cost reductions, the greenroof area difference was calculated and the tonnage reduction calculated in the structural breadth were used. The greenroof was downsized by 480 ft^2 by subtracting the areas of the three skylights. A nominal price per square foot for a greenroof in America was found on multiple websites of $20/$ft^2$. For the tonnage cost of steel, the SteelBenchmarker Report #216 was used for the current cost of steel at $473/ton.

The SkyCalc results for the three skylights without lighting control were used for the cooling and heating savings. For the lighting savings, it was decided to use the SkyCalc approximation for 5% dimming instead of the DAYSIM results due to the fact that most likely both lighting zones could be dimmed rather than just the one. The results for SkyCalc with electric light dimming are shown below.

SkyCalc: Skylight Design Assistant - Tabular Results

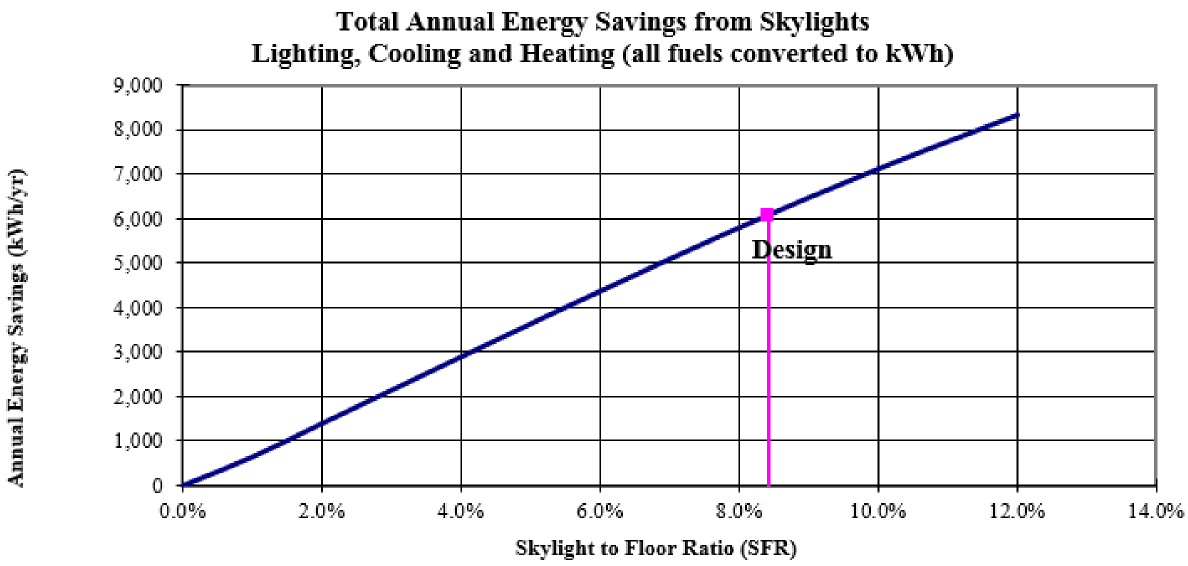
Company Name:	John Conley
Project Description:	Oakland University Engineering Center

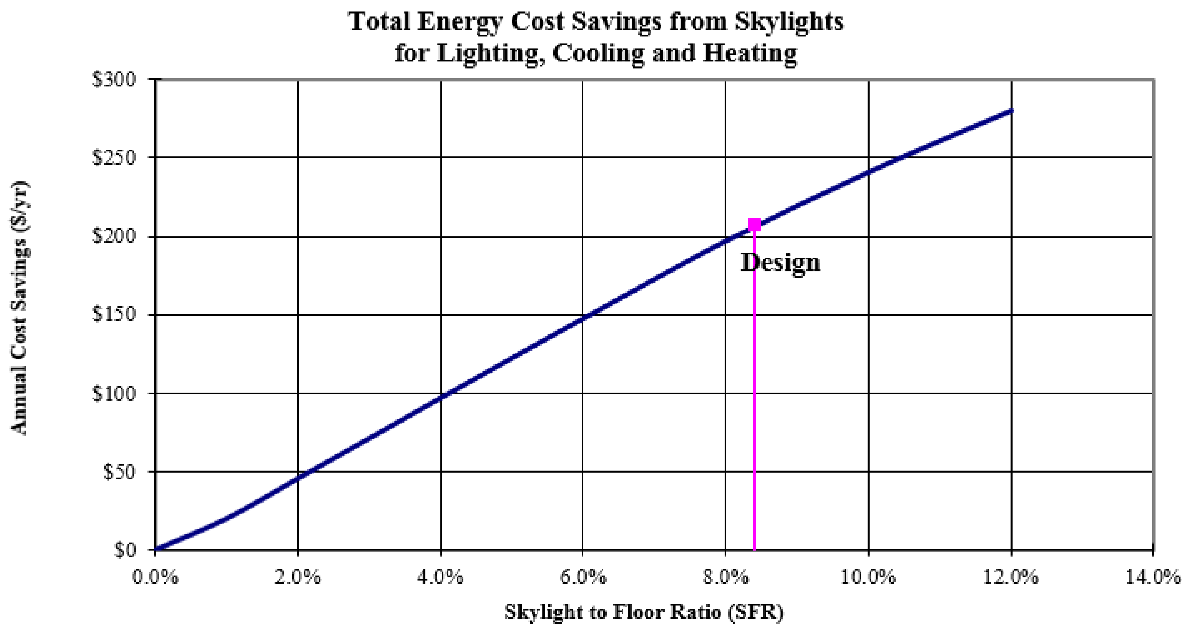
Electric Lighting Usage	**kWh/yr**		
Ltg. Energy without Skylights	20,163	Lighting Fraction Saved	11%
Lighting Energy w/ Skylights	17,998	Full daylighting (h/yr)	112

Update Results

Savings from Design Skylighting System

Savings	**Annual Energy Savings (kWh/yr)**	**Annual Cost Savings ($/yr)**
Lighting	2,165	$116
Cooling	-37	-$2
Heating	3,948	$92
Total	**6,077**	**$207**





Company Name: John Conley

Project Description: Oakland University Engineering Center

Dome Skylight   Effective Aperture = 0.92%,   Skylight to Floor Ratio (SFR) = 8.42%

Average daylight footcandles (fc)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Jan	0	0	0	0	0	0	0	0	2	8	15	19	20	20	16	11	4	1	0	0	0	0	0	0
Feb	0	0	0	0	0	0	0	1	5	13	20	25	28	27	23	17	9	3	0	0	0	0	0	0
Mar	0	0	0	0	0	0	0	4	12	20	27	32	33	34	31	22	14	6	1	0	0	0	0	0
Apr	0	0	0	0	0	0	3	10	20	30	38	40	42	42	37	28	21	11	3	0	0	0	0	0
May	0	0	0	0	0	1	7	17	30	38	44	47	49	50	45	34	26	16	6	1	0	0	0	0
Jun	0	0	0	0	0	2	9	19	29	38	46	50	54	50	48	40	32	19	9	3	0	0	0	0
Jul	0	0	0	0	0	1	7	16	28	36	47	48	53	51	44	38	29	20	9	3	0	0	0	0
Aug	0	0	0	0	0	0	4	13	25	36	43	47	48	46	40	34	28	15	6	1	0	0	0	0
Sep	0	0	0	0	0	0	2	8	17	27	36	41	44	40	36	27	16	7	2	0	0	0	0	0
Oct	0	0	0	0	0	0	0	4	11	20	27	29	32	28	23	16	8	2	0	0	0	0	0	0
Nov	0	0	0	0	0	0	0	1	5	12	17	21	21	18	14	8	3	0	0	0	0	0	0	0
Dec	0	0	0	0	0	0	0	0	2	7	13	16	19	17	13	7	2	0	0	0	0	0	0	0

Design Illuminance = 50 fc

< 1 fc;   < 25 fc;   < 50 fc;   > 50 fc;

Location = Pontiac

Once all of this information was collected, the simple payback period was calculated in the table below.

	No. Units	Price per Unit	Dollar Amount
Initial Cost For 3 Pre-Engineered Kalwall SkyRoof Products			$ 30,700.00
Initial Cost Reductions			
Reduction in the Area of GreenRoof	480	$ 20.00	$ 9,600.00
Reduction in the Tonnage of Steel Beams	0.33975	$ 473.00	$ 160.70
Total Initial Cost			$ 20,939.30
Annual Savings From SkyCalc			
Lighting Dimming Savings			$ 116.00
Heating Savings			$ (3.00)
Cooling Savings			$ 108.00
Total Annual			$ 221.00
Payback Period (Years)			**94.7**

Table 5 Payback Period with Greenroof Reduction

Since this payback period of almost 95 years is outrageous, a payback period for the addition of the skylights while taking the whole greenroof was looked into.

	No. Units	Price per Unit	Dollar Amount
Initial Cost For 3 Pre-Engineered Kalwall SkyRoof Products			$ 30,700.00
Initial Cost Reductions			
Reduction in the Area of GreenRoof	1436.2	$ 20.00	$ 28,723.85
Reduction in the Tonnage of Steel Beams	0.33975	$ 473.00	$ 160.70
Total Initial Cost			$ 1,815.45
Annual Savings From SkyCalc			
Lighting Dimming Savings			$ 116.00
Heating Savings			$ (3.00)
Cooling Savings			$ 108.00
Total Annual			$ 221.00
Payback Period (Years)			**8.2**

Table 6 Payback Period with No Greenroof

This payback period of 8.2 years is much more reasonable to go to the owner with as a suggestion.

Conclusion

After analyzing the effects of the skylights on the heating and cooling of the space and most importantly on the costs involved, the following recommendations are made for using the Kalwall skylights. Because of the daylighting benefits of the skylights as well as the heating cost reduction, it is recommended that the owner consider adding the skylights to the project. The skylights would only be 0.0539% of the total project cost so it may be reasonable to justify the cost mainly on the qualitative benefits. Because of the large payback period though, if the cost is a problem, this would not be recommended. And if cost is a problem, since these skylights are considered a great addition to the space, it would be recommended that the greenroof be taken out completely. The result of this would be a payback period of 8.2 years with a continuous savings afterwards and the University would see the benefit in a decent time-frame.

SUMMARY + CONCLUSIONS |

SUMMARY |

Through the course of this senior thesis project, the wide base of knowledge acquired from the past five years was utilized in a manner to show individual capabilities in the Architectural Engineering field. The lighting, electrical, mechanical, and structural systems of the Engineering Center as well as the daylighting aspects of the project were studied to explore many aspects of real world engineering problems to come up with appropriate conclusions.

This project, even though not perfect, was a very valuable process to go through at the end of my studies here at Penn State. I have to admit that I am not fully satisfied with my own quality of work or range of studies done in the course of this report. That being said, the determination that it took to spend many upon many hours of work on a project that ends up losing its feeling of excitement towards the end is an invaluable attribute that I feel I have acquired throughout this project. In the future there are bound to be long workdays and long nights working on projects with difficulties. I have a more realistic and more broad mindset having completed this report and I look forward to moving on to real world projects with the knowledge I have from my time here at Penn State.

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DaysimPS

eQUEST 3-65

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My amazing AE friends and the support, help, and opinions they have provided and good times we have had these past few years

My Lord and Savior with whom all of this was possible

I'm going to miss Penn State and the Architectural Engineering department and I know I'll cherish these times. I'm eternally grateful for the broad range of knowledge and experiences that this program has given me and I'm extremely excited to take this knowledge into the real world starting this summer with the Lighting Practice in Philadelphia.

And finally, I could not have gotten through the semester without my old friend Netflix who is my loyal and mindless help through all of the tough times.