SYNDICATE

AEI Team 01-2019

Final Design of the Jack H. Miller Center for Musical Arts

2019 AEI Student Design Competition

TABLE OF CONTENTS

CODES & STANDARDS

Structural

- 2015 International Building Code
- ASCE 7-16, Minimum Design Loads for Buildings and Other Structures
- 2018 NDS, Supplement and SDPWS
- CLT Handbook by FPInnovations
- AITC Timber Construction Manual , 5th edition
- AISC Steel Construction Manual , 15th edition
- ACI 318-14, Building Code Requirements for Structural Concrete
- ASTM E1300—04, Standard Practice for Determining Load Resistance of Glass in Buildings
- Kawneer 1600 LR Wall—Curtain Wall System Product Information

Mechanical

- ASHRAE Standard 62.1 - 2016
- ASHRAE Standard 90.1 - 2016
- ASHRAE Standard 55 - 2017
- International Energy Conservation Code (IECC) - 2009
- National Fire Protection Association (NFPA) 13 & 14

Lighting/Electrical

- 2012 International Building Code
- ASHRAE 90.1 2013
- NFPA 70 – National Electric Code – 2011 Edition
- NFPA 72 – National Fire Alarm and Signaling Code - 2011
- The IES Lighting Handbook – 10th Edition

Construction

- Occupational Safety and Health Administration (OSHA)
- RS Means

INTEGRATION REPORT

EXECUTIVE SUMMARY

Syndicate is a multidisciplinary integrated design-build firm consisting of construction, lighting/electrical, mechanical, and structural teams. For the AEI Student Design Competition, *Syndicate* designed and engineered a high-performance center for musical arts, known as The Miller Center. The Miller Center is on the campus of Hope College located in Holland, Michigan. Throughout the duration of the project, team members were assigned to the major disciplines and to specialty multidisciplinary teams including building integration, enclosure, acoustics, and architecture. *Syndicate* collaborated to surpass building standards for mechanical and electrical systems, design a sustainable wood structure, and develop an overall budget of $23,926,850. Syndicate's Optimized Design falls $1,073,150 below the given budget. By rotating the building on the site and reordering various spaces, *Syndicate* was able to increase the percentage of commonly occupied spaces receiving daylight, significantly reduce the amount of solar heat gain entering the lobby and create an acoustical buffer zone for the central symphonic concert hall. *Syndicate* focused on integrating high quality acoustics in each type of space by meeting or surpassing the desired acoustical sound transmission class (STC) and impact isolation class (IIC) levels for wall and floor assemblies, as well as falling within optimum reverberation times (RT) for each space of the building. Areas of critical integration are shown:

CONCERT HALL

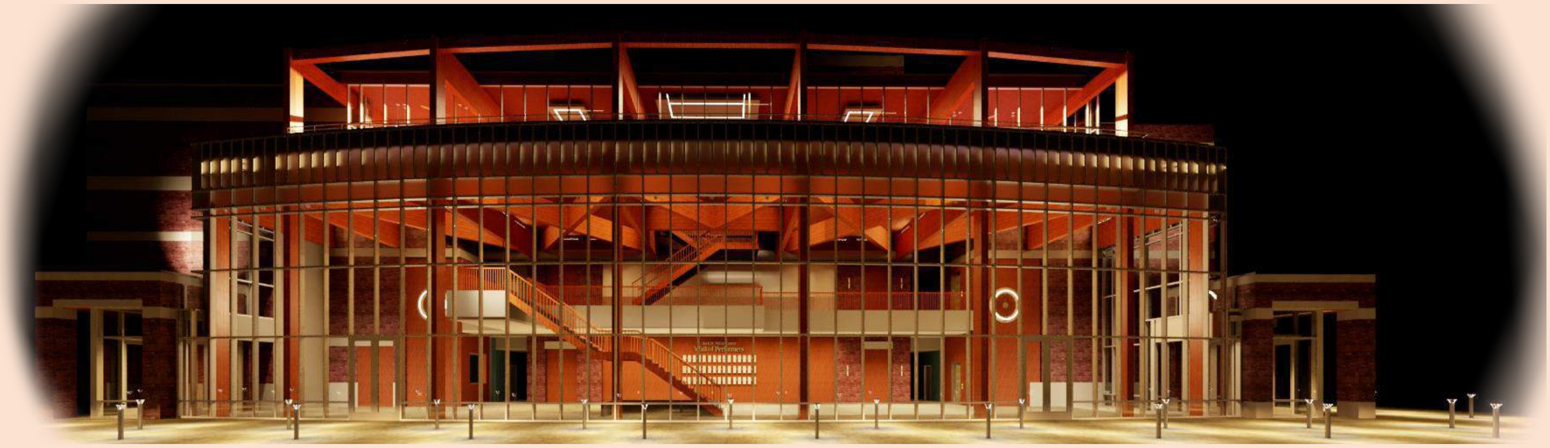
- 72' long span steel truss
- Displacement ventilation underground ducts integrated with foundations
- Fiber optic DMX lighting scheme coordinated with acoustical ribbons
- Solar photovoltaic rooftop array
- High quality and adaptable acoustics
- 300-ton 2250 series 3 Manitowac crawler crane for precast panel installation

OCCUPIABLE ROOF

- Usability Occupancy: 100 people
- Enclosed space: 1500 SF
- Heating system for winter use
- Sliding glass doors to open the space and allow natural ventilation
- Programmable time schedule for electric lighting
- Provides fundraising opportunity for the owner
- Showcasing sustainability through exposed wood beams, columns, and floor system

WEST CORRIDOR

- Allows for ample daylight into all three classrooms
- Connection between north and south lobbies
- High performance enclosure
  - Utilizes solar heat for heat recovery in winter, exhausts warm air in warmer months
  - Reduces yearly utility cost by 7%
  - System modularized for constructability



SUSTAINABILITY PLAN

- Incorporated a sustainability display to showcase dynamic and static building statistics
- Categories:
  - Waste Reduction
  - Indoor Environment
  - Materials and Resources
  - Energy Conservation

NORTH LOBBY

- Reduced direct sunlight levels into the atrium by 70%
- Reduced solar heat gain in space by 85%
- Hanging balcony design to limit obstruction of view
- Cross-beam wood design accented by wall grazers

MECHANICAL SPACE

- Fully isolated structure
- Mechanical equipment isolation springs and concrete inertia pads
- Isolation joints within slab on grade and CLT floor system
- Reduce structural borne sound and vibrations

Integration Table of Contents

1.0 PROJECT OVERVIEW

The Jack H. Miller Center for Musical Arts (The Miller Center) is a proposed building project for Hope College located in Holland, Michigan. *Syndicate* is an integrated design-build team that produced a high-quality design and construction plan for this project. The project site is situated in the northeast corner of campus across from downtown Holland, near Lake Michigan. The Miller Center acts as an investment for the future of Hope College and as a showcase pilot for a new sustainability plan on campus. The addition of an occupiable roof and south lobby allows this building to act as a gateway space for connecting Hope College campus to downtown Holland. The Miller Center can be seen in *Figure 1.*

***Figure 1**: Syndicate's Design*

Syndicate's final design is a three-story building designed for serving the educational and performance requirements of Hope College. Totaling 70,000 square feet (SF), The Miller Center includes an 800-seat symphonic concert hall, a smaller recital hall for intimate chamber performances, and two large rehearsal spaces for choirs and orchestras. The building also includes classrooms, faculty studios, and student practice rooms distributed throughout the three stories.

2.0 VISION STATEMENT

Through a multidisciplinary team strategy, *Syndicate* produced a high-quality center for musical arts that met the goals and mission of Hope College. As a team, *Syndicate* chose to pursue this project with a vision statement that would contain individualized team and discipline goals. The vision statement is HOPE and the goals are to:

Enhance H ope College Campus

Maximize O ccupant Experience

Create Premier P erformance Spaces

Minimize E nergy Impact

Refer to Integration SD-A for details about the vision statement.

3.0 INTEGRATED PROJECT GOALS

To achieve HOPE, *Syndicate* created specific integration goals for these four vision statements.

3.1 Enhance Hope College Campus

Syndicate set one of their goals as enhancing Hope College campus through design iterations and promoting sustainability. Metrics to evaluate this goal are:

- Developing a sustainability plan that optimizes the goals of Hope College
- Designing a CHP Plant with room for expansion of the campus by at least 400,000 SF of building
- Developing a construction schedule of 16 months
- Fall below the given budget of $25,000,000
- Adding a rooftop amenity space for 100 people
- Generating a captivating aura through the night time lighting design that will draw in occupants

3.2 Maximize Occupant Experience

After studying the given design of the building's architectural features, *Syndicate* chose to set metrics to maximize the occupant experience:

- Reduce the building's solar heat gain by 50%
- Reduce the amount of annual sunlight exposure (ASE) entering the lobby to IES acceptable levels
- Increase amount of commonly occupied spaces receiving daylight to at least 90%
- Achieve STC and IIC values greater than 50 to increase quality of acoustics for floor and roof assemblies
- Minimize perceived floor vibrations transmitted throughout the building using equipment isolators and an isolated structure for mechanical space
- Design a versatile concert hall

3.3 Create Premier Performance Spaces

The Miller Center is diverse because it contains classrooms, faculty studios, a recital hall, rehearsal spaces, and a grand concert hall. It is imperative that the studios and practice spaces allow for world-class acoustics. Refer to Integration Drawings I-4.0 and I-5.0 for acoustical data. To create premier performance spaces, the following criteria needed to be met or exceeded:

- Achieve acceptable reverberation times at various frequency values and noise criterion for each space *(Figure 2)*
- Achieve optimum music clarity index (C) 80 for the concert and recital halls, as well as optimum speech clarity index (C) 50 for the concert hall
- Achieve STC values greater than 65 for acoustical quality of wall assemblies in performance spaces
- Reduce transfer of noise through ducts
- Achieve optimum lateral energy fraction for the concert and recital halls
- Properly coordinated LED fixtures with the appropriate drivers to mitigate noise generation

3.4 Minimize Energy Impact

Hope College expressed its goal for total-building sustainability of The Miller Center through a design challenge. *Syndicate* chose to set the following metrics that go beyond current standards to positively impact the environment:

- Develop a customized sustainability plan for Hope College

Optimum Acoustical Criteria			
Type of Space	Reverberation Time Acceptable (seconds)	Reverberation Time Optimum (seconds)	Acceptable Noise Criteria (NC) Value (dBA)
Orchestral, chours, or organ	1.9 - 3.4	2.0 - 3.4	30
Symphony (romantic)	1.6 - 2.2	1.7 - 2.1	20
Secular choral works	1.6 - 2.2	1.7 - 2.0	30
Contemporary orchestral works, recitals, and chamber music	1.2 - 1.9	1.4 - 1.7	30
Semi-classical concerts and choral groups using sound system	1.1 - 1.9	1.2 - 1.6	20
Small Theatres	1.1 - 1.5	1.2 - 1.4	40
Lecture and conference rooms	0.6 - 1.4	0.9 - 1.1	25

***Figure 2**: Reverberation Times and Noise Criterion*

- Incorporate 25% minimum structural renewable wood products by volume into the design of the building
- Reduce building energy usage by 40% when compared to ASHRAE 90.1 2016 baseline building
- Reduce carbon content of structural system by 25% when compared to a steel construction baseline
- Properly coordinate all lighting, HVAC, and plug load controls to reduce energy demands by 20%
- Reduce building's carbon footprint by providing alternate electric systems that allow for clean energy production
- Exceed ASHRAE 90.1-2013 for lighting control standards by 20%

4.0 INTEGRATED DESIGN AND DELIVERY

***Figure 3**: Delivery Method*

Syndicate operates under an integrated design-build delivery method. This delivery method allows streamlined communication between the owner and the project team, as seen in *Figure 3*. *Syndicate* wants to ensure that Hope College is an integral part of the design and construction processes when providing this premier space for its occupants. Through this delivery method, Hope College will only have one project contract and one point of contact for the designers and construction professionals.

This method ensures that the team is providing the best quality while budgeting reasonably. The designers and construction professionals will be delivering on a fast-tracked timeline because they are under one roof and collaborate from project conception.

4.1 Stakeholder Analysis

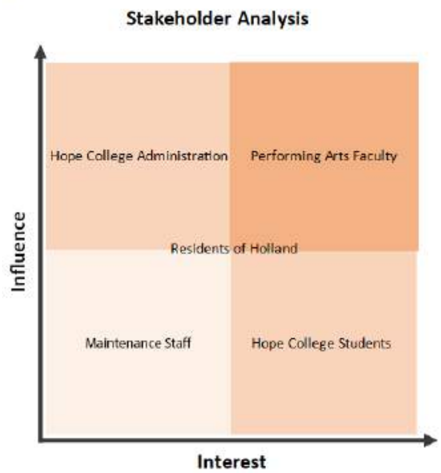


***Figure 4**: Stakeholder Analysis*

Syndicate performed a stakeholder analysis in order to determine how each stakeholder should be incorporated into the project and at what stage, as seen in *Figure 4.* The Hope College Administration has the highest level of influence over this project because they control the funds and programming but will not experience the day to day performance of the building like the students and faculty. Therefore, *Syndicate* will include the Hope College Administration heavily at the beginning of the project and keep them informed throughout the project at a high level. The faculty and students will be involved at a more detailed level, such as classroom layout and storage spaces. They will participate in design reviews with *Syndicate* at various times throughout the design process to ensure the spaces are meeting their needs. Refer to Construction Report Section 4.1 for details.

4.2 Prevention Through Design

Prevention through Design (PtD) is an initiative that aims to anticipate and remove safety hazards, both during the construction and operation of the facility, in the early design phases of the project. This level of detail requires a highly integrated team. Therefore, an integrated design-build team like *Syndicate* is the perfect candidate to implement this up-and-coming concept. Refer to Construction Report Section 5.5.1 for more detail.

5.0 AEI TEAM CHALLENGES

Syndicate was commissioned to design The Miller Center systems concurrently with these three challenges: high performance/adaptable acoustics, engineered wood design, and a rooftop amenities space.

5.1 High Performance/Adaptable Acoustics

The Miller Center is versatile by design through its adaptability to various types of performances, public events, and ceremonies using moveable curtains and several wall finishes. *Syndicate's* disciplines collaborated and incorporated an acoustical software program known as ODEON, shown in *Figure 5*, to go beyond industry standard levels of STC and IIC of 65. Noise criterion (NC) levels and reverberation times were also analyzed in all spaces within The Miller Center. Refer to Integration Report Section 10.0 for acoustical design and Integration Drawings I-4.0 and I-5.0 for acoustical analysis and enhancements.

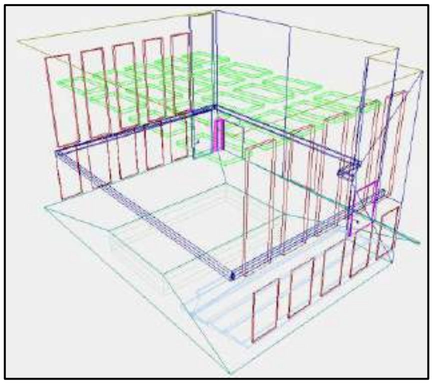


***Figure 5**: Acoustical Model*

5.2 Wood, Timber, and Engineered Wood

Syndicate was tasked with incorporating a minimum of 25% wood into the design of The Miller Center. In conjunction with *Syndicate's* sustainability plan and the wood challenge, the team incorporated heavy timber products within the structural system to promote sustainable and environmentally conscious practices. Glued-laminated (glulam) and cross-laminated timber (CLT) members were used in all spaces. Refer to Structural Report Sections 8.3 and 8.4 for details. The team also incorporated wood finishes throughout the building where applicable for acoustics and aesthetics. The end design surpassed the 25% minimum by volume of structural material and utilized 86% wood products for the structural system. The use of wood products reduced the carbon content of the structural system by 27% of a comparative baseline steel building, as seen in *Figure 6*. This is highlighted in the Materials and Resources category of the Hope College Sustainability Plan. Refer to Structural Drawing S-10.0.

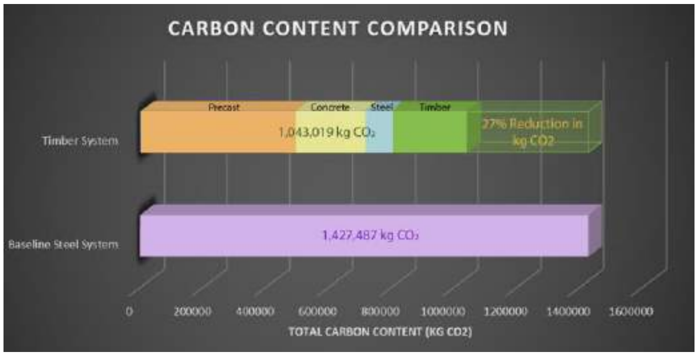


Figure 6: *Carbon Content of Structural System*
Reference: Inventory of Energy and Carbon (ICE) Version 2

5.3 Rooftop Amenities Space

Figure 7*: Occupiable Roof Space*

Our team created a solution for Hope College's expressed interest in adding a rooftop amenities space that could accommodate up to 100 people and be accessible for both university and public events. *Syndicate* incorporated architectural elements such as sliding door systems and exposed wood features to encourage sustainable thinking (*Figure 7)*. To accommodate both public and campus events, *Syndicate* utilized *Revit* to evaluate the existing architectural layout of The Miller Center and create a plan to allow user flow to our amenity space. *Syndicate*'s design is accessible throughout the full year and adaptable to the various seasonal climates in Michigan. More is discussed in Integration Report Section 8.1.

6.0 DESIGN FACILITATION

Syndicate set up several important approaches to encourage integration among disciplines to ensure the goals were attainable, as discussed below.

6.1 Multidisciplinary Team Emphasis

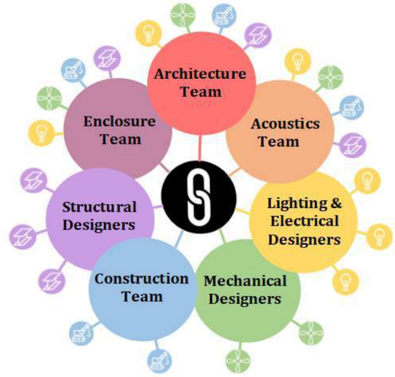


Figure 8*: Syndicate Team Breakdown*

Syndicate is comprised of ten members across four disciplines including three lighting/electrical designers, two mechanical designers, three structural designers, and two members of the construction team, as displayed in *Figure 8*. At the start of the design process, *Syndicate* discussed roles that would be crucial in the design of The Miller Center. Acoustics became an additional essential discipline to consider alongside architecture and building enclosure for this project. Members of the team volunteered to take on these roles in addition to their own discipline through collaborative multidisciplinary teams. These teams aided in the improvement of interdisciplinary coordination, collaboration, and total building performance. Refer to Integration SD-D for details.

6.2 Decision-Making

Decision-making was a core component of design throughout the duration of the project. *Syndicate* incorporated decision matrices to assist in making

SYNDICATE	DECISION MATRIX: Integration															
Team Goals :	Enhance Hope College Campus			Maximize Occupant Experience			Create Premier Performances			Minimize Energy Impacts				Weighted Score	Rank	Final Outcome
	Construction Schedule	Aesthetics	Cost	Comfortability	Accessibility	Quality	Reduced disturbance	Sound Quality	Flexibility	Waste Reduction	Carbon Footprint	Life Cycle	Efficiency			
BUILDING ORIENTATION																
Weights :	0	2	2	3	1	2	3	3	0	2	0	3	2			
Current Orientation	0	3	2	1	1	1	1	1	0	1	0	1	1	29	2	
Rotation of 90 with large lobby facing North	0	2	3	3	2	2	2	2	0	2	0	2	2	51	1	X
Additional Comments :	The team's final decision was to rotate the building with the large lobby facing north. This would allow for the most efficient design and limit the solar heat gain and the direct daylight penetration into the large lobby.															

Rating - Weighting	
High Importance	3
Medium Importance	2
Lowest Importance	1
Scoring	
Best	3
Middle	2
Worst	1

Figure 9: *Decision Matrix for Building Rotation*

unbiased decisions across all disciplines for the betterment of the project over a sole discipline. Design decisions were constantly measured against the goals of the project. One example of a decision matrix being adopted was in deciding whether to rotate The Miller Center on site, as seen in *Figure 9*. For the decision, the sound quality was a major consideration for the building and therefore was weighted a three, whereas construction schedule was minimally impacted by this decision and therefore was weighted a lower weight of two. This interdisciplinary process of decision making is further explained in Integration SD-C.

6.3 Collaborative Environment

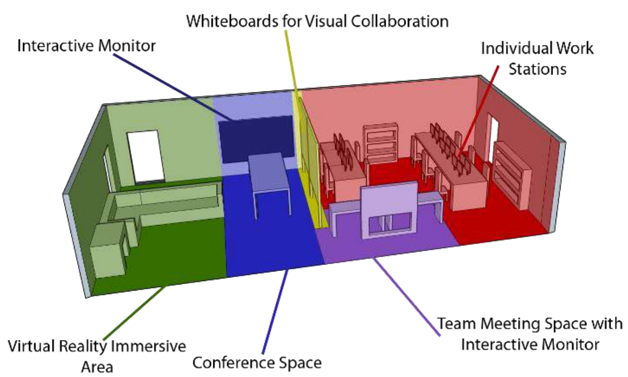


Figure 10: *Workspace*

An open, multidisciplinary work environment promoted *Syndicate*'s integration and communication. *Syndicate* designated their workspace by discipline, but kept the plan open to allow for cross-disciplinary communication and collaboration, as seen in *Figure 10.* Whiteboards were used during discussions and decision-making to further visualize integrated design solutions. Large-scale monitors were provided at all work stations to utilize BIM software, such as *Revit* and *Sketchup*, to promote collaboration. The setup of this collaborative environment is explained further in Integration SD-B.

6.4 Virtual Reality

Syndicate implemented the use of an *HTC Vive* virtual reality system. This system allowed the team to delve into details of each space aiding in the integration of disciplines for clash detection, design review, and team approval of architecture. *Revit Live* coupled to the *HTC Vive* allowed *Syndicate* to visualize the different architectural features of various spaces, as seen in *Figure 11.*

Figure 11: *Virtual Reality Usage*

6.5 Team Planning

Syndicate utilized a program known as *Trello* to keep track of tasks and deadlines among disciplines. Each discipline created their own board to set up and check off responsibilities per person, as seen in *Figure 12* on the next page. These boards allowed team members to see what parts of the project were completed by other disciplines and therefore be able to identify any see key areas of integration or participation. *Trello* also allowed disciplines to assign tasks to other team members to be completed with specified due dates. Refer to Integration SD-A for more information.

Figure 12: *Trello Board*

6.6 Team Meetings

Early decisions were made that the entire group would meet formally twice during the week. The first meeting would take place at the beginning of the work period on Mondays to discuss tasks to be accomplished in the week and to discuss any upcoming action items. The second weekly meeting would be at the end of the work period on Fridays to discuss the progress made through the week. Whenever the team received feedback, all options sat down to discuss the critiques provided. This created additional meetings when necessary to ensure the team stayed on track. Not only was verbal communication important for team organization, but nonverbal communication was equally vital.

6.7 Nonverbal Communication

Syndicate employed technological programs for nonverbal communication including *GroupMe, Trello, Bluebeam Studio, Google Drive, Revit, and Google Calendar,* as seen in *Figure 13*.

Figure 13: *Integration Software*

GroupMe was used to discuss meeting times, deadlines, and any inspirations that group members chose to share with one another. *Google Calendar* allowed members to find times that worked best to meet within everyone's schedules. *Bluebeam Studio, Revit*, and *Google Drive* were the main platforms for team collaboration and integration. These programs allowed for multiple members of the team to be working on the same presentation, document, or model simultaneously and acted as storage for documentation, as well as electronic file backup. Refer to Integration SD-B for further detail about software collaboration.

7.0 EARLY DESIGN DEVELOPMENT

Syndicate analyzed the given design of The Miller Center through integrated software and collaborative analysis. This analysis drove multiple iterations for architectural layout optimization and constructability. Refer to Integration Drawing I-1.0 for details.

7.1 Construction Type

In pursuit of The Miller Center's design, *Syndicate* had to decide which IBC construction type they would implement. The team originally was designing for Type 2A based on the given design, but this construction type did not allow for the use of wood construction, which would limit sustainability efforts.

The team went through multiple consultations and team discussions regarding this construction type as discussed in Structural Report Section 7.0. In the end, *Syndicate* chose to design with construction Type IIIA that allows for the concealment of wood structural members using their char rate as the fire-rating. This helped with the integration of disciplines by:

- Allowing the team to decide space-by-space if the structure would be exposed
- Improving acoustical properties of each space by varying material finishes
- Adjustability of room heights to improve acoustical intimacy
- Allowing the team to conceal mechanical and electrical equipment within a plenum space
- Enhancing sustainable design using wood material

7.2 Layout Evaluation

After analyzing the given building design (see *Figure 15* on next page) for performance evaluation, it became clear that there were areas for improvement relative to our team goals:

- Lobby facing towards the west allowed a lumen level 87% ASE into the space and 34 tons of solar gain into the lobby

- 25% of commonly occupied spaces not receiving daylight
- Amtrak route running behind The Miller Center causes undesired vibrations and sound transmittance
- Mechanical room located directly behind the large concert hall

Refer to Lighting/ Electrical Report Section 4.3 for information on daylighting redesign.

7.3 Layout Enhancement

To enhance these areas for improvement, *Syndicate* incorporated the following design optimizations:

- Building rotation on site
- South lobby and west corridor addition
- Third floor addition
- Vibration and sound transmittance mitigation

7.3.1 Building Rotation

A 90º clockwise rotation was performed to reduce ASE and solar heat gain in the lobby (*Figure 16).* With this rotation, an opportunity for a buffer zone was presented using the solid mass on the east and south facades to limit the acoustical issues. This action allowed for the following benefits:

- Reduced the light levels entering the north lobby from 87% to 1.8 % ASE
- Created a larger buffer zone to mitigate sound transmission through wall assemblies rated at an STC of
- Reduced solar heat gain entering the building, as seen in *Figure 14*

	Solar Heat Gain (TON)		
	Current Orientation	Rotated	Percent Change %
North Lobby	34	5	85% reduction
Rest of Building	4	9	25% increase
Total Building	38	14	63% reduction

Figure 14: *Solar Heat Analysis*

This site rotation presented a challenge for *Syndicate* to assess the acoustical transmission into the recital hall, as well as the choral and orchestral rehearsal spaces along the east façade. To address this challenge, the team implemented acoustical treatment in the recital hall for live performance and felt that the rehearsal spaces were sufficient. Refer to Integration Drawing I-1.0 for further information about the building rotation.

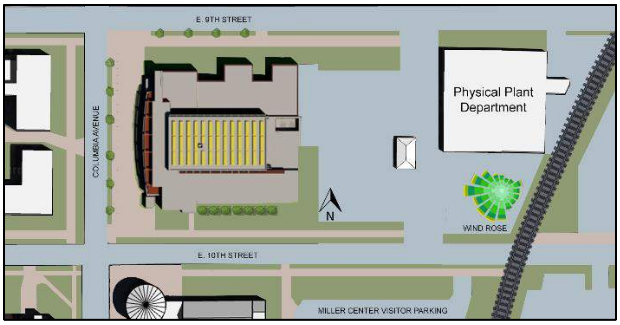


Figure 15: *Given Design and Orientation*

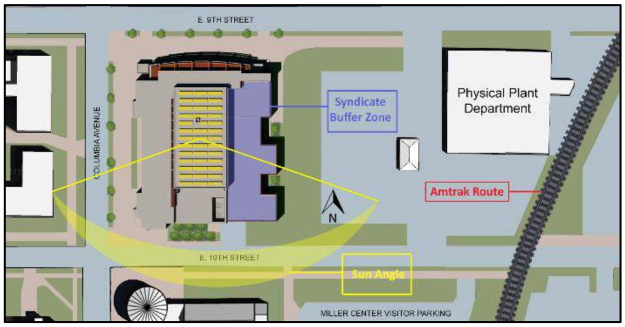


Figure 16: *Syndicate's Design with Buffer Zones*

7.3.2 South Lobby and West Corridor Addition

To create a link between campus and downtown Holland, *Syndicate* designed a south lobby that promotes student and patron interaction. A stronger connection between The Miller Center and the campus itself was achieved by *Syndicate* taking inspiration from The Martha Miller Center for Global Communication's rotunda, located directly south of The Miller Center.

Further analysis of the new south lobby design showed the connection to the north lobby had become indirect and congested allowing people to walk through a hallway with classrooms and faculty studios. *Syndicate* reconfigured the floor plan layout to mitigate this by introducing a west corridor along the exterior façade. Refer to Integration Report Sections 8.3 and 8.4 for details about the west corridor and south lobby. Refer to Lighting/ Electrical Report Section 4.3 for south lobby daylighting analysis.

7.3.3 Third Floor Addition

To incorporate an occupiable roof space per the competition challenge into the design of the building, a third floor was created above the north lobby. This additional floor would allow for better flow to the occupiable roof space, as well as providing the opportunity for daylight optimization. The third floor also allowed *Syndicate* to move the exterior row of faculty studios from the first floor to this level. The team further added skylights onto the third floor that would allow 9 additional spaces to receive daylight. A major benefit from this addition was the reduction of commonly occupied spaces without daylight from 25% to 4%. Refer to Integration Drawing I-1.0 for *Syndicate's* optimized floor plans and daylighting breakdown.

The team pursued an iterative process in the design of the occupiable roof space and upon further consideration of the AEI challenges, *Syndicate* designed a versatile, partially enclosed space. The rooftop is designed as a 1500 SF pre-function and post event area for both private and public parties. The addition of a green roof with this space was also highly considered, but the additional weight of the assembly would increase the structural depth by 19% and increase the cost of the roof assembly by $25/ SF. Therefore, Syndicate opted to not include a green roof within their design. Refer to Mechanical Report Section 7.2 for the green roof analysis.

7.3.4 Vibration and Sound Transmittance Mitigation

To accommodate the issue of the Amtrak route, *Syndicate* considered different wall assemblies for the recital hall and symphonic concert hall. These walls were designed to go beyond the industry standard of an STC level of 65 for performance spaces. Refer to Structural Drawing S-8.0 for more information.

Syndicate aimed to decrease the structural borne noise and vibration from the mechanical space behind the concert hall. The addition of an isolated structure, as seen in *Figure 17,* along with mechanical equipment isolators mitigates structural borne vibrations to ensure no vibrations will disturb performances. The implementation of an isolated structural system allowed the team to reduce the cost of mechanical equipment by not needing to design mechanical equipment isolation as standard isolators instead of designing for stealth equipment (extra quiet). The team also decided to include an option on mitigating train vibrations by using a neoprene isolation mat under the footings and slab on grade within the concert hall.

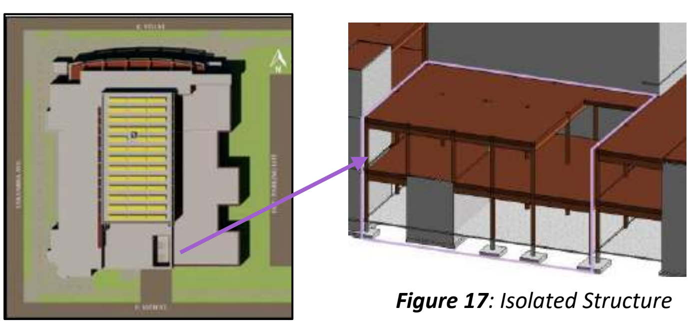


***Figure 17**: Isolated Structure*

Syndicate not only considered the negative effects of the vibrations throughout the building, but also discovered an opportunity to utilize these vibrations. While small, the structure has natural vibrations caused by factors such as wind or foot traffic. While completely unnoticeable to occupants, equipment known as Vibration Energy Harvesters (VEH) are sensitive enough to pick up these vibrations. *Syndicate* implemented these energy harvesters to power all low voltage sensors in The Miller Center, including wireless lighting control sensors and automatic lavatory fixtures. This energy will be used to power the 128 lighting control sensors and 70 automatic fixture sensors that would normally require wiring or disposable batteries. Over the course of a 15-year time period, the VEH devices are able to reduce the building's CO_2 emissions by 700,000 kg, which is equivalent to removing 168 passenger vehicles from the road. Refer to Lighting/ Electrical SD-D for more details.

8.0 Final Integrated Design

Within the following sections, *Syndicate* focuses on the final design of the following areas of integration:

- Occupiable Roof
- North Lobby
- West Corridor
- South Lobby
- Concert Hall

8.1 Occupiable Roof Final Design

Syndicate collaborated to design an occupiable roof that would act as a gathering space between downtown Holland residents and Hope College community. The space is versatile to a multitude of events and designed to be used year-round. A hybrid ventilation system,

Figure 18: *Occupiable Roof Rendering*

Figure 19: *North Lobby Rendering*

exposed wood structure and optimized lighting controls allowed *Syndicate* to create a space to be utilized by the community and campus that showcases sustainable design.

8.1.1 Occupiable Roof Systems Integration

Syndicate designed the occupiable roof structure with deep glulam beams and drop panels with recessed linear lighting to create depth and variability within the space, as shown in *Figure 18*. Minimal disruption on the ceiling was achieved by an exposed wood structure and optimized mechanical system. This unobstructed view allowed for cove lighting to highlight the exposed wood members and bring a warm aesthetic to the space. The team integrated the glulam columns and curtain wall facade with the lighting controls to maximize natural indirect daylight into the space.

Syndicate integrated sliding glass doors into the facade along with overhead fans to encourage air movement and maximize comfort during the warmer months. A heating ventilation system was designed to allow for winter use so that the occupiable roof can be used year-round, while acting as an additional thermal barrier. The space adds an additional R-value of 20 to the roof of the north lobby, saving 90 MMBTU/hr in energy usage. Refer to Mechanical Report Section 7.3.

The team was able to include the occupiable roof in their budget but saw the space as an opportunity for promoting a fundraising initiative to allow donors to assist in the expense of this versatile space. Options for fundraising presented to Hope College include holding a performance gala for school of music students, advertising for local business sponsorship, and naming opportunities for the rooftop space. To assist with this fundraising initiative, Syndicate will provide free design of models, renderings, and virtual reality walkthroughs of the space to allow potential donors to experience the design, while also matching donations up to $50,000.

8.2 North Lobby Final Design

Syndicate's multidisciplinary team designed the north lobby of The Miller Center to showcase sustainability while welcoming occupants from both the Holland community and campus. This was accomplished using vertical lighting techniques to accent exposed glulam and CLT systems to emphasize the curtain wall's transparency at night (*Figure 19).* Lighting and HVAC controls synced with *Lutron's Quantum* software are to be displayed along with static building data on an interactive dashboard. The north lobby is further designed for sustainability through an integrated high-performance façade and underfloor displacement ventilation to reduce mechanical equipment present in the space.

8.2.1 North Lobby Systems Integration

The team integrated through multiple iterations of an exposed wood roof structure to showcase sustainable design that aligns with the materials and resources category of the sustainability plan. This structure incorporates deep wood glulam cross beams supporting a CLT floor system with double story glulam columns integrated along the exterior façade. Refer to Structural Report Section 11.0. In order to ensure quality of these glulam members, the team designated a special laydown area for the heavy timber that is larger than normal, elevated, and protected from weather.

The team collaborated through constructability of glazing layouts and façade connections to meet thermal

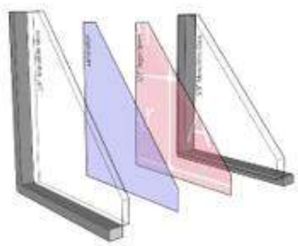


***Figure 20**: Glass Layout*

and solar capacity enabling a high-performance façade.

The team designed the glass and mullions of the north lobby facade for structural capacity based off controlling wind pressures. Refer to Structural Report Section 13.1. Once the minimum glass size was chosen based off loading, the team analyzed the daylight and thermal penetration to find acceptable coatings and glass thicknesses. This façade faces north, therefore, sun coatings were not necessary, but the team's final design did incorporate laminated glass for safety of occupants *(Figure 20). Syndicate's* design enhances the campus by providing views from the building and into the building to maximize occupant experience. Refer to Integration Drawing I-7.0 and Structural Drawing S-6.0 for details regarding this façade. The façade was analyzed for the practicality of incorporating a ventilated double wall façade but ha d a payback period of 30 years.

As mentioned earlier in Integration Report Section 7.3.1, *Syndicate* optimized the north lobby orientation to reduce ASE coming into the space, while also reducing the solar heat gain by over 50%. Time schedules are incorporated to allow for full light on between 7 AM and 7 PM but can be overwritten through daylight sensors to conserve energy. Accent lighting was also incorporated in key areas, such as the custom clock designed by Jack H. Miller and the exposed wood members of the ceiling, to showcase the features of the space. The use of lighting controls along with the amount of daylight entering the north lobby allowed *Syndicate* to reduce the kwh/year by 86% which aided in a total building energy reduction of 53% when compared to the baseline model.

The team collaborated to place duct runs along the first and second story heights, as well as underfloor ventilation displacement to efficiently cool and heat the high-volume space. *Syndicate* altered the layout of the balcony in the north lobby to allow a stairwell to take occupants to the occupiable roof space. The staircase in this space was offset from the concert hall wall in order to allow for mechanical return ducts running at the second story height. The balcony was extended out 16 feet into the lobby and then hung using steel rods from the structure above. The hanging balcony along with displacement ventilation minimized the presence of mechanical and structural systems by eliminating the need for columns.

8.3 West Corridor Final Design

Syndicate designed a hallway along the first-floor west façade in order to act as a grand corridor between the north and south lobbies. Refer to Integration Drawing I-1.0 for optimized floor plans. This space was designed with a glass curtain wall along the exterior façade to provide ample daylight into the three classrooms.

8.3.1 West Corridor Systems Integration

When analyzing this space, the team realized that the design had allowed 75.5 MMBTU/hr of unwanted solar heat gain into the west corridor. *Syndicate* researched ways to utilize this solar heat gain and implemented a ventilated double wall façade along the west corridor (*Figure 21* on the next page). This system efficiently utilizes the solar heat gain for heat recovery in the colder months, while exhausting the heated air to cool the space in the warmer months. This wall will be constructed on site to modularize the system and then installed into the building to improve quality of construction. Operable glass panels were designed in the ventilated double wall facade to open to the building's interior to allow for maintenance. The team incorporated continuous insulation above and below the system to enhance thermal performance by mitigating thermal bridges. Refer to Mechanical SD-D for further information.

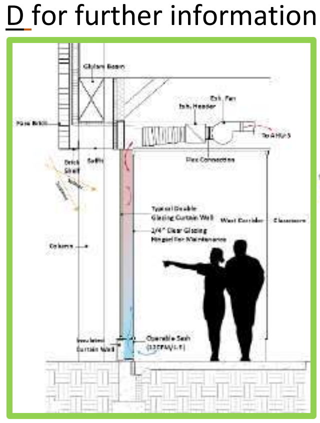


***Figure 21**: Ventilated Double Wall Façade(left) and Classroom/Corridor Daylight Section (top)*

Syndicate encountered that the interior glass wall of the classroom would create glare challenges. To mitigate sunlight and daylight penetration, the team incorporated a smart tint adhesive film to block any direct sunlight while still allowing for a partial view. An electrochromic tint film by *Smart Tint* was chosen that varies from 3% to 97% transparent. An additional blackout shade from *Lutron's Serena Shades* for situations where the lecturer would be using the projector was implemented. This self-adhesive electronic film can be controlled through switches that provide the ability to dim the transparency. As seen in Lighting Drawing L-6.0, *Syndicate* was able to increase daylight autonomy within the classrooms to 82% while limiting the ASE to 23% through the addition of the smart tint glazing. This system allowed the team to recover 8.4 MMBTU/hr through heat recovery utilizing the unwanted solar heat gain. After analyzing the practicality of this system, it provided a reduction in annual utility services by 7%, or $6600 annually, and a payback period of 8 years, which Syndicate deemed to be acceptable to implement into design.

8.4 South Lobby Final Design

Syndicate designed the south lobby to provide a direct connection between campus and The Miller Center to be used primarily by students and faculty. The team created a space that felt both open and flexible, as seen in *Figure 22*. This was accomplished through all disciplines optimizing designs for the space's potential. Within the south lobby there are two functions, a comfortable lounge space for students to sit and study and a transition space to encourage visitors to move through the building.

8.4.1 South Lobby System Integration

A combination of CLT, glulam beams and columns, and pendant fixtures resulted in an open design that framed out a lounge space to be used by students and faculty. The uninterrupted double height space benefitted from a minimal structure, displacement ventilation, as well as mounting all track lights to the beams rather than the ceiling.

Mentioned in Integration Report Section 7.3.2, the façade mimics the Martha Miller Center rotunda,

***Figure 22**: South Lobby Rendering*

providing a balance between natural light and occupancy comfort by alternating the large high-performance windows with solid brick walls. This allowed *Syndicate* to maximize the views from the south lobby but presented a challenge of solar heat gain and direct sunlight penetration entering the space.

To overcome this challenge, horizontal louvers were *incorporated* along with 70% tinted glazing to limit the ASE from 84% to 48%. Refer to Lighting Drawing L-6.0. The glass layup for the façade of the south lobby incorporates laminated glass and an argon filled space along with the above-mentioned louvers and tint glazing to enhance thermal, daylight, and safety criteria for the façade. The use of displacement ventilation allowed the team to minimize mechanical presence in the space and provided a more open, exposed structural system. Displacement ventilation was incorporated to provide superior indoor air quality or "well-being" for occupants when compared to ceiling supplied distribution systems. The integration of all systems resulted in a south lobby that met the goals of Hope College and the team, while still providing an open and flexible space for occupants. *Syndicate* analyzed the practicality of designing the façade of the south lobby as a ventilated double wall façade to utilize the solar heat gain, but like the north lobby, the payback period was not deemed acceptable at a period of 15 years.

8.5 Concert Hall Final Design

Syndicate designed a world class symphonic concert hall *(Figure 23)* that enhanced the occupant experience while creating a premier performance space through a collaboration of disciplines. This was achieved through the design of concrete precast panels, coordination

***Figure 23**: Rendering of Performance Hall*

between underground ventilation displacement and footings, as well as a steel truss roof structure integrated with catwalk layouts, fiber optic lighting, and acoustical ribbon coordination.

8.5.1 Underground Ducts

This large volume space incorporated a displacement ventilation system to efficiently cool and improve air quality to occupants. The system directly cools the utilized space and allows for stratification in the upper zones that can be exhausted instead of cooled. The Blue Duct system runs a 48" duct from the mechanical room to the concert hall below the slab. Refer to Mechanical Drawing M-3.0 for details about displacement ventilation, *Syndicate* collaborated heavily using clash detection in *Navisworks* and *Revit* for a below-grade with the strip footings surrounding the concert hall. The concrete strip footings surrounding the concert hall were lowered by 6' in order to accommodate a frost depth of 42" and the additional depth for the size of the underground ducts. The concrete shear walls were then designed to be prefabricated with holes to allow for duct travel into the space as seen in *Figure 24.* During construction, the team properly sequenced the concert hall to efficiently install and protect each system. Refer to Construction Drawings C-1.0 for details.

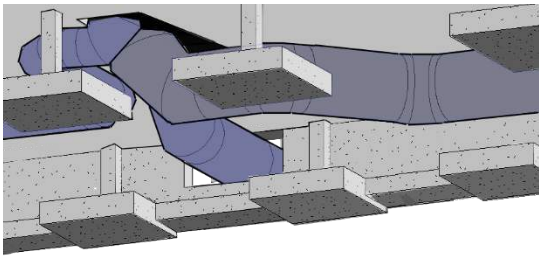


***Figure 24**: Clash Detection for Underground Ducts*

8.5.2 Concert Hall Roof

The concert hall roof incorporates all disciplines within the final design. A catwalk layout was determined to correspond with the layout of the structural roofing system to allow for access to performance equipment and maintenance. *Syndicate*'s structural and construction teams collaborated to perform and analyze, respectively, three iterations of the roof structure. After further consideration for budget, *Syndicate* selected the roof structure as a steel truss system to reduce the cost of large wood members with expensive connection details. For more detail about the roof structure options refer to Structural Report Section 10.1.

The roof structure was designed to support lighting and mechanical equipment loads. The use of underground ducts minimized the necessity for mechanical equipment in the ceiling plenum and allowed the team to only need three return ducts sized up to 30"x42". Collaboration among disciplines allowed *Syndicate* to strike a balance between a fiber optic lighting scheme, general snooted house lighting, and the placement of acoustical ribbons. These ribbons enhance the acoustics of the space and therefore, require specific placement in the ceiling and a specific height to maximize reverberation times. The fiber optic lighting was then coordinated to be hung from the truss above and placed in between these ribbons to create the feeling of a starry night while aiding to blackout the equipment above. Refer to the Lighting/Electrical Report Section 5.2 for details on the lighting scheme.

The team further collaborated to incorporate a photovoltaic array system on the concert hall roof. The minimal disruptions in sunlight allows the array to ultimately generate 3.26 GWh of energy resulting in a total net savings of $350,000 over its 35-year lifespan. Refer to Lighting/ Electrical Report Section 6.1. When originally analyzing site conditions, *Syndicate* discovered that Michigan's average annual snowfall is 70 inches, compared to the United States average annual snowfall is 26 inches. This allowed the team to incorporate a snowmelt system into their roof assembly with a water storage capacity of 5000 gallons to be used for grey water. Refer to Mechanical Report Section 10.2.

The installation of this snowmelt system along with low flow options for toilets allowed *Syndicate* to reduce the water consumption of The Miller Center by 30%. The roofing assembly is further optimized to mitigate moisture transmittance and heat loss through a sustainable roof design including 4" polyiso rigid insulation and other materials as seen in *Figure 25,* that surpasses ASHRAE 90.1 standards.

***Figure 25**: Roof assembly*

8.6 Faculty Studios Final Design

The faculty studios serve as a space for professors to work and meet with students throughout the day. *Syndicate* wanted to create areas for the faculty that optimizes workflow and comfort (*Figure 26*). Every faculty studio has windows or skylights to provide natural light for improved mental health of the users. The acoustics of the space was important during design considerations since many faculty and students will be meeting and rehearsing in these studios. Integrated acoustical lighting fixtures were intermixed with radiant panel modules to create a dynamic ceiling that provided thermal comfort, artificial light, and proper acoustical qualities. The radiant panels and acoustical lighting fixtures are designed in 2'x2' and 2'X4' modules for

***Figure 26**: Faculty Studio*

easier constructability. In addition, the CLT structure above the dynamic ceiling provides an air space to trap in unwanted sound reflections and further improve the acoustics of the space. By integrating all the systems together, *Syndicate* was able to eliminate extra acoustical paneling on the walls. Refer to Integration Report Section 10.1 for further acoustical analysis.

9.0 Hope College Sustainability Plan

Rather than follow standards, such as *LEED* or *Well,* that focus on point accumulation rather than technical goals, *Syndicate* created a unique sustainability plan personalized to Hope College. This sustainability plan would allow *Syndicate* to aspire to Hope College's goal of sustainable design by using The Miller Center as a pilot for future projects.

***Figure 27:** Lutron Quantum Display System*

The team chose to focus on waste reduction, indoor environment, materials and resources, and energy conservation. Refer to Construction Report Section 7.0. *Syndicate* incorporated a *Senseware* interactive dashboard display that will showcase the dynamic sustainability aspects of the design during operation (*Figure 27).*

Behind the scenes, the *Lutrons Quantum™* will talk to the *Senseware* system to portray all savings made by the lighting controls, HVAC controls, and electrical systems. The *Senseware* system will also manage the savings from water consumption and solar payback. Statistics such as cost and reduced carbon footprint through the utilization of a wood structure will be on the dashboard, as well. *Figure 22* provides an example of the dashboard display and portrays the analysis of carbon content based off volume of building structural materials compared to passenger vehicles on the road. This system will be used in lieu of a "plaque" for The Miller Center to proudly present to the community and encourage their contribution to a more energy efficient future. Refer to Integration Drawing I-10.0 for integrated use of this plan and dashboard display boards.

10.0 Integrated Acoustics

Syndicate collaborated in the design of The Miller Center to incorporate world class, adaptable acoustics. This was achieved through analyses using a program, known as *ODEON,* to measure acoustical criteria of each area, as well as analyzing the enclosure of the critical performance spaces. The team analyzed reverberation time (RT), lateral energy fraction, musical clarity, early decay time (EDT), and speech clarity within the various performance, rehearsal, and faculty spaces. (*Figure 28).*

Definitions	
Reverberation Time	The time it takes for sound to decrease by 60dB
Clarity	Implies a shorter RT and is best for rapid passages
Early Decay Time	A short EDT is a good indicator of speech clarity
Lateral Energy Fraction	Measure of the spaciousness of a room
Sound Transmission Class	Rating of how well a building partition reduces airborne sound
Impact Insulation Class	Rating of how well a building floor reduces impact sound

Figure 28: *Acoustical Definitions*

10.1 ODEON Results

The concert hall is the main feature of The Miller Center and entertains various performance types. After analysis, it was found that no changes were required because the given design already provided acoustical excellence. Commencement ceremonies and other spoken events will take place in this space, so a specific metric to the concert hall was the speech clarity, which is how well speech is interpreted by the listener. By drawing the curtains on the side of the hall, there is an improvement in speech clarity that provides adaptability. The recital hall is similar to the concert hall except that it is a smaller, more intimate performance space for soloists and chamber ensembles. Speech clarity was not considered because there are no spoken events. When considering the other metrics, again, there were no changes necessary.

The practice rooms, faculty studios, and orchestra and choir rehearsal rooms were analyzed using only RT. This single metric is used because these spaces are specifically for practice and a low RT will better allow the instructors and students to hear each distinct note length and intonation. The choir and orchestra rooms did not require any changes, but the practice rooms and faculty studios did. The practice rooms analysis resulted in a low RT, therefore some of the acoustic panels were able to be removed. Integration with all disciplines led to the development of the radiant panel and acoustic light fixture grid in the faculty studios. The acoustical panels within this fixture are good low frequency absorbers for sound while the lighting fixture itself is a great high frequency absorber. This custom fixture allowed for acoustic wall panels to be removed, and premier acoustics to be maintained. Refer to Integration Drawing I-4.0 for *ODEON* results and Construction Drawing C-3.0 for cost savings.

10.2 Sound and Vibration Transmittance

A multi-disciplinary approach was critical when addressing the sound and vibration in the building. A large portion of this sound and vibration comes from the mechanical equipment. *Syndicate's* solution to the vibrations included isolating the structure for the mechanical room. The team designed a system that implements isolation pads between the columns and piers along with isolation joints in the floor system to mitigate vibration transmission from the mechanical room. Equipment specific vibrational isolation includes a varying combination of spring isolators and concrete inertia pads. The equipment also creates airborne noise that travels through the ducts. To prevent this sound from disturbing sound sensitive spaces, duct silencers, duct lining, long duct runs, and multiple mitered elbows were implemented. Refer to Mechanical Report Section 9.0 for details on equipment acoustics.

The concert hall was an acoustically critical space due to the performances that would be taking place. Therefore, the team further isolated this system using isolation padding between embed plates and beams framing into the concrete precast panels. To further improve the acoustical quality of the concert hall, the team built-up the wall assembly of the concert hall to meet STC 65. The floor assembly was built-up as well to surpass STC and IIC values of 50. See Structural Drawing S-8.0 for details. Throughout construction, the team will ensure acoustical quality through reminders at weekly foremen meetings and utilizing QR code tracking system in each space. Refer to Construction Drawing C-2.0 for more detail.

11.0 Lessons Learned

During the design of The Miller Center, *Syndicate* grew as a team to improve on the individual and collaborative levels, as well as the overall design process resulting in these valuable lessons to be taken away:

- Communication is the foundation for collaboration, without it the team will fail along with the design.
- Every design choice has the potential to bring both seen and unseen results for other disciplines.
- Building Information Modeling (BIM) is the catalyst for coordination between disciplines, spanning all lifecycle phases of design.
- Cross-disciplinary interactions provide a unique perspective that can refine solutions.
- Consultation with experts and professionals can lead to a better understanding of the end user's needs and wants.
- A good design is revealed through mistakes, innovations, and integration.

12.0 Conclusions

Syndicate utilized iterative and integrative design approaches to sustainably and economically create a combined design of The Jack H. Miller Center for Musical Arts. The team operated under an integrated design-build delivery method to streamline communication between the owner and their project team, while providing the best quality of work on a fast-tracked timeline. *Syndicate* was able to complete the project within a 16-month schedule and successfully develop a budget of $23,926,850 with donations covering the cost of the occupiable roof. Refer to <u>Integration Drawing I-6.0.</u> The final design of The Miller Center provided Hope College with an educational and performance center that improved the campus and downtown Holland with numerous benefits as shown in *Figure 29.*

OWNER DEFINED GOALS	SYNDICATE DEFINED GOALS	IMPROVEMENT	BENEFIT	DISCIPLINE
Connection	Enhance Hope College Campus	Layout optimization	Create a connection between downtown Holland and campus	
		Occupiable roof addition	Space versatile to a multitude of activities and events for the school, public, and a combination of both	
		Rotation of building	Reduces solar heat gain entering the lobby by 63%	
			Reduces annual sunlight exposure of large lobby by 85.2%	
Versatility	Maximize Occupant Experience	High Performance/ Adaptable Acousics	STC standards met or exceeded for each roof and wall assembly	
			NC of each space met	
			IIC standards met or exceeded for floor assemblies	
		Skylight on third floor roof	Increases amount of commonly occupied spaces receiving daylight by 11%	
		Finish material selection Moveable curtains in central performance hall	Met or exceeded reverberation times for each type of performance	
		Mutli-purpose design	Spaces designed for educational and performance activities	
Performance	Create Premier Performance Spaces	Ventilated double wall façade	Decrease annual utility cost by 14%, or $6600 annually	
			Increases amount of commonly occupied spaces receiving daylight by 10%	
		High performance wall assemblies	Exceeds required R-value for thermal barrier by at least 28%	
			Meets required STC of 65 for performancehalls	
		Concert Hall room finishes and acoustical ribbon height	Allowed for optimum early decay times, lateral energy fraction, and musical clarity	
		QR codes used during construction	Increase quality control and assurance	
		Isolated structure for Mechanical Space	Mitigate structural borne vibrations	
Sustainability	Minimize Energy Impact	Implementation of a Lutrons Quantum™ display system	Provides a pilot for sustainable design for future projects	
		Incorporating wood engineered products into structural system	Reducing carbon content of the building by 27% when compared to a steel structure	
		PV array system on concert hall roof	Total net savings of $350,000 over a 35-year lifespan, generates 3.26GWh of energy	
		CHP option	Capability for 90% further expansion of campus connection	
		Low flow toilets	Reduce Water consumption by 30%	
		Snowmelt and rainwater collection system	Can hold up to 3400 gallons of water to be used for grey water	
		Overall energy reduction	Reduced overall building energy usage by 44%	
		Skylight on third floor	Overal net energy reduction of 2,647 kwh/year	
		Monitoring construction waste on a biweekly basis	Reduce carbon footprint impact	

Figure 29: *Team Conclusions*

HOPE OWNER DEFINED GOALS

VERSATILITY
Adaptable acoustical performances were a key factor in the design of The Miller Center. This allows for each type of space to be flexible to lecturers, performances, and any other events or ceremonies that might take place.

CONNECTION
Hope College expressed A desire for connection through the occupiable roof challenge to create a space that could be shared by students, faculty, and the residents of Holland, Michigan for various events .

SUSTAINABILITY
A sustainable focus was introduced to the design by Hope College through a design challenge. This challenge requests the use of wood products into the design of the structure, enclosure, or finishes of the building.

PERFORMANCE
Hope College set a goal for high acoustic quality performances, represented through a design challenge. This encouraged each space to have the best quality acoustics for all types of performances that would take place.

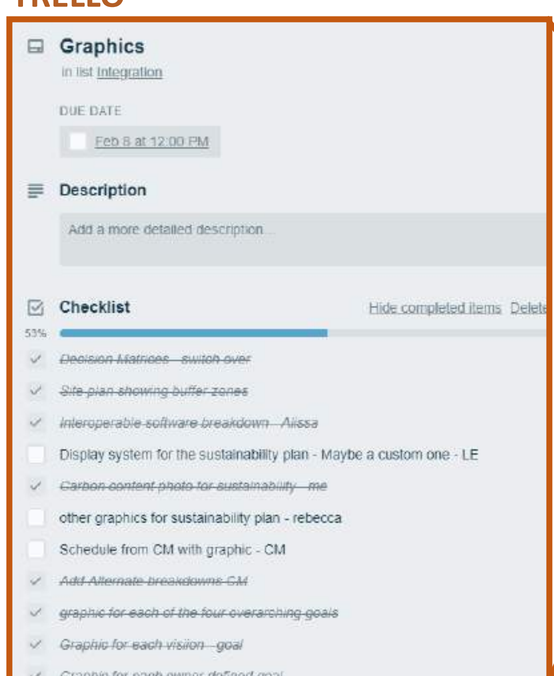
HOPE + *SYNDICATE'S* VISION STATEMENT OF HOPE

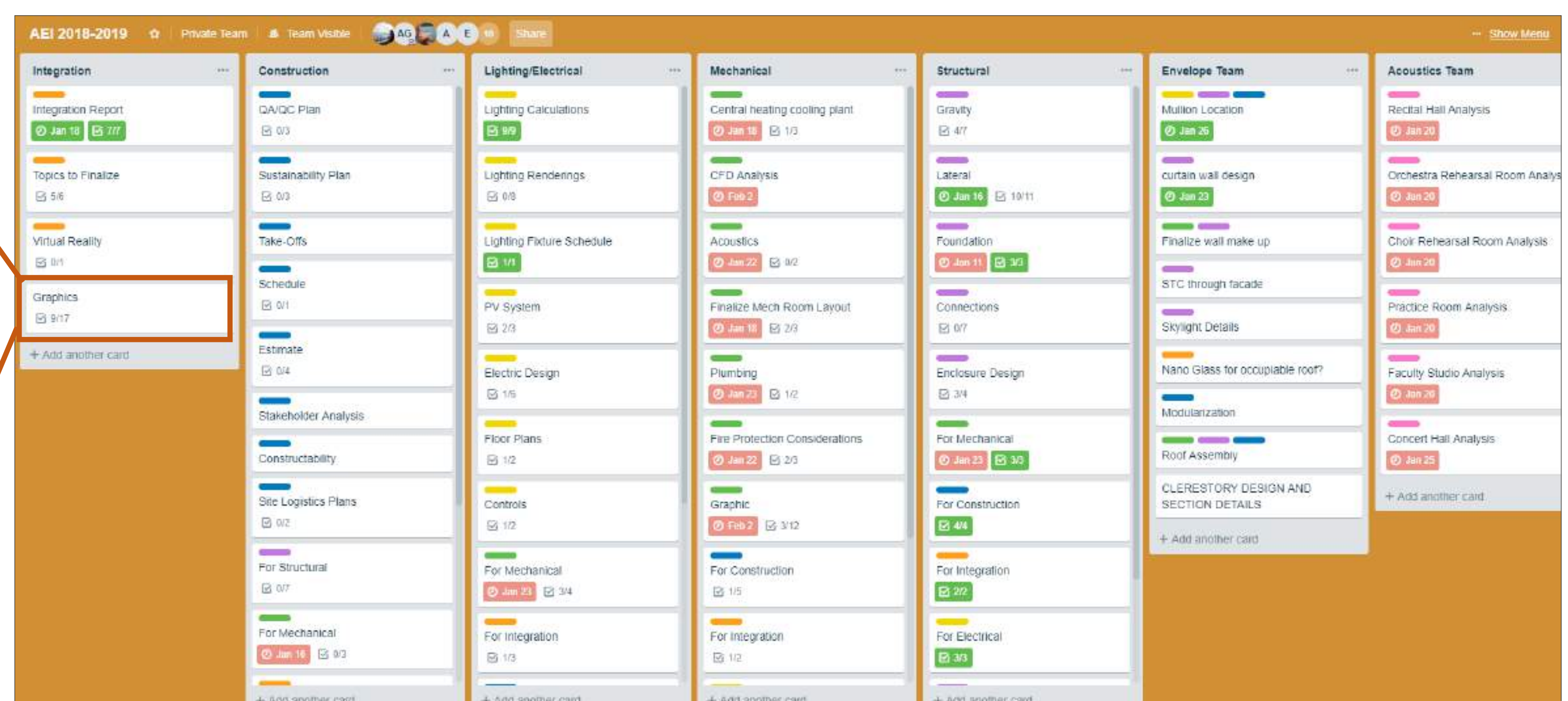
- Enhance Hope College Campus
- Maximize Occupant Experience
- Create Premier Performance Spaces
- Minimize Energy Impact

SYNDICATE'S PROJECT GOALS

- Construction Schedule
- Aesthetics
- Cost
- Comfortability
- Accessibility
- Quality
- Reduced Disturbances
- Sound Quality
- Flexibility
- Waste Reduction
- Sound Quality
- Life Cycle
- Efficiency

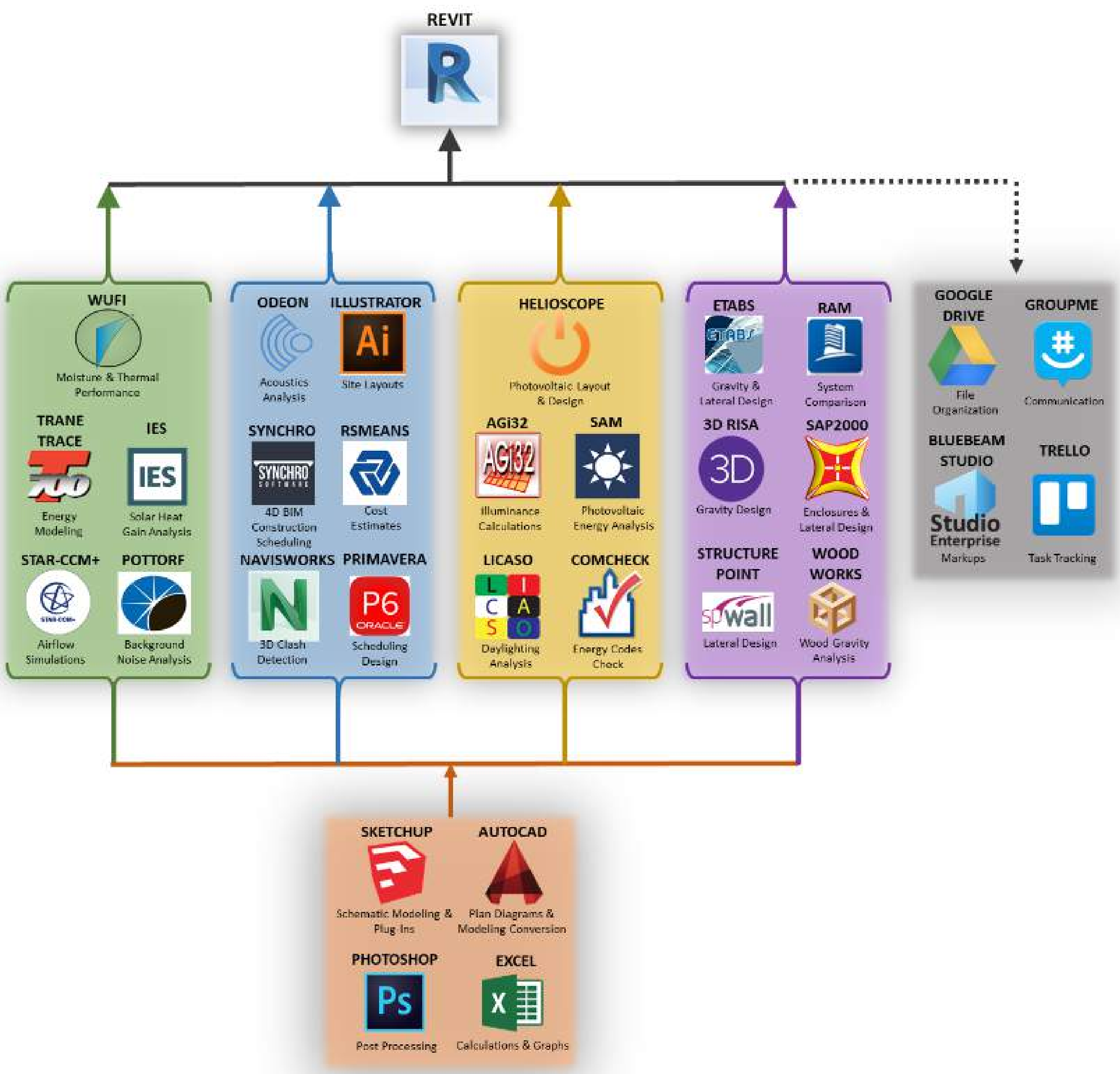
TRELLO





Syndicate utilized Trello to allow the team to function in a dynamic manner. Throughout design, all disciplines had their own tasks to complete along with information and tasks to complete for other disciplines. To keep track of these tasks, as well as, deadlines throughout the project, boards were set up for the different disciplines and subcommittees. As seen to the left, these boards were broken down by category into different checklists. This software program allowed the team to maximize their collaborative efforts and efficiently follow strict deadlines.

INTEROPERABLE SOFTWARE USAGE



Interoperable software became a key component to collaboration among all disciplines. Each discipline used the software programs listed above for information storage, design, analysis, and planning. *Syndicate* utilized a central model within the building information modeling (BIM) software of *Revit* to assist with clash detection, layout optimization, and visualization of spaces. This program allowed the team to input their own discipline specific design into the building and promoted easier team communication. The team created storage locations for shared files and information within *Google Drive* and *Bluebeam Studio* for easy access among team members. *Trello* also became a main collaborative platform for sharing deadlines and tasks required for each team member to complete.

COLLABORATIVE SPACE

An open, multidisciplinary work environment promoted integration and communication more readily. As shown below, *Syndicate* designated their workspace by discipline, but kept the plan open to allow for cross-disciplinary communication and collaboration. Each team member had their own work station with two monitors as seen below. Within the space, two white boards separated the work space from a conference space. These white boards were used during discussions and decision making to sketch graphics and further visualize ideas for integration. *Syndicate* chose to utilize the conference space for consultations with industry professionals and advisors.

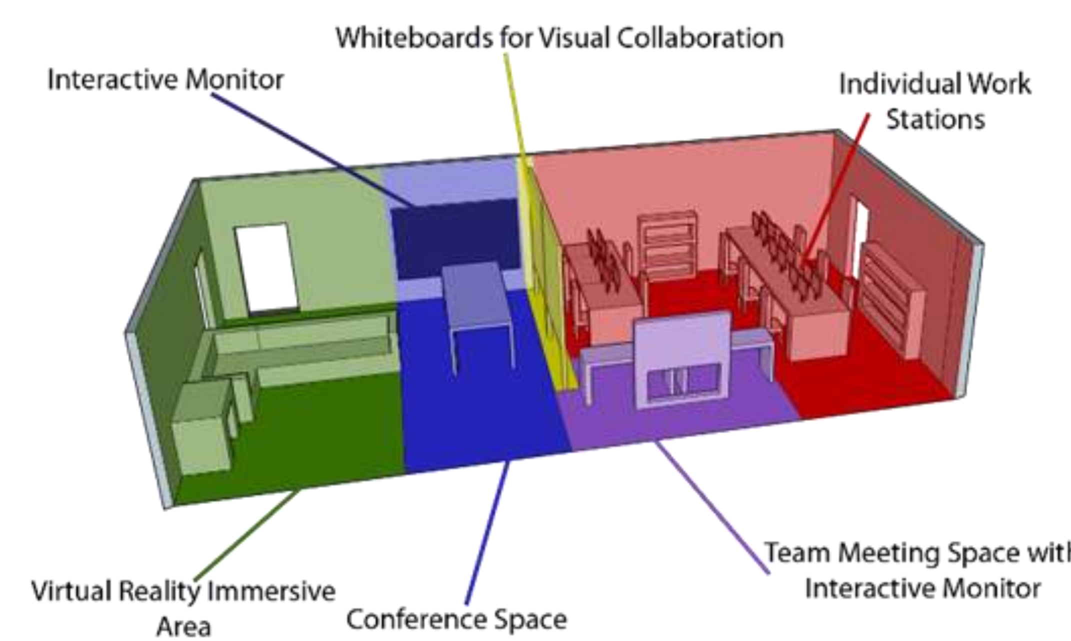
An interactive large-scale monitor was placed in the center of the work room. *Syndicate* chose to set up two tables in front of this monitor to create a meeting space so that the monitor could be utilized to bring up models and meeting minutes. This interactive monitor also acted as a tool to assist in discipline collaboration and integration.

Intradisciplinary Collaboration

To create as successful of a work space as possible, *Syndicate* chose to designate work station location for each member based on discipline. This allowed for the best intradisciplinary communication and collaboration. The success of the intradisciplinary interaction led to success within the interdisciplinary interaction as well.

Interdisciplinary Collaboration

Syndicate found that interdisciplinary collaboration was key in creating a successful project. The open plan for the work space assisted in open communication among disciplines. The interactive tables, whiteboards, and technology also aided *Syndicate* creating and discussing graphics to further discuss and visualize integrated aspects of the project.



DECISION MATRICES

Syndicate utilized a decision matrix to make unbiased decisions that connected back to their vision statement of HOPE. The use of decision matrices was necessary when making decisions for the design as it aided in a faster decision being made, as well as, an easy way for all members of the group to be integrated and involved.

SYNDICATE — DECISION MATRIX: Integration

Team Goals :	Enhance Hope College Campus			Maximize Occupant Experience			Create Premier Performances			Minimize Energy Impacts					
	Construction Schedule	Aesthetics	Cost	Comfortability	Accessibility	Quality	Reduced disturbance	Sound Quality	Flexibility	Waste Reduction	Carbon Footprint	Life Cycle	Efficiency	Weighted Score	Rank	Final Outcome
BUILDING ORIENTATION																
Weights :	0	2	2	3	1	2	3	3	0	2	0	3	2			
Current Orientation	0	3	2	1	1	1	1	1	0	1	0	1	1	29	2	
Rotation of 90 with large lobby facing North	0	2	3	3	2	2	2	2	0	2	0	2	2	51	1	X
Additional Comments :	The team's final decision was to rotate the building with the large lobby facing north. This would allow for the most efficient design and limit the solar heat gain and the direct daylight penetration into the large lobby.															
MECHANICAL EQUIPMENT ISOLATION																
Weights :	2	2	2	3	1	2	3	3	1	0	3	0	1			
Basement Addition	3	2	3	2	2	2	2	2	3	0	1	0	0	46	3	
Detached Structure	2	1	2	3	1	3	3	3	3	0	2	0	0	53	2	
Isolated Structure within Building	1	2	2	3	3	3	3	3	2	0	2	0	0	54	1	X
Additional Comments :	The location of the mechanical equipment was considered for not only how the mechanical equipment itself impacts the building, but also how the space acts as a buffer zone from the sound transmitted from the train. Syndicate's design incorporated an isolated structure within the building.															
SOUTH LOBBY ADDITION																
Weights :	1	2	3	3	3	2	0	0	1	0	1	1	2			
Creation of South Lobby	1	3	1	3	3	2	0	0	3	0	1	1	3	43	1	X
Creation of South Entrance	2	2	2	2	3	2	0	0	2	0	2	2	2	41	2	
Given Design	3	2	2	2	2	2	0	0	2	0	2	2	2	39	3	
Additional Comments :	Syndicate's final design incorporates the addition of a south lobby to act as both an antrance and a student gathering space. Syndicate's decision matrice indicated that the best choices were both the additon of a lobby or just an entrance on the south. After further discussion, Syndicate felt that the south lobby would create more of a statement and create a nice student space.															
WEST CORRIDOR																
Weights :	1	3	2	3	3	0	2	2	2	2	1	2	2			
West Corridor Addition with Third Floor	1	2	1	2	3	0	2	0	0	1	0	1	1	34	1	X
Given Design	2	1	2	1	1	0	1	0	0	2	0	2	2	29	2	
Additional Comments :	Syndicate's final design incorporates the addition of a west corridor that moves the faculty studios and practice rooms to be distributed along the second and third floors of the building. This allows for more clear accessibility to the north lobby from the south lobby.															
HOPE COLLEGE SUSTAINABILITY PLAN																
Weights :	0	0	0	3	3	3	0	2	2	3	3	3	3			
WELL	0	0	0	3	2	3	0	1	1	1	3	1	2	49	3	
LEED	0	0	0	2	1	3	0	1	1	2	2	3	3	52	2	
Sustainability Plan specific to Hope College	0	0	0	2	1	3	0	2	1	3	3	3	3	60	1	X
Additional Comments :	Syndicate's final design incorporates the addition of a west corridor that moves the faculty studios and practice rooms to be distributed along the second and third floors of the building. This allows for more clear accessibility to the north lobby from the south lobby.															

SYNDICATE — DECISION MATRIX: Integration

Team Goals :	Enhance Hope College Campus			Maximize Occupant Experience			Create Premier Performances			Minimize Energy Impacts					
	Construction Schedule	Aesthetics	Cost	Comfortability	Accessibility	Quality	Reduced disturbance	Sound Quality	Flexibility	Waste Reduction	Carbon Footprint	Life Cycle	Efficiency	Weighted Score	Rank	Final Outcome
TYPICAL STRUCTURAL FRAMING																
Weights :	2	3	3	3	0	0	2	3	2	3	3	2	3			
Glulam Frame with CLT Deck	2	3	1	3	0	0	2	2	3	3	3	3	2	71	1	X
Glulam Frame with Concrete on Metal Deck	2	3	3	2	0	0	1	2	2	2	2	2	2	62	2	
Steel Frame with Concrete on Metal Deck	1	2	2	2	0	0	3	2	3	1	1	1	2	52	3	
Additional Comments :	The stuctural team decided to pursue the glulam frame with CLT deck system. Even though this system was predicted to be the highest in cost it provided many benfits that outweighed that aspect. This system allowes for a significantly smaller waster reduction, carbon footprint and life cycle. It also provides an increased aesthetic to the space which will improve the occupant experience															
MECHANICAL CENTRAL PLANT																
Weights :	2	1	3	3	0	1	3	2	1	2	2	2	3			
Campus Central Plant	3	2	1	2	1	3	2	3	2	2	2	3	3	57	1	X
Geothermal	1	2	1	2	1	2	2	2	2	3	3	1	2	47	2	
Standard Plant	3	2	3	2	1	2	2	2	2	2	2	3	2	57	1	X
Additional Comments :	The campus central plant and a standard in house mechanical plant tied in the decision matrix. Syndicate decided to propose two options for Hope College to consider. Option 1 is a standard mechanical plant with chillers and a steam station, while Option 2 is proposing a brand new campus central plant that has gas turbines for CHP and chillers for a chilled water plant.															
PHOTOVOLTAIC TECHNOLOGY																
Weights :	1	2	3	2	0	3	0	0	1	1	3	2	3			
Photovoltaic Rooftop Array	2	1	3	1	0	3	0	0	1	2	3	2	3	24	1	X
Photovoltaic Glass	1	2	1	2	0	1	0	0	2	2	1	2	2	19	2	
Additional Comments :	A photovoltaic array was selected against the photovoltaic glass due to it's higher annual generation, lower cost, and faster payback period. This sytem will allow for ample savings to reduce the overall buildings energy usage.															
ADDITION OF DROP CEILINGS																
Weights :	1	3	2	1	2	1	2	3	1	2	1	2	1			
Addition of drop Ceilings	1	3	1	2	1	1	2	3	1	1	1	2	1	39	1	X
No drop ceilings	2	1	2	1	2	2	1	1	1	2	2	1	2	38	2	
Additional Comments :	Syndicate designed their spaces according to acoustical quality, constructability, and aesthetics. The option to incorporate drop ceilings into spaces in the Miller Center allowed the team to optimize these factors for each space. The only spaces not using drop ceilings for aesthetic or acoustical purposes were the north and south lobbies, as well as, the recital, choral, orchestral and symphonic concert hall.															

Rating - Weighting	
High Importance	3
Medium Importance	2
Lowest Importance	1

Scoring	
Best	3
Middle	2
Worst	1

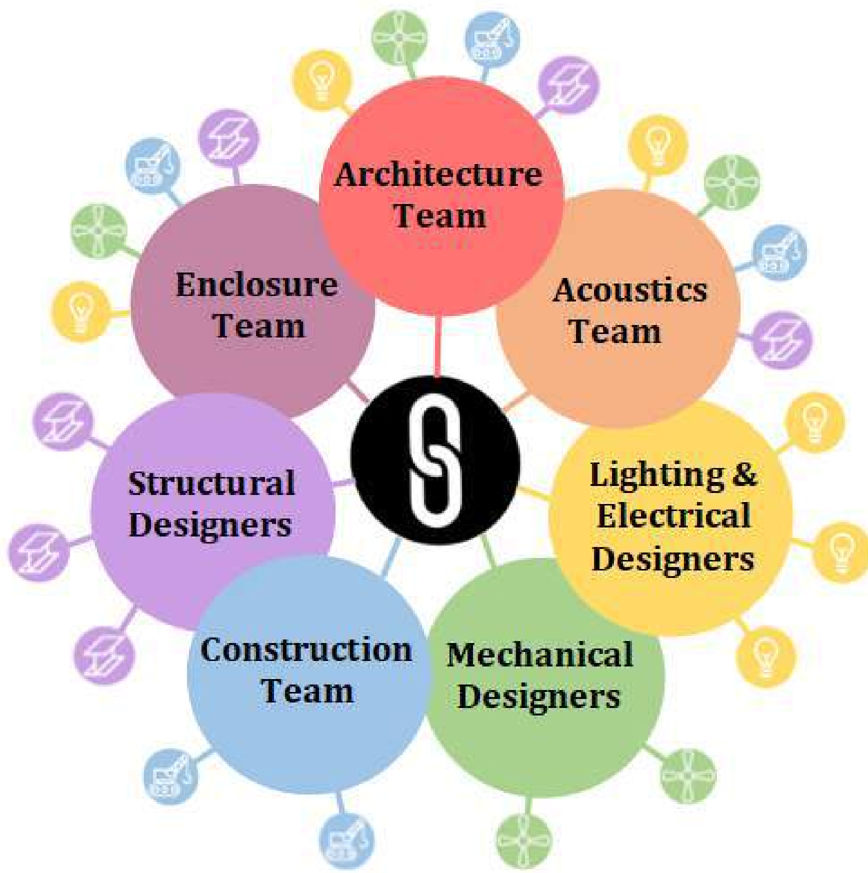
DECISION MAKING PROCESS

The four overarching goals that *Syndicate* incorporated into the matrix from the vision statement of HOPE were broken down into design based criteria. These criteria were kept consistent throughout all disciplines in order to connect all decisions to the original four overarching goals.

When choosing the weight of the specific criteria, one member would weigh all criteria and then at least three other members of the team would analyze the weights and give their input. If there were any discrepancies, the team would have a group discussion regarding the weighting of the criteria. This was the procedure not only for decisions that had cross-disciplinary criteria, but also for decisions that were discipline specific. For example, one discipline would have at least one member from every other discipline review their matrices and provide feedback. This interdisciplinary process ensured that the design decisions were constantly measured against the goals of the project.

The weighting of the criteria varies from a weight of one through three, with a three being very important to the project goals and a one being the least important. The specific rating is then based on a one to three scale with a one being the worst option for that criteria and a three being the best option.

MULTIDISCIPLINARY TEAM BREAKDOWN



Syndicate is comprised of ten members with the following breakdown by discipline:

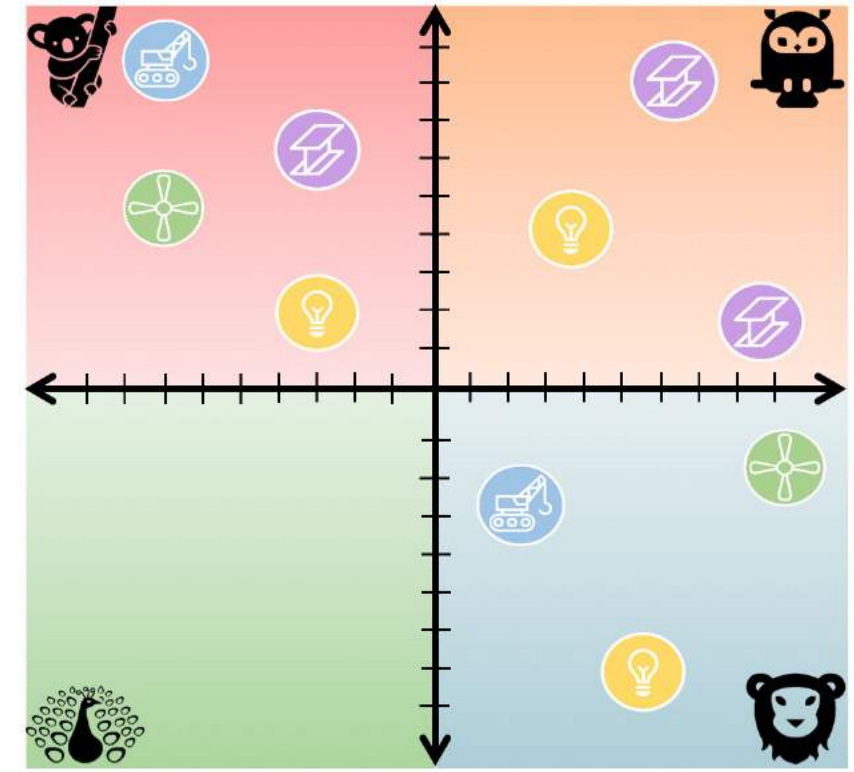
- Three structural designers
- Two mechanical designers
- Two construction members
- Three lighting/ electrical designers

The team was then broken down into multidisciplinary teams based off of the goals of the project. The multidisciplinary teams include acoustics, architecture, and building enclosures. All members of *Syndicate* took part in the architecture decisions being made throughout the design Each team consisted of one member of each discipline to promote collaboration and integration among disciplines, as seen above.

Within the multidisciplinary teams, design iteration and decisions were made. Each member of each discipline was responsible for discussing the decision with their own discipline members and the decisions were then brought up in full team meetings as well. These teams allowed *Syndicate* to optimize integration and collaborative thinking while mitigating biased design decisions.

DOMINANT PERSONALITY MATRIX

From the time of forming the team, *Syndicate* realized that analyzing and understanding each member's personality would be crucial for creating a cohesive and trustworthy group. Every team member took a personality test known as the Personality Matrix which uses a more generalized range of personal qualities, allowing for simpler comparisons within a smaller team. The construction team used these results to plan for situations like team bonding, conflict mediation, and indicating stress amongst other members. As seen to the right, the *Analyzer*, *Controller,* and *Supporter* were all equally represented in *Syndicate*. Overall, *Syndicate* felt that the team was well-rounded and allowed every member to grow throughout the duration of the project. Seen to the left is a grid displaying where members from each discipline fell into each personality type. Since the individual disciplines are required to divide their work amongst two or three people, understanding each person's strengths and weaknesses becomes crucial to delegating tasks. Somebody with a dominant "Owl" personality is more likely to be more detail oriented and organized, whereas somebody with a dominant "Koala" personality may have the ability of reflective thinking and therefore expressive writing and speaking.



Analyzer "Owl" | Controller "Lion"

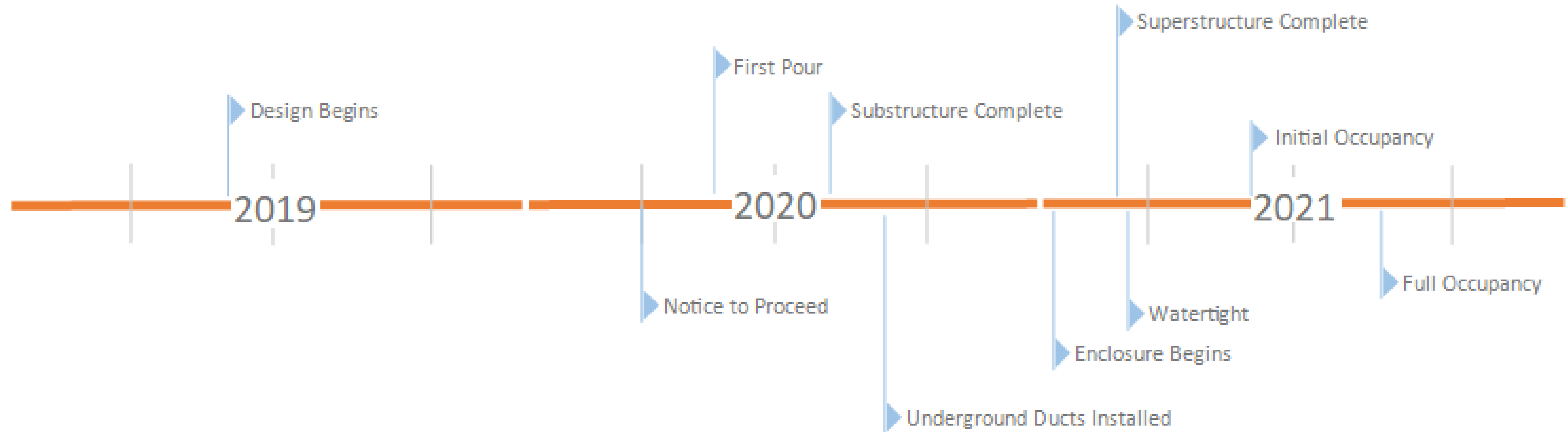
Supporter "Koala" | Promoter "Peacock"

VIRTUAL REALITY

The team utilized Virtual Reality (VR) to aid in systems integration, space visualization, and decision making. The ability to walk through a space, experience the architecture, and witness the features allowed the team to optimize their design.

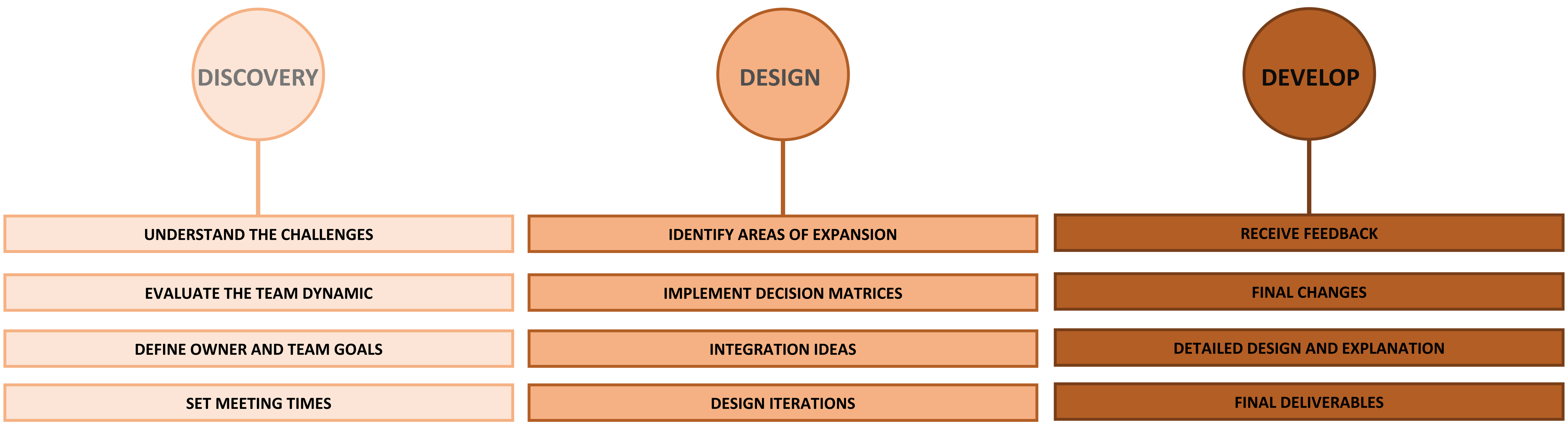
MILESTONE SCHEDULE

Syndicate created a 26 month total design and construction schedule for The Jack H. Miller Center for Musical Arts. Sixteen of those months consist of the construction phase of the project. Shown to the left is the milestone schedule for the project that was created to give the owner a high-level summary of the project activities. This also aids in determining total duration of construction and ensuring any major conflicts with campus events are mitigated. Due to *Syndicate's* design-build delivery method, the project can be fast-tracked, meaning the construction period begins before the design is complete. The notice to proceed for construction happens in the early second quarter of 2020, and construction of the project ends in the third quarter of 2021. Further schedule detail can be found on Drawing C-4.0 and Drawings C-5.0.

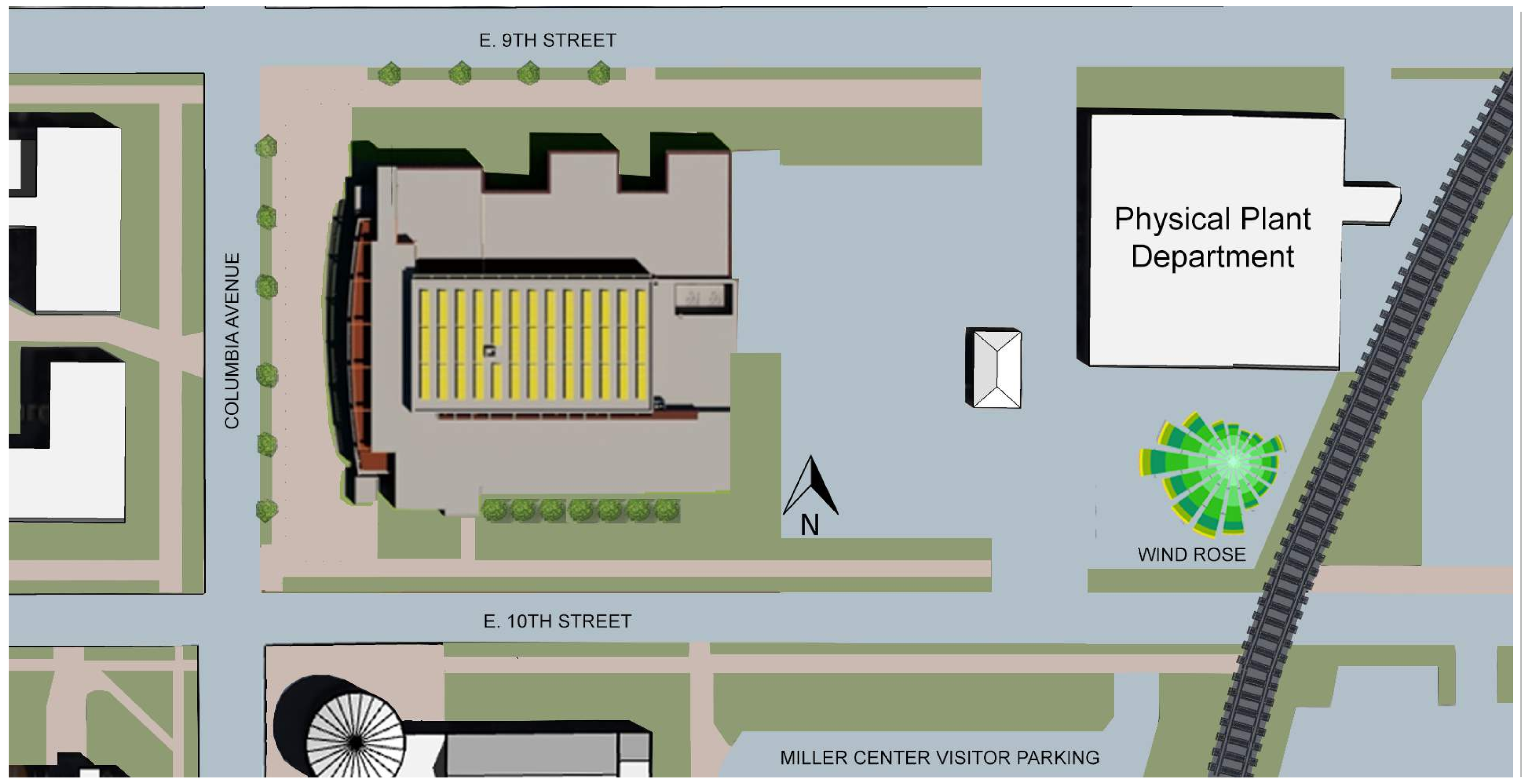


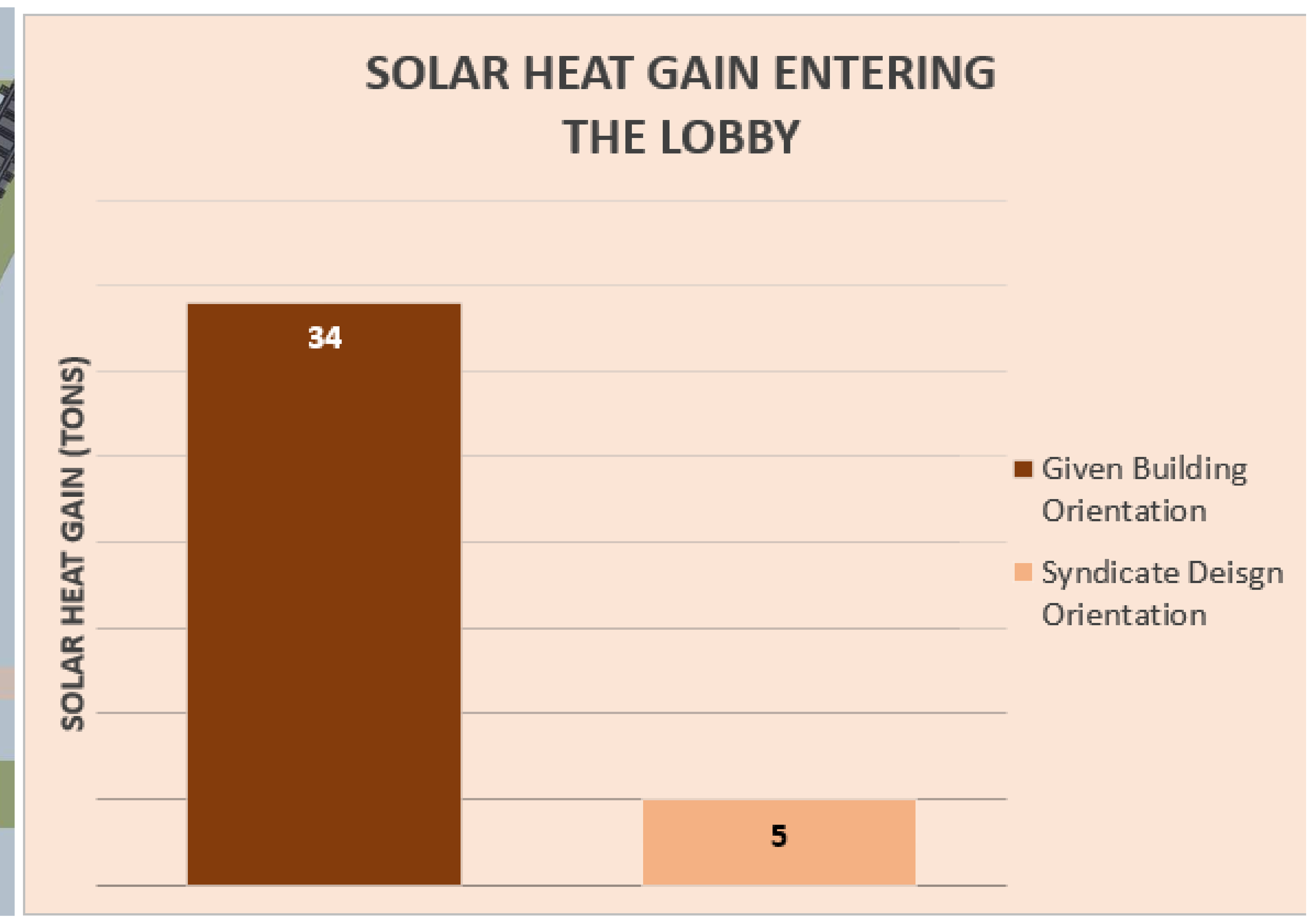
TEAM DESIGN PROCESS

Syndicate 's design process neatly categorized into three main phases: discovery, design, and develop. With this movement of collaboration, *Syndicate* was able to better their integration skills and keep all team members on the same pace. During the first few months of meeting the discovery phase occurred. By taking the time to better understand the challenges given to us, one another's personalities and working skills, defining the overall end goals for the project, and setting core hours to meet, *Syndicate's* disciplines were able to better design with common mindsets. Moving through the design phase, large amounts of integration occurred, finding key spaces to expand on together, implementing decision matrices that would incorporate all disciplines, and constantly reiterating designs to make sure all disciplines were thought of. Once all designs were finished with contentment, *Syndicate* took feedback from all teammate as well as outside voices to catch anything that could use some final adjustments. Detailed designs, explanations, and final deliverables were then created to make sure anybody viewing the project could fully understand the intent that *Syndicate* put forward.

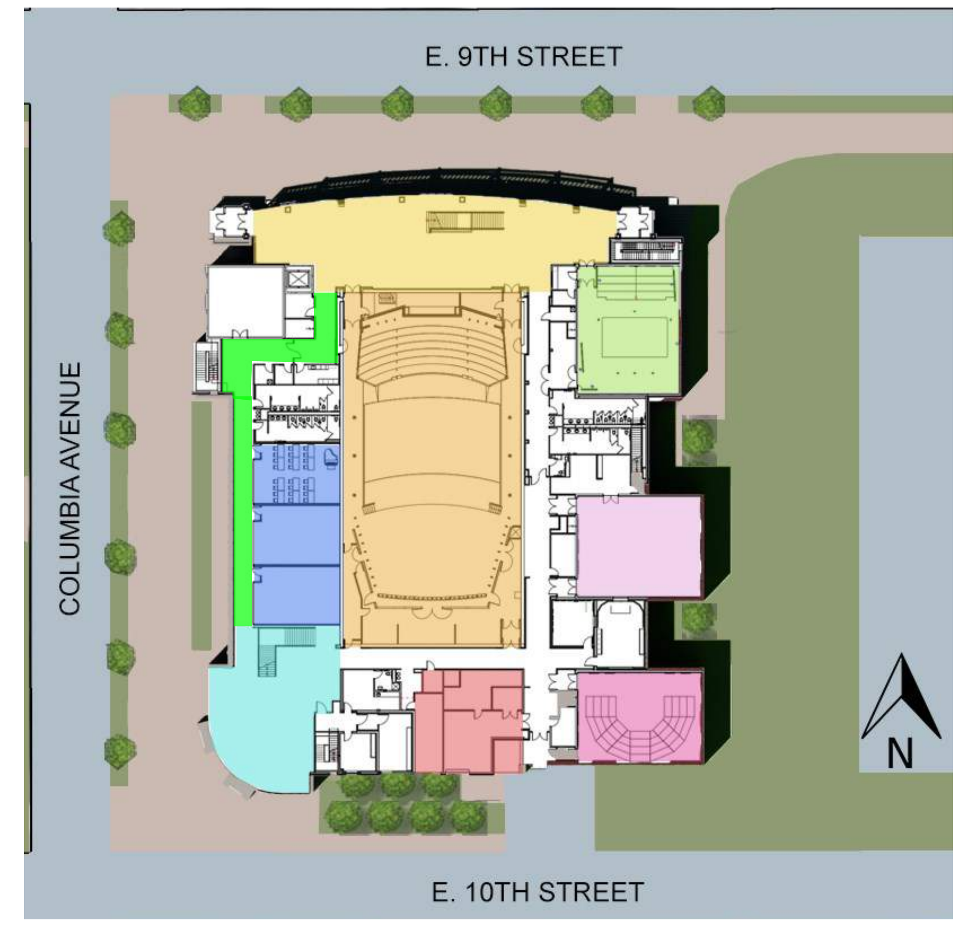


GIVEN BUILDING ORIENTATION

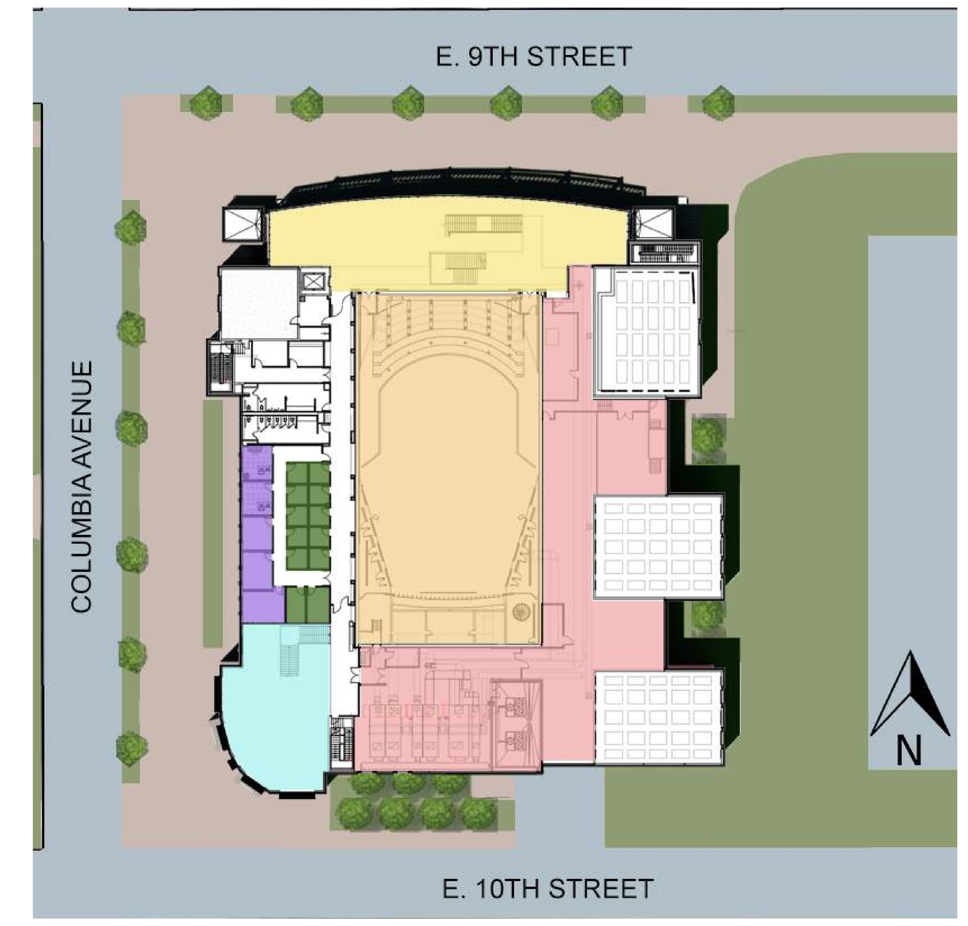




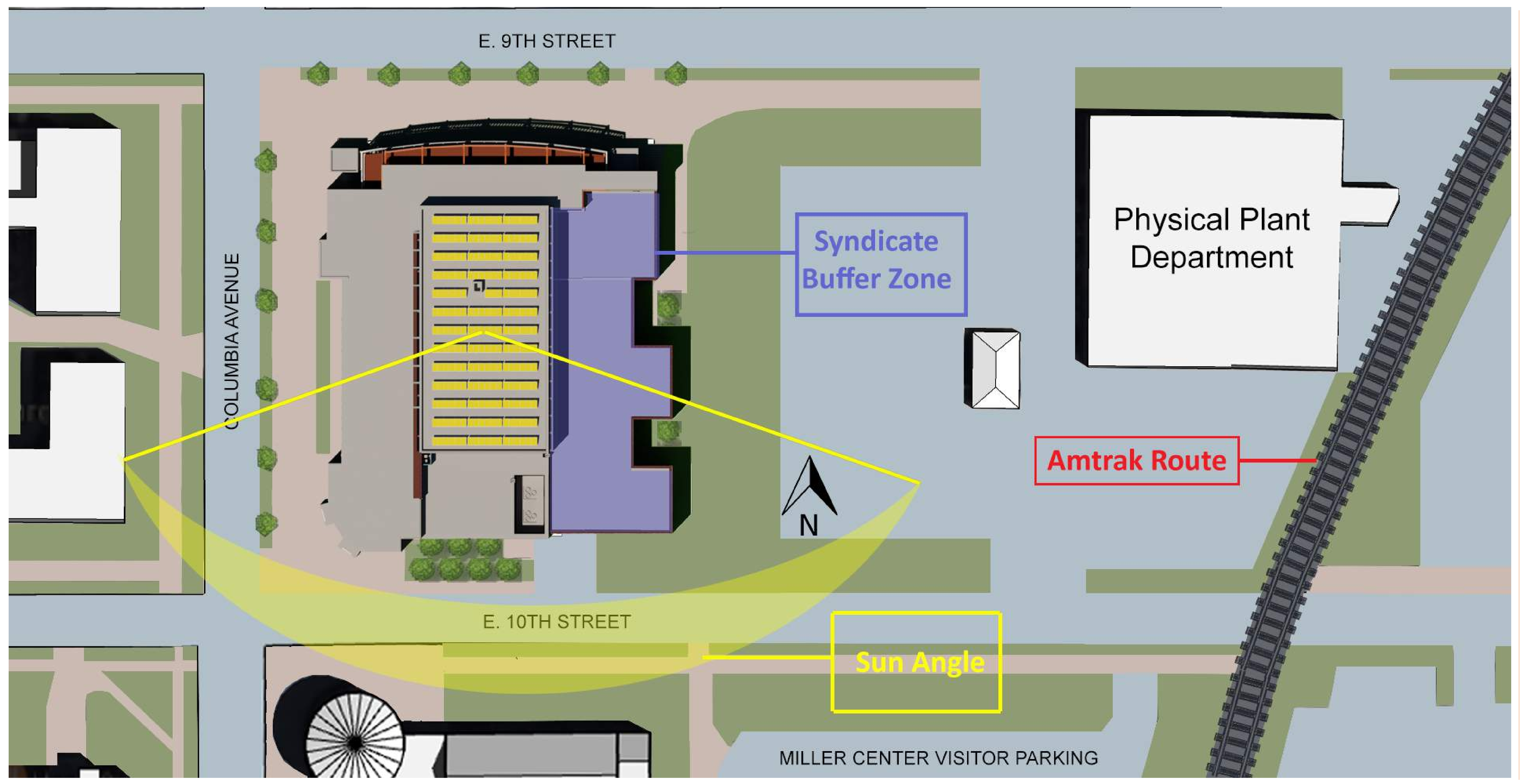
Optimized First Floor Plan

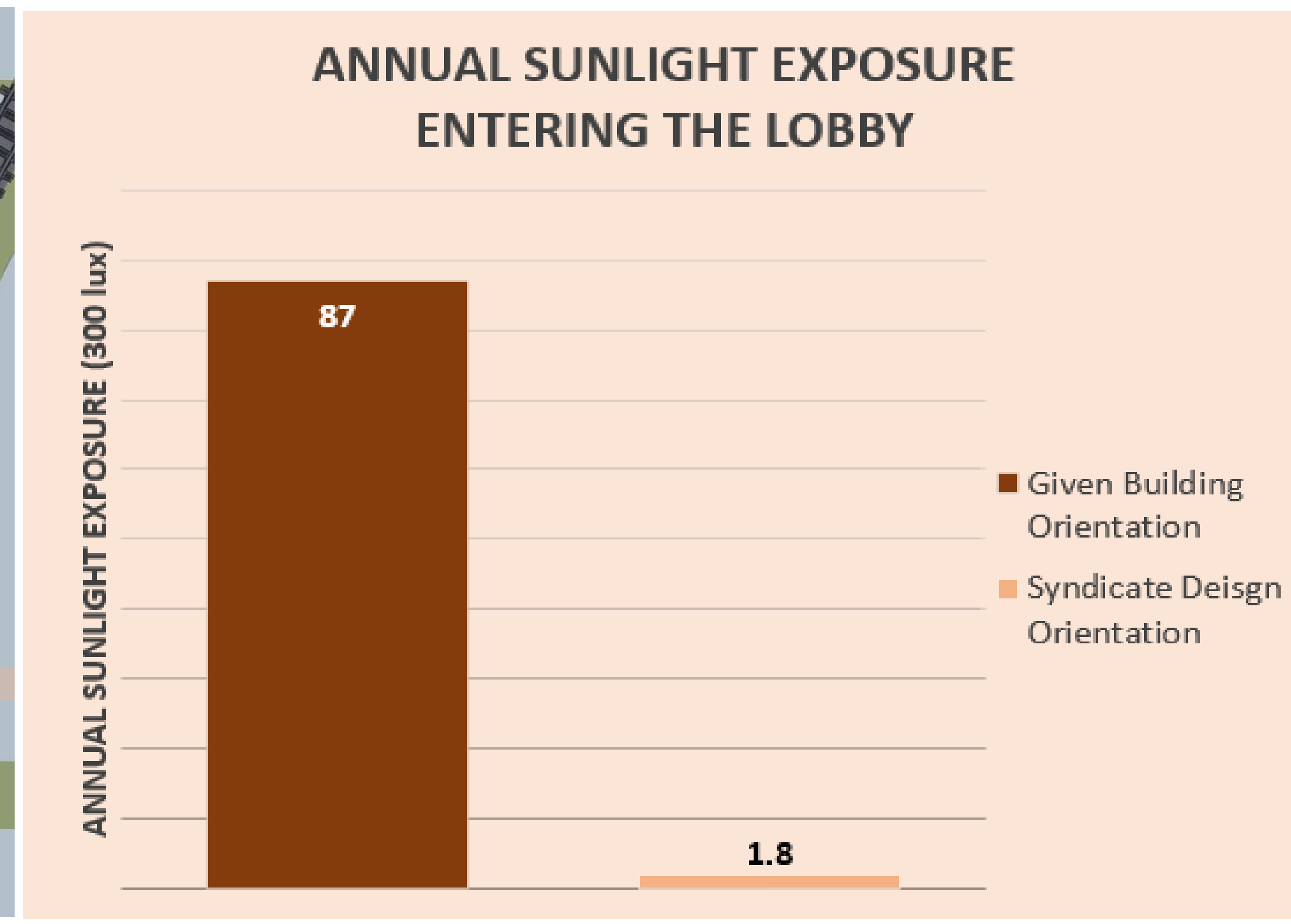


Optimized Second Third Plan



SYNDICATE DESIGN ORIENTATION





Floor Plan Legend

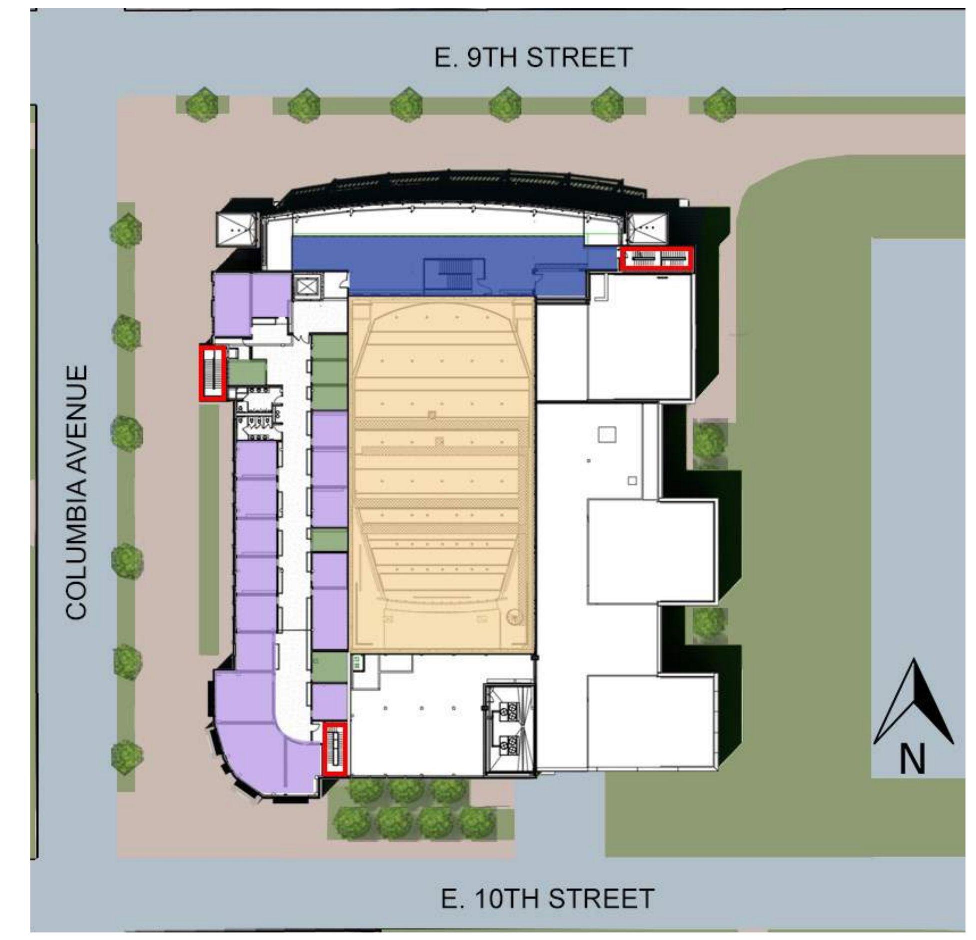
- South Lobby
- Classroom
- Recital Hall
- Concert Hall
- Mechanical
- Orchestral Rehearsal
- North Lobby
- Practice Rooms
- Faculty Studios
- Occupiable Roof
- Choral Rehearsal
- West Corridor

Fire-rated Stairwells

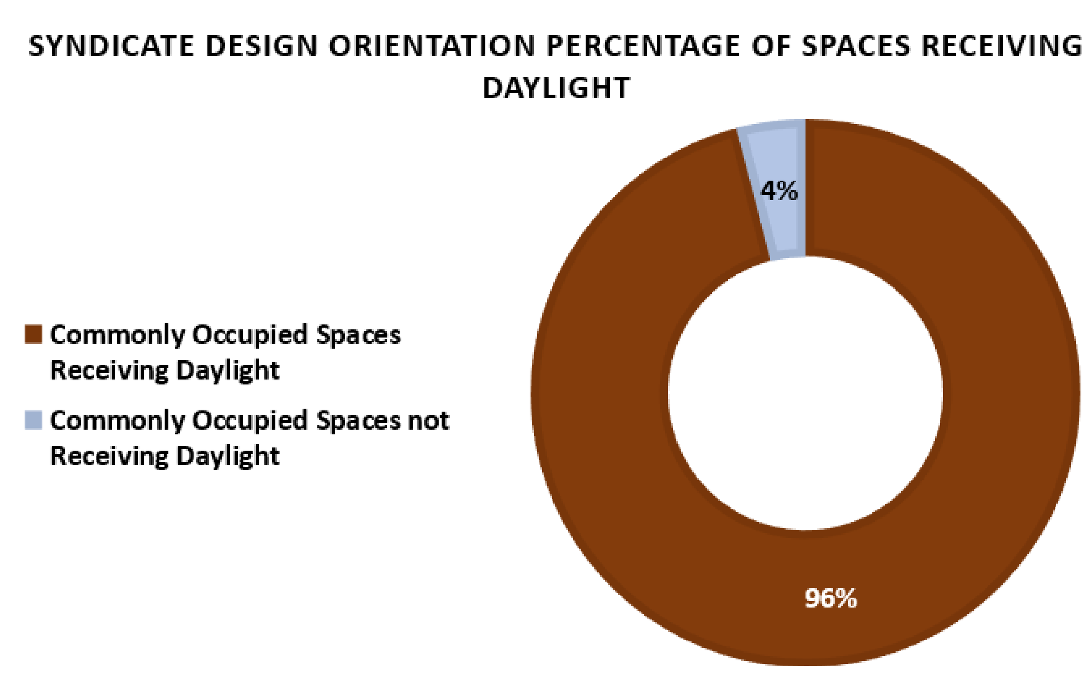
The addition of the third floor required *Syndicate* to design fire-rated stairs based off of the IBC 2018 requirements.

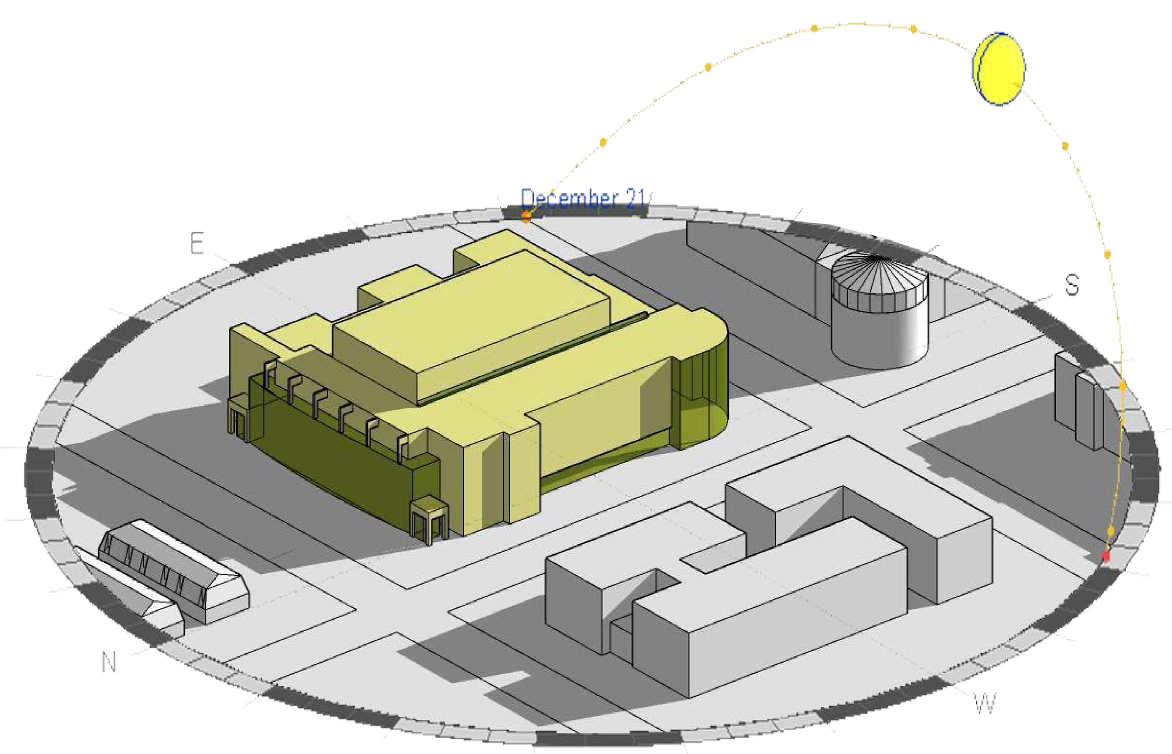
= Fire Rated Stairwell

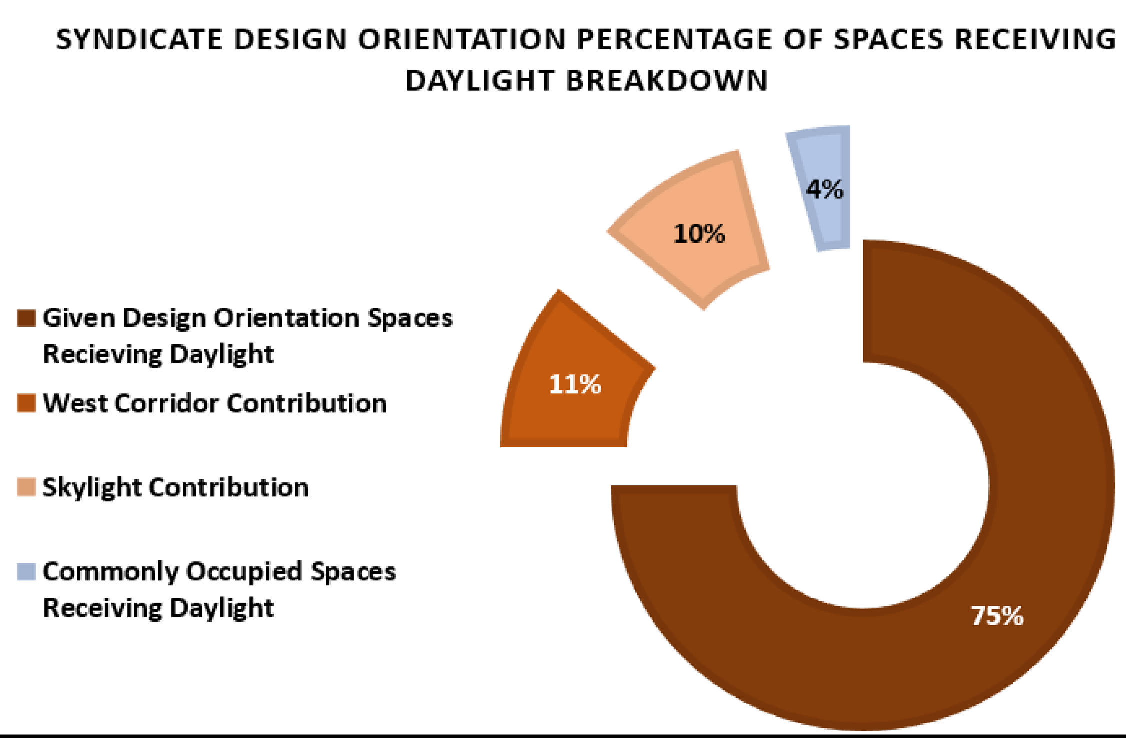
Third Floor Addition



OPTIMIZED DAYLIGHTING

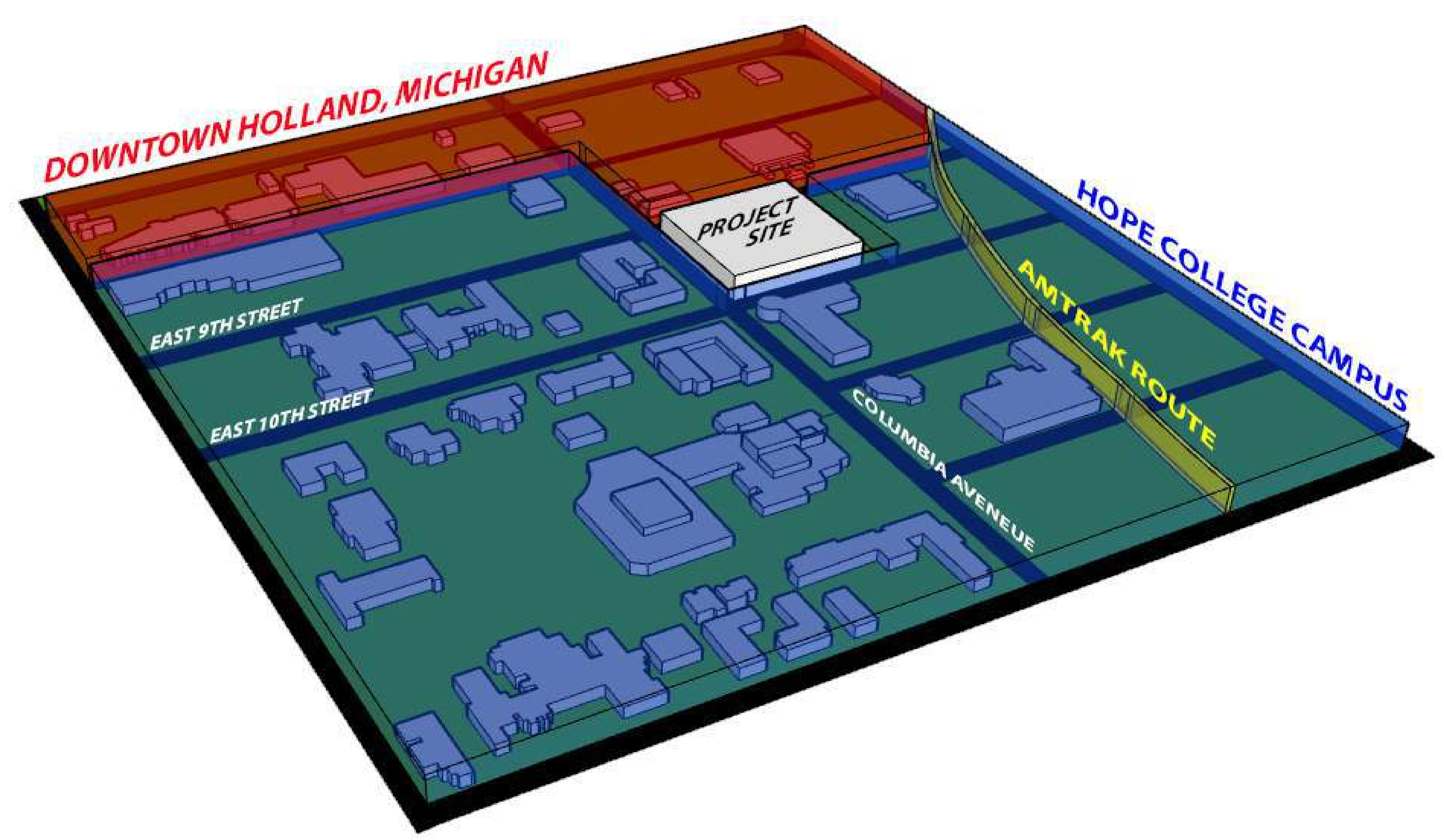






Schematic Detail of a faculty studio with a punch window (left) and a skylight (right)

SITE LOGISTICS



The project site for The Miller Center is located on the northeast corner of Hope College campus s and south of downtown Holland, as seen below. There is an Amtrak route approximately 100 feet behind the site, as well as a highly trafficked east 9th street and a less frequented east 10th street.

SYNDICATE

PROJECT

JACK H. MILLER CENTER FOR MUSICAL ARTS

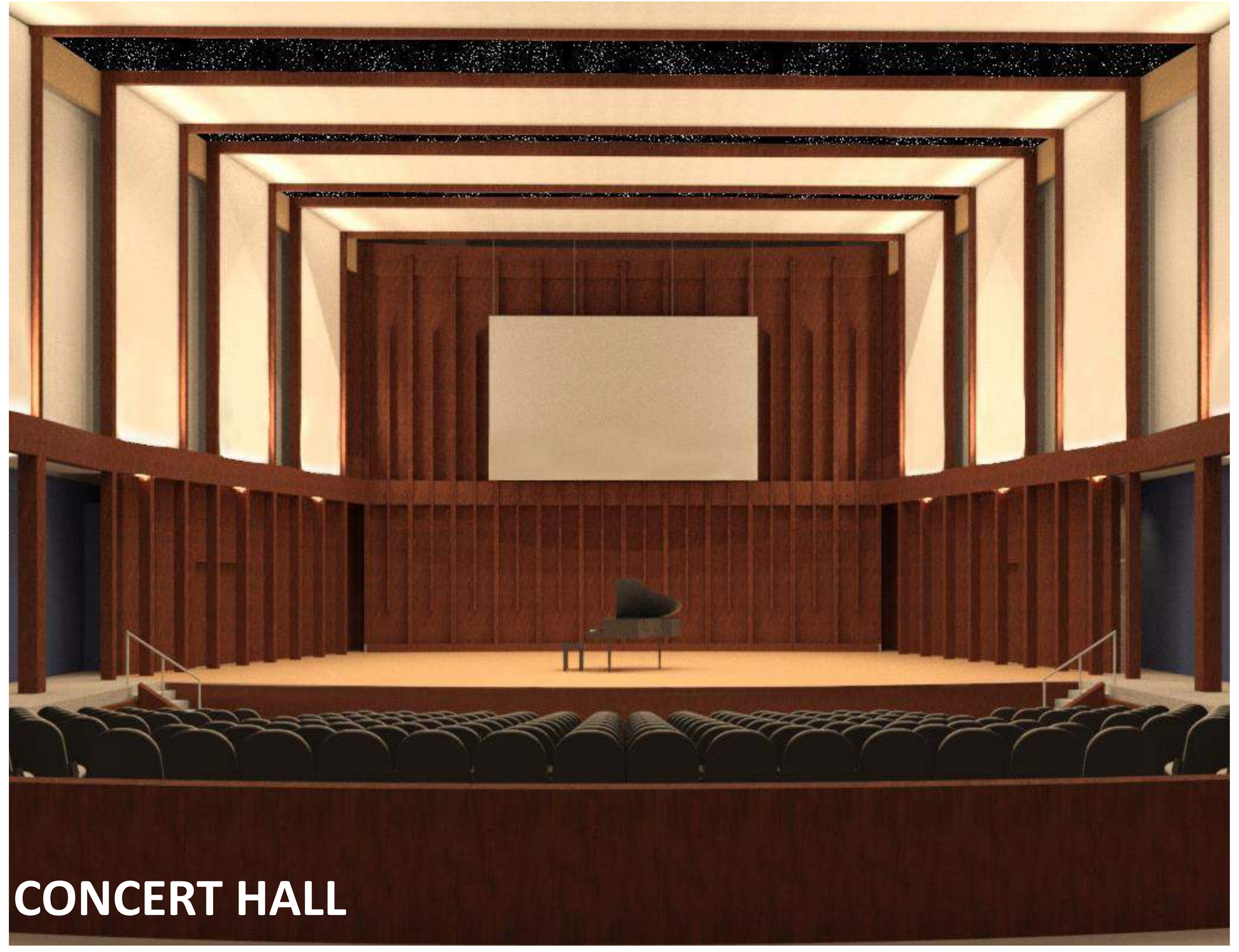
HOLLAND, MICHIGAN

SHEET TITLE

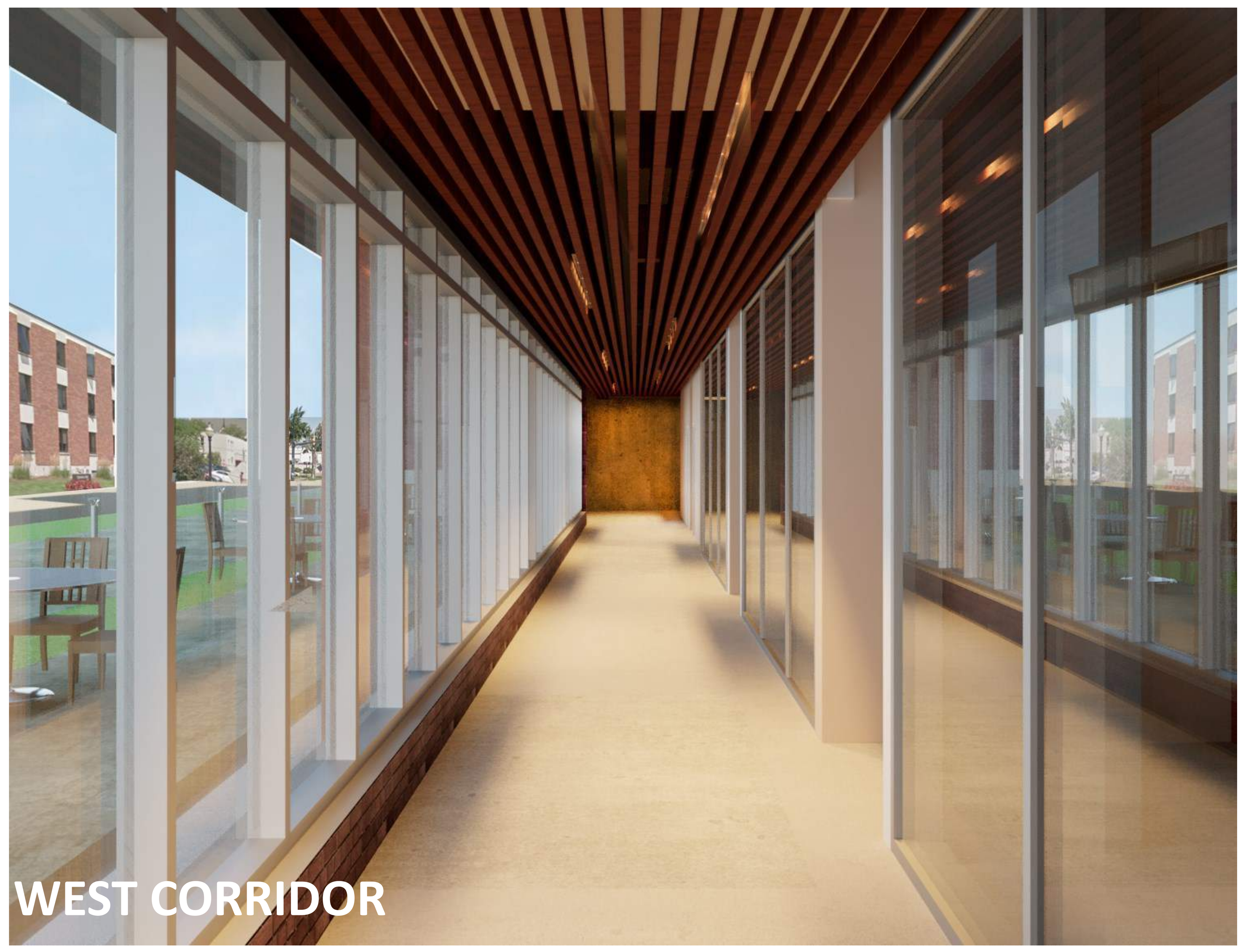
DESIGN OPTIMIZATION AND LOGISTICS

NOT FOR CONSTRUCTION	AEI TEAM NO. 01-2019
DATE February 18th, 2019	SCALE NOT TO SCALE
DRAWING NO. I-1.0	PAGE NO. 21


SOUTH LOBBY (DAY)

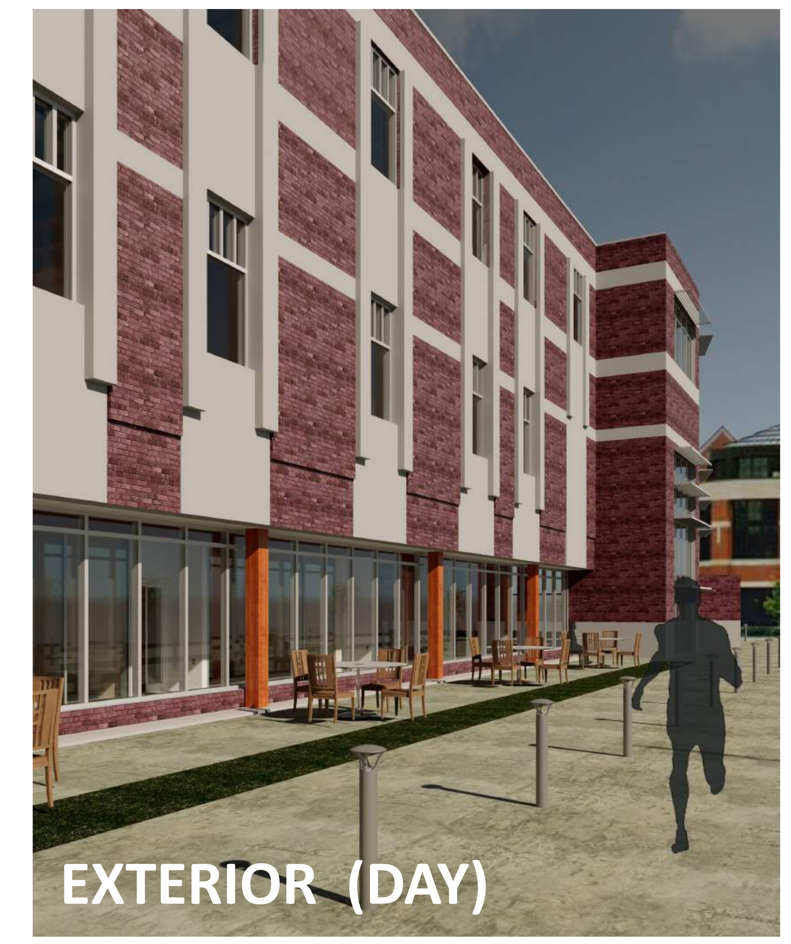

CONCERT HALL

EXTERIOR NORTH LOBBY (DAY)

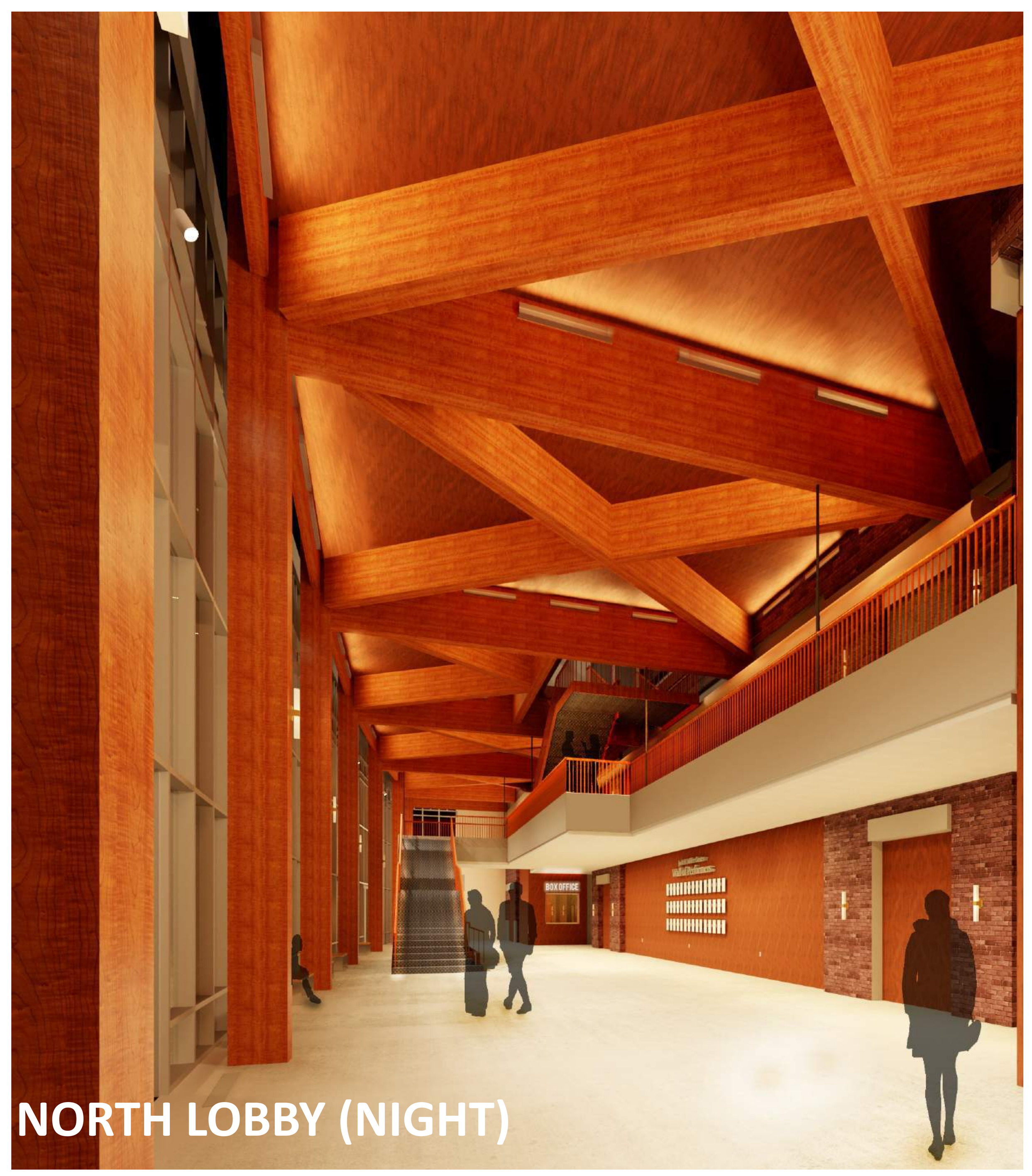

WEST CORRIDOR


FACULTY STUDIO


EXTERIOR SOUTH LOBBY (NIGHT)


EXTERIOR (DAY)


OCCUPIABLE ROOF


NORTH LOBBY (NIGHT)


EXTERIOR NORTH LOBBY (NIGHT)

SYNDICATE

PROJECT

JACK H. MILLER CENTER FOR MUSICAL ARTS

HOLLAND, MICHIGAN

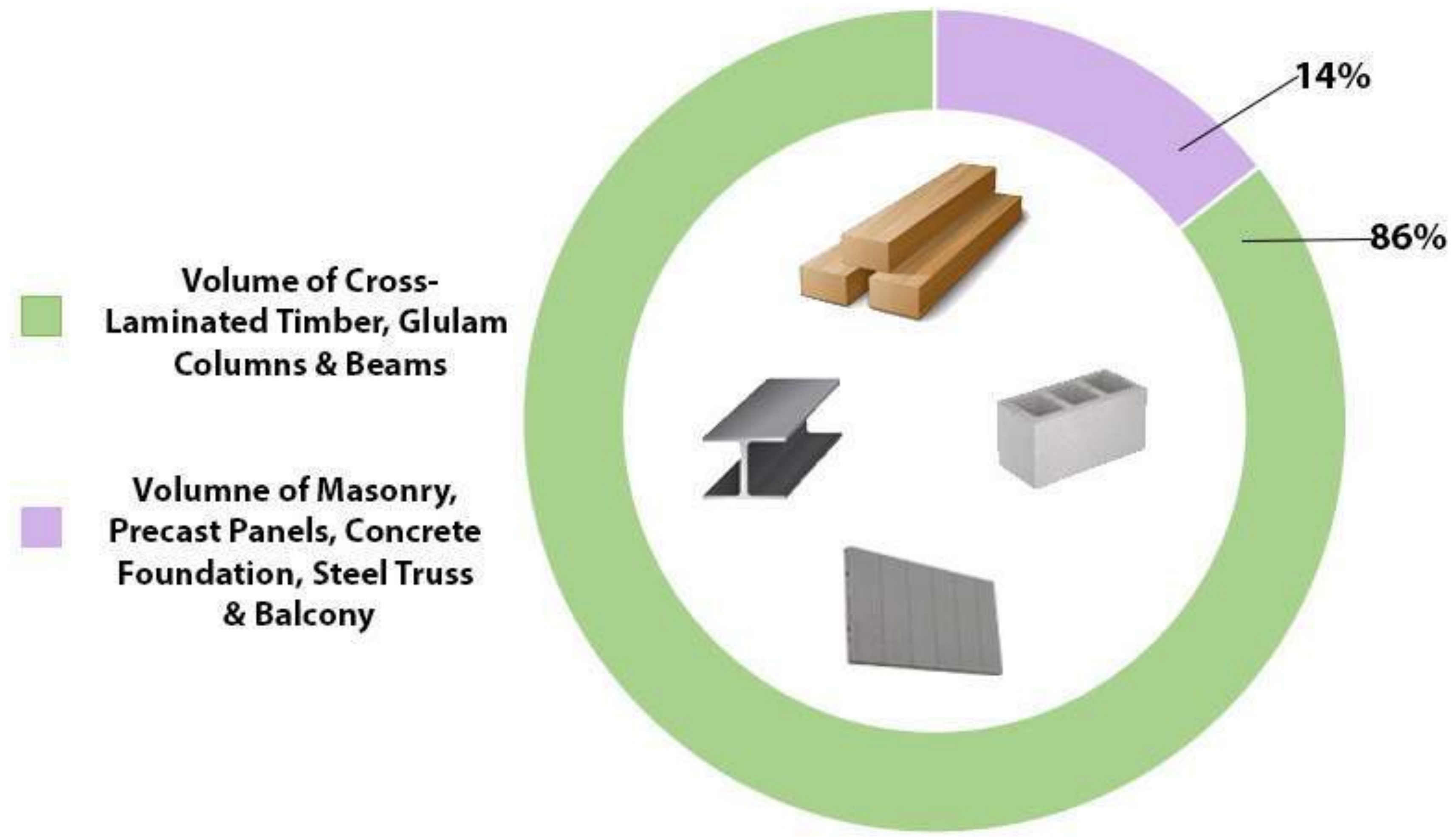
SHEET TITLE

RENDERINGS

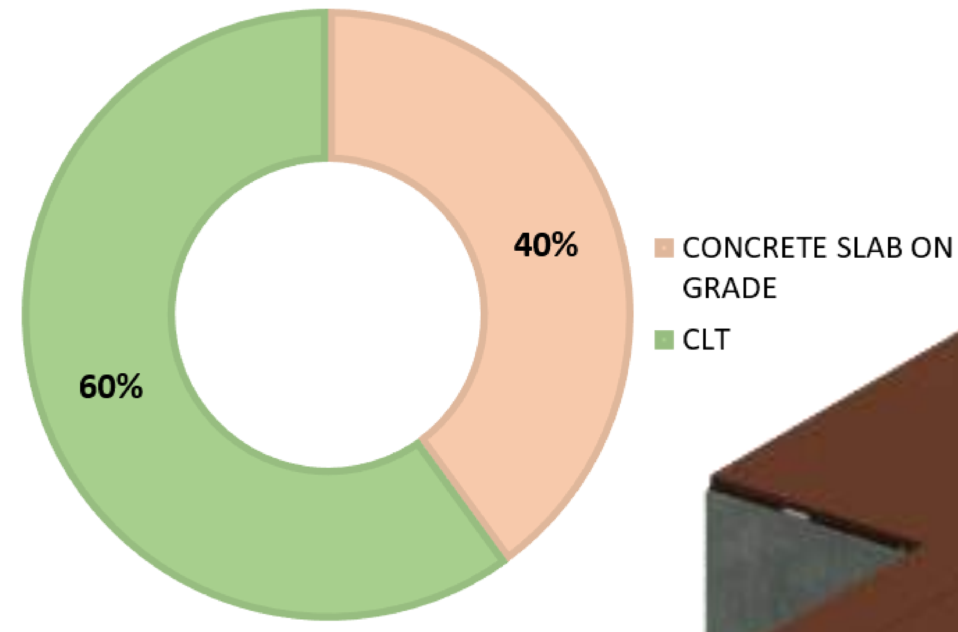
NOT FOR CONSTRUCTION	AEI TEAM NO. 01-2019
DATE February 18th, 2019	SCALE NOT TO SCALE
DRAWING NO. I-2.0	PAGE NO. 22

WOOD CHALLENGE

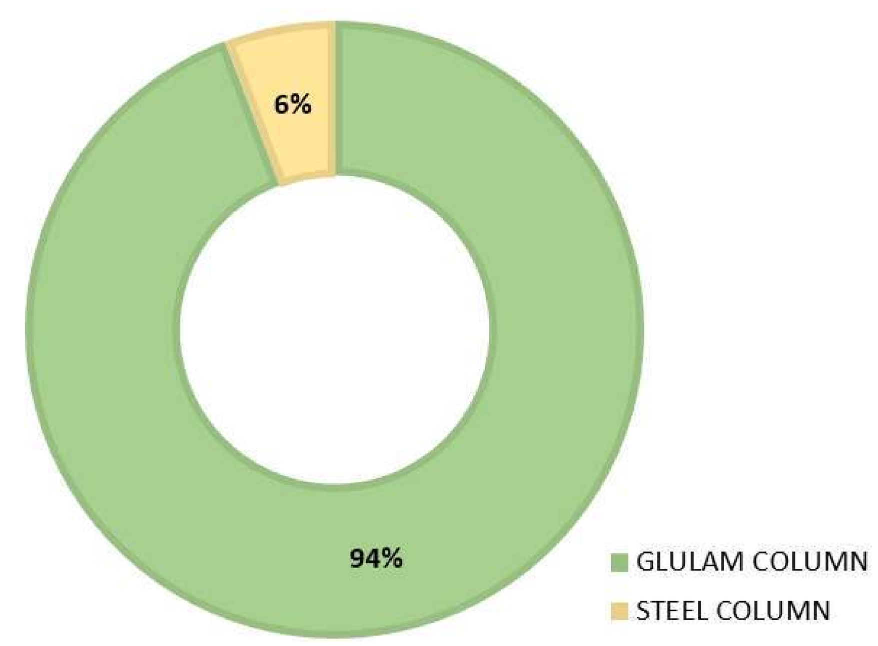
Syndicate took on Hope College's challenge to use a minimum of 25% wood products in the design of The Miller Center. To accommodate this, the team collaborated to design and showcase glued-laminated timber beams and columns, as well as, a cross-laminated timber floor system. The team measured the wood challenge through volume of material designed within the Miller Center's superstructure. At the completion of design, *Syndicate* calculated the volumes of concrete, steel, and wood used in the superstructure and found that they had completed the wood challenge by designing 90% of the superstructure by volume of material as wood products as seen below.



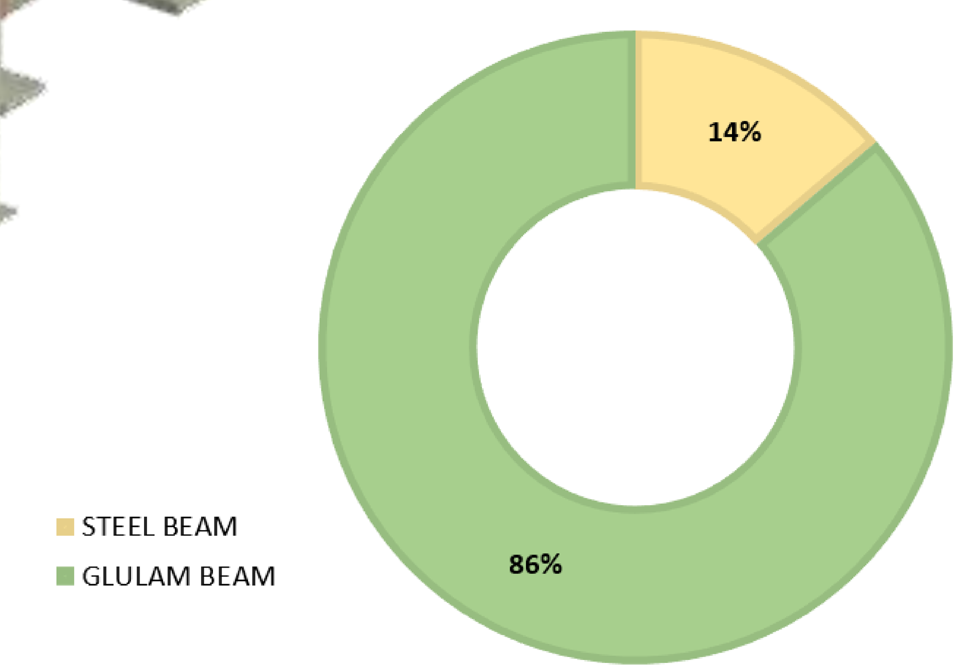
Cross-Laminated Timber (CLT) Floor System



Glued-Laminated Columns

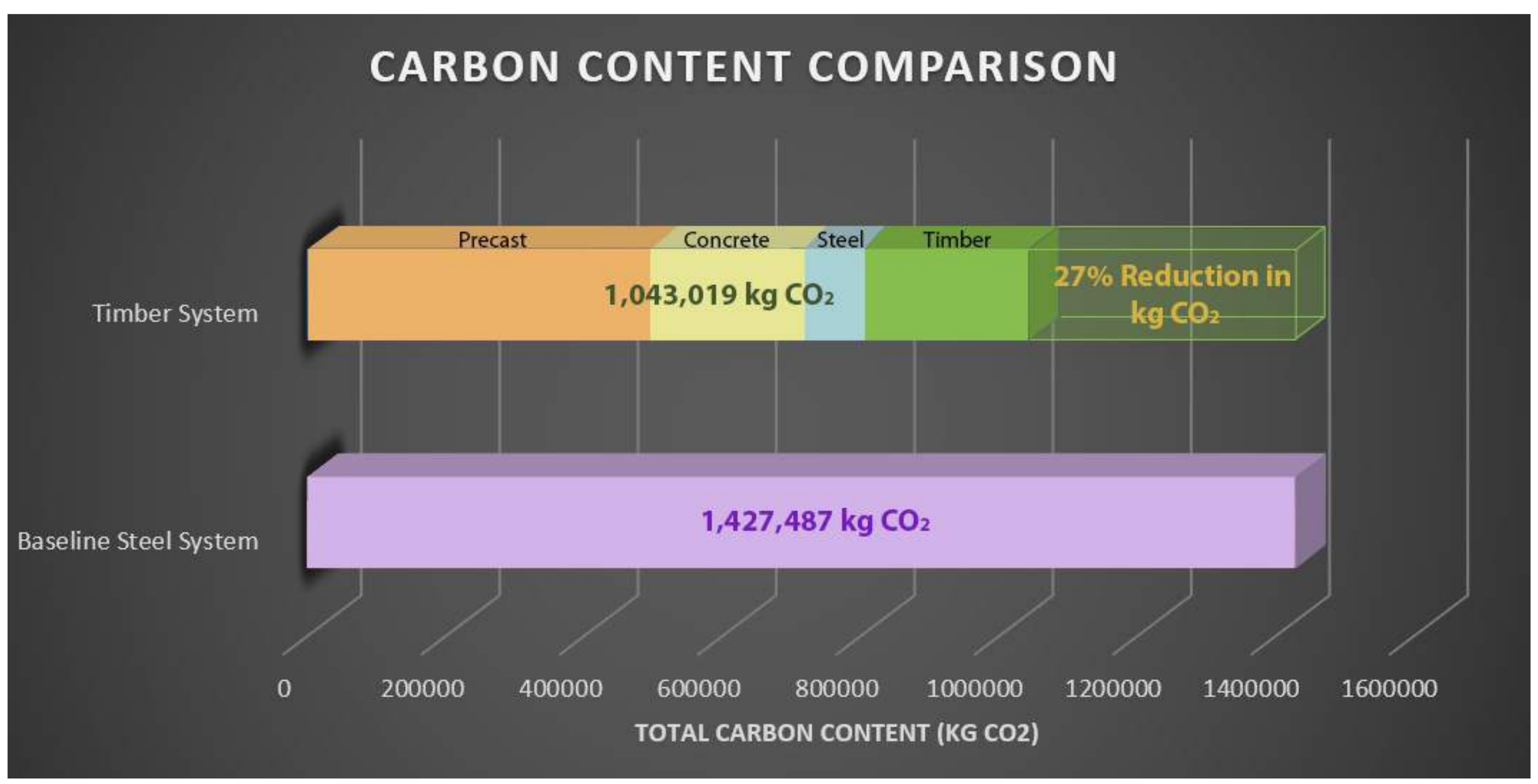


Glued-Laminated Beams

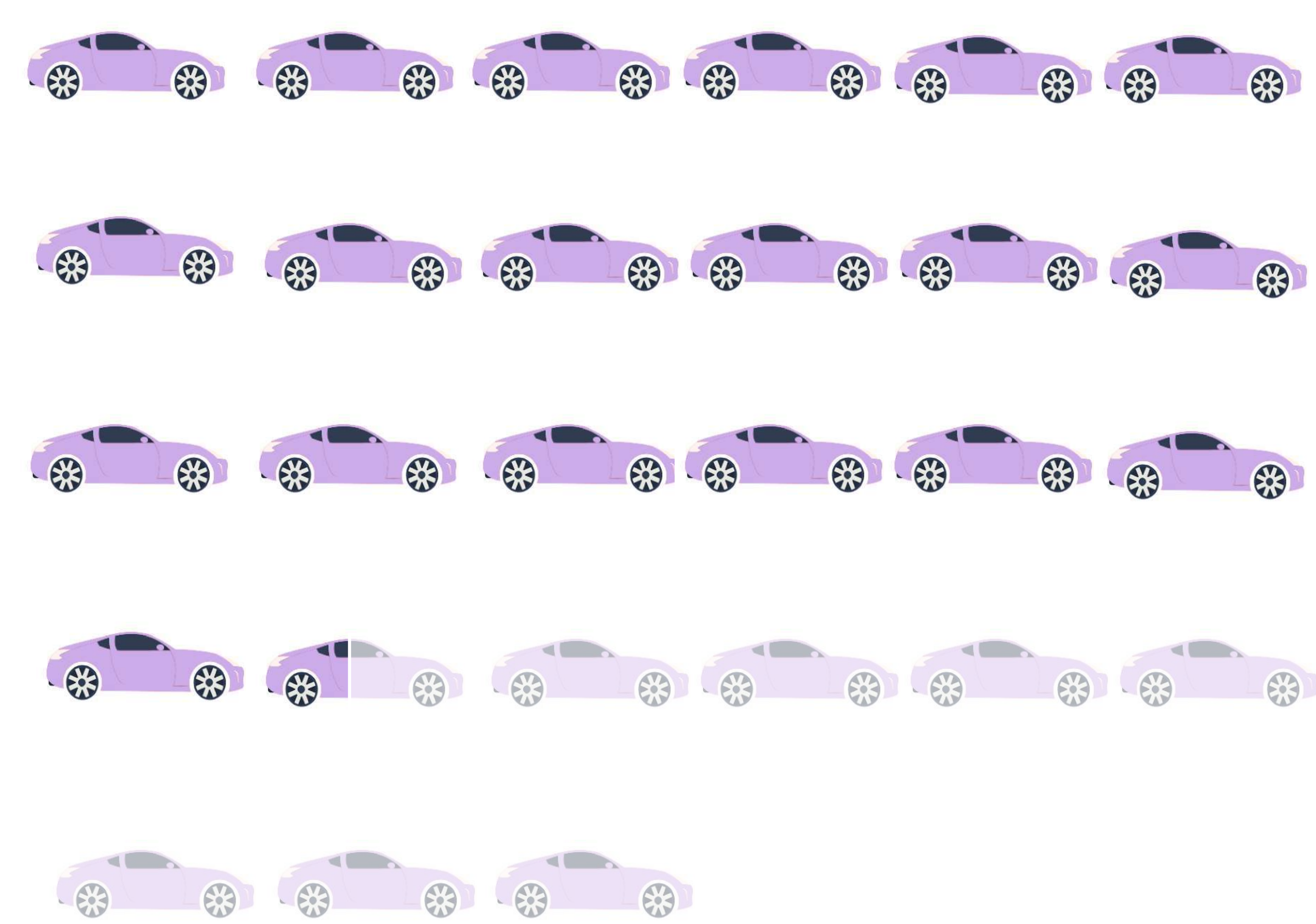


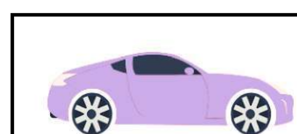
CARBON CONTENT ANALYSIS

Syndicate analyzed the carbon content associated with the materials incorporated into the structural system. As seen below, through the use of sustainable materials, the team was able to decrease the kilograms of carbon dioxide of The Miller Center by 27%. This is equivalent to removing about 86 cars from the road for a year.



CARBON EQUIVALENT





SYNDICATE

PROJECT

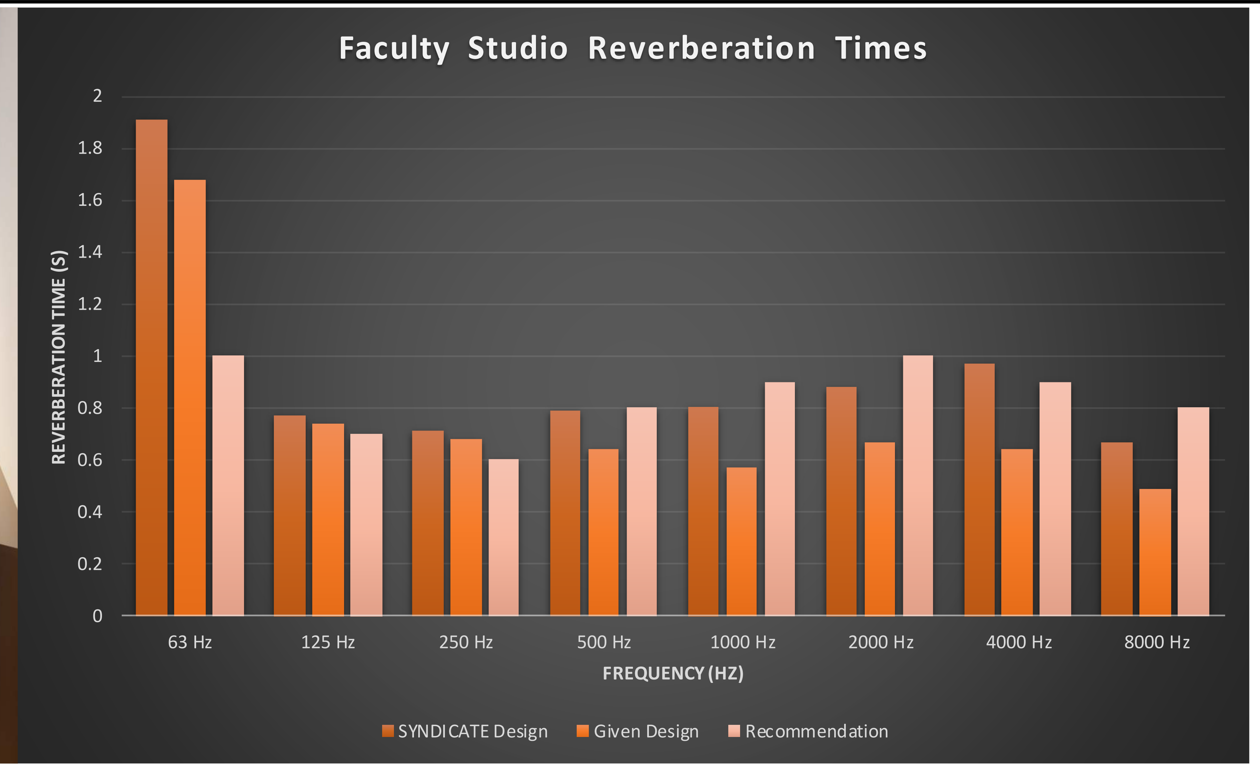
JACK H. MILLER CENTER FOR MUSICAL ARTS

HOLLAND, MICHIGAN

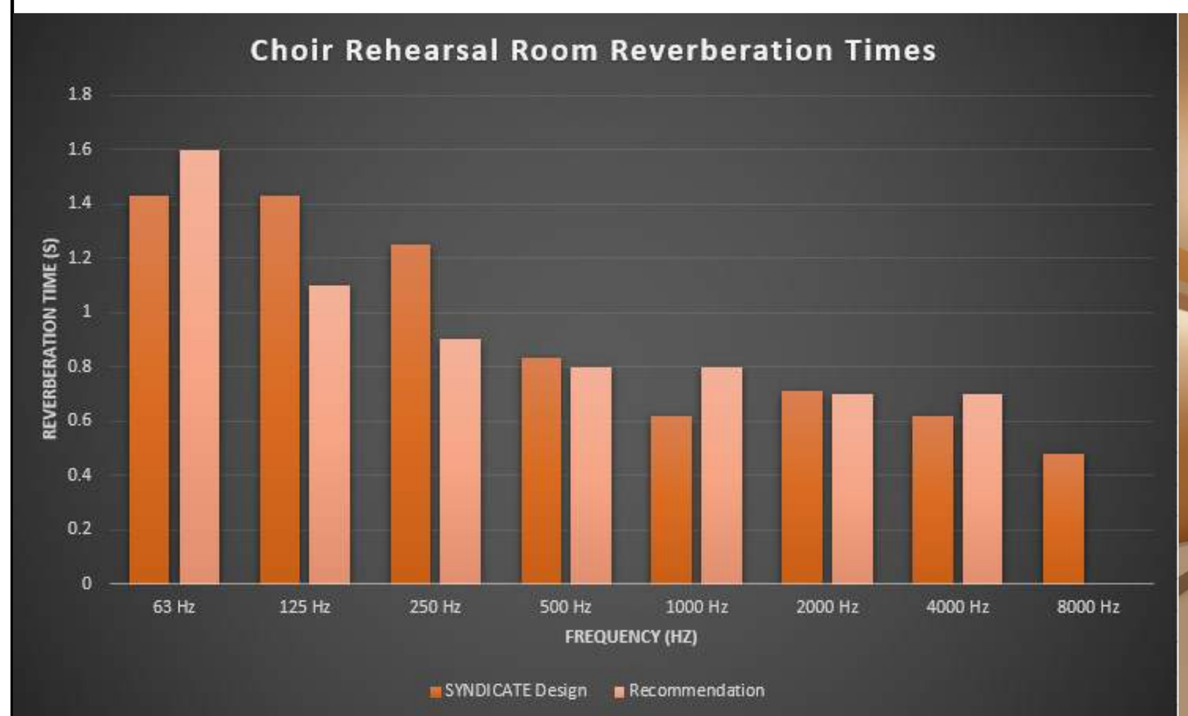
SHEET TITLE

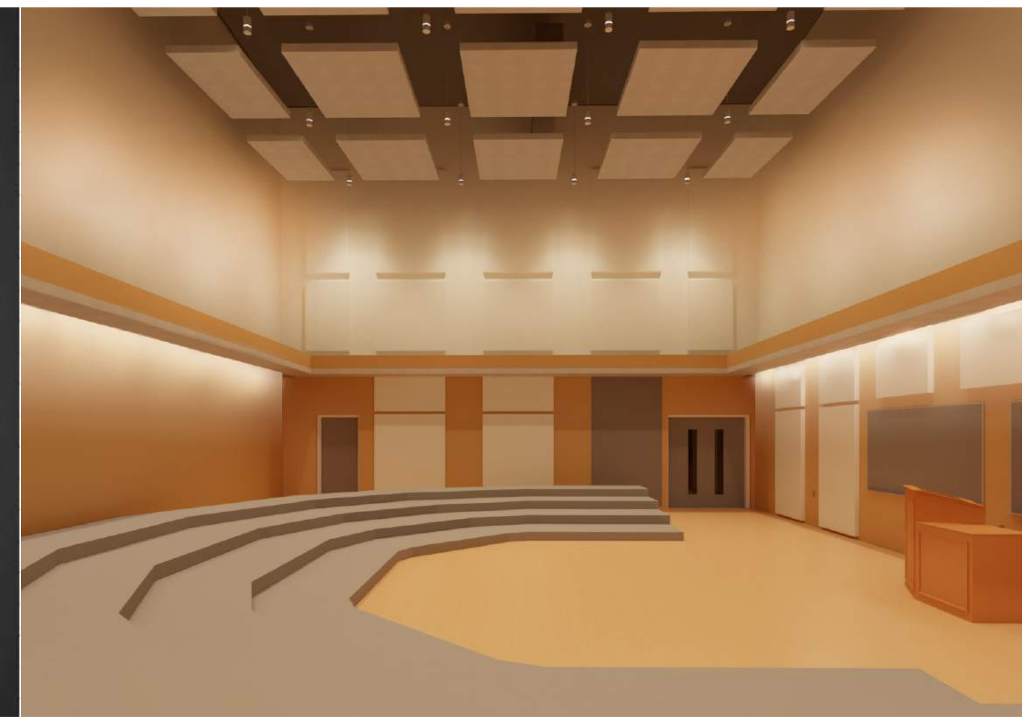
WOOD CHALLENGE

NOT FOR CONSTRUCTION	AEI TEAM NO. 01-2019
DATE February 18th, 2019	SCALE NOT TO SCALE
DRAWING NO. **I-3.0**	PAGE NO. 23

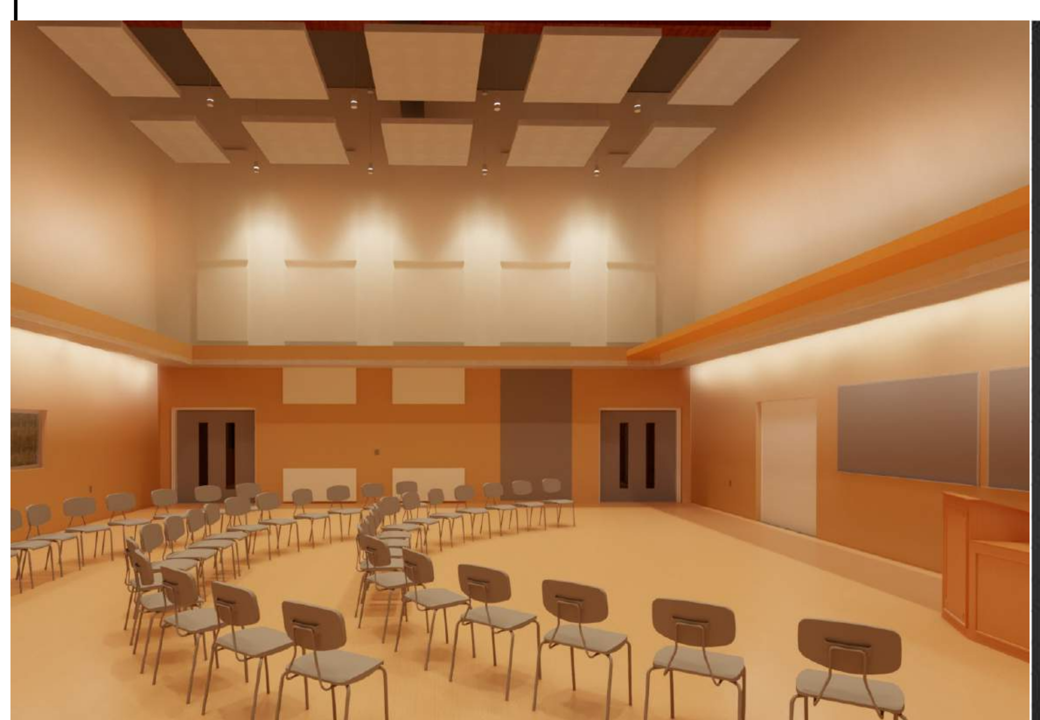


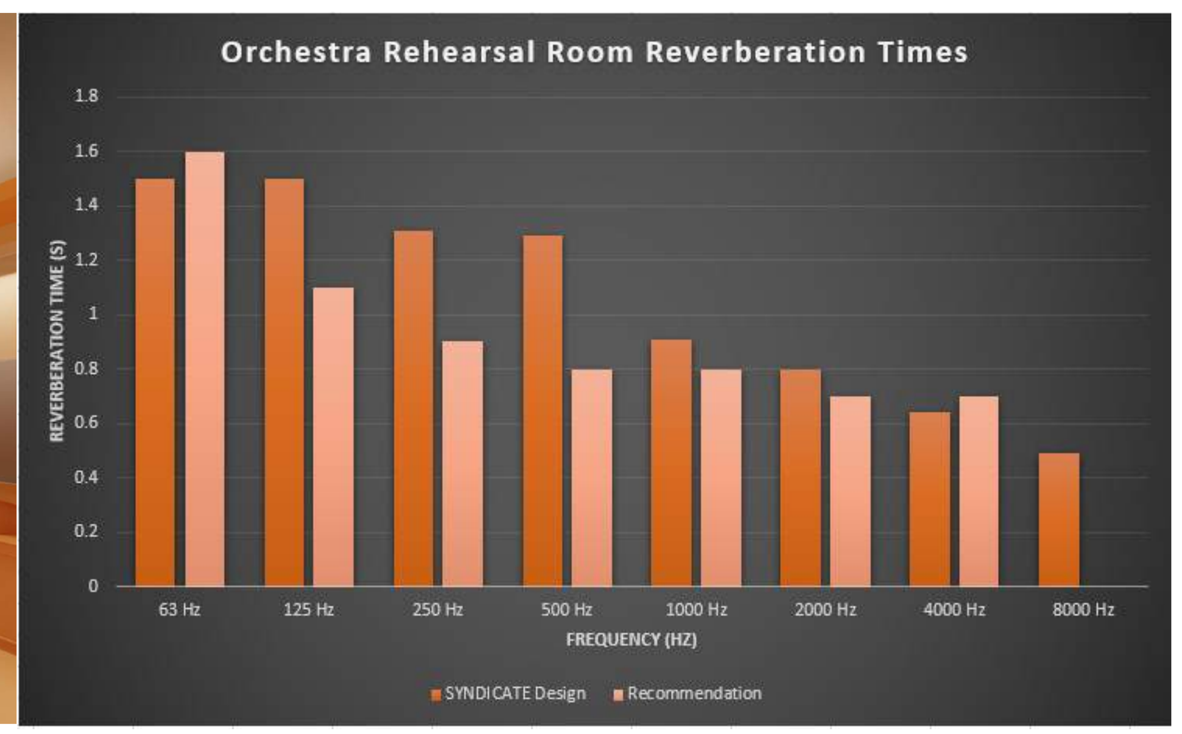
The **Faculty Studios** are utilized by Hope College professionals to train a wide variety of music students. Syndicate was able improve the *reverberation times* of these spaces at several frequencies by installing custom radiant panels and acoustic lighting fixtures, while saving money by removing the original wall panels.



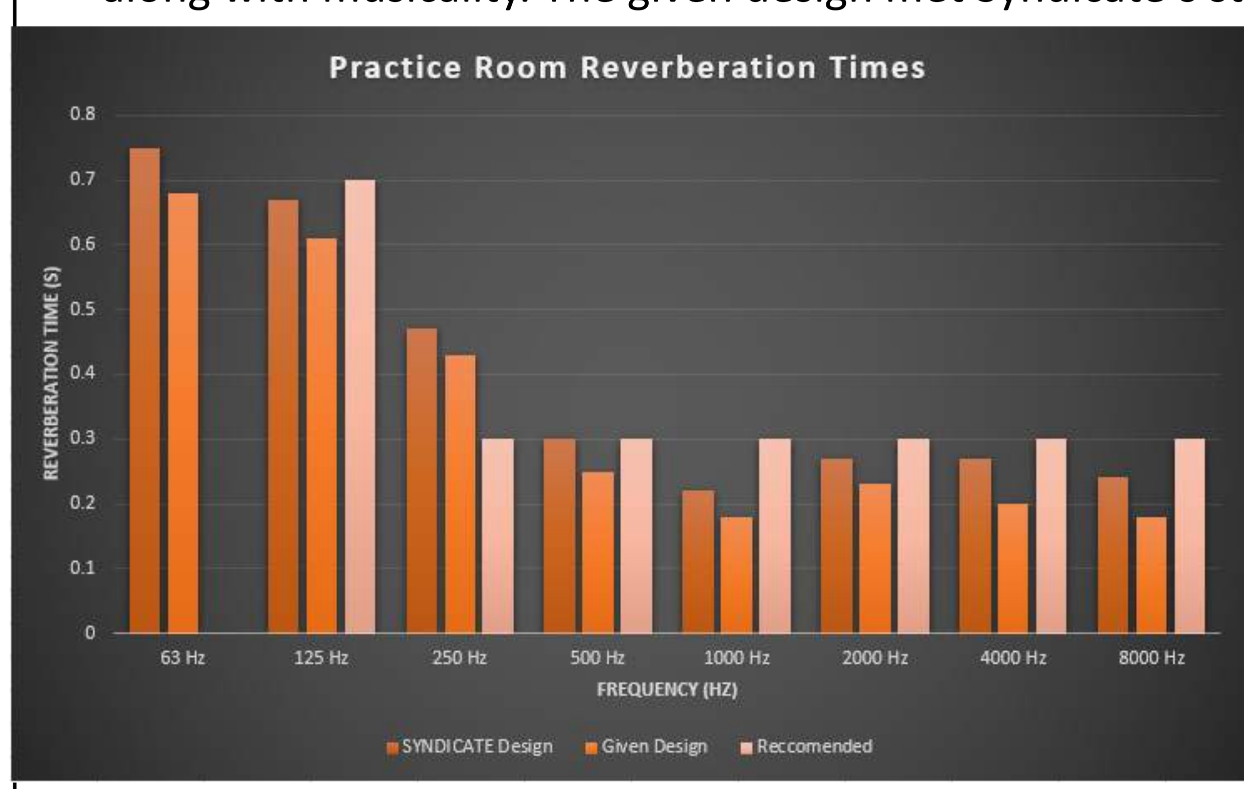


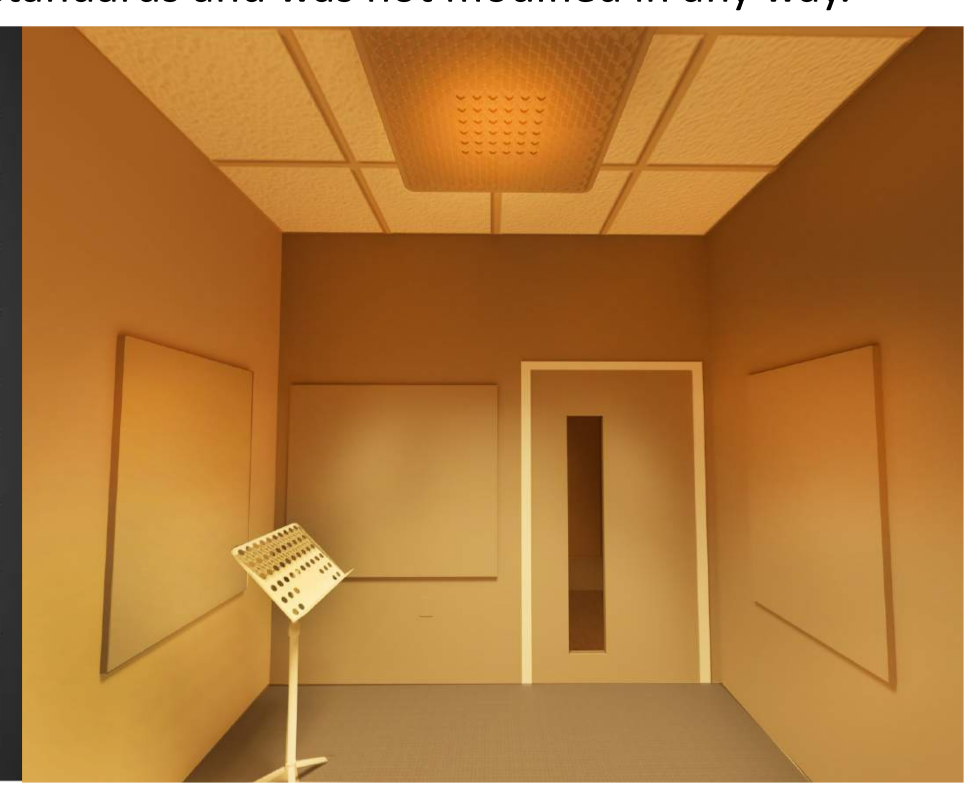
The **Choir Rehearsal Room** allows choirs of all sizes and voices to rehearse. A lower *reverberation time* is desired here as well so vocalists may hone on their technical skills. As with the orchestra rehearsal Room, Syndicate deemed this space acoustically acceptable and chose not do modify the given design.



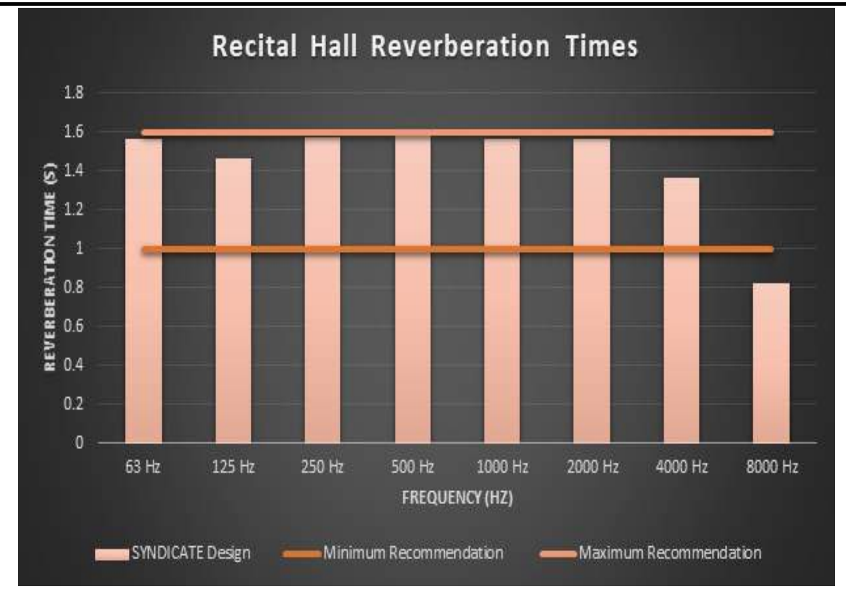


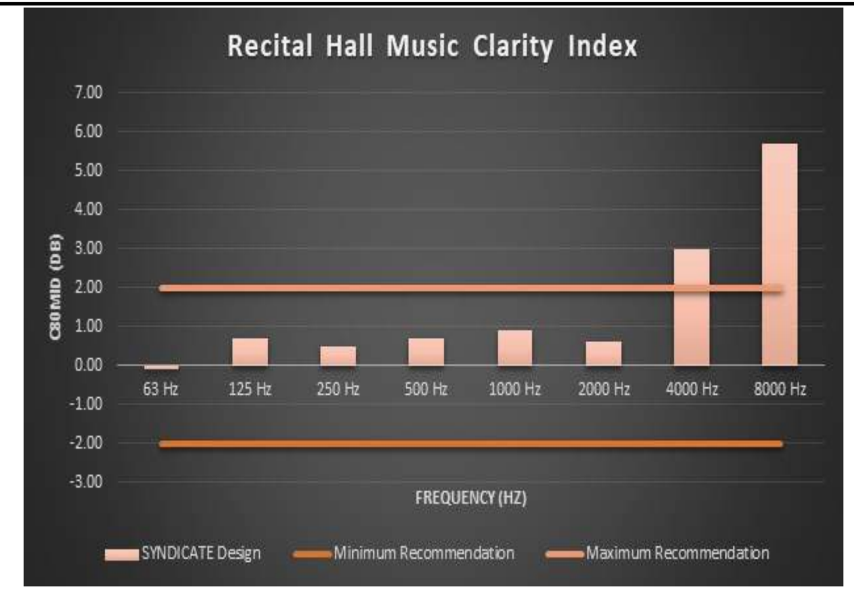
The **Orchestra Rehearsal Room** provides a space for instrumental ensembles of all sizes to rehearse. A lower *reverberation time* is desired here so that instrumentalists and conductors can focus on precision along with musicality. The given design met Syndicate's standards and was not modified in any way.

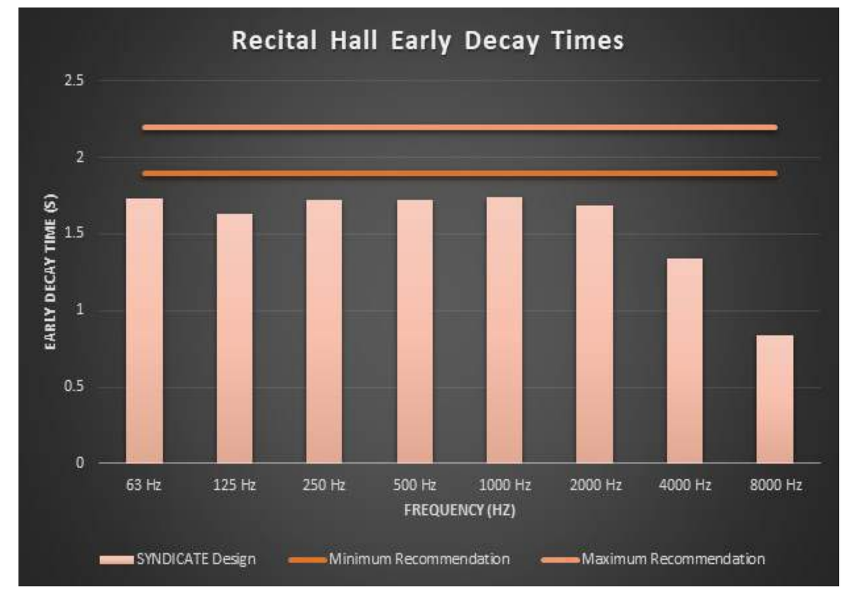


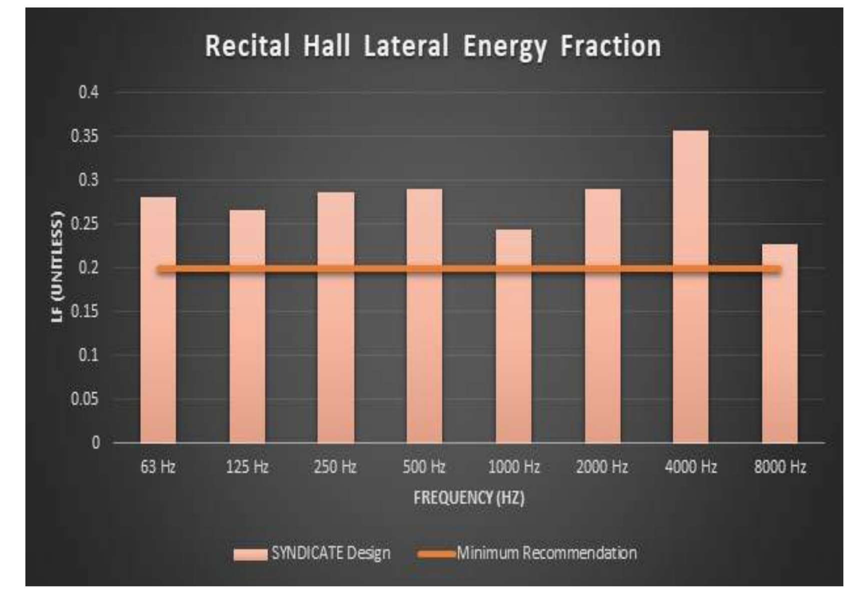


The **Practice Rooms** are crucial to Hope College students enrolled in the music department, as they are designed specifically for individual vocal and instrumental practice. Syndicate found that by removing half of the given acoustic wall panels, the *reverberation times* at most frequencies shifted closer to an ideal value.





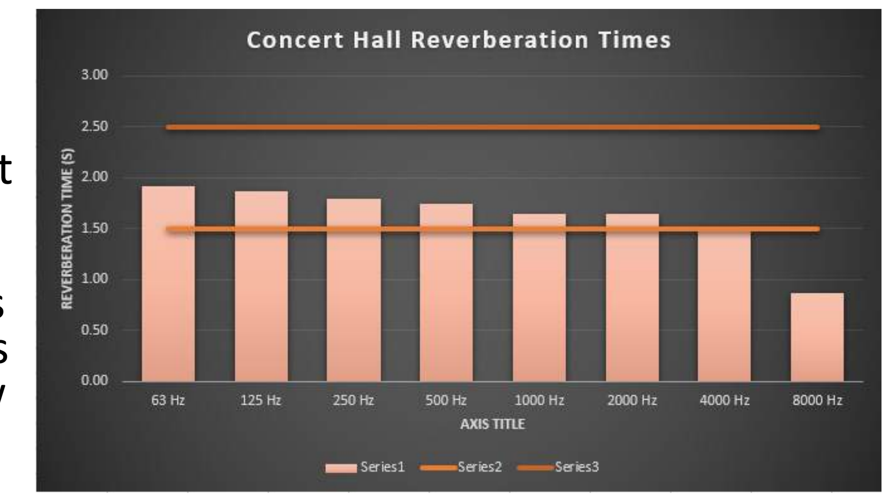


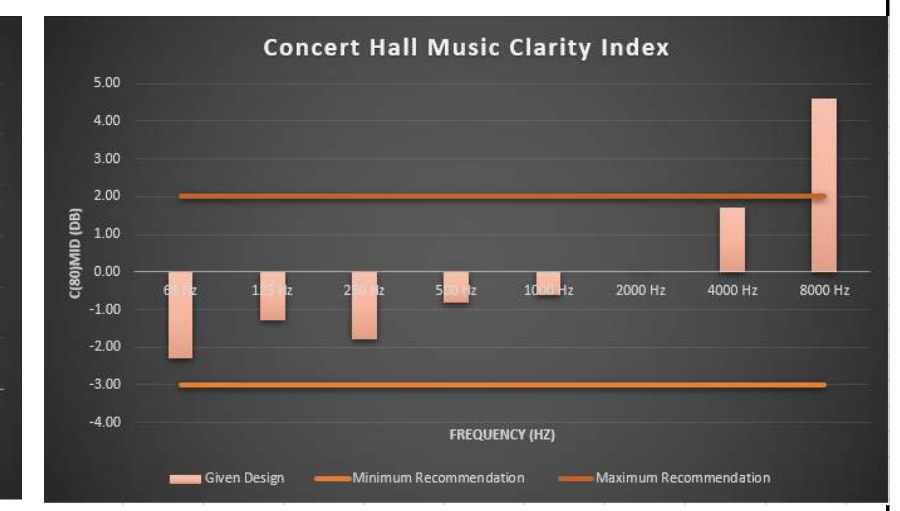


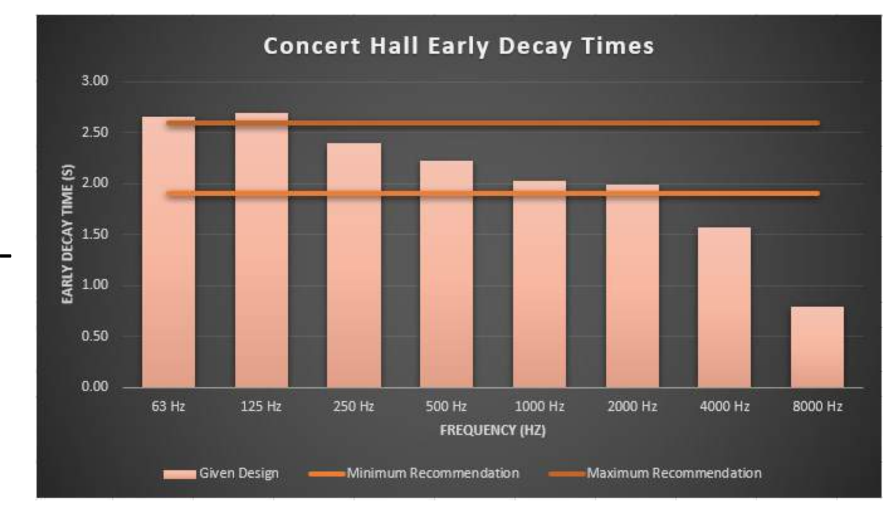
The **Recital Hall** offers a more intimate performance space for soloists and chamber ensembles. In order to ensure quality musical performances, acoustical qualities such as *lateral energy fraction* and *musical clarity* were observed in addition to *reverberation times* and *early decay times*. Given that the only variation Syndicate introduced was the exposed CLT ceiling structure, it was determine that the given design could be deemed adequate.

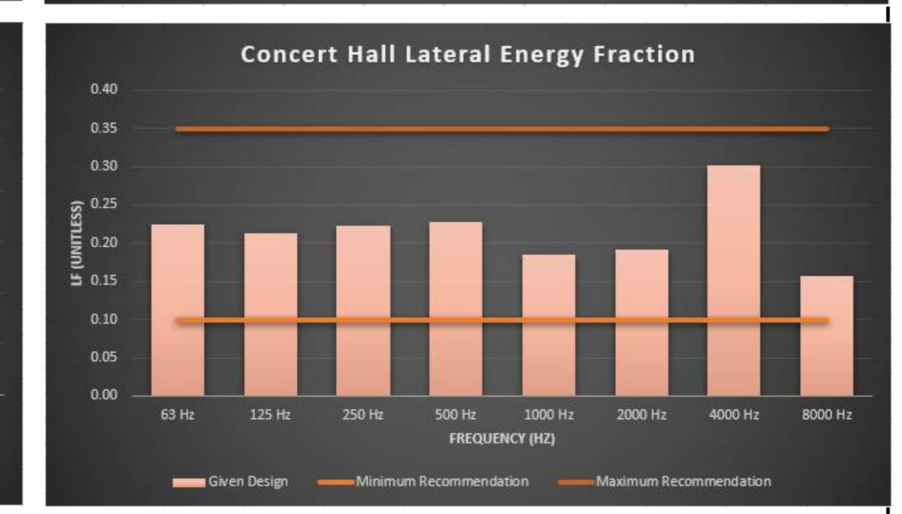
CONCERT HALL

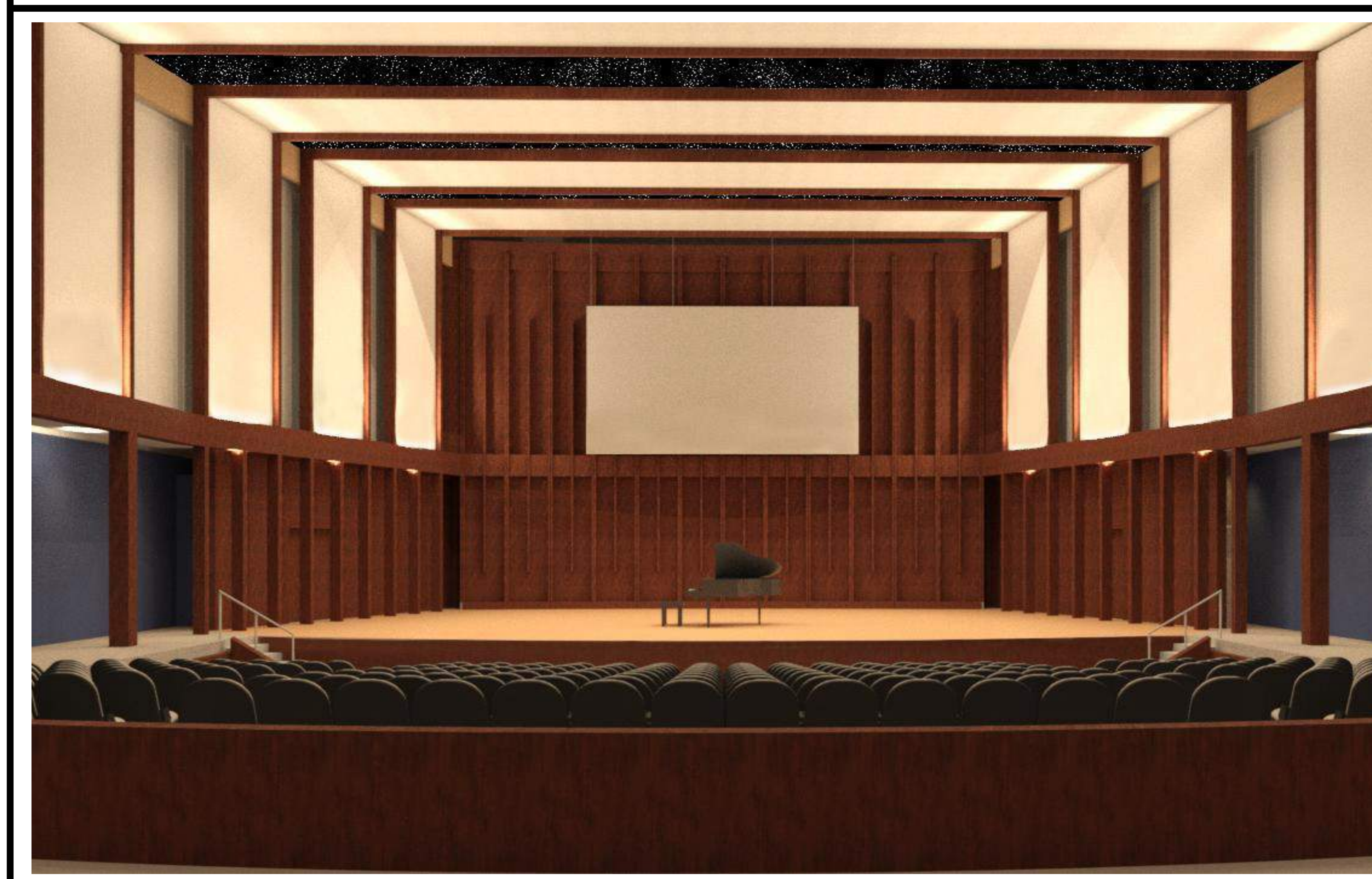
The **Concert Hall**, being the main feature of the Miller Centre, required the highest degree of acoustical analysis from Syndicate. Since Syndicate made no design changes that directly affected the Concert Hall, the original design was modeled in ODEON. The *reverberation times* were found to be within an ideal range for almost all frequencies, as well as the *early decay times* for most frequencies. These two values are critical in large performance spaces as they relate to how much musical sound "rings" in a space, which creates the sense of liveliness that audiences crave. *Lateral energy fraction*, which quantifies the spaciousness of a room, was also shown to be within range of the ideal values for a typical concert hall. *Musical clarity* is also an important quality in large performance spaces as it defines how well the intricacies within an ensemble can be heard. Once again, the original design proved to be more than adequate within this criteria. Since the concert hall will also house commencement ceremonies, *speech clarity* was also analyzed and was found to be within an acceptable range when the side curtains of the hall are drawn. See Drawing C-3.0 for all cost-related impacts to acoustical changes.











SYNDICATE

PROJECT

JACK H. MILLER CENTER FOR MUSICAL ARTS

HOLLAND, MICHIGAN

SHEET TITLE

ACOUSTICS CHALLENGE: *ODEON* RESULTS

NOT FOR CONSTRUCTION

AEI TEAM NO. 01-2019

DATE February 18th, 2019

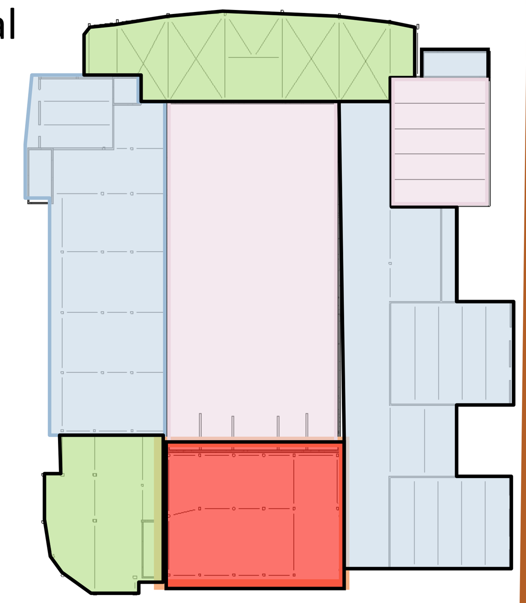
SCALE NOT TO SCALE

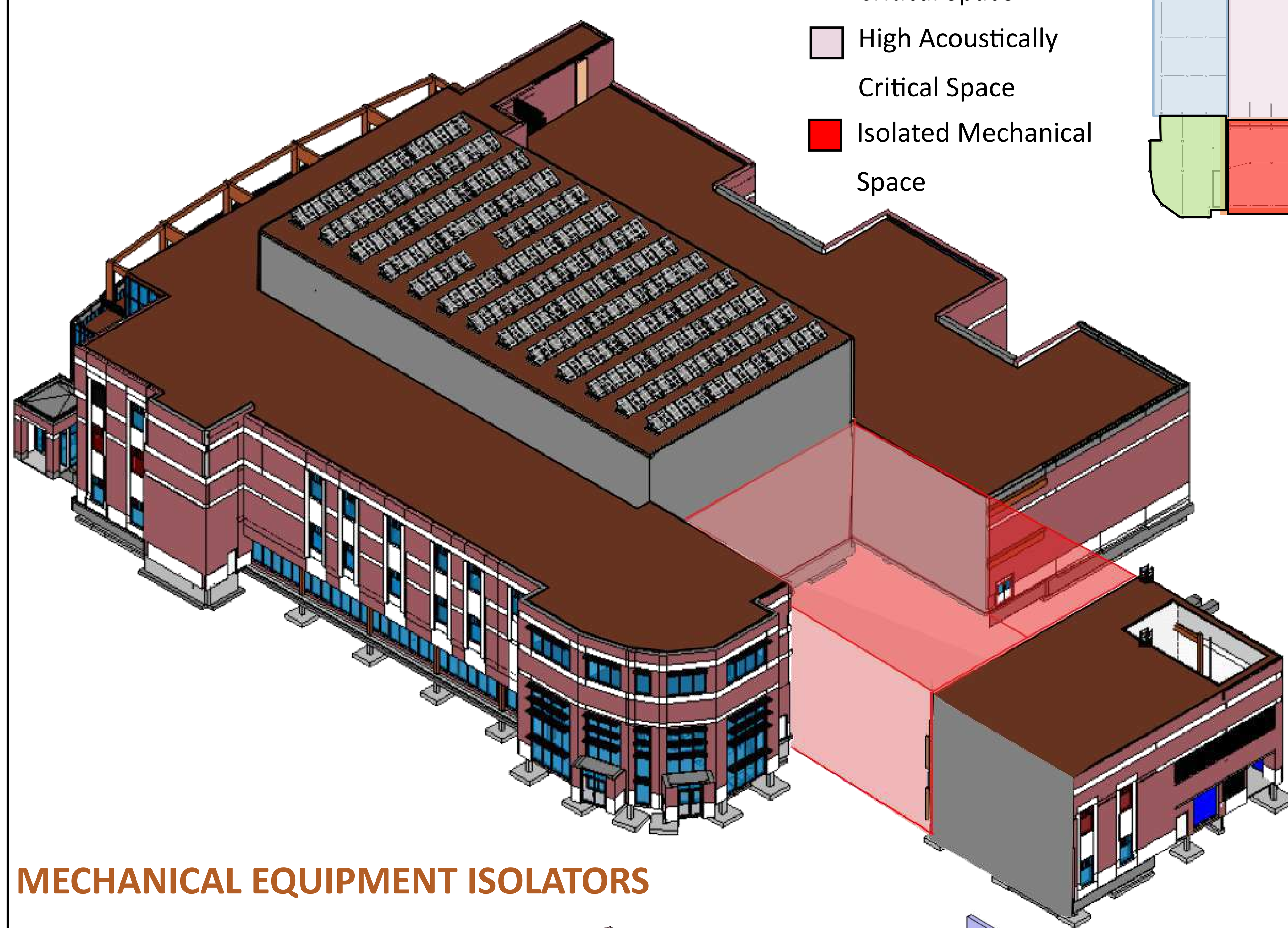
DRAWING NO. **I-4.0**

PAGE NO. 24

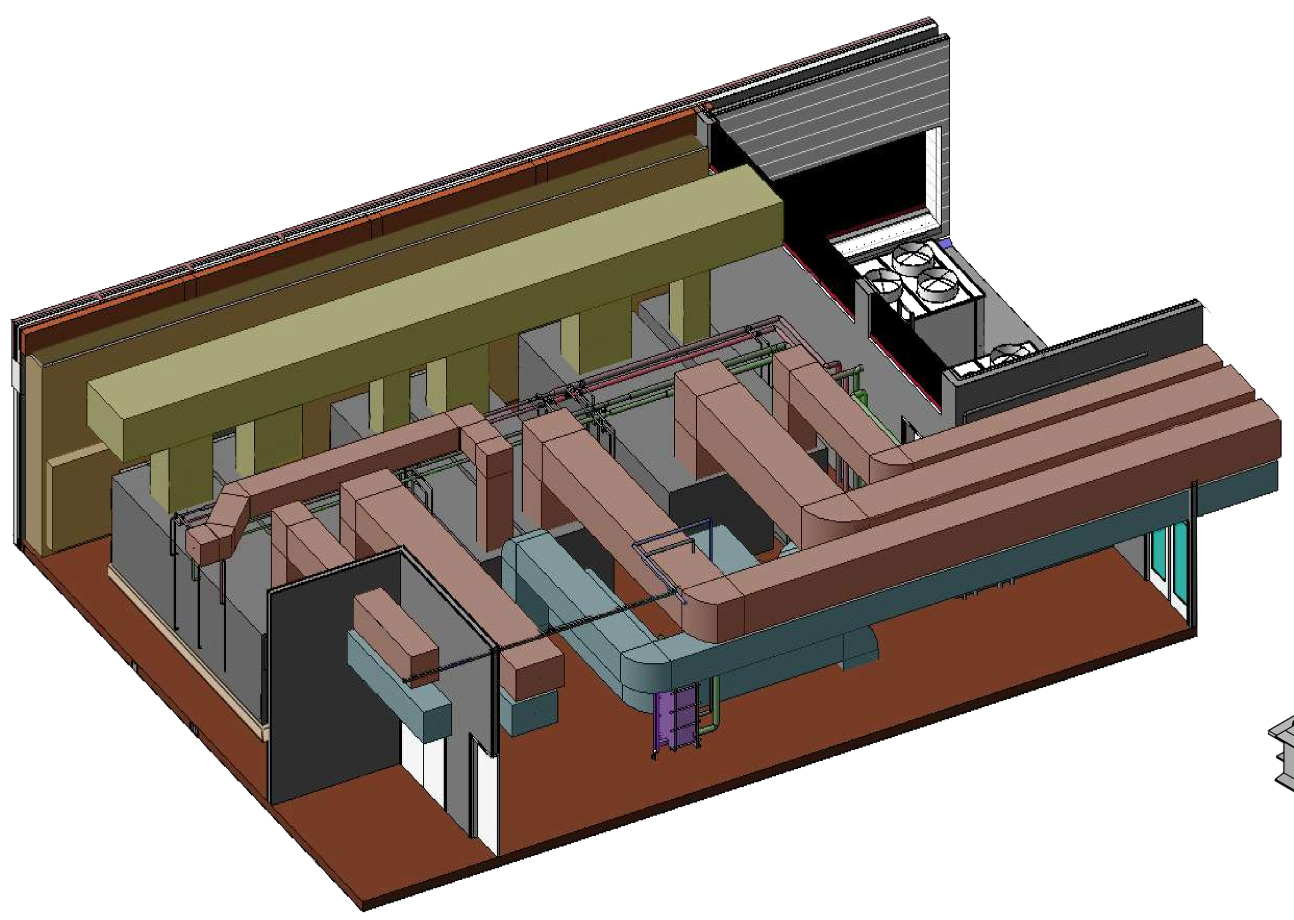
MECHANICAL ROOM ISOLATION

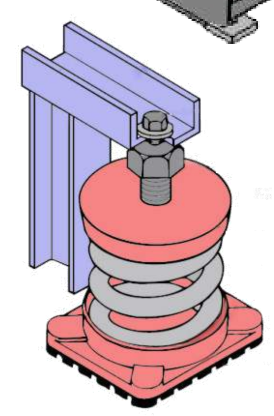
- Acoustically Noncritical Space
- Mid-level Acoustically Critical Space
- High Acoustically Critical Space
- Isolated Mechanical Space



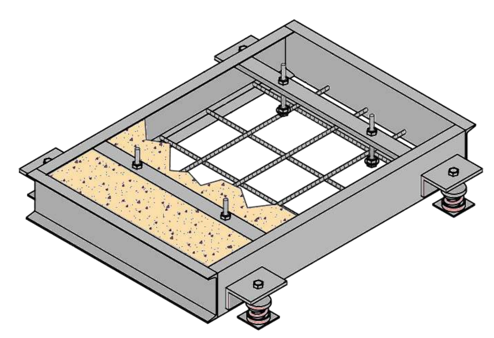


MECHANICAL EQUIPMENT ISOLATORS



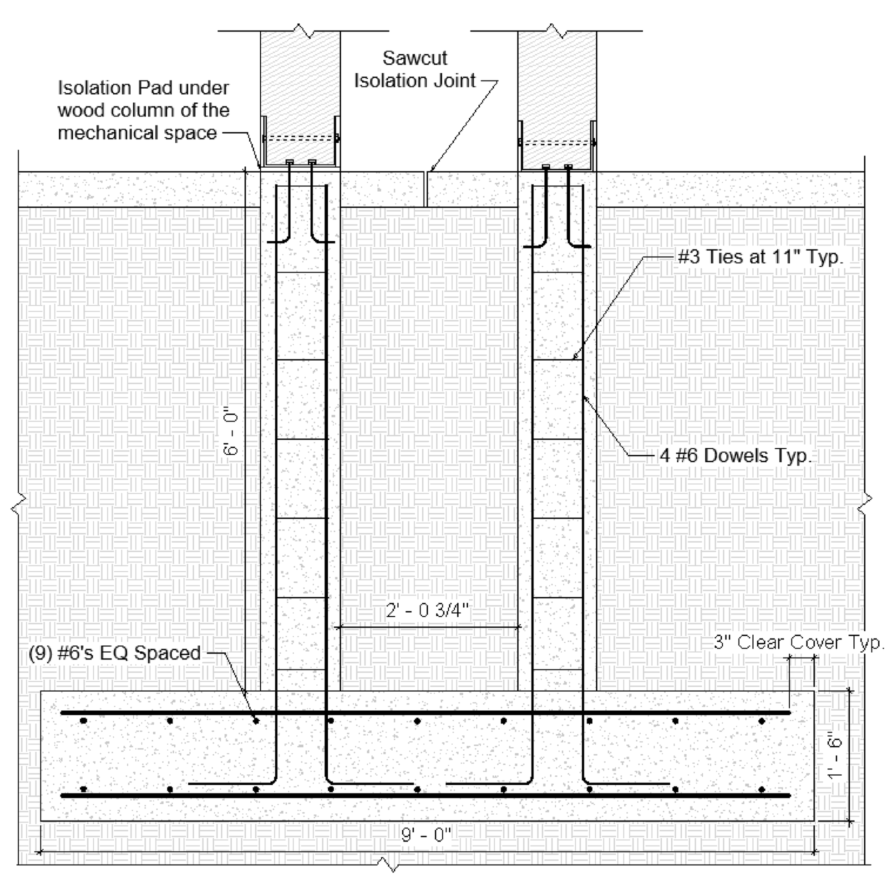


Air Handling and Chiller Isolation



Pump Isolation

ISOLATED STRUCTURE

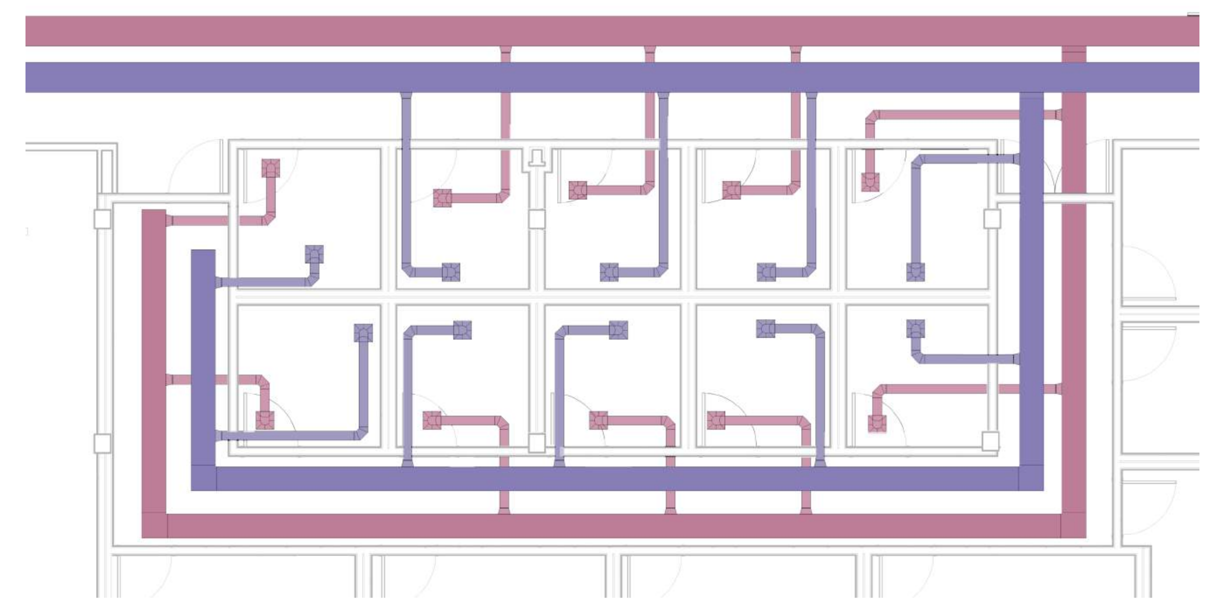


The isolated structure consists of a double columns along the perimeter to frame out the space. An isolated pad was placed between the wood column and concrete pier on the mechanical side to further reduce the vibrations entering the footing. Within this isolated structure, the team also incorporated isolation joints into the slab on grade, as well as the CLT floor assembly to further isolate the mechanical vibration and structural borne sound transmittance.

TYPICAL BUILDING ACOUSTICS

Cross Talk

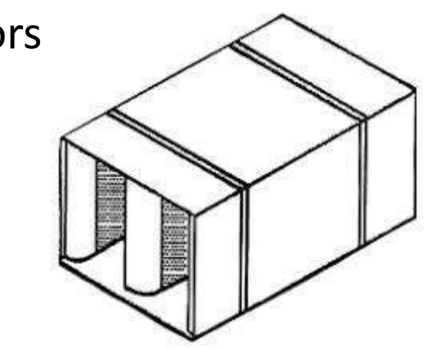
Cross talk, which is defined as when sound travels from one space to another space, through ductwork is mitigated by increasing the length of duct between the spaces and adding elbows.



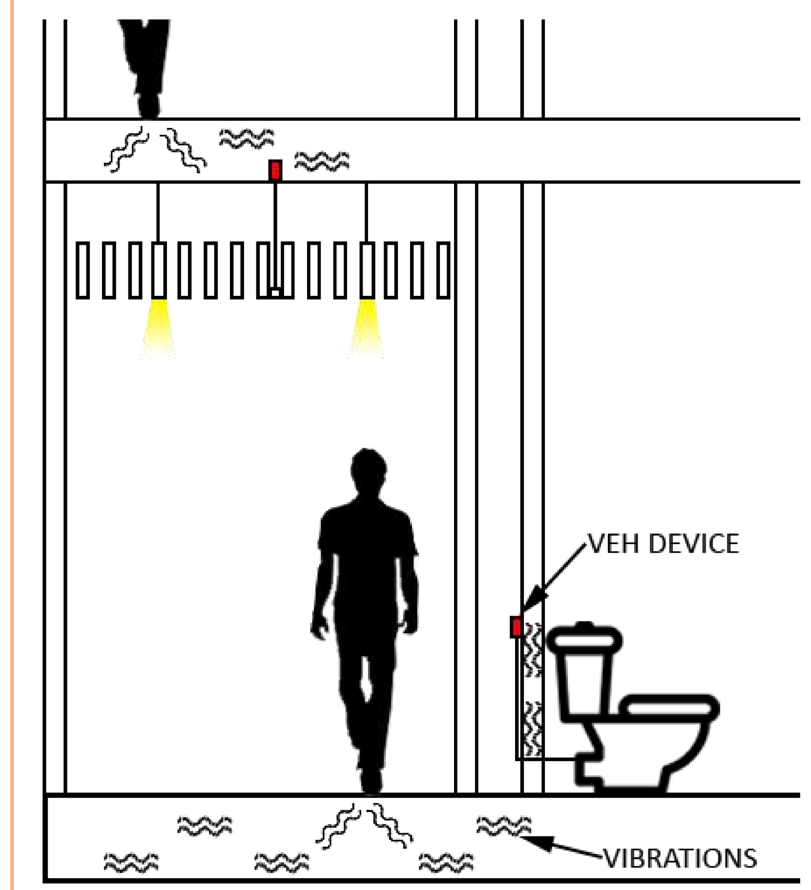
Duct Acoustical Treatment

The team implemented various techniques to mitigate sound travel through ducts:

- Long duct runs
- Duct silencers
- Duct lining
- Mitered elbows
- Round ducts
- Duct attenuators



Vibration Energy Harvesters (VEH)



QR CODE FOR QUALITY

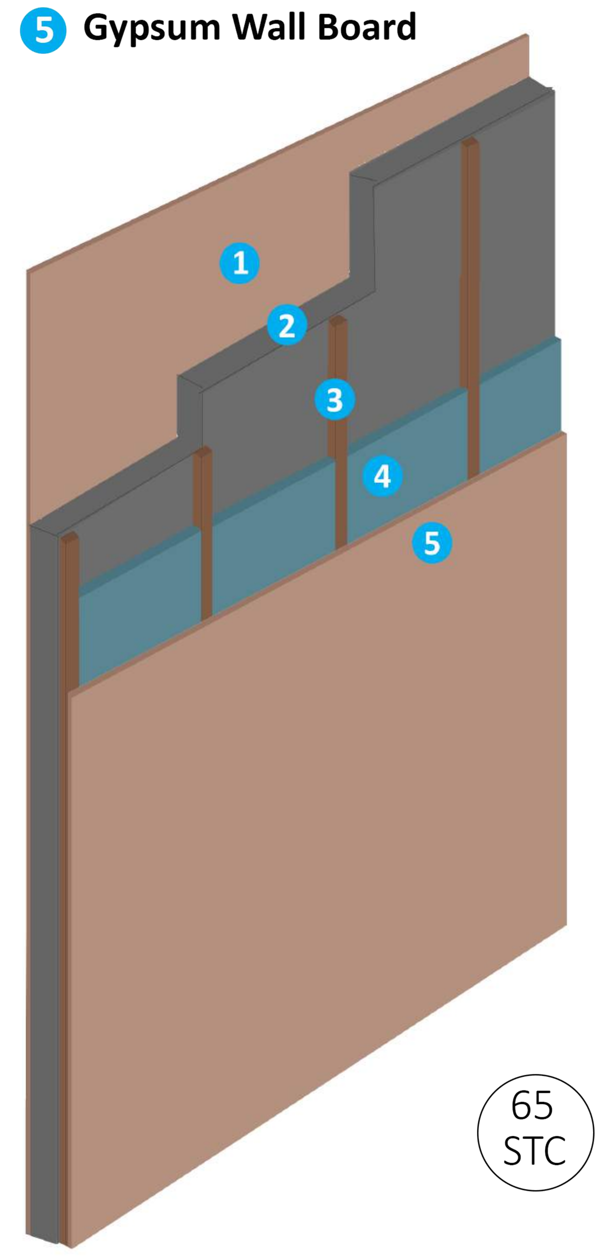
QR Codes will be used in the acoustically sensitive spaces as a quality assurance measure. When scanned, they will show any critical information needed including a checklist to ensure that worker knows exactly what is expected for that space. Every time the code is scanned, it logs which device was used, so if there are any quality issues, it is easy to determine the responsible contractor. **(QR code is iPhone compatible)**

Checklist

ACOUSTICAL TREATMENT OF WALL AND FLOOR ASSEMBLIES

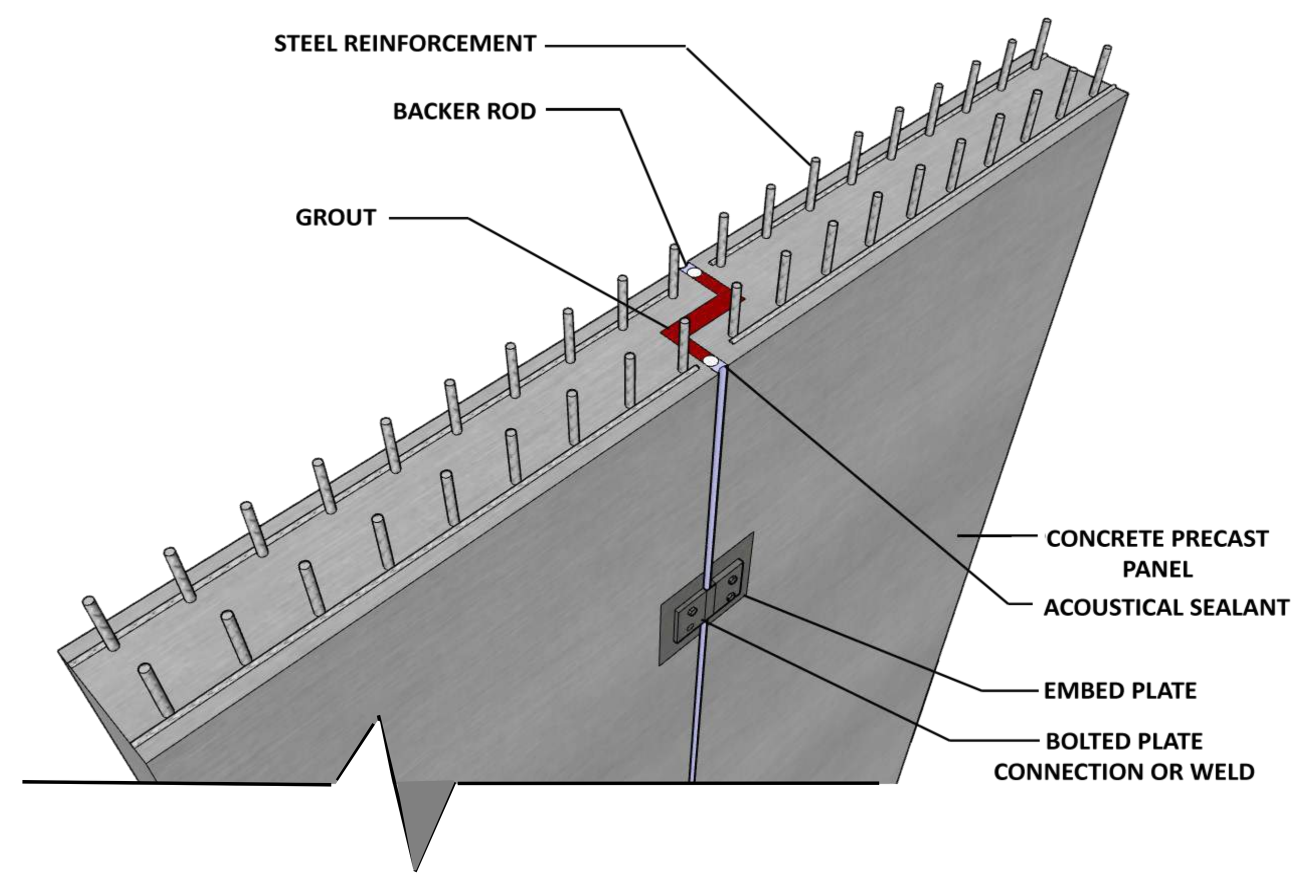
Concert and Recital Hall Wall Assembly

1. Gypsum Wall Board
2. 12" Precast Concrete Wall Panel
3. 2x2 Vertically 24" O.C.
4. 4 pcf Rockwood
5. Gypsum Wall Board

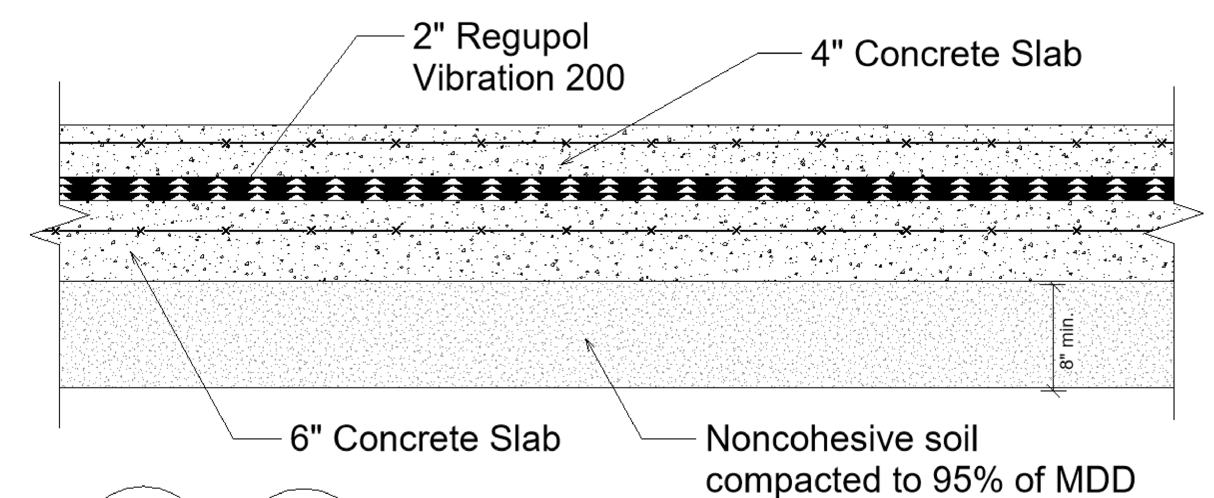


65 STC

Precast Panel Acoustical Joint for Concert and Recital Halls

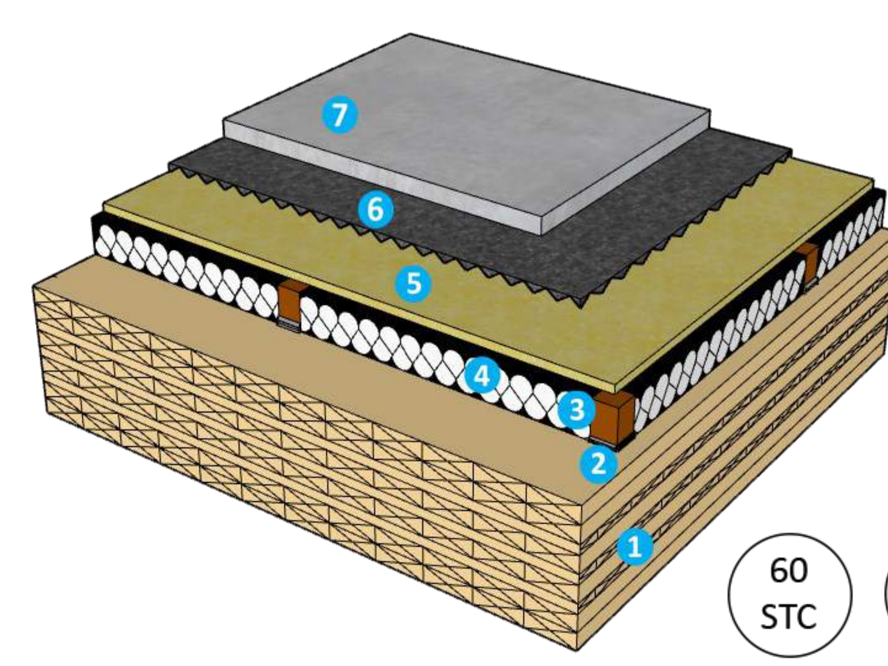


Concert Hall Slab on Grade Assembly



59 STC | 70 IIC

Typical Floor Assembly



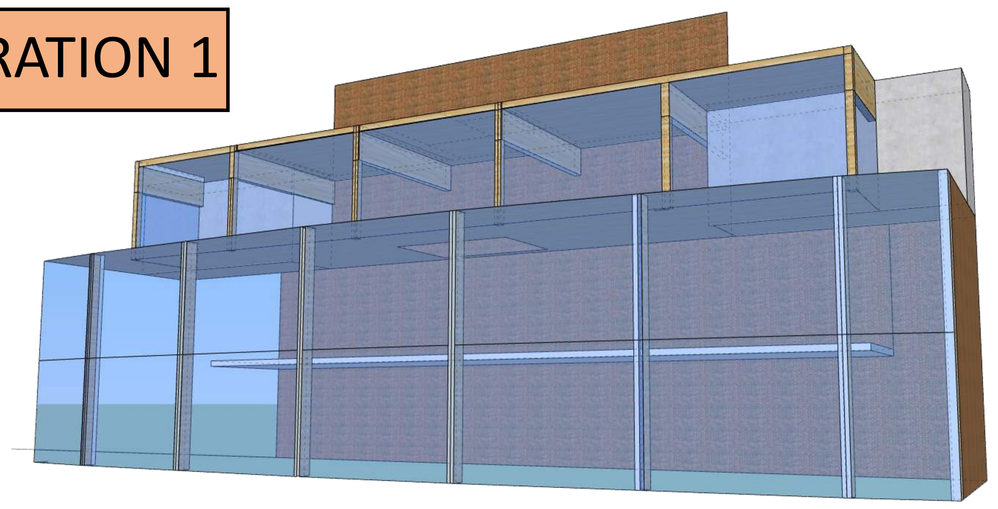
1. 10-1/2" Cross-Laminated Timber
2. 3/8" Rubber Membrane
3. 2x3 Wood Batten
4. 2-1/2" Fiberglass Insulation
5. 11/16" OSB
6. 11/16" Regupol Sonuswave
7. 1-1/2" Concrete Topping

60 STC | 54 IIC

SYNDICATE	
PROJECT **JACK H. MILLER CENTER FOR MUSICAL ARTS** HOLLAND, MICHIGAN	
SHEET TITLE **ACOUSTICS CHALLENGE: VIBRATION AND SOUND MITIGATION**	
NOT FOR CONSTRUCTION	AEI TEAM NO. 01-2019
DATE February 18th, 2019	SCALE NOT TO SCALE
DRAWING NO. **I-5.0**	PAGE NO. 25

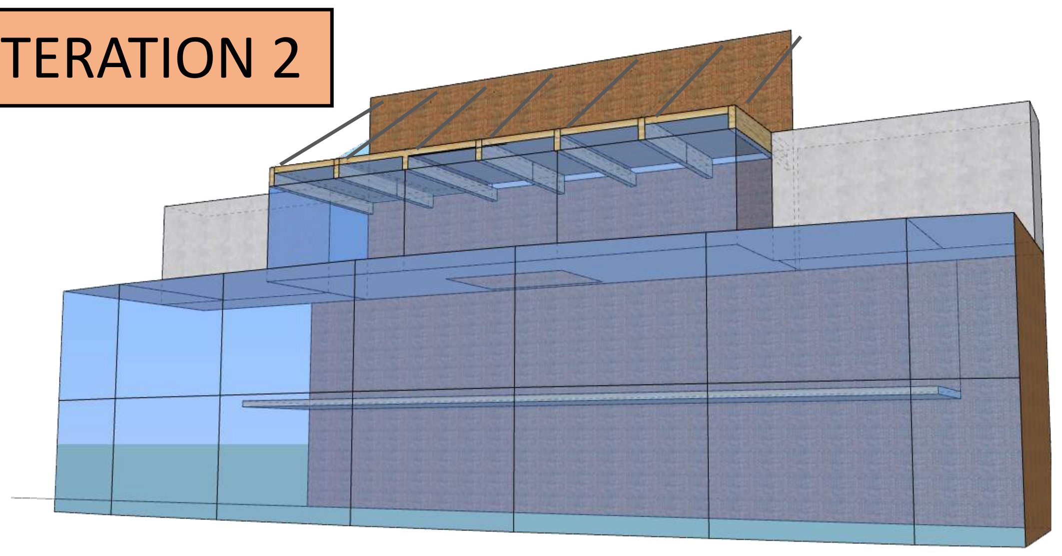
ROOF STRUCTURE ITERATIONS

ITERATION 1



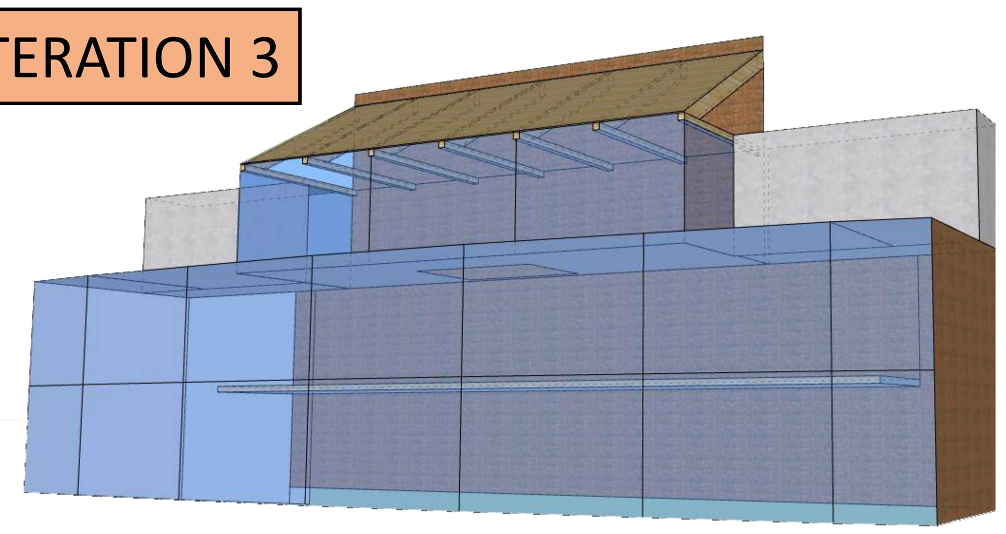
This was the team's first iteration that resulted in columns placed at midspan of beams and negatively affecting load path.

ITERATION 2



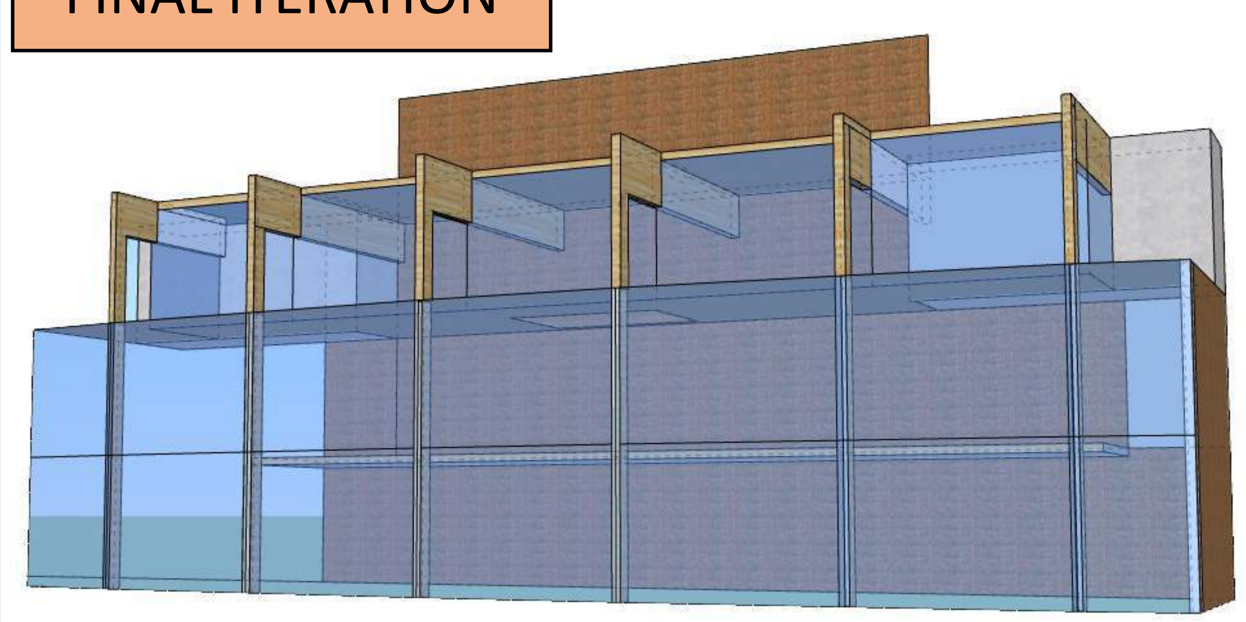
To reduce the need for midspan columns, the team then considered using steel rods to anchor back into the concrete wall. After consultation, this aesthetic did not harmonize with the idea of sustainability.

ITERATION 3



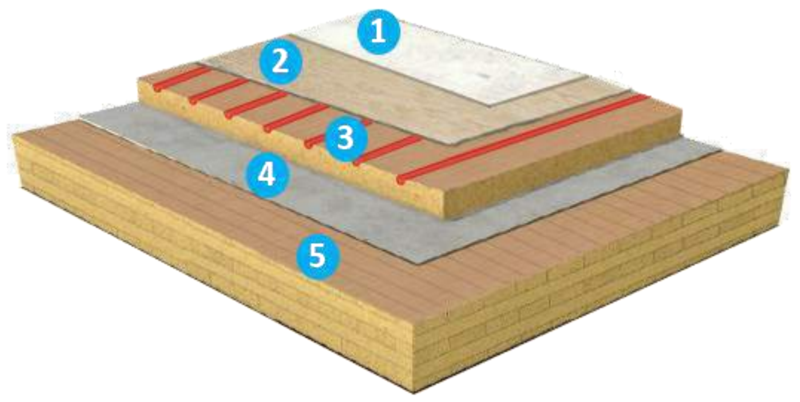
The next iteration was the design of a truss-like wood system that would once again tie back into the concrete wall. With 16 ft ceiling height already incorporated, the team felt that this would reduce the intimacy of the space.

FINAL ITERATION

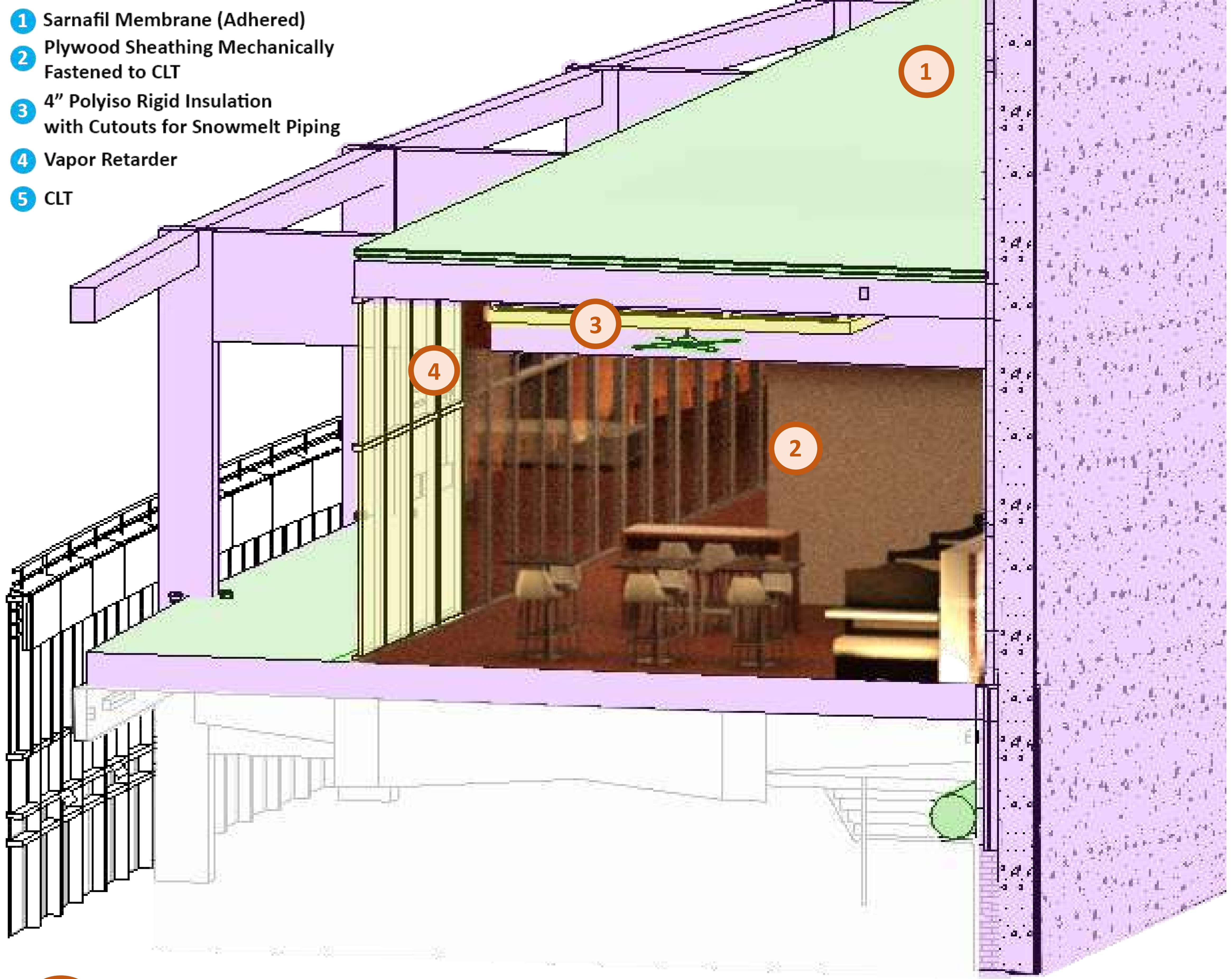


The team decided on a final design as seen in the final iteration. This design includes deep beams extending out to columns in line with the north lobby columns. These deep beams aided in showcasing sustainable design while creating depth and variability to the space.

1 ROOF ASSEMBLY



1. Sarnafil Membrane (Adhered)
2. Plywood Sheathing Mechanically Fastened to CLT
3. 4" Polyiso Rigid Insulation with Cutouts for Snowmelt Piping
4. Vapor Retarder
5. CLT

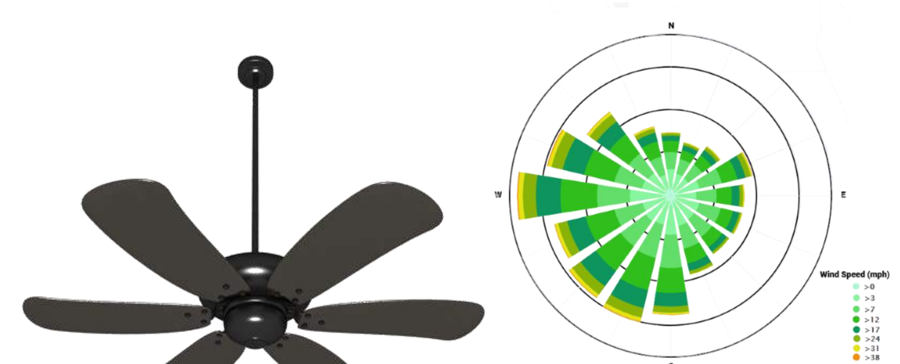


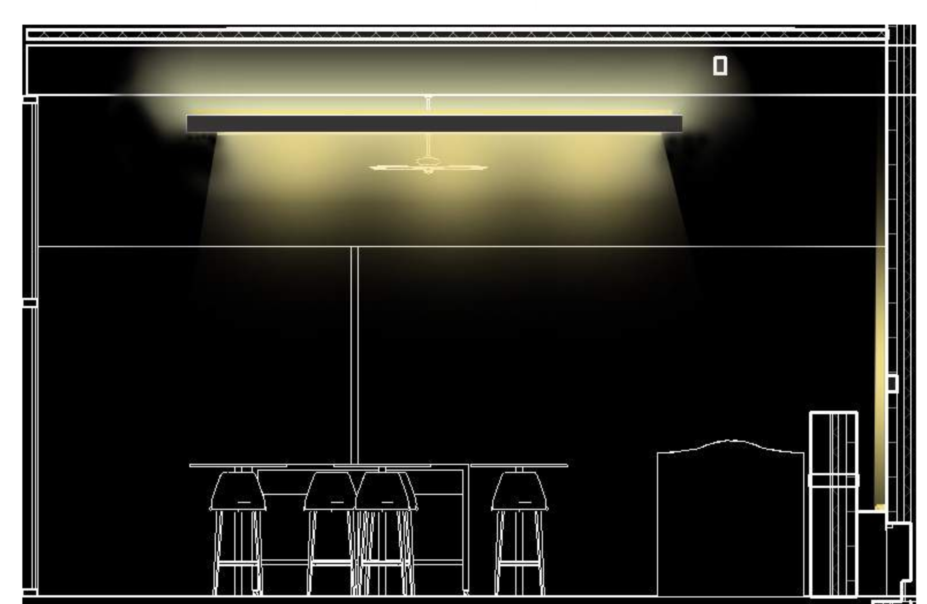
2 FUNDRAISING OPPORTUNITIES

Although the cost of the occupiable roof was covered within the Optimized Design budget, *Syndicate* would like to offer Hope College with another way to cover the cost of an occupiable roof for their patrons, rather than including it in the project budget. We suggest that the college pursues a fundraising strategy for this feature. Some options for this could include:

- Program advertising for local business sponsorship
- "Patron Levels" program with incentives for donors
- Performance gala for school of music students
- Naming opportunities for rooftop space

As the construction team, Syndicate's role would be to provide a free design of the roof, provide models, renderings, and virtual reality walkthroughs for the potential donors, and match the donations up to $50,000.





Schematic Detail of the light sources directional output

3 A SIMPLIFIED CEILING SPACE

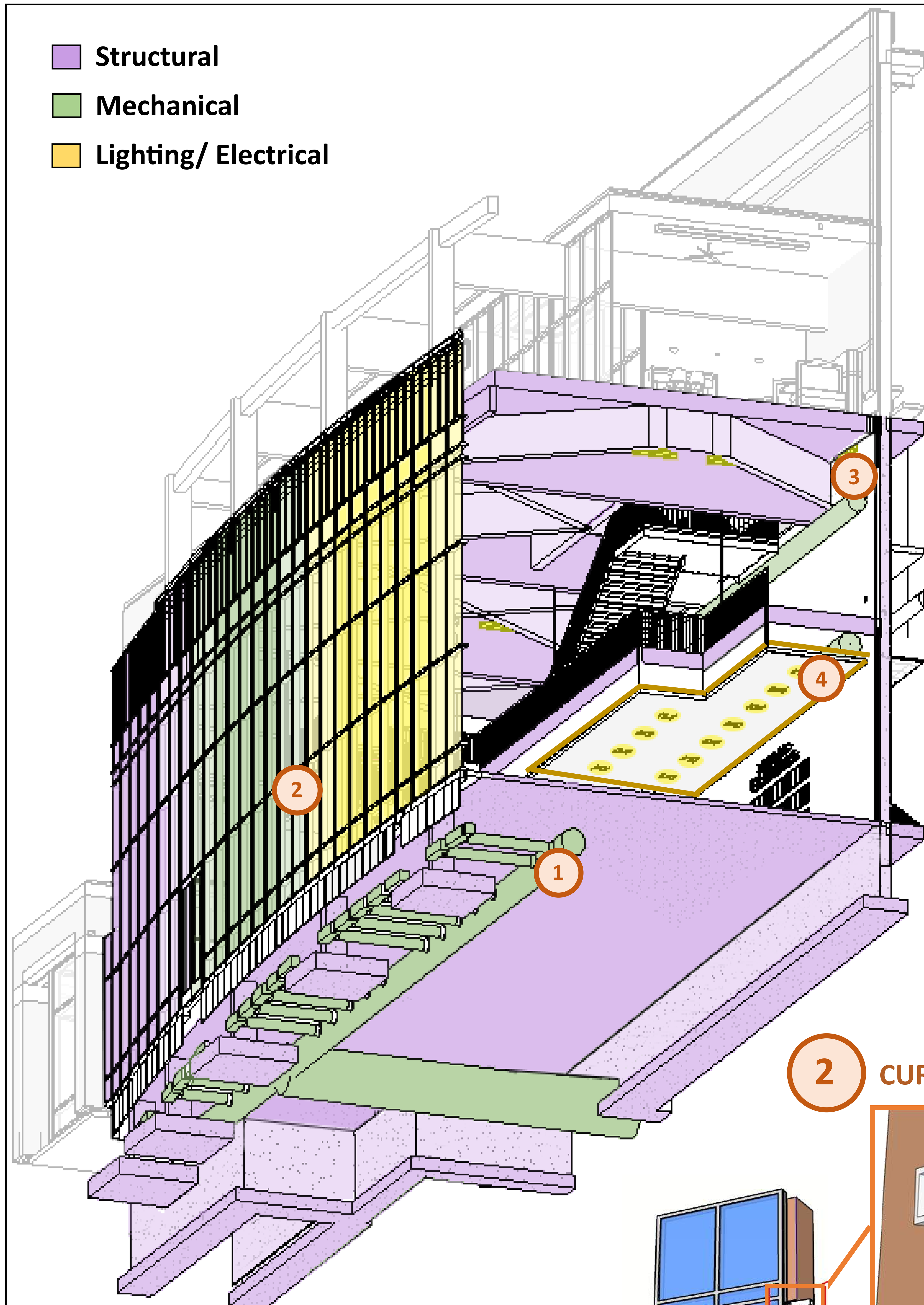
The placement of the occupiable roof on the north side was advantageous for natural ventilation because of the light summer breezes coming from the north. To encourage air movement during the summer months, fans were placed throughout the space. The simplicity of the occupiable roof mechanical system increases constructability and ceiling coordination. With minimal mechanical equipment and flat CLT ceilings, a drop-ceiling panel was able to be placed in three bays to house recessed lighting and an LED tape-light cove.

SYNDICATE	
PROJECT **JACK H. MILLER CENTER FOR MUSICAL ARTS** HOLLAND, MICHIGAN	
SHEET TITLE **OCCUPIABLE ROOF CHALLENGE**	
NOT FOR CONSTRUCTION	AEI TEAM NO. 01-2019
DATE February 18th, 2019	SCALE NOT TO SCALE
DRAWING NO. **I-6.0**	PAGE NO. 26

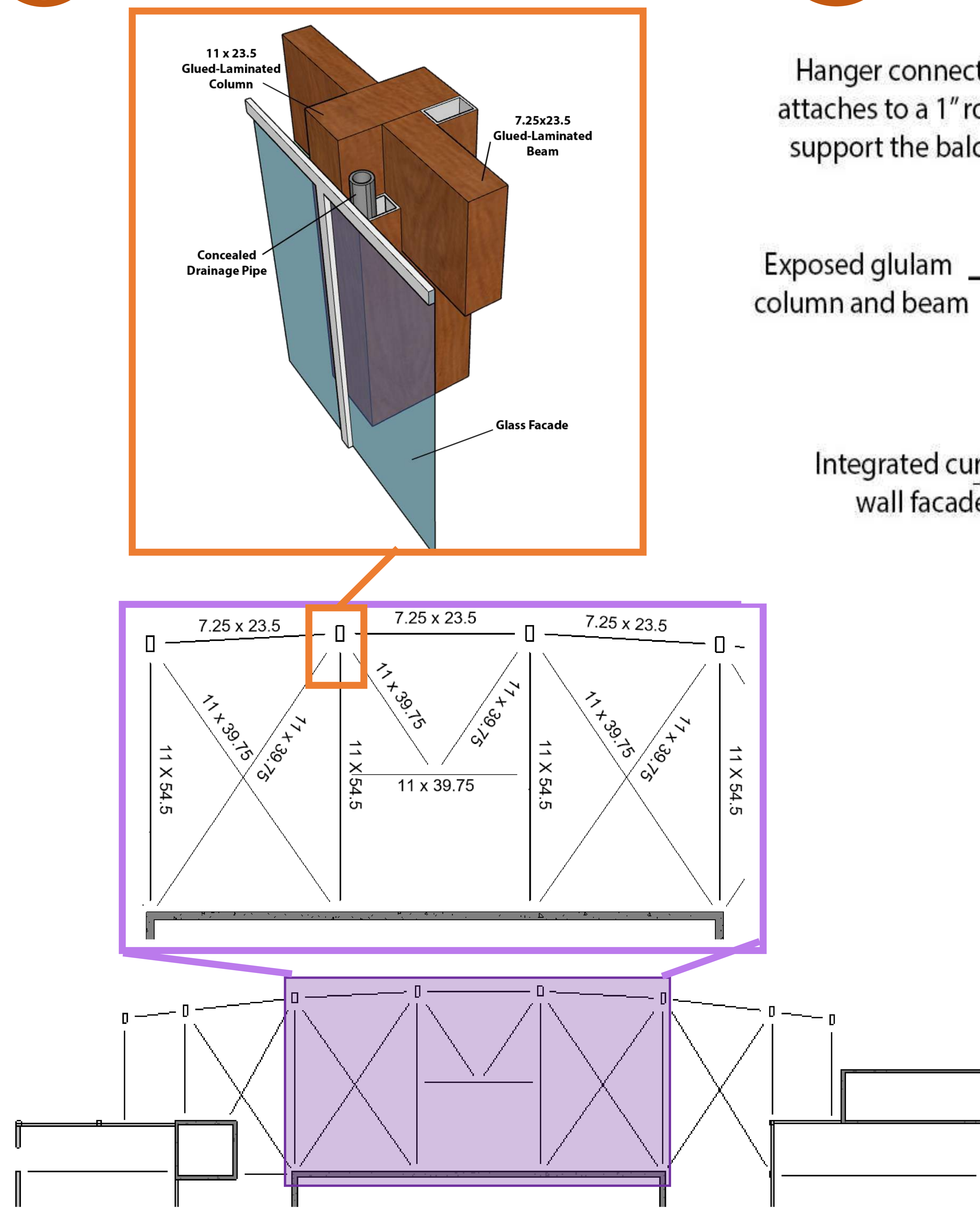
Structural

Mechanical

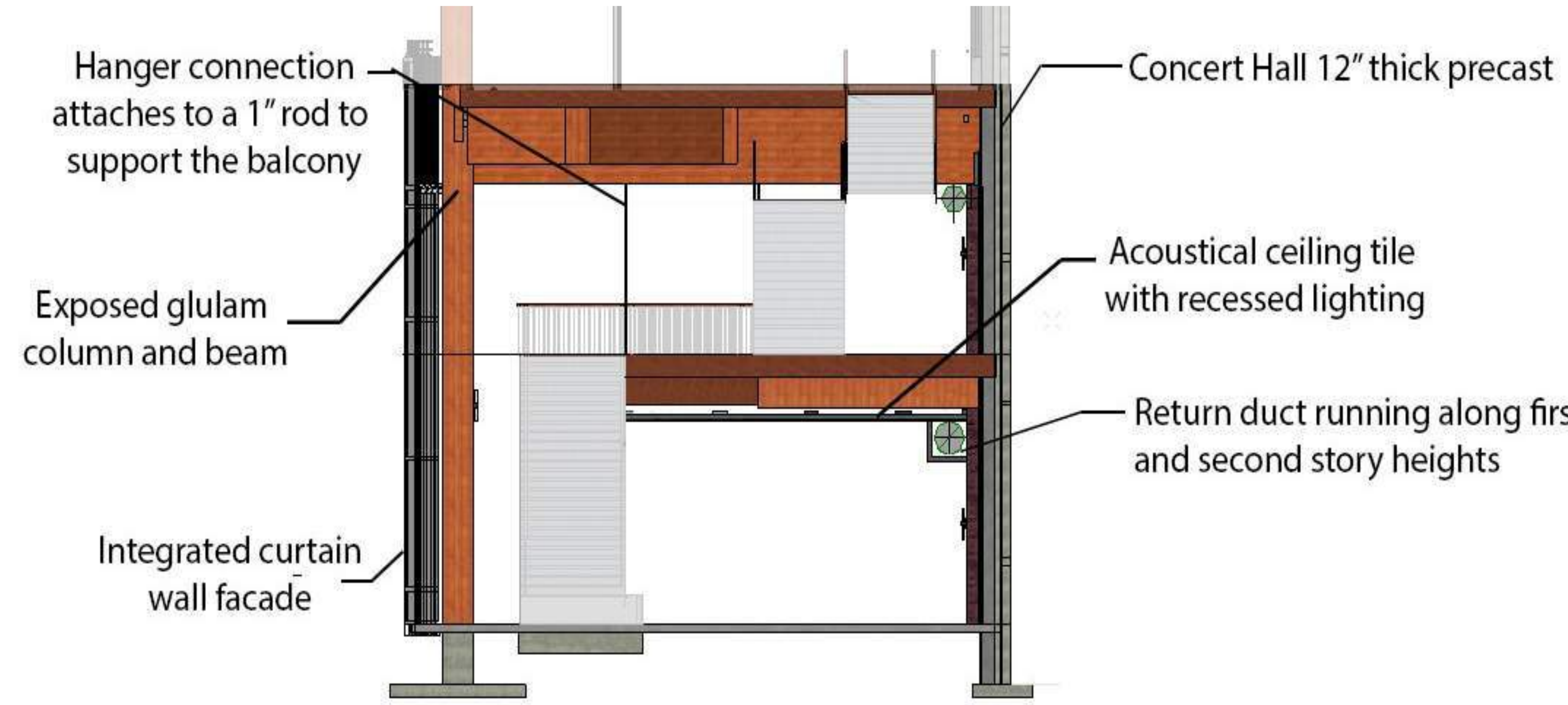
Lighting/ Electrical

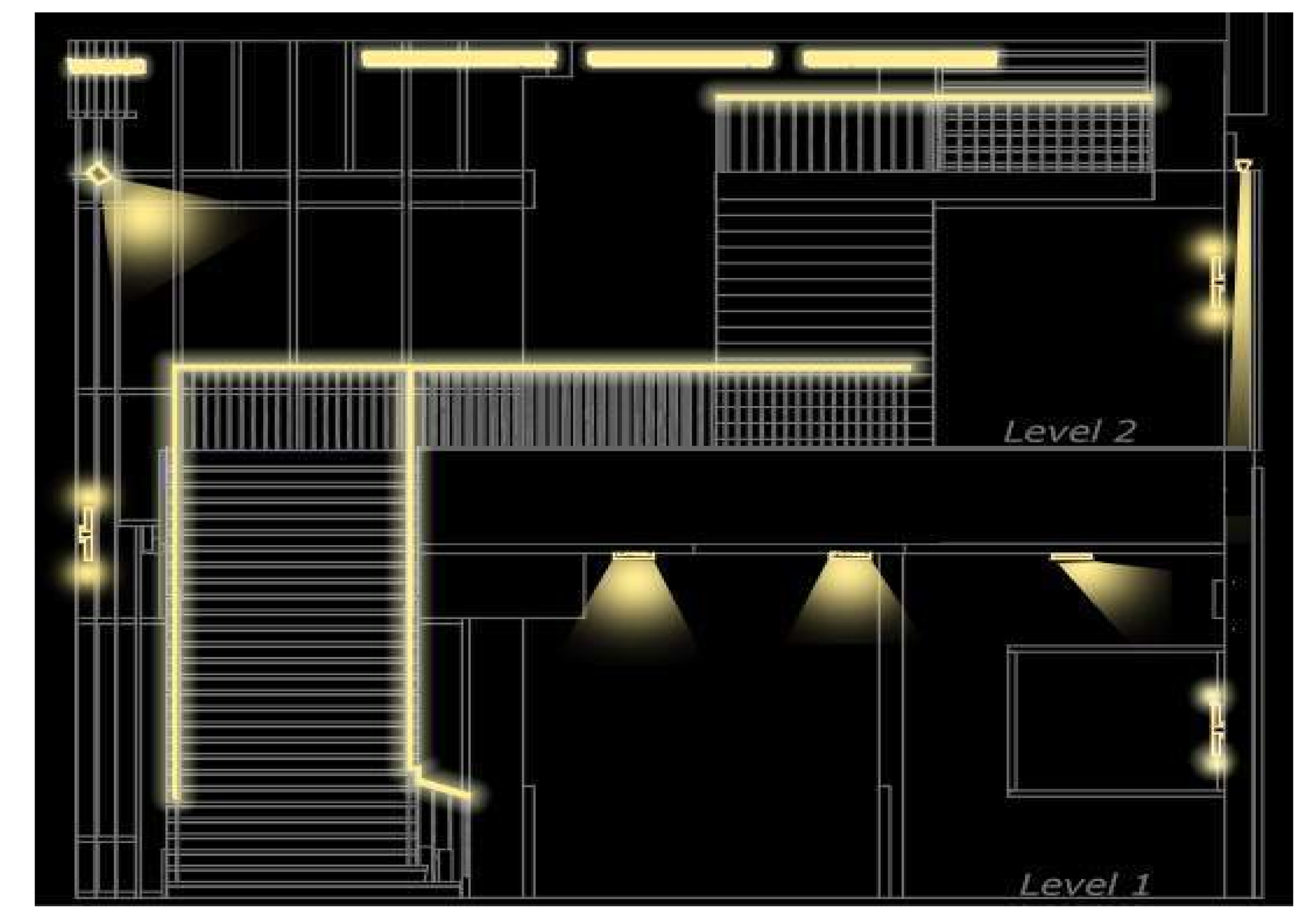


3 ROOF STRUCTURE INTEGRATION



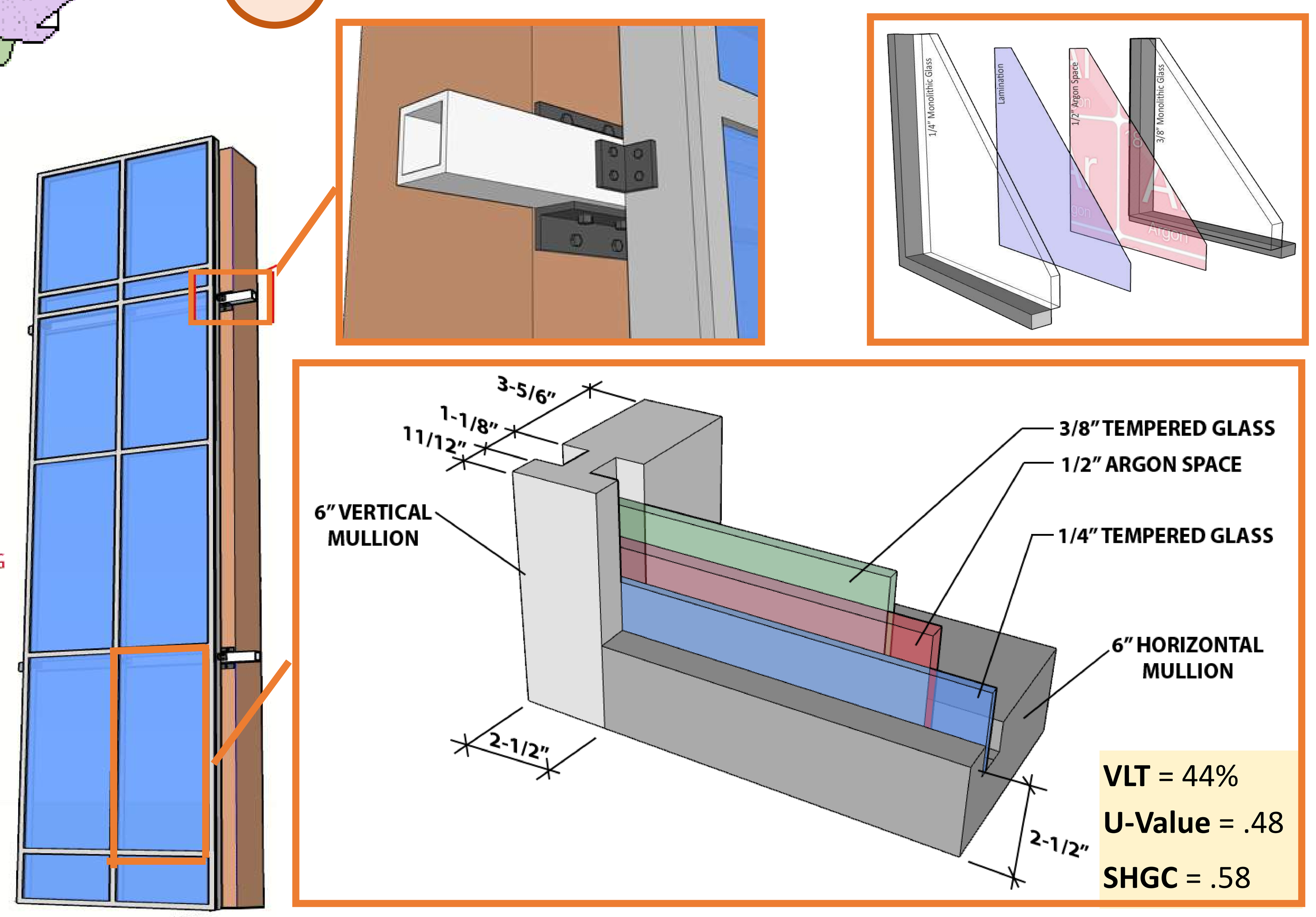
4 SYSTEMS INTEGRATION





Schematic Detail of the light sources directional output

2 CURTAIN WALL INTEGRATION

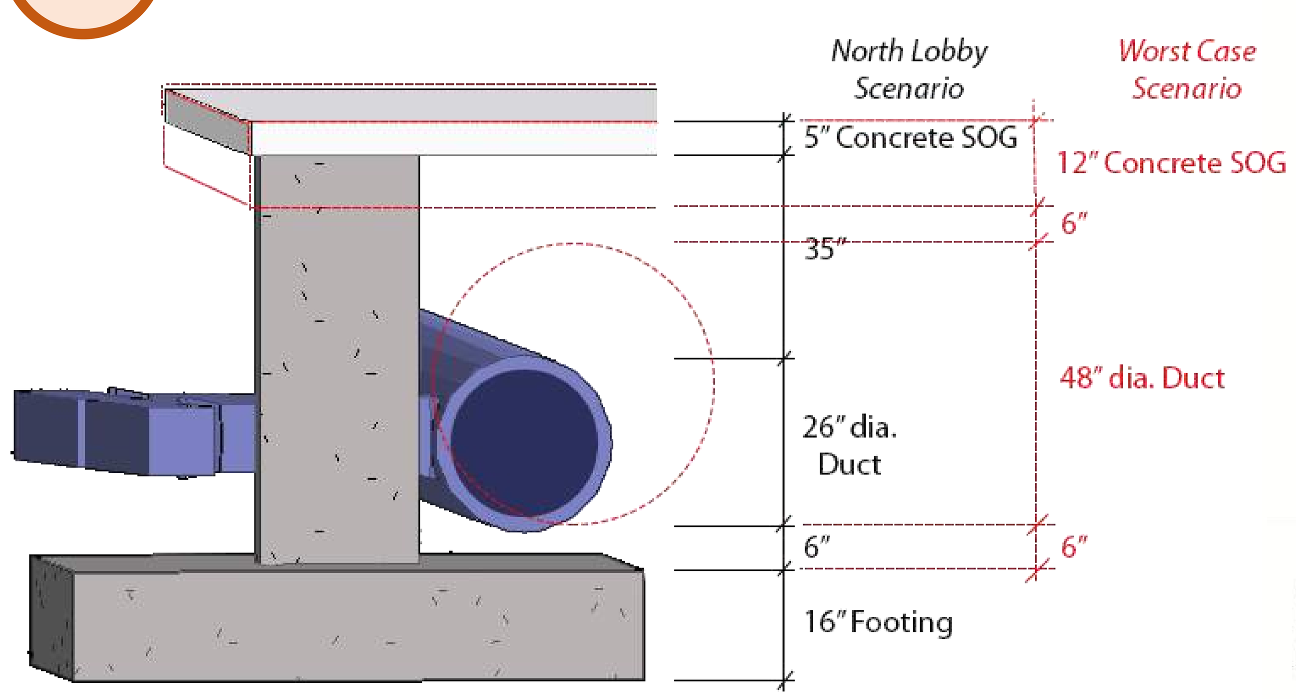


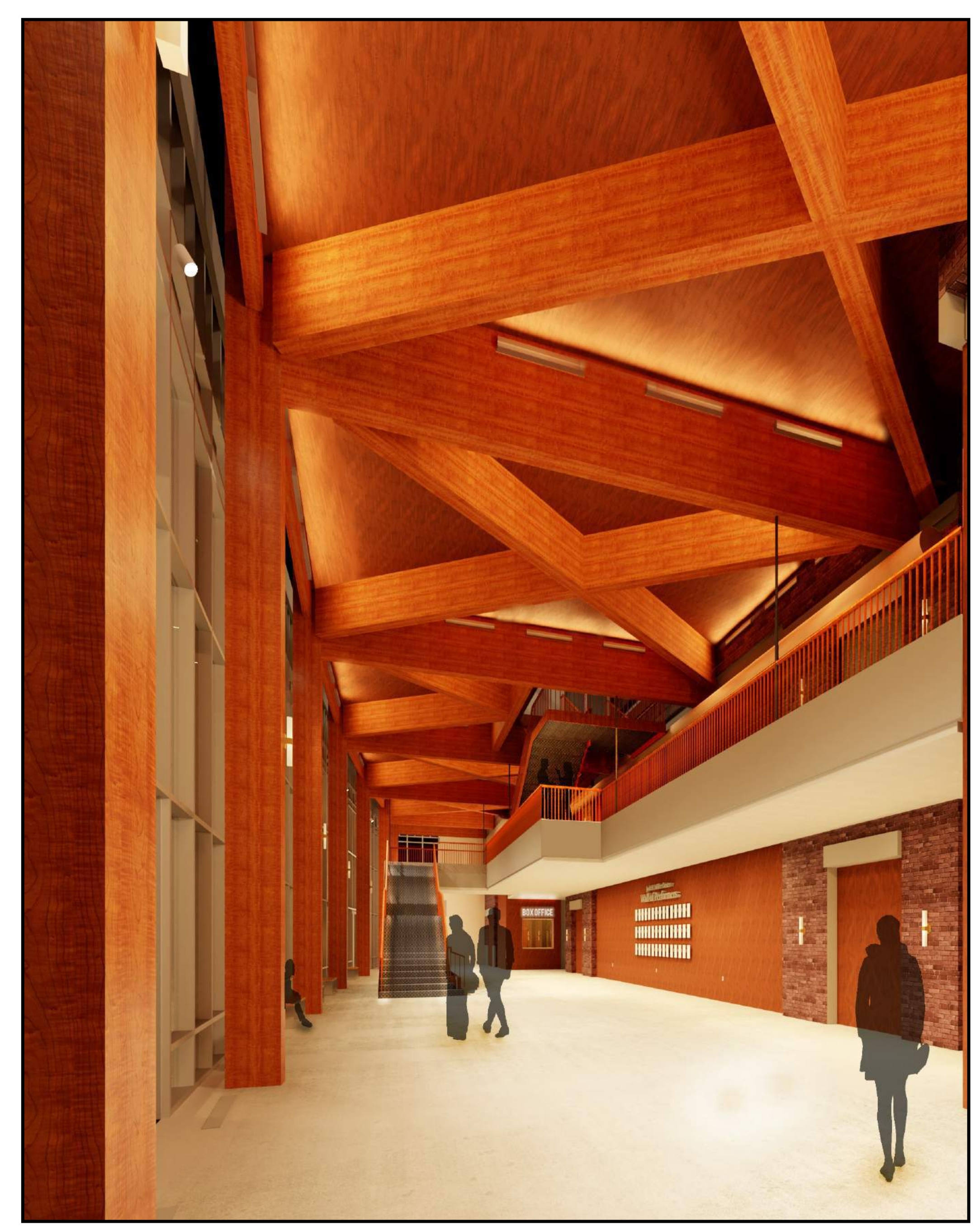
VLT = 44%

U-Value = .48

SHGC = .58

1 UNDERGROUND COORDINATION





SYNDICATE

PROJECT

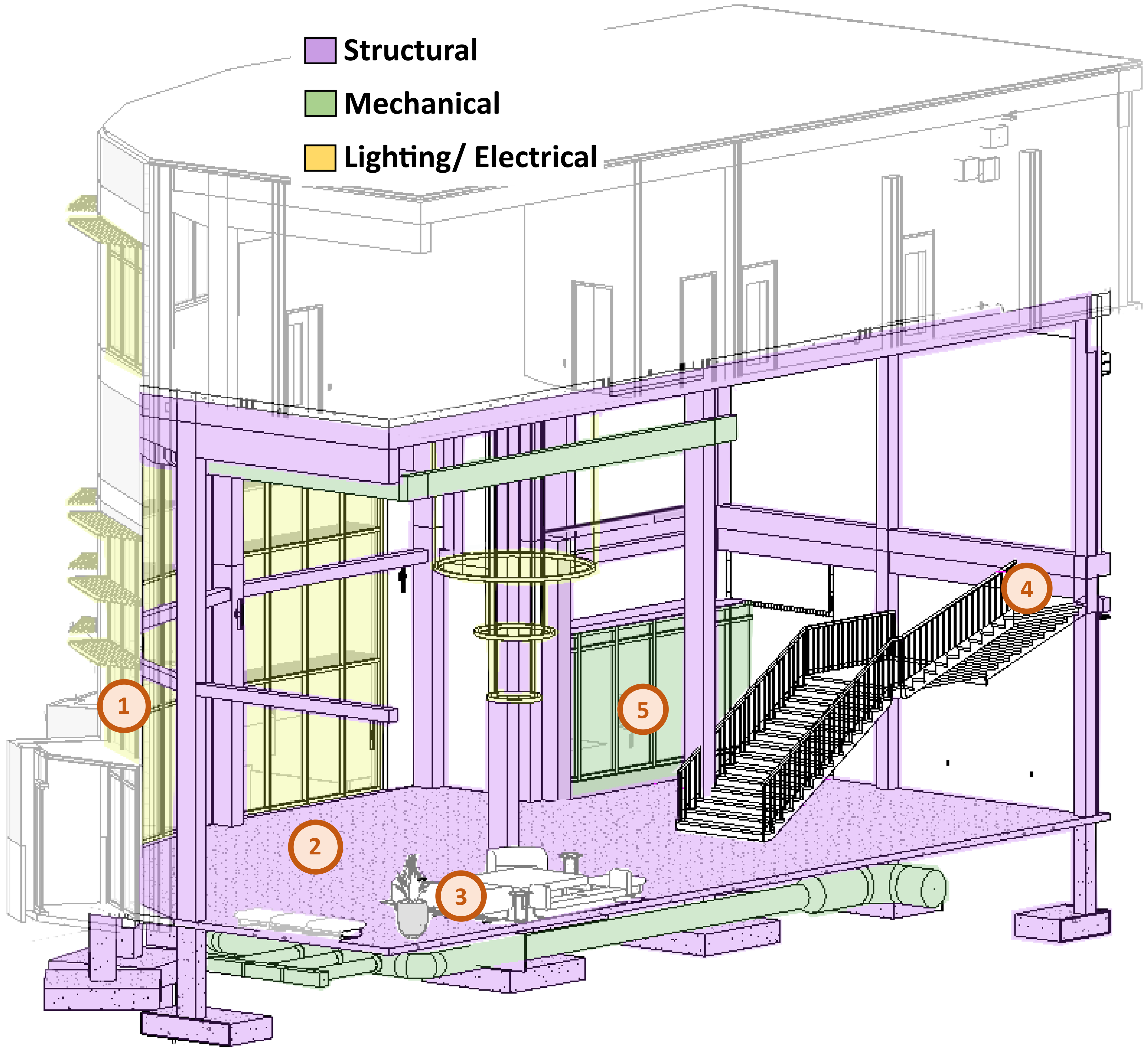
JACK H. MILLER CENTER FOR MUSICAL ARTS

HOLLAND, MICHIGAN

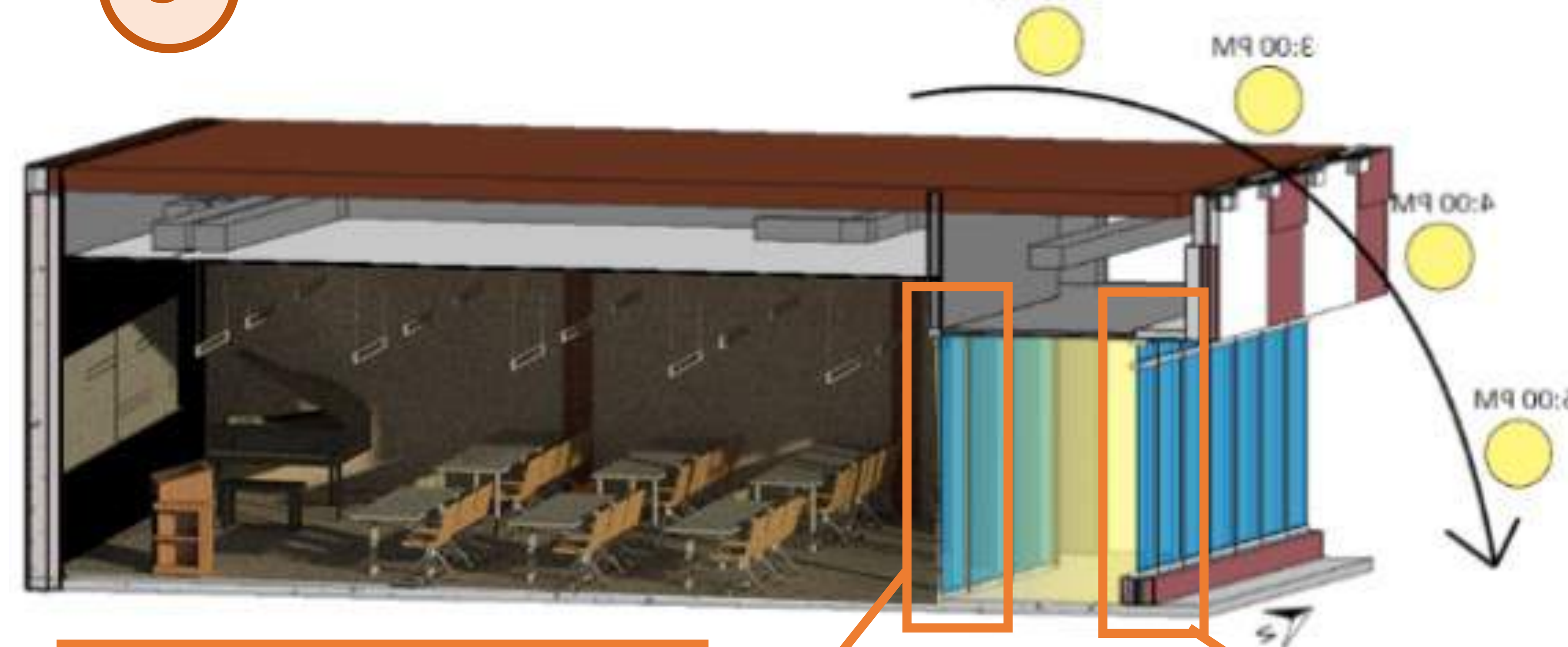
SHEET TITLE

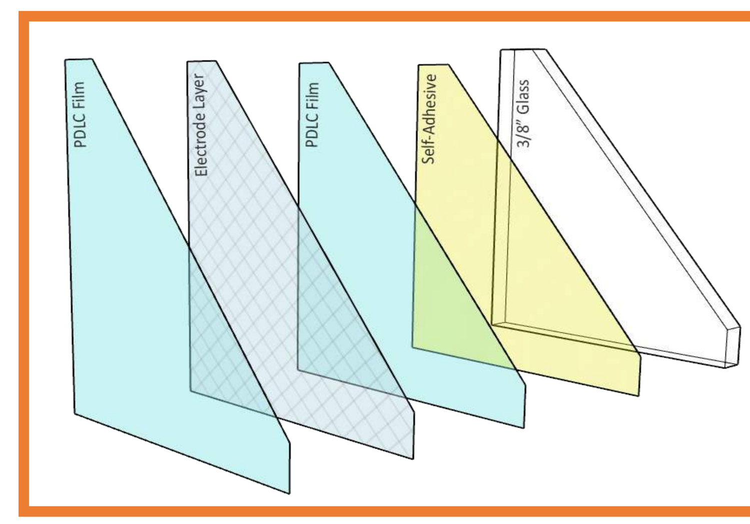
NORTH LOBBY INTEGRATION

NOT FOR CONSTRUCTION	AEI TEAM NO. 01-2019
DATE February 18th, 2019	SCALE NOT TO SCALE
DRAWING NO. **I-7.0**	PAGE NO. 27

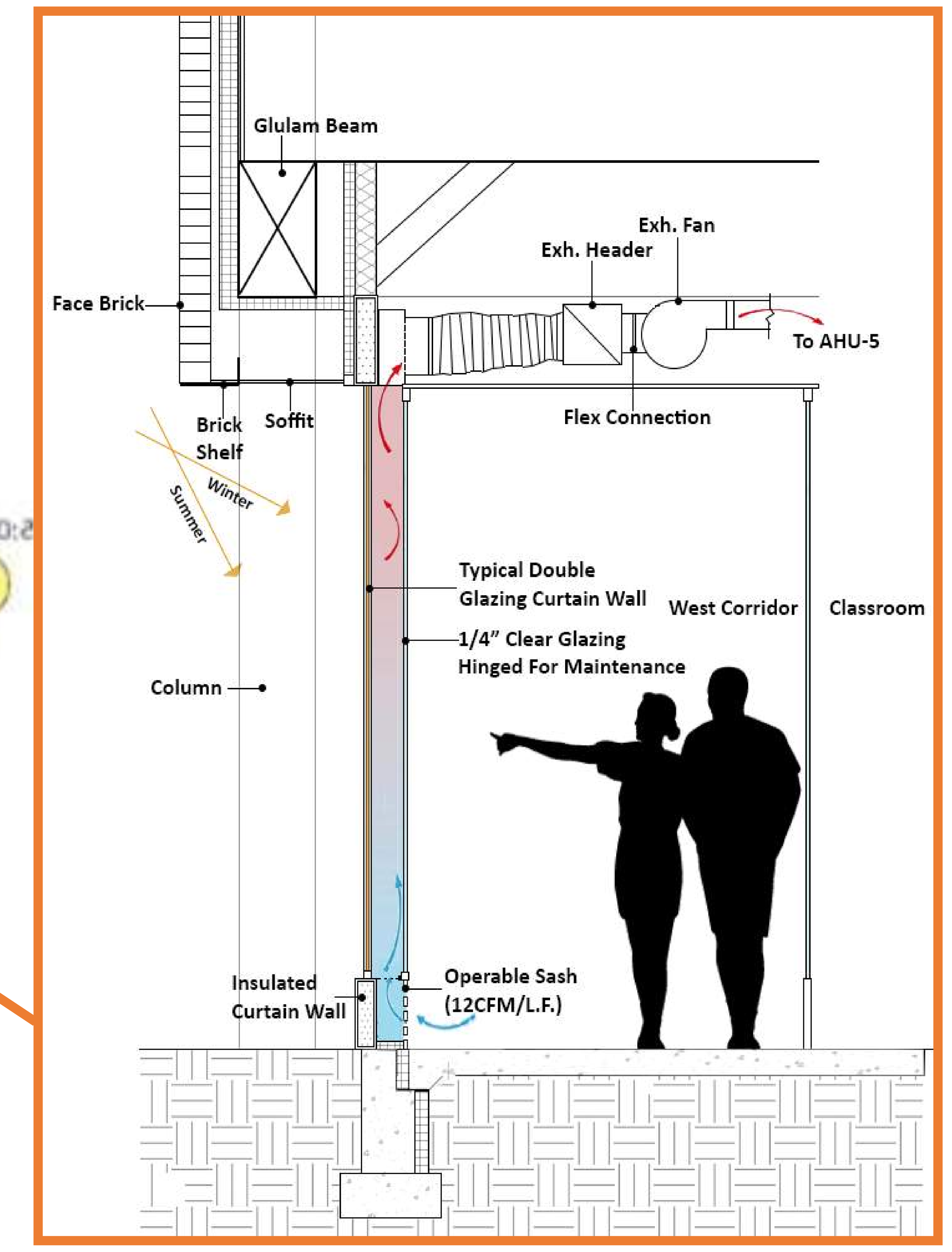


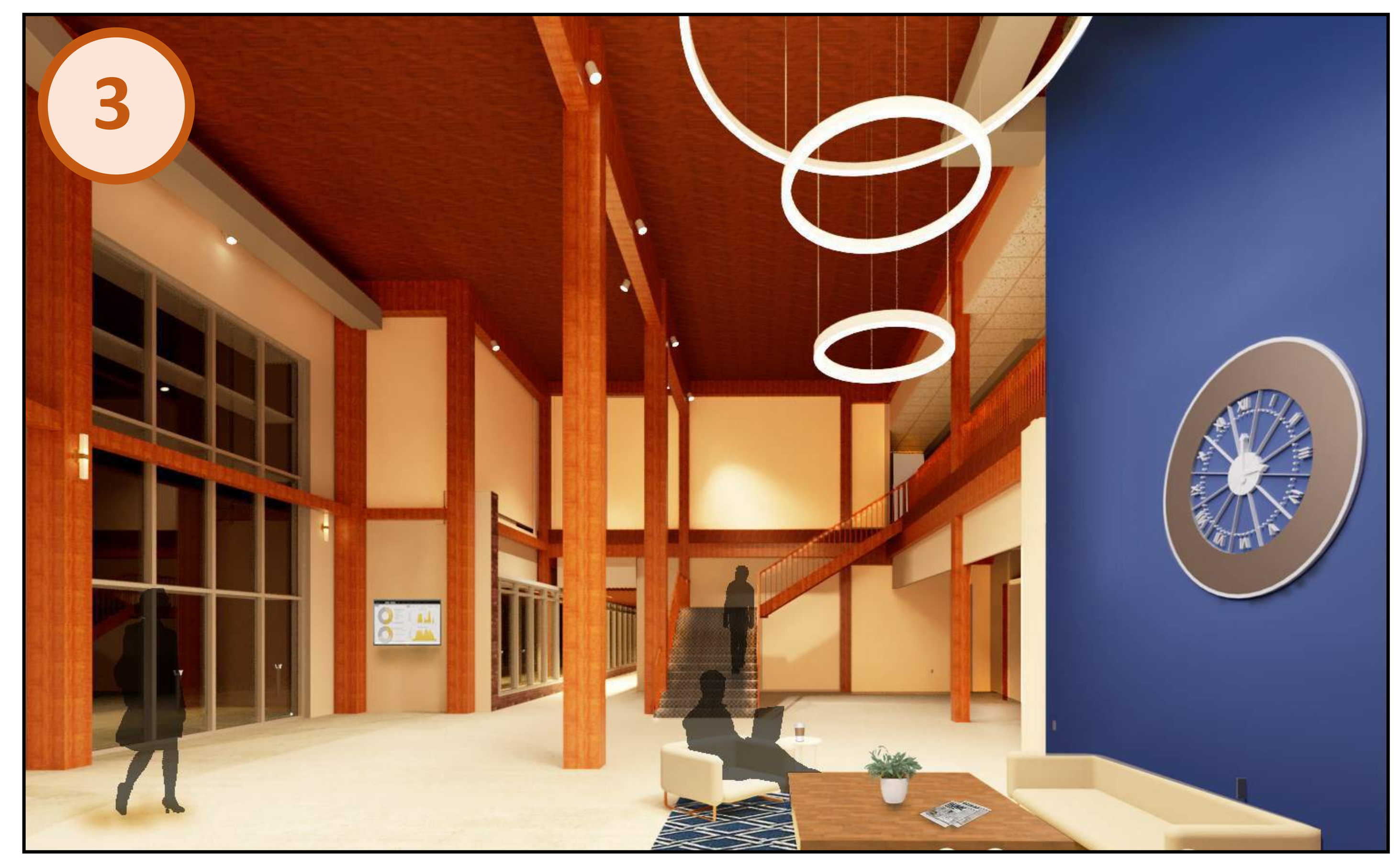
5 VENTILATED DOUBLE WALL FACADE



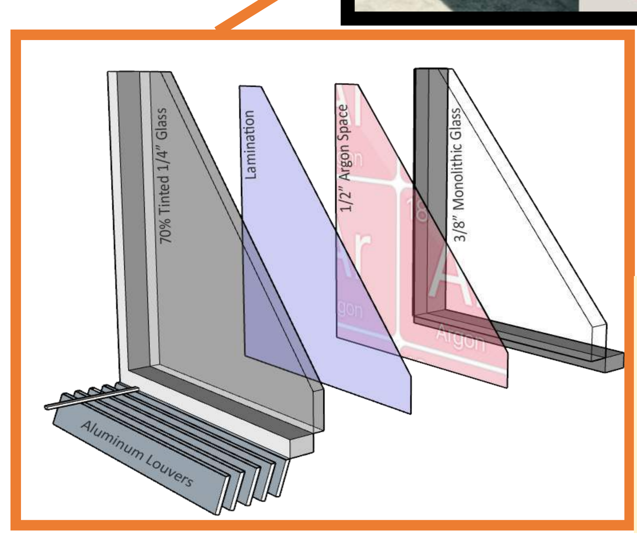


VLT = 4-98%
SHGC = .71



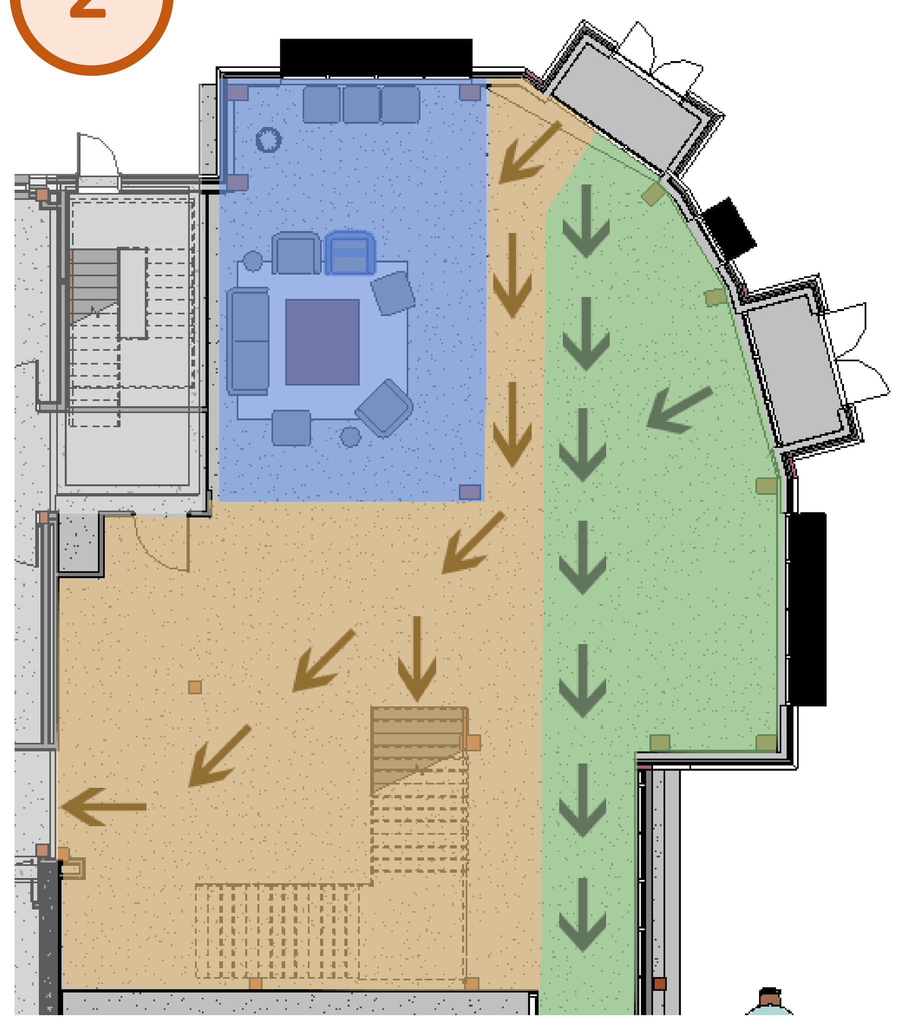


1 SHADING AND GLAZING SYSTEM



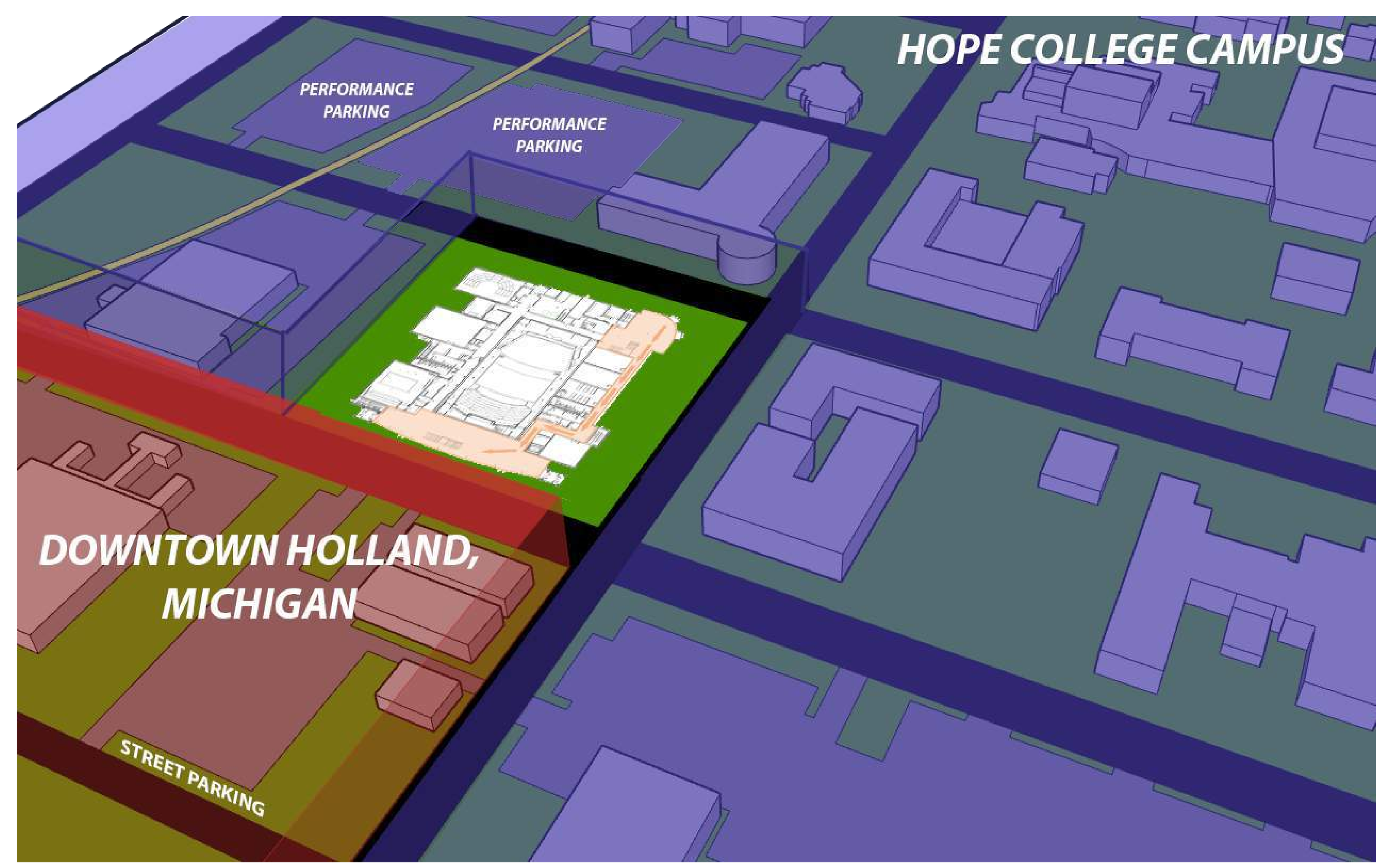
VLT = 44%
SHGC = .58
U-Value = .48

2 FLEXIBLE SPACE



- Student/Faculty Lounge Area
- Transition to Educational Spaces
- Gateway to West Corridor and North Lobby

CONNECTING CAMPUS TO DOWNTOWN



SYNDICATE

PROJECT

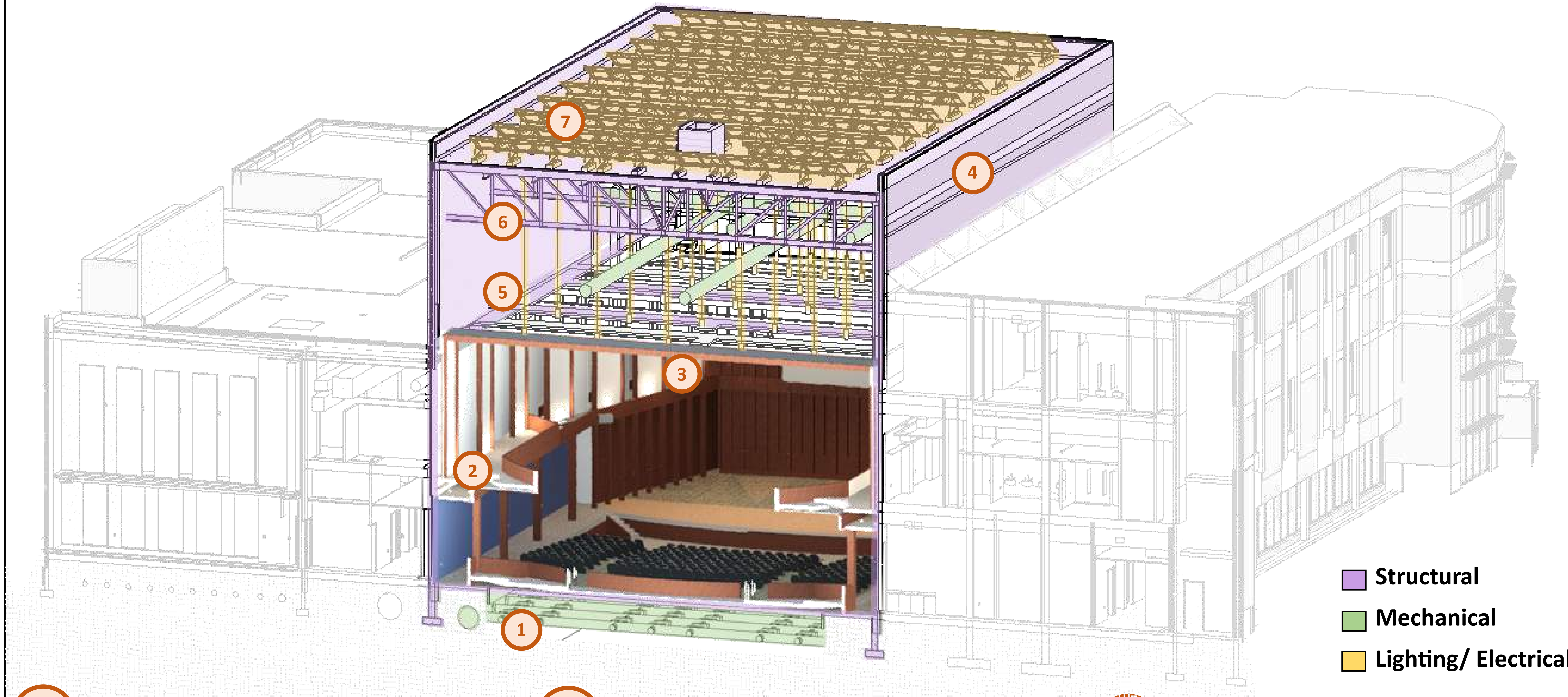
JACK H. MILLER CENTER FOR MUSICAL ARTS

HOLLAND, MICHIGAN

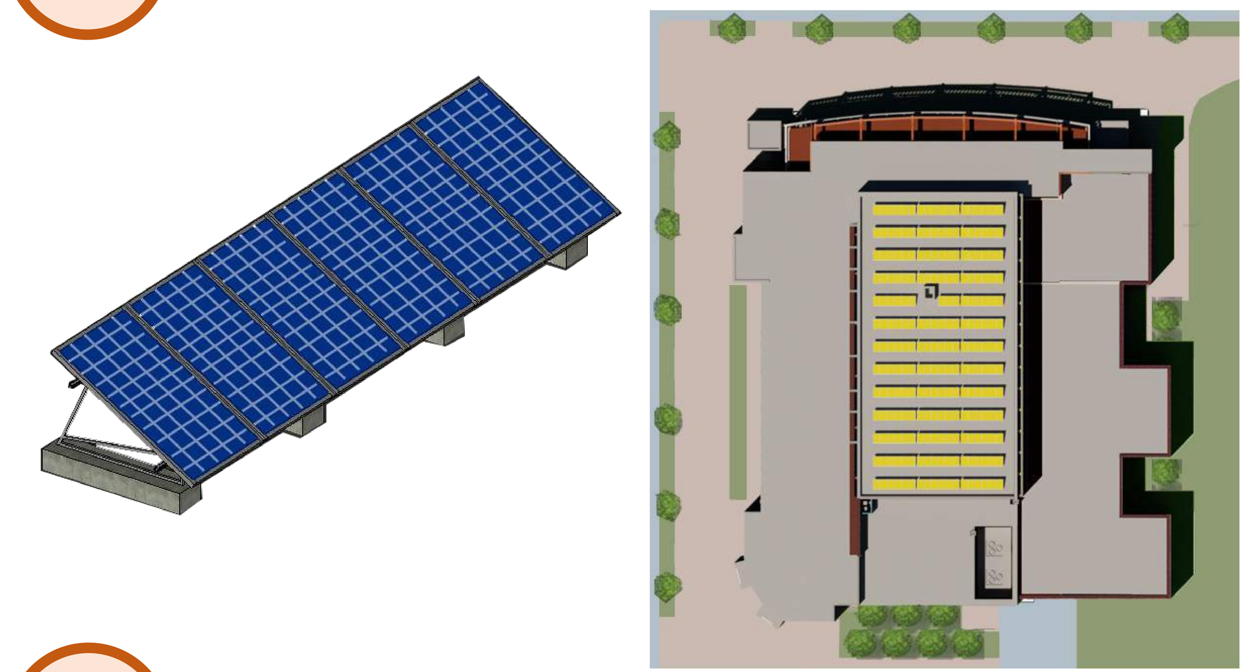
SHEET TITLE

SOUTH LOBBY, WEST CORRIDOR, AND CLASSROOM INTEGRATION

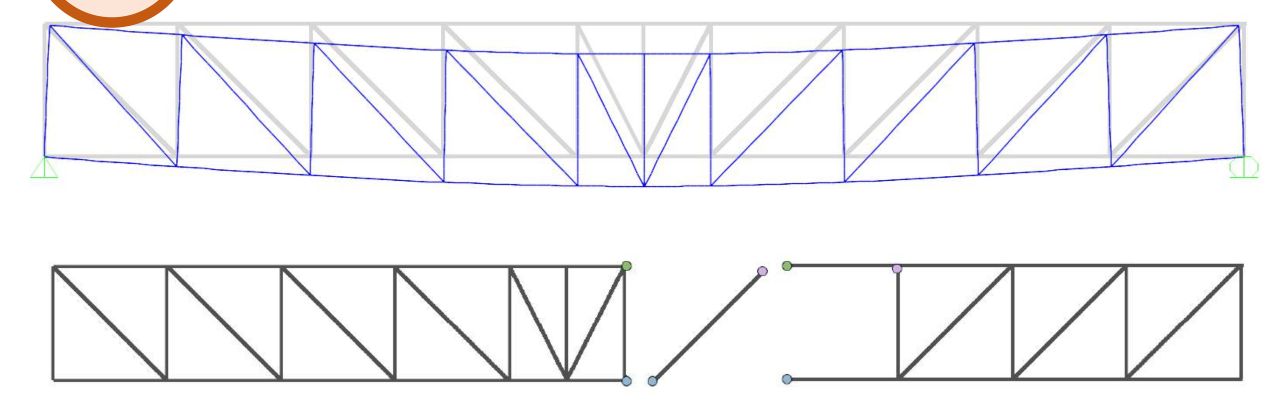
NOT FOR CONSTRUCTION	AEI TEAM NO. 01-2019
DATE February 18th, 2019	SCALE NOT TO SCALE
DRAWING NO. I-8.0	PAGE NO. 28



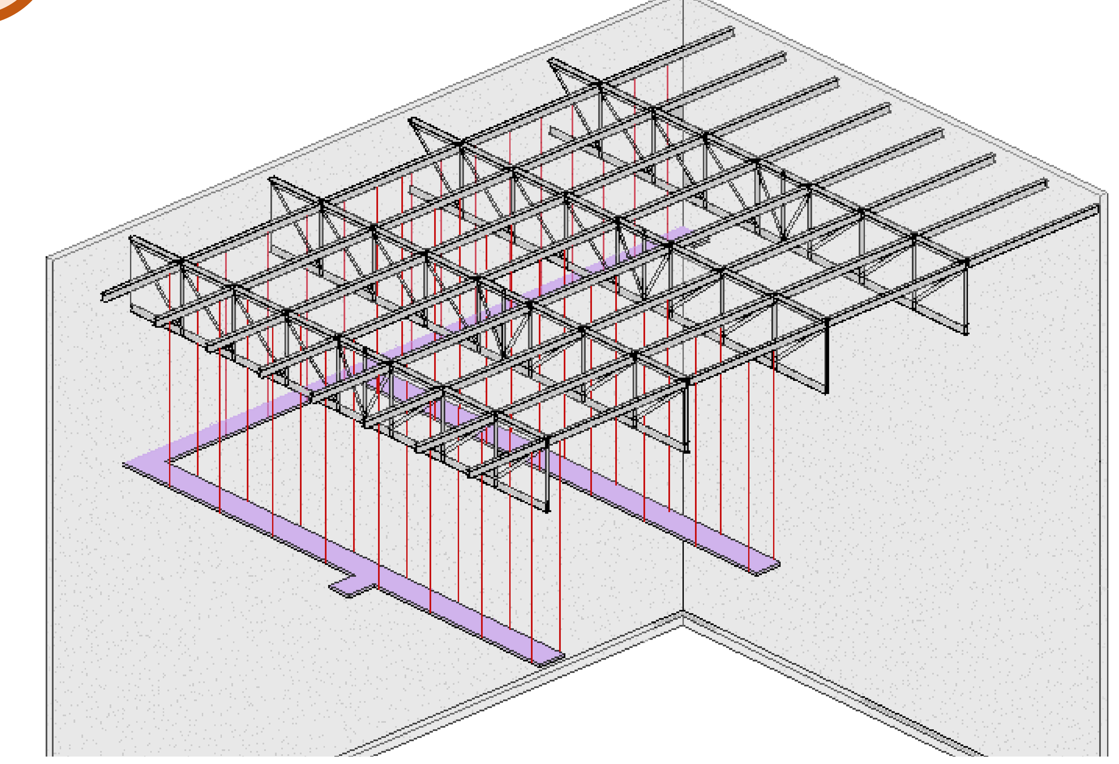
7 PHOTOVOLTAIC ARRAY



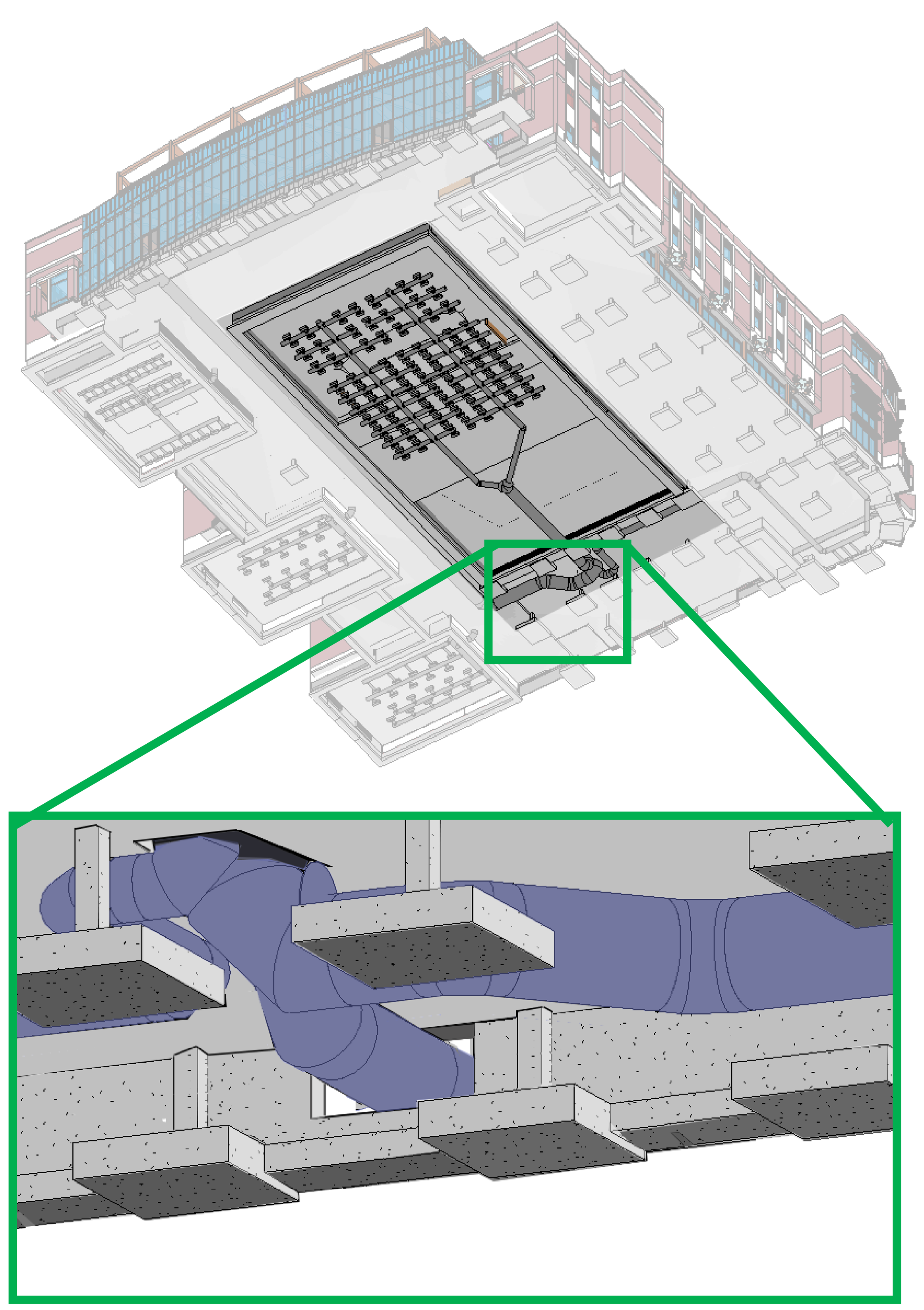
6 LONG SPAN STEEL ROOF TRUSS



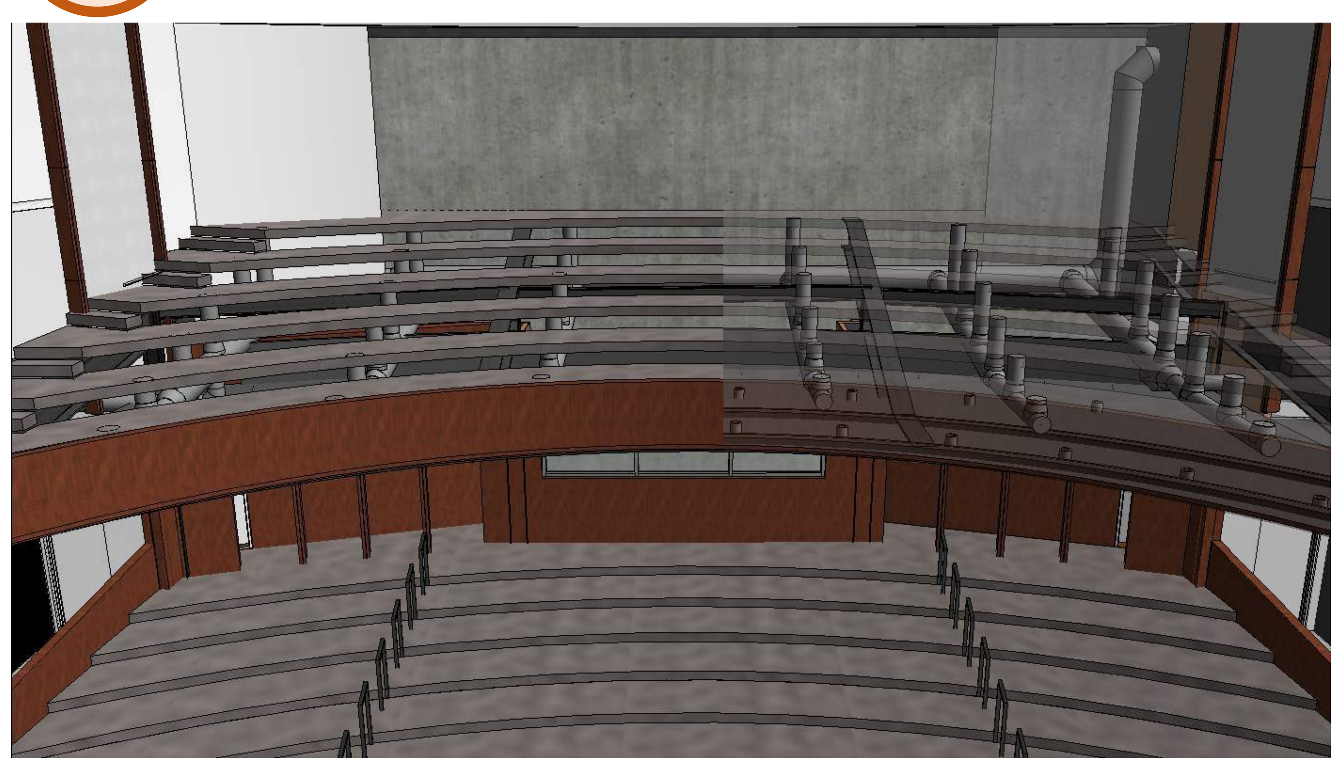
5 CATWALK LAYOUT COORDINATION



1 BELOW SEAT DISPLACEMENT VENTILATION INTEGRATION

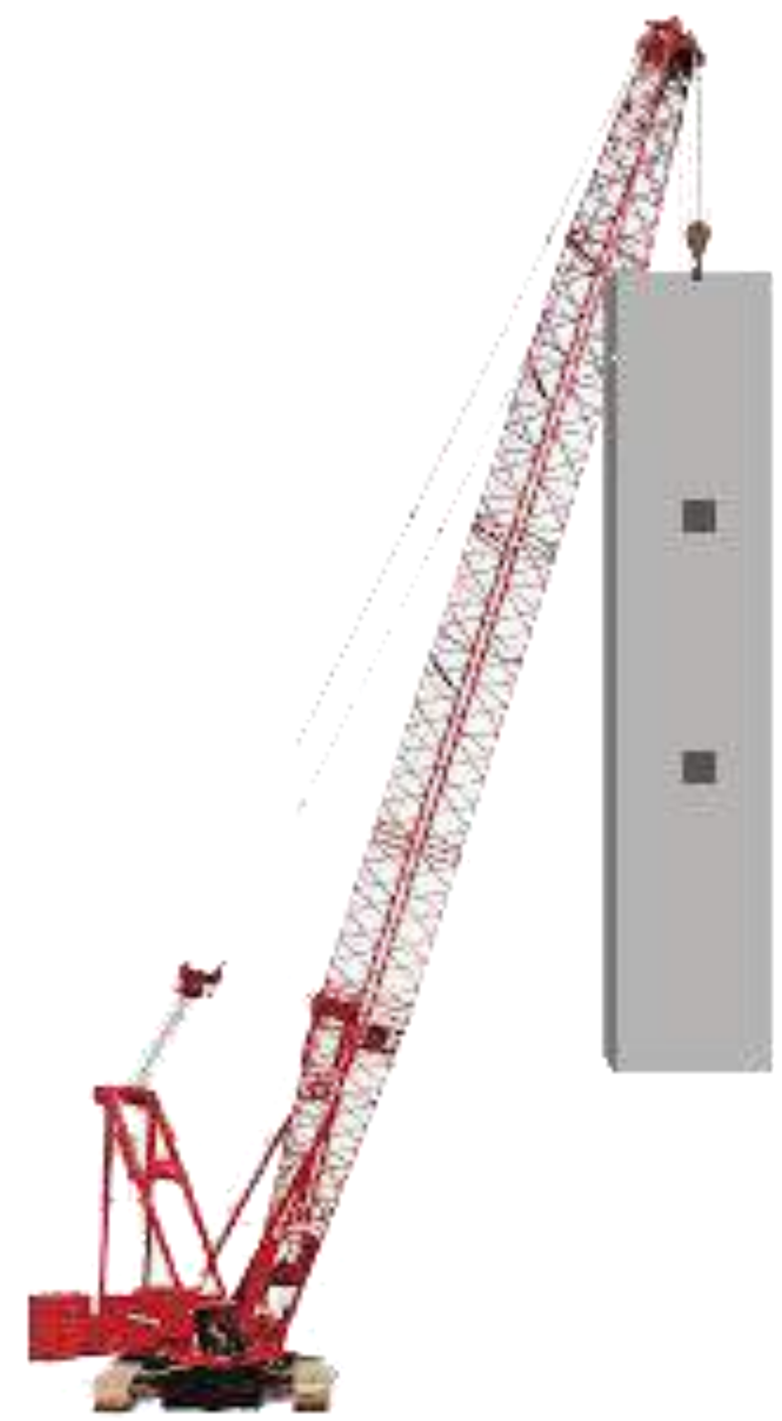


2 BALCONY COORDINATION

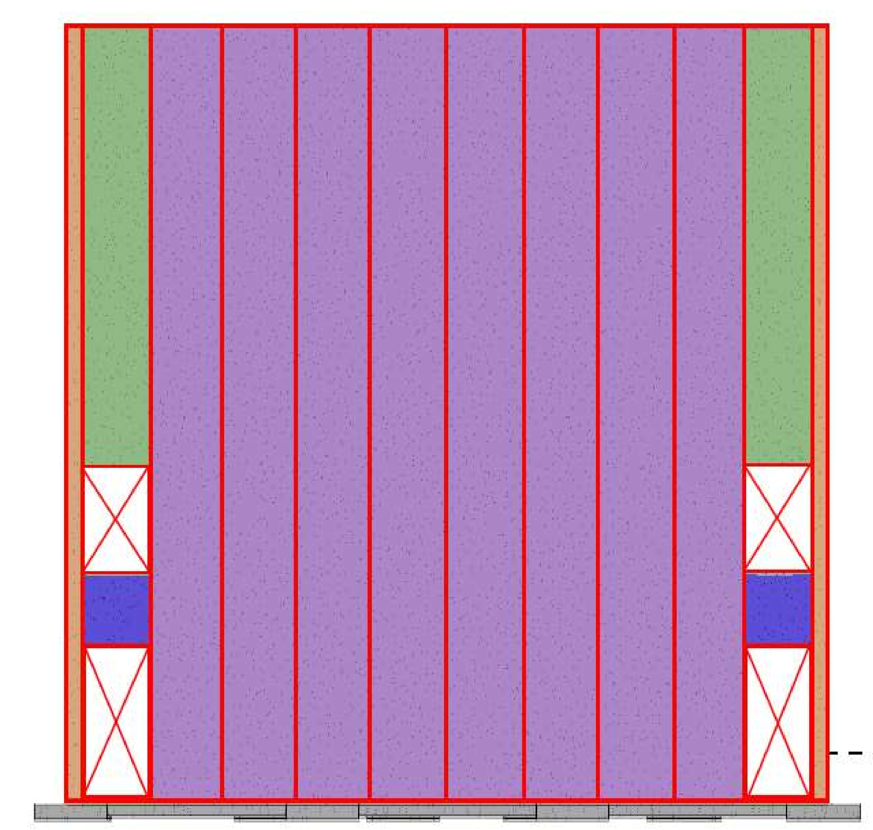


3 ACOUSTICAL RIBBON/ FIBER OPTIC INTEGRATION

4 CRANE SELECTION AND PRECAST PANEL LAYOUT



300-TON 2250 SERIES 3 MANITOWAC CRAWLER CRANE



TYPICAL PANEL A
TYPICAL PANEL B
ADJACENT WALL PANEL FRAMING IN
TYPICAL PANEL C

SYNDICATE

PROJECT

JACK H. MILLER CENTER FOR MUSICAL ARTS

HOLLAND, MICHIGAN

SHEET TITLE

CONCERT HALL INTEGRATION

NOT FOR CONSTRUCTION	AEI TEAM NO. 01-2019
DATE February 18th, 2019	SCALE NOT TO SCALE
DRAWING NO. I-9.0	PAGE NO. 29

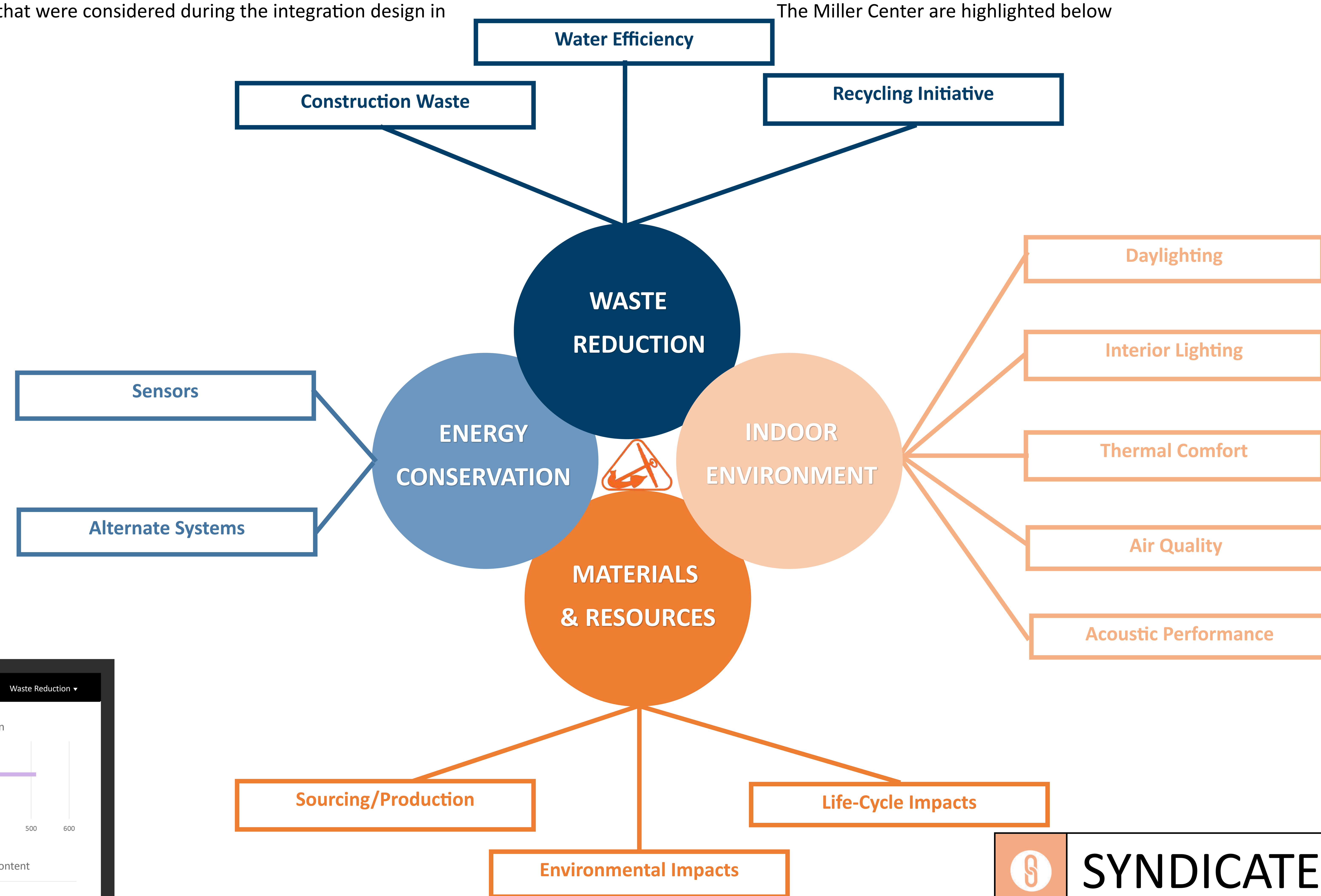
JACK H MILLER PILOT PROGRAM

Syndicate has implemented this Sustainability Plan on the Miller Center project. Below are the specific aspects of the plan that are highlighted on this project, color-coded by responsible discipline.

CANNON	CATEGORIES	DISCIPLINE INTEGRATION
ENERGY CONSERVATION	ALTERNATE SYSTEMS	
	SENSORS	
MATERIALS AND RESOURCES	SOURCING/PRODUCTION	
	ENVORONMENTAL IMPACTS	
	LIFE-CYCLE IMPACT	
INDOOR ENVIRONMENT	DAYLIGHTING	
	INTERIOR LIGHTING	
	THERMAL COMFORT	
	AIR QUALITY	
	ACOUSTIC PERFORMANCE	
WASTE REDUCTION	CONSTRUCTION WASTE	
	WATER EFFICIENCY	
	RECYCLING INITIATIVE	

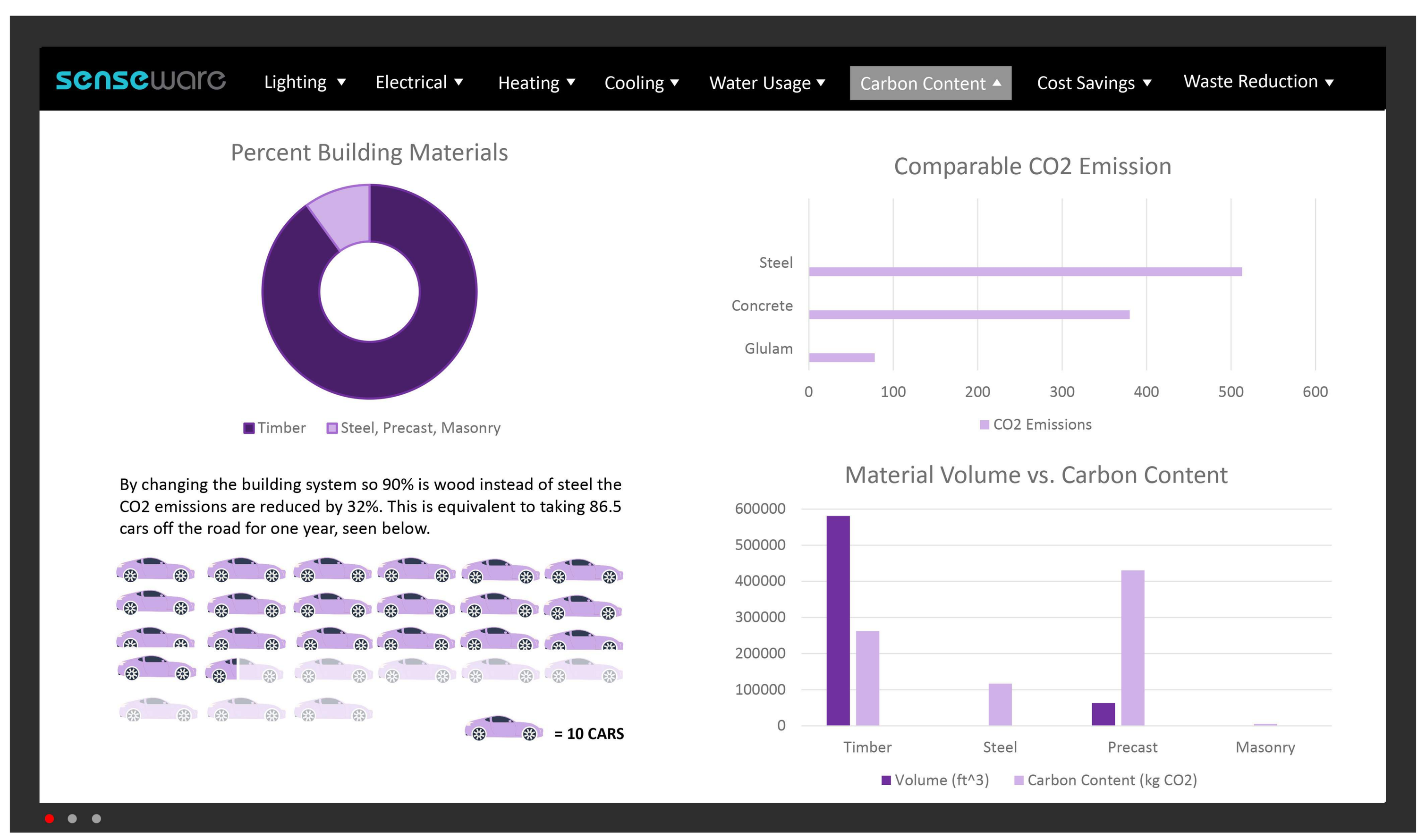
THE HOPE COLLEGE SUSTAINABILITY PLAN

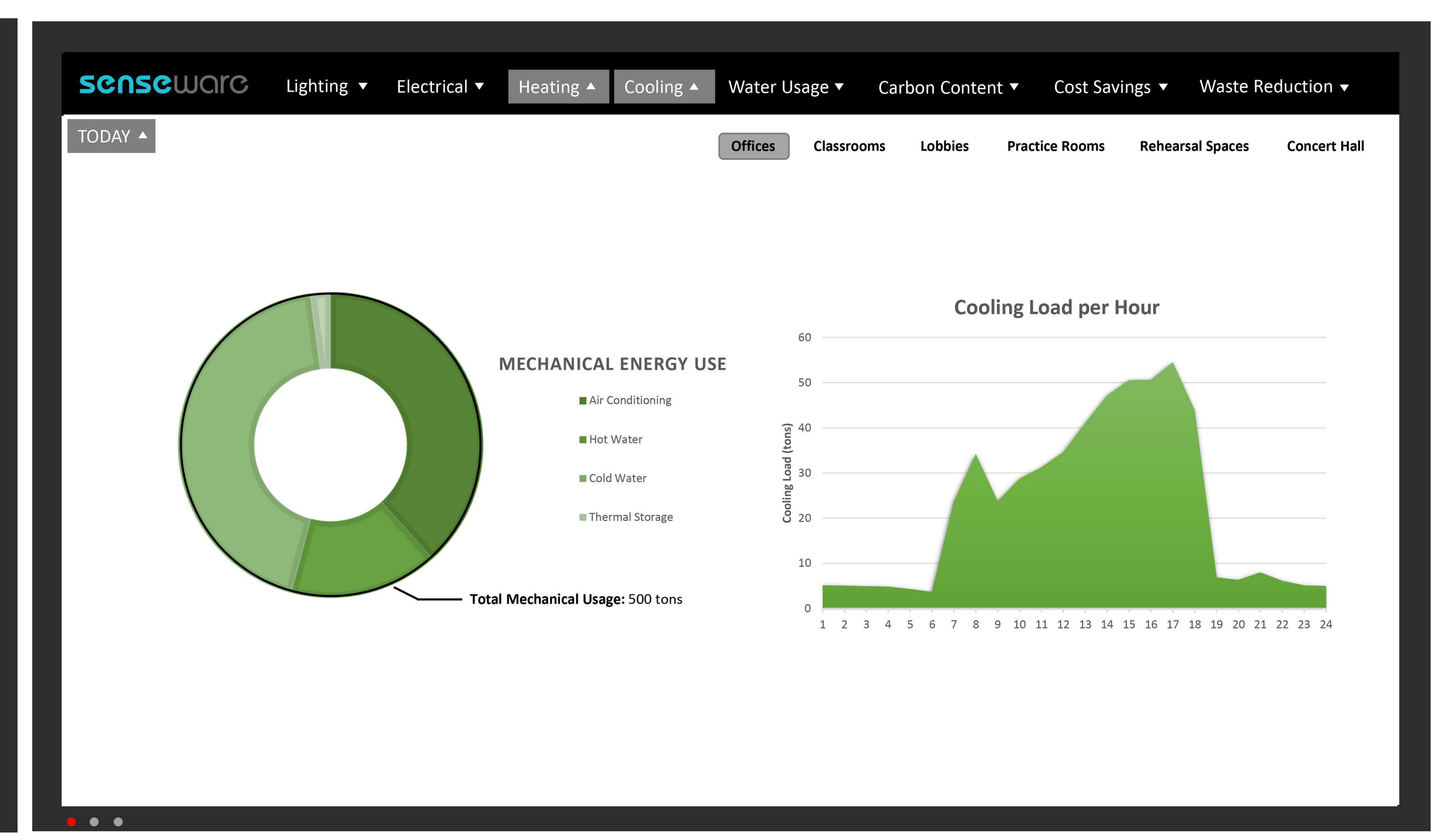
Syndicate, after considering aspects of the LEED and WELL plans and the efforts that Hope College is already making, has created a customized sustainability plan for Hope College. This plan allows Hope to pursue environmentally-minded goals without sacrificing their academic objectives. There are four main canons that encompass large sustainability aspects, and those four are broken down into several implementation categories (shown below). The objectives that were considered during the integration design in The Miller Center are highlighted below



DASHBOARD DISPLAY

Syndicate analyzed criteria across all disciplines to incorporate through-out design within the sustainability plan. This information will be provid-ed to the public and Hope College through a dashboard system located in the north and south lobbies that tracks dynamic building statistics along with static information. As seen in the dashboards, this infor-mation has been presented within a user friendly interface through sim-plified graphics





SYNDICATE

PROJECT

JACK H. MILLER CENTER FOR MUSICAL ARTS

HOLLAND, MICHIGAN

SHEET TITLE

SUSTAINABILITY PLAN

NOT FOR CONSTRUCTION	AEI TEAM NO. 01-2019
DATE February 18th, 2019	SCALE NOT TO SCALE
DRAWING NO. **I-10.0**	PAGE NO. 30

0.0 STRUCTURAL EXECUTIVE SUMMARY

GRAVITY SYSTEM

- CLT panel floor system supported by glulam girders and columns
- Superstructure composed of 86% engineered wood products by total structural volume
- Fire-resistance rating achieved through char design

LATERAL SYSTEM

- 8” & 12” precast concrete wall panel system serving as the main lateral force-resisting system
- Precast panels enclose acoustically sensitive spaces
- Building drift limited to H/400

ROOF SYSTEMS

- Long-span glulam beams in recital hall, rehearsal rooms and organ faculty studio
- Pre-fabricated steel truss in the main concert hall
- CLT panels used as structural roof decking

NORTH LOBBY

- Exposed, heavy-timber framing system creates a sustainability statement
- Integrated and high-performing curtain wall system
- Steel rods used to hang the balcony to minimize view interference

FOUNDATION

- Concrete spread footings under all columns
- Continuous strip footings under all precast wall panels
- 5” slab-on-grade throughout the building
- Special slab-on-grade system in the concert hall consisting of 4” slab, 2” *Regupol vibration 200* pad and 6” slab to mitigate vibration disturbance

ISOLATED STRUCTURE

- Vibration isolators under columns of the mechanical space to prevent vibration transmittance
- Separate structure housing the building system equipment to prevent noise transfer

Structural Table of Contents

1.0 PROJECT OVERVIEW

The Jack H. Miller Center for Musical Arts (The Miller Center) is a proposed building project for Hope College located in Holland, Michigan. Syndicate is an integrated design-build team that produced a high-quality design and construction plan for this project. The project site is situated in the northeast corner of campus across from downtown Holland, near Lake Michigan. The Miller Center acts as an investment for the future of Hope College and as a showcase pilot for a new sustainability plan on campus. The addition of an occupiable roof and south lobby allows this building to act as a gateway space for connecting Hope College campus to downtown Holland. The Miller Center can be seen in *Figure 1.*

***Figure 1**: Syndicate's Design*

Syndicate's final design is a three-story building designed for serving the educational and performance requirements of Hope College. Totaling 70,000 square feet (SF), The Miller Center includes an 800-seat symphonic concert hall, a smaller recital hall for intimate chamber performances, and two large rehearsal spaces for choirs and orchestras. The building also includes classrooms, faculty studios, and student practice rooms distributed throughout the three stories.

2.0 VISION STATEMENT

Through a multidisciplinary team strategy, *Syndicate* produced a high-quality center for musical arts that met the goals and mission of Hope College. As a team, *Syndicate* chose to pursue this project with a vision statement that would contain individualized team and discipline goals. The vision statement is HOPE and the goals are to:

Enhance **H**ope College Campus
Maximize **O**ccupant Experience
Create Premier **P**erformance Spaces
Minimize **E**nergy Impact

Refer to Integration SD-A for details about the vision statement.

3.0 PROJECT GOALS

To achieve HOPE, *Syndicate* created specific integration goals for these four vision statements. Below are the objectives for the structural team to meet the integrated team goals.

3.1 Enhance Hope College Campus

The structural team worked closely with other disciplines to produce a structure that is economical, efficient and accommodating of the other building systems within The Miller Center. Furthermore, *Syndicate* showcased and optimized the wood structure. To accomplish this, the structural team set out to:

- Minimize the cost of a wood structural system through mindful member placement, resulting in reduced member quantities.
- Target a SF cost that is within 15% of a comparable steel system.
- Optimize gravity members to be within 85%-95% of capacity with respect to their controlling limit state.
- Reduce erection schedules through prefabrication, construction engineering and integration of wood and precast concrete.
- Develop early integration efforts to establish each discipline's design intentions at the start of the project, allowing for a strategically laid out structure

3.2 Maximize Occupant Experience

The structural design team strategically exposed the building's structure in the double story north lobby and the occupiable roof space with the intent to:

- Create prominent spaces of interest and drama in areas that serve as a display for a unique system.

These spaces are framed by large, glued-laminated (glulam) timber members with cross-laminated timber (CLT) panels left exposed to create a wood-finish ceiling. The natural rhythm of the structure echoes throughout these spaces and strives to compliment the sensory experience of musical arts.

The team also recognized that limiting structural borne noise and building movement was significant. To address these concerns and further enhance occupant experience, the team set forth to:

- Achieve and surpass the minimum sound transmission class (STC) and impact insulation class (IIC) of 50 for the structural floor system.
- Mitigate floor vibrations by designing the gravity system to minimize perceived walking floor movement.
- Isolate mechanical equipment to prevent incidental vibrations from being transferred to occupiable areas.

3.3 Create Premier Performance Spaces

Superior acoustical performance was the primary metric that influenced all design decisions throughout the project, including structural. For each performance space, *Syndicate* aimed to:

- Design concert hall and recital hall wall assemblies that achieve a minimum STC value of 65.
- Structurally design the balcony for unobstructed views.
- Provide flexibility in the roofing system for flexible catwalk placements or future modifications.

To ensure that the building performs acoustically as intended, the structural and construction teams will work together to create details and construction procedures that exceed acoustical standards.

3.4 Minimize Energy Impact

Energy impacts resulting from the built environment are substantial. As such, endeavors to create a building that embodies sustainability was crucial. We set forth with the following goals in mind:

- Design a structural system composed of at least 25% engineered wood products by structural volume.
- Reduce the structure's embodied carbon content by 25% as compared to a traditional steel system.
- Source materials from a manufacturer that is conscious of sustainability.
- Limit the number of individual members through numerous layout iterations and optimize their efficiency to be within 15% of the controlling limit state.

4.0 BUILDING STRUCTURE OVERVIEW

To achieve these goals, the structural team of *Syndicate* conducted an iterative and multidisciplinary design process that produced a superior final design. The team's final design is shown in *Figure 2*.

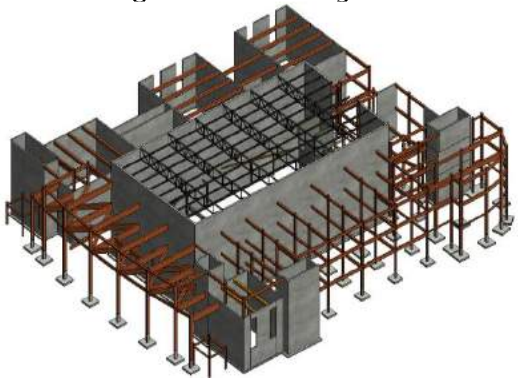


Figure 2*: Structural System for The Miller Center*

Syndicate surpassed its original goal of incorporating engineered wood products into 25% of the structure's volume by delivering 86%. The primary products used to achieve this 86% are CLT panels as the floor system, along with glulam members serving as the beams and columns. A precast concrete wall panel system was designed to serve as the main lateral force resisting system that is also load bearing to assist with gravity loads. These walls surround the concert hall, recital hall, two rehearsal spaces, organ faulty studio, elevator shaft, and stairwells and act conjunctionally as acoustical barriers to reduce sound transmission into or out of the various performance spaces. The foundation system consists of cast-in-place reinforced concrete spread footings and continuous strip footings under columns and walls, respectively. These foundations are able to effectively distribute the building loads on the soil while also remaining above the water table. This reduced the cost and simplified the construction processes.

5.0 DESIGN AND ANALYSIS SOFTWARE

No single program could analyze every system. The team utilized multiple programs to aid in efficiently designing the gravity, lateral and foundation systems. These programs include *ETABS*, *SAP2000*, *Woodworks Sizer*, *RAM*, *RISA*, and *Microsoft Excel*. See Structural SD-A for a flowchart explaining how the structural team designed and verified our systems with these technologies.

6.0 CODES AND STANDARDS

The structural design of The Miller Center was completed in accordance with the 2015 Michigan Building Code, which adopts the 2015 International Building Code (IBC 2015) with amendments. The following publications were most notably referenced as well throughout the duration of the project.

- ASCE 7-16
- 2018 NDS, Supplement and SDPWS
- *CLT Handbook*

A more extensive list of the publications utilized during the project can be found in in Structural SD-A.

7.0 CONSTRUCTION TYPE

As a collective, an interdisciplinary collaboration was established to put sustainability forward in the overall design of The Miller Center, including structural. The given design was classified as Type IIA Construction, which does not allow for combustible structural, this limits utilizing the highly renewable structure material, wood. To forward focus on a wood structure, *Syndicate* studied three construction types to maximize their opportunity for wood implementation (*Figure 3).*

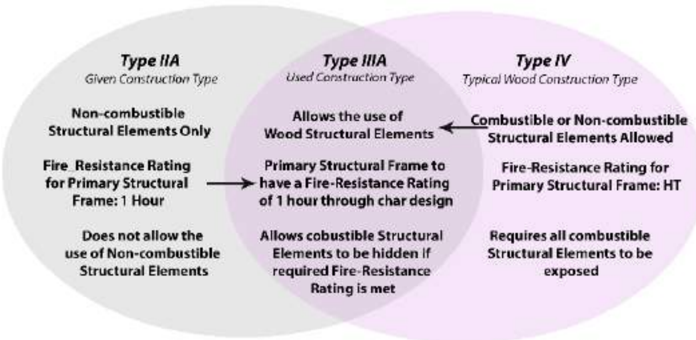


***Figure 3**: Construction Type Comparison*

7.1 Limitations of Type IV Construction

Syndicate initially planned to design The Miller Center according to Type IV Construction requirements. While a Type IV classification does allow the use of heavy timber elements in structures, it requires that they be left exposed for fire safety concerns. As a result, the team was not able to conceal unsightly mechanical, electrical, and plumbing equipment with closed ceiling plenums. This inability to conceal equipment took away from the team's architectural vision to align with the rest of Hope College. In addition to the concerns over appearance, the exposed equipment would have diminished the acoustical performance of the spaces as well.

7.2 Type IIIA Construction

To achieve our desired vision for The Miller Center, *Syndicate* researched further into construction type requirements and found that Type IIIA does allow for the concealment of combustible structural systems.

To attain a Type IIIA classification, several criteria had to be met for this change to be permissible. The two primary areas of concern were the building size and the fire-resistance requirements. The 2015 IBC Table 506.2 sets a basic maximum allowable square footage of 14,000 SF per floor in Type IIIA Construction. After applying the appropriate factors for frontage increase and sprinklers, the allowable enclosed area rose to 52,500 SF per floor or 157,500 SF total. The Miller Center, which totals 70,000 SF after the team's architectural changes, is within these limits. Table 504.4 also established a maximum of 4 stories for sprinklered buildings and The Miller Center meets that mandate. A one-hour fire-resistance rating is required on all primary structural elements and on all floor and roof assemblies (2015 IBC Table 601). After consulting with several industry professionals and a building code official, the consensus was that all of the criteria could be achieved to reclassify the building as a Type IIIA Construction. It was also determined that the fire-resistance rating could be achieved through member charring (discussed in Section 7.3 below).

By reclassifying the building, *Syndicate* was able to better achieve the team's aesthetic goals for The Miller Center. This also resulted in more design flexibility, allowing for better mechanical, electrical and acoustical integration to optimize each space.

7.3 Fire Protection Design

Syndicate found that the best way to achieve the proper fire-resistance rating for the structure that promoted visual aesthetics was through char design. Char during a fire protects the member the more it burns, thus the wood protects itself as the fire progresses. The column and beam members followed the prescribed steps presented in the *2018 NDS*.

For CLT char design, two credible design procedures were found. The first method is also outlined in the 2018 NDS while the second can be found in the *CLT Handbook* by FPInnovations.

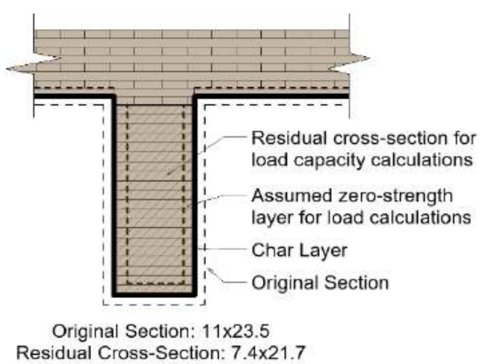


Figure 4*: Theory of char design*

To present a conservative structural design for The Miller Center, both methods were used for the CLT analysis, with the more stringent condition of the two ultimately being selected. The schematic shown in *Figure 4* displays the theory behind designing a beam for char. The same basic concept is similarly applied to all other wood structural elements in The Miller Center.

To achieve the mandated IBC 1-hour char fire-rating for glulam beams, an effective area of 1.8" deep on all exposed sides is not considered to contribute to capacity. For example, *Figure 4* shows a beam exposed on three sides. This would reduce an 11"x23.5" member to an effective cross section of 7.4"x21.7". Due to their initial size, the controlling limit state for many of the longer span CLT and glulam beams are vibration and deflection, respectively, instead of char design. However, when smaller initial cross-sections are considered, like for many of the columns, it often becomes the controlling limit state. Due to the highly specialized nature of these construction materials, the structure was designed to exceed basic code-level requirements. Given that this design strategy was only recently adopted, *Syndicate's* approach may require special approval from the governing code official and/or certification from our Engineer of Record (EOR).

8.0 GRAVITY SYSTEM DESIGN

Numerous materials and systems were investigated and refined to arrive at the final design of heavy timber glulam framing with CLT for the gravity system. The engineered wood products are sourced from Nordic Structures. This manufacturer was chosen due to their sustainability efforts. Nordic is environmentally-focused and has a strict forest management system to ensure that all tress that are used for their structures are immediately replaced. See <u>Structural Drawing S-10.0</u> for more details.

The CLT chosen has a stress grade of E1 with a 267-9I layup combination that has a thickness of 10.5". The CLT panels were carefully designed to limit vibrations, as discussed later in <u>Structural Section 8.4.1</u>, "Vibration Analysis". The glulam members have a stress grade of 24F-ES/NPG. Additionally, the precast wall panel system is utilized for load bearing throughout the structure.

Steel Beams with Concrete on Metal Deck		
Benefits	**Trade Offs**	**Goals Met**
- Concrete slab is non-flammable and acts as fire barrier between levels at certain thickness - Fast erection time with steel - Concrete acts as sound insulator	- Cast in place concrete slabs have long durations and are labor intensive - Steel has highest construction noise - Greatest possibility for structural borne noise and noise transfer - Concrete slabs require infill beams every 8-12 feet - Steel members require seperate fireproofing	- Create Premier Performance Spaces
Glulam Beams with Concrete on Metal Deck		
Benefits	**Trade Offs**	**Goals**
- Concrete slab is non-flammable and acts as fire barrier between levels at certain thickness - Glulam char acts as fire protection on members - Glulam can be left exposed for aesthetics - Concrete acts as sound insulator	- Cast in place concrete slabs have long durations and are labor intensive -Heavy slabs will result require considerably larger members than steel solutions	- Maximize Occupant Experience - Minimize Energy Impact - Create Premier Performance Spaces
Glulam Beams with Cross Laminated Timber Floor		
Benefits	**Trade Offs**	**Goals**
- Lightest structure - High strength per unit area - 20% less carbon dioxide emissions compared to steel - Abundent prefabrication opportunities - fastest erection schedule - Infill beams not required with CLT panels - Timber can be left exposed for aesthetics	-Most expensive structural system -Larger member sizes as compared to steel -Most expensive unit	- Minimize Energy Impact - Maximize Occupant Experience - Enhance Hope College Campus - Create Premier Performance Spaces

Table 1: Typical Bay Analysis

8.1 Gravity Loading

Gravity loads were determined in accordance with IBC 2015, and ASCE 7-16. Typical dead loads and live loads are shown on Structural SD-B and Structural Drawing S-2.0 respectively.

At the roof levels, snow loads controlled. The flat roof load was 35 psf with areas subject to drift had additional loads varying between 17 psf and 95 psf. See Structural SD-B for a sample drift calculation. The structure was designed to withstand the full snow loads of the region even though a snow melt system was incorporated into the roof assembly. This was done to provide added redundancy in the event it goes offline. Refer to the Mechanical Section 10.2 for more details regarding the snow melt system.

8.2 Design Progression

During the early stages of design, *Syndicate's* structural team researched a wide variety of gravity systems. The system analysis table on Structural Drawing S-1.0 gives a complete list of all the systems considered and was used to weigh the pros and cons of each option.

During preliminary system selection, the team aimed to establish relatively square bays typically ranging between 20'-0" and 30'-0" for architectural and MEP system coordination.

A typical bay for three systems (composite steel beams with concrete on metal deck, glulam beams with concrete on metal deck and glulam beams with a CLT floor) was designed for a more in-depth evaluation (*Table 1*). The information was analyzed with the decision matrix, found in Structural SD-A, to compare all three systems using criteria such as embodied carbon content, cost, MEP coordination and acoustical performance.

After a thorough review of the itemized table, the structural team determined that glulam beams with CLT floor was the best system for *Syndicate's* vision and sustainability goals. Early identified drawbacks of this system were:

- An increased cost of 14% compared to the glulam beams with concrete on metal deck.
- Bays with glulam beams have an approximately 172% increase in system depth compared to steel beams

However, our decision to choose the glulam beam and CLT system was driven by:

- A cost within 1% of the system of steel beams with concrete on metal deck
- Achieving the building program goal of a sustainable system and reduced overall carbon content
- Decreasing the schedule
- Easier framing connections
- Limiting the number of individual members. Due to the spanning capacity of CLT panels, no infill beams are required, which takes the beam count down from 7 to 2 per bay.

Within the many early framing layout iterations, a column was added near midway along one of the longest beam spans. This addressed the drastic increase in beam depth between the wood and steel systems. The now improved design created an extra 21.5" of uninterrupted ceiling space to coordinate with the MEP system. This negative component determined through the typical bay analysis no longer existed allowing for smooth integration between the systems. This can be seen below in the cross section shown in *Figure 5*.

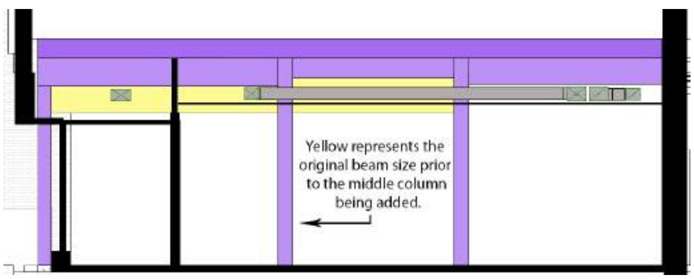


Figure 5: Structural Depth Optimization

The time spent on early iterations also allowed us to refine our lay-out design, which continually resulted in reduced member quantities, and therefore, reduced cost. Once the architectural changes were complete, the current framing plans shown on Structural Drawing S-3.0 were finalized, which optimized efficiency and serviceability requirements under the given architectural and structural constraints.

8.3 Beam and Column Design

The final design of the gravity system resulted in glulam beams typically ranging from 7.25"x23.5" to 11"x54.5" in size. The wood framing elements were sized using NDS's procedures for the ASD design. Beams were appropriately sized to meet the criteria for strength, serviceability and char. For deflection allowances, live load deflections were limited to L/360 and total load deflections to L/240. The only exception to these criteria were at exterior beams, where the total load deflection was limited to L/600 to uphold the brick veneer. *Syndicate's* efficiency target of being within 15% of the controlling limit state was achieved for each individual member.

Typical columns were selected as square or near-square sections to optimize their biaxial performance. As a result, the typical columns ranged between 11"x11" and 11"x12.5". With constructability concerns over placing the large CLT panels, columns are spliced at every level to minimize crane obstructions. To simplify construction and connection detailing, columns have the same cross section from the ground to the roof.

8.4 Cross-Laminated Timber (CLT) Design

A CLT floor system was chosen to minimize energy impact and promote sustainability. The CLT panels were designed as one-way slabs spanning between simple end supports. The panels are arranged with a typical width of 8'-6", which can be easily altered in the fabrication shop for geometric constraints. The team evaluated several limit states when designing the system, including flexural strength, shear strength, deflection, char and vibrational effects.

To address *Syndicate's* goal of maximizing occupant experience, the floor assembly was specifically designed to exceed ASTM E90 and ASTM E492 standards, which specify a minimum STC and IIC rating of 50. Because music will be played throughout the building, a higher focus was placed on attaining the proper STC rating, which helps to prevent sound transmission between rooms. The final assembly, seen on Structural Drawing S-8.0, has an STC value of 60 and an IIC rating of 54, both of which do exceed the ASTM standards.

8.4.1 Vibration Analysis

To achieve *Syndicate's* goal of maximizing the occupant experience, special attention was taken with the gravity system to limit the amount of structural borne noise and occupant discomfort caused by excessive vibrations. The structural team followed the design procedures presented in the *CLT Handbook* by FPInnovations since neither the AITC or NDS publish design guides for vibrations.

Transient vibration responses are the preferred of the two forms because they disappear quickly while resonance responses can become amplified and last for some time. Achieving the transient response behavior was largely dependent on a proper mass and stiffness proportion in the system, which are represented as EI_{eff} and GA_{eff} respectively. The team was ultimately able to use the handbook's procedures to find a span and section combination that performed within the acceptable vibration limits. The selected CLT floor system has a limiting span of 25'-6" to not be vibration controlled. This condition ensures that we achieved our goal of maximizing occupant experience by mitigating floor vibrations as our largest span is 25'-3".

8.5 Gravity Summary

By implementing an all-wood gravity system, the carbon content of the structure was reduced by 27% as compared to the team's baseline steel system (*Figure 6*). Additionally, *Syndicate's* design obtained 86% engineered wood products by structural volume (*Figure 7*), which surpassed our goal of 25%.

This gravity system does have an increased cost of roughly $3 per SF when compared to a more traditional steel system. This small difference was possible because the CLT floor panels only require support on two opposite sides, which significantly reduced the quantity of beam members in the building. In all, the total cost of the building's gravity superstructure was estimated at $21 per SF, which is only slightly higher than the $19 per SF that a similar steel system would have cost. These numbers come from material and labor costs. This hit the team's goal of remaining within a 15% difference.

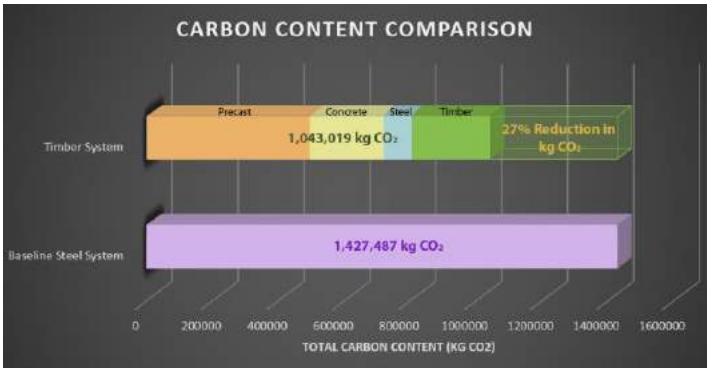


Figure 6: *Carbon Content Comparison*

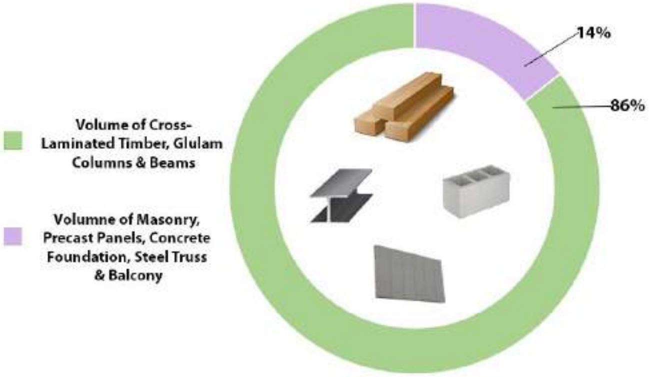


Figure 7: *Percent wood by Volume*

9.0 LATERAL SYSTEM DESIGN

The structural design team chose a loadbearing, precast concrete panel shear wall as the lateral system. To mitigate vibrations from the mechanical rooms to the concert hall, the building is split into two separate structures (each with its own lateral system). This separation is created from an expansion joint along the CLT panels and slab on grade with the wall segments via double column lines. *Syndicate* designed the precast panels to act as a versatile wall that meets flexural strength and building drift, while maximizing acoustical properties of the wall assembly.

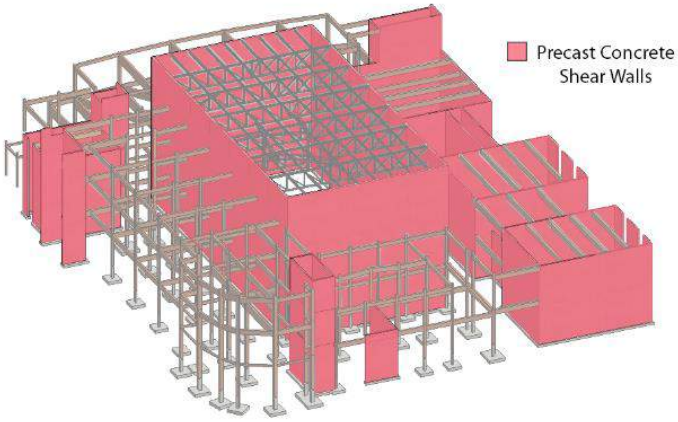


Figure 8: *Lateral System*

9.1 Lateral Loading

Syndicate performed initial wind and seismic loading calculations based on ASCE 7-16 to determine the controlling loads. Wind loading was calculated in accordance with MWFRS, and seismic loading was calculated according to ELFP for SDC B. Refer to Structural Drawing S-2.0 for loading summaries. Wind loading governed the lateral system's design, although seismic drift was verified. *Etabs* models were analyzed for in- and out-of-plane strength, mandated by ACI 318-14. *Syndicate* designed the reinforced concrete precast panels according to ACI 318-14 for flexural strength, shear capacity, and a building drift of H/400 for brick cladding and non-structural components.

9.2 Design Progression

When considering all options for the lateral system, acoustical sound transmittance became an integrated driving factor for the decision to use concrete shear walls for the lateral system. Due to concrete's mass, it has a significantly higher acoustical STC level when compared to steel or wood. The team decided early on that due to the desired 16-month construction schedule, a faster installation system would be optimal for the lateral system, which meant that masonry and cast-in-place concrete were deemed as non-optimal. The team analyzed further system drawbacks and benefits as shown below (*Table 2*).

Lateral System Comparison		
System	Benefit	Drawback
CLT	• Sustainable material • Quick installation • Wood contractors already on site	• Expensive • Sourcing • Connection between panels • Connections to members framing in
Cast in Place Concrete	• Mass acts as great sound insulator • Local Sourcing	• Slow installation • Connections to members framing in
Precast Concrete	• Mass acts as sound insulator • Quick installation • Local sourcing • Connections prefabricated	• Expensive to prefabricate

Table 2: *Lateral System Comparison*

9.3 Final Lateral Design

Syndicate's construction and structural teams collaborated heavily in the design of the panels. The team considered two options for the height of the panels. Due to the precast manufacturer being located 20 miles away with limited turns along the route, the team decided that designing the panels for the main concert hall to be 64' tall would be more efficient than mid-height connections.

The large concert hall was a main concern for undesired sound transmitting into or out of the space. To accommodate this concern, shear walls were designed to have a thickness of 12". To achieve an STC of 65, *Syndicate* chose a built-up wall assembly, shown in Structural Drawing S-8.0. Furthermore, special attention was provided to the joints in the panels to maximize construction as well as acoustic isolation, discussed in Structural Drawing S-9.0. Due to the uneven loading on either side of the walls for the central concert hall, the walls were further analyzed for out-of-plane loading. The northern shear wall was found to have the highest load irregularity coming from two balconies along with the north lobby and occupiable roof structures (*Figure 9*). To analyze this out-of-plane loading, *Syndicate* utilized *SPWall* to create an interaction diagram for the wall section. End reactions and moments were then calculated. The results were then plotted in the interaction diagram to verify that the section was within capacity (Structural SD-E). For the erection sequence of the precast panels, refer to Construction Drawing C-1.0.

The east and south facades also became important components to mitigate sound transmittance and were designed as 8" thick precast panel shear walls. *Syndicate* also designed the stairwells and elevator shafts as concrete precast panels to increase sound insulation from outside sources into the performance center. The precast shear wall panels sizes are designed to be between 6' and 11' in width and between 32' and 64' in height for the main building with thicknesses varying from 8" to 12".

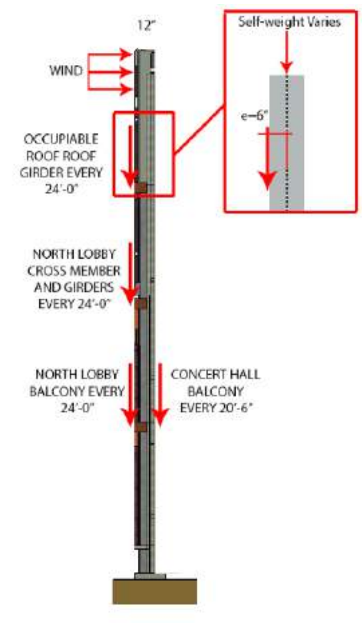
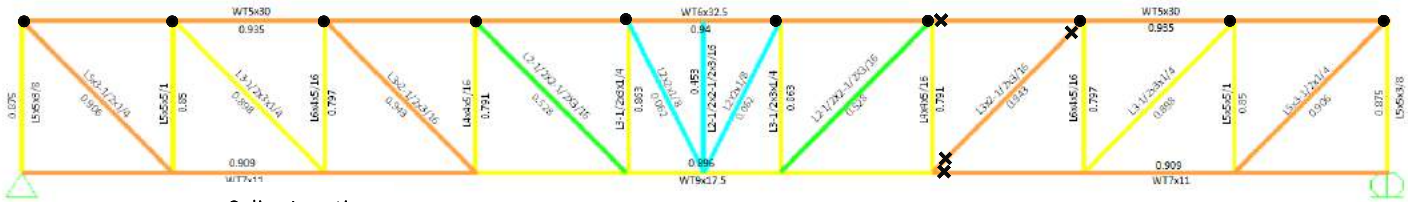


Figure 9: *Out-of-plane Wall Loading*

During analysis it became important to limit drift in the isolated area of the building to avoid unwanted collision with the rest of the building. These shear walls were placed strategically within interior wall partitions or along an exterior façade. The panels in the isolated



× = Splice Location
● = Bracing Point

***Figure 10**: Steel Truss Demand/Capacity Ratio*

structure are two-stories tall and vary between 11’ and 13’ in width with a thickness of 8”.

9.4 Lateral System Summary

The design thickness was governed by ACI and acoustical performance requirements with coordinated constructability input. These panels are prefabricated in shop to include embed plates for the connection of glulam beams spanning into the walls. The design of the lateral system assisted in meeting *Syndicate’s* goals by reducing sound transmittance to create premier performance spaces. The shear walls also promote versatility because they act as thermal and acoustical barriers in exterior locations.

10.0 ROOF DESIGNS

CLT panels were used as the primary roof decking. The heavy snow loads, combined with long spans between supporting beams, made this option the most viable and it was more economical to carry the same system throughout the entire building.

10.1 Performance Spaces Roofs

In order to span 72’-0” for the concert hall roof, *Syndicate* developed a custom steel truss design to accommodate special loading, such as the catwalk and lighting equipment (*Figure 10*). The rehearsal and recital spaces required a shorter span, the longest being 41’-3”, which allowed the structural team to continue to use glulam beams for the roofing systems there.

10.1.1 Design Progression

The structural team considered several different options that could be used in the main concert space, such as long-span glulam beams, long-span wooden trusses, and steel joists (Structural Drawing S-1.0). Due to complexities with hanging the catwalk, steel joists were not pursued in the design iterations. *Syndicate’s* structural team first designed multiple iterations of wooden trusses, as well as glulam beams to span these distances. However, both systems were eventually ruled out due to fabrication issues and the inability to ship full-length members without significant shipping costs. Shipping the members in pieces was ruled out due to complex field splices in wood.

After ruling out all three previous ideas, a new design had to be developed. A custom steel truss would be easier to fabricate, could be transported in halves and spliced on site, was accommodating of the unique catwalk loading and required the least number of individual trusses. All connections are welded in the shop except for the splices, which are bolted on site. The catwalk may be placed in any combination that allows one branch per truss.

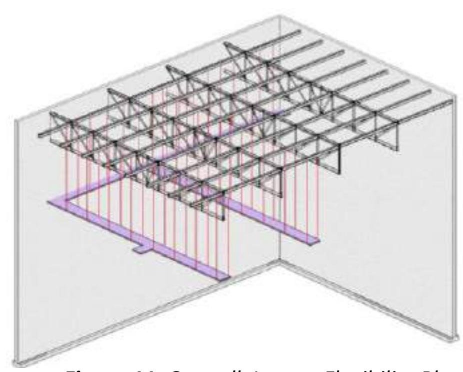


***Figure 11**: Catwalk Layout Flexibility Plan*

10.1.2 Final Design

The final trusses are 8’-0” deep with nine 8’-0” panels and are spaced at 20’-0” o.c.. The panel points also align with the connection intervals of the hanging catwalk (*Figure 11*). Additionally, the top cord of the truss is braced by steel purlins at the same interval, allowing for further flexibility in the catwalk placement. Finally, 4-1/8” thick CLT panels make up the roof deck.

The rehearsal and recital spaces utilize glulam beams spaced in 10' intervals with a CLT deck that has a stress grade E1 and a 105-3s layup combination. Due to the shorter span, shipping was not an issue and mid-span moment connections are not required. The deepest roof beam in either area is 29".

The team had to compromise on using a sustainable material in favor of a recyclable material in the concert hall in order to accommodate the budget and design requirements. However, glulam beams were still a viable option for the smaller recital and rehearsal spaces.

10.2 Occupiable Roof

Syndicate considered four occupiable roof designs. These iterations are described and can be seen in Structural Drawing S-5.0.

The third and fourth iterations developed simultaneously in response to concerns regarding the beam depth in the second design to evaluate if a shallower beam depth was preferred. After consultations with an industry professional, *Syndicate* saw the beams in the second iteration as a way to break up the space, add dimension and showcase sustainability. Ultimately, the team decided that the second iteration was the best for the vision of The Miller Center.

11.0 NORTH LOBBY DESIGN

A key feature of The Miller Center is its grand north lobby. *Syndicate* immediately identified the north lobby as a space that could leave a lasting impact on visitors of The Miller Center. To promote sustainability and minimize energy impact, *Syndicate* created a structural system for the lobby that showcases the wood structure. This area was heavily coordinated with mechanical, construction and lighting/electrical to achieve our vision of HOPE.

11.1 Design Progression

The best way to maximize the occupant experience was by exposing the structure to make not only an architectural statement, but also a sustainability statement. Four iterations were performed, discussed in *Table 4*, to determine the best way to achieve the desired atmosphere.

North Lobby Design		
Iteration	Description	Conclusion
1	• 24' x 35' rectangular bay • girders spanning 35' • CLT running one-way in the 24' direction	• Girders resist a large moment of 750 k-ft • More efficient & impactful layout
2	• Design of two cross beams within existing bays • Queen stud designed at center of cross with cables spanning back to supports	• Reduced depth of main girders • Created depth and rhythm in the space • Constructability issues and high cost • Cables did not reduce beam depth significantly
3	• Two cross beams within existing bays • Column supported balcony	• The structure is efficient • Broken line of view and separation from columns
4	• Two cross beams within existing bays • Balcony is hung from by rods from the main girders above	• Main girder increased by 37% • Unobstructed space on the ground level • Iteration that is best suited for *Syndicate's* vision

Table 3: *North Lobby Design Iterations*

Due to the complexity of the tributary area in the iterations, *RISA* was implemented. Four bays were modeled to determine the maximum forces that occur at any point in the system, since the glulam properties were not in the database. After verifying the forces from the model, they were compared to the allowable capacities calculated using *Excel*. To determine the increase of member sizes due to hanging the balcony, hand calculations were performed to determine the max moment and shear. These forces were superimposed with the model forces and compared, once again, to the allowable capacities calculated using *Excel*.

11.2 Final Design

The final design of the North Lobby utilizes the same glulam species and grades as the rest of building for consistency. The same design methodology and limiting criteria were also used to select proper beam and column members within the spaces. This resulted in the main glulam roof girders being 11”x54.5” while the intermediate crossing members are 11”x39.75”. Member sizes were governed by either deflection or flexure. While deep, the sizes allow for a robust statement to be made about the prominence of sustainability throughout the structure. It further allows for depth and dimension throughout the ceiling.

All roof members are attached directly to the concert hall walls on the south end and attach to 11”x23.5” columns about the strong axis. Rectangular column cross-sections are used because lateral bracing is only present in the weak-axis direction from the supporting structure of the curtain wall. These columns also serve as the main attachment point for the full-height curtain wall enclosure (discussed later in Structural Section 13.0). The CLT floor spanning the girders is continued into this space to span the 24’-0” which carry the load of the occupiable roof above the lobby. The underside of the panels is left exposed to reveal the wood-finish that matches the framing members. As for the balcony, 1” diameter F1554 Grade 55 steel tension rods were used to suspend the structure from the roof members, see Structural Drawing S-5.0. This created a floating appearance that kept the lobby’s open feel.

The north lobby required coordination between the structural, mechanical and lighting/electrical teams. The structure remained exposed on the second level with a duct place against the concert hall wall. Wall grazers were placed on the beams to highlight the structure and the space below. See *Figure 12* for more details.

11.3 Summary

The structural design of the north lobby achieved our initial goal of maximizing the occupant experience by creating a structural rhythm within the room, while also providing added interest to the building’s most prominent gathering space. The attention of viewers is immediately drawn to the monumental wood

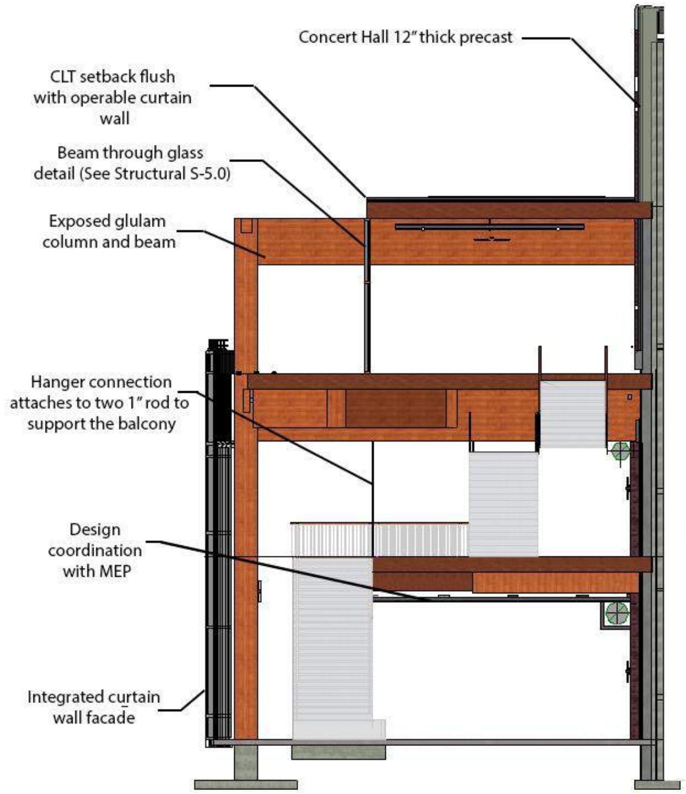


Figure 12: *Lobby Coordination Section*

members, showcasing our unique design and making Hope College’s sustainability efforts very clear.

12.0 FOUNDATION SYSTEM DESIGN

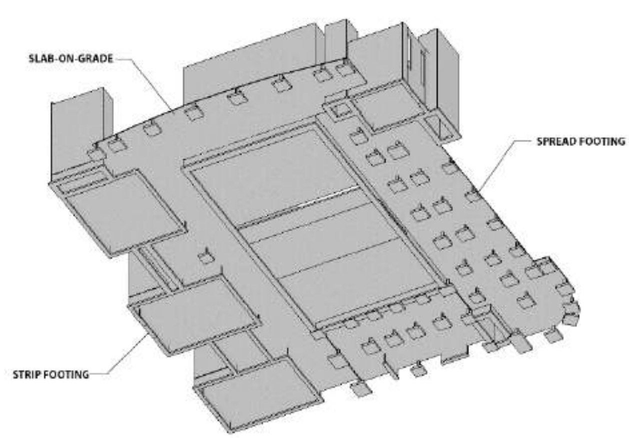


Figure 13: *Structural Foundation*

The soil profile is topsoil, brown to dark brown sand with trace silt, and very loose to loose, light brown, fine to medium sand. Groundwater was encountered from 8.8’-12.3’ below grade with a frost line at 42”. Following the suggestions of the geotechnical report, the structural design team pursued spread and strip footings for the foundation system below The Miller Center. Vibro-compaction must be applied to the native sand to improve the allowable bearing capacity.

After compaction, *Syndicate* utilized the soil bearing capacity of 4,500 psf by picking a shallow foundation that allows for higher cost savings and simpler construction procedures.

Syndicate utilized a slab-on-grade system to shape the concert hall floor. Following the geotechnical report's recommendation, the final slab assembly consists of a 6" slab, 2" Regupol vibration 200 mat and then another 4" slab on top. The high mass of the assembly, along with the isolation pad, will help reduce the vibrations of the nearby train from entering the space. For the remainder of the building, a typical 5" slab was deemed acceptable.

The spread footing plan dimensions ranged from 6'-0"x8'-0" to 9'-0"x7'-6" and thickness varied between 16" to 20". Column loads on the footings range from 184 to 324 kips. For all foundation elements, a concrete grade of 4,000 psi was used. For further information on the spread and strip footings refer to Structural Drawing S-4.0. A short concrete pier, matching the dimensions of the columns above, was placed on the footing up to the top-of-slab to prevent the wooden columns from being in contact with the ground. The connection places a steel base plate between the wood column and concrete pier to prevent the wood from absorbing any moisture.

The foundations between the isolated mechanical space and the rest of a building were shared. Much of the vibrations from the mechanical equipment were reduced through springs and concrete inertia pads under the equipment. To further diminish the vibrations before it reaches the footing, an isolation pad was placed between the wood column and the concrete pier. With these provisions, the benefit of placing two separate footings did not outweigh the extra costs. To prevent the transfer of vibrations in the superstructure an isolation joint was implemented between the two structures.

Special foundation coordination was implemented with the mechanical team to avoid clashing between the structural footings and the underground blue ducts. The ducts had to enter the main spaces, such as the concert hall, recital, choral and orchestral rooms. These spaces are enclosed by the precast shear walls that extend below grade to a strip footing. To allow the blue ducts through, openings are preformed slightly larger than the duct passing through. Furthermore, the footings are moved down an extra 2'-6" to ensure they are below the plane of the largest duct, which is 48" in diameter. This was only performed at locations where the blue ducts interacted with footing which can be seen in *Figure 14*.

12.1 Summary

Syndicate's structural team applied the information and recommendations provided in the geotechnical report. The foundation system accommodated the blue ducts passing below grade while also reducing the train vibrations. The spread and strip footings withstand the loads from The Miller Center in a cost-efficient system.

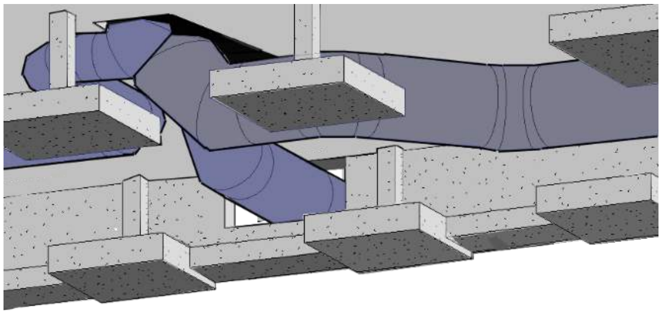


Figure 14: *Foundation and Blue Duct Coordination*

13.0 BUILDING ENCLOSURE DESIGN

13.1 Sustainable Curtain Wall

The north lobby curtain wall was a multidisciplinary design effort involving the entire team. After finalizing the architectural changes of The Miller Center, the structural team determined wall loadings based on ASCE 7-16 components and cladding (C&C) procedures. A schematic showing the different building zones and respective pressures can be found on Structural Drawing S-6.0. The north lobby was specifically designed to withstand a pressure of 25 psf.

In coordination with architecture and lighting/electrical, the structural team began preliminary sizing calculations for the glazing panels under geometric constraints. The final glazing design is composed of insulated glass units (IGU's) with the following layers: ¼" monolithic glass, ½" argon space and 3/8" monolithic glass. All glass is fully tempered for safety reasons.

Due to the relatively low wind pressure, the design was an iterative process largely governed by achieving the proper combination of U-value and VLT percentage. To ensure that our glazing configuration was of sufficient strength, ASTM E-1300 was used to verify that the system's load capacity was adequate. While the 3/8" lite is not required for structural purposes, it does improve the curtain wall's acoustical performance because IGU's with panes of dissimilar thickness absorb a greater range of sound frequencies. The STC of this glazing assembly is 39.

As an architectural preference, *Syndicate* opted to select a uniform mullion size for the entire wall. The window mullions are a traditional stick-built system produced by Kawneer for low-rise building applications. Manufacturer product data provided tables to size mullions based on applied loads, span length and spacing. The resulting design is a 5.75"x2.5" mullion to resist the worst-case C&C loading. A separate FEM model was also built in *SAP2000* to verify that all strength and deflection criteria of L/175 were successfully met. Schematics and calculations relevant to the curtain wall design can be seen on Structural Drawing S-6.0.

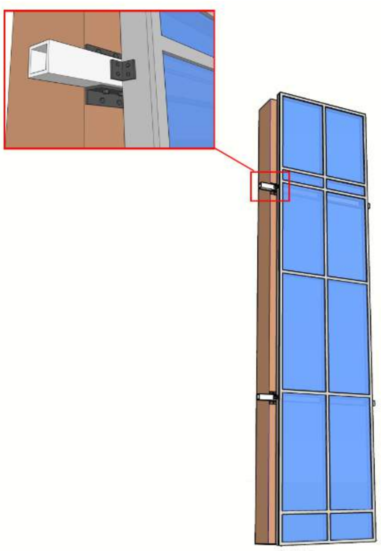


Figure 15: *Curtain Wall Assembly Detail*

13.2 Curtain Wall Connection

To support the curtain wall, horizontal HSS 4 ½x4 ½x½ tube sections span between the exterior columns along two horizontal mullion lines (14'-10 ½" spacing vertical). Connections are provided at every vertical mullion along the HSS that were sized for curtain wall self-weight and wind loads. Slotted bolted connections accommodate for both construction tolerances and building drift. HSS blind bolts are used for constructability. The connection between the tube and mullions is shown in *Figure 15* while a detailed model of the curtain wall can be seen on Structural Drawings S-6.0.

14.0 SPECIALTY DESIGN

14.1 Concert Hall Balcony Design

The balcony of the main concert hall presented a unique challenge for the structural team because of the large cantilever. Initially entirely wood solutions were explored but member sizes became too large to fit in the balcony cross section as there are large mechanical ducts, explained in Mechanical Section 8.2.1, running through the balcony, further limiting allowable depth.

Under these constraints, a steel solution was the most practical. The final design is composed of a series of four steel raker beams. The two outside members are supported by the precast walls on one end and steel columns on the other. For the interior raker beams, they are connected to the walls but are propped by columns 10'-0" inward of the wall. This reduced the cantilever length from 24'-0" to a manageable 14'-0". All the raker beams are W21x111 shapes, which fit within the geometric constraints. Like the rest of the building, CLT floor panels serve as the structural floor system of the balcony. The balcony structure can be seen on Structural Drawing S-7.0.

14.2 Isolated Mechanical Structure

With the mechanical equipment room located along the stage side of the concert hall and near faculty offices, there was a team concern over accidental vibration transmittance into these spaces through the structure. To reduce the source vibrations, the pumps were placed on spring mounted concrete inertia pads and the chillers and air handling units are on springs. Furthermore, due to the sensitive nature of the adjacent spaces, *Syndicate* decided to isolate this section of the building that houses the mechanical equipment via double column lines and expansion joints. These joints are carefully detailed to dissipate any incidental vibrational energy. See Structural Drawing S-8.0 for more information.

14.3 Heavy-Timber Connections

The structural team designed two of the typical wood connections in the project. The first of which was the beam-to-wall connection. *Syndicate* initially pursued dowel-type connections here, but after considering the large member sizes and end reactions, found that a bearing-type connection was optimal. A seated, saddle-like configuration made from built up ½" A36 steel plates are used to set the beams while two ¾" through-bolts restrain movement. This "saddle" assembly would be welded to embed plates in the precast panels prior to setting the beam. Isolation pads line the saddle to add acoustic isolation from the concert hall.

For the standard beam-to-column shear connection, a similar methodology was used. The same saddle configuration is present at each column face supporting a beam but they are joined to a steel plate bearing directly on top of the column section. This top plate is then used as the surface to build the column splice on. This provides a single built-up section that serves as both a beam connection and column splice. These prefabricated elements can be attached to columns on the ground prior to erection, allowing for a simpler and thus faster structural erection.

Alternative knife-plate configurations were developed as well using the same principals, giving the supplier multiple options to best fit their fabrication preferences as well as architectural ability to hide the saddles. The saddle beam-column connection can be seen below in *Figure 16,* while the knife plate types can be seen on Structural Drawing S-3.0.

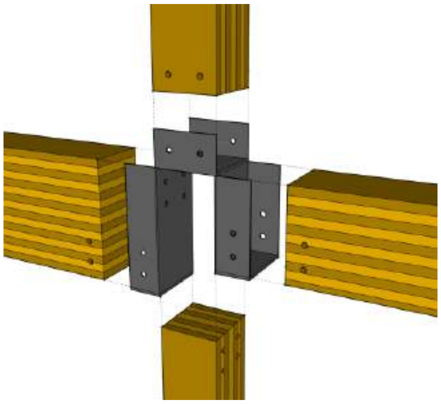


Figure 16: *Beam-Column Connection*

15.0 LESSONS LEARNED

Through the design process, the structural team learned to coordinate and adapt to the ever-changing design. Out of the box thinking had to be employed in order to accommodate the specific needs of The Miller Center, such as maximizing acoustical performance, developing an eye-catching structure, creating sustainability and versatility. The team developed throughout the process to maximize the collaboration effort and efficiency.

16.0 CONCLUSION

The team enhanced Hope College through an optimized gravity system, which in turn reduced the cost of the structure. Furthermore, the wood enabled a faster construction process which minimized the impact on students and residents of Holland, Michigan.

Special attention was given to mitigating structural borne vibrations and to creating assemblies with STC and IIC ratings that exceed industry standards. In addition to this, the exposed structure in the north lobby and occupiable roof showcased the sustainability aspects of the building as well as brought warmth and dimension to the spaces.

The roof structure is designed to allow for flexibility in the layout of the catwalk and for future additions. Also, the shear walls are sized to ensure an STC of 65 was met and the balcony in the back of the hall was cantilevered to reduce the use of columns allowing for an unobstructed view.

Throughout the project, a focus was placed on providing the owner a sustainable building. The structural team was able to achieve this using engineered wood structural members sourced from a sustainable manufacturer, for 86% of the building. This, in turn, reduced the carbon content by 27% in comparison to a steel system.

Structural Decision Matrix

Syndicate used the decision matrix below to select design solutions that best aligned with the project goals. More information regarding the design iterations shown in the matrix can be found in the structural report.

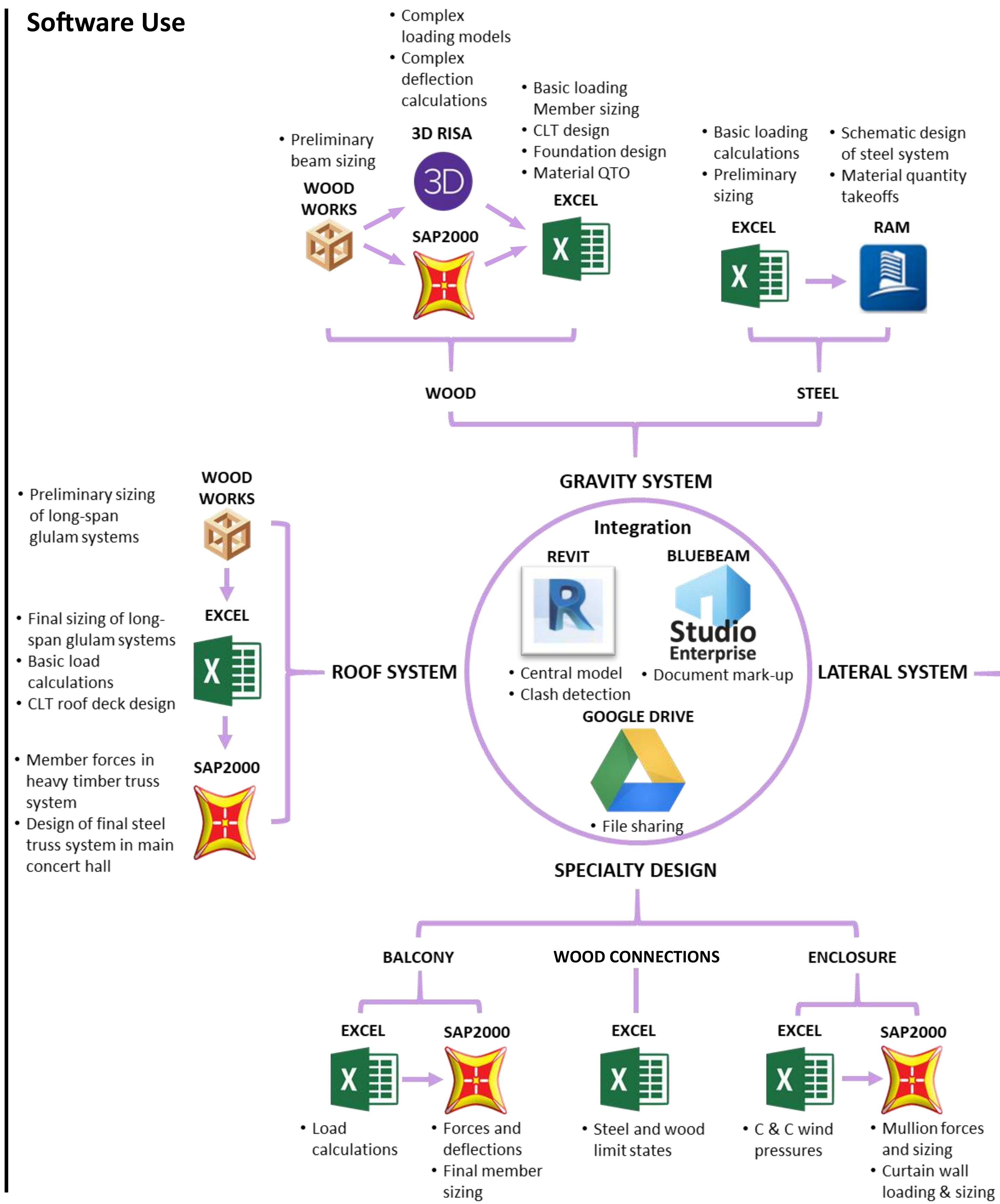
SYNDICATE — DECISION MATRIX: STRUCTURAL

Team Goals :	Enhance Hope College Campus			Maximize Occupant Experience			Create Premier Performances			Minimize Energy Impacts				Weighted Score	Rank	Final Outcome
	Construction Schedule	Aesthetics	Cost	Comfortability	Accessibility	Quality	Reduced disturbancec	Sound Quality	Flexibility	Waste Reduction	Carbon Footprint	Life Cycle	Efficiency			
TYPICAL FRAMING																
Weights :	2	3	3	3	0	0	2	3	2	3	3	2	3			
Glulam Frame with CLT Deck	2	3	1	3	0	0	2	2	3	3	3	3	2	71	1	X
Glulam Frame with Concrete on Metal Deck	2	3	3	2	0	0	1	2	2	2	2	2	2	62	2	
Steel Frame with Concrete on Metal Deck	1	2	2	2	0	0	3	2	3	1	1	1	2	52	3	
Additional Comments :	Syndicate decided to pursue the glulam frame with CLT deck system. Even though this system was predicted to be the highest in cost it provided many benfits that outweighed that aspect. This system allowes for a significantly smaller waster reduction, carbon footprint and life cycle. It also provides an increased aesthetic to the space which will improve the occupant experience.															
CONCERT HALL ROOFING SYSTEM																
Weights :	2	0	3	0	0	0	2	0	2	3	3	2	3			
Wood Truss	2	0	1	0	0	0	2	0	2	3	3	3	3	48	1	
Glulam	2	0	1	0	0	0	2	0	1	3	3	3	2	43	3	
Steel Truss	2	0	3	0	0	0	2	0	3	2	2	2	3	48	1	X
Additional Comments :	Even though the wood truss and steel truss hold the same weight within the decision matrices, Syndicate decided that the steel truss is best suited for the project. The steel truss allows for increased flexibility for the future changes to the concert hall and less constructability issues. Shipping a 72' - 0" member is not feasible and creating a moment connection in the glulam members added increased cost. The sizes required for the wood truss gave constructability issues. Ultimately, due to these reasons, the steel truss was a viable option.															
LATERAL SYSTEM																
Weights :	2	0	3	0	0	0	2	3	3	2	3	0	0			
Precast	3	0	2	0	0	0	3	2	3	3	1	0	0	42	1	X
CIP Concrete	1	0	2	0	0	0	2	2	2	2	1	0	0	31	3	
CMU	1	0	3	0	0	0	2	3	1	2	1	0	0	34	2	
Additional Comments :	The increased speed of construction was crucial for the construction schedule since the gravity system tied into the lateral. Due to this, the lateral system has to be up in a timely manner to continue with construction. The shear quanitity of walls reduced the need for a high strength material, however, thickness was needed for acoustical performance which could be achieved with all systems. Furthermore, the system would not be exposed so the effect on the occupants was not considered.															

Structural Codes and Standards

- 2015 International Building Code
- ASCE 7-16, Minimum Design Loads for Buildings and Other Structures
- 2018 NDS, Supplement and SDPWS
- CLT Handbook by FPInnovations
- AITC Timber Construction Manual , 5th edition
- AISC Steel Construction Manual , 15th edition
- ACI 318-14, Building Code Requirements for Structural Concrete
- ASTM E1300—04, Standard Practice for Determining Load Resistance of Glass in Buildings
- Kawneer 1600 LR Wall—Curtain Wall System Product Information

Software Use



Process

Syndicate utilized multiple programs throughout the project because no single program could be used to design every system. The structural team implemented an iterative process between programs to verify and optimize the design.

DEAD LOAD CALCULATIONS

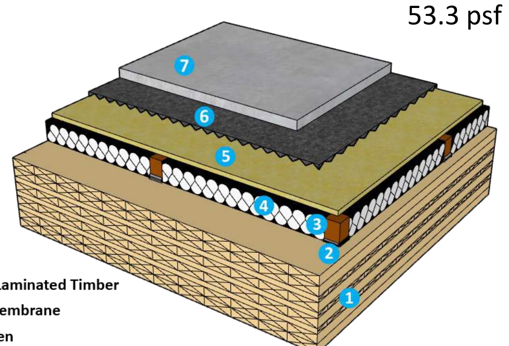
Floor Superimposed Dead Load

The superposed dead load is to provide an additional load allowance for the weight of miscellaneous building components. These include, but are not limited to; floor/ceiling finishes, ducts, light fixtures, plumbing, electrical equipment and partitions.

Floor Finishes	2 psf
ACT	2 psf
MEP	10 psf
Partitions	15 psf
	29 psf

CLT Floor + Acoustic Topper Assembly Weight

1 ½" Concrete Topper	20.5 psf
Regupol Sonuswave	2 psf
OSB	2.2 psf
Battens +Insultation+Membrane	0.50 psf
CLT Panel (10.5")	28.1 psf
	53.3 psf



1 10-1/2" Cross-Laminated Timber
2 3/8" Rubber Membrane
3 2x3 Wood Batten
4 2-1/2" Fiberglass Insulation
5 11/16" OSB
6 11/16" Regupol Sonuswave
7 1-1/2" Concrete Topping

60 STC

54 IIC

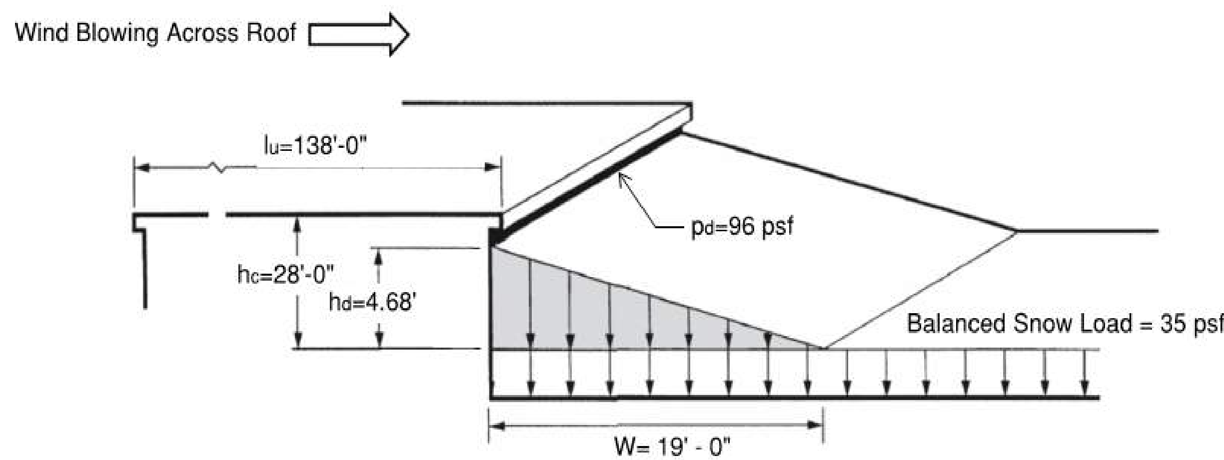
Roof Superimposed Dead Load

Ballast	15 psf
Roofing Materials	2 psf
Rigid Insulation	6 psf
Snow Melt System	2 psf
MEP	10 psf
	35 psf

SNOW LOAD CALCULATIONS

$p_f = 0.7C_eC_tI_sp_g$	
C_e (Partially Exposed Terrain Category B)	1.0
C_t (Heated Building)	1.0
I_s (Risk Category IV)	1.0
p_g (Holland, MI Building Code)	50 psf
p_f	35 psf

There are no drifting effects from surrounding buildings, however, The Miller Center has significantly varying roof heights and parapets that create localized areas of drift build-up. The most severe case occurs at the **interface between the main concert hall wall and the southern roof**. A sample calculation utilizing the ASCE 7-16 procedures is provided below for this space.



$$h_d = 0.43\sqrt[3]{l_u}\,\sqrt[4]{p_g + 10} - 1.5$$

$$\text{Snow density (pcf): } \gamma =_{min} \left| \begin{matrix} 0.13p_g + 14 \\ 30 \end{matrix} \right.$$

$$\text{If } h_d \le h_c\text{, } W = 4h_d \text{ and } p_d = \gamma\, h_d$$

All equations at left are from ASCE 7-16 Section 7.7-Drifts on Lower Roofs. h_d represents the height of the drift while W is the length until drift termination. P_d is the snow weight at the drift peak and is found by multiplying density by drift height.

h_d = 0.43 x 1381/3 x (35+10)1/4 -1.5 = 4.68'

Snow Density = Min (.13 x 50 + 14; 30) = 20.5 pcf

W = 4 x 4.68 = 18.7'

P_d = 20.5 x 4.68 = 96 psf

WIND LOAD PARAMETERS

Holland, MI Wind Loading Parameters	
Risk Category	1
Basic Wind Speed (V)	115 mph
Wind Directionality Factor (Kd)	0.85
Exposure Category	B
Topographic Factor (Kzt)	1
Gut Factor Effect	0.85
Enclosure Classification	Enclosed
Interior Pressure Coefficient (Gcpi)	0.18
Terrain Exposure Constants	α = 11.4
	zg = 760
Wind Pressure (qh)	25.6 PSF

Reference Structural Drawing S-2.0 for further information on lateral loading.

Wall Pressure Coefficients		
Cp	N-S	E-W
Windward	0.8	0.8
Leeward	-0.45	-0.5

Wind Direction	Building Dimensions (ft)	L/B	Cp
N-S	190	1.25	-0.45
E-W	237	0.80	-0.5

SEISMIC LOAD PARAMETERS

USGS Report Data	
Ss	0.087
S1	0.049
Sms	0.139
Sm1	0.117
Fa	1.6
Fv	1.4
Sds	0.093
Sd1	0.078
TL	12
PGA	0.042
Seismic Design Category	B

Seismic Data	
Seismic Site Class	D
Building Class	III
Ie	1
Risk Category	I

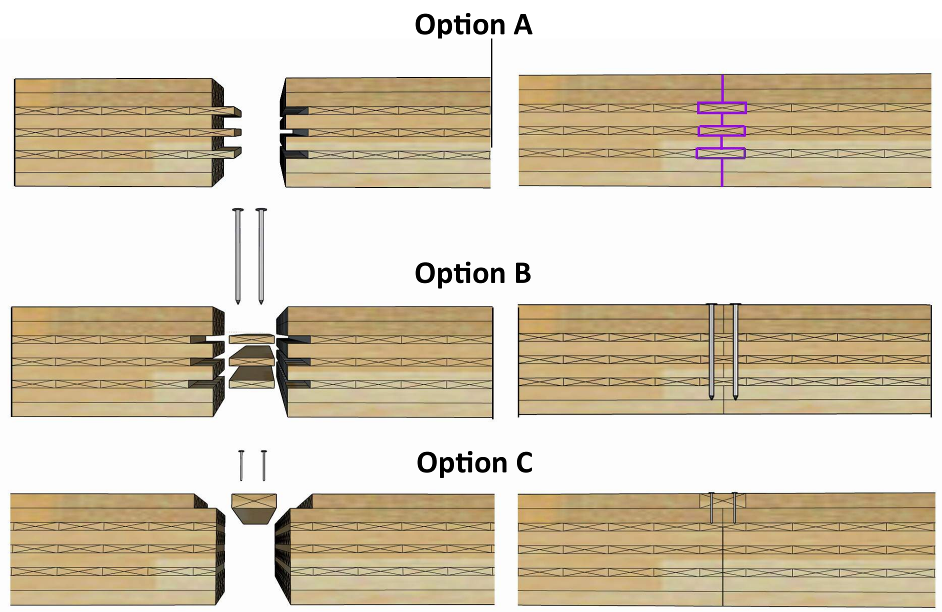
ASCE 7-16 Data	
Lateral System	Bearing Wall
R	3
Cd	3
Ω	2.5

Calculated Values	
Seismic Weight	7268.9
Cs	0.031
Base Shear (kip)	225.3

Typical Connections

Diaphragm CLT Connection

Syndicate's structural team designed the CLT floor system to act as a rigid diaphragm. To do so, the panels had to be joined together so that the entire floor plate moves uniformly as a single element. Multiple methods for panel-to-panel connections were considered, with the team ultimately selecting Option C. Option C was best suited for The Miller Center because the loads between panels were relatively low and it was the easiest to construct.



Beam to Column Saddle-Type Connection Limit States

Each saddle-type connection has two side plates, therefore, the limit states for each side plate failure mode need to be doubled. The controlling load for this connection is 55.6k. This particular connection can be seen on Structural Drawing S-3.0.

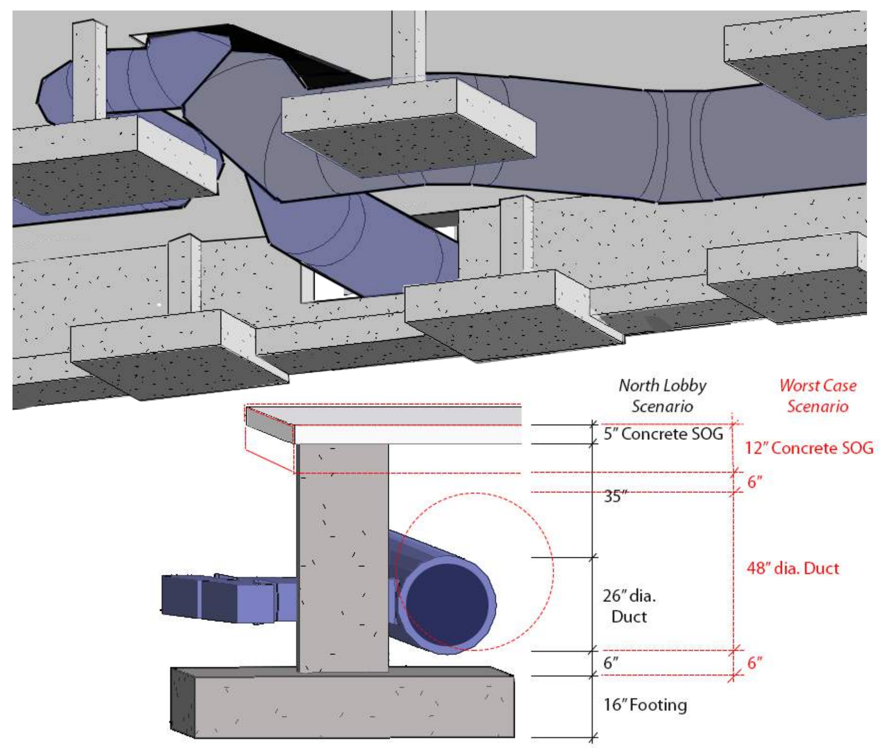
11" x 22.5 Saddle-Type Connection

DL=23k , LL=16k; Factored load = 39 k (ASD), 53.2 k (LRFD); 6" x 11" bearing area req'd as per 2018 NDS

Limit State	Applied Load	ΦRn	Notes
Bottom Plate Flexural Strength	4.06 k-ft	4.31 k-ft	7/8" A572 Gr. 50 Plate
Saddle Flexural Strength	13.3 k-ft	223 k-ft	Saddle flexural strength
Bottom Plate/Side Plate Weld	26.6 k	31.3 k	3/16" fillet weld, 5" on each side
Side Plate Tension Yield	26.6 k	48.6 k	1/4" A36 plates
Side Plate Tension Rupture	26.6 k	53.0 k	
Side Plate/Backer Plate Weld	26.6 k	27.8 k	1/8" fillet weld, 10" on each side
Base Metal Strength	26.6 k	65 k	
Backer Plate Tension Yield	53.2 k	89.1 k	1/4" A36 plate
Backer Plate Tension Rupture	53.2 k	95.2 k	
Backer Plate/Top Plate Weld	53.2 k	62.6 k	3/16" fillet weld, 10 inches
Top Plate Shear	53.2 k	143.5 k	1/2" A36 plate

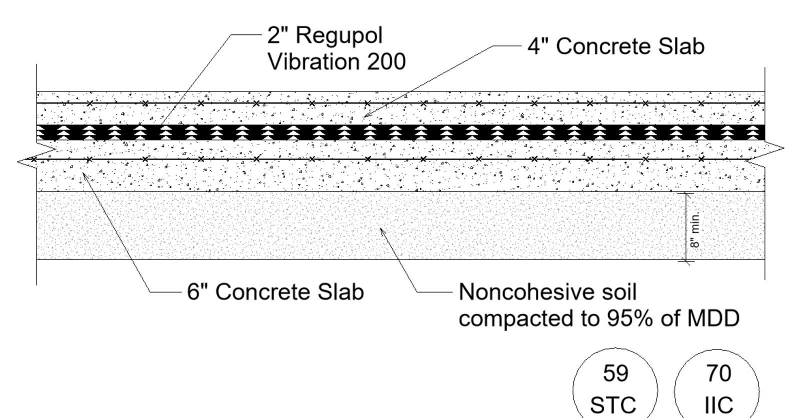
Foundation Coordination

At the locations that the blue ducts pass over the foundation, the spread and strip footings were moved from 3'-6" to 6'-0" below top-of-slab. The extra 2'-6" was determined to accommodate the largest of the underground blue ducts (48" in diameter). At the tightest point there is 6" of clearance on either side of the blue duct.



Concert Hall Slab on Grade

The built-up assembly shown below implements the use of a 2" thick Regupol Vibration 200 isolation mat to achieve an STC of 59 and an IIC of 70.



Spread Footing

Hand Calculation for an 12.875x12.875 Column

Loading/Sizing

DEAD LOAD: 164 k
LIVE LOAD: 73 k
SNOW LOAD: 22 k

$q_a = 4500$ psf
$f'_c = 4000$ psi
$f_y = 60{,}000$ psi

$P_{SERVICE} = 164 + 73 + 22 = 259^k$

$q_a \geq \frac{P_{SERVICE}}{AREA}$

$B = \sqrt{\frac{259(1000)}{4500}} = 7.6\text{ ft} \therefore 8\text{ ft}$

CHECK: $\frac{259{,}000}{8^2} = 4047 < 4500$ OK

$P_u = 1.2(164) + 1.6(73) + 0.5(22) = 324^k$

$q = \frac{324(1000)}{8^2(144)} = 35.2$ psi

Punching Shear

$\beta_c = \frac{11.5}{11.5} = 1$

$\alpha_s = 30$

$V_c = \begin{cases} 0.75(2 + 4/1)\sqrt{4000} = 285 \\ \phi(\frac{\alpha_s d}{b_o} + 2)\sqrt{f'_c} \rightarrow \text{CHECK LATER} \\ \text{min } 0.75(4)\sqrt{4000} = 190 \end{cases}$

Determined Depth

$d^2[190 + 35.2/4] + d[190 + 35.2/2](11.5) = \frac{35.2}{4}[96^2 - 11.5^2]$

$d = 14.9"$

$h = 14.9 + 3 + 0.75 = 18.7"$

$V_c = 0.75\left(\frac{30(14.9)}{106} + 2\right)\sqrt{4000} = 295 > 190$ OK

$d_L = 19 - 3 - 0.75(0.5) = 15.625$

$d_s = 19 - 3 - 0.75(1.5) = 14.875$

Wide Beam Shear

$V_{us} = 5.06\left[\left(\frac{96 - 11.5}{2}\right) - 14.875\right](1/12) = 11.5^k$

$V_{uL} = 5.06\left[\left(\frac{96 - 11.5}{2}\right) - 15.625\right](1/12) = 11.2^k$

$\phi V_n = 0.75(2)\sqrt{4000}(12)(14.875) = 16934$ lb

$\phi V_n > V_{us}$ & V_{uL} OK

Reinforcement

SHORT

$l = \left(\frac{96 - 11.5}{2}\right)(1/12) = 3.521$ ft

$M_u = \frac{5.06(3.521)^2}{2} = 31.4^{k\text{-ft}}$

$a = \frac{60}{0.85(4)(12)} = 1.47A_s$

$0.9A_s(60)\left(14.875 - \frac{1.47A_s}{2}\right) = 31.4(12)$

$A_s = 0.46\text{ in}^2$

$\boxed{\text{USE \#6 @ 10"}}$ $A_{s\,prov} = 0.53\text{ in}^2 > 0.46\text{ in}^2$ OK

SPACING OKAY BY INSPECTION

$\rho = \frac{0.53}{12(19)} = 0.0023 > 0.0018$ OK

$c = \frac{1.47(0.53)}{0.85} = 0.91$

$\varepsilon_s = 0.003\left(\frac{14.875 - 0.91}{0.91}\right) = 0.048\text{ in/in} \geq 0.005 \therefore \phi = 0.$

LONG

$l = \left(\frac{96 - 11.5}{2}\right)(1/12) = 3.521$ ft

$M_u = \frac{5.06(3.521)^2}{2} = 31.4$ k-ft

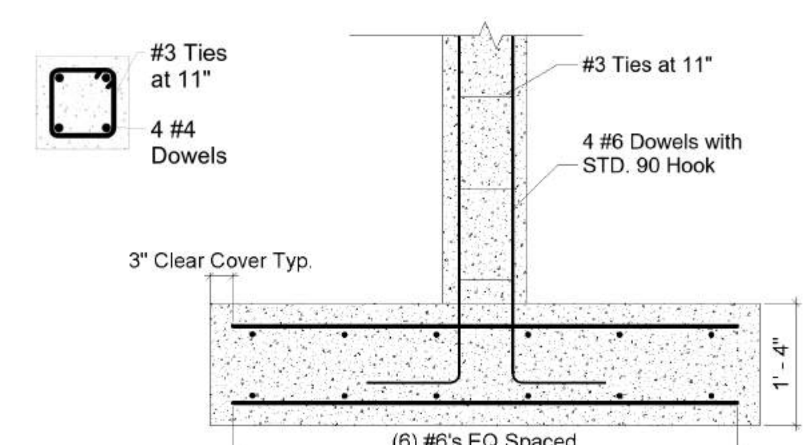
$0.9A_s(60)\left(15.625 - \frac{1.47A_s}{2}\right) = 31.4(12)$

$A_s = 0.48\text{ in}^2 \therefore$ USE SAME AS SHORT DIRECTION

Bearing

$\phi B_n = 0.65(0.85)(4000)(11.5^2) = 292^k > 259^k$ OK

Foundation Detail for an 11x11 Wood Column



Typical Glulam Beam Calculations

Loading

LOADS: DEAD LOAD = 107 psf
LIVE LOAD = 75 psf
MEMBER: LENGTH = 17 ft
TRIB WIDTH = 24 ft

Deflection Check

$$\Delta_{TL} = \frac{L}{240} = \frac{17(12)}{240} = 0.85''$$

$$0.85 = \frac{5(1.5(107)(24) + 75(24))(17)^4(1728)}{384(1.8E6)(I)}$$

$$I = 6942 \text{ in}^4$$

TRY $\underline{11 \times 23.5}$ $I = 11{,}896 \text{ in}^4$ OK

$$\Delta_{LL} = \frac{L}{360} = \frac{17(12)}{360} = 0.57''$$

$$\Delta_{LL} = \frac{5(17)(24)(17)^4(1728)}{384(1.8E6)(11896)}$$

$\Delta_{LL} = 0.04'' < 0.57''$ OK

Flexure

$F_b^* = 2400(1.0)(1.0)(1.0)(1.0)(1.0)(1.0)$
$F_b^* = 2400$ psi
$C_L = 1.0$ SINCE CLT CONT. BRACES

$$C_V = \left(\frac{21}{17}\right)^{1/10}\left(\frac{12}{23.5}\right)^{1/10}\left(\frac{5.125}{11}\right)^{1/10} = 0.885 < 1.0 \text{ OK}$$

$F_b' = 2400(0.885) = 2124$ psi

$$f_b = \frac{M}{S} = \frac{158(12)}{1012} = 1874 \text{ psi} \quad M = \frac{(107+75)(24)(17)^2}{8(1000)} = 158 \text{ k-ft}$$

$F_b' = 2124$ psi $> f_b = 1874$ psi OK

Shear

$F_V' = 600(1.0)(1.0)(1.0)(1.0) = 600$ psi

$$f_v = \frac{3}{2}\left(\frac{V}{A}\right) = \frac{3}{2}\left(\frac{37128}{11(23.5)}\right) = 215 \text{ psi}$$

$$V = \frac{(107+75)(24)(17)}{2} = 37128 \text{ lb}$$

$F_V' = 600$ psi $> f_v = 215$ psi OK

Char

NDS TABLE 16.2.1B
$a_{eff} = 1.8''$ FOR 1 HOUR RATING
WIDTH: $11 - 2(1.8) = 7.4''$
DEPTH: $23.5 - 1.8 = 21.7''$

$F_b' = 2.85(2400)(1)(0.85) = 6052$ psi
$F_b = 6052$ psi $> f_b = 1874$ psi OK
$F_V' = 2.85(600)(1.0)(1.0)(1.0)(1.0) = 1710$ psi
$F_V' = 1710$ psi $> f_v = 215$ psi OK

Typical Glulam Column Calculations

Column Capacity	
Variable	11x11
Length (in)	192
Depth (in)	11
Le/D	17
E'min (10^6)	1
Fce	2564
Cd	1
Cm	1
Ct	1
Fc	2300
Fc*	2300
Fce/Fc*	1
c	1
Cp	1
Fc'	1837
Width (in)	11
Depth (in)	11
P allow	222220
X-section area	121
Fire Rating Considered	
Burned off	2
New Width	7
New Depth	7
Length	192
New Le/d	26
New Fce	1160
New Fc*	2300
Fce/Fc*	1
New Cp	0
New Fc'	2755
Pallow	150877

Cross-Laminated Timber

Floor/Roof Slabs – Design Properties

Floor/Roof Slabs – Design Properties

CLT stress grade	E1 (L = S-P-F 1950f MSR and T = S-P-F No. 3)								
Layup combination	89-3s	105-3s	143-5s	175-5s	197-7s	213-7l	244-7s	244-7l	267-9l
Bending in the major strength direction (y-y)									
Bending moment capacity, M_0 (lbf-ft/ft) [a]	3,350	4,525	7,725	10,400	13,725	18,700	18,375	23,700	28,325
Shear capacity, V_0 (lbf/ft)	1,260	1,490	2,030	2,480	2,800	3,025	3,475	3,475	3,775
Bending stiffness, $EI_{eff,0}$ (10^6 lbf-in.^{2}/ft)	72	115	267	440	654	963	1,089	1,404	1,831
Shear rigidity, $GA_{eff,0}$ (10^6 lbf/ft)	0.48	0.46	0.96	0.92	1.4	1.6	1.4	1.4	2.0
Bending in the minor strength direction (x-x)									
Bending moment capacity, M_{90} (lbf-ft/ft) [a]	45	160	615	1,370	1,410	615	3,150	1,370	1,410
Shear capacity, V_{90} (lbf/ft)	270	495	1,040	1,490	1,800	1,040	2,480	1,490	1,800
Bending stiffness, $EI_{eff,90}$ (10^6 lbf-in.^{2}/ft)	0.51	3.1	26	81	101	26	313	81	101
Shear rigidity, $GA_{eff,90}$ (10^6 lbf/ft)	0.39	0.61	0.78	1.2	1.2	0.93	1.8	1.3	1.3

a) The bending moment capacity values in the major strength direction, M_0, include the adjustment factor of 0.85 as defined in ANSI/APA PRG 320.

The same design process was used to design the CLT members and the glulam beams/columns. The CLT panels were treated as a one-way system, simply supported on each end by a glulam beam.

Allowable Area For Type IIIA Construction

Allowable Number of Stories

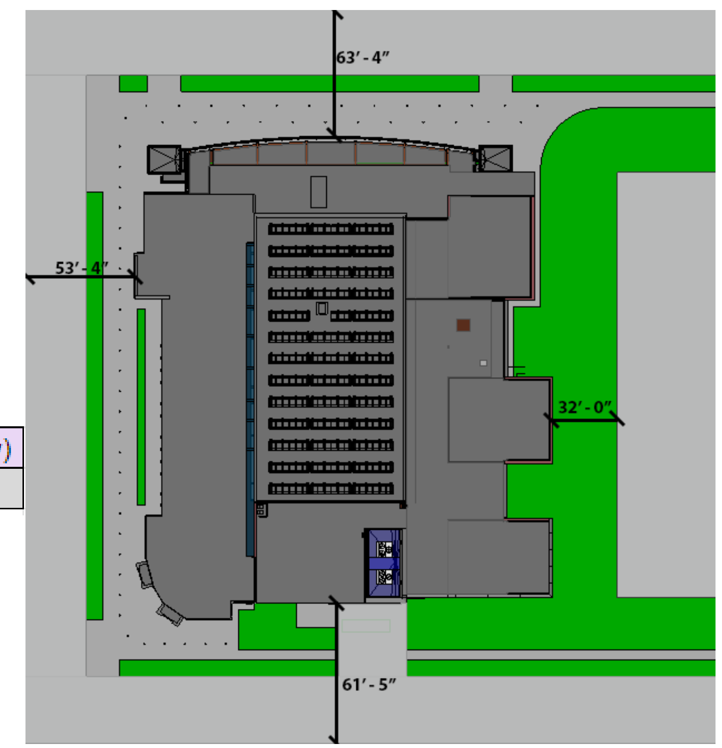
TABLE 504.4
ALLOWABLE NUMBER OF STORIES ABOVE GRADE PLANE[a, b]

OCCUPANCY CLASSIFICATION	SEE FOOTNOTES	TYPE OF CONSTRUCTION								
		TYPE I		TYPE II		TYPE III		TYPE IV	TYPE V	
		A	B	A	B	A	B	HT	A	B
A-1	NS	UL	5	3	2	3	2	3	2	1
	S	UL	6	4	3	4	3	4	3	2

Frontage Calculation

Minimum Width of Public Way (W)

Building Perimeter (ft)	Side	Setback (ft)	Length (ft)	W (ft)
972.6	West	30	257.7	30
	East	30	319.9	
	South	30	225.7	
	North	30	169.4	



Square Feet / Floor

$$A_a = [A_t + (NS \times I_f)]$$

	Table 506.2				
Type	Group	At (sq. ft.)	If	NS (sq. ft.)	Aa (sq.ft./story)
IIIA	A	42,000	0.75	14000	52,500

Precast Panel Sizing Calculations

Load Combination $1.2D + 1.0L + 1.6W + 0.5S$

Loading

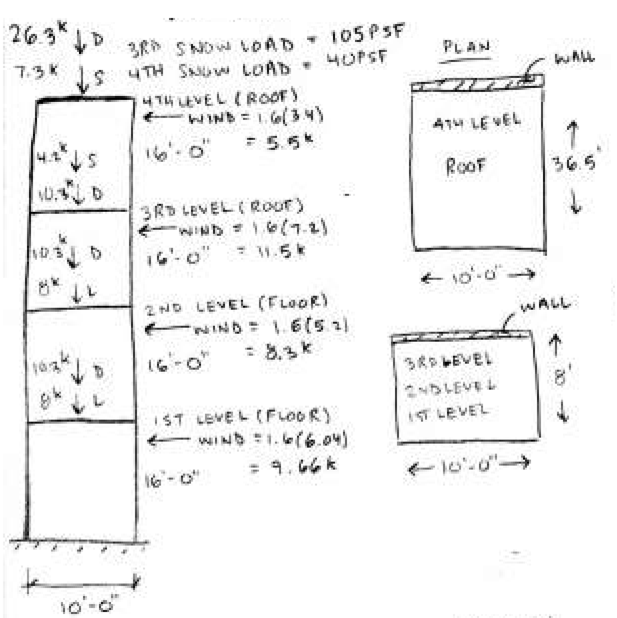
ROOF DEAD = 60 PSF
FLOOR DEAD = 107 PSF
LIVE LOAD = 100 PSF

• 4TH LEVEL ROOF LOADS:
SNOW - $10'(36.5')(40^{PSF})(0.5) = 7300$ lb
ROOF DEAD - $(10')(36.5')(60^{PSF})(1.2) = 26280$ lb

• 3RD LEVEL ROOF LOADS:
SNOW - $10'(8')(105^{PSF})(0.5) = 4200$ lb
DEAD - $10'(8')(107)(1.2) = 10272$ lb

• 2nd LEVEL FLOOR LOADS: / 1ST LEVEL FLOOR LOADS
DEAD - 10 272 lb
LIVE - $100(10')(8') = 8000$ lb

Loading Diagram



Minimum Thickness of Wall

$H_{min} = \max \begin{cases} 4'' \\ \frac{1}{25} \min \begin{cases} \text{UNSUPPORTED LENGTH} = 73'\text{-}0'' = 35'' \\ \text{UNSUPPORTED HEIGHT} = 16'\text{-}0'' = 7.68'' \end{cases} \end{cases}$

$\boxed{\text{CONTROLLING} = 7.68'' \sim 8'' \text{ minimum THICKNESS}}$

Assumption
VERT. RFT = 2 curtains #6 @ 18"
HORIZ. RFT = 2 curtains #4 @ 18"
WALL THICKNESS = 12"
$f'_c = 4000$ PSI / $F_y = 60{,}000$ PSI

Horizontal Reinforcement Check

HORIZ. RFT CHECK: 2 curtains #4 @ 18"

$\rho_t = \frac{A_{v,horiz}}{h \times s_t} = \frac{2(0.2)}{12(18)} = 0.0019 < 0.0025 = \rho_{t,min}$ X

$\boxed{\text{TRY 2 CURTAINS \#4 @ 12''}}$

$\rho_t = 0.0028 > 0.0025$ ✓ GOOD

$s_{t,max} = \min \begin{cases} 3h = 36'' \\ 18'' \\ \frac{l_w}{5} = 24'' \end{cases} \rightarrow s_{t,max} = 18'' > 12'' = s_{prov}$ ✓

Vertical Reinforcement Check

VERTICAL RFT CHECK: $\boxed{\text{2 curtains \#6 @ 18''}}$

$\rho_l = \frac{A_v}{h s_l} = \frac{2(0.44)}{12(18)} = 0.0041 > \rho_{min}$ ✓

$\rho_{l,min} = \begin{cases} 0.0025 + 0.5\left(2.5 - \frac{h_w}{l_w}\right)(\rho_t - 0.0025) \\ 0.0025 \rightarrow \text{CONTROLS} \end{cases}$

Neutral Axis Depth

$M_{base} = 1.0[5.5(64) + 11.5(48) + 8.3(32) + 9.66(16)] = 1325^{K\cdot FT}$

$N_u = 0.9(26.3 + 10.3(3)) = 57.2$ KIP $\quad \beta_1 = 0.85$

$\omega = 0.0041\left(\frac{60}{4}\right) = 0.061 \quad \alpha = \frac{N_u}{h l_w f'_c} = \frac{57.2}{12(120)(4)} = 0.01$

$c = \left[\frac{0.01 + 0.061}{0.85(0.85) + 2(0.061)}\right](120) = 10.09'' << 0.8 l_w = 96''$

$\therefore \phi = 0.9$ (TENSION CONTROLLED)

Moment Capacity Check

$A_{st} = 2(0.44)\left(\frac{120}{18}\right) = 5.87 \text{ in}^2$

$T = 5.87 \text{ in}^2 (60)\left(\frac{120 - 10.09}{120}\right) = 322.4$ KIP

$M = 322.4\left(\frac{120}{2}\right) + 57.2\left(\frac{120 - 10.09}{2}\right) = 19397$ K·in $= 1616.4$ K·FT

$\phi M_n = 0.9(1616.4) = 1455$ K·FT $> M_u = 1325$ K·FT ✓

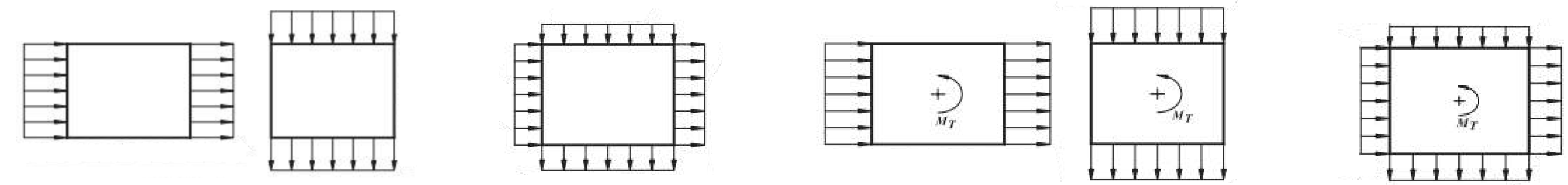
Shear Capacity Check

$V_u = 5.5 + 11.5 + 8.3 + 9.66 = 34.96^{K}$

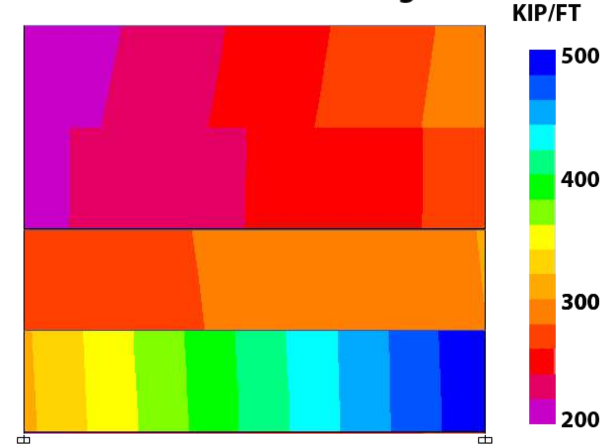
$V_c = \min \begin{cases} 3.3\sqrt{4000}(12)(96) + \frac{57.2(96)}{4(120)} = 241 \text{ KIP} \\ \left[0.6(\sqrt{4000}) + \frac{120\left[1.25\sqrt{4000} - 0.2\left(\frac{57.2}{120(12)}\right)\right]}{\frac{1325}{34.96} - \frac{120}{2}}\right](12)(96) \end{cases}$

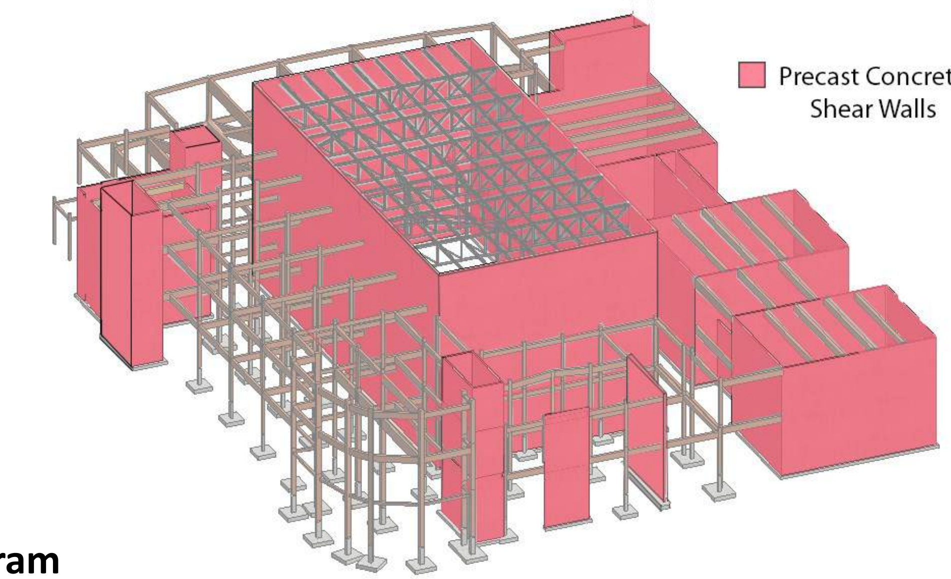
$\phi V_c = 241(0.75) = 180$ KIP $> V_u = 34.96$ KIP ✓

Lateral System Analysis

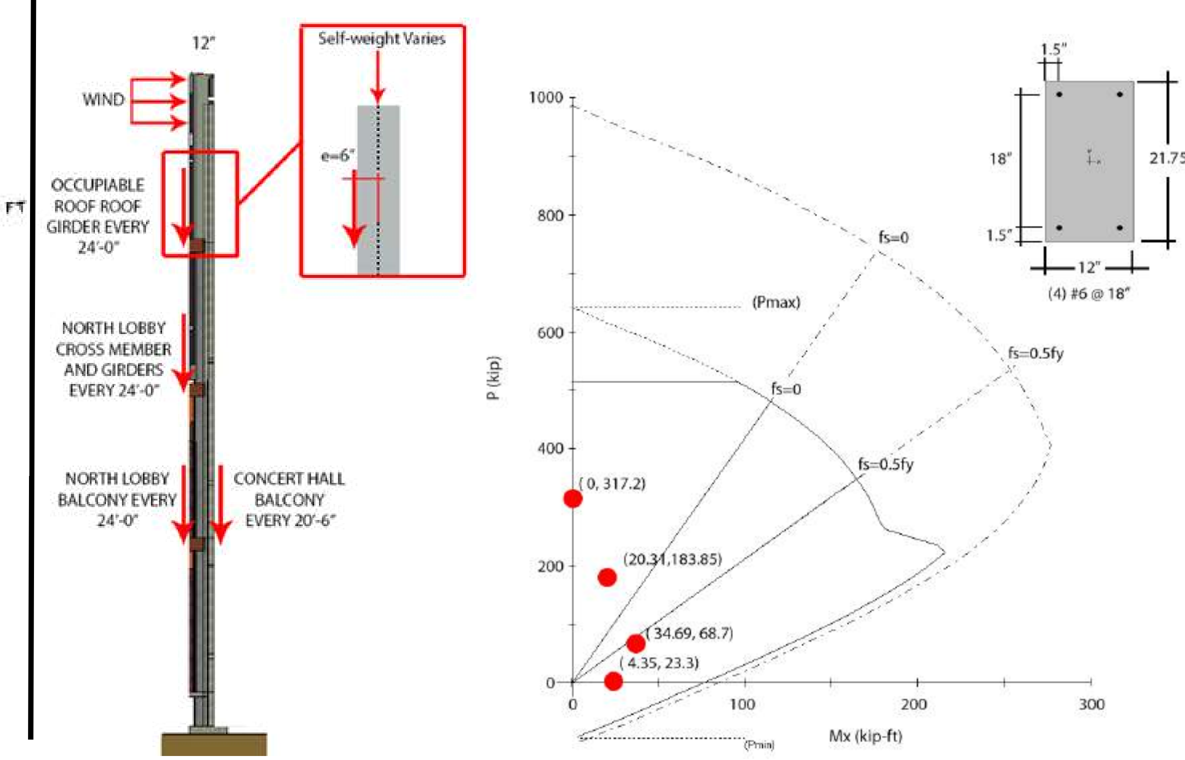


Resultant Shear Force Diagram





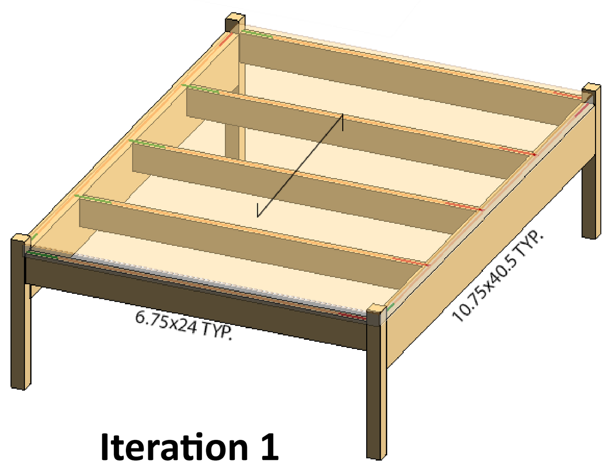
Out of Plane Loading — Interaction Diagram



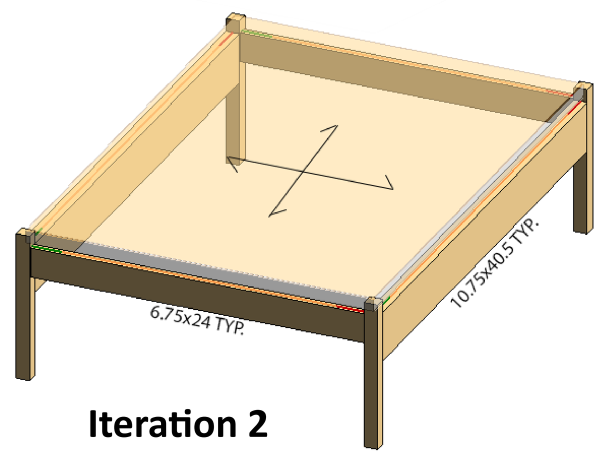
When designing the precast panels for the shear wall, *Syndicate* considered the out of plane loading from members framed into the wall. The worst case scenario is shown to the right with loading from balconies, floor systems, a roof, and wind pressures.

The wall was analyzed using the unit strip method for the flexural and axial capacities at varying heights along the wall. After modeling the member in *SAP2000*, *SPWall* was utilized in order to obtain an interaction diagram. The various loadings were input as shown to the left. The points fell within the interaction diagram and verified that the current design has the capacity to handle the out of plane load demands.

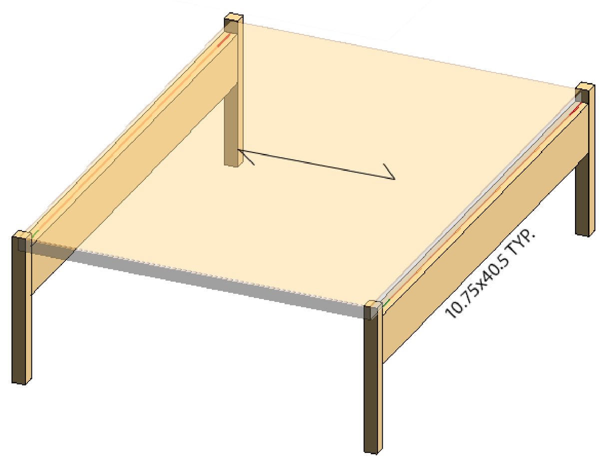
System Analysis									
Steel		CIP Concrete		CMU		Precast		Heavy Timber	
Pro	Con	Pro	Con	Pro	Con	Pro	Con	Pro	Con
. Ability to span long distances . Available locally	. Fire proofing is required and costly . Structure borne vibrations	. Available locally . Well insulated	. Constructability issues during winter months . Large contributor to green house gases	. Naturally fire resistant	. Very labor intensive . Requires greater coordination between trades	. Naturally fire resistant . Fast construction	. Requires skilled workmanship on site . Longer lead times	. Reduces carbon dioxide emissions between 15-20% from steel . Fast construction	. Manufacturers are far away . Requires skilled workmanship on site



Iteration 1

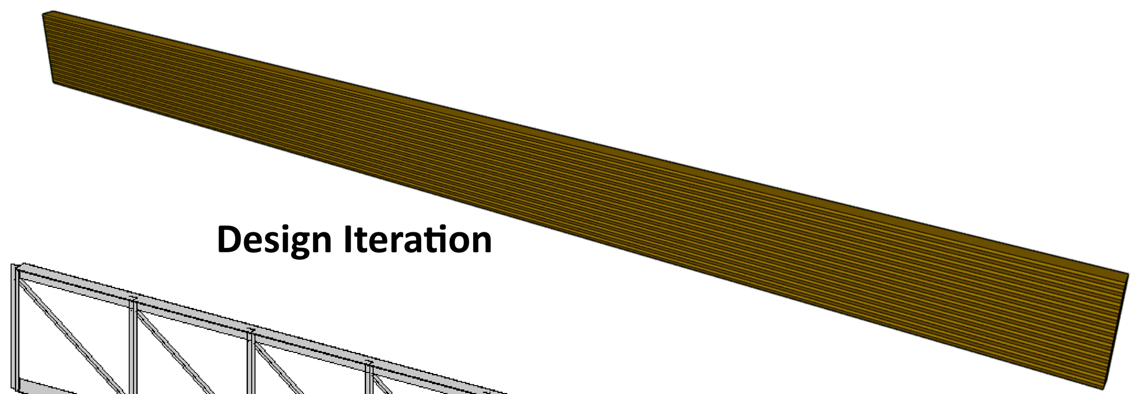


Iteration 2

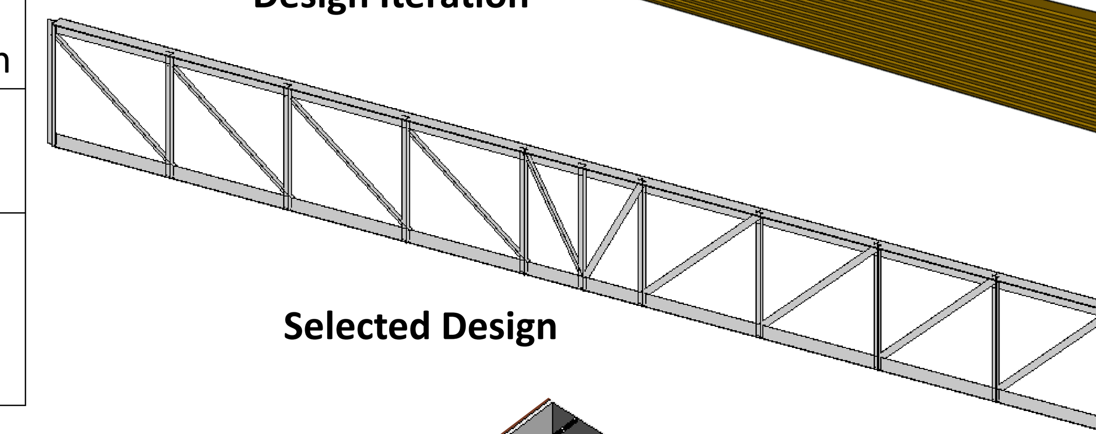


Iteration 3—Selected

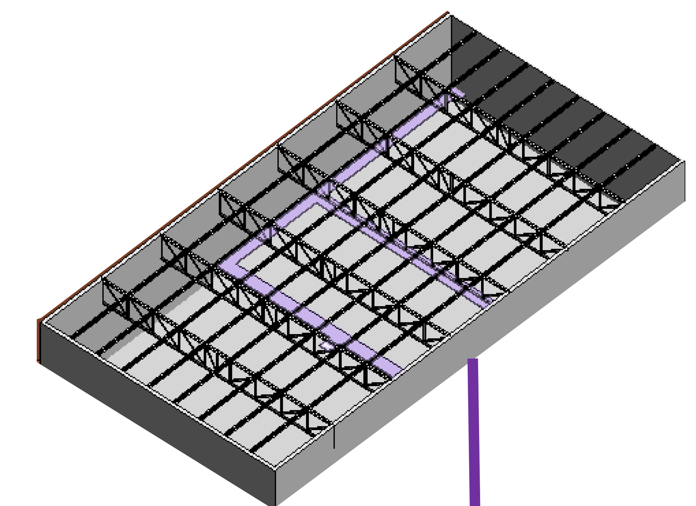
Lateral System Comparison		
System	Benefit	Drawback
CLT	. Sustainable material . Quick installation . Wood contractors already on site	. Expensive . Distant sourcing . Connection between panels and members framing in
Cast in Place Concrete	. Mass acts as great sound insulator . Local sourcing	. Slow installation . Connections to members framing in
Precast Concrete	. Mass acts as sound insulator . Quick installation / connections prefabricated . Local sourcing	. Expensive to prefabricate



Design Iteration



Selected Design



GENERAL SYSTEM ANALYSIS

TYPICAL BAY DESIGNS

BAY OPTIMIZATION

NORTH LOBBY

LATERAL

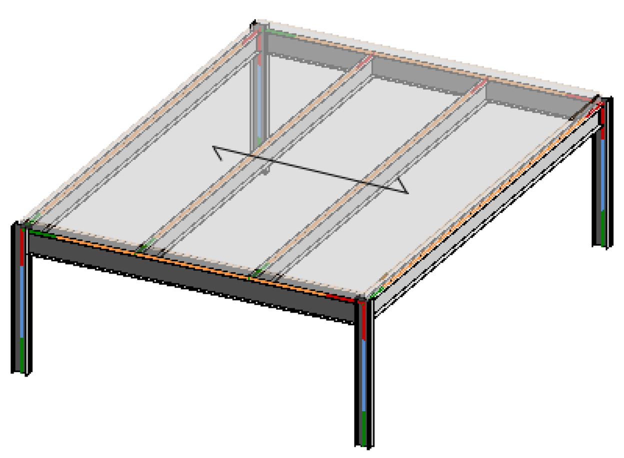
OCCUPIABLE ROOF

FOUNDATION

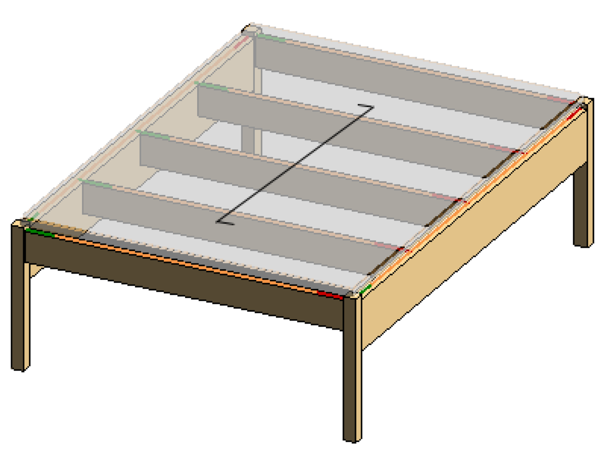
STRUCTURAL ENCLOSURE

CONCERT HALL ROOF

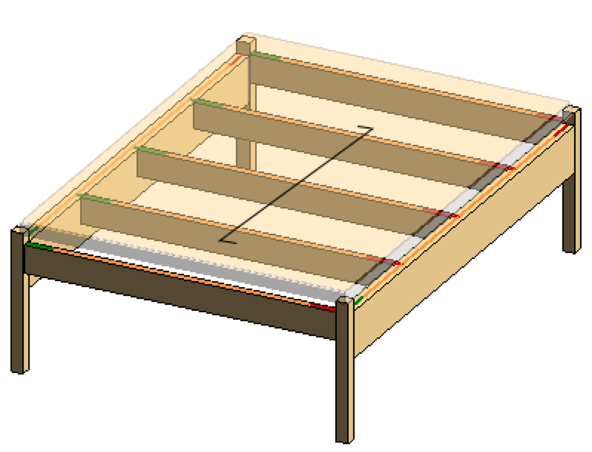
A composite steel system with a W18x35 as the deepest beam. The deck is a 1.5VLI19 with 4 1/2" NWC topper.

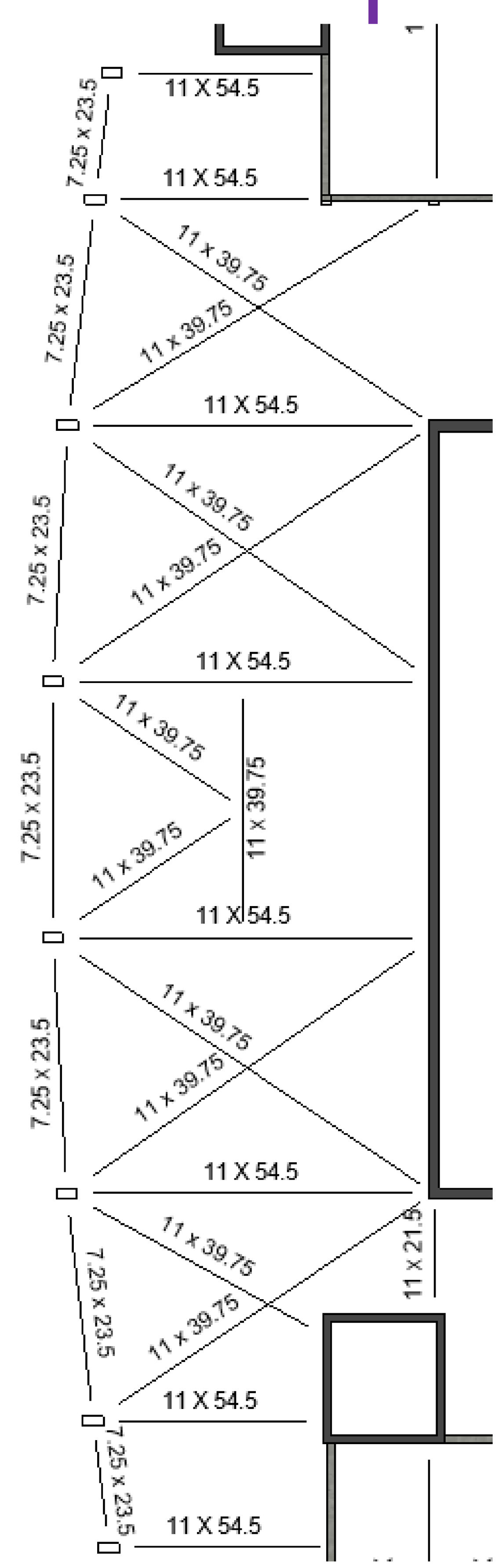


Glulam beams and columns with the deepest beam being a 10.75x43.5. A deck consisting of 1.5VLI19 with 4 1/2" NWC topper.

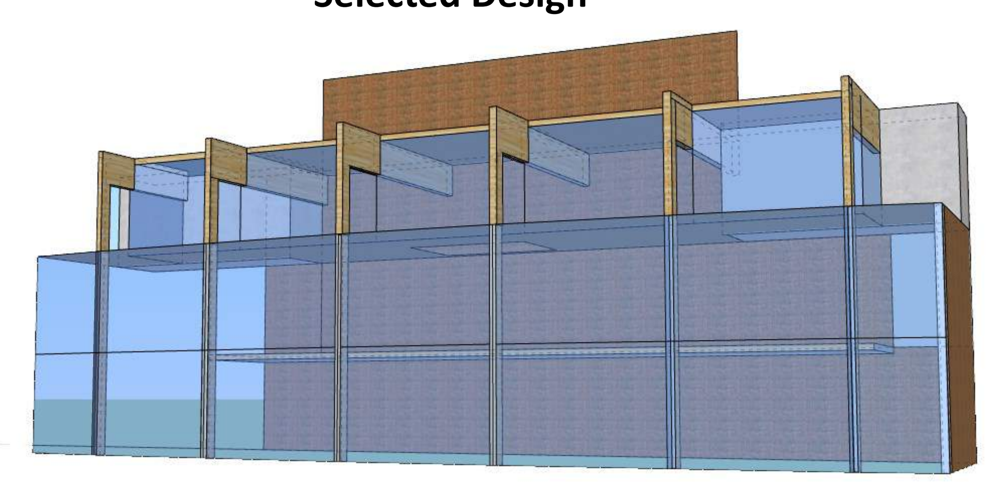


Glulam beams and columns with the deepest beam being a 10.75x40.5. A CLT deck with a E1 stress grade and a and a combination of 244-7s with 2" LWC.

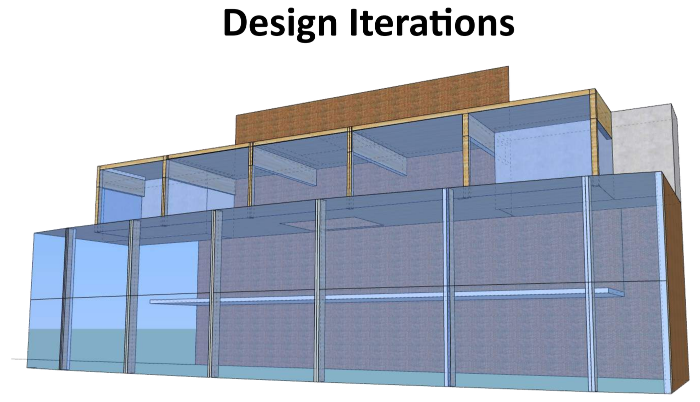


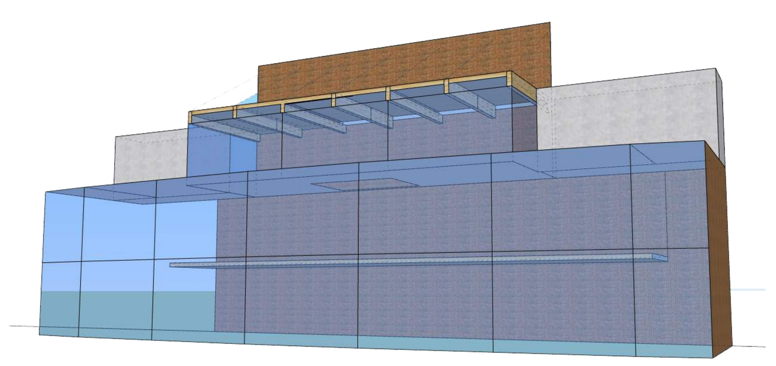


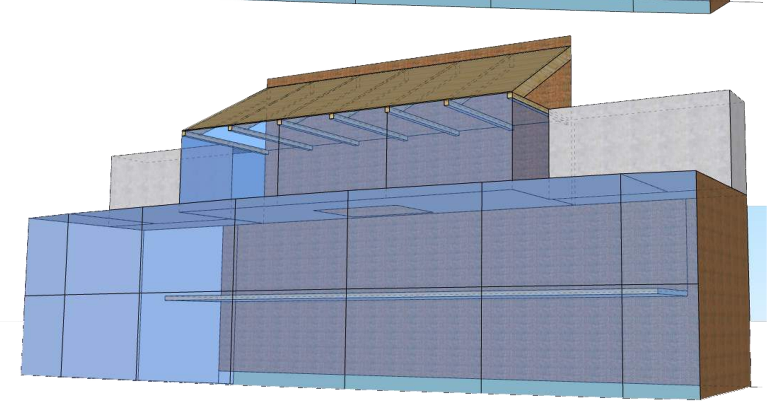
Selected Design

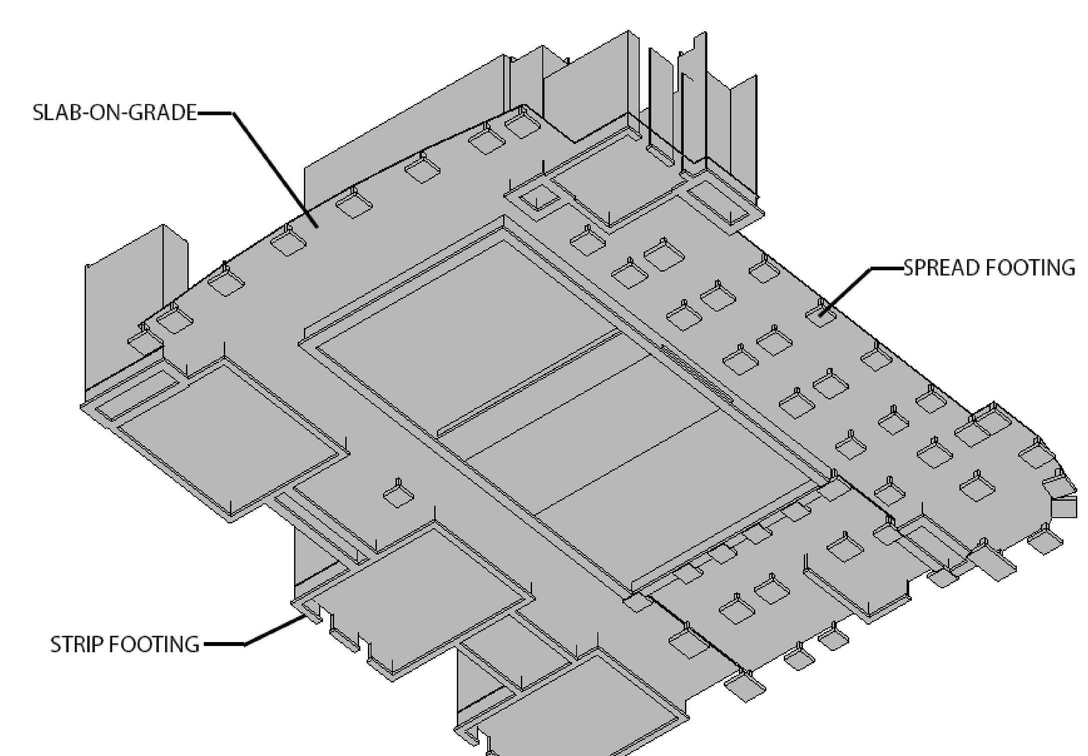


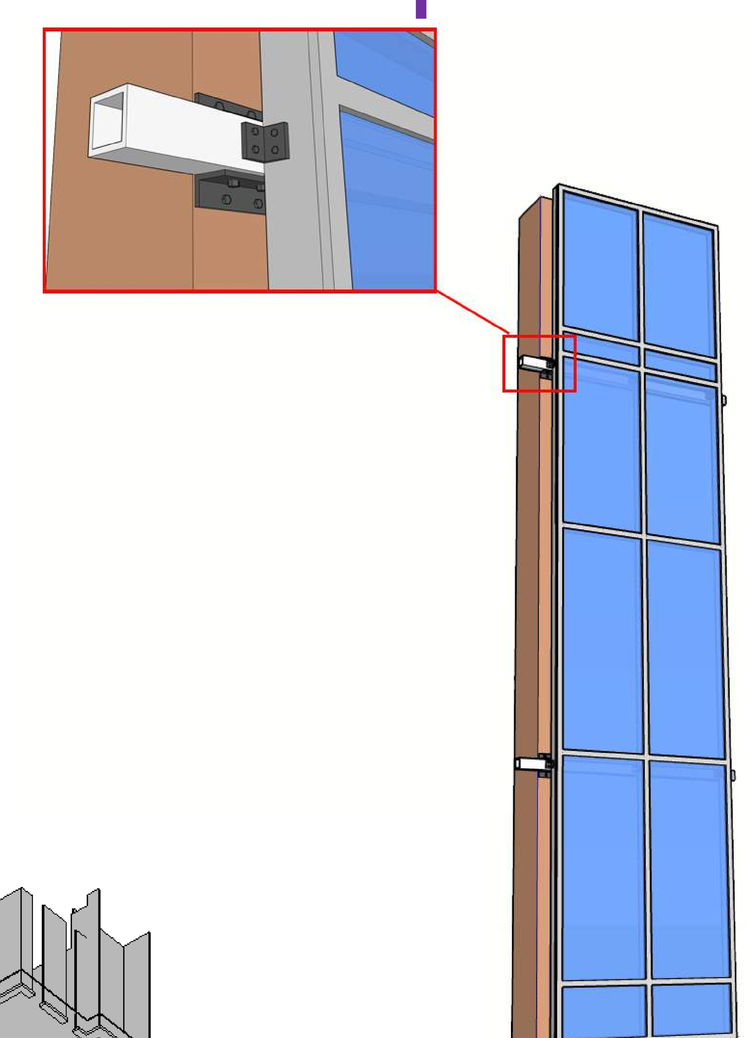
Design Iterations











SYNDICATE

PROJECT

JACK H. MILLER CENTER FOR MUSICAL ARTS

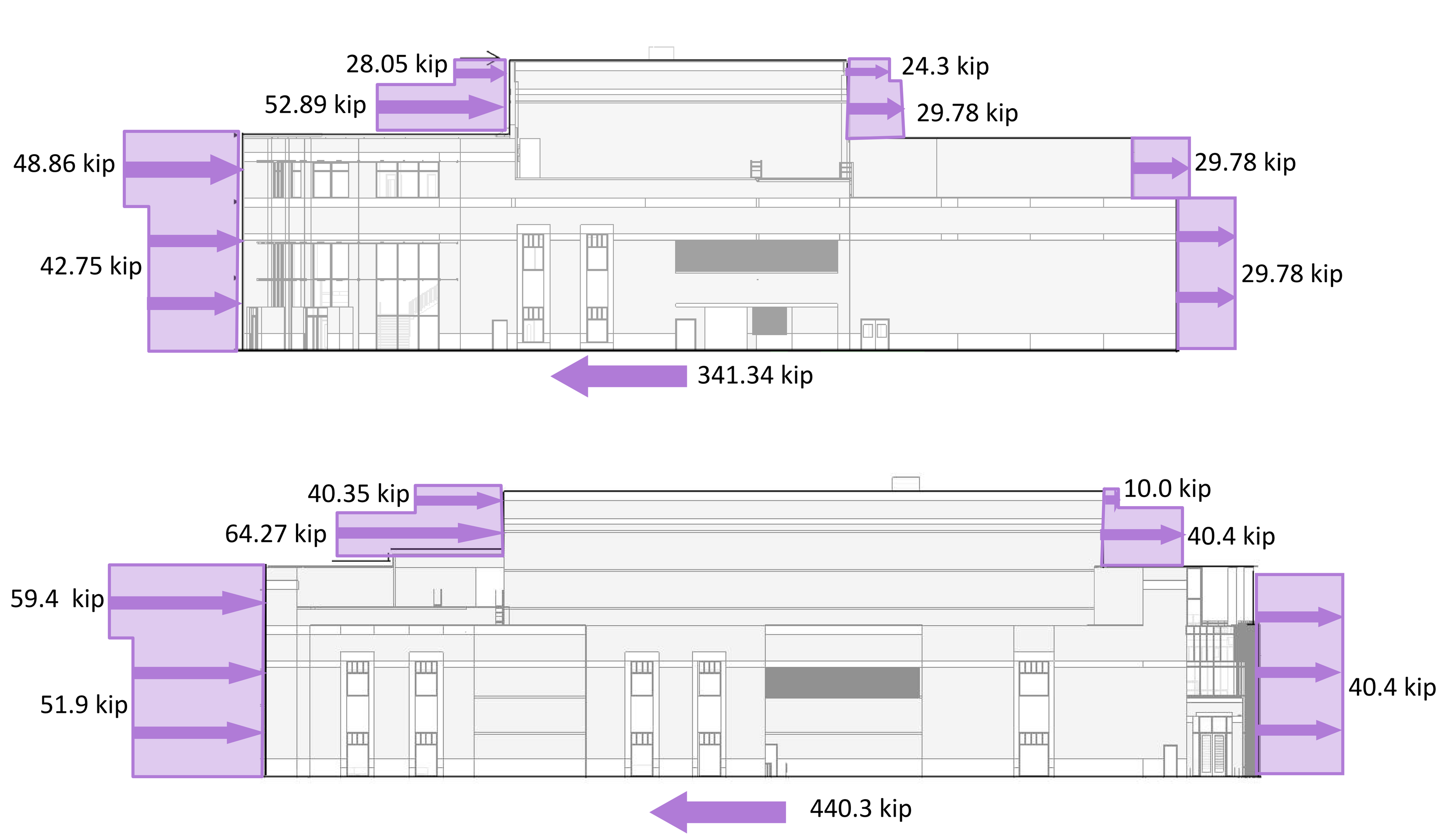
HOLLAND, MICHIGAN

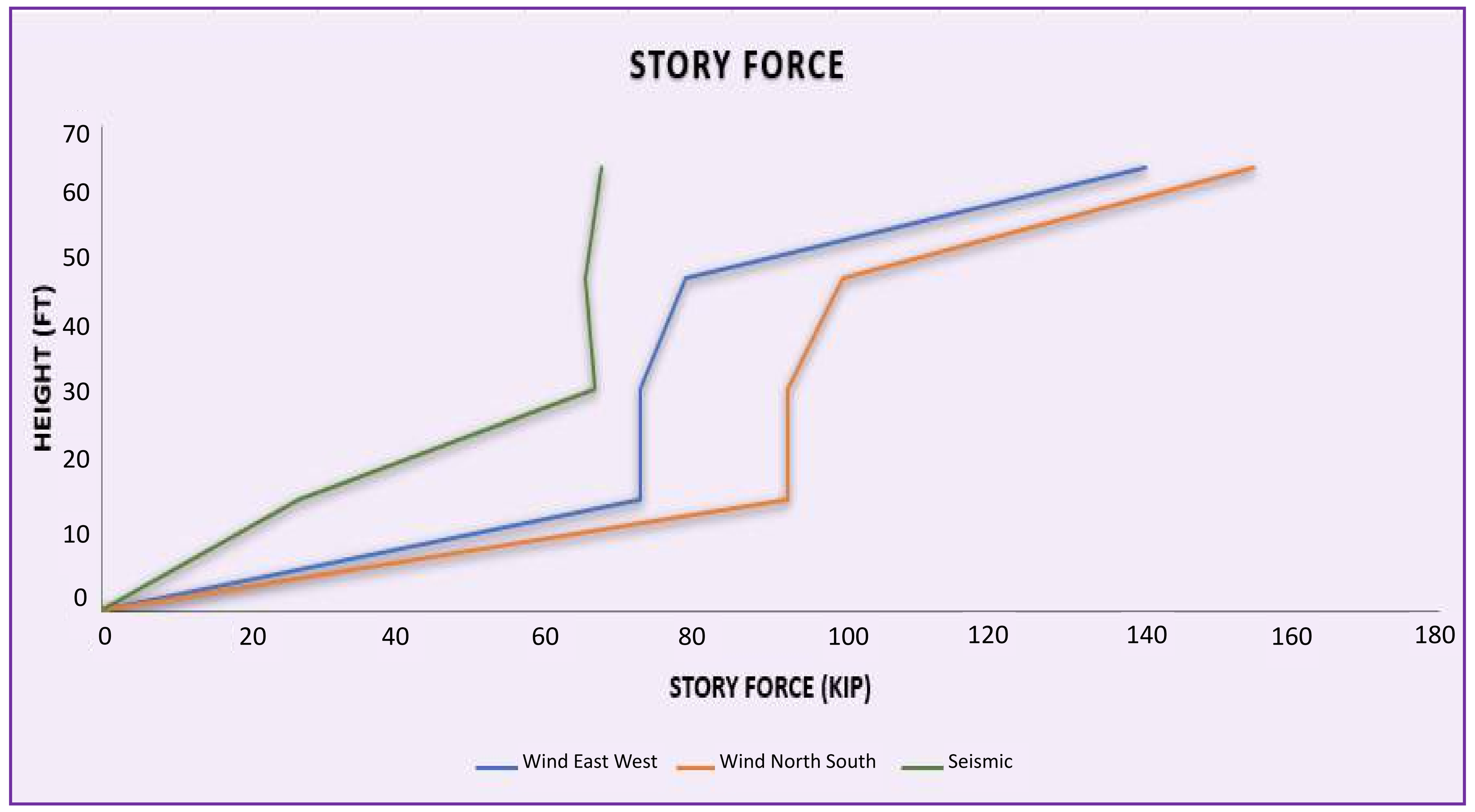
SHEET TITLE

DESIGN TIMELINE

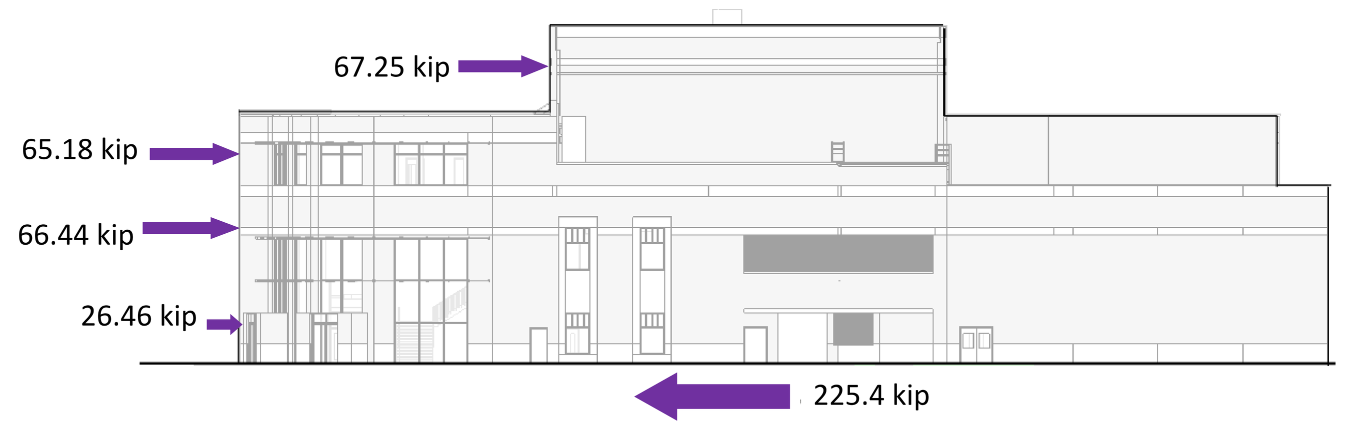
NOT FOR CONSTRUCTION	AEI TEAM NO. 01-2019
DATE February 18, 2019	SCALE NOT TO SCALE
DRAWING NO. S-1.0	PAGE NO. 51

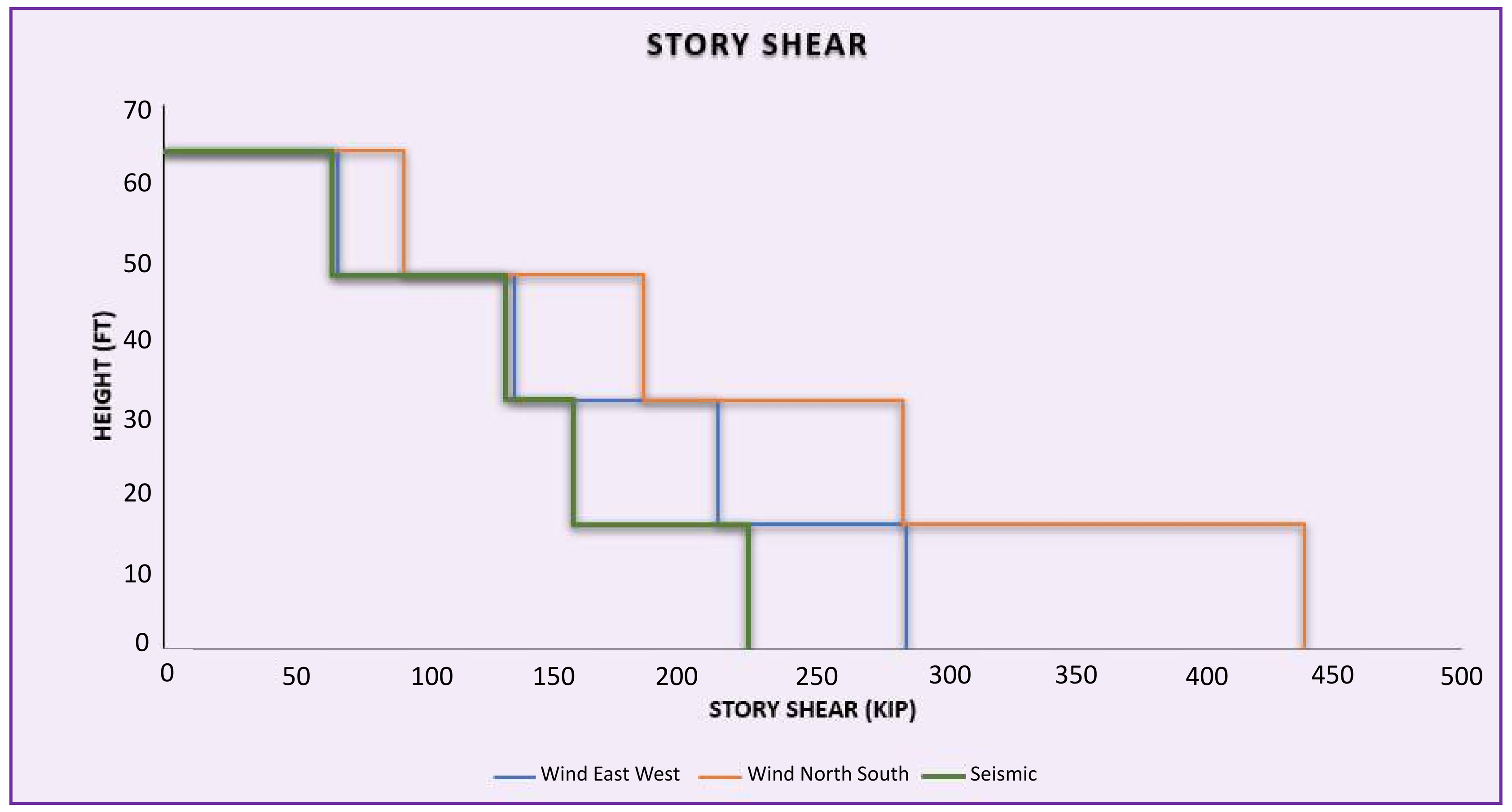
WIND STORY FORCES





SEISMIC STORY FORCES





GEOTECHNICAL DATA

Geotechnical Data	
Groundwater Height	8' - 9.6"
Frost Line	42"
qa	4500 psf

WIND LOAD PARAMETERS

Holland, MI Wind Loading Parameters	
Risk Category	1
Basic Wind Speed (V)	115 mph
Wind Directionality Factor (Kd)	0.85
Exposure Category	B
Topographic Factor (Kzt)	1
Gust Factor Effect	0.85
Enclosure Classification	Enclosed
Interior Pressure Coefficient (Gcpi)	0.18
Terrain Exposure Constants	α = 11.4
	zg = 760
Wind Pressure (qh)	25.6 psf

Wall Pressure Coefficients		
Cp	N-S	E-W
Windward	0.8	0.8
Leeward	-0.45	-0.5

Wind Direction	Building Dimensions (ft)	L/B	Cp
N-S	190	1.25	-0.45
E-W	237	0.80	-0.50

SEISMIC LOAD PARAMETERS

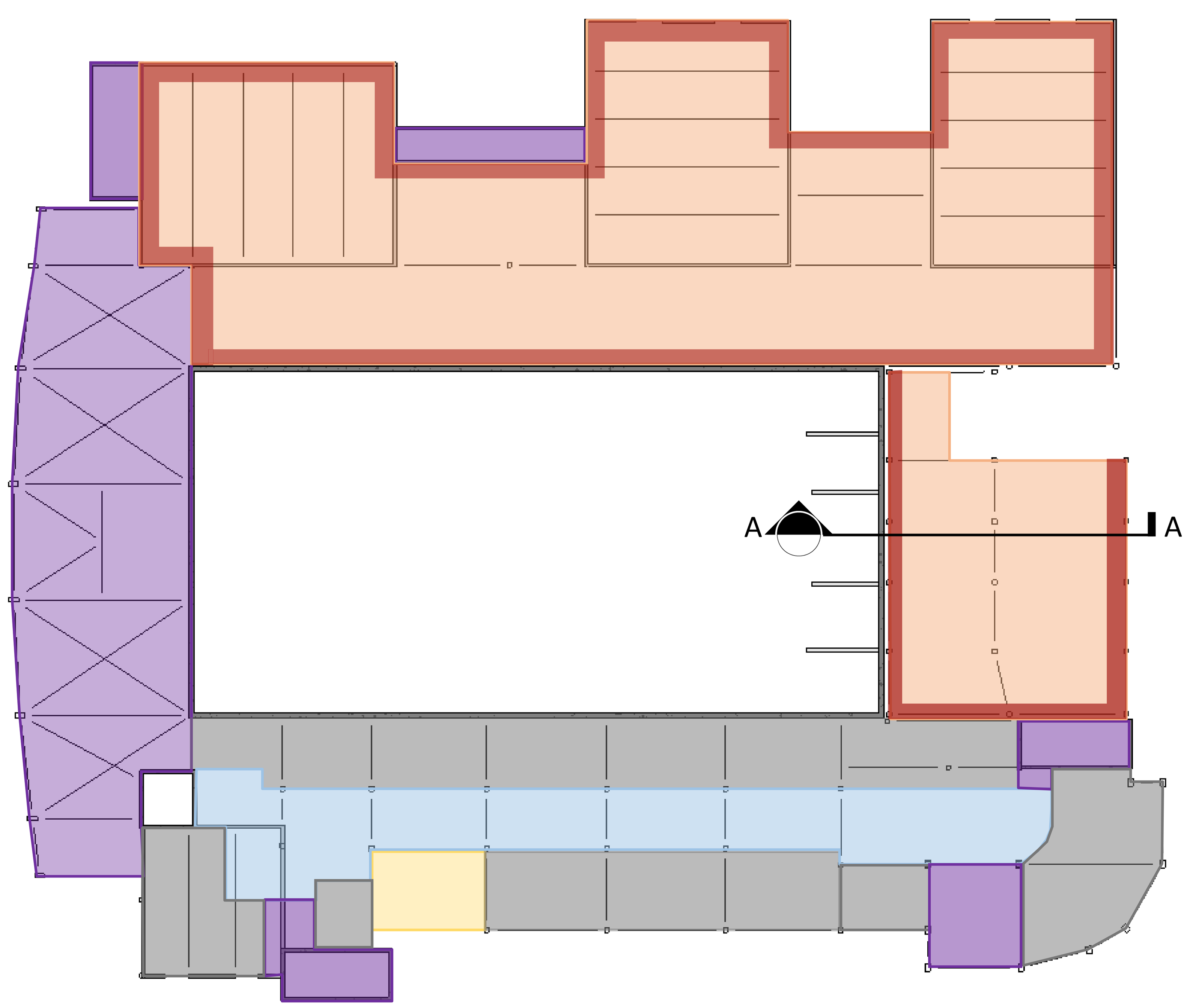
Calculated Values	
Seismic Weight	7268.9
Cs	0.031
Base Shear (kip)	225.3

USGS Report Data	
Ss	0.087
S1	0.049
Sms	0.139
Sm1	0.117
Fa	1.6
Fv	1.4
Sds	0.093
Sd1	0.078
TL	12
PGA	0.042
Seismic Design Category	B

Seismic Data	
Seismic Site Class	D
Building Class	III
Ie	1
Risk Category	I

ASCE 7-16 Data	
Lateral System	Bearing Wall
R	3
Cd	3
Ω	2.5

GRAVITY LOADING



Live/Snow Load Map

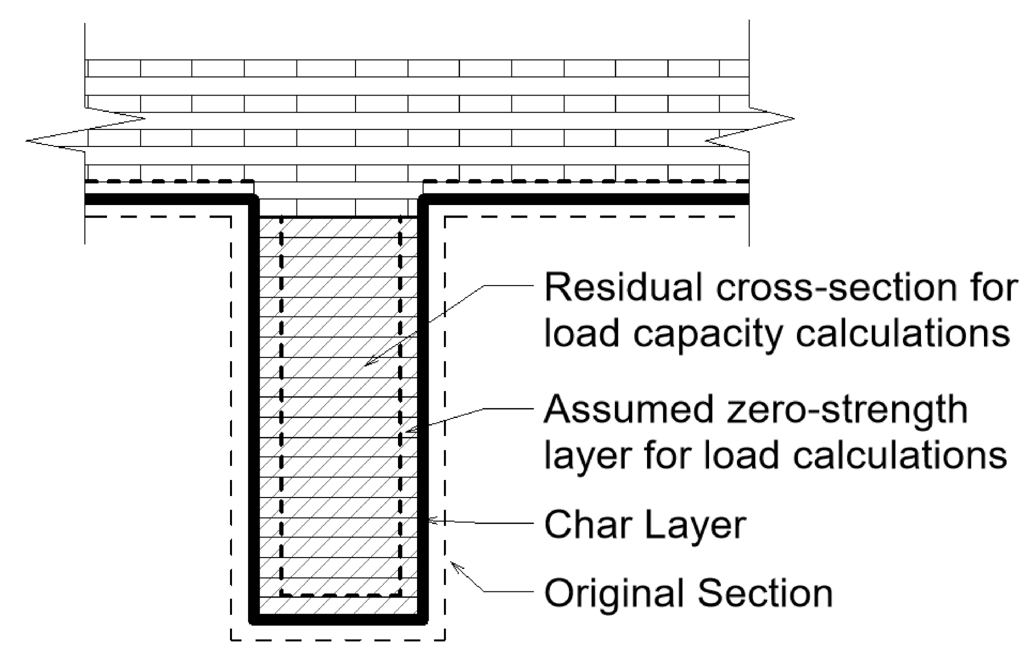
Live Load	Weight (psf)
Stage Floor	150
Stairs	100
Library	100
Lobbies	100
Mechanical	100
Corridor above First Floor	80
Bathroom	60
Assembly (fixed seats)	60
Offices	50
Catwalk	40

LOADING KEY

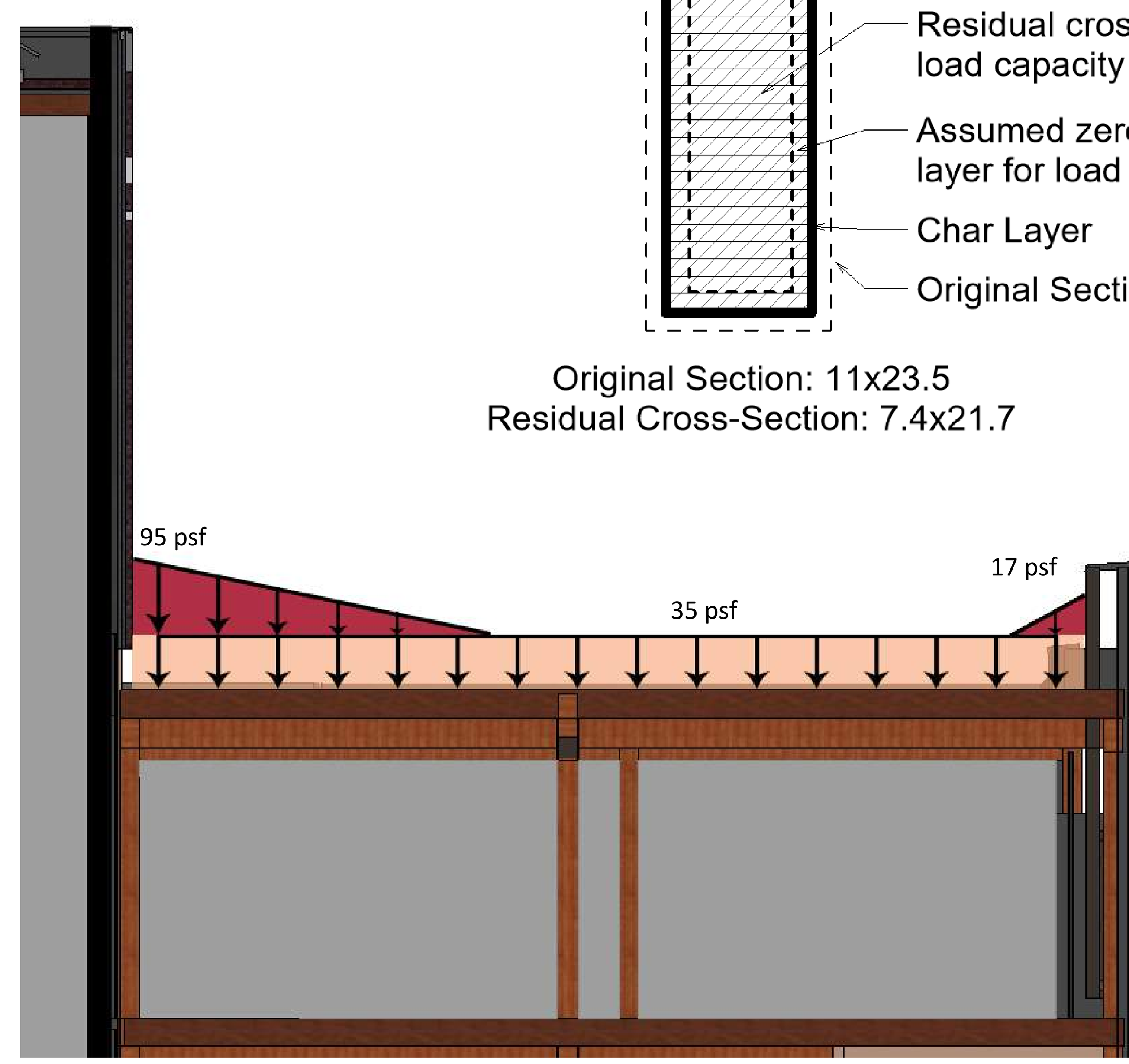
Live Loads
- 100 psf - Library, Stairs, Assembly
- 80 psf - Corridor
- 60 psf - Bathroom
- 50 psf - Offices

Snow Loads
- 35 psf - Flat Roof Snow Load
- Varies - Snow Drift

BEAM CHAR THEORY



Original Section: 11x23.5
Residual Cross-Section: 7.4x21.7



Snow Drift (Section A-A)

SYNDICATE

PROJECT
JACK H. MILLER CENTER FOR MUSICAL ARTS
HOLLAND, MICHIGAN

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LOADING

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AEI TEAM NO.
01-2019

DATE
February 18, 2019

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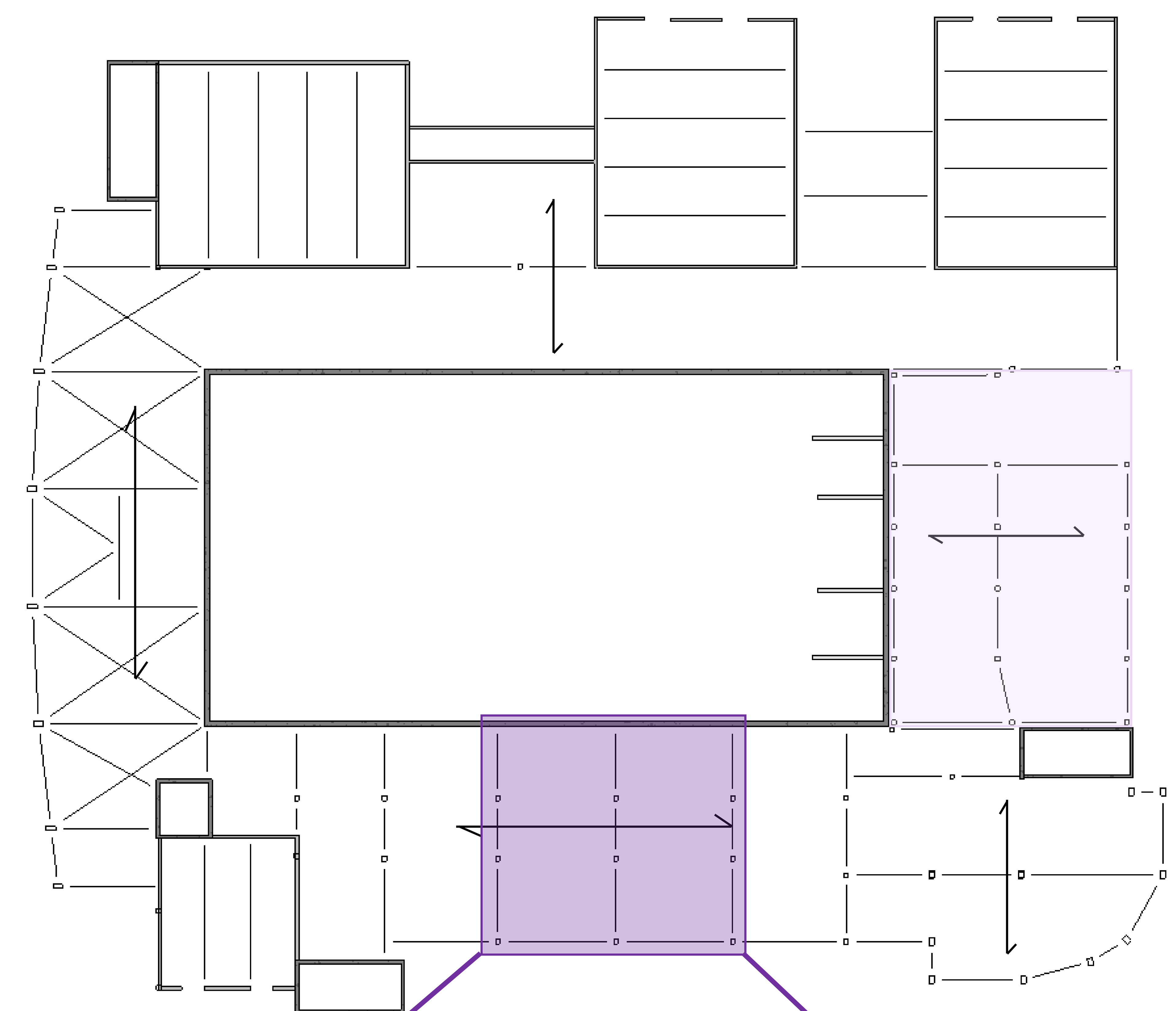
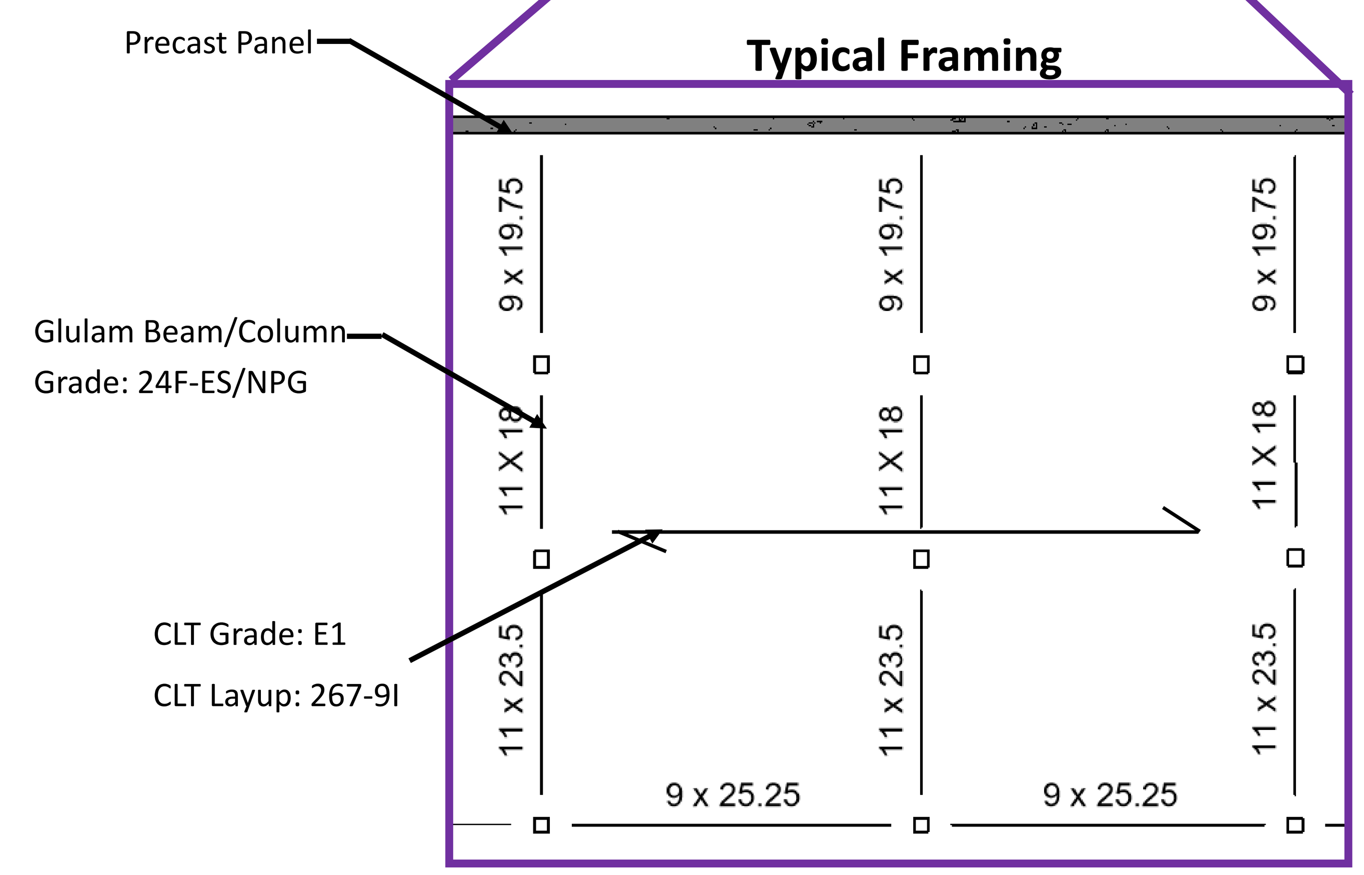
DRAWING NO.
S-2.0

PAGE NO.
52

LEVEL 2 FRAMING PLAN





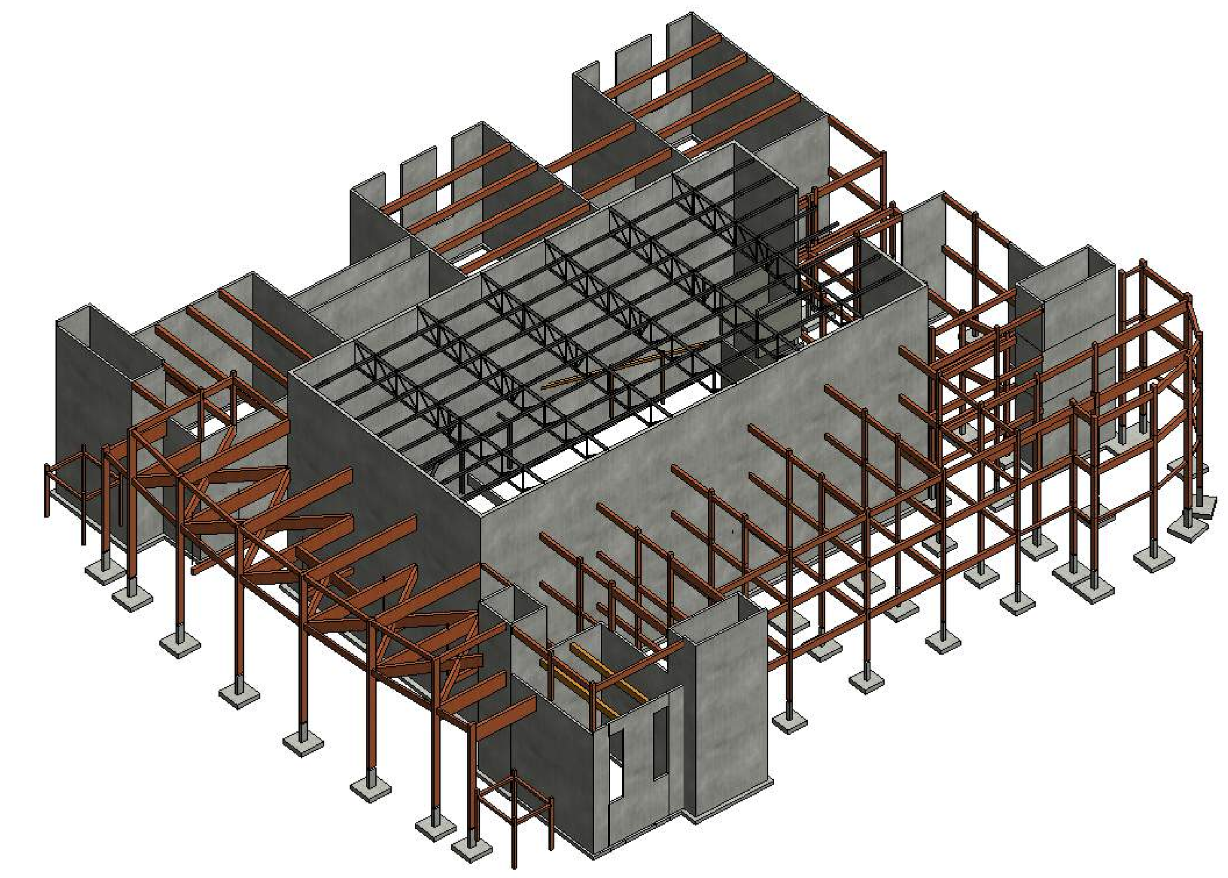
TAKEOFFS

Glue-Laminated Timber Beams				
Quantity	With	Depth	Length	
			Min	Max
7	7.25	23.5	11' - 0"	24' - 0"
12	9	9	5' - 8"	17' - 8"
1	9	10.5	11' - 0"	11' - 0"
4	9	14.25	11' - 0"	13' - 8"
4	9	16	11' - 0"	15' - 9"
1	9	18	15' - 9"	15' - 9"
5	9	19.75	14' - 7"	14' - 7"
9	9	21.5	14' - 7"	24' - 6"
8	9	25.25	24' - 6"	24' - 6"
1	9	24	29' - 0"	29' - 0"
6	11	16	12' - 5"	14' - 0"
30	11	18	12' - 5"	25' - 0"
7	11	19.75	14' - 8"	16' - 0"
17	11	21.5	10' - 0"	27' - 0"
16	11	23.5	10' - 7.5"	21' - 9"
40	11	25.25	6' - 4"	28' - 0"
1	11	29	24' - 0"	24' - 0"
5	11	30.75	20' - 9"	28' - 0"
2	11	32.5	24' - 0"	28' - 0"
1	11	34.25	28' - 0"	28' - 0"
1	11	36.25	29' - 2"	29' - 2"
14	11	39.75	21' - 2.5"	42' - 4"
3	11	41.5	16' - 8"	28' - 7"
4	11	50.75	34' - 7"	34' - 7"
8	11	54.5	35' - 0"	35' - 0"
6	12.875	25.25	28' - 0"	37' - 0"
8	12.875	29	41' - 0"	42' - 0"

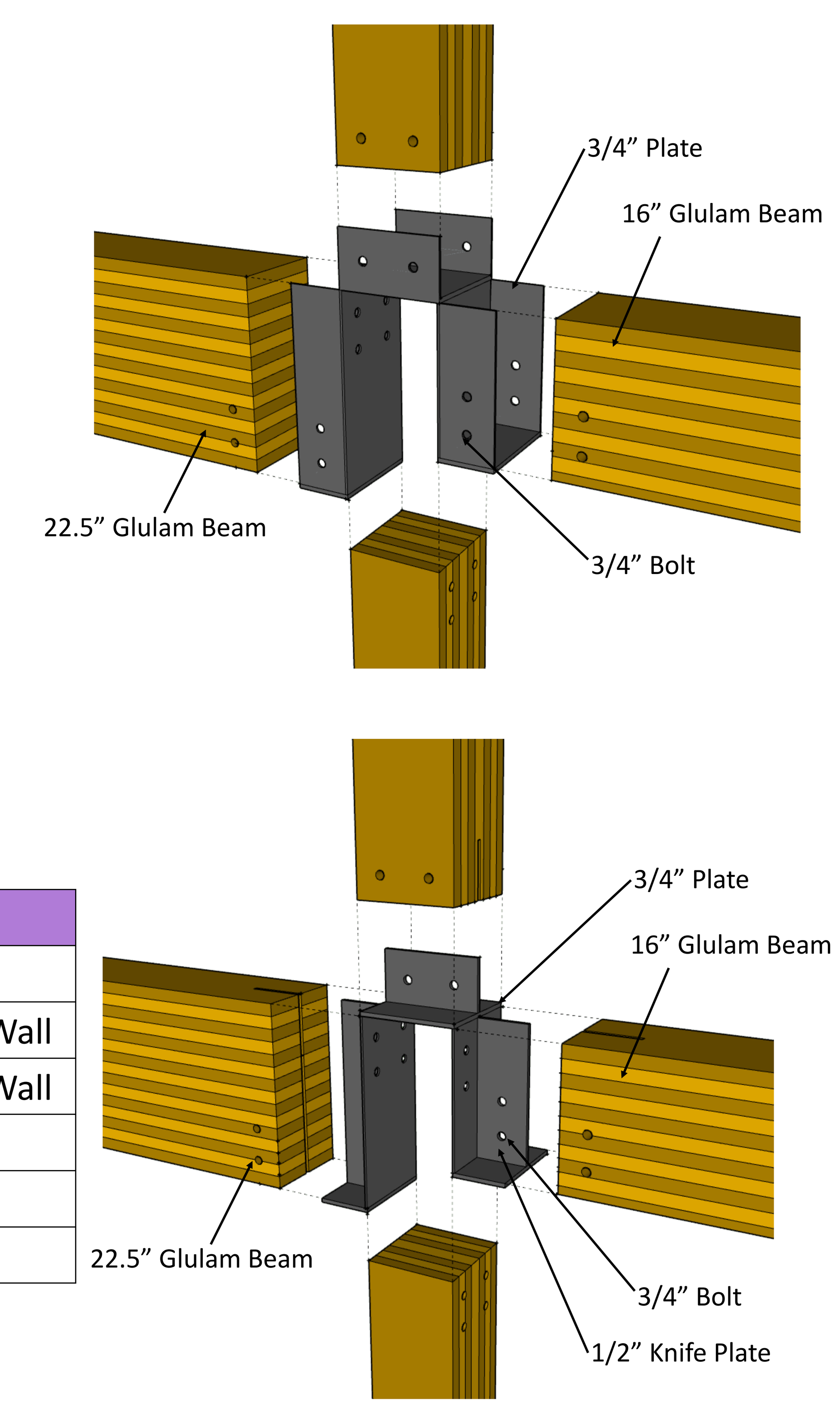
Glue-Laminated Timber Columns			
Quantity	width	depth	Lenth
8	9	9	16' - 0"
65	11	11	
32	11	12.5	
22	11	23.5	
4	12.875	12.875	
28	12.875	18	

Building Element	Type 3A (hours)	Design
Primary Structural Frame	1	Char
Exterior Bearing Walls	2	Minimum 4.6" Precast Wall
Interior Bearing Walls	1	Minimum 3.2" Precast Wall
Interior Nonbearing Walls and Partitions	0	N/A
Floor Construction	1	Char
Roof Construction	1	Char

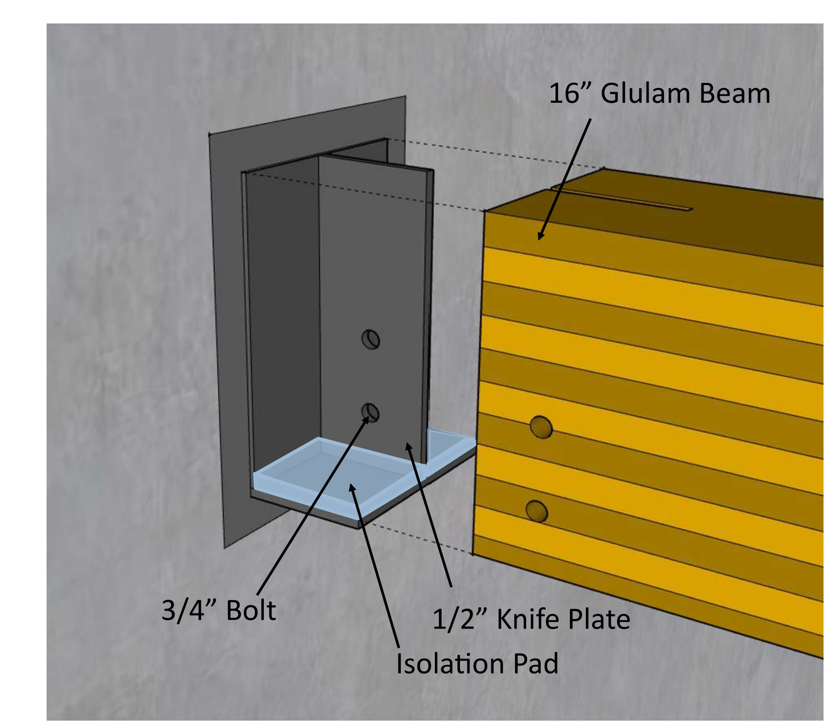
3D MODEL OF STRUCTURE



BEAM-COLUMN CONNECTIONS

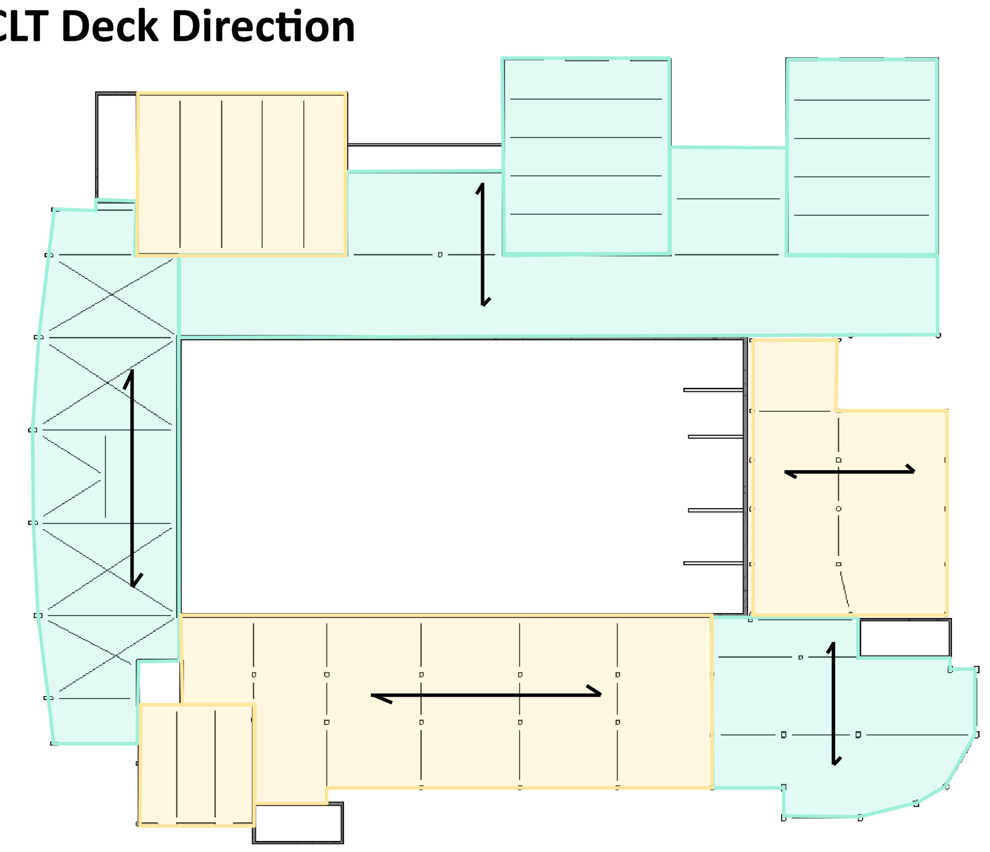


BEAM-WALL CONNECTIONS



Two standard connection configurations were designed to provide the glulam manufacturer with multiple fabrication options. The knife plate option can also be used in locations where hidden connections are preferred.

CLT Deck Direction



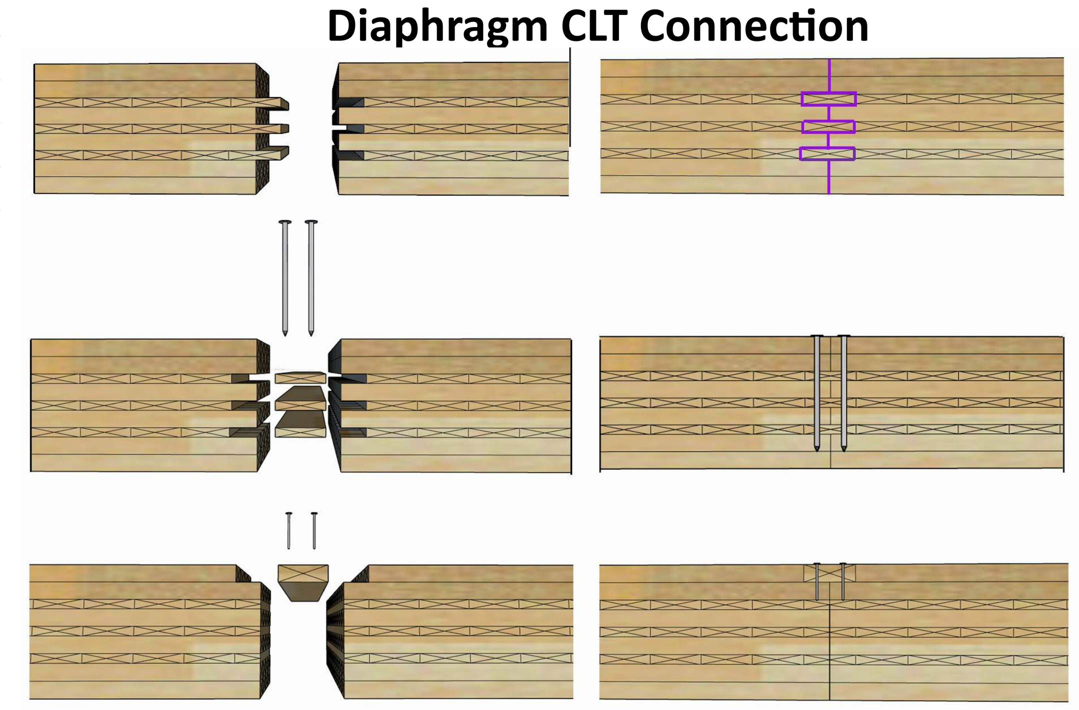
CROSS LAMINATED TIMBER

CLT Layer Thickness									
Layer	1	2	3	4	5	6	7	8	9
E1: 267-9l	1.375	1.75	0.75	1.375	0.75	1.375	0.75	1.375	1.375
E1: 105-3s	1.375	1.375	1.375						

Cross-Laminated Timber					
Thickness	Quantity	Width		Length	
		min	max	min	max
10.5"	282	1' - 6"	9' - 0"	6' - 0"	24' - 2"
6.875"	69	2' - 0"	8' - 6"	20' - 0"	30' - 0"

Syndicate's structural team designed their diaphragm to act as a rigid diaphragm. To do so, multiple options for panel-to-panel connections for the cross-laminated timber were considered. The team opted to choose Option 3 for constructability purposes.

Diaphragm CLT Connection



SYNDICATE

PROJECT

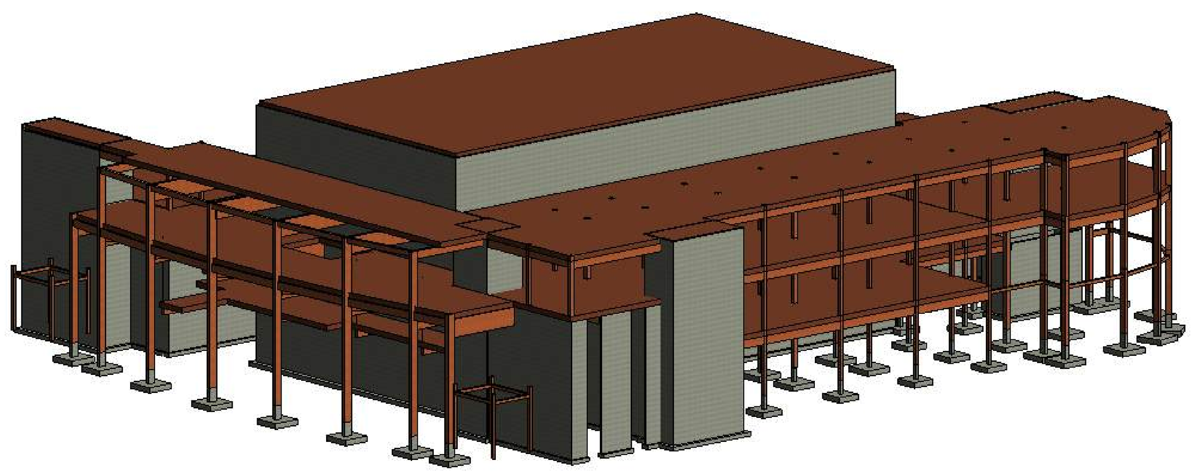
JACK H. MILLER CENTER FOR MUSICAL ARTS

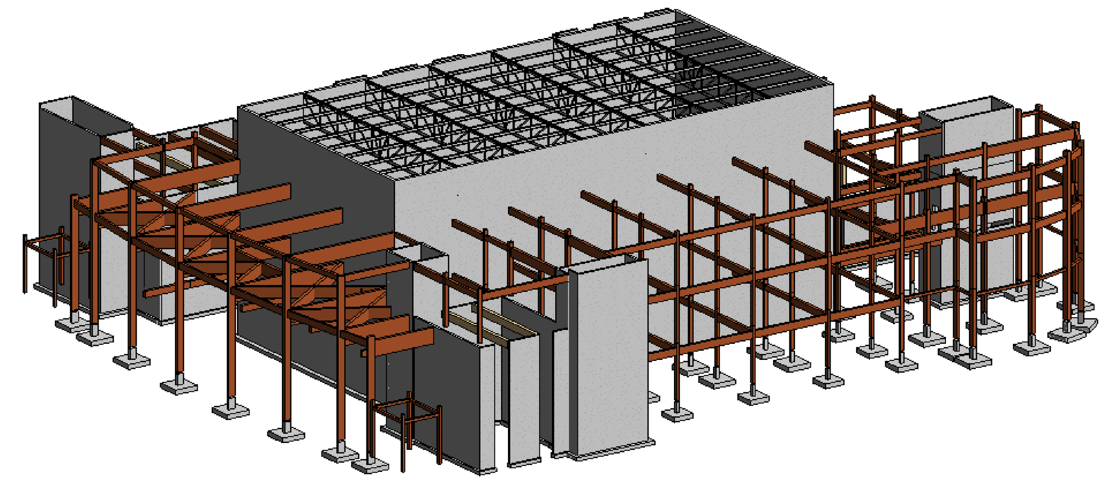
HOLLAND, MICHIGAN

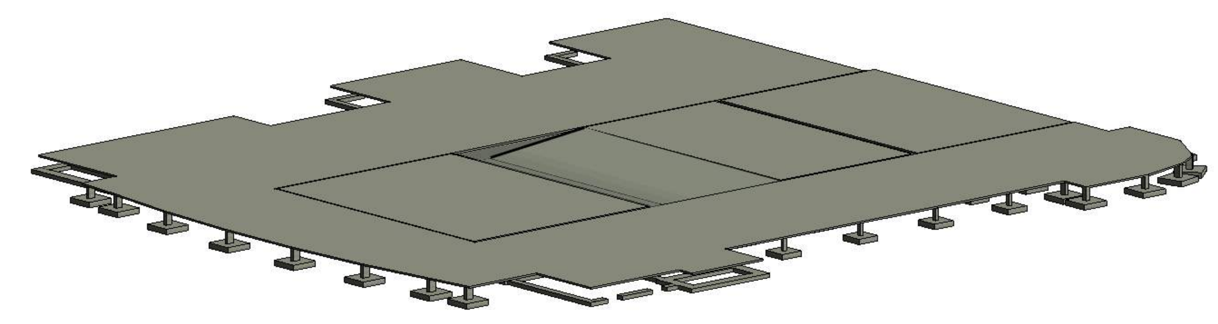
SHEET TITLE

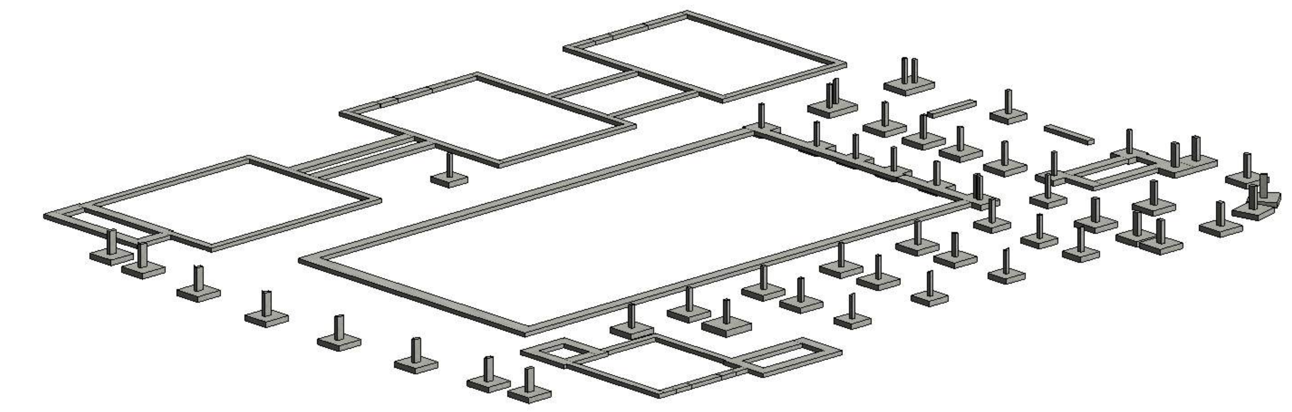
TYPICAL FLOOR PLAN

NOT FOR CONSTRUCTION	AEI TEAM NO. 01-2019
DATE February 18, 2019	SCALE NOT TO SCALE
DRAWING NO. S-3.0	PAGE NO. 53

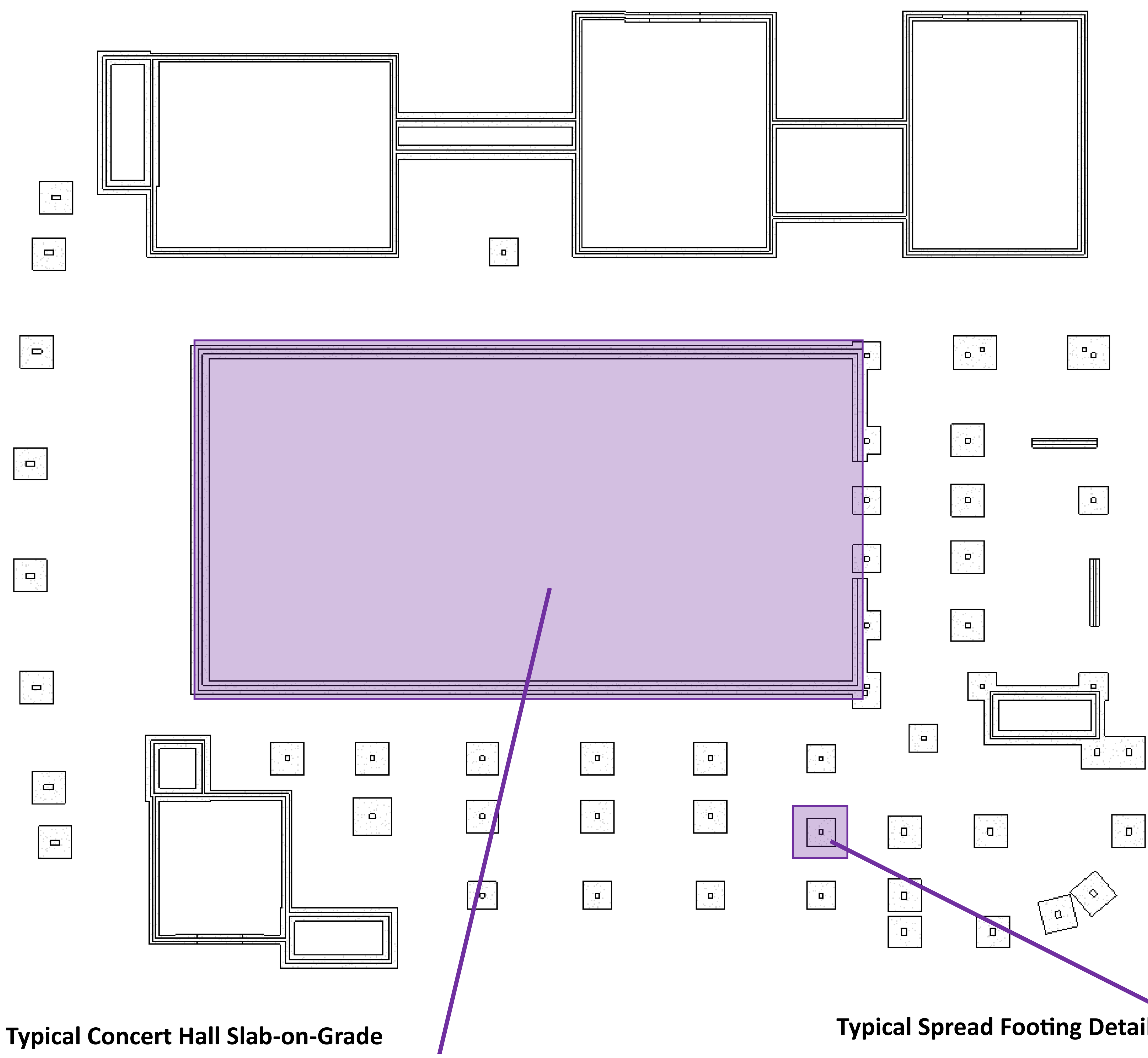

Complete Structure


Structure without Decking

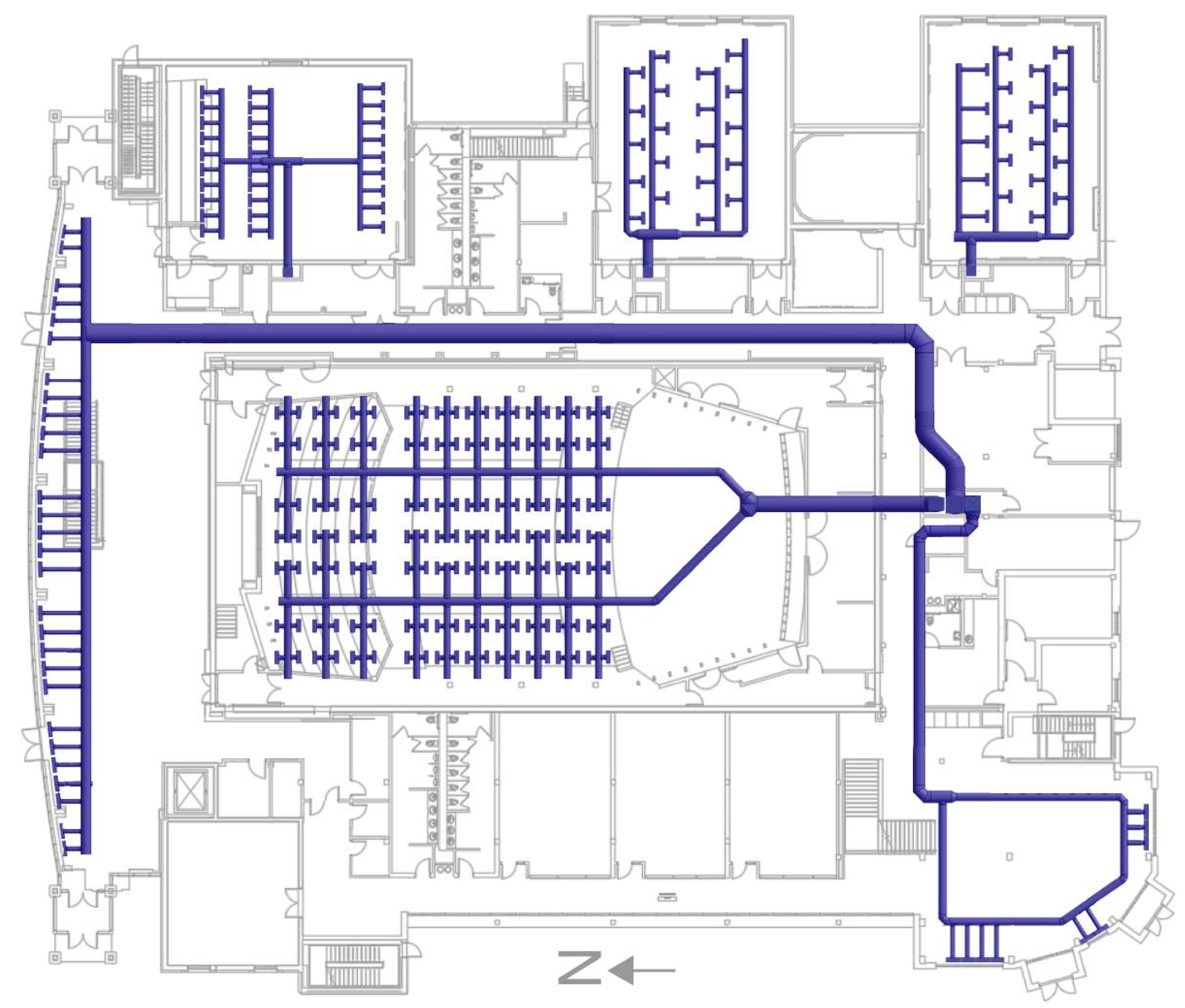

Spread and Strip Foundations with Slab On Grade


Spread and Strip Foundations

FOUNDATION PLAN



Mechanical Underground Blue Duct Plan

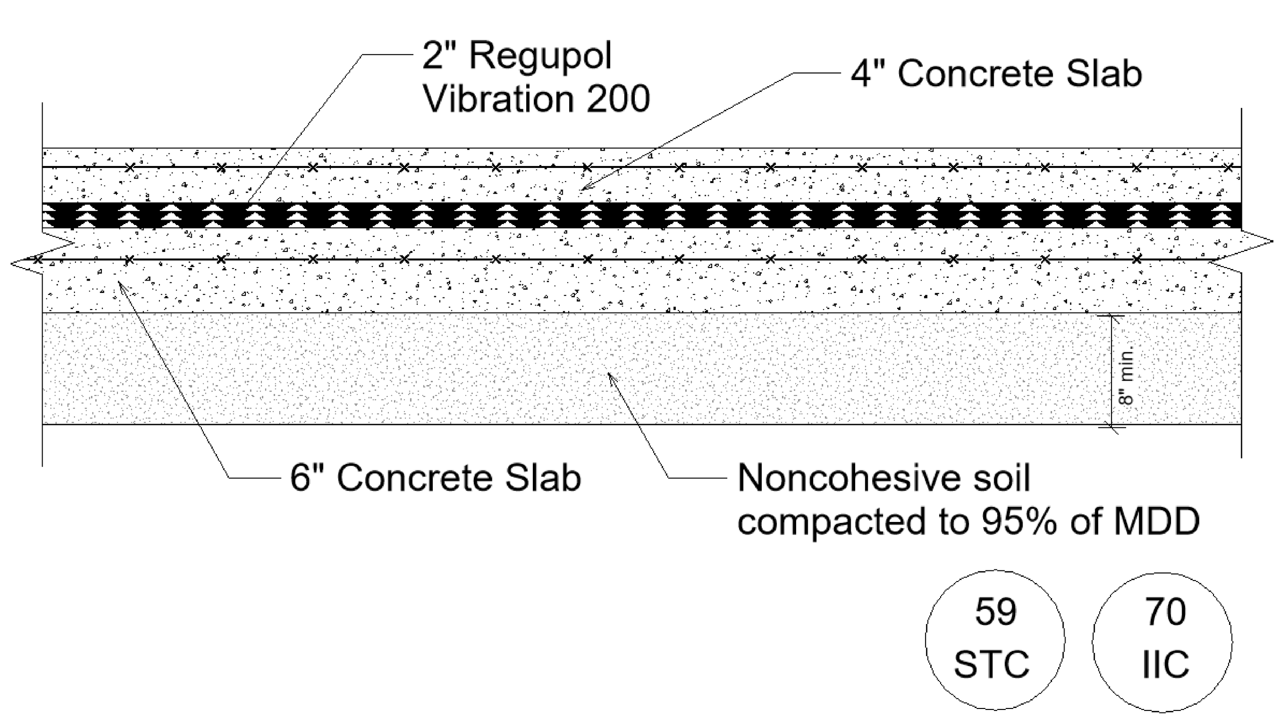


Spread Footing Schedule					
Depth (in)	Width (ft)	Compressive Strength Concrete (psi)	Reinforcing Bars	Spacing	Amount
20	8' - 0" x 8'- 0"	4000	#6	10" O.C.	1
16	6' - 0" x 6' - 0"		#6	12" O.C.	17
16	7' - 0" x 7' - 0"		#6	12" O.C.	29
16	9' - 0" x 7' - 6"		#6	12" O.C.	3

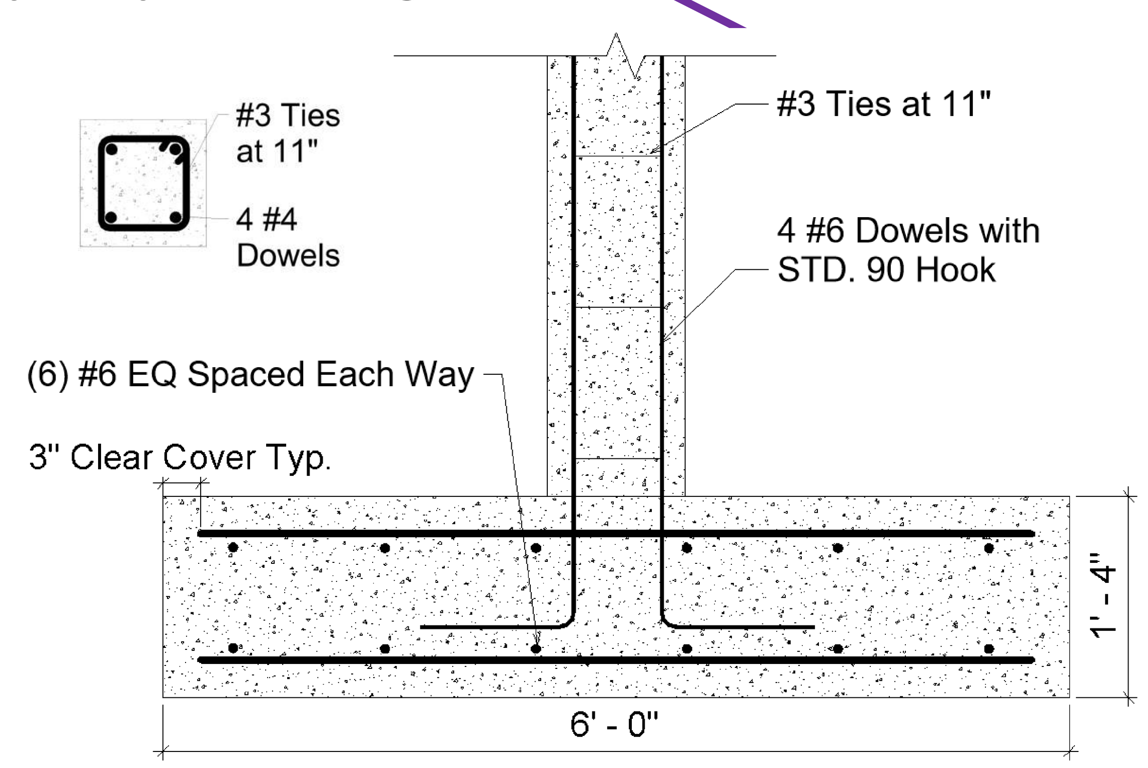
Concrete Pier Schedule						
Depth (in)	Width (in)	Length (in)	Compressive Strength Concrete (psi)	Reinforcing		Amount
				Vertical	Ties	
11	11	72	4000	4 #5	#3 @ 10" O.C.	22
11	12.5			4 #6	#3 @ 11" O.C.	12
12.875	12.875			4 #5	#3 @ 10" O.C.	1
12.875	18			6 #6	#3 @ 12" O.C.	10
11	23.5			6 #6	#3 @ 11" O.C.	8

Strip Footing Schedule						
Location	Depth (in)	Width (ft)	Length	Compressive Strength Concrete (psi)	Reinforcing Bar	Temperature & Shrinkage
Long Concert Hall Wall	12	4	279' - 0"	4000	#4 @ 6" O.C.	#4 @ 6" O.C.
North Concert Hall Wall	12	4	73' - 4"		#4 @ 8" O.C.	#4 @ 8" O.C.
South Concert Hall Wall	12	3	73' - 4"		#4 @ 8" O.C.	#4 @ 8" O.C.
Recital/Rehersal Walls	12	2	576' - 8"		#4 @ 12" O.C.	#4 @ 12" O.C.
Stair/Elevator Walls	12	3	321' - 0"		#4 @ 12" O.C.	#4 @ 12" O.C.
Organ/Mechanical Space Walls	12	2	154' - 6"		#4 @ 12" O.C.	#4 @ 12" O.C.

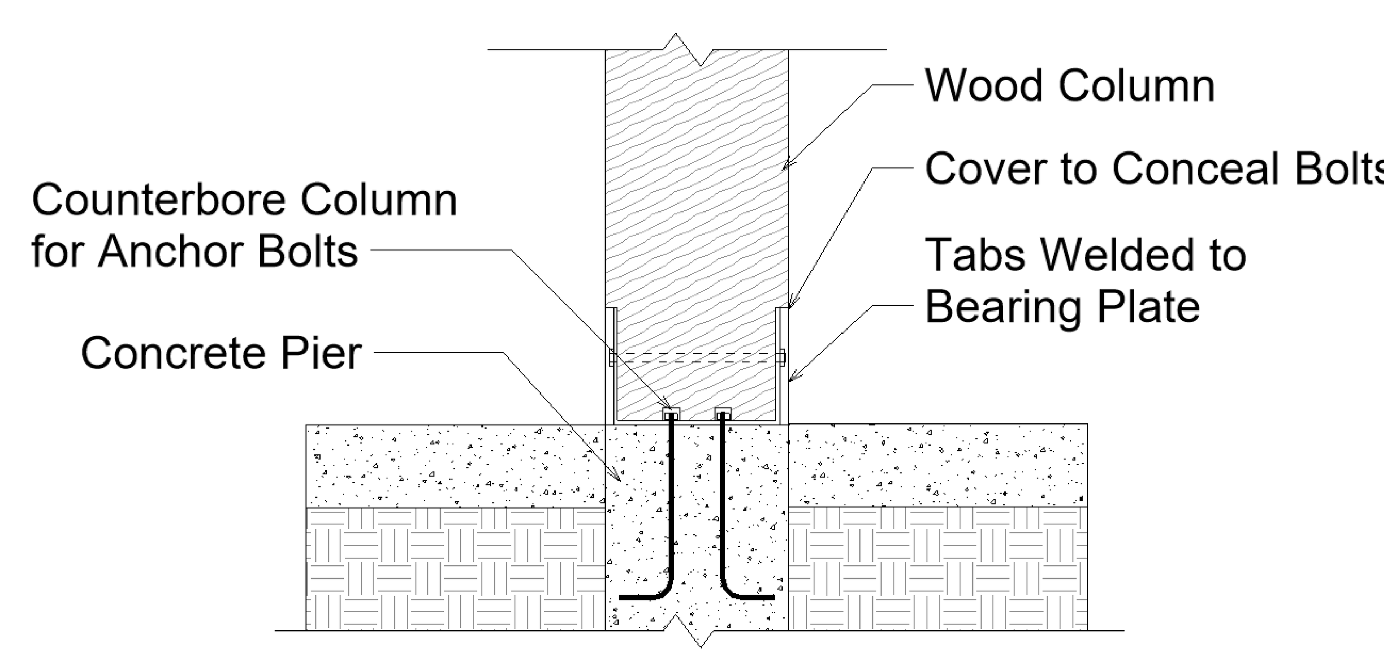
Typical Concert Hall Slab-on-Grade



Typical Spread Footing Detail



Wood Column to Concrete Pier Connection Detail



SYNDICATE

PROJECT

JACK H. MILLER CENTER FOR MUSICAL ARTS

HOLLAND, MICHIGAN

SHEET TITLE

FOUNDATION PLAN

NOT FOR CONSTRUCTION

AEI TEAM NO. 01-2019

DATE February 18, 2019

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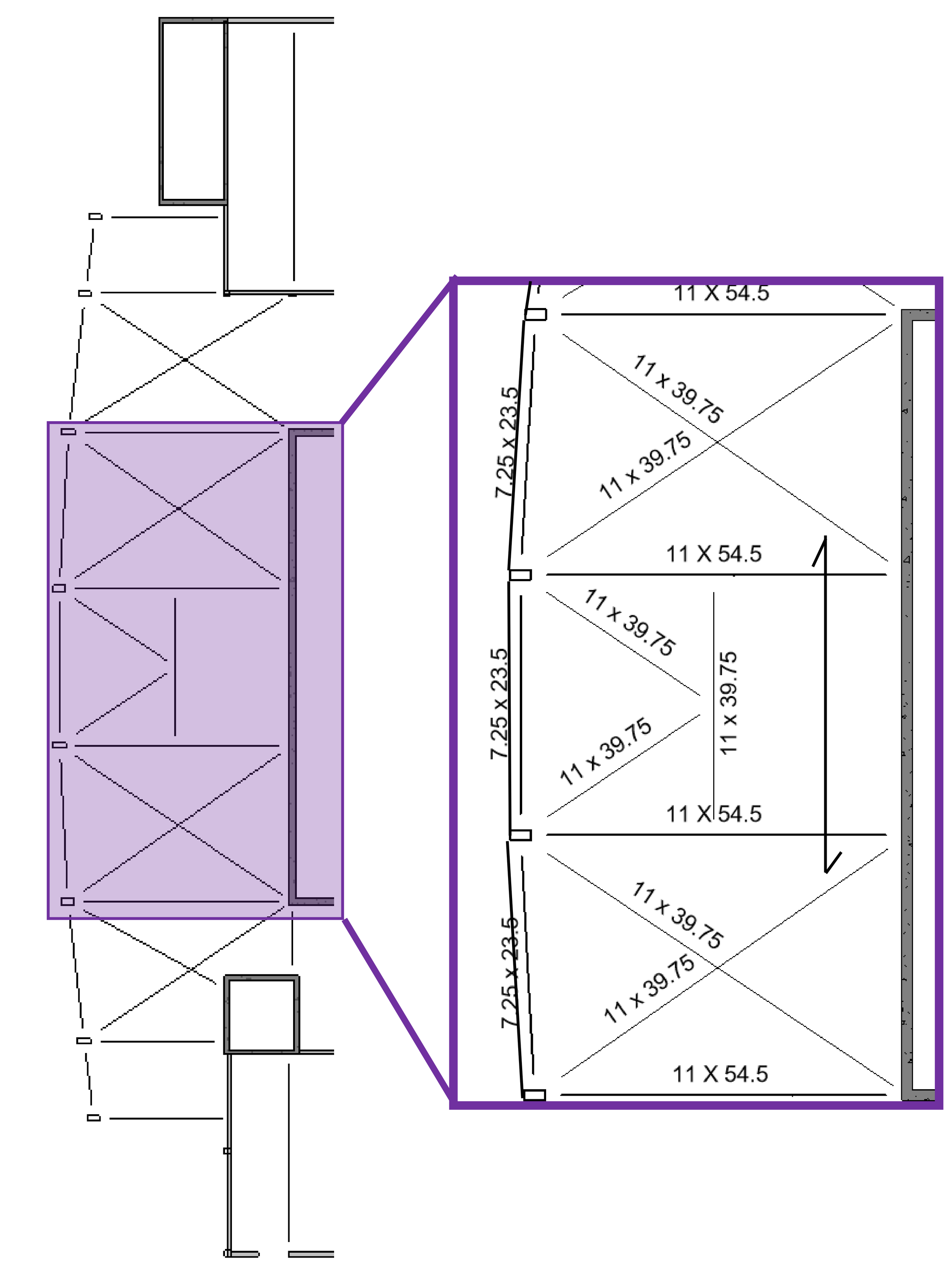
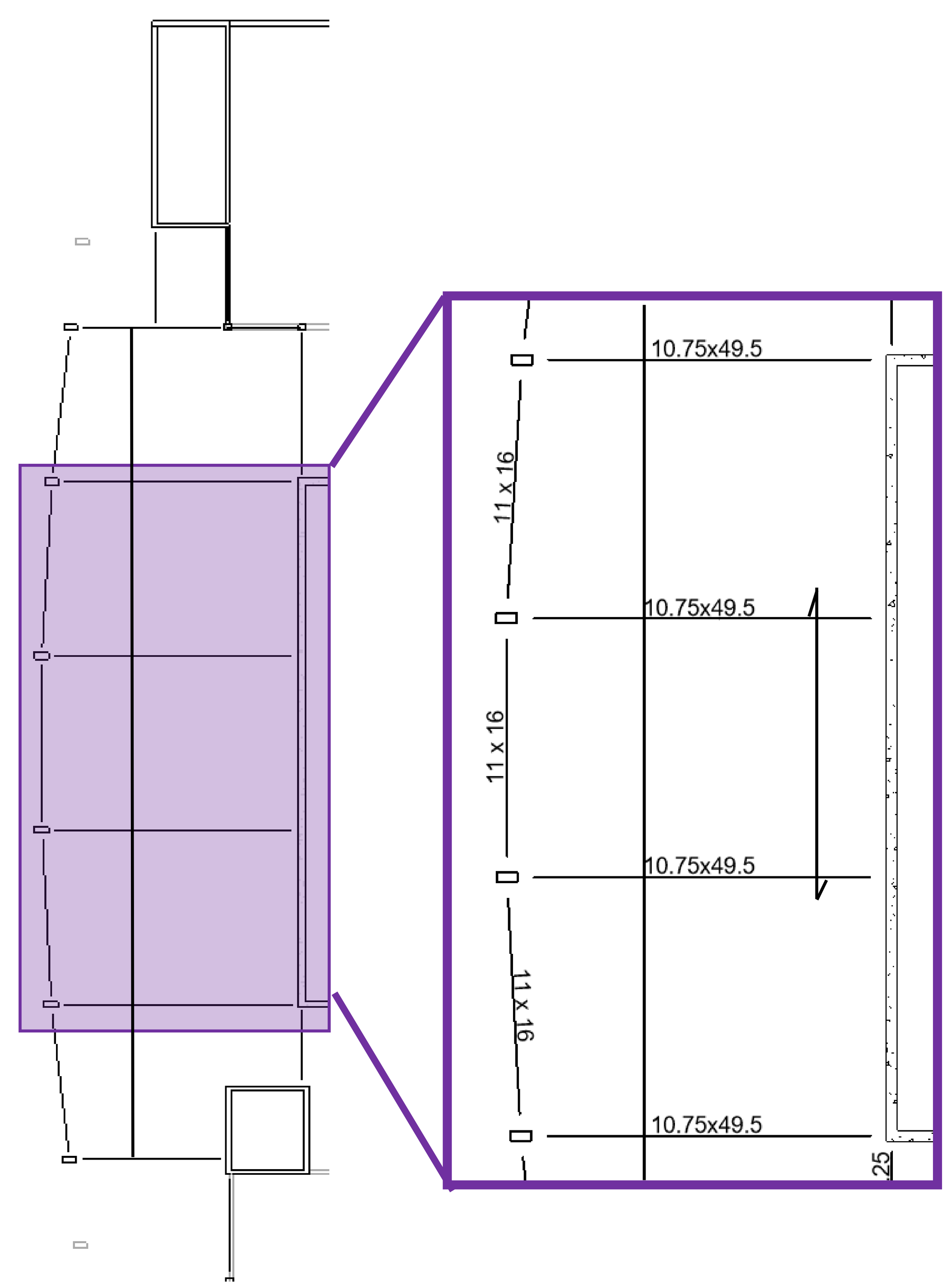
DRAWING NO. S-4.0

PAGE NO. 54

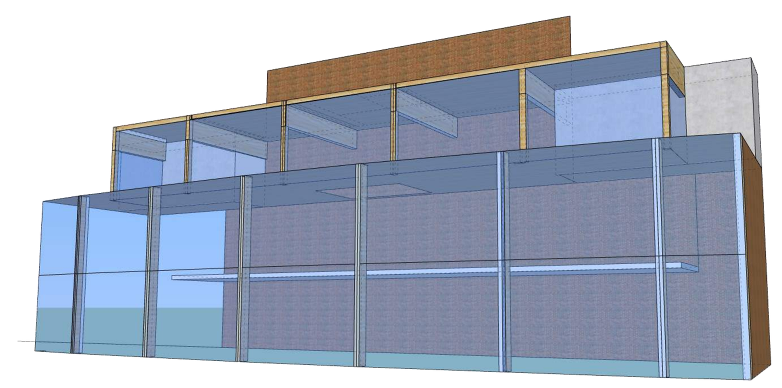
ATRIUM LAYOUT

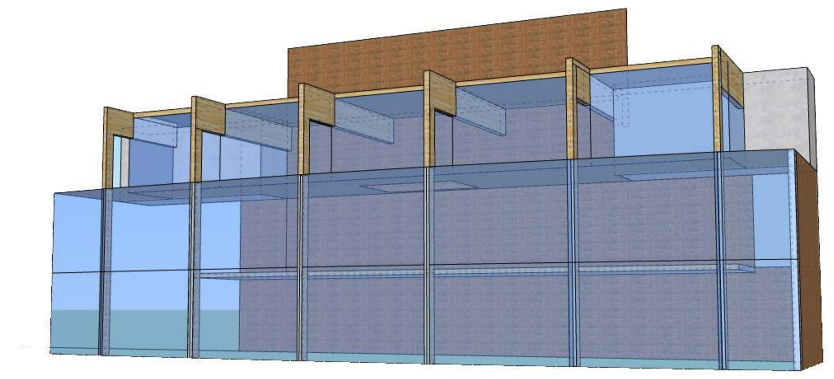


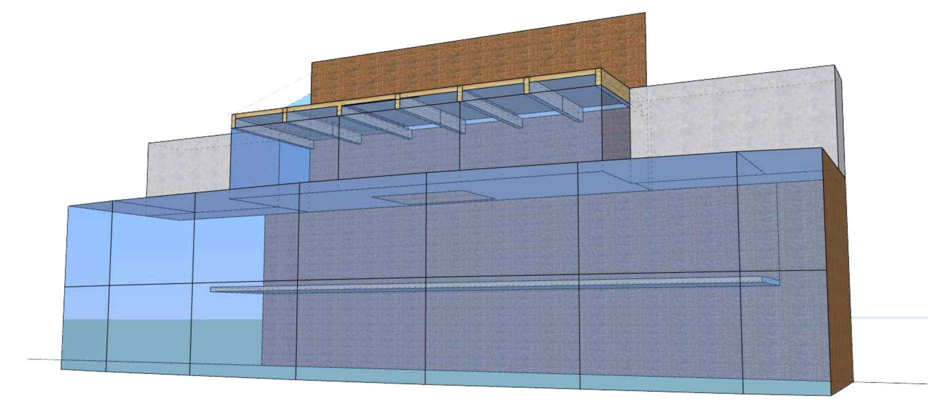
OCCUPIABLE ROOF LAYOUT

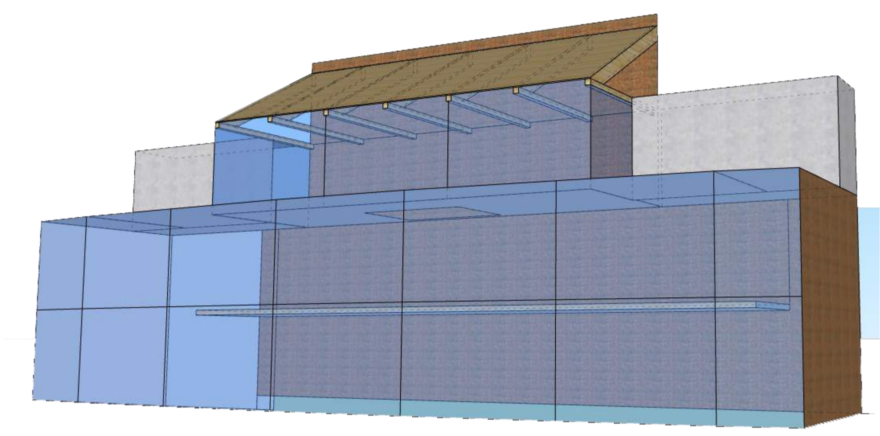


OCCUPIABLE ROOF ITERATIONS


Iteration 1


Iteration 2

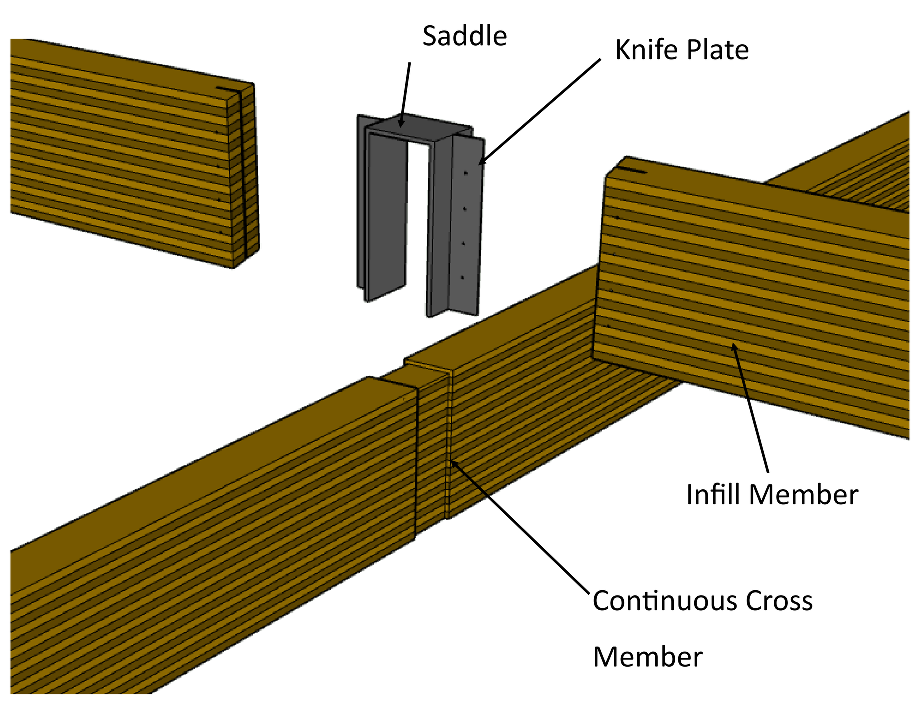

Iteration 3a


Iteration 3b

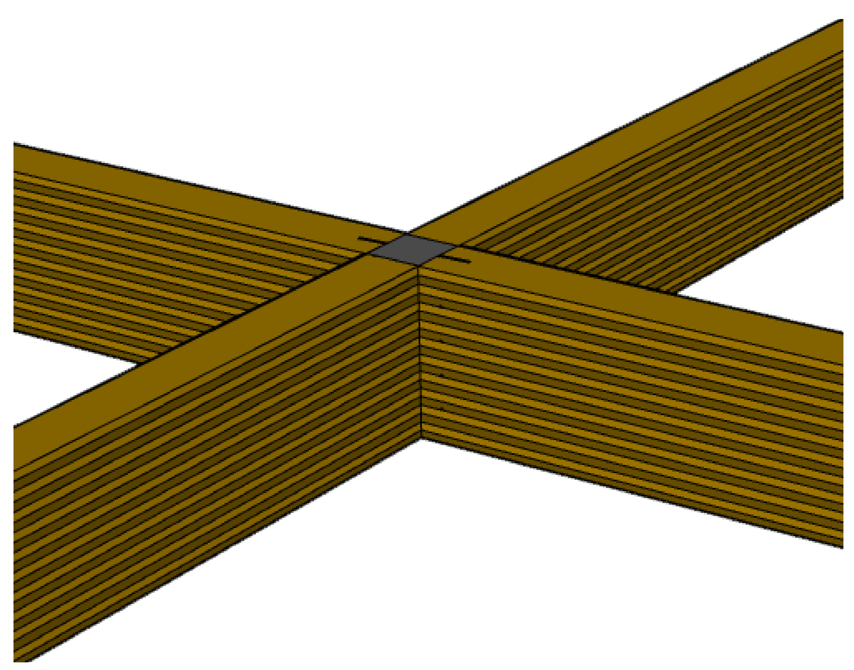
The four iterations above were performed to determine the optimum layout for the occupiable roof to maximize the occupant experience and create a statement of sustainability. For the final design *Syndicate* chose iteration 2. This structure, due to its depths, added dimension to the space, demonstrated sustainability and continued the same aesthetic that was developed in the north lobby.

Occupiable Roof Design		
Iteration	Description	Conclusion
1	• Columns sit at the face of the curtain wall on the occupiable roof • Bay size: 24' x 24'-6" • Girders span: 24' – 6" • CLT span: 24'	• Applied point loads on the main girders in the North Lobby, increasing the member size by 13%
2	• Columns line up with the columns in the North Lobby below • Bay size: 24' x 35' • Girders size: 11 x 49.5	• Reduced load on the North Lobby beams below • Increased beam size due to longer spans • Columns and exterior beams are visible from the street level
3a	• Girders span 24' – 6" and a steel tension rods are used to tie back the roof overhang to the concert hall walls above • Bay size: 12' x 24' – 6" • Glulam beam: 11 x 21.5 • CLT sits on the flat glulam beams	• Reduced visual impact from street level due to the small size of the rod
3b	• Girders span 24' – 6" and are tied back by glulam members to the concert hall at a 30-degree angle • Bay size: 12' x 24' – 6" • Flat glulam beam: 11 x 11 • Angled glulam beam: 11 x 29 • CLT sits on the angled member	• Angled roof line is visible from street level • Vault ceiling visible from the interior of the space

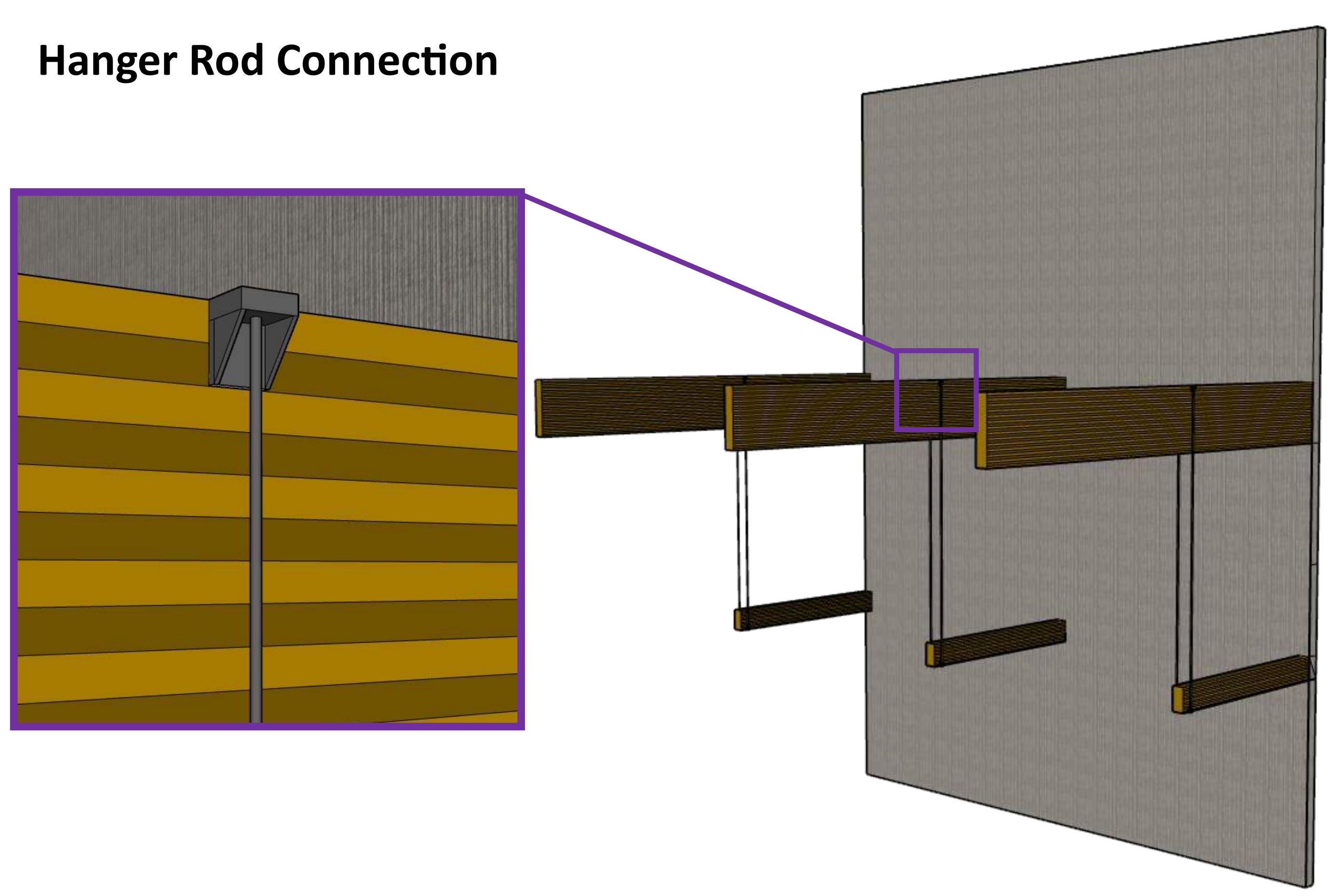
Cross Member Connection



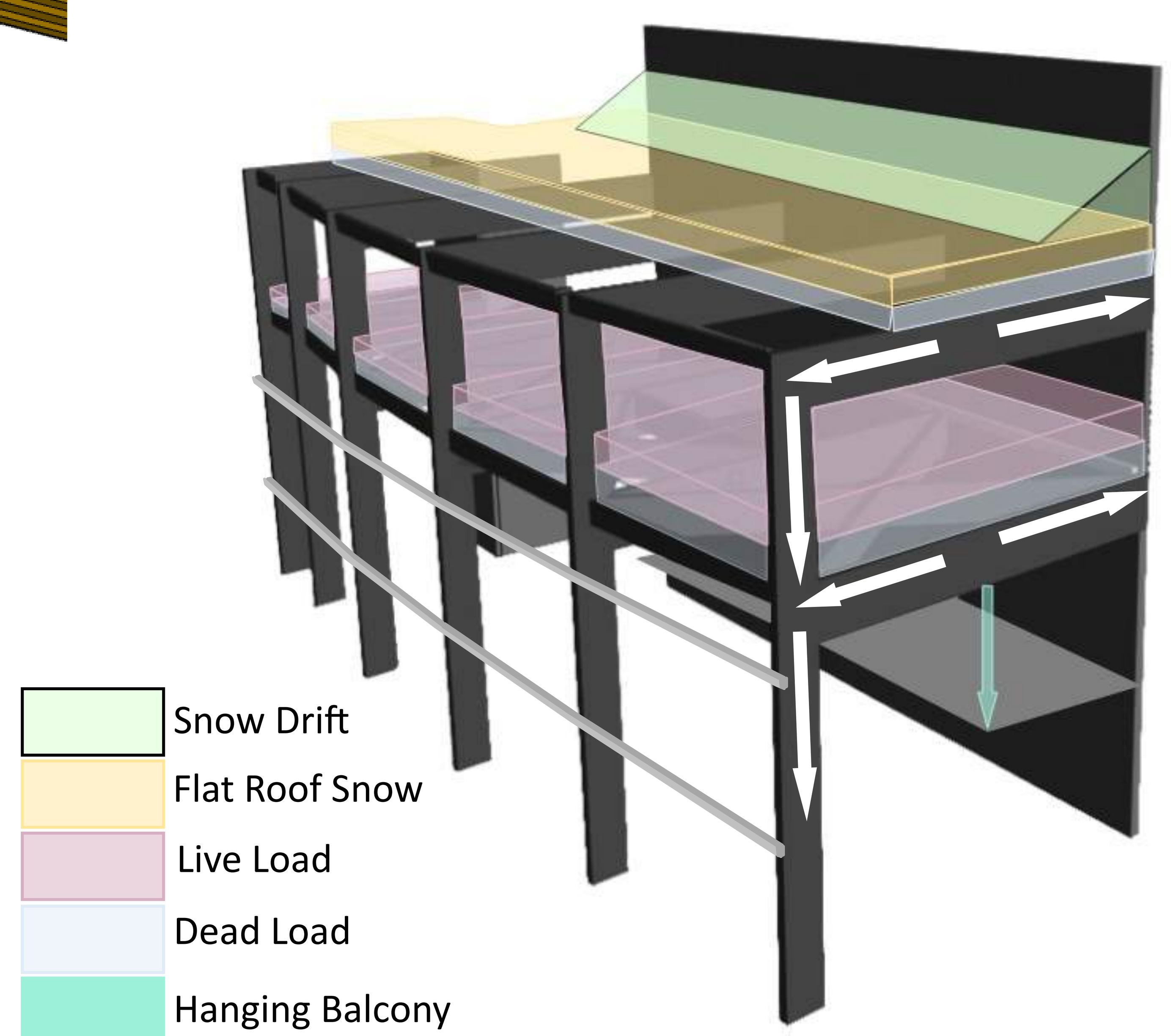
Exploded View


Constructed View

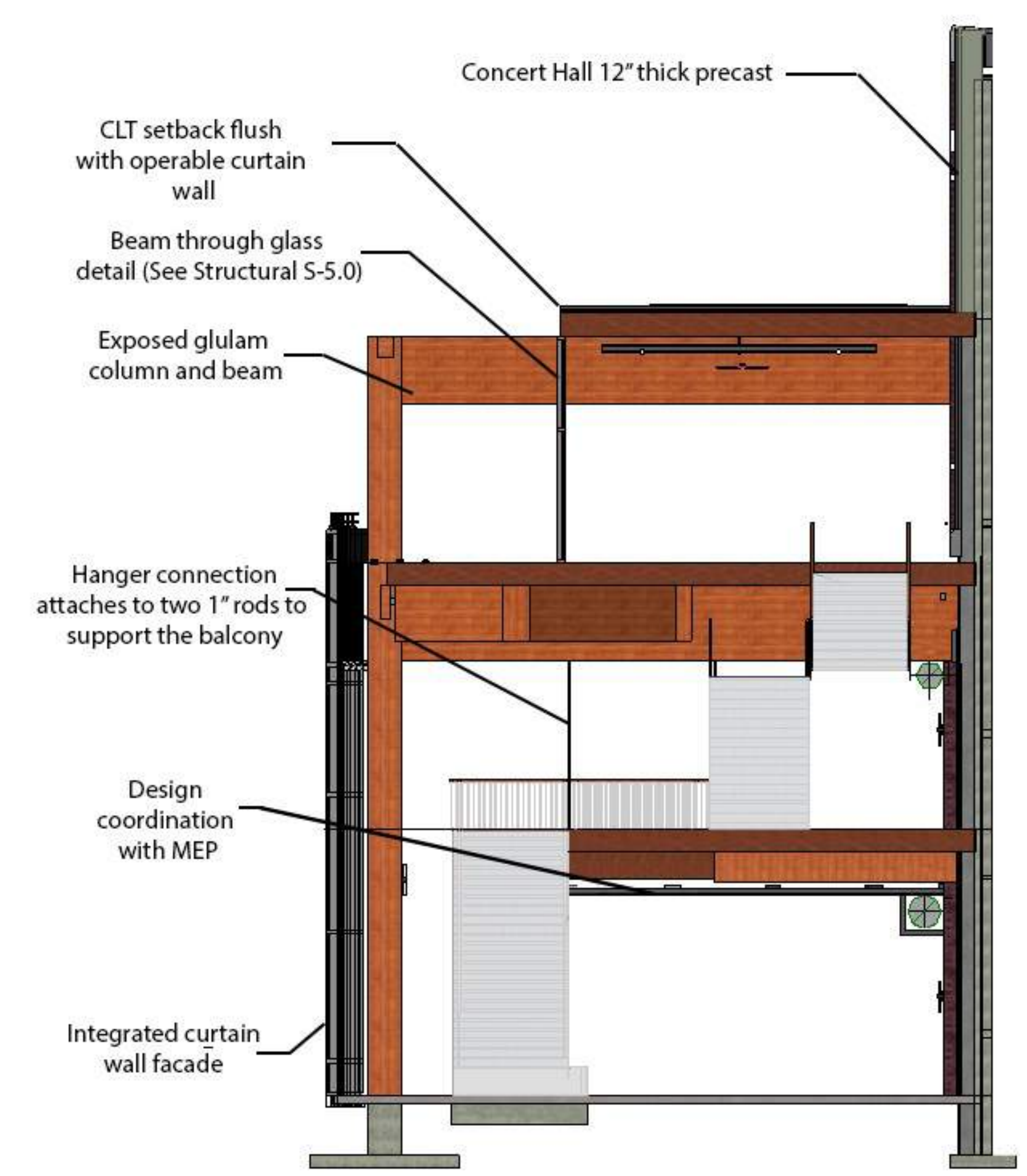
Hanger Rod Connection



Load Path Analysis



System Coordination



SYNDICATE

PROJECT

JACK H. MILLER CENTER FOR MUSICAL ARTS

HOLLAND, MICHIGAN

SHEET TITLE

ATRIUM / OCCUPIABLE ROOF

NOT FOR CONSTRUCTION

AEI TEAM NO. 01-2019

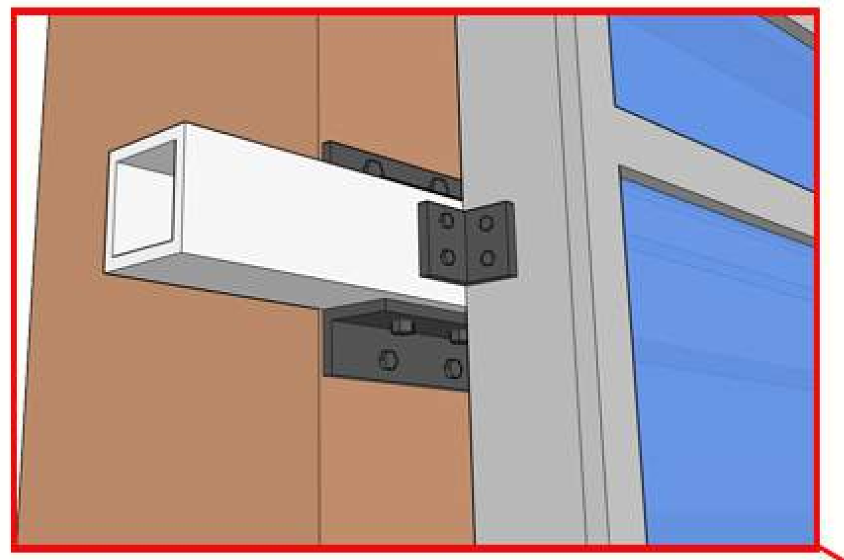
DATE February 18, 2019

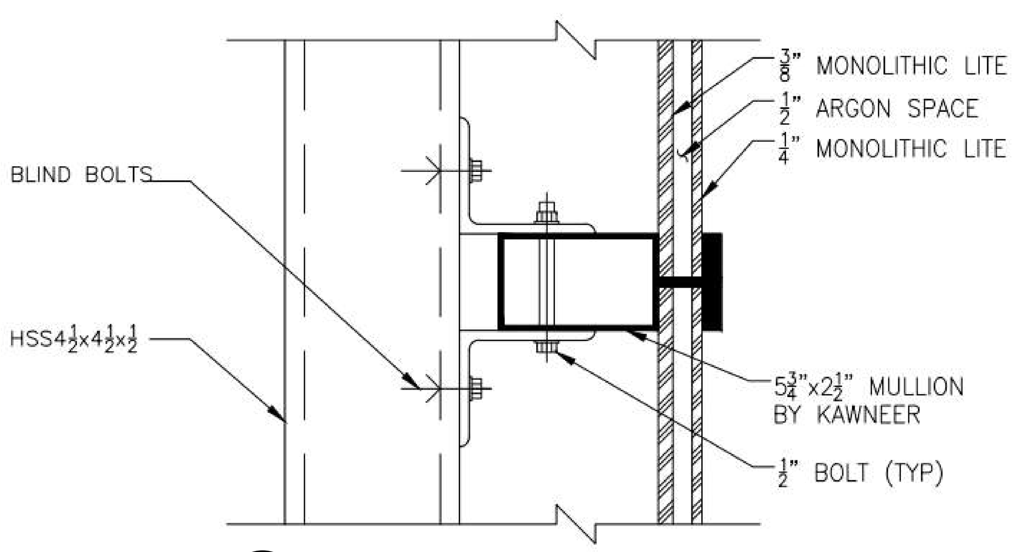
SCALE NOT TO SCALE

DRAWING NO. S-5.0

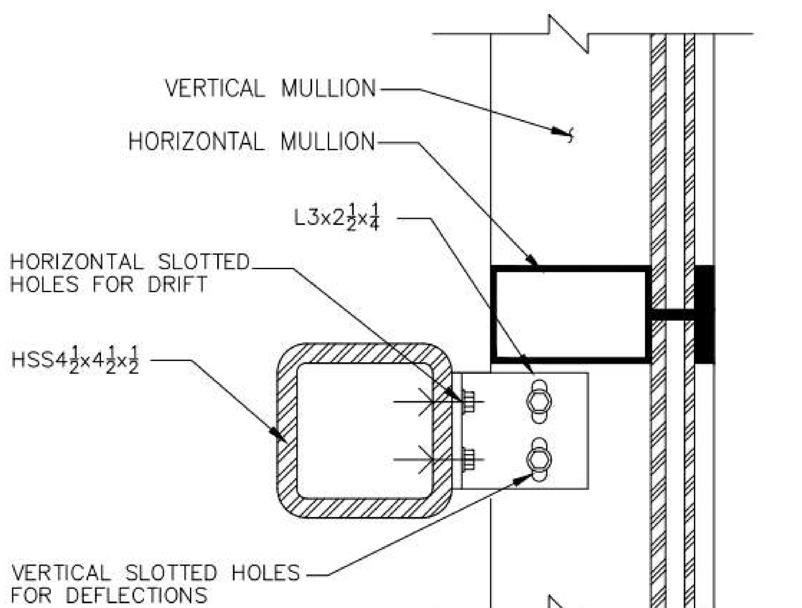
PAGE NO. 55

MULLION DESIGN AND CONNECTIONS

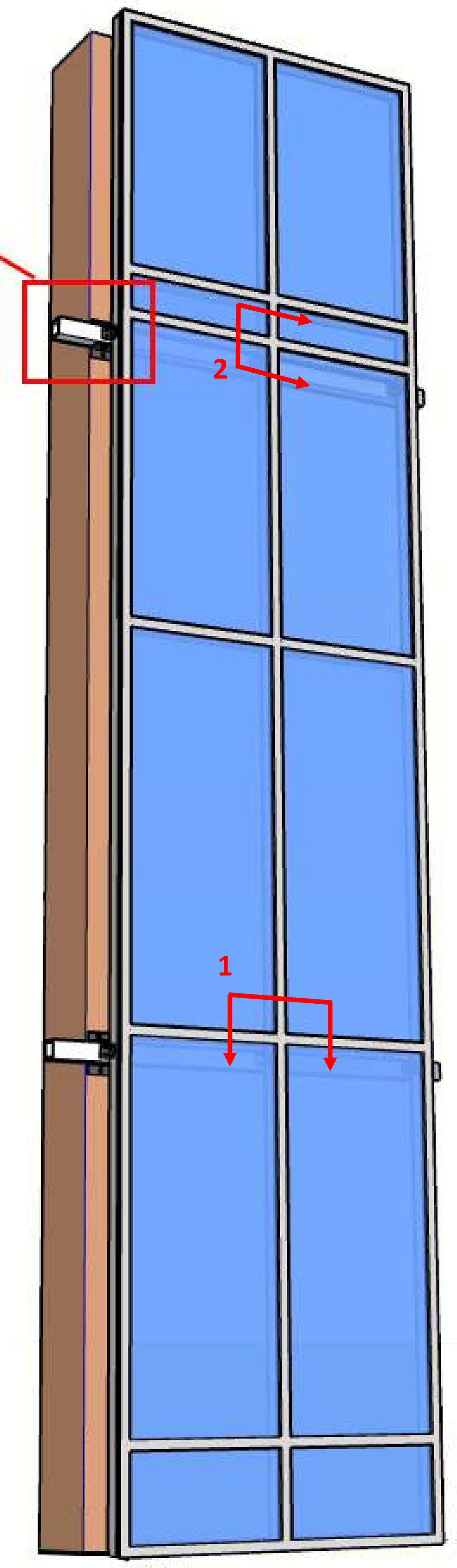




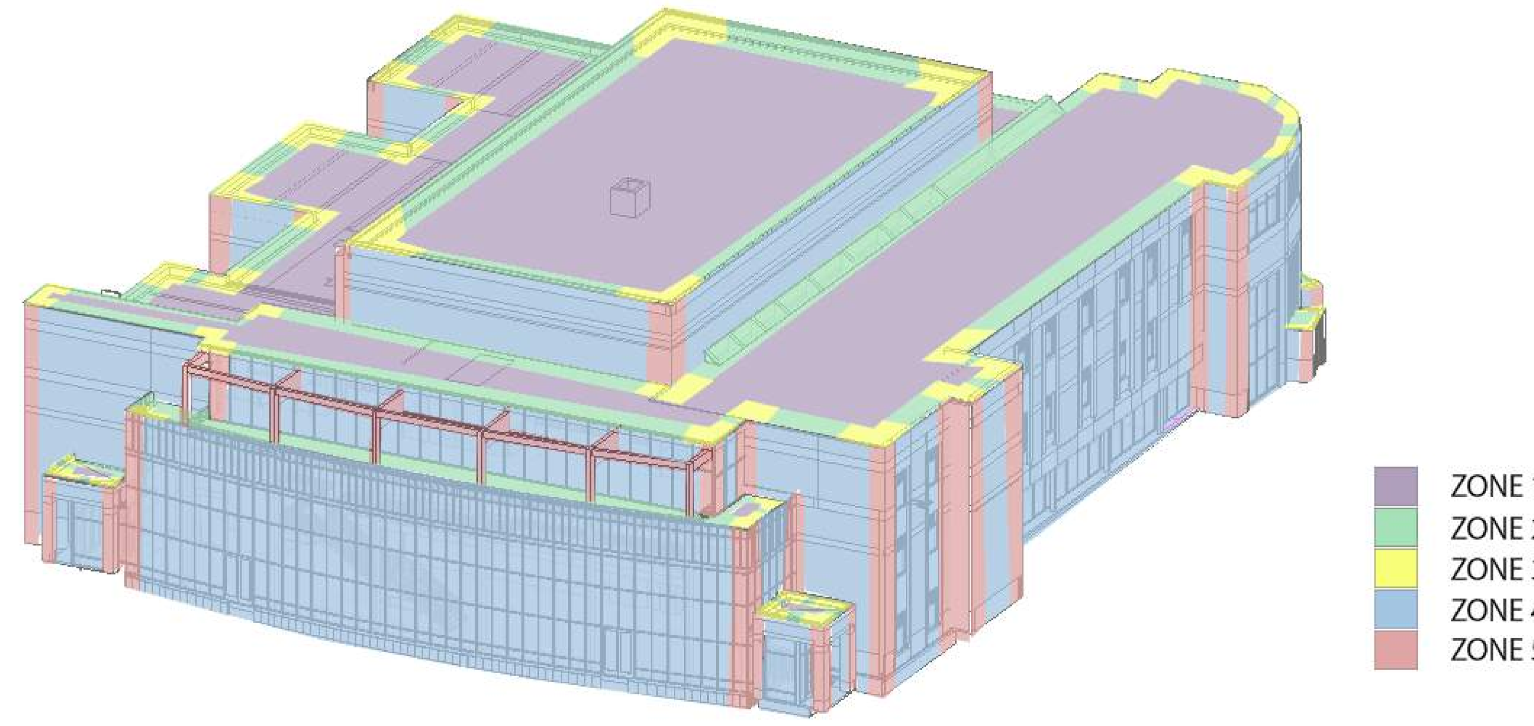
1 Vertical Mullion Detail



2 Horizontal Mullion Detail



C&C WIND PRESSURES



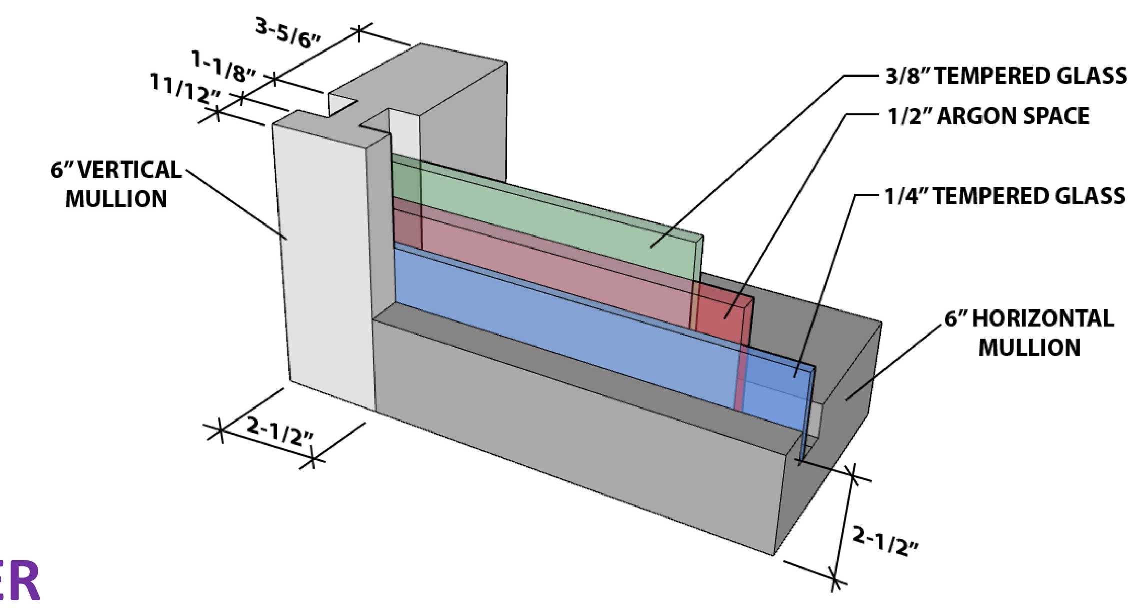
Glazing panel sizes ranged from 2'-0"x3'-2" to 8'-0"x3'-2". ASTM E-1300 tables for "4 sides simply supported" were used to design the glass for both strength and serviceability. The final IGU assembly is 1 1/8" thick with 1/4" and 3/8" monolithic lites separated by a 1/2" argon filled space. All of the glass is fully tempered in areas accessible to occupants.

The curtain wall mullion system chosen for the Miller Center is Kawneer's 1600 LR Wall. Using the charts provided in the published product data, it was determined that a 5 3/4" mullion could withstand the given loads with a 10'-0" span. While the twin span condition did not directly apply to the project since there are two unequal spans (10' and 14'), the chart was beneficial for preliminary sizing. A model of the mullion and loading was created in SAP2000 and the 5 3/4" mullion was found to satisfy all deflection and strength criteria under the unequal span condition.

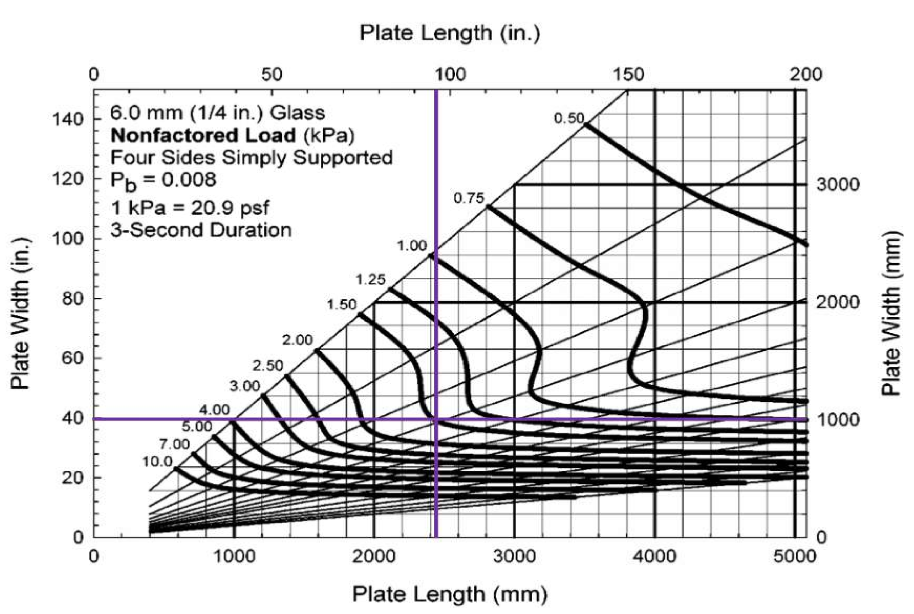
To carry the gravity and lateral loads from the curtain wall to the structure, HSS tubes spanning between the columns were used as support. Vertically and horizontally slotted holes were provided as well to allow ample room for both deflection and drift.

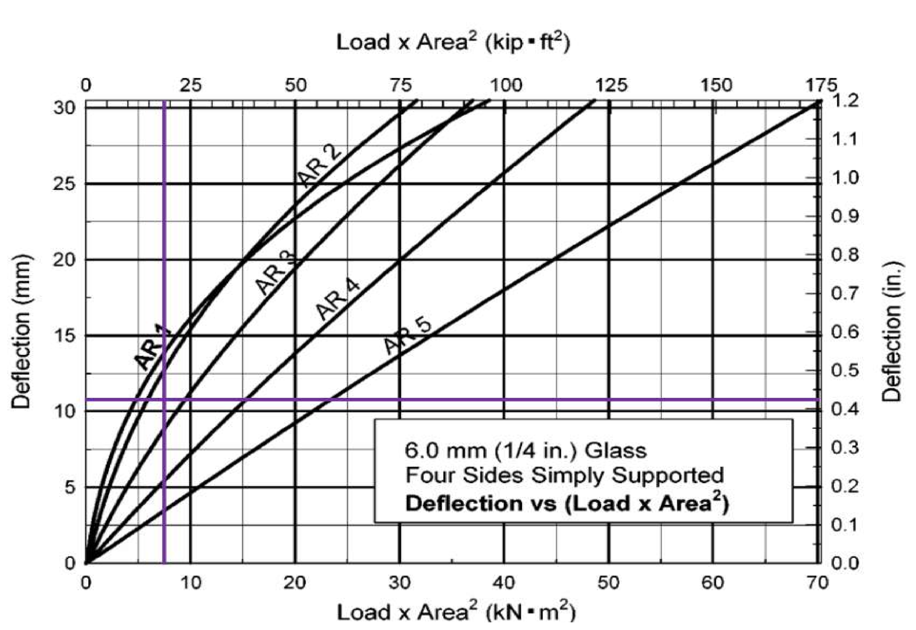
Zone	Load Case	Height	P(table)	Gust Factor (Gf)	P(table)*Gf	Kzt	P (psf)
1	1	70	-53.4	0.85	-44.8	1	-33.9
		66	-52.7				
		60	-51.7				
		P(table) = -52.7					
2	1	70	-83.8	0.85	-70.6	1	-53.4
		66	-83				
		60	-81.8				
		P(table) = -83.0					
3	1	70	-114.2	0.85	-95.8	1	-72.5
		66	-112.8				
		60	-110.6				
		P(table) = -112.8					
4	1	70	-36.5	0.85	-30.6	1	-23.2
		66	-36.0				
		60	-35.3				
		P(table) = -36.0					
	2	70	36.5	0.85	30.6	1	23.2
		66	36.0				
		60	35.3				
		P(table) = 36.0					
5	1	70	-66.9	0.85	-56.2	1	-42.5
		66	-66.1				
		60	-64.8				
		P(table) = -66.1					
	2	70	36.5	0.85	30.6	1	23.2
		66	36.0				
		60	35.3				
		P(table) = 36.0					

FINAL IGU/MULLION ASSEMBLY



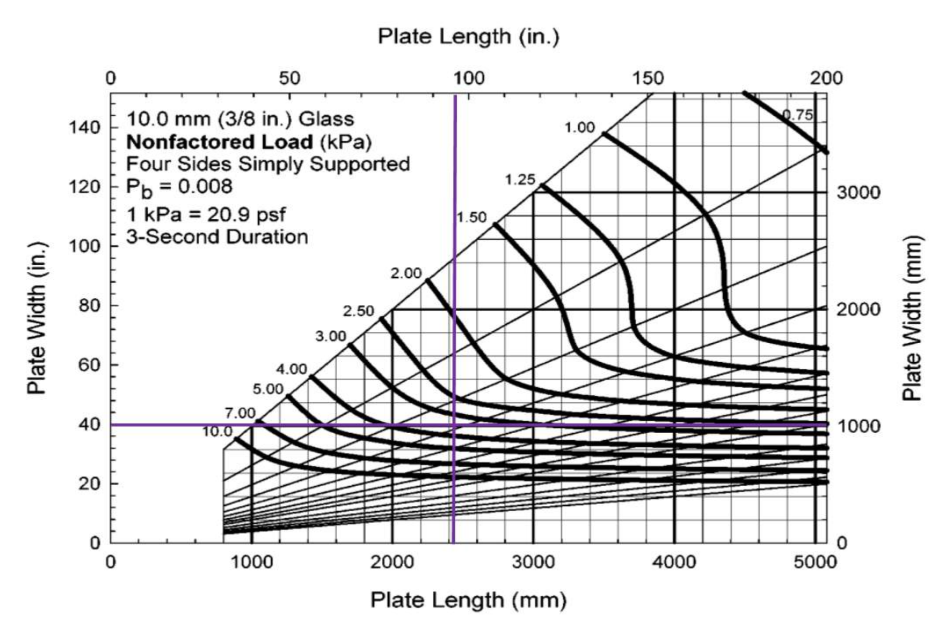
IGU GLAZING CALCULATIONS

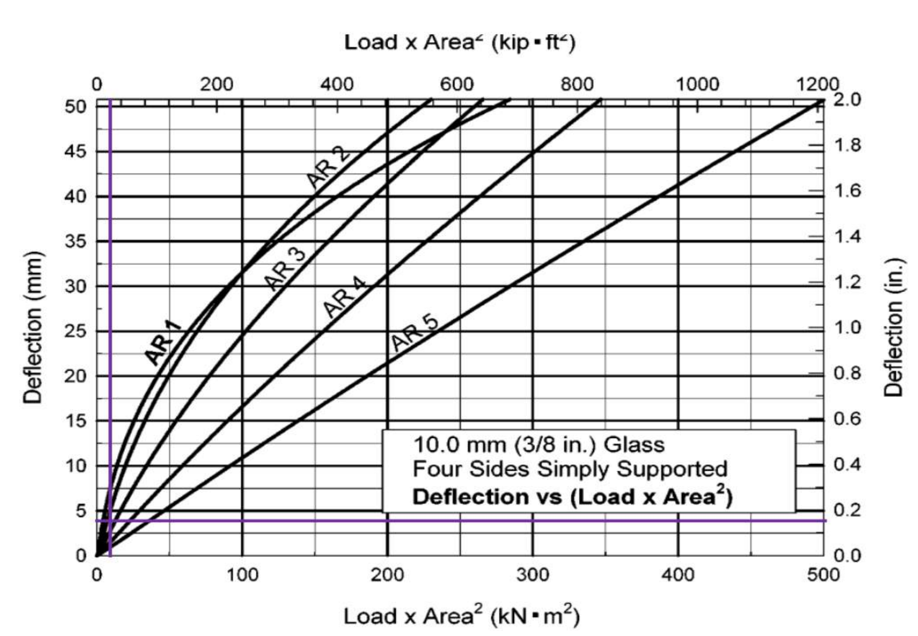




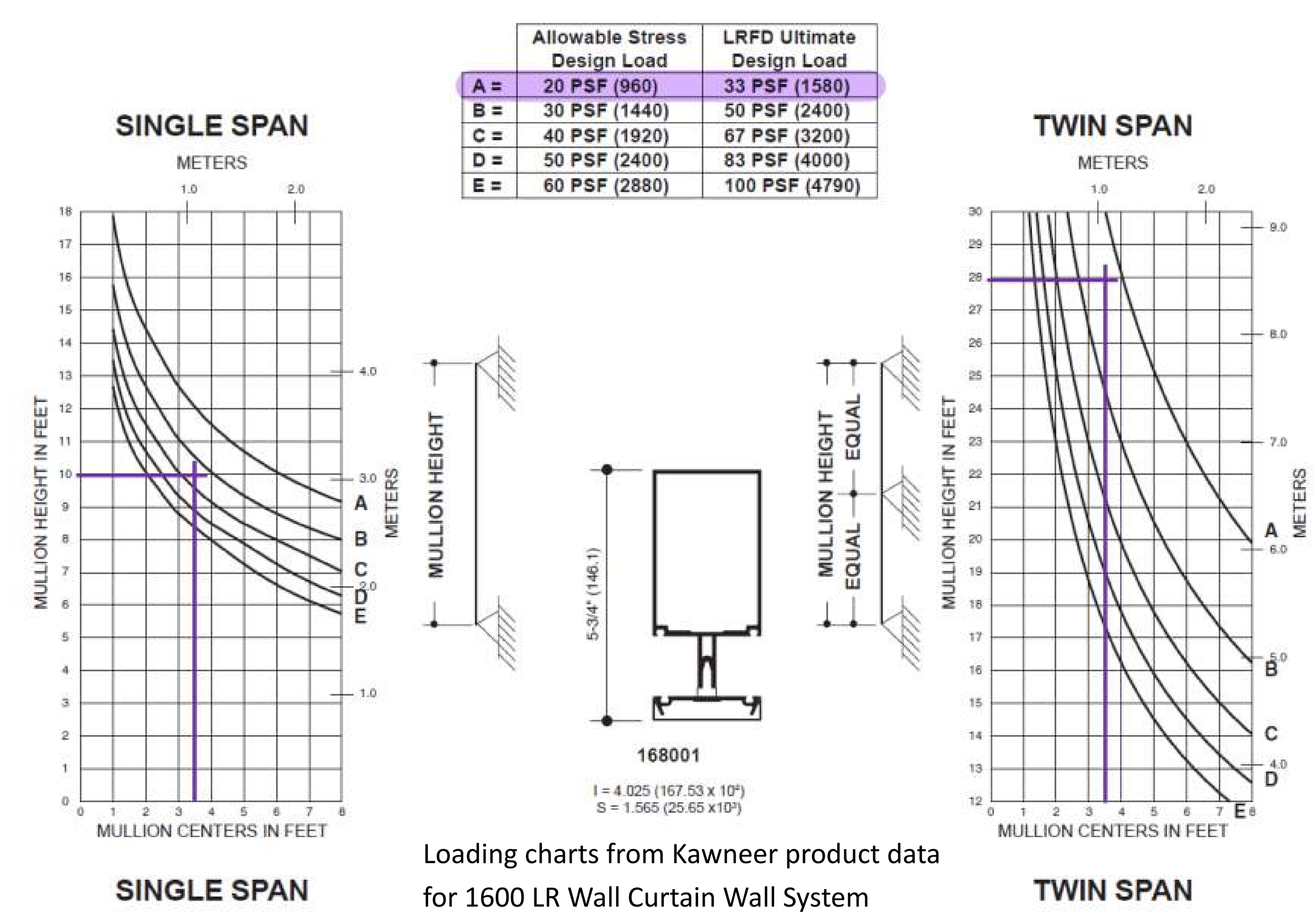
1-1/8" IGU		
	Lite no. 1 (1/4" monolithic)	Lite no. 2 (3/8" monolithic)
L (in)	96	96
W (in)	40	40
Aspect Ratio (L/W)	2.4	2.4
t (in)	0.25	0.375
NFL (kpa)	1.45	3.4
NFL (psf)	30.3	71.1
Glass Type Factors (Fully Tempered)	3.6	3.6
Load Share Factor	5.26	1.23
Load Resistance (psf) of lite	573.9	314.7
IGU Load Resistance (psf)	314.7	
Required Load Resistance (psf)	25	

Tables from ASTM E-1300





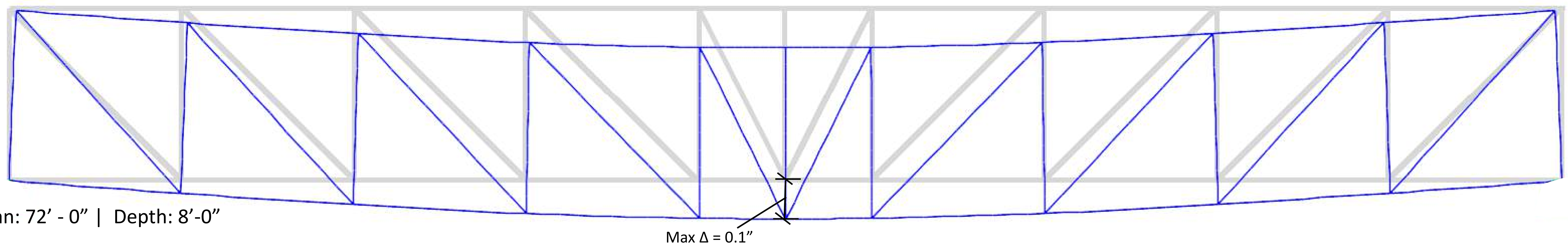
MULLION STRENGTH CHARTS BY KAWNEER



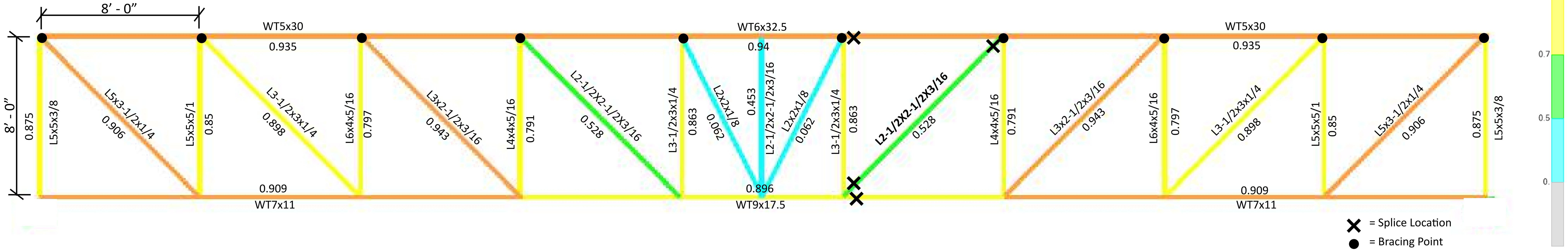
Loading charts from Kawneer product data for 1600 LR Wall Curtain Wall System

PROJECT	**JACK H. MILLER CENTER FOR MUSICAL ARTS** HOLLAND, MICHIGAN
SHEET TITLE	ENCLOSURE
NOT FOR CONSTRUCTION	AEI TEAM NO. 01-2019
DATE February 18, 2019	SCALE NOT TO SCALE
DRAWING NO. S-6.0	PAGE NO. 56

CONCERT HALL ROOF TRUSSES

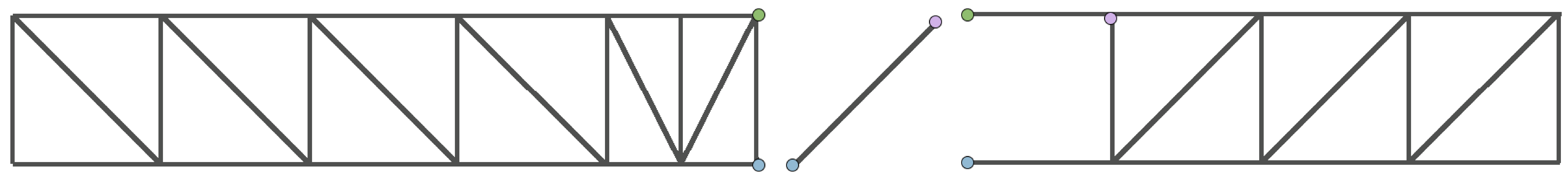


Span: 72' - 0" | Depth: 8'-0"



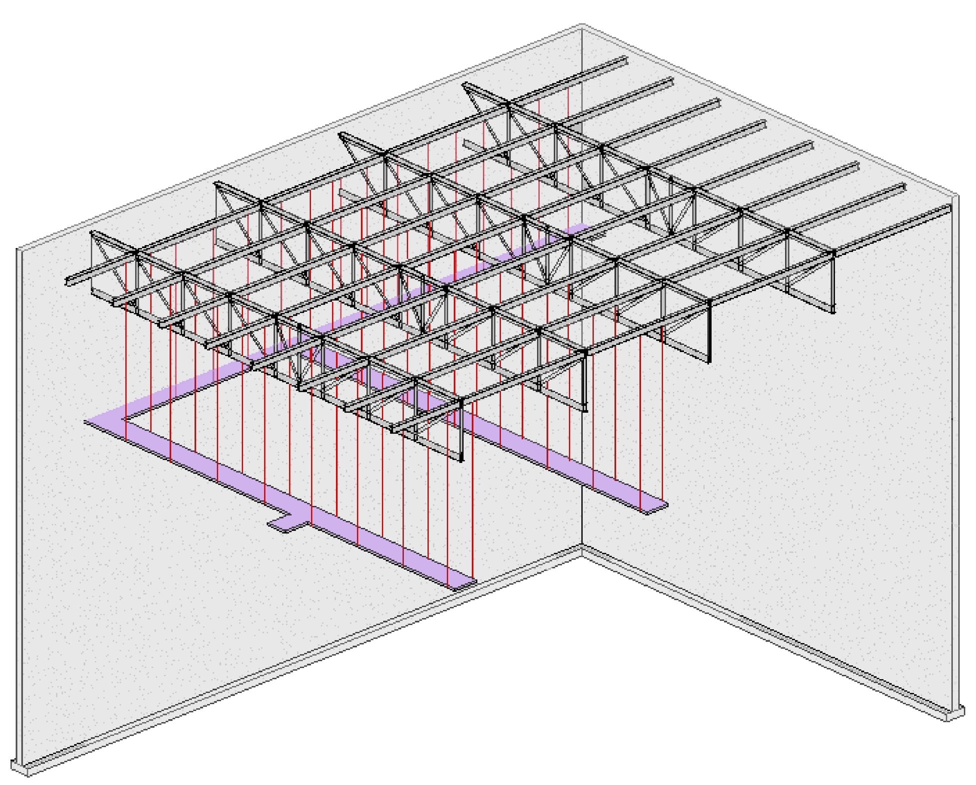
Steel Truss per Truss		
Member	Quantity	Length
L5x5x3/8	2	8' - 0"
L5x5x5/16	2	8' - 0"
L6x4x5/16	2	8' - 0"
L4x4x5/16	2	8' - 0"
L3.5x3.5x1/4	2	8' - 0"
L2.5x2.5x3/16	1	8' - 0"
L2x2x1/8	2	8' - 11"
L2.5x2.5x3/16	2	11' - 3.5"
L3x2.5x3/16	2	11' - 3.5"
L3.5x3x1/4	2	11' - 3.5"
L5x3.5x1/4	2	11' - 3.5"
WT5x30	6	8' - 0"
WT9x32.5	3	8' - 0"
WT7x11	6	8' - 0"
WT9x17.5	3	8' - 0"
Bracing		
W10x33	56	20' - 0"

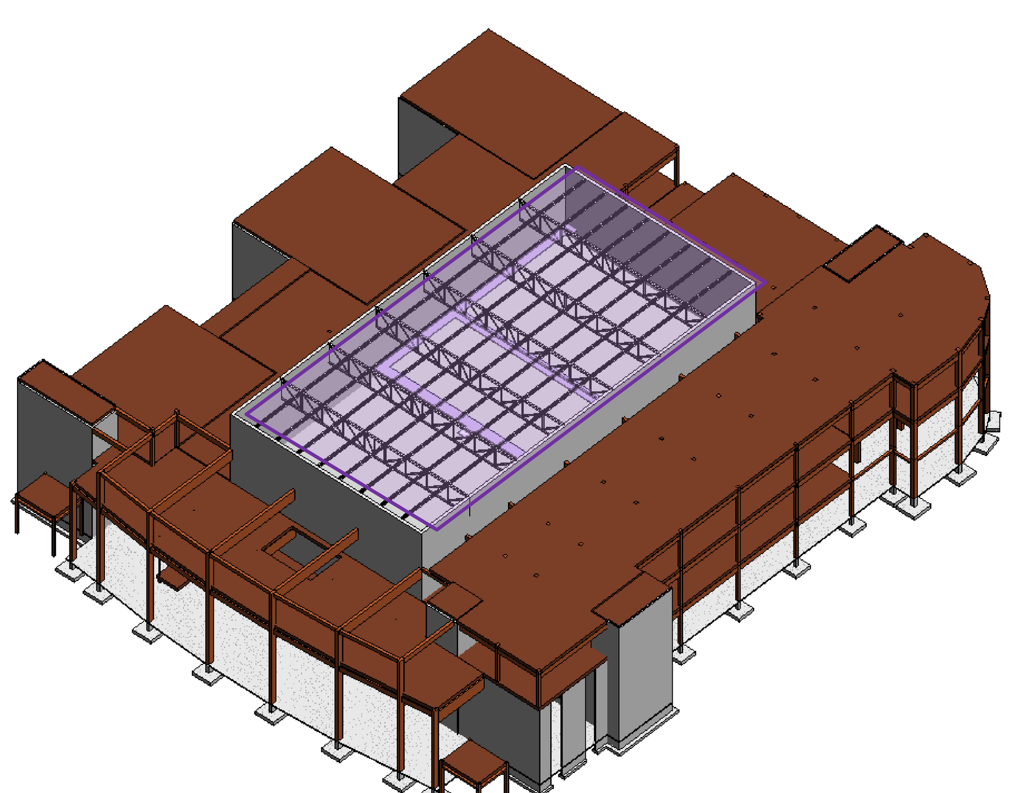
The 72'-0" truss poses an issue for transportation. To provide easier transportation, each truss was separated into two pieces consisting of a 32'-0" and a 40'-0" section. Both preassembled sections will consist of shop welded joints. At the splices, indicated by x's in the middle truss image, will be field bolted connections. A further breakdown can be seen in the bottom truss image.



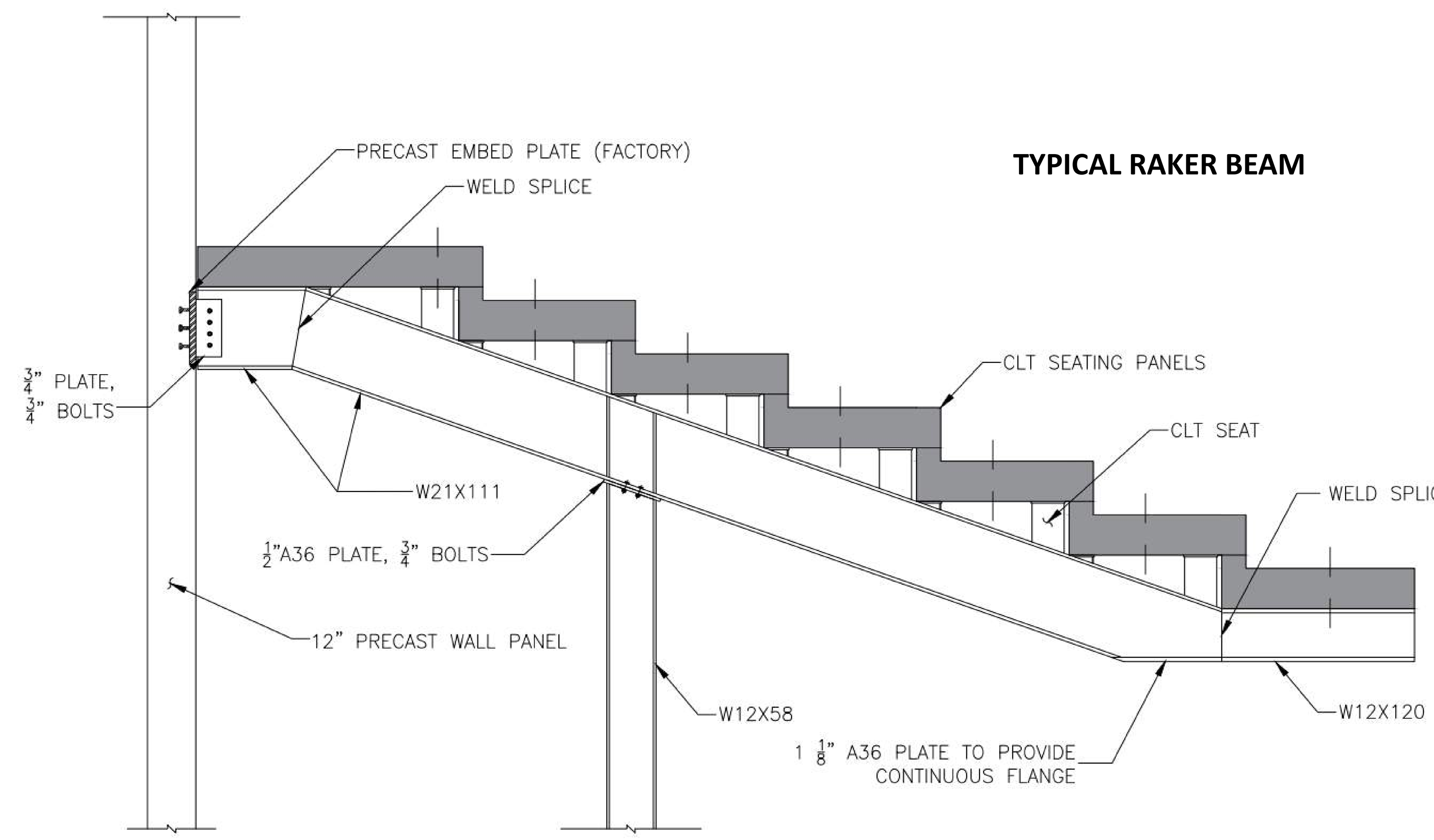
CONCERT HALL CATWALK

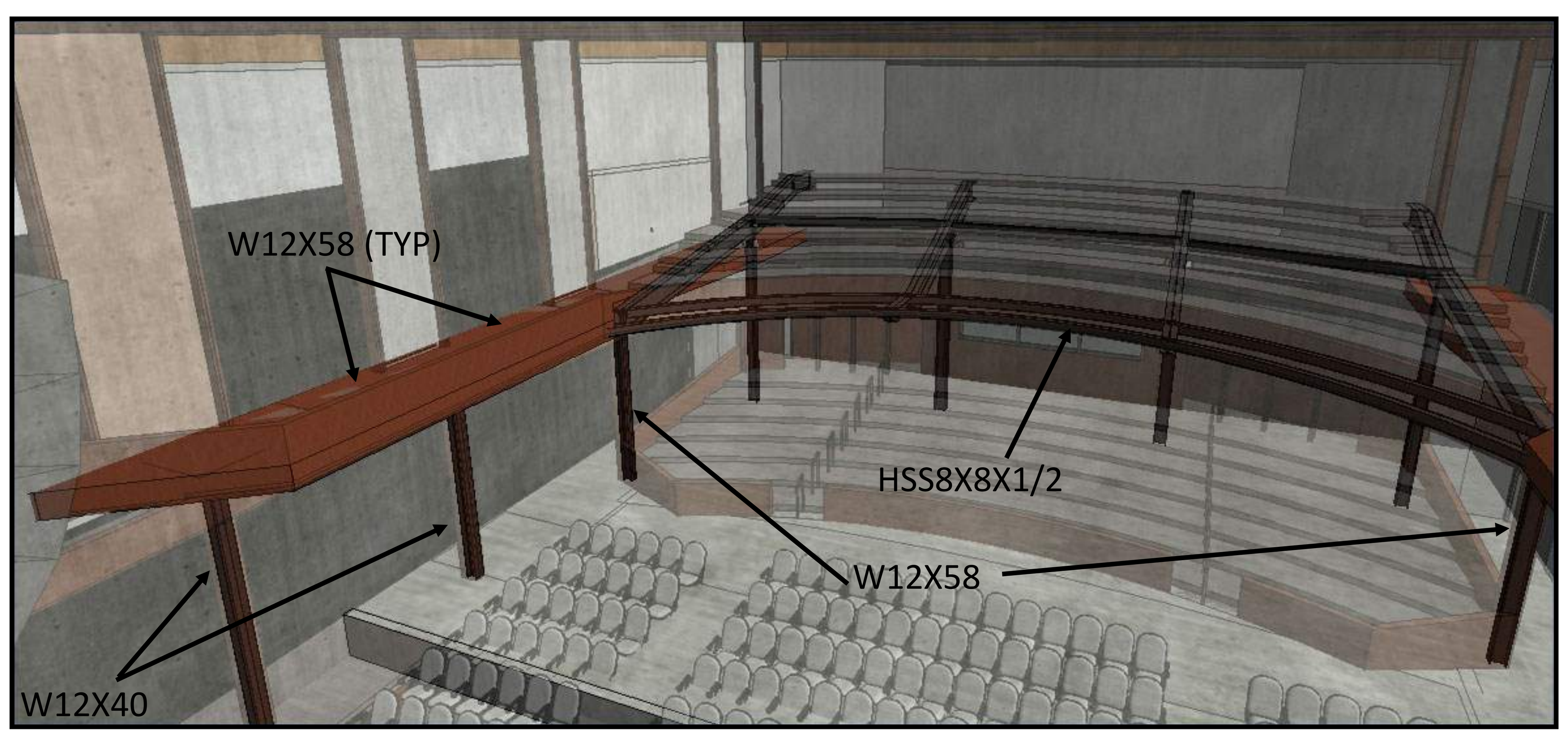
The above image shows the current layout of the catwalk that is hung from the purlins spanning the steel trusses in 8'-0" increments. Since the purlins line up with the rod supports for the catwalk it is able to be shifted seamlessly. Furthermore, the truss design allows the catwalk to be moved to any location within the concert hall. Additional catwalks may be added as long as the load is equivalent to one catwalk per truss.





CONCERT HALL BALCONY





Balcony		
Member	Quantity	Length (ft)
Columns		
W10x33	8	16' - 0"
W12x58	2	16' - 0"
Beams		
HSS8x8x1/2	1	74' - 8"
	1	68' - 4"
W12x120	2	4' - 3"
W12x26	2	15' - 10"
	2	15' - 2"
W21x132	2	19' - 10"
	2	20' - 2"

SYNDICATE

PROJECT

JACK H. MILLER CENTER FOR MUSICAL ARTS

HOLLAND, MICHIGAN

SHEET TITLE

CONCERT HALL

NOT FOR CONSTRUCTION

AEI TEAM NO. 01-2019

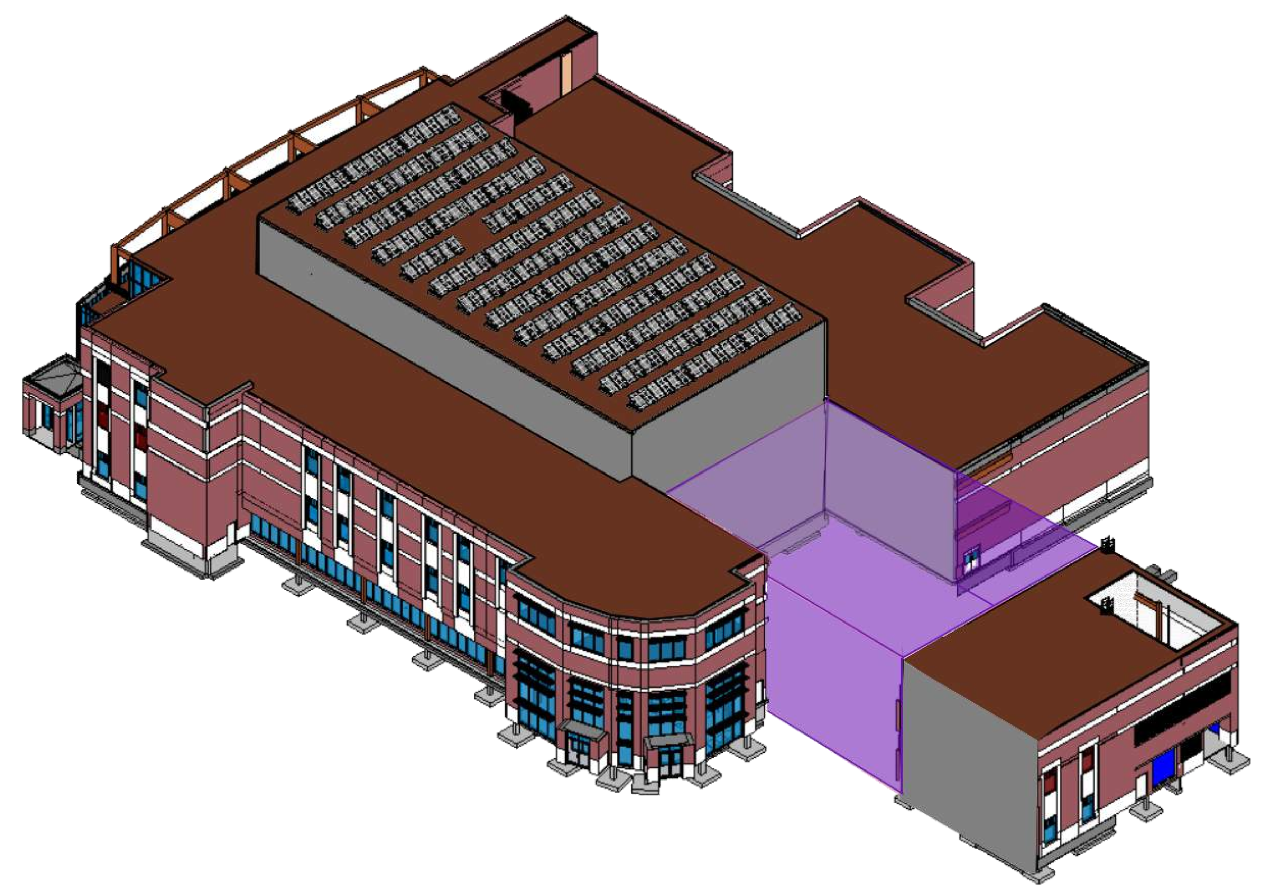
DATE February 18, 2019

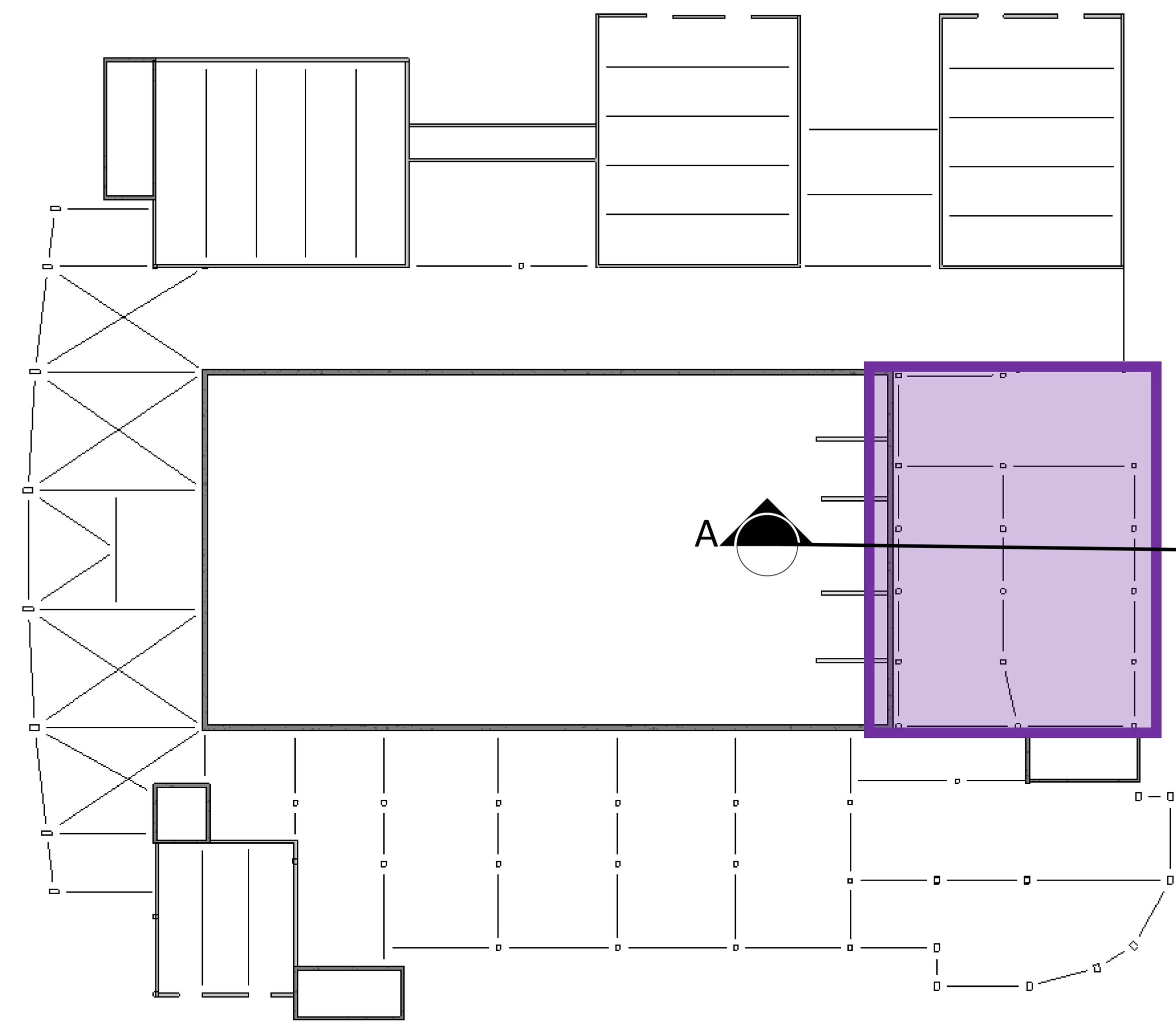
SCALE NOT TO SCALE

DRAWING NO. S-7.0

PAGE NO. 57

STRUCTURAL ISOLATION OF MECHANICAL SPACE

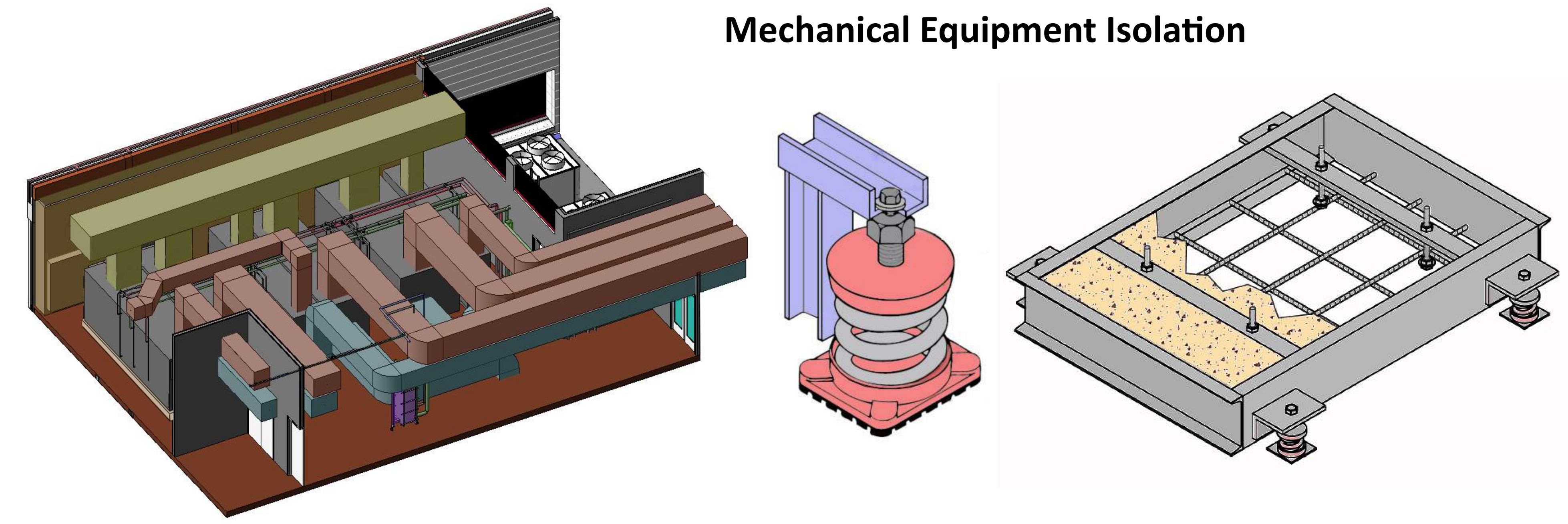




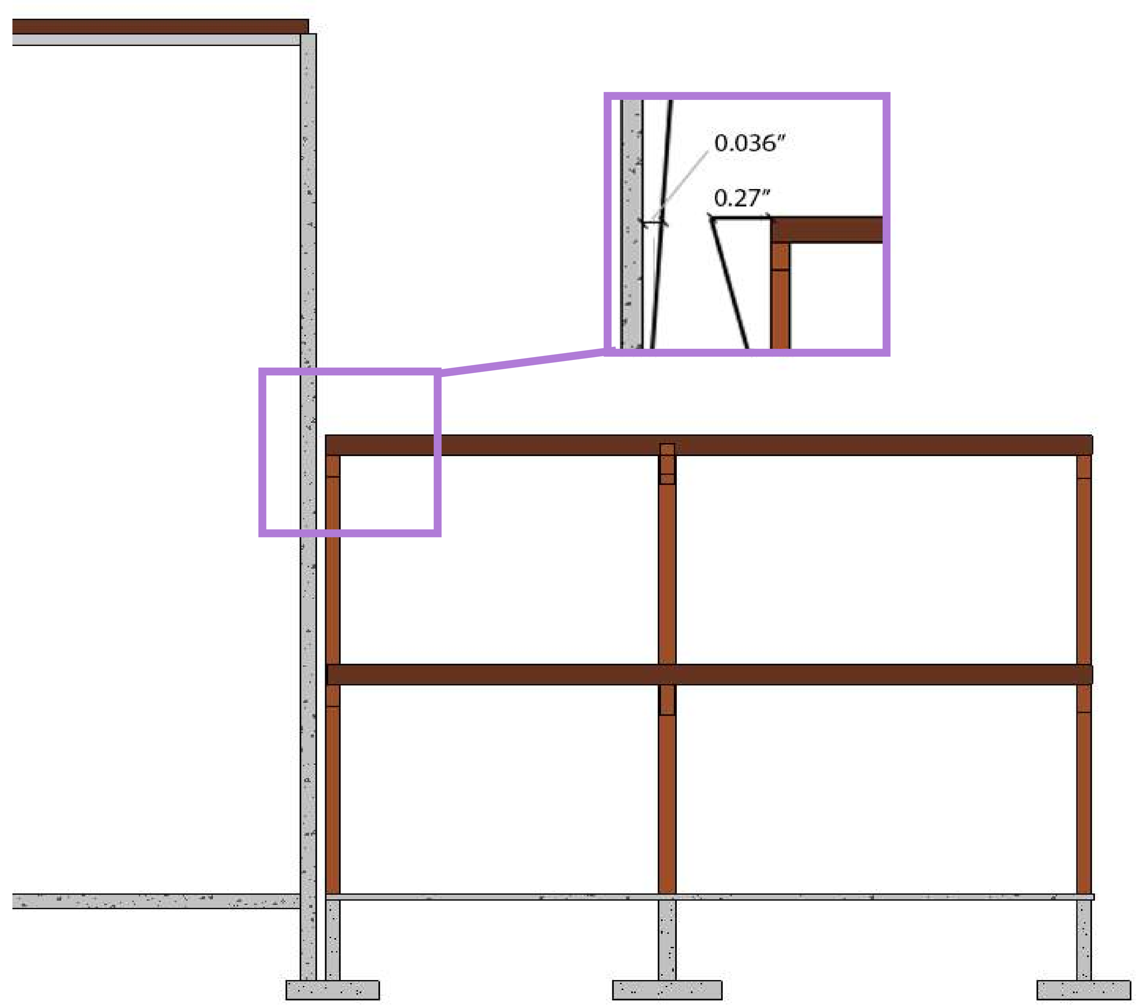
MECHANICAL SPACE LAYOUT

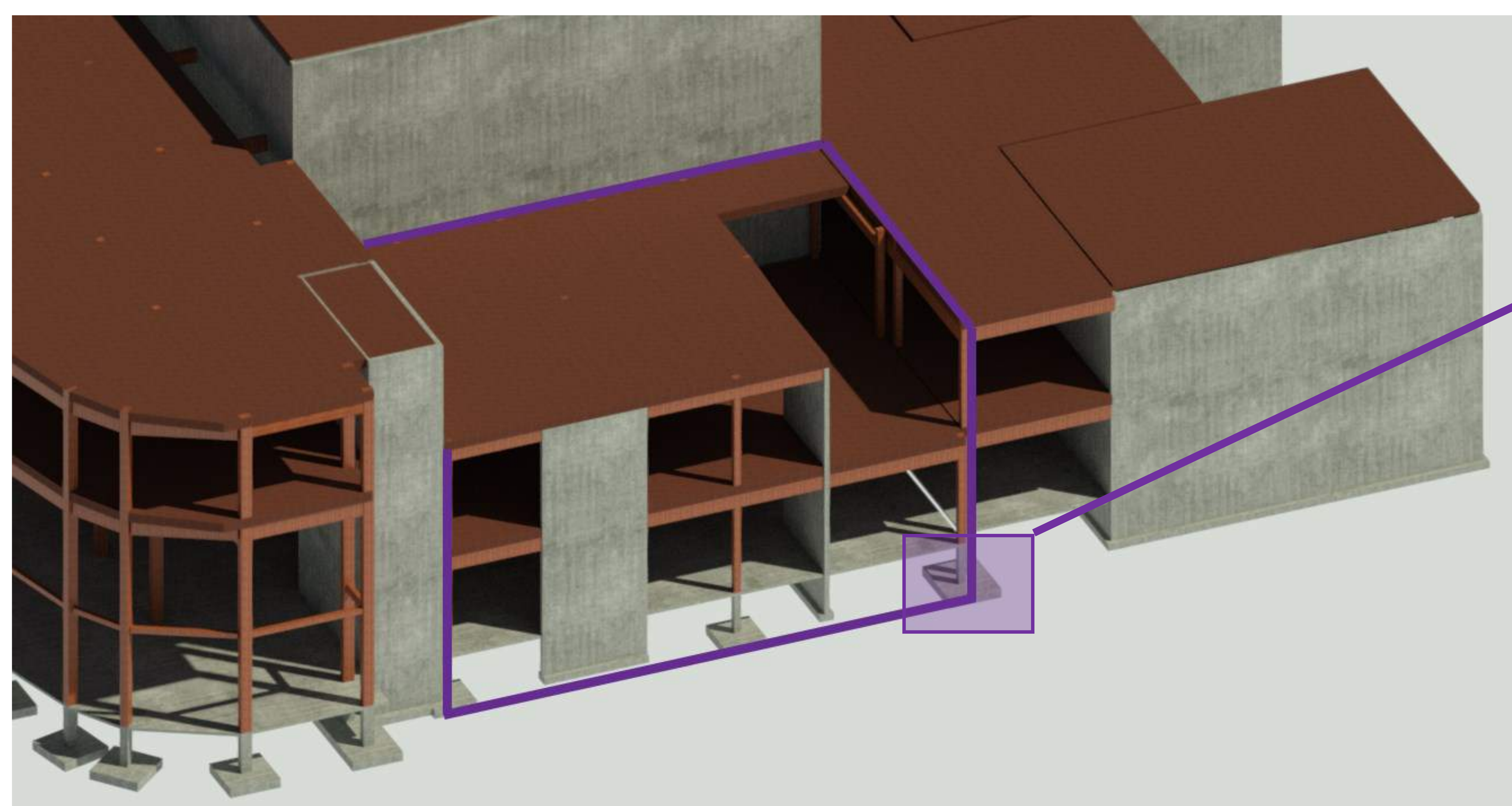
The pumps are also housed on spring mounted concrete inertia pads to reduce the vibratory motion during operations. Rubber connections are also installed between the pumps and pipe connections to reduce noise travelling through pipes. The air handling units and chillers are also mounted on springs to reduce the oscillatory movement they make during operations.

Mechanical Equipment Isolation



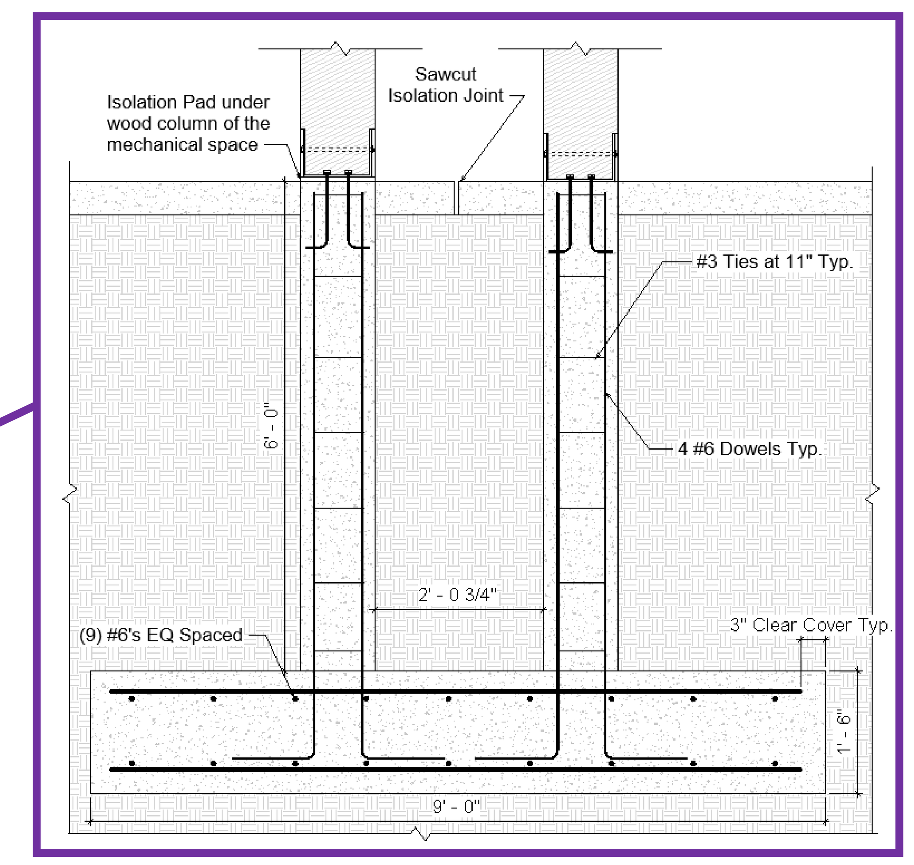
BUILDING DRIFT (SECTION A-A)





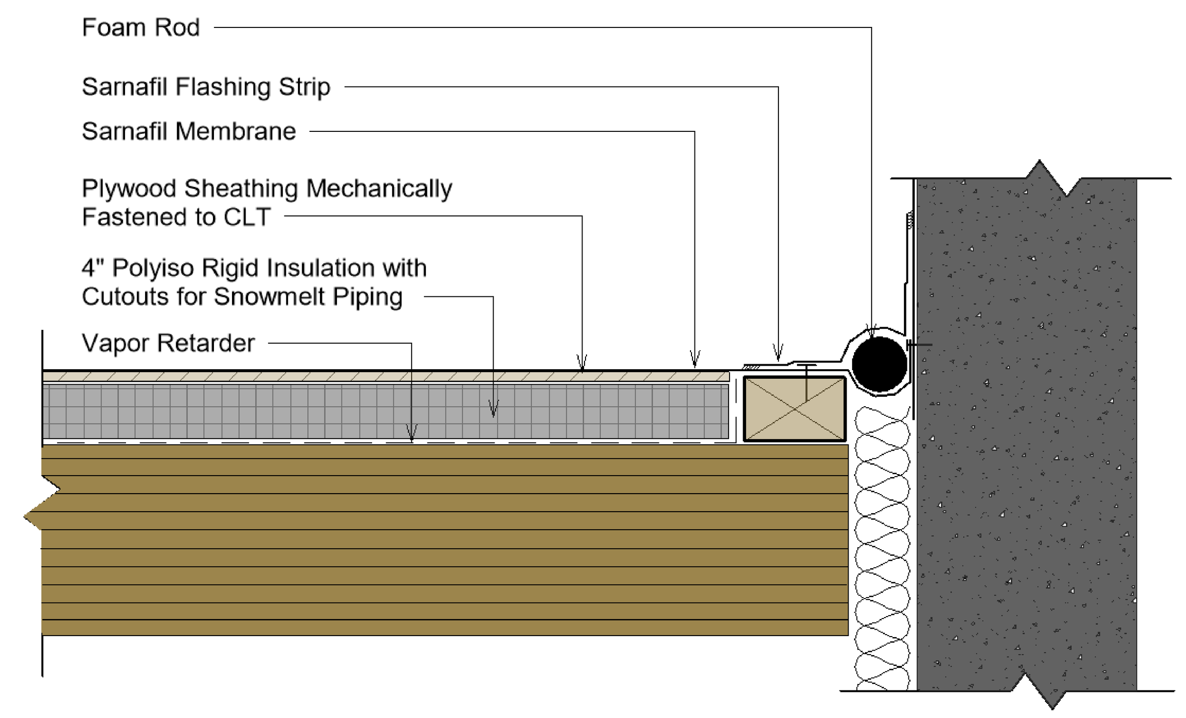
FOUNDATION ISOLATION

Typical Isolated Footing



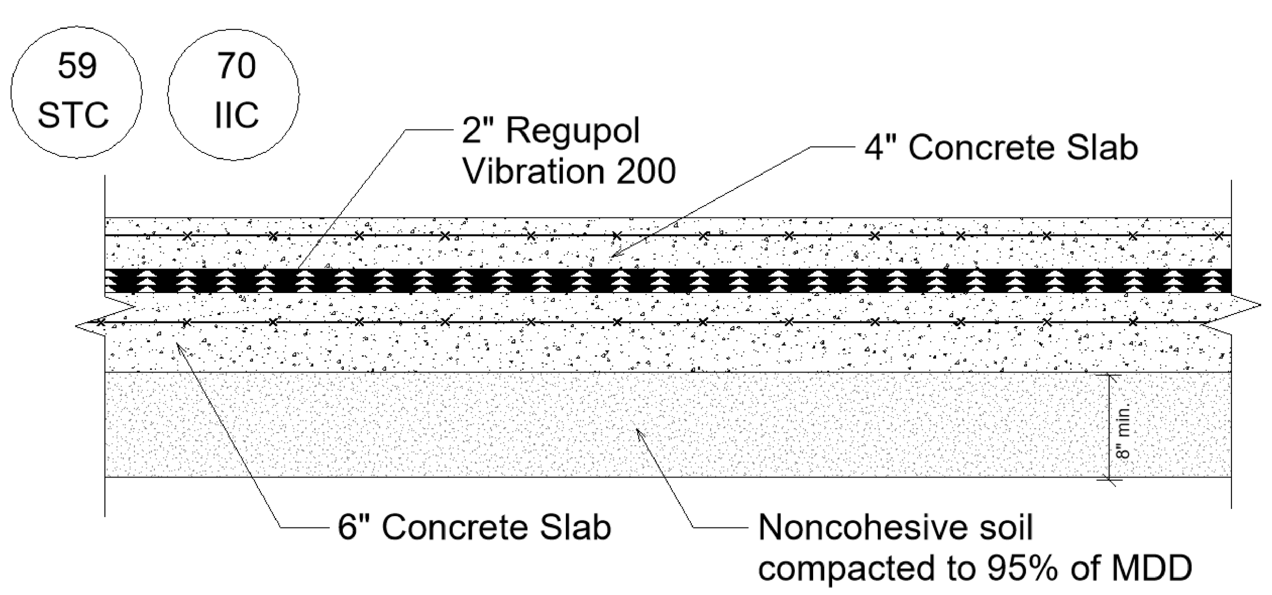
The isolated structure consists of double columns along the perimeter. An isolation pad was placed between the wood column and concrete pier on the mechanical side to reduce the vibrations entering the footing. A single spread footing is used for each double column location along the perimeter.

ROOF ISOLATION JOINT

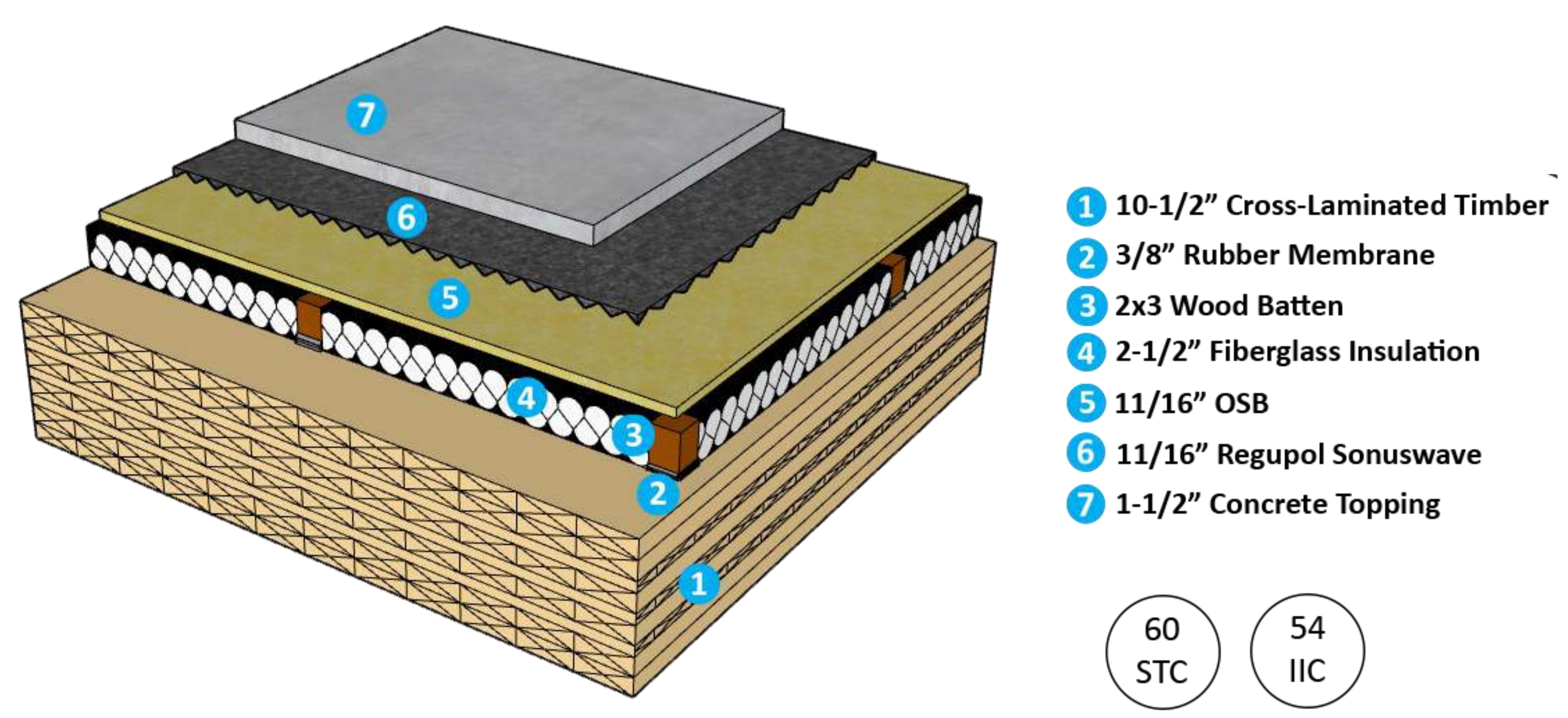


ASSEMBLIES

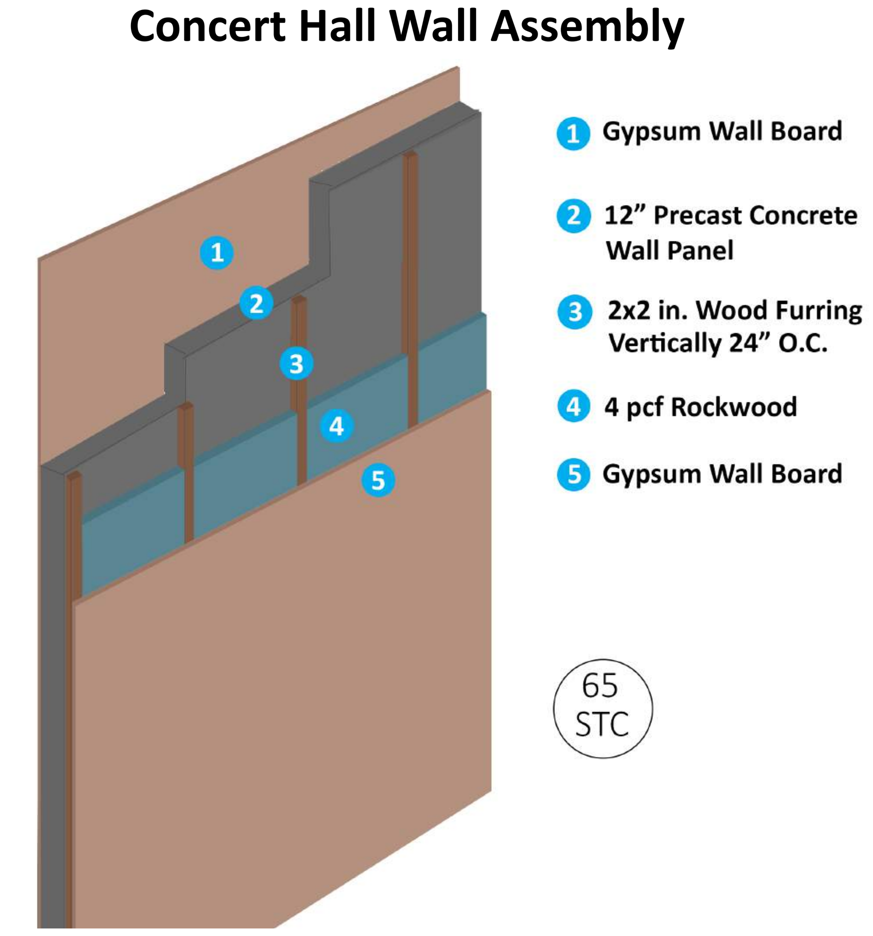
Concert Hall Slab-on-Grade



Typical Floor Assembly



Concert Hall Wall Assembly



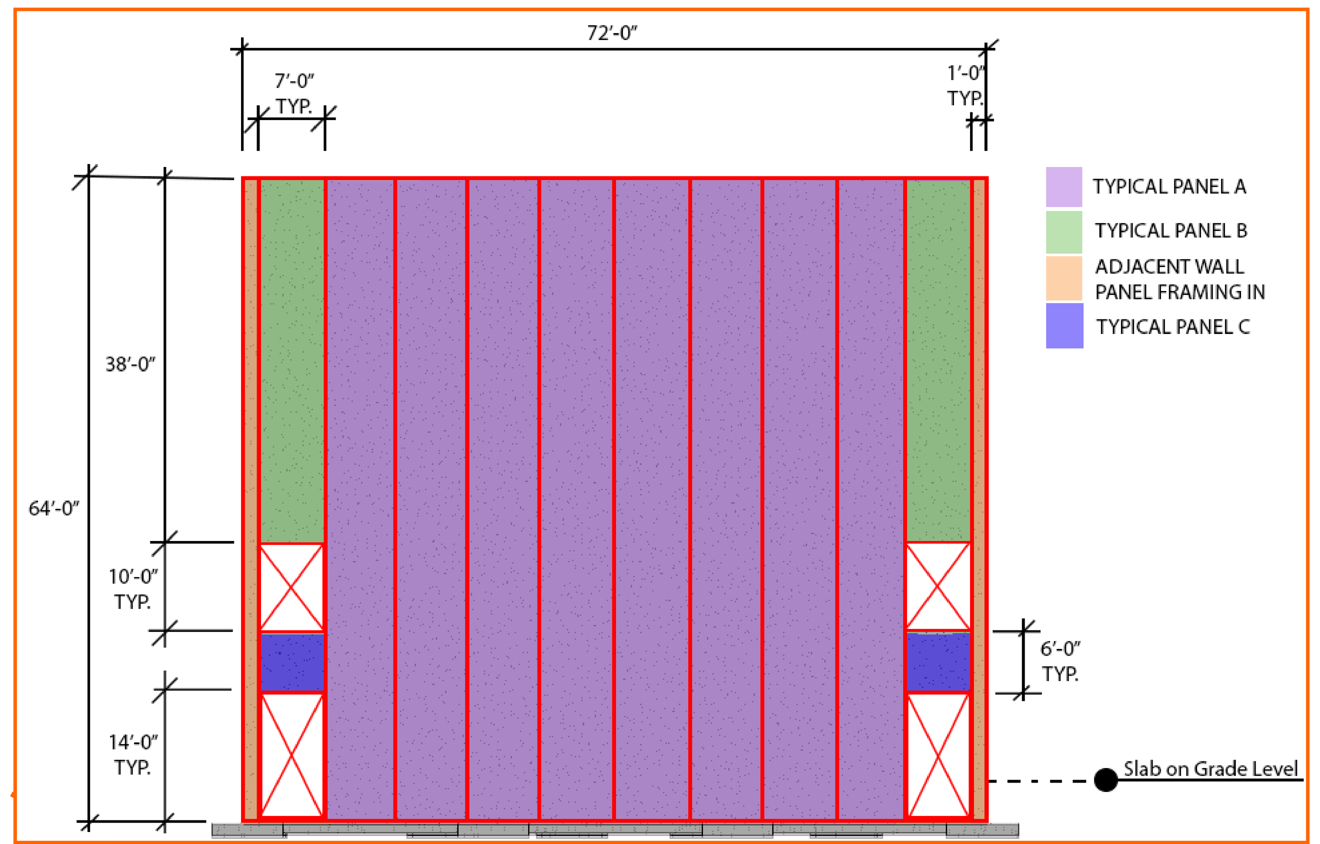
Both the concert hall slab-on-grade and typical floor assemblies were tested for STC (how well a building system attenuates airborne sound) and IIC (how well a building system attenuates impact sound) values by Regupol.

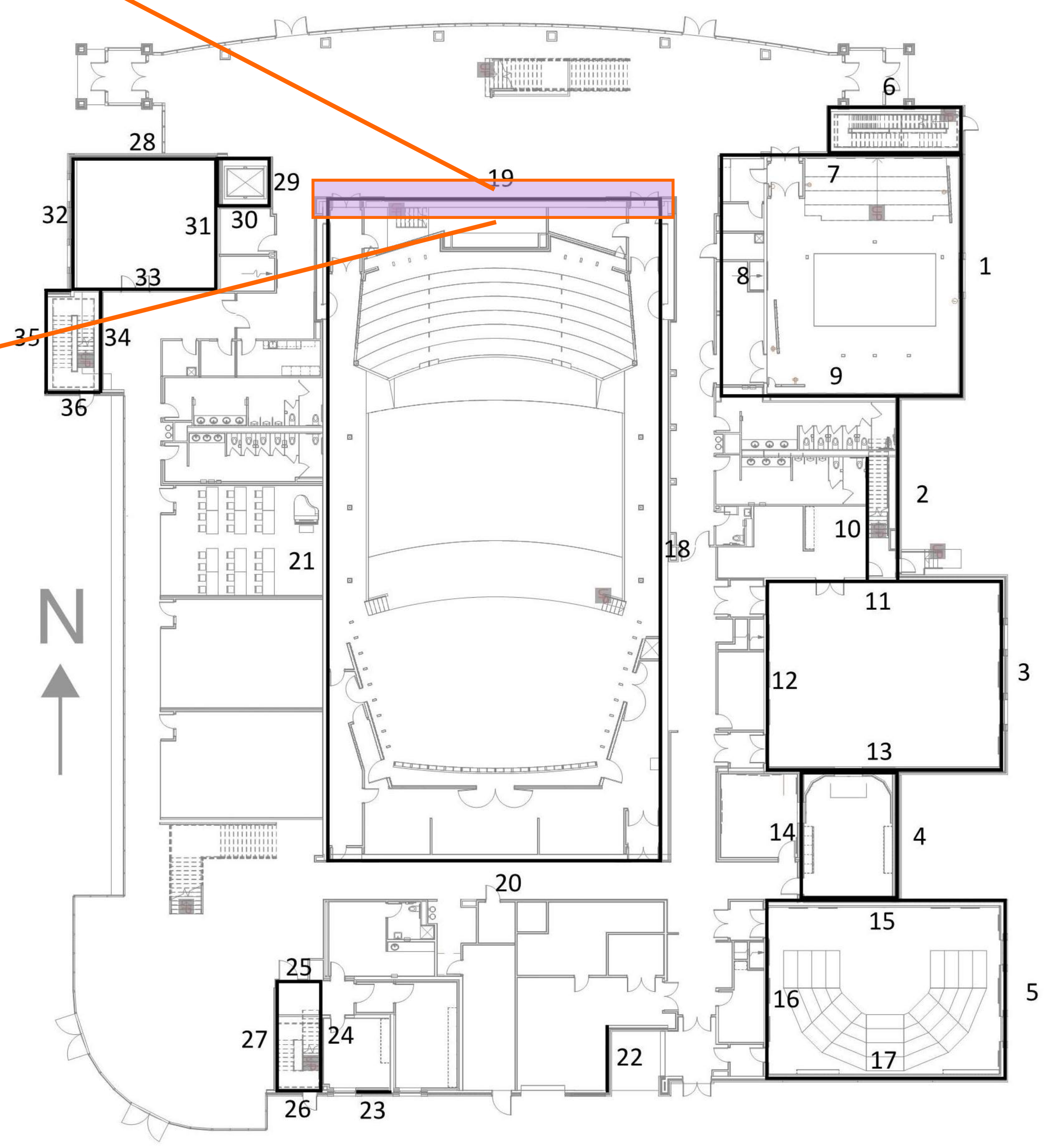
SYNDICATE	
PROJECT **JACK H. MILLER CENTER FOR MUSICAL ARTS** HOLLAND, MICHIGAN	
SHEET TITLE SOUND & VIBRATION	
NOT FOR CONSTRUCTION	AEI TEAM NO. 01-2019
DATE February 18, 2019	SCALE NOT TO SCALE
DRAWING NO. S-8.0	PAGE NO. 58

PRECAST PANEL SCHEDULE

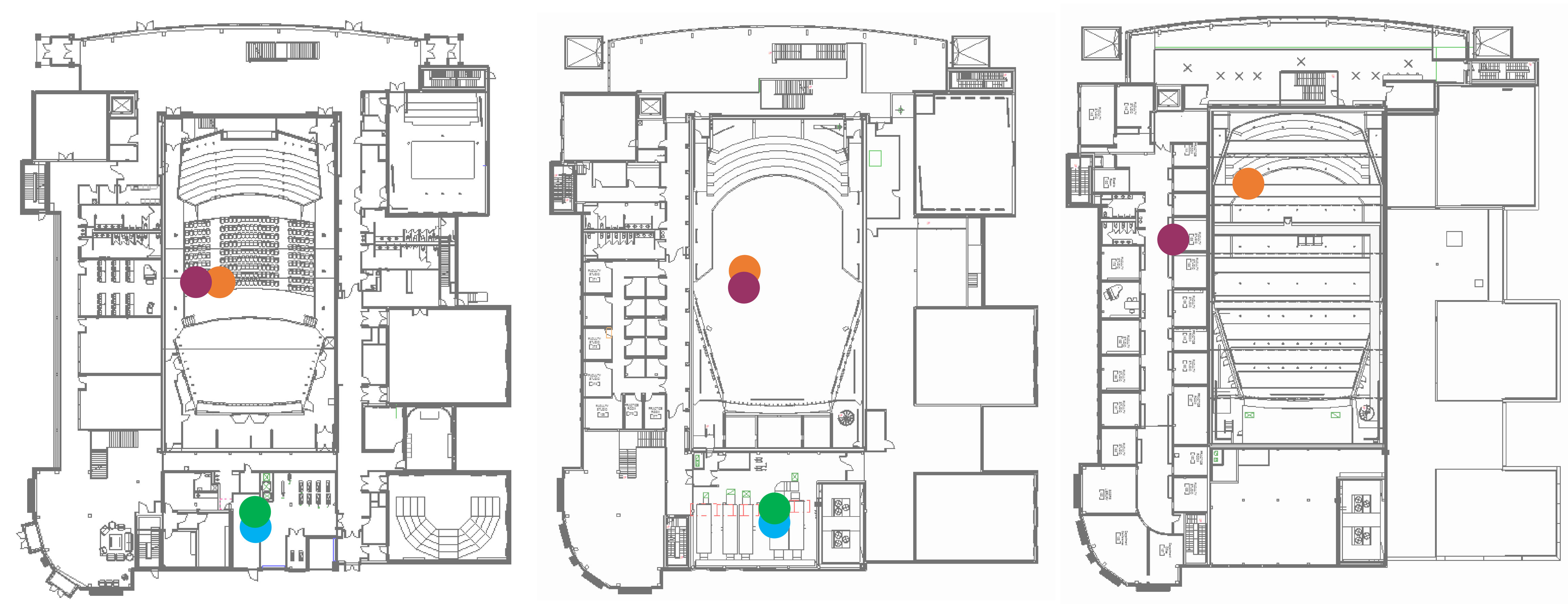
Wall Number	Panel Designation	No. of	Panel Height (ft)	Panel Width (ft)
1	A	5	32	10
	B	5	32	10
2	A	3	32	9.5
	B	1	32	9.5
3	A	2	32	10
	B	2	32	10
4	A	4	32	7
5	A	4	32	9.5
6	A	4	48	7
7	A	3	32	10.5
	B	1	32	10.5
8	A	3	32	13
	B	1	32	13
9	A	4	32	10.5
10	A	3	32	9.5
	B	1	32	9.5
11	A	3	32	10
	B	1	32	10
12	A	2	32	10
	B	2	32	10
13	A	3	32	10
	B	1	32	10
14	A	2	32	7
	B	1	32	7
	C	1	32	7
15	A	5	32	10
16	A	2	32	9
	B	1	32	9
	C	1	32	9
17	A	5	32	10
18	A	23	64	6
19	A	8	64	7.25
	B	2	38	7
	C	2	6	7.25
20	A	8	64	7.25
	B	2	54	7.25
21	A	23	64	6
22	A	2	16	12
23	A	1	16	13
24	A	2	48	11
25	A	1	48	10
26	A	1	48	10
27	A	2	48	11
28	A	3	32	14
29	A	1	48	11
30	A	1	48	11
31	A	2	32	14
32	A	2	32	14
33	A	2	32	10
	B	1	48	11
34	A	2	48	10.5
35	A	2	48	10.5
36	A	1	48	11

North Concert Hall Panel Layout





CENTER OF MASS AND CENTER OF RIGIDITY



FIRST FLOOR   SECOND FLOOR   THIRD FLOOR

Center of Rigidity (COR)
Center of Mass (COM)

Isolated Structure Lateral

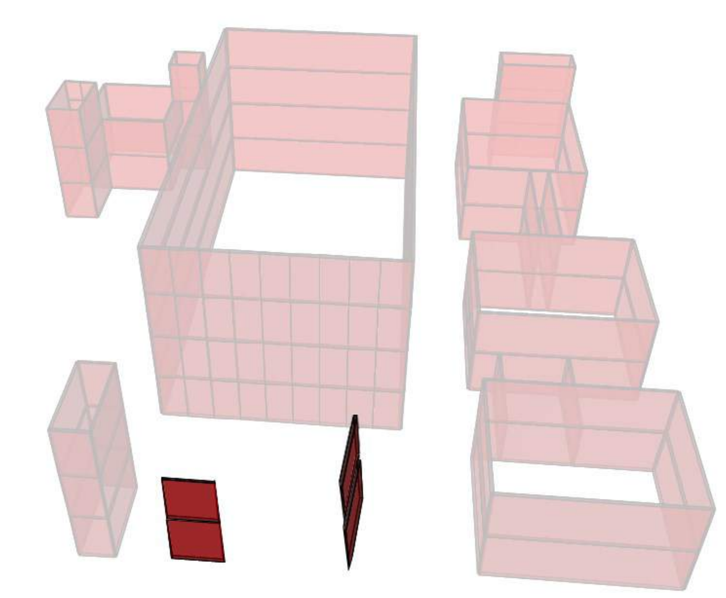
Center of Rigidity (COR)
Center of Mass (COM)

SHEAR WALL REINFORCEMENT SCHEDULE

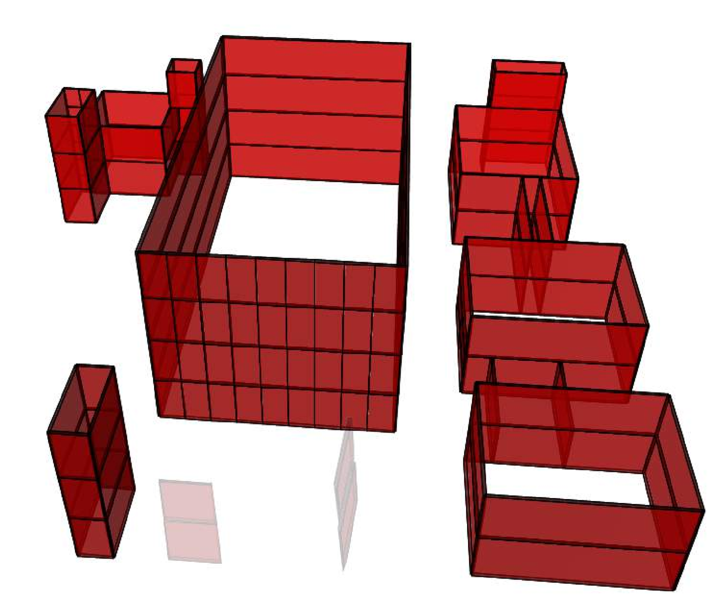
Isolated Structure Lateral System			
Precast Panel Shear Wall Location	Thickness (in)	Longitudinal Reinforcement	Transverse Reinforcement
North-South Mechanical Space	8	(2) curtains #4 @18"	(2) curtains #4 @ 18"
East-West Mechanical Space	8	(2) curtains #4 @14"	(2) curtains #4 @18"

Main Building Lateral System			
Precast Panel Shear Wall Location	Thickness (in)	Longitudinal Reinforcement	Transverse Reinforcement
Stairwells	8	(2) curtains #4 @18"	(2) curtains #4 @ 18"
Elevator Shaft	8	(2) curtains #4 @18"	(2) curtains #4 @18"
Recital Hall	8	(2) curtains #4 @18"	(2) curtains #4 @18"
Orchestral Hall	8	(2) curtains #4 @18"	(2) curtains #4 @18"
Organ Hall	8	(2) curtains #4 @18"	(2) curtains #4 @18"
Choral Hall	8	(2) curtains #4 @18"	(2) curtains #4 @18"
Performance Hall	12	(2) curtains #6 @18"	(2) curtains #4 @12"

Isolated Structure Lateral System

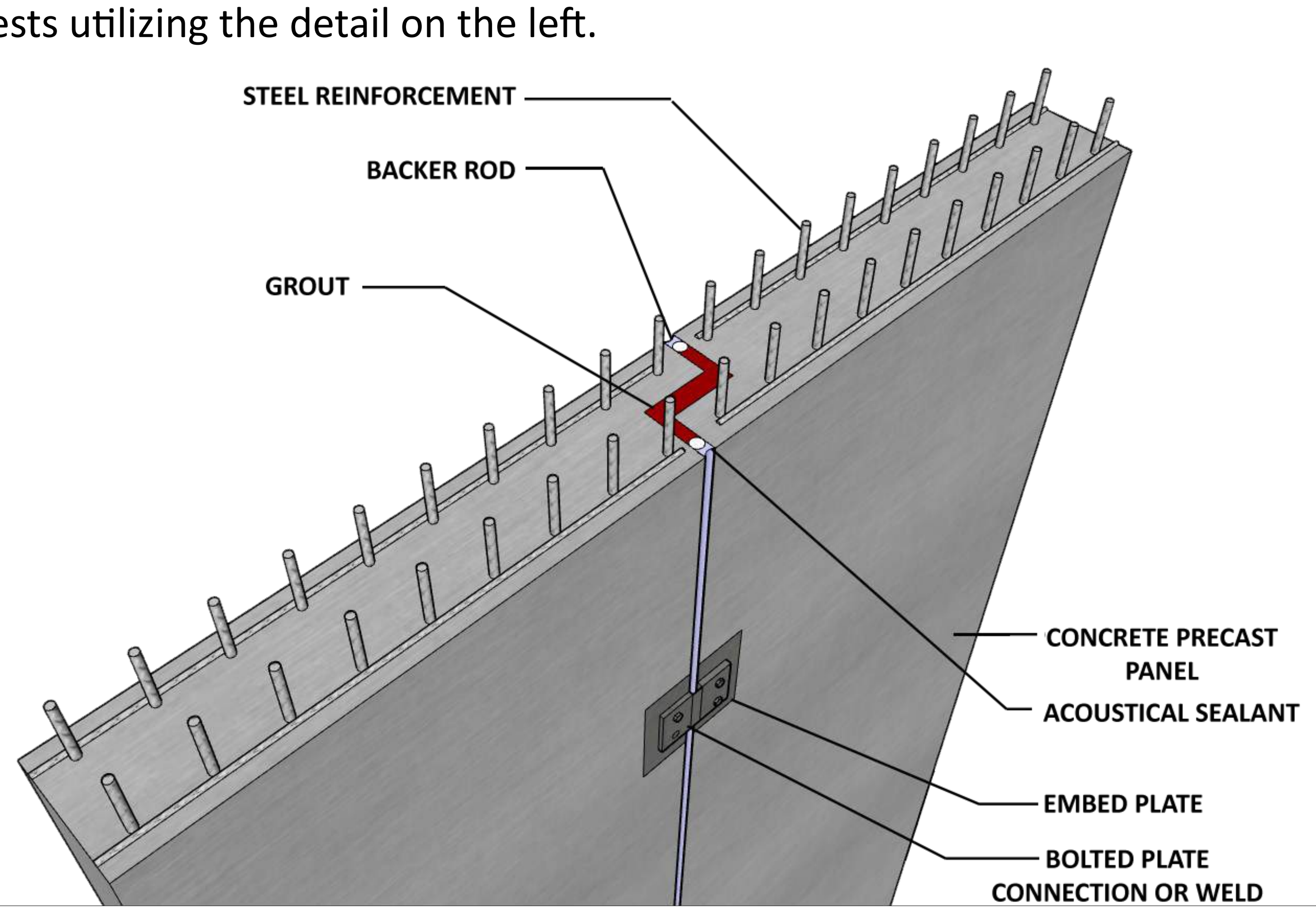


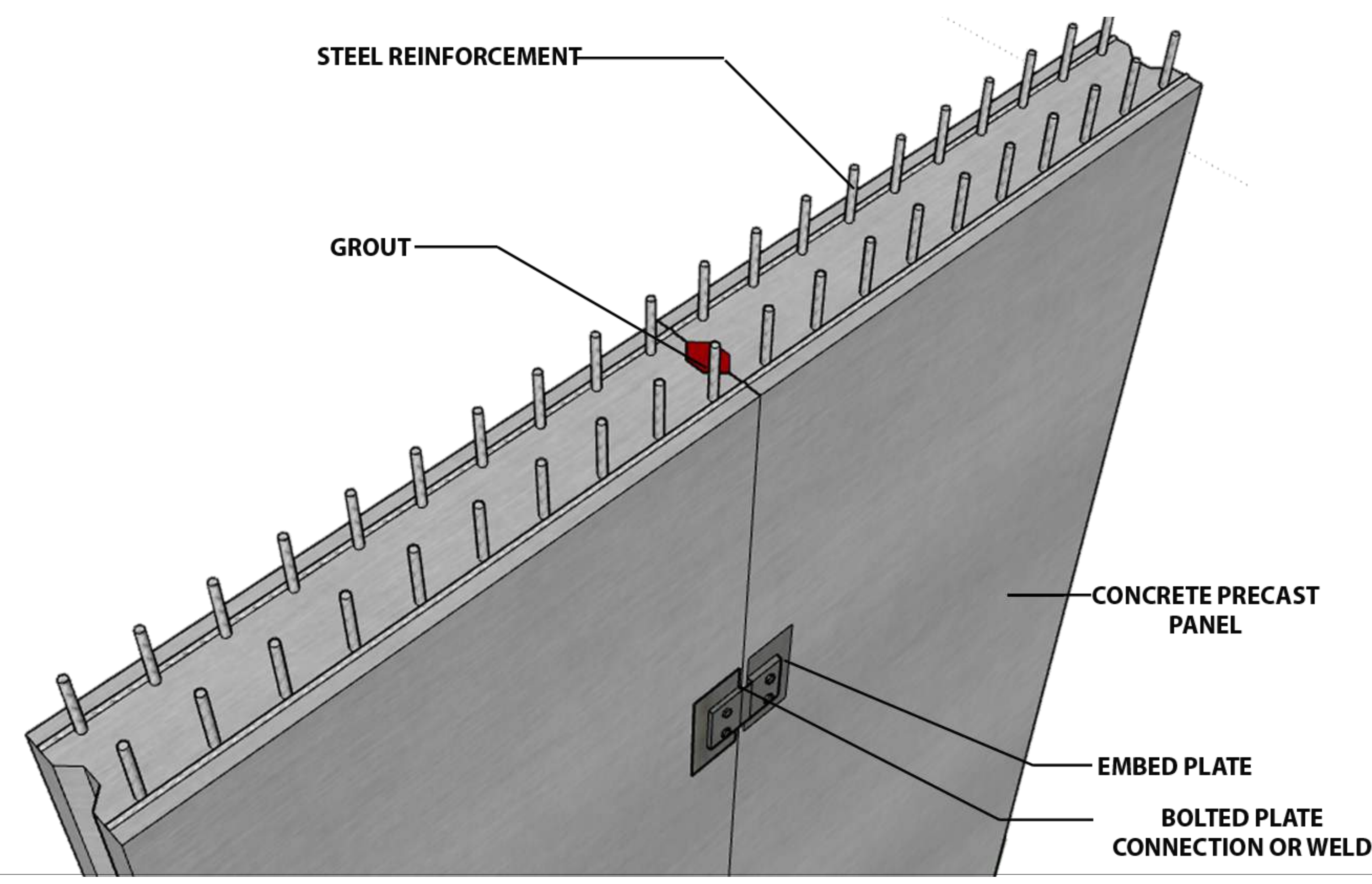
Main Building Lateral System



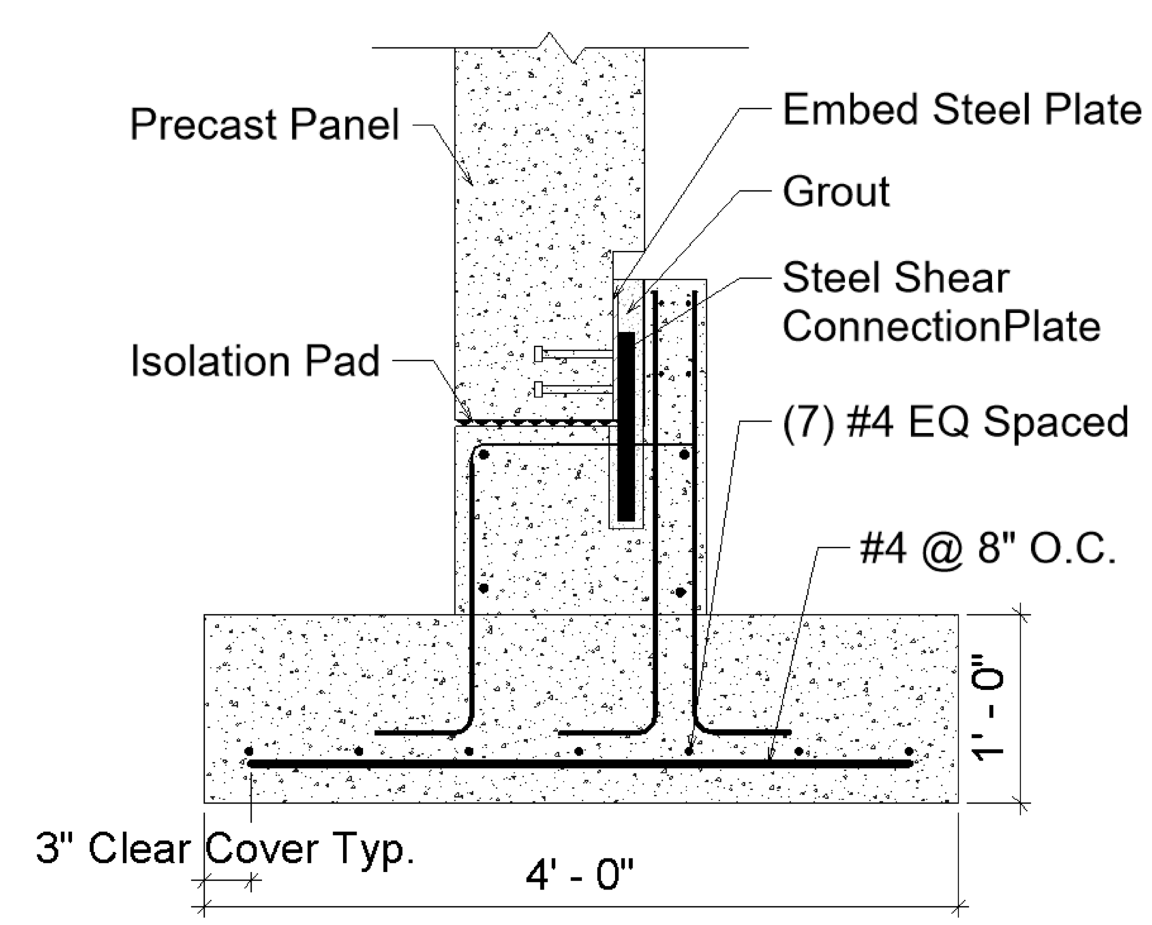
ACOUSTICAL DETAILS FOR PRECAST PANELS

Syndicate is proposing to consider the following two details for panel to panel connection. The image on the left incorporates the use of acoustical sealant along with a staggered joint to mitigate sound transmittance from exterior sources coming into the acoustically sensitive space. The team suggests utilizing the detail on the left.





Precast Foundation Detail



SYNDICATE

PROJECT

JACK H. MILLER CENTER FOR MUSICAL ARTS

HOLLAND, MICHIGAN

SHEET TITLE: LATERAL

NOT FOR CONSTRUCTION

AEI TEAM NO.: 01-2019

DATE: February 18, 2019

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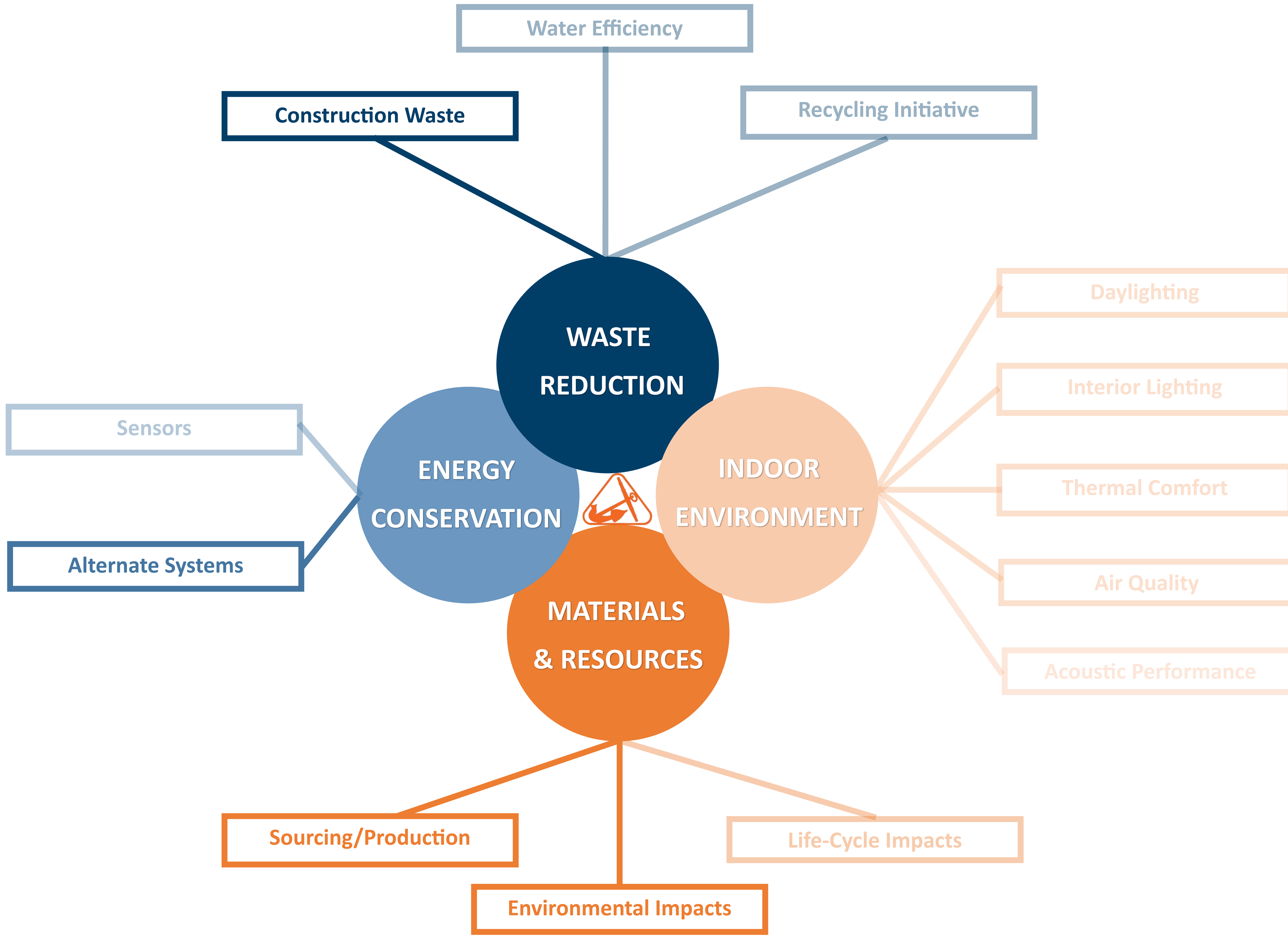
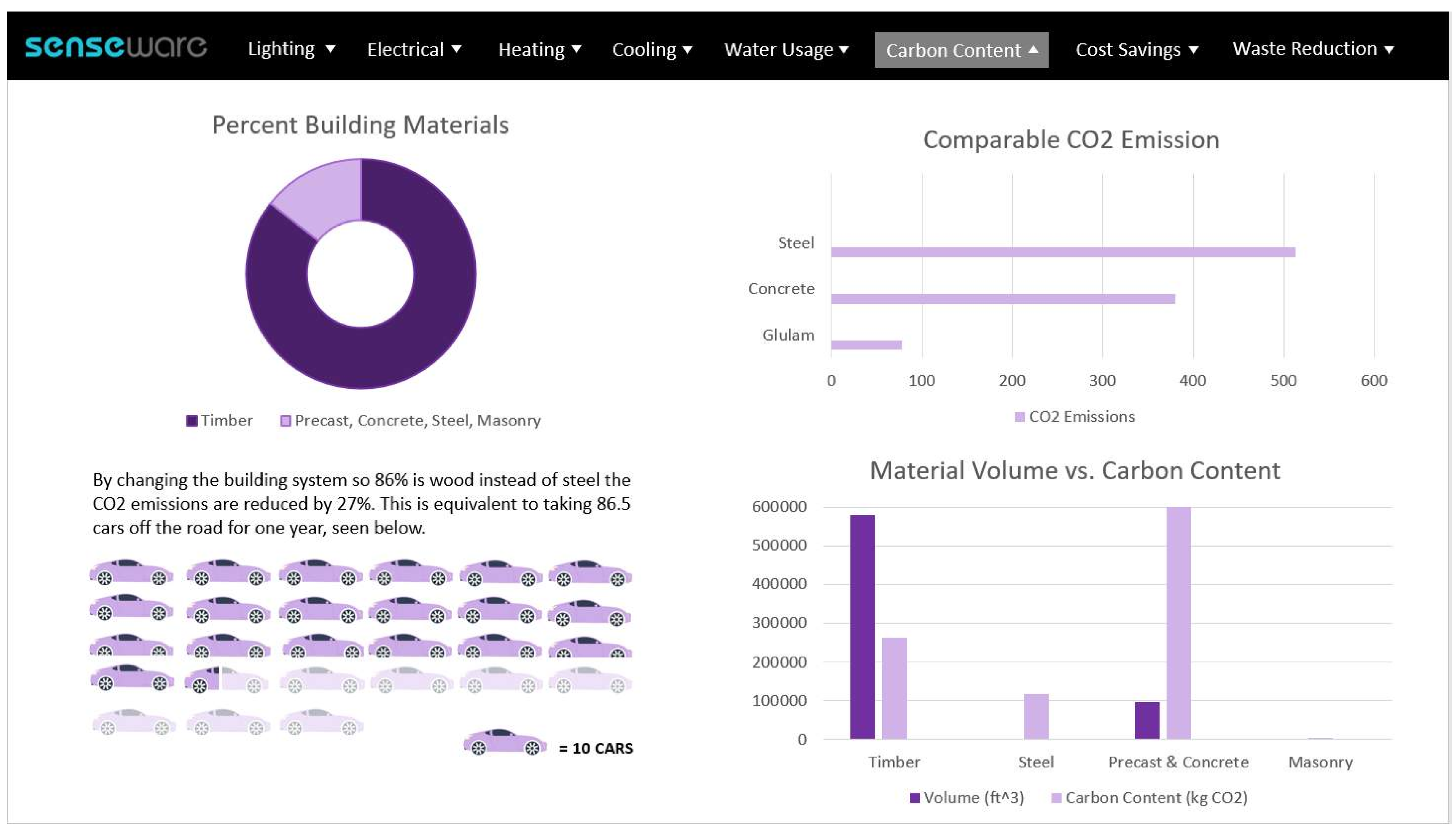
DRAWING NO.: S-9.0

THE HOPE COLLEGE SUSTAINABILITY PLAN

Syndicate, after considering aspects of the LEED and WELL plans and the efforts that Hope College is already making, has created a customized sustainability plan for Hope College. This plan allows Hope to pursue environmentally-minded goals without sacrificing their academic objectives. There are four main canons that encompass large sustainability aspects, and those four are broken down into several implementation categories (shown below). The objectives that were considered during the structural design of The Miller Center are highlighted below.



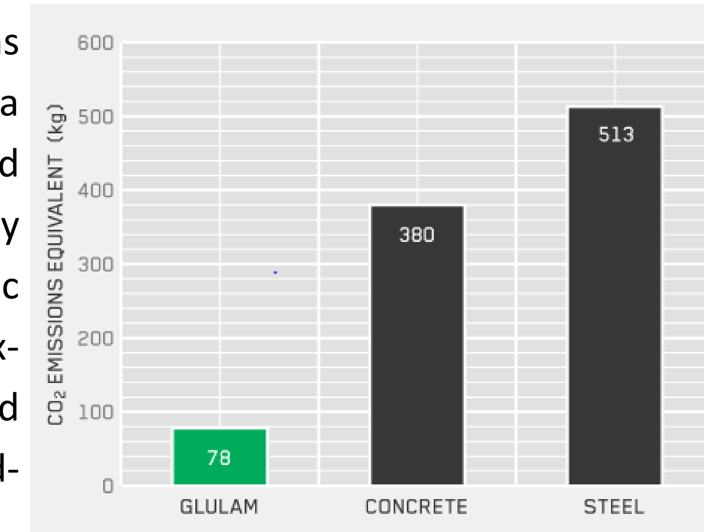


JACK H MILLER PILOT PROGRAM

Syndicate has implemented this Sustainability Plan on the Miller Center project. Below are the specific aspects of the plan that are highlighted on this project, color-coded by responsible discipline.

Environmental Impacts

The structural system of The Miller Center is CLT and glulam, which emits significantly less greenhouse gas than concrete or steel. It also works to trap carbon dioxide that other systems emit. In total, choosing a wood structure reduced the carbon content by 70%. Below is a graphic depicting the carbon dioxide emissions of standard structural systems provided by Nordic Structures.



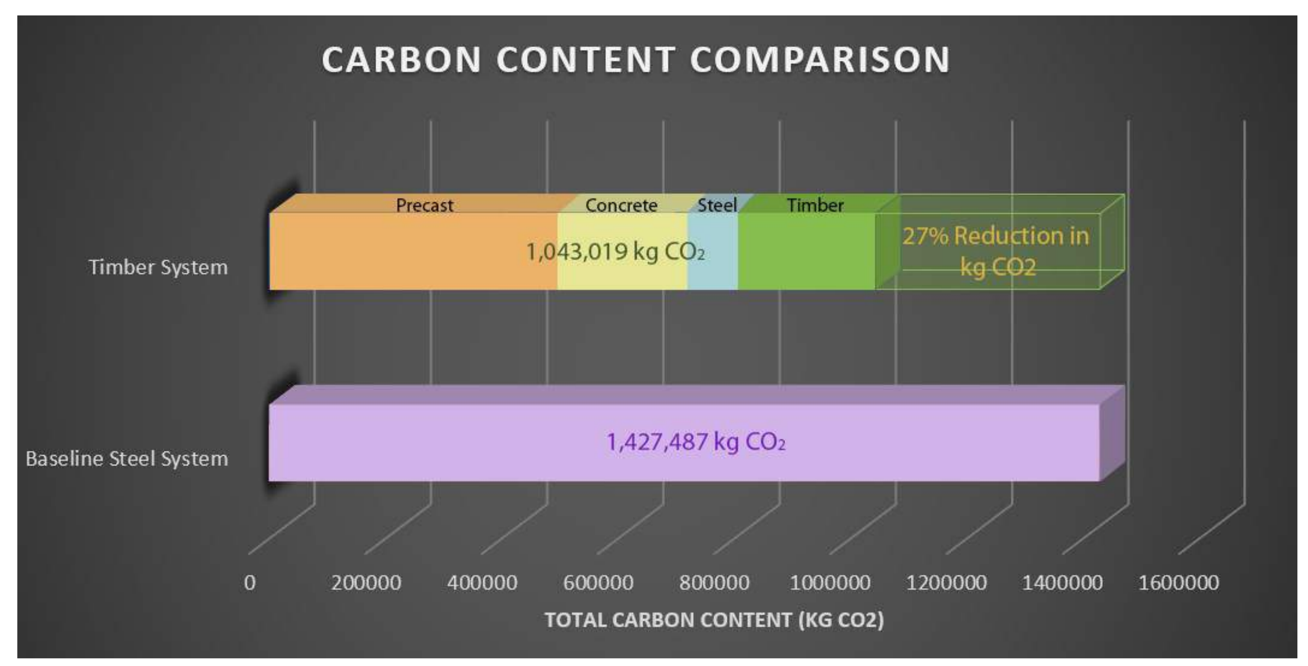
Construction Waste

There was a site wide effort on The Miller Center project to minimize waste. Prefabrication was heavily utilized to through the precast lateral system and the CLT assemblies.

Alternate Systems

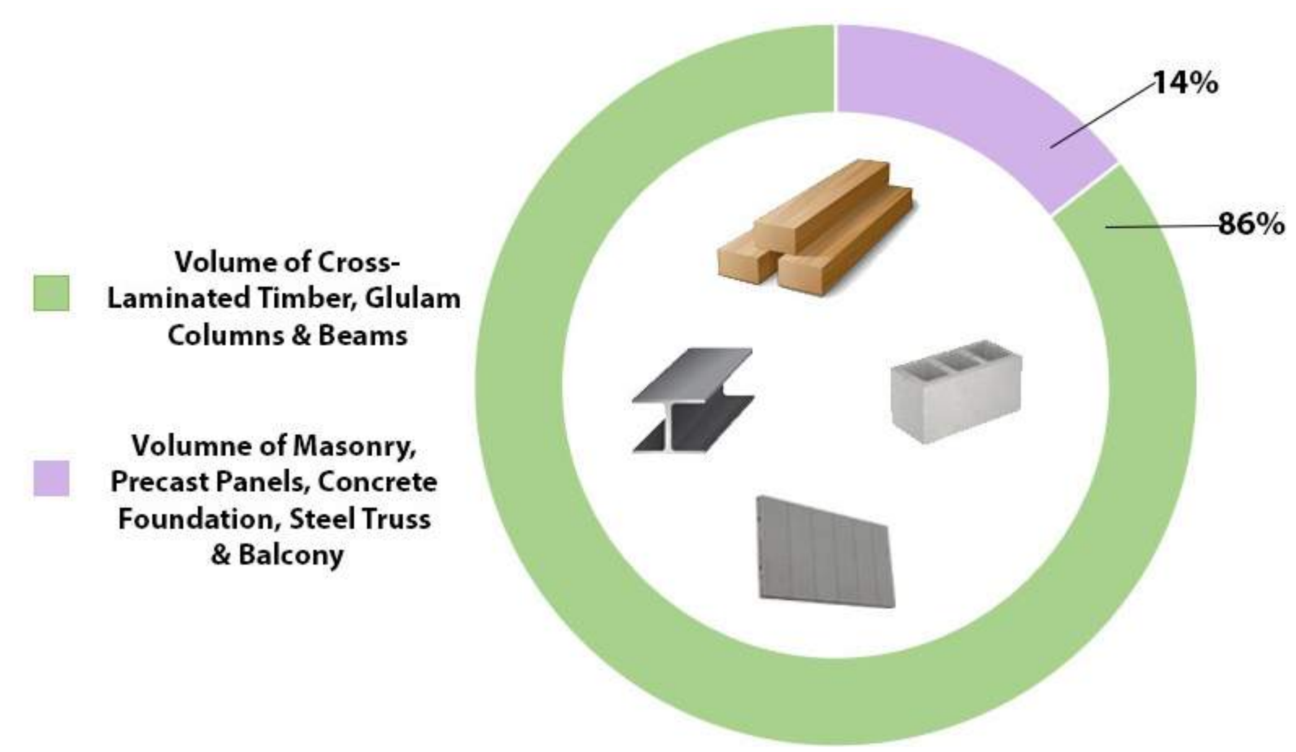
Syndicate chose to implement a sustainable design by choosing a wood structural system over a steel structural system.

CARBON CONTENT



PERCENT WOOD

Designing the gravity system to be majority wood allowed Syndicate to achieve 80% wood by volume for the superstructure. The wood consisted of glulam beams and columns and CLT decking. Due to the factors, such as cost, constructability, acoustics and efficiency, steel was used for the balcony and truss in the concert hall and precast for the lateral system.



Acoustic Performance

One of Syndicate's primary goals is to create a world class acoustic space for premier performances. In the typical structure, the flooring system was developed to help mitigate vibrations and exceed the industry standards for STC and IIC. The concert hall has a slab-on-grade of high mass with an isolation pad in the middle to help diminish the vibrations from the train nearby. Also, the wall assembly, which is part of the lateral system, is thickened to achieve a higher acoustical performance. Through the mass and layup an STC of 65 was achieved. Furthermore, the mechanical section of the building was isolated to prevent vibrations produced by the mechanical equipment from transmitting into the rest of the building.

Sourcing/Production

The manufacturer chosen for the CLT and glulam members of The Miller Center is heavily involved in the forest operations where the wood is harvested. This company is cognizant of the amount of wood that they use and ensures that every tree is replaced to minimize the impact on the environment and the integrity of the forest.

CASE STUDY

An article published by *Structure Magazine* titled *Mid-Rise Wood-Frame Buildings* discusses safety, sustainability and cost of wood structures. It concludes that:

- **Safety:** Wood structures are just as safe as any other since it has to meet the same rigorous requirements outlined in the code.
- **Sustainability:** There is a smaller carbon footprint with wood, reducing the environmental impact.
- **Cost:** IIC Building Valuation Data compared the cost of buildings under different construction types. Wood is allowed, and often used, in Type IIIA and IIIB. However, noncombustible materials are not allowed in Type IIA and IIB. Below is a table listing their findings.

Construction Type	Decrease in Cost/SF
Type IIA —> Type IIIA	$20
Type IIB —> Type IIIB	$18

SYNDICATE

PROJECT

JACK H. MILLER CENTER FOR MUSICAL ARTS

HOLLAND, MICHIGAN

SHEET TITLE

SUSTAINABILITY PLAN

NOT FOR CONSTRUCTION

AEI TEAM NO. 01-2019

DATE February 18, 2019

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DRAWING NO. S-10.0

PAGE NO. 60

0.0 MECHANICAL EXECUTIVE SUMMARY

SNOWMELT SYSTEM

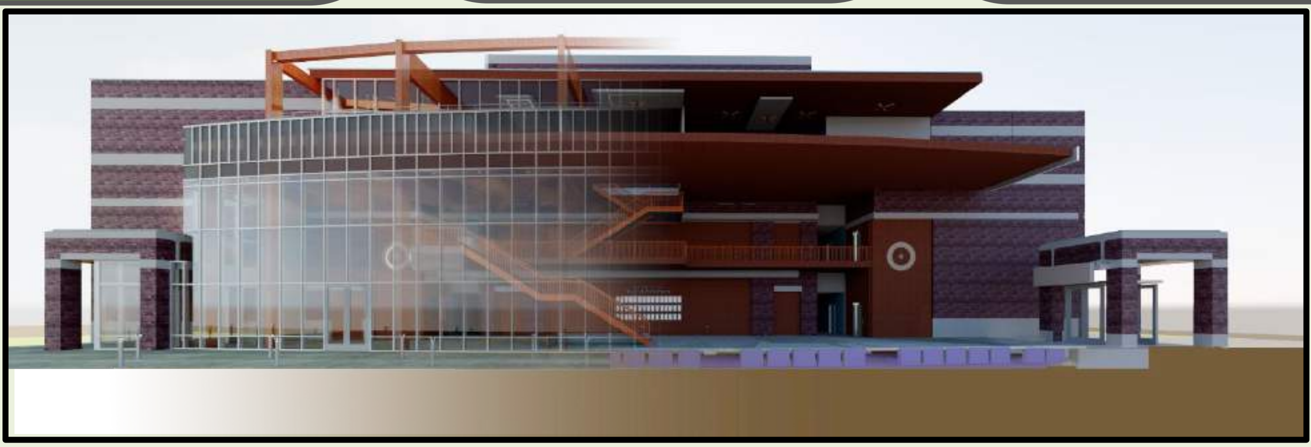
- Located in both the roof and plaza.
- Uses free heating energy from steam condensate.
- Melted precipitation reused for building as grey water.
- Saves 200,000 gallons of water every year.
- Prevents snow from accumulating on horizontal surfaces.

CENTRAL PLANT OPTION

- Contains a combined heat and power plant coupled with a chilled water plant.
- Provides Hope College the flexibility for to increase the campus building square footages by 900,000.
- The plant will be placed in an open site already on campus and allow for cleaner energy and electric production.

VENTILATED DOUBLE WALL FAÇADE

- An integrative glass façade that provides natural light with minimal added envelope load.
- Reduces heating and cooling cost by $6,600 per year.
- Modularized assembly allows for easier constructability.



DISPLACEMENT VENTILATION

- Underground ducts serve large volume spaces to reduce plenum clutter.
- Direct supply of air to the occupants elevates indoor air quality.
- Saves energy by not conditioning upper unoccupied zones in high volume spaces.

ACOUSTICS

- Ductwork was ensured to not transmit disruptive background noise by installing duct silencers and sound insulation.
- All mechanical equipment was assessed to provide proper vibration isolation.
- The mechanical rooms are structurally isolated from the building to mitigate vibrations.

THERMAL STORAGE

- Reduces peak utility usage demand by load leveling the peak demands
- Saves $16,200 per year with little additional first cost.
- The cooler chilled water for thermal storage also provides cool water for dehumidification in air handling units.

Mechanical Table of Contents

1.0 PROJECT OVERVIEW

The Jack H. Miller Center for Musical Arts (The Miller Center) is a proposed building project for Hope College located in Holland, Michigan. *Syndicate* is an integrated design-build team that produced a high-quality design and construction plan for this project. The project site is situated in the northeast corner of campus across from downtown Holland, near Lake Michigan. The Miller Center acts as an investment for the future of Hope College and as a showcase pilot for a new sustainability plan on campus. The addition of an occupiable roof and south lobby allows this building to act as a gateway space for connecting Hope College campus to downtown Holland. *Syndicate*'s final design is a three-story building designed for serving the educational and performance requirements of Hope College. Totaling 70,000 square feet (SF), The Miller Center includes an 800-seat symphonic concert hall, a smaller recital hall for intimate chamber performances, and two large rehearsal spaces for choirs and orchestras. The building also includes classrooms, faculty studios, and student practice rooms distributed throughout the three stories.

2.0 VISION STATEMENT

Through a multidisciplinary team strategy, *Syndicate* produced a high-quality center for musical arts that met the goals and mission of Hope College found in. As a team, *Syndicate* chose to pursue this project with a vision statement that would contain individualized team and discipline goals. The vision statement is HOPE and the goals are to:

Enhance **H** ope College Campus

Maximize **O** ccupant Experience

Create Premier **P** erformance Spaces

Minimize **E** nergy Impact

Refer to Integration SD-A for details about the vision statement

3.0 PROJECT GOALS

To achieve HOPE, *Syndicate* created specific integration goals for these four vision statements. Below are the objectives for the mechanical team to meet the integrated team goals.

3.1 Enhance Hope College Campus

Syndicate wanted to ensure that the goals of Hope College as well as the individual goals of The Miller Center were not only met but exceeded. There was a push from the beginning to not only meet codes but also optimize the energy performance of the building as well as the entire campus. In addition to optimizing energy, a design should be proposed to allow for Hope College to expand the entire campus by an additional 400,000 of building square footage.

3.2 Maximize Occupant Experience

The Miller Center hosts numerous events every year that range from musical performances to graduation ceremonies. In addition to the performances, there are faculty and students in the building during the academic school year. With the various occupant uses come different thermal performance considerations that must be addressed to create an environment that is comfortable, healthy and meets the mission of the college.

3.3 Create Premier Performance Spaces

One major aspect of the building is the performances that bring together the campus and the community of Holland. One of *Syndicate's* main points of focus from the start of the project was to ensure the building mechanical systems provide an NC level of 20 in performance spaces to create the intended experiences. In addition, the mechanical equipment vibrations should be prevented from travelling to acoustically critical spaces.

3.4 Minimize Energy Impact

Syndicate aims to reduce the amount of energy that The Miller Center uses. This reduction of energy begins with the optimization of the mechanical system to set a new standard for sustainability. The overall goal is to reduce the mechanical energy consumption by 40% when compared to the ASHRAE 90.1 baseline model. To help with this, advantageous architectural changes should be made in the design phase to reduce energy consumption from the start.

4.0 CODES AND SOFTWARE

The mechanical design team used IECC 2009, as required for projects in Michigan, ASHRAE 62.1 for ventilation requirements, and ASHRAE 90.1 for energy requirements. A full list of codes utilized by *Syndicate* can be found on the Codes and Standards page. By using these codes and standards as a baseline, mechanical design team was able to create a design that exceeds the requirements for this project type.

4.1 Design and Analysis Software

Syndicate used a variety of industry programs to complete the site analysis and design the mechanical system's load profiles. *Trane Trace 700* was the primary resource in determining the load profile of The Miller Center and in analyzing various parametric studies on the energy usage of the building. *IES Virtual Environment* was a supplemental tool to obtain detailed hour by hour profiles of multiple variables that affect energy consumption of the building. *Syndicate* also utilized *Star-CCM+* to produce a CFD model, proving the effectiveness air movement in spaces. In addition, hand calculations, *WUFI Pro*, *Bluebeam*, *Microsoft Excel*, *Revit*, and *AutoCAD* were used throughout the design process to calculate and document the final mechanical design, seen on Mechanical SD-A.

4.2 Climate Zone

The Miller Center is in climate zone 5A according to the International Energy Conservation Code. This climate zone is characterized by typically having cold and humid weather. The Miller Center contains storage space for musical instruments that require a relative humidity level between 40-60%, so the high humidity levels in this climate would have to be addressed.

5.0 BUILDING AND SITE ANALYSIS

A site analysis was initially done to determine the weather variation, solar paths, and wind conditions that will influence the final design.

5.1 Proximity Factors

The Miller Center is located seven miles from Lake Michigan and a quarter-mile from Lake Macatawa. Both lakes are too far for access to heat rejection. In addition, the Holland Amtrak railroad is located 100ft to the east of our building, which posed acoustical and vibration concerns that *Syndicate* found important to address during the design process. Utility connections are located south of the site running along 10th street.

5.2 Solar Analysis

After running simulations in *IES Virtual Environment* and *Licaso*, a plugin of AGi32, *Syndicate* determined there was not an adequate amount of daylight in most spaces, while a large amount of direct sun comes in the given design's lobby with an addition of 38 tons of solar gain during peak days. The lobby faces directly west, meaning throughout the year the sun penetrates into the space creating an uncomfortable space in regard to solar heat gain as well as direct glare with an average of 1200 lms/SF, see Lighting Drawing L-6.0. *Syndicate* decided to add daylighting with minimal solar heat gain as a priority when moving forward with design changes.

5.3 Climate Analysis

Using ASHRAE Fundamentals 2017, the design conditions for Holland, Michigan were estimated from

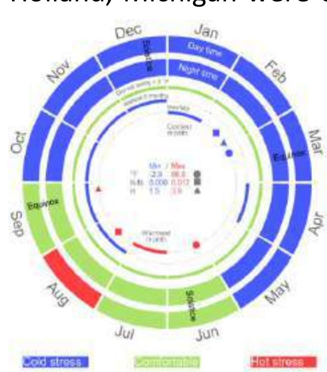


Figure 1: *Holland, Michigan IES Stresses*

the nearby Muskegon Airport weather station as shown in *Figure 1* on previous page.

Due to the dominance of cold stresses coinciding with the academic year, the envelope heating load needed to be addressed. Additionally, an analysis of Holland's humidity levels, displayed in *Figure 2*, showed that only 554 hours out of the year would be appropriate to use natural ventilation.

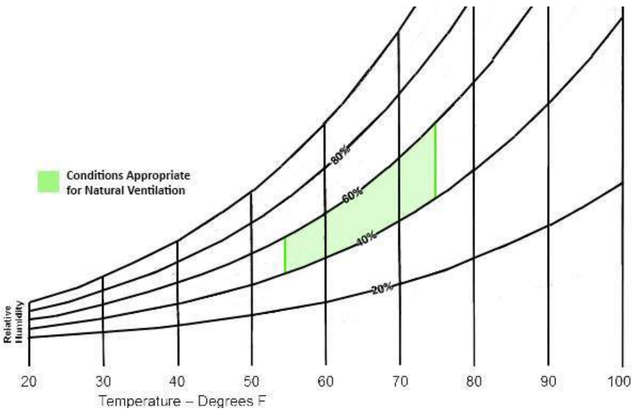


Figure 2: *Natural Ventilation Analysis*

This analysis constrained natural ventilation conditions to temperatures between 55-75F for thermal comfort. In addition, to ensure humidity levels are maintained between 40%-60% relative humidity for instrument storage, a psychrometric chart and bin data were used to predict how often the humidity conditions were met. Due to the combination of tight temperature and humidity constraints, natural ventilation is not a recommended strategy for the portion of The Miller Center where instruments are used.

Holland, Michigan receives on average 36.75" of rain and 70" of snow per year. Most recently, Holland, Michigan received 15" of snow accumulation over a one-week span. These parameters were important in designing the stormwater conservation system. See Mechanical SD-B for further climate analysis.

5.4 Wind Analysis

The wind rose in *Figure 3* indicates that the strongest winds come from the northwest from lake michigan during the winter months and shift to strong winds from the south during the summer months. The average wind speed is 12 mph, but can reach speeds up to 38 mph in the winter.

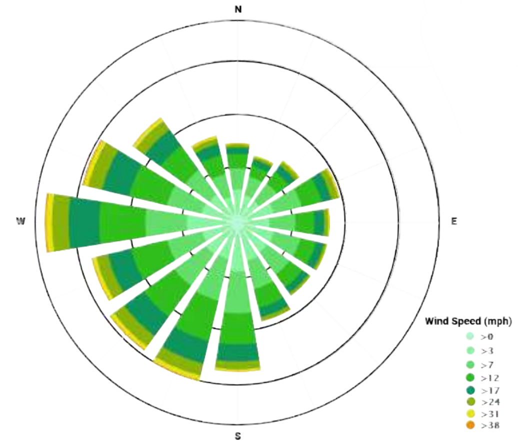


Figure 3: *Wind Rose for Holland, Michigan*

The wind speed and direction were considered when placing an occupiable roof on The Miller Center. To avoid strong, obtrusive winds from the south and west the occupiable roof was placed on the north side of the building to encourage light summer breezes to enter the space, see Mechanical Section 7.3.

6.0 ARCHITECTURAL DESIGN ANALYSIS

Syndicate created decision metrics to assist in determining the best alterations to make to the given design of the building.

6.1 Building Orientation

The first alteration *Syndicate* analyzed was the orientation of the building. The given design had the main lobby facing due west. However, *Syndicate* concluded the combination of harsh direct sunlight and high solar gain throughout the year warranted a redesign. The revised design involved rotating the building 90 degrees clockwise so that the main lobby faced north towards the town of Holland. The given design placed the emphasis on a single connection point between campus and the town. The redesign reduced the solar heat gain in the lobby space and the building overall (*Table 1*).

Table 1: *Solar Heat Gain Reduction*

	Solar Heat Gain (TON)	
	Current Orientation	Rotated
North Lobby	34	5
Rest of Building	4	9
Total Building	38	14

To address the pedestrian relationship to central campus, an additional southern entrance is provided as a secondary connection point to the student-oriented spaces while maintaining a grand entry for the performance venue. As the given design intended, the southern entrance design draws inspiration from the surrounding buildings on campus. Between the south and north entrances, a one-story glass hallway was placed to act as a merging point between campus and the town of Holland.

Through the architectural modifications, the annual overall building mechanical energy load was reduced by 44% which surpasses the goal of 40%. See Mechanical SD-C for further energy analysis.

6.2 Third Floor Addition

Daylighting for the occupants was a major design driver when considering architectural changes. The building program requested the addition of an occupiable roof, presenting the need to extend the elevator and main stairwells. Due to the infrastructure already being implemented and desire to increase the number of spaces with daylight, *Syndicate* decided to reduce the footprint of the first and second levels on the west and add an additional third floor. This addition increased the façade area as well as the number of windows, so *Syndicate* had to ensure the building enclosure would mitigate any increase in envelope load from the given design.

7.0 BUILDING ENCLOSURE

Designing the enclosure required a highly integrative design process across all disciplines. A high-performance enclosure must be a balance of being an acoustical barrier, acting as a thermal air barrier, providing adequate daylight performance, being structurally sound, and providing an architectural statement for Hope College.

The facade is split into two wall assembly types as seen in *Figure 4*. Both wall assemblies are clad with 4" modular brick to maintain the aesthetic of Hope College's Campus. 3" polyisocyanurate board is run continuously to mitigate any thermal bridging in both assemblies. For the shear wall assembly, 12" precast walls will be used as the structural component. See

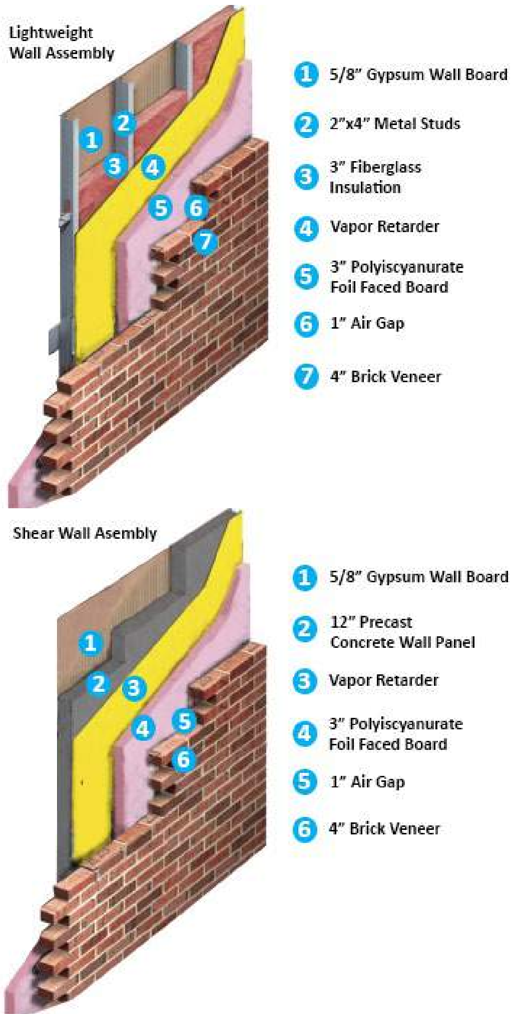


Figure 4: *Typical Light Weight Framing and Shear*

Structural Drawing S-9.0 for information on precast shear walls. For the typical wall assembly, 2"x4" metal studs filled with R-13 fiberglass insulation are placed to further increase the thermal resistance of the wall assembly (*Table 2*), see Mechanical SD-D for detail.

Table 2: *Wall Assembly R-Values*

	R-Value	Baseline Improvement
Light Weight Framed Wall	30	40%
Precast Concrete Shear Wall	25	28%

Moisture control is addressed with the addition of a continuous vapor retarder on the interior side of the 3" polyisocyanurate board. This was purposeful since the polyisocyanurate board will not act as a proper vapor retarder. The interior foil-facing side cannot be sealed when installed against metal studs or concrete precast walls, creating holes where moisture can penetrate the wall. *WUFI*, which is a moisture transport analysis software, was used to analyze whether water would accumulate in the assemblies, displayed in *Figure 5*.

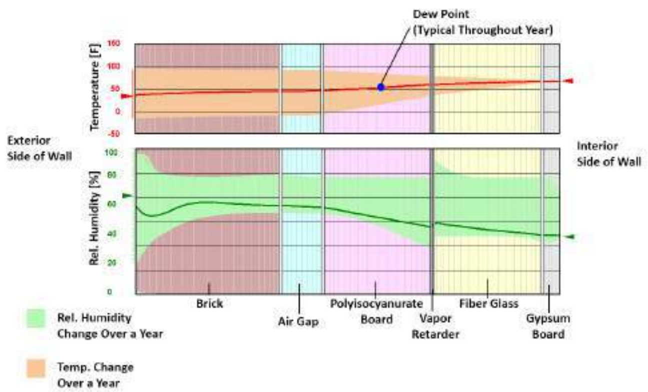


Figure 5: *Thermal and Moisture Analysis of Wall Assembly*

Both wall assembly types were proven to permeate water through the exterior layers without condensation occurring in the fiberglass insulation and metal stud, which is the critical component of the wall assembly. This was determined by ensuring the fiberglass insulation never reached the dew point.

7.1 Ventilated Double Wall Facade

To maximize occupant experience and to minimizing energy impact were main drivers in the mechanical team's facade design. *Syndicate's* architectural changes created a ring of circulation surrounding the main functions of the building. The south, north, and west transient spaces have windows for natural daylight to enter the building. Because of this, the solar heat gain through the main public spaces were analyzed and it was determined that the heat could be captured in the transient spaces before it reached the occupant. To optimize performance and thermal comfort, *Syndicate* analyzed the benefits of utilizing a ventilated double wall facade in the north lobby, west corridor, and the south lobby, detailed in *Figure 6*.

The ventilated double wall façade allows daylight to enter while serving as an additional method to heat and cool the space. The exhaust from the ventilated double wall facade will connect to the air handling units with dampers so that in the summer the air can be directly exhausted, but in the winter the solar heat gain can be recovered by the air handling units to preheat the outside air. See <u>Mechanical SD-D</u> for further details.

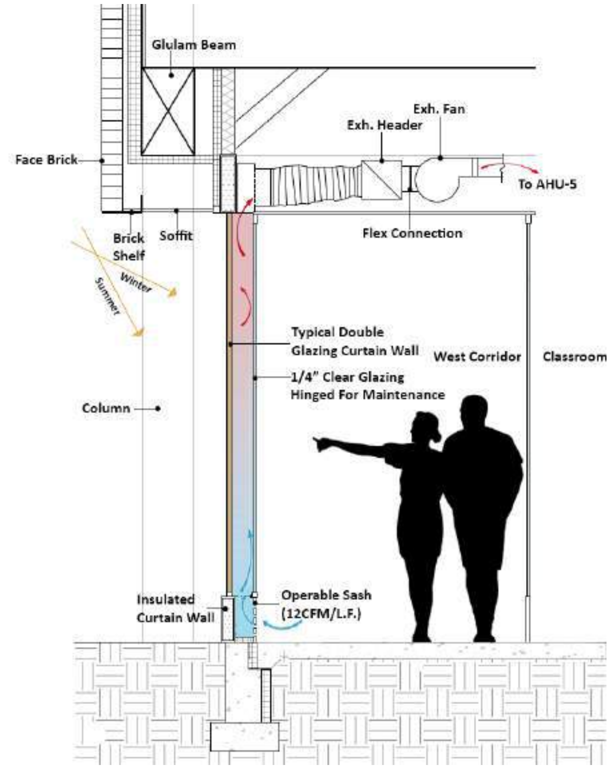


Figure 6: *Ventilated Double Wall Facade Detail*

The ventilated facade on the north lobby and south lobby were deemed inappropriate because of a 30-year and 15-year payback period respectively. This is due to the cost and maintenance of a double height dynamic facade. In the west corridor, the return air can recover up to 8.4MMBTU/hr in the winter and prevent 75.5MMBTU/hr from entering the corridor. This provides up to $6,600 and 14% in annual utility savings which results in an 8-year payback period; therefore, *Syndicate* chose to implement the ventilated double wall façade in the west corridor in the summer.

7.2 Roof

Syndicate aimed to comply with the requirement set by ASHRAE 90.1 to provide an adequate thermal barrier to mitigate unwanted heat transfer. Coordination between disciplines provided a sustainable roof solution.

Factors that were analyzed included the weight and cost of the roof. One option considered a green roof design, but further analysis showed that it added around 13 lbs/SF in weight, which increased the depth of beams in a typical bay by 19%. The current built up roof membrane costs $5.36/SF, but with the addition of a green roof assembly the cost per square foot would increase by $25. When considering all these factors, *Syndicate* determined not to pursue a green roof.

A cross laminated timber (CLT) based roof provides more thermal mass than a typical roofing system. This mass slowly releases or absorbs heat, preventing sudden fluxes in heat flow through the roof. The roof incorporates a snow melt system in order to capture the precipitation to use as grey water throughout the year. For more details see Mechanical Section 10.2. The total makeup of the roof provides an R-Value of 36 that exceeds the ASHRAE 90.1 standard by 20% (*Figure 7*).

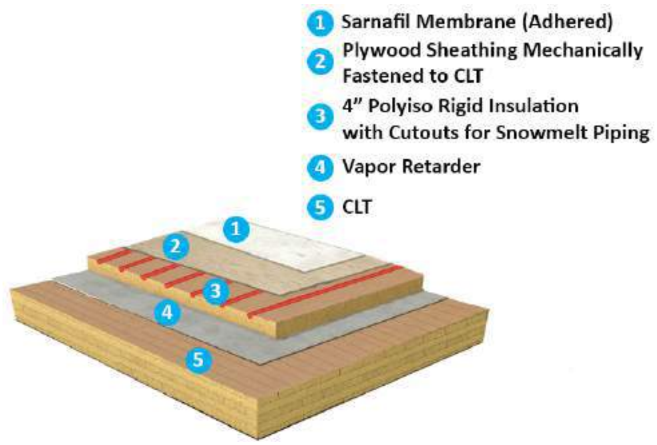


Figure 7: *Typical Roof Detail*

To allow daylight to enter more faculty studios and practice rooms on the third floor, skylights were designed into the roof. With the addition of solar gain, the skylights added 2,226 kWh/year to the overall cooling energy. However, with the addition of natural light, the electrical energy usage is reduced by 4,955 kWh/year, resulting in a net reduction of 2,647 kWh/year by adding skylights. In regard to the mechanical design in the faculty studios and practice rooms with skylights, the return air grille will be placed adjacent to the skylight opening. The placement will allow for hot air to be directly exhausted from the skylight opening rather than allow it to enter the space.

7.3 Occupiable Roof

As requested by the building program *Syndicate* has provided the option of adding an occupiable roof space that can be used year-round. In order to be utilized in the varying weather of Holland, Michigan, the space was designed with sliding glass doors incorporated into the facade, shown in *Figure 8*, that can be kept open in the summer months to provide natural ventilation for cooling and closed during the winter months to block north-west wind. Natural ventilation is viable in this space because there is no constraint on the temperature and humidity control that other spaces have due to instrument storage.

Figure 8: *Glass Openings in Occupiable Roof*

In accordance with ASHRAE Comfort Standard 55, overhead fans will be utilized to encourage air movement over the occupants, keeping them comfortable in the outdoor space. During the winter months, the glass doors will be closed, and a heating ventilation unit will be used to heat and provide fresh air in order to maintain a comfortable condition for performance receptions. The heating ventilation unit will be set back to 45°F during unoccupied times and be raised to 65°F two hours before a scheduled event.

The occupiable roof also acts as an additional thermal barrier above the north lobby. The space adds an equivalent R-value of 20 to the north lobby roof, saving 90MMBTU/hr in energy usage.

8.0 SYSTEM DESIGN

The overall HVAC system design is an integrative solution that complies with code and creates an environment where students, faculty, and the community of Hope College alike can enjoy. The design provides energy savings as well as acoustical considerations that reduce the sound transmitted by the mechanical equipment, which helps create an environment for superb performances. There was careful planning with other disciplines for seamless integration into the building.

8.1 Central Plant Options

When considering the mechanical system, *Syndicate* wanted to look at multiple heating/cooling system options to provide the optimum design for Hope College.

Option 1 - A standard mechanical central plant with thermal storage. This would include a typical decentralized plant with connection to campus steam and individual chillers that utilized an ice storage system to offset a portion of the peak electric load.

Option 2 – A centralized campus plant that includes a combined heat and power plant as well as a chilled water plant. This would take advantage of the ability to produce electricity and chilled water in addition to generating steam.

Option 3 - A geothermal based central plant. This option offers the use of the ground as a heat sink with the use of geothermal heat pumps.

See Mechanical Section 8.1.4 for central plan recommendations and Mechanical SD-A for decision matrix.

8.1.1 Decentralized Mechanical Central Plant

Currently, Hope College has a small steam plant on campus. Limited by the competition rules, an assumption is made that it serves the resident halls, office buildings and bigger buildings around campus, including The Miller Center. It is inferred that steam-to-hot water heat exchangers will convert steam to heat in the building's hot water loops.

On the cooling side, *Syndicate* decided to analyze thermal storage approaches to offset the peak mechanical load due to the high electric demand charges in Holland. An internal freeze/ internal melt system was finally selected due to its ability to accommodate smaller scale projects, such as The Miller Center, see Mechanical Drawing M-6.0. "Internal freeze/internal melt" systems use a secondary coolant, such as glycol, as the charging and discharging heat transfer fluid, which is circulated through coils that are submerged in water tanks. To make the ice, a chiller cools the glycol to 24F so ice can form on the outside of the coils. Ice is released from the coil in the discharging cycle when warm glycol flows through the coils and melts the ice from the inside out. The released ice chunks, in turn, reduces the primary coolant temperature. (*Figure 9*).

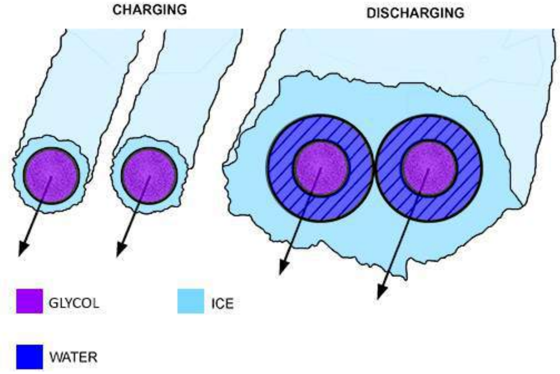


Figure 9: *Internal Freeze/Internal Melt Diagram*

The final design thermal storage capacity is 400 ton-hrs, allowing for the reduction in total chiller capacity from 200 tons to 160 tons. Two 80-ton air cooled scroll chillers were chosen to meet the required load and fully charge the thermal storage overnight (*Figure 10).* Air cooled chillers were selected because of the low wet bulb depression due to high humidity levels throughout the year in Holland. Normally, a cooling tower would be more effective than an air-cooled chiller when the wet bulb is much lower than the dry bulb, but in this specific climate this advantage is not as prominent. Furthermore, air cooled chillers operate at higher efficiencies at night because of the diurnal outside temperatures, which is ideal for ice making. A closed loop system with glycol was chosen to mitigate any freeze/thaw concerns in the primary building distribution loop. The chilled glycol goes directly to the air handling unit cooling coils, and then is sent through a flat-plate heat exchanger for the radiant panel chilled water supply, see Mechanical Drawing M-5.0.

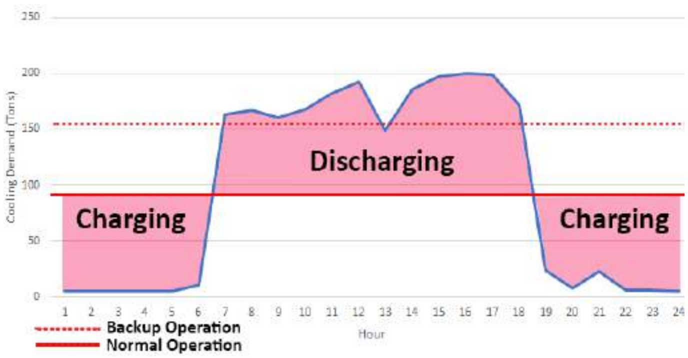


Figure 10: *Thermal Storage Load Profile*

By having two chillers and thermal storage, there are several control scenarios in the instance of mechanical failure. In the case of thermal storage failure on the worst design day with everything running simultaneously, the building cooling load is met with a 65% full concert hall. The building operator can have the choice of completely cooling a full concert hall or balance cooling of the entire building. Similarly, in the case of a chiller failure on the worst design day, the thermal storage and one chiller can cover the entire building plus 50% of the full concert hall load. If Hope College wishes to guarantee 100% operation on the worst design day in the case of a storage system failure, an additional air cooled 40-ton chiller can be added at a cost of $39,500.

With thermal storage levels equaling the load during on-peak hours for design days, this strategy eliminates the need for day time chiller use on most non-performance days. The on-peak demand charge for Holland, Michigan is $14.50/kW, so by reducing the chiller capacity during the on peak hours, the annual utility bill is decreased by $16,200/year. Due to the reduction of 40 tons in needed chiller capacity and significantly lower monthly utility cost, the economic analysis proved thermal storage to have a payback period of 1.4 years.

8.1.2 Central Heating/Cooling Plant

Examining the existing Hope College steam plant, it can be assumed that the plant is at full capacity. Option 2 introduces a combined heat and power (CHP) plant as a staged replacement of the steam plant as well as a proposed central chilled water plant. The addition of CHP would increase the capacity of steam that is produced to not only cover the existing buildings but allow for campus expansion. In addition to the steam produced, there will be electricity produced to introduce into the campus grid. The current capacity of the steam plant is estimated to be 11,500 lbs/hr of steam and the estimated campus electricity demand is 3 MW. Based on these requirements, the smallest efficient package unit for size was specified to provide optimal operational efficiency. The enclosure access and maintenance space can be seen in *Figure 11*.

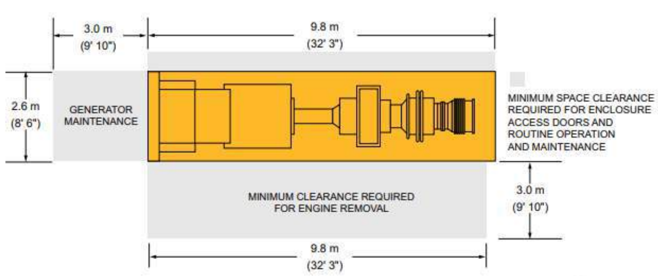


Figure 11: *CHP Unit Clearances*

There is an adjacent plot of land to the east of The Miller Center that can be utilized for the new central plant building (*Figure 12*). The total estimated cost of this additional building is $500,000, and the total area of the space is 6,500 SF. The building will include space for the gas turbine, the chillers for the central chilled water system, and the offices for maintenance and operation monitoring.

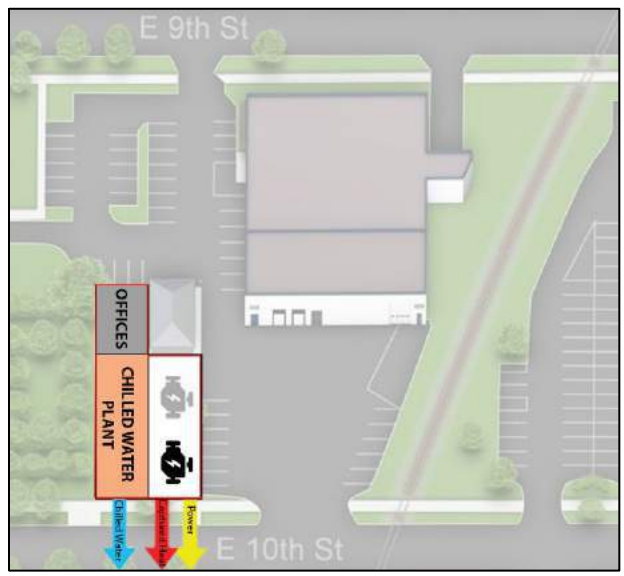


Figure 12: *Central Plant Proposed Building*

There is ample space in the new plant for additional CHP units. By only adding one more unit, the campus will have the ability to almost double in building square footage, or close to 900,000 SF expansion. The upfront cost of the CHP equipment is around $2 million while the standard boiler system equipment was estimated to be around $400,000, but the savings of fuel use each year is where CHP surpasses the standard system. Fuel cost for the standard system includes both natural gas and electrical costs which are estimated to around $1.5 million per year while the CHP fuel cost is estimated at half of this. The CHP system provides a simple payback period of around 4 years for the equipment.

On the other hand, the campus steam plant currently does not have a central chilled water system. Option 2 will introduce a campus chilled water loop. This addition will be modularized as well and added as needed for future expansion of the college for a more economical approach. Included in the plant are absorption chillers that use the steam in order to run the CHP units at close to full load in the summer to prevent any inefficient operation.

In order to phase Option 2 into the campus, there will be a switch over period that includes the existing steam plant still operating while the CHP system gradually becomes available. The central chilled water system would be phased into any new buildings and is not intended for retrofitting any existing buildings to use this technology. Option 2 takes advantage of a central plant for both cooling and heating that detaches energy generation from individual buildings. This reduces the mechanical noise generated in buildings by having the major equipment in a central plant. See Mechanical SD-E for further details.

8.1.3 Geothermal Heat Pumps

Geothermal heat pumps were considered as an innovative central plant system for Hope College. *Syndicate* wanted to mitigate disruptions to additional areas on campus, so geothermal bores were only considered on the given site and neighboring Physical Plant Department site. A full geothermal heat pump system and hybrid geothermal heat pump system were considered, but both produced a negative simple payback of greater than 50 years. Also considering the accessibility of campus steam for heating, geothermal heat pumps are not recommended for The Miller Center.

8.1.4 Central Plant Recommendation

Considering all options, *Syndicate* recommends Option 1, the standard mechanical central plant with thermal storage. Option 1 best fits within the given budget constraints when compared to the other options. On the other hand, Option 2 is forward thinking and invests in the future potential of Hope College. *Syndicate* recommends pursuing Option 2 because of the potential campus wide energy savings and the added flexibility for campus expansion despite the increased initial investment.

8.2 Distribution Systems

The distribution system was zoned by space design criteria and space usage as seen below:

Table 3: *Distribution Strategies*

Space Type	Distribution Strategy
Large Public Spaces	Displacement Ventilation
Faculty Studios and Practice Rooms	Radiant Panels and DOAS
Stage and Storage	Typical VAV Ceiling Supplied

8.2.1 Displacement Ventilation

To minimize energy impact and improve the occupants experience, the mechanical team pursued the use of displacement ventilation in large volume spaces. The supply diffusers are located to ensure every occupant receives outside air and maintains optimal indoor air quality and thermal comfort. Supply air between 63-68°F is sent through ductwork at 900 fpm into a plenum that reduces the air speed further to 50 fpm before reaching supply diffusers. In the auditorium the diffusers are located in front of the seats. This is done to prevent occupant belongings from covering the outlet while also providing each occupant with fresh supply air, detailed in *Figure 13.* Gradual transitions are used at duct take offs to reduce turbulence that generates airborne noise.

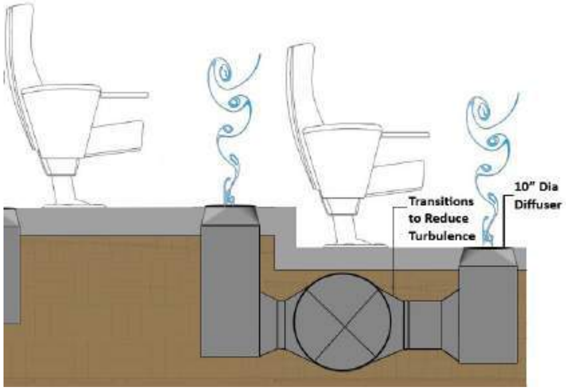


Figure 13: *Auditorium Supply Diffusers*

When the supply air absorbs heat from the occupants, buoyancy will cause it to rise. The air is returned in the ceiling above any theatrical lights. When passing the lights, the air will take care of the load they emit before it reaches the occupants. The return air is then sent to the air handling units at a higher temperature then is typical because of the reduced amount of cfm needed in the space. This reduction in cfm, in turn, reduces the duct size as well as the fan size. A smaller duct decreases

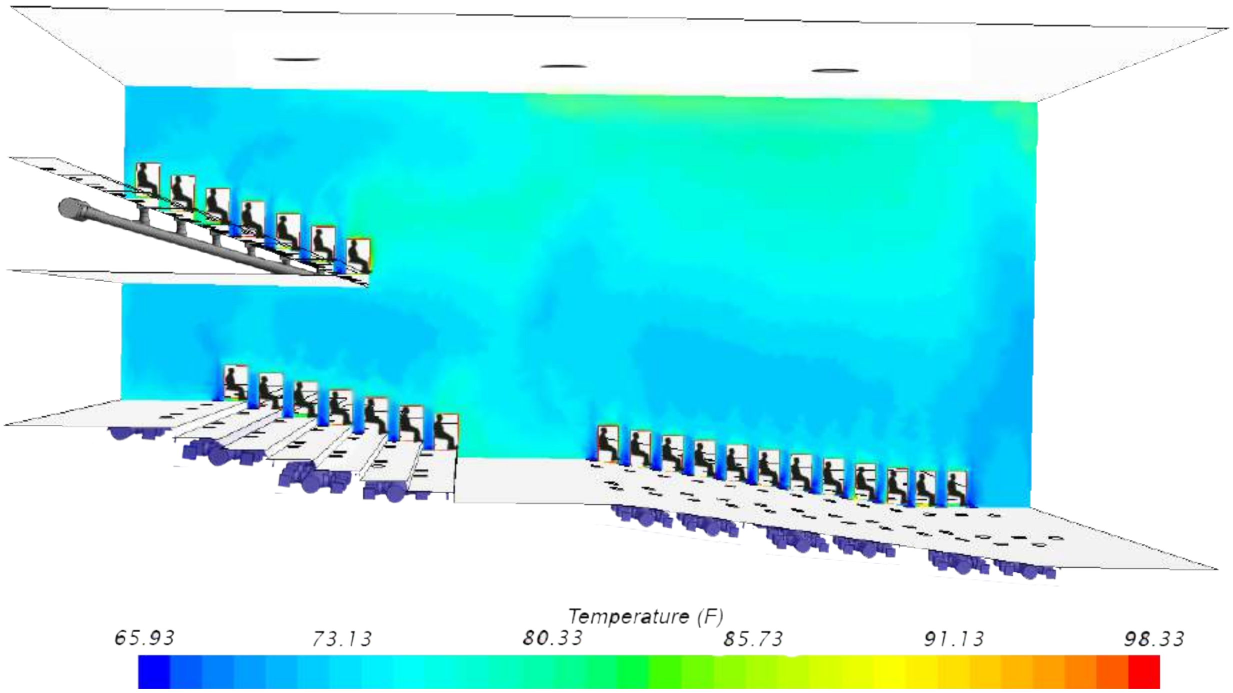


Figure 14: *Concert Hall CFD Analysis*

the cost of the distribution system and lowers the fan energy used. A CFD analysis was done to ensure there were no negative impacts on the space (*Figure 14*).

Displacement ventilation will serve the concert hall, recital hall, south lobby, north lobby, orchestra rehearsal and choral rehearsal spaces. All of these rooms are high volume areas that will benefit from supplying air from the floor and returning it at the ceiling. See Mechanical Drawing M-3.0 for a detailed underground duct plan view. In the concert hall, the balcony will also be served by displacement ventilation to avoid higher temperature stratified air at the occupant level. A small air handling unit will be placed adjacent to the concert hall to directly supply the balcony. The lobbies are supplied around the perimeter as those spaces are envelope load dominant, and this will take care of that load before it reaches the interior space. Perimeter placement also reduces the maintenance of the floor diffusers due to lower foot traffic.

The Blue Duct system was chosen for the below ground section of ductwork, insuring structural integrity and corrosion protection of runs. This is a prefabricated, pre-insulated duct system that can be kept clean during construction and operation, *Figure 15*.

Three main ducts are routed from the mechanical spaces under the first-floor hallway to have minimal impact on structural foundations and duct installation. A fourth duct travels through the second-floor ceiling and drops down through three predefined shafts that then serve the recital and two rehearsal spaces via displacement ventilation. The ductwork will be coordinated with contractors and kept clean and capped during the construction process, see Construction Section 7.1 for constructability of underground ducts. The penetrations through the precast panels will be coordinated as seen on Mechanical Drawing M-3.0.

Figure 15: *AQC Blue Duct System provided by AQC*

8.2.2 Radiant Panels

For the smaller rooms, such as faculty studios and practice rooms, a dedicated outdoor air system is provided to meet ventilation requirements as set by ASHRAE 62.1. The fresh air supplied to the spaces will meet 100% of the latent load and part of the sensible load. A typical supply air temperature 55°F and 95% RH and return temperature 75°F and 50% RH was used. With these setpoints, it is assumed that a room has a room sensible heat ratio (RSHR) around 0.90. However, most rooms are interior and latent load dominant with a RSHR between 0.50 and 0.75. To account for this, the return air temperature was adjusted to 75°F 45% RH and the supply air temperature adjusted to 60°F 55% RH. This allows for a better control of humidity in the room as well as a higher change in humidity ratio, which means more latent load is taken care of per cfm. See Mechanical Section 8.2.3 for DOAS details.

Since the DOAS system does not take care of the full sensible load, a supplemental system will need to be implemented. *Syndicate* analyzed multiple supplemental systems to provide additional cooling and heating for the smaller rooms. It was determined that radiant panels were the most appropriate in order to best aligned with the project goals, see Mechanical SD-A.

A four-pipe radiant panel system is implemented in order to provide each zone with the flexibility of heating or cooling on demand throughout the year based on thermostat controls.

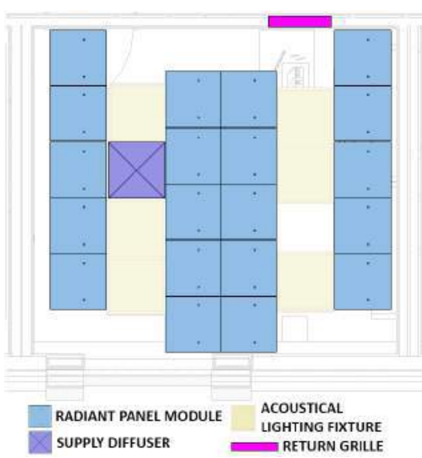


Figure 16: *Typical Radiant Panel Ceiling Layout*

Typical 2'x2' prefabricated radiant panel modules were used for ease of constructability. The modules were coordinated with acoustical lighting fixtures in faculty studios and practice rooms in order to provide an aesthetically pleasing and functional space, *see Figure 16* and Lighting Drawing L-4.0 for mounting details.

For the small practice rooms, the fresh air supplied by the DOAS is sufficient to cover the cooling load. However, supplemental heating is still needed so radiant panels will still be installed these rooms as well. Additionally, the classroom areas on the first floor do not require radiant panels as ventilation air covers the cooling and heating load required throughout the year. This is due to the solar load being taken care of by the ventilated double wall facade as explained in Mechanical Section 7.1.

8.2.3 Ventilation System

For the air distribution within the building, 4 main types will be used: displacement ventilation, perimeter VAV floor supplied, DOAS ceiling supplied and typical VAV ceiling supplied. Seven air handling units are installed in the building using these distribution strategies as seen in *Table 4* and Mechanical Drawing M-1.0.

Table 4: *AHU Zones*

AHU - #	Zone	Distribution	SA Set Point
AHU - 1	First Floor Concert Hall	Displacement Ventilation	65F, 45%RH
AHU - 2	Stage, BOH	Typical VAV Ceiling Supplied	55F,95%RH
AHU - 3	North Lobby	Perimeter VAV Floor Supplied	55F, 95%RH
AHU - 4	Orchestra, Choir Rehearsal, Recital Hall	Displacement Ventilation	65F, 45%RH
AHU - 5	Faculty Studios, Practice Rooms	DOAS, Ceiling Supplied	60F, 55%RH
AHU - 6	South Lobby	Perimeter VAV Floor Supplied	55F, 95%RH
AHU - 7	Balcony of Concert Hall	Displacement Ventilation	65F, 45%RH

Due to critical humidity levels in spaces where instruments are stored, the design of the air handling units were crucial to ensure each space maintains the correct design temperatures. The supply air setpoint for the floor supplied and DOAS systems posed a problem for the air handling unit design because of the elevated supply temperatures. The 80-ton air cooled chillers are already designed to produce lower than normal temperatures for thermal storage, so the air handling unit cooling coils will be designed to cool the mixed outside/return air to 44°F. Instead of wasting energy to reheat the air, a flat plate heat exchanger will be placed before the supply air discharges from the unit to be heated by the entering return air. See Mechanical Drawing M-2.0 for detailed analysis.

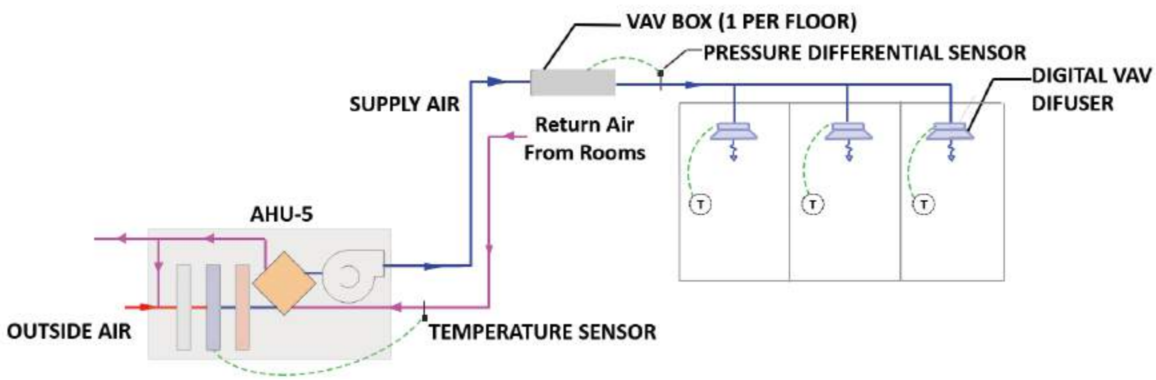


***Figure 17**: VAV Diffuser Control*

The earlier shown climate analysis showed that a simple economizer cycle would not be appropriate to use because of the high humidity levels in Holland, Michigan. An enthalpy sensor will be placed in the air handling unit to ensure the outside air meets the humidity and temperature constraints before entering the space.

Digital VAV diffusers will be implemented in each of the spaces supplied by AHU-5. In each room, a thermostat will be installed to control the diffusers to allow for individual control. One VAV box will be placed on each floor to control the distribution of air flow among these rooms. A pressure differential sensor will detect when the VAV diffusers are mostly closed and will reduce the amount of airflow entering the zones (*Figure 17*). Reference Lighting Drawing L-5.0 for further control details.

In the mechanical rooms, the spaces will be directly ventilated during the short cooling season and conditioned by 2 pipe fan coil units during the heating season. In other equipment room spaces, 2 pipe fan coil units with minimum ventilation are used to counter the load from electrical and AV equipment.

9.0 ACOUSTICS

Acoustics was an important driver in the mechanical team's design in order to provide premier performances with little interrupting background noise. The mechanical equipment produces noise and vibrations that had to be analyzed with respect to different factors, such as distance from noise sensitive spaces. Both the airborne and structural borne noise was considered in the analysis. The airborne noise was first addressed by analyzing the sound transmission class (STC) of the walls between the mechanical room and noise sensitive spaces such as the concert hall. There was also a combination of round and rectangular ducts and sound attenuators used to mitigate noise traveling through the ductwork. The structure borne noise travels through the structure, so structural isolation of the mechanical room and equipment isolation reduced this travel.

9.1 Mechanical Room

After considering various sound and vibration isolation methods, *Syndicate* decided upon an isolated structural system that will separate the mechanical room structure from the rest of the building. This means the mechanical room structure is completely independent from the rest of the building which helps by eliminating the travel route for the structure borne noise. See Structural Drawing S-8.0 for further details on the isolated structure. Pumps generate high levels of vibration during operation, so they have been strategically placed in the first-floor mechanical room to direct more of the vibrations through the slab and into the ground. Each pump is installed on a concrete inertia base that is spring mounted, see *Figure 18*.

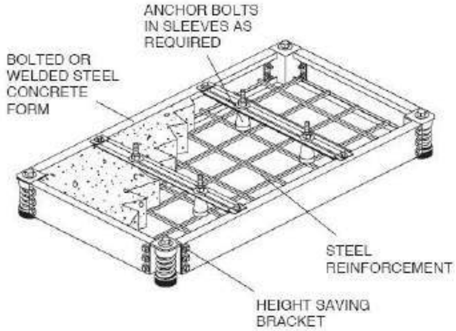


***Figure 18:** Concrete Inertia Base Provided by Mason Industries*

The inertia base reduces the vibratory motion that the pumps produce while also acting as a rigid machine base. The pipe connections to each pump will have molded rubber flex connectors to mitigate any vibrations travelling from the pump through the pipes in the building.

In order to reduce vibrations that may travel through the structure, each second floor AHU will be spring mounted on molded acoustical neoprene isolation pads. The scroll chillers will also be spring mounted on a neoprene pad, but the mount will limit the vertical movement to prevent any safety concerns with high wind speeds outdoors. The chiller pipe connections will also have a molded rubber flexible joint to mitigate vibrations travelling through pipes.

9.2 Acoustical Isolation within Spaces

Syndicate wanted to ensure the mechanical design had minimal impact on the acoustics of each space. The air handling units emit large amounts of sound that travel through the ducts at all frequencies. The program *AIM by Pottorff* was used to determine the NC ratings for each space. In order to achieve these ratings, duct silencers, duct lining, long duct runs, and mitered elbows were all utilized where needed. The silencers and liners are more effective at higher frequency sounds while the long duct runs, and mitered elbows help with the lower frequency sounds. Rectangular and round ducts were used in specific areas respectively due to their differing abilities. The square ducts work well with allowing breakout noise and were utilized in the mechanical spaces and the hallways. The round ducts were used closer to and around the acoustically critical spaces because they prevent breakout noise from entering a space. See Mechanical Drawing M-4.0 for more details on acoustics.

10.0 PLUMBING

Syndicate pursues minimizing environmental impact and enhancing Hope College throughout all the system designs for The Miller Center.

10.1 Fixture Improvements

In the average year, The Miller Center plumbing fixtures are predicted to consume 7,600 gallons of water. With the installation of low flow fixtures, the plumbing water consumption can be reduced by 30%. This will save roughly $3,800 a year in terms of water and sewage cost creating a payback period of less than 1 year, see Mechanical Drawing M-7.0 for breakdown.

10.2 Rainwater Collection and Reuse

Responsible rainwater management was one of the key components of our design. The annual rainfall in Holland, Michigan accounts for 1.25 million gallons in potential water collection for The Miller Center. In addition, the collection of annual snowfall would add an additional 200,000 gallons in potential greywater collection.

The daily estimated greywater demand is 5,200 gallons. The average daily collection potential including snow and rainfall ranges from 2,500 gallons to 5,000 gallons. By selecting a 5,000 gallon underground storage tank for the rainwater collection system, the maximum amount of daily precipitation will be able to be collected and stored for greywater use the next day.

The snowmelt system will be served by a glycol-water mix loop that gains energy from the returning condensate from the central steam plant. After the campus steam is sent through the hot water and radiant panel heat exchanger, the condensate is sent through a secondary flat plate heat exchanger that will heat up a glycol water mixture to 80°F. The snow melt water loop is then sent to the roof to melt any snow accumulating in the winter months. In addition to collecting more greywater, melting the snow and ice means *Syndicate* prevents any snow from drifting or falling from the roof during heavy snowfall. The City of Holland currently has a snowmelt system for the roads and sidewalks within the city, so The Miller Center's plazas will be included in plans to be a part of the city's snowmelt expansion. See Mechanical Drawing M-5.0 for more details.

When precipitation falls on the roof or plazas, it is then captured by drains. The drains either send the water to rainwater collection tanks located underground adjacent to the mechanical room or sent directly to the filtration system. After being filtered, the greywater will be sent to the toilets and urinals throughout the building based on demand. By reusing the site's rainwater, the collection system will save $9,100/year based on the current water and sewer utility rate and has a payback period of 7 years, see Mechanical Drawing M-7.0 for additional snowmelt details.

11.0 FIRE PROTECTION

When adjusting the architectural design and floor plans of the building, fire protection and life safety was a main concern. With the addition of the occupiable roof and third floor, Class I standpipes needed to be added since the highest occupied floor was greater than 30' above fire truck access. A Class III standpipe also needed to be placed by the stage since there is a higher risk of fire in this area. Throughout the building, sprinklers will be implemented to manage flames at the source, see Mechanical Drawing M-8.0 for sprinkler layout. According to NFPA 13, automatic sprinklers with extended coverage can be placed at most 15 ft apart for light hazard use. In every faculty studio two side wall sprinklers will be placed on the walls, and in every practice room one side wall sprinkler will be placed. The north and south lobbies do not need a designated smoke exhaust system since the open second levels are designated as mezzanines and not an atrium.

12.0 ENERGY STANDARDS

Syndicate has decided to help Hope College create a sustainability plan that helps them become a leader in sustainability. The four main pillars of the sustainability plan are waste reduction, energy conservation, indoor environment, and materials/ resources. The mechanical design team was able to use this sustainability plan to help promote a culture of forward thinking at Hope College, see Mechanical Drawing M-9.0 for further details.

13.0 LESSONS LEARNED

The design process of The Miller Center was a series of lessons learned for all disciplines involved. The mechanical team learned quickly that one design change can have a domino effect with other discipline designs. Meeting as a team to discuss these design changes and evaluate the best solution was quickly adopted in order to mitigate this domino effect. By collaborating and communicating together, the mechanical design team was able to create an effective mechanical system that fulfilled all the goals of the team.

14.0 CONCLUSION

Syndicate has given Hope College the option to enhance its future by designing a central heating and cooling plant that will allow for an additional 900,000 SF of building space for future expansion throughout the campus. This option combined with the personalized sustainability plan sets Hope College on a path to be a leader in sustainability and clean energy.

By utilizing displacement ventilation in high volume spaces, fresh air is directly supplied to the occupants, which increases the quality of air in the occupant's zone. Furthermore, the ventilated double wall façade and reorienting the building prevents direct glare and uncomfortable solar heat gain from deterring from the occupant's experience within the spaces.

All spaces were analyzed to ensure the background noise level and vibrations from the mechanical equipment did not impede on acoustically critical spaces. In addition, the mechanical rooms are completely separate from the structure of the rest of building to mitigate structure borne noise from travelling to acoustically critical rooms.

Performance and sustainability were an integral part of *Syndicate's* design. Making advantageous architectural changes and system selections, the building was optimized to have minimal impact on the environment. The system saves 44% in mechanical energy demand in reference to the ASHRAE 90.1 baseline design.

SYNDICATE -Mechanical Central Plant — DECISION MATRIX: Mechanical

Team Goals :	Enhance Hope College Campus			Maximize Occupant Experience			Create Premier Performances			Minimize Energy Impacts						
	Construction Schedule	Aesthetics	Cost	Comfortability	Accessibility	Quality	Reduced disturbancec	Sound Quality	Flexibility	Waste Reduction	Carbon Footprint	Life Cycle	Efficiency	Weighted Score	Rank	Final Outcome
Weights :	2	1	3	3	0	1	3	2	1	2	2	2	3			
Campus Central Plant	3	2	1	2	1	3	2	3	2	2	2	3	3	57	1	x
Geothermal	1	2	1	2	1	2	2	2	2	3	3	1	2	47	2	
Standard Plant	3	2	3	2	1	2	2	2	2	2	2	3	2	57	1	x

Additional Comments : The campus central plant and a standard in house mechanical plant tied in the decision matrix. Syndicate decided to propose two options for Hope College to consider. Option 1 is a standard mechanical plant with chillers and a steam station, while Option 2 is proposing a brand new campus central plant that has gas turbines for CHP and chillers for a chilled water plant.

SYNDICATE - Distribution System for Student And Faculty Areas — DECISION MATRIX: Mechanical

	Construction Schedule	Aesthetics	Cost	Comfortability	Accessibility	Quality	Reduced disturbancec	Sound Quality	Flexibility	Waste Reduction	Carbon Footprint	Life Cycle	Efficiency	Weighted Score	Rank	Final Outcome
Weights :	2	3	2	3	0	2	3	3	1	2	2	1	3			
VRF	1	3	1	3	1	3	3	2	2	2	2	3	3	65	2	
Chilled Beams	2	2	2	2	1	3	2	2	1	2	3	3	3	61	3	
WSHP	3	1	3	2	1	2	1	1	1	2	2	2	2	48	4	
Radiant Panels	2	2	2	3	1	3	3	3	1	2	3	3	3	70	1	x

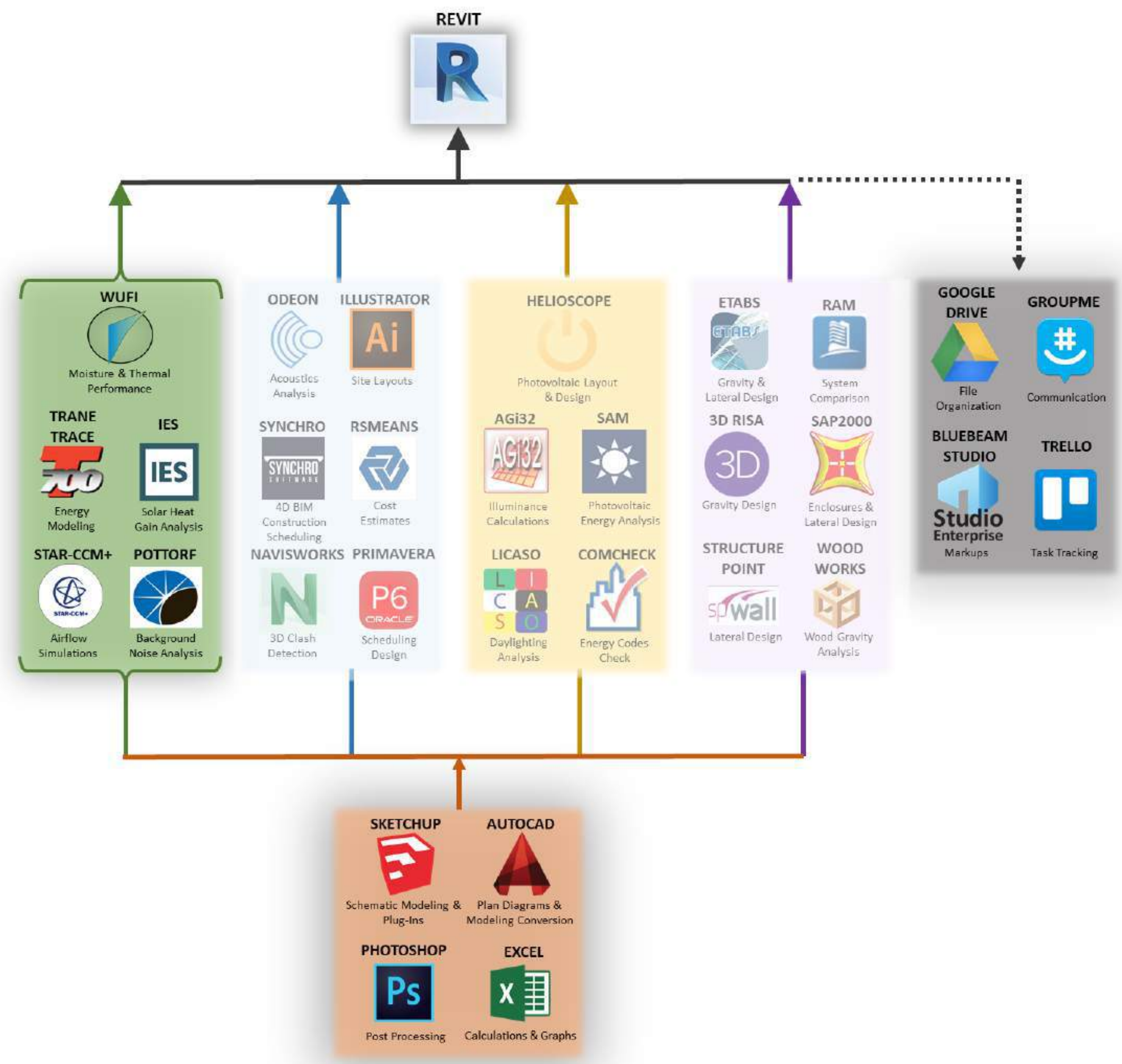
Additional Comments : Radiant Panels were selceted by Syndiacte as the main cooling and heating distribution system in the faculty offices and practice rooms. This system will allow for seamless integration with lighting, plumbing and fire protection i the ceiling of these paces.

SYNDICATE - Distribution System for Large Volume Spaces — DECISION MATRIX: Mechanical

	Construction Schedule	Aesthetics	Cost	Comfortability	Accessibility	Quality	Reduced disturbancec	Sound Quality	Flexibility	Waste Reduction	Carbon Footprint	Life Cycle	Efficiency	Weighted Score	Rank	Final Outcome
	2	1	3	3	0	1	3	2	1	2	2	2	3			
Displacement Ventilation	1	3	1	3	1	3	2	2	2	3	2	2	3	55	1	x
Ceiling Supplied Variable Volume	3	2	3	1	1	1	2	2	2	1	2	2	2	49	2	
Radiant Floors	1	3	2	1	1	1	3	3	1	2	2	2	2	49	2	

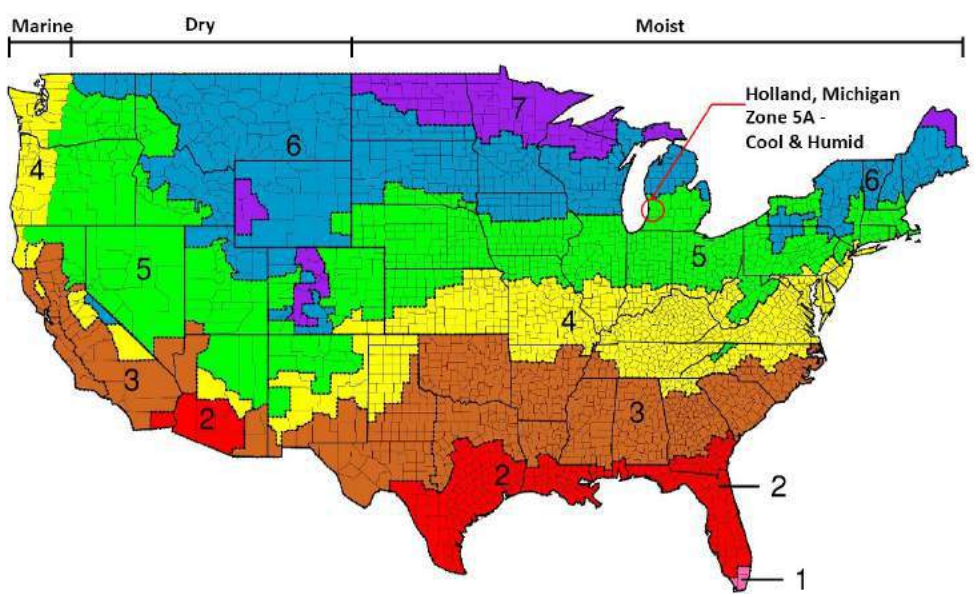
Additional Comments : Displacement Ventilation was selected as the way to provide heating and cooling in large volume spaces. By providing air directly to the occupants, Syndicate can save energy and increase the indoor air quality for the occupants.

Rating—Weighting	
High Importance	3
Medium Importance	2
Lowest Importance	1
Scoring	
Best	3
Middle	2
Worst	1

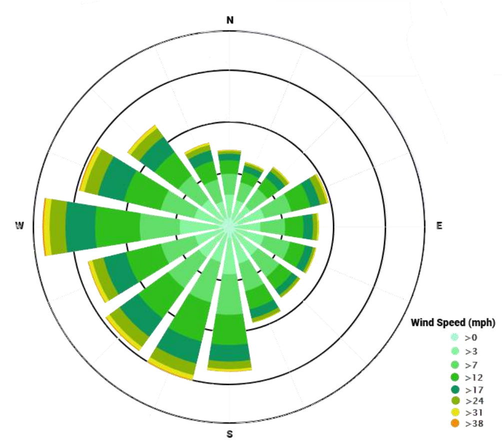


Climate Analysis

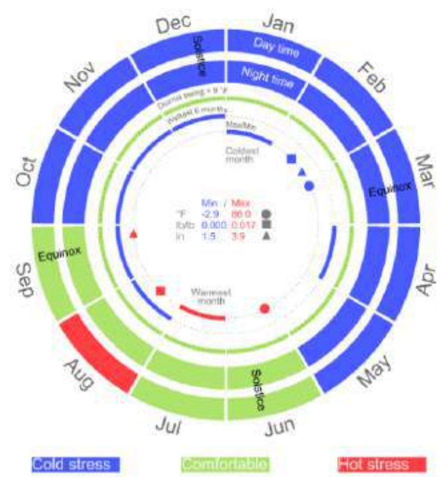
ASHRAE Climate Zone Map



Wind Analysis



IES Virtual Environment
Holland, Michigan Weather Analysis

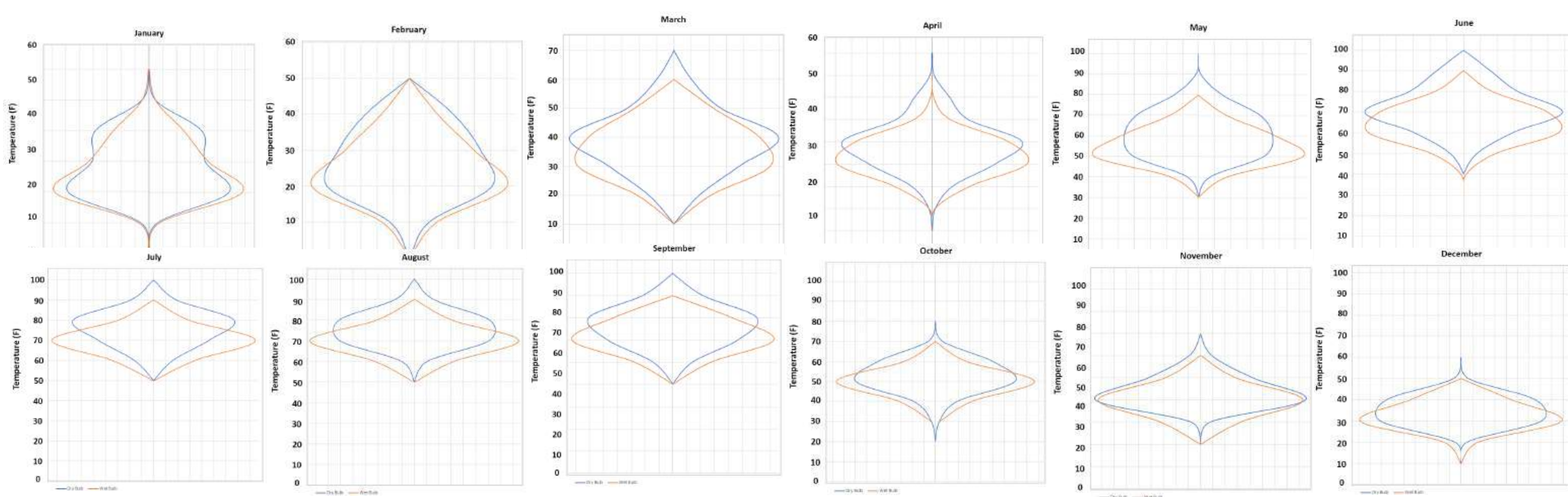


Throughout the year, humidity poses an issue in Holland, Michigan. As can be seen in the tear drop graphs, every month has concentrations of high wet bulb temperatures that will be an issue for the humidity constraints in The Miller Center due to instrument storage.

ASHRAE Handbook 2017 Design Conditions
West Michigan Regional

Environmental Conditions		Temperature
Cooling	Dry Bulb	86.4 °F
	Wet Bulb	74.5 °F
Heating	Dry Bulb	10.1 °F

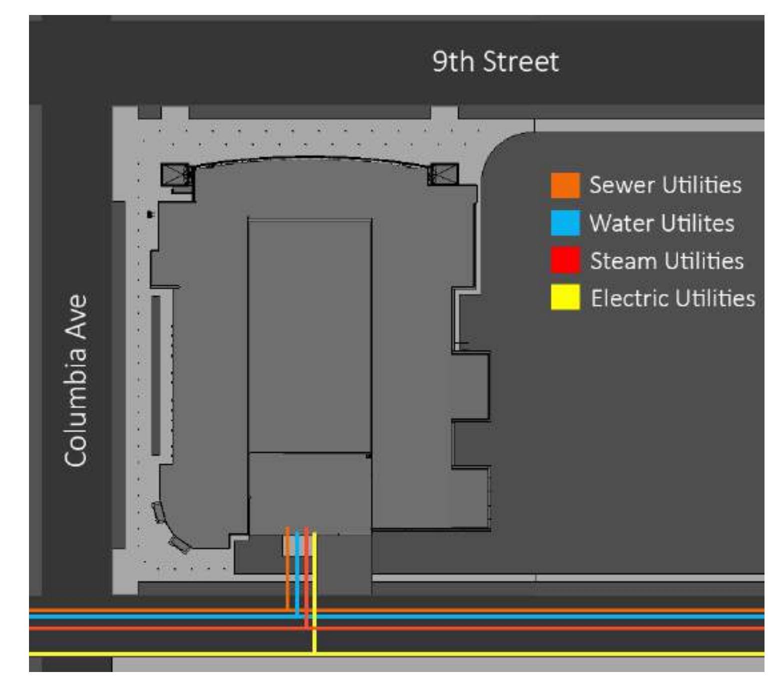
Monthly Temperature Tear Drop Graph



Site Analysis

Hope College Site Map with Assumed Steam Plant Connections

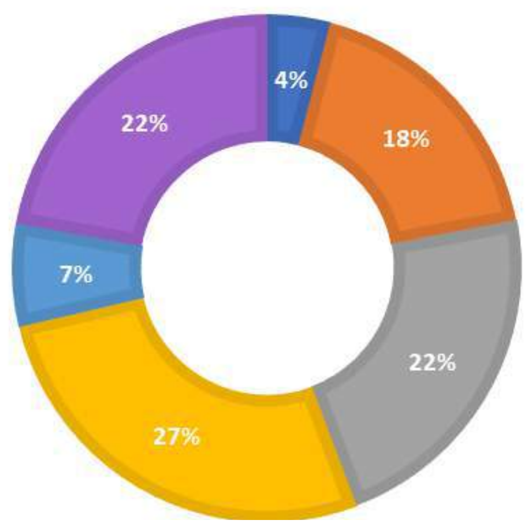
Utility Connections



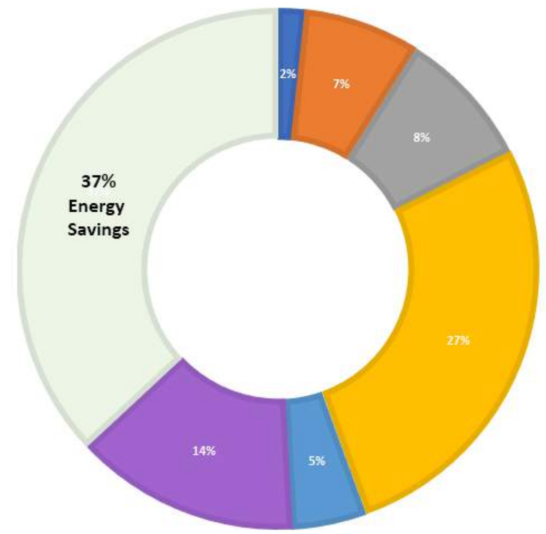
Peak Cooling Loads

- Envelope Conduction
- Solar Gain
- Lighting Load
- People Load
- Misc Load
- Mechanical Load

ASHRAE 90.1 Baseline

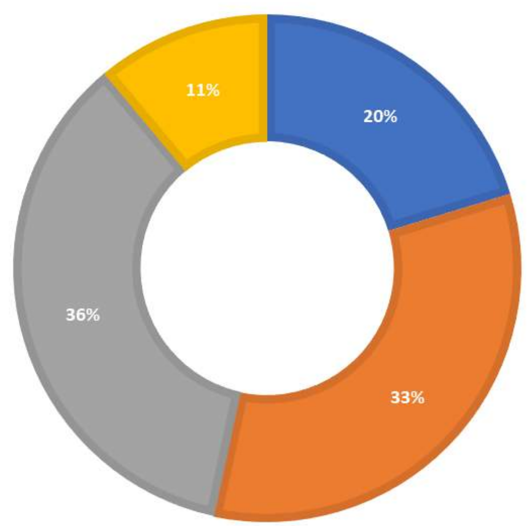


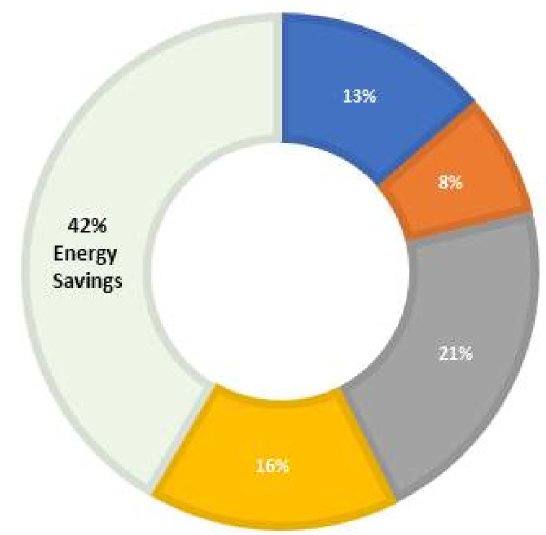
Optimized Design



Peak Heating Loads

- Envelope Conduction
- Ventilation Load
- OA/RA Preheat Diff.
- Additional Reheat

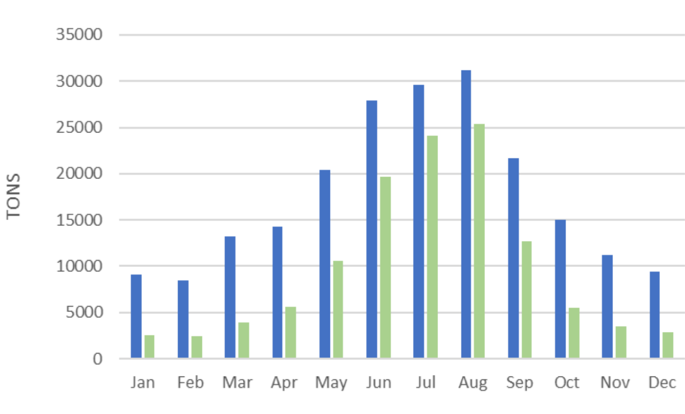




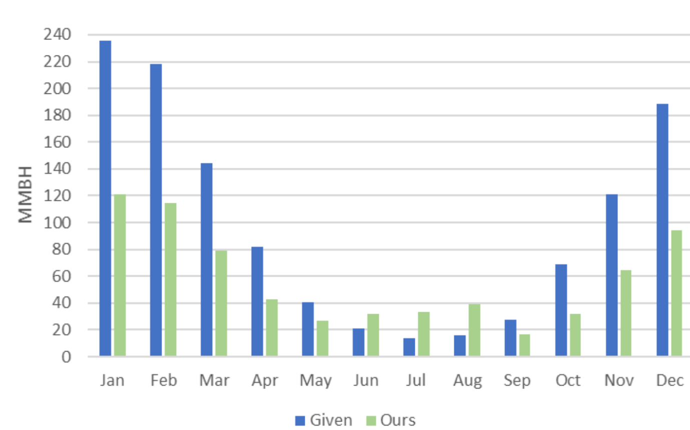
Peak Cooling Load							
		ASHRAE 90.1 Baseline			Optimized Design		
		BTU/hr	Overall %		BTU/hr	Overall %	
Envelope	Roof Cond	38782	1.24%	21.98%	23682	1.21%	14.13%
	Glass Solar	558129	17.91%		224451	11.43%	
	Glass Conduction	40370	1.30%		15343	0.78%	
	Wall Conduction	47627	1.53%		14147	0.72%	
Internal Loads	Lights	694957	22.31%	56.36%	267619	13.62%	63.77%
	People	842293	27.04%		840356	42.78%	
	Misc	203882	6.54%		144794	7.37%	
Mechanical	Ventilation Load	700505	22.48%	22.85%	461435	23.49%	23.49%
	Supply Fan Heat	29074	0.93%		24191	1.23%	
	Exhaust Heat	-40127	-1.29%		-51571	-2.63%	
Total		2835118			1964447		
Savings						1,151,045	36.95%

Peak Heating Load							
		ASHRAE 90.1 Baseline			Optimized Design		
		BTU/hr	Overall %		BTU/hr	Overall %	
Envelope	Roof Conduction	-76068	4.06%	20.27%	-40330	3.73%	60.35%
	Glass Conduction	-211481	11.29%		-124836	11.55%	
	Wall Conduction	-92189	4.92%		-59158	5.48%	
Mechanical	Ventilation Load	-620189	33.11%	79.73%	-147357	13.64%	39.65%
	OA/RA Preheat	-666086	35.56%		-407494	37.71%	
	Additional Reheat	-207336	11.07%		-301325	27.89%	
Total		1873349			1080500		
Savings						792,849	42.32%

Monthly Cooling Load Comparison



Monthly Heating Load Comparison

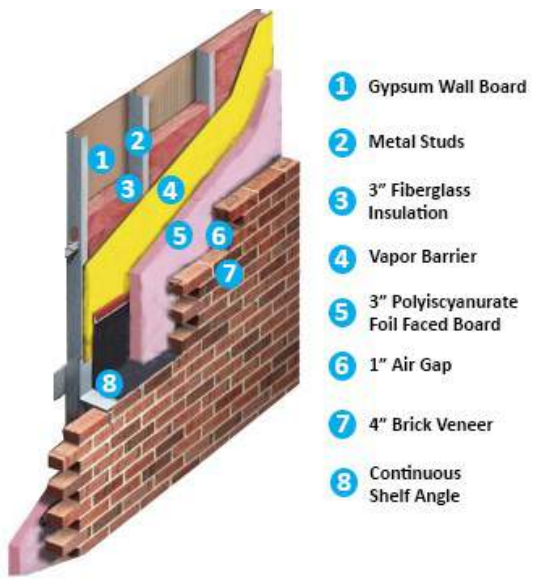


By reorienting the building and going beyond the 90.1 baseline envelope standards, *Syndicate* was able to significantly reduce the building load. The inclusion of an enthalpy wheel and the ventilated double wall façade allowed for significant reduction in cooling and heating load on the air handling unit coils as demonstrated in the pie charts.

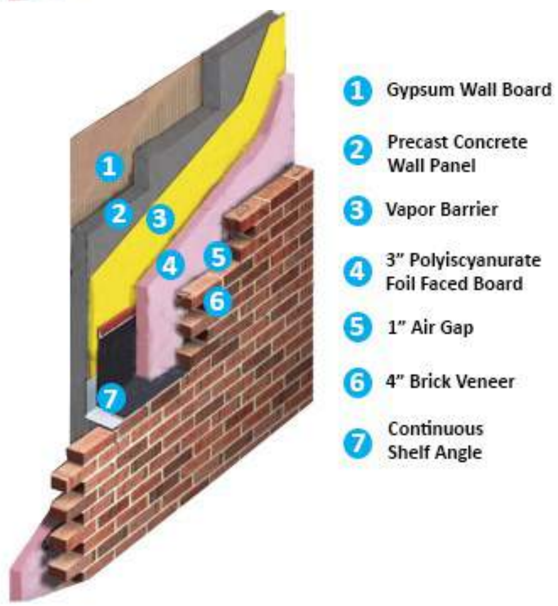
Total Building Profile Loads				
Design	Cooling Load Total (MMBH)	Heating Load Total (MMBH)	Total (MMBH)	% Savings
ASHRAE 90.1 Baseline	17,616,712	1,177	2616.4	
Optimized Design	9,890,512	696	1521.1	44%

Baseline Envelope Comparison						
	Wall		Glass		Slab	Roof
	Assembly	U-Value	U-Value	SHGC	F-Value	U-Value
ASHRAE 90.1 2016 Values for Climate 5A	Climate 5A Baseline	0.051	0.38	0.38	0.52	0.032
Optimized Design	Brick Veneer	0.033	0.27	0.33	0.51	0.027

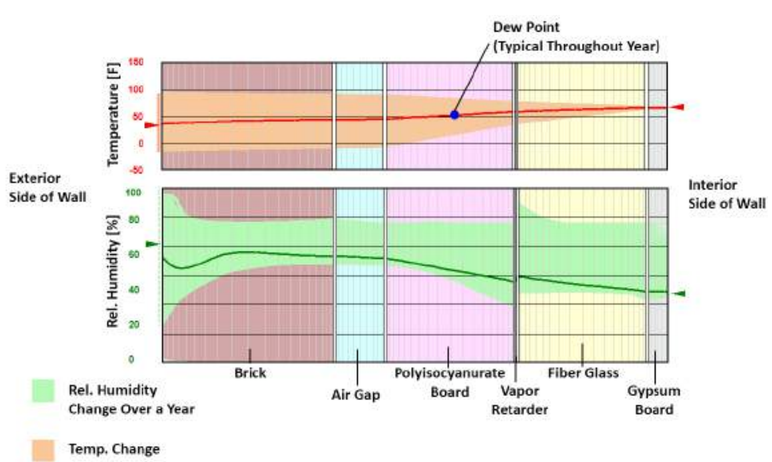
Wall Assemblies



Typical Wall Assembly	
Material	R-Value
Outside Air Film	0.17
4" Brick Veneer	0.35
1" Air Gap	3.59
3" Polyisocyanurate Board, Foil Facing	17.4
Vapor Barrier	-
3" Fiberglass Insulation/Metal Studs	6
Gypsum Wall Board	1.81
Inside Air Film	0.68
TOTAL R VALUE	30

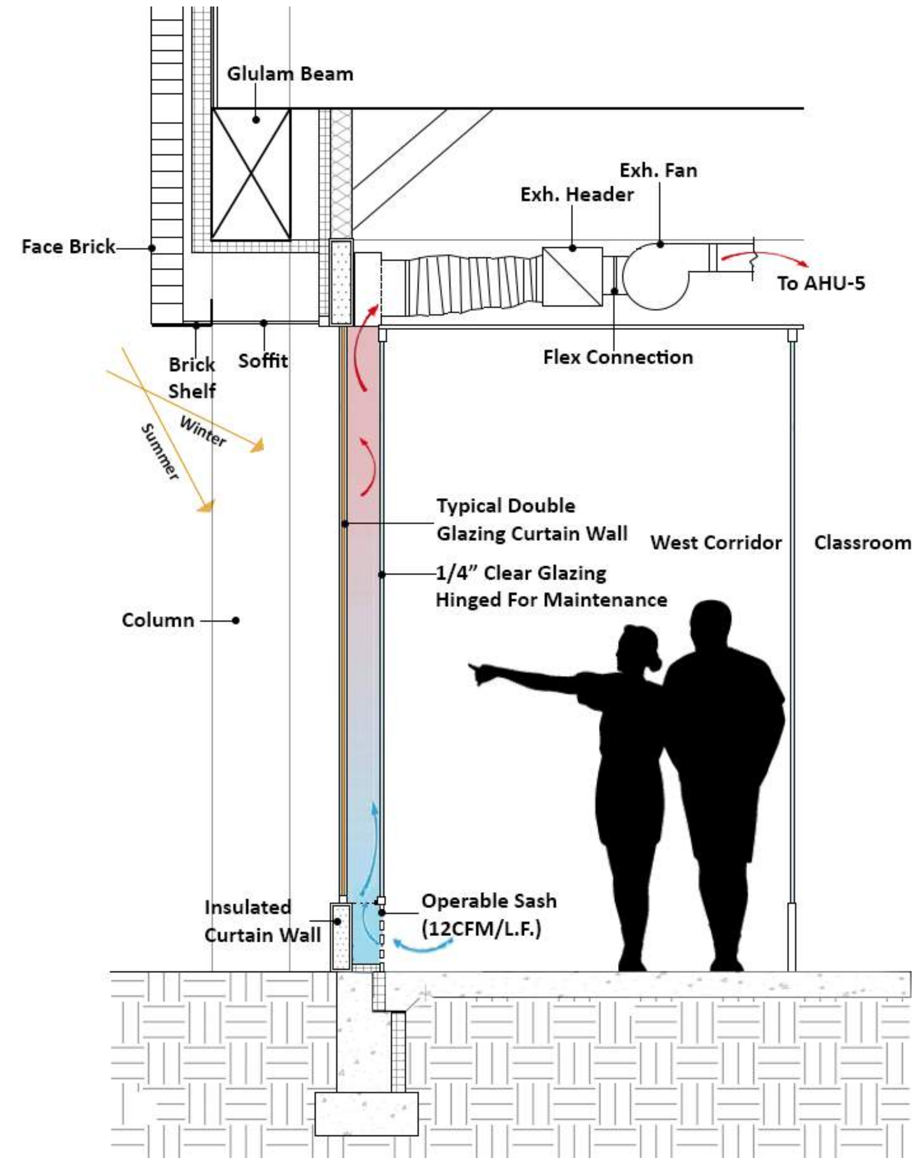


Shear Wall Assembly	
Material	R-Value
Outside Air Film	0.17
4" Brick Veneer	0.35
1" Air Gap	3.59
3" Polyisocyanurate Board, Foil Facing	17.4
Vapor Barrier	-
Precast Concrete Wall Panel (12" Typical)	1.4
Inside Air Film	0.68
TOTAL R VALUE	25



Thermal and Moisture Analysis done in *Wufi* for the typical wall assembly. Moisture does not condense in the fiberglass insulation, which is the critical component of the assembly.

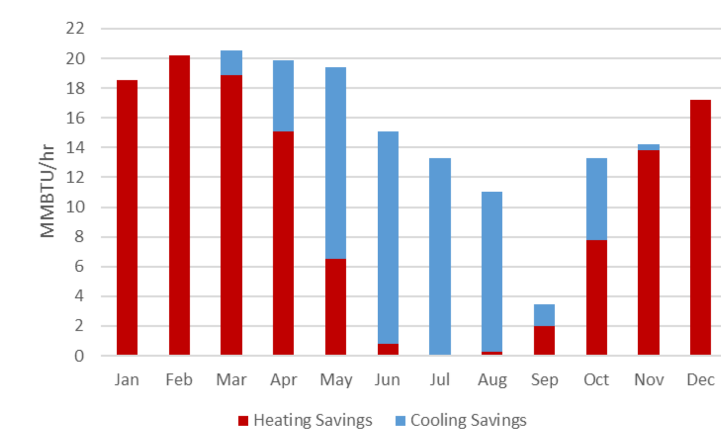
Ventilate Double Wall Façade



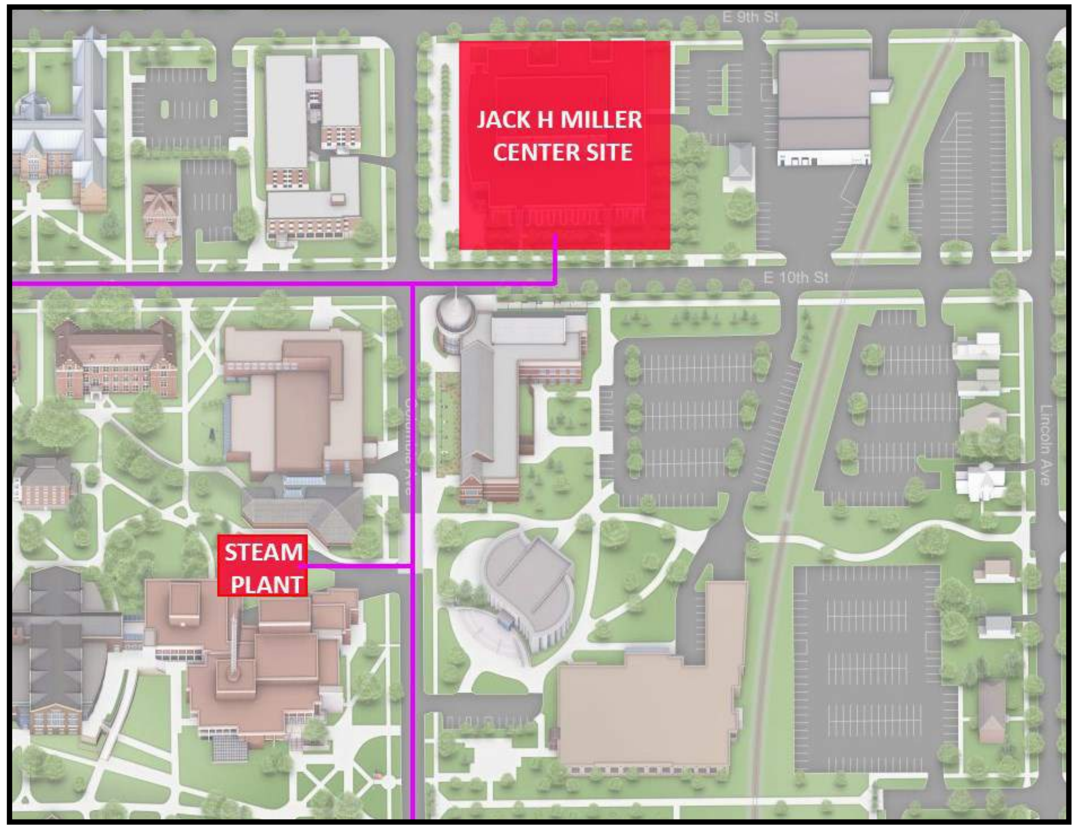
Ventilated Double Wall Façade Detail

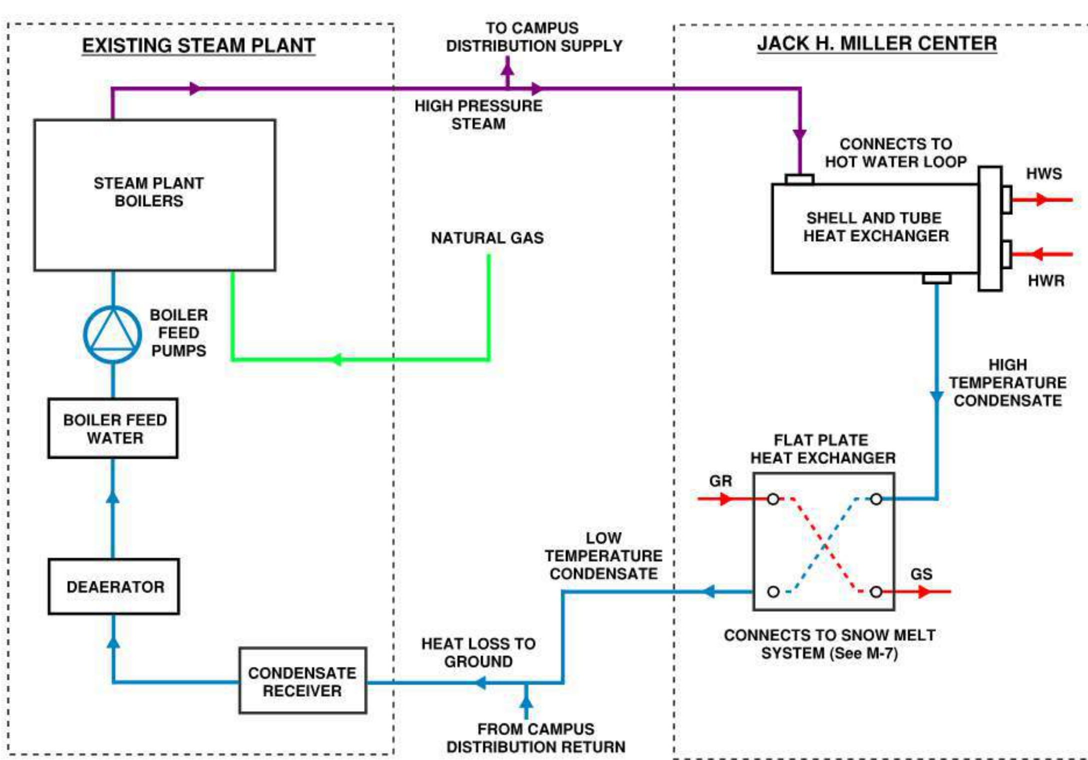
The ventilated double wall façade is implemented on the west hallway glass façade. The glass panels are designed in modular panels that allow for easy constructability. The 2 exterior glass panes are 1/4" panes with low-e coating that are separated by a 1/2" airgap. The middle glass pane has an extra tinted film on the exterior side to capture the solar heat gain traveling through the window. A tertiary 1/4" glass pane with a grille at the top and bottom of the assembly is added to create a 4" airgap for airflow. The tertiary glass pane is hinged at the mullions to open up and allow for maintenance access. Through the bottom grille, 1000 cfm enters a 4" air, which then is heated up by the solar heat gain and exhausted through a grille at the top of the assembly connected to a forward curved fan. The hot air is then either exhausted during the cooling season, or sent back to the air handling unit through the enthalpy wheel to preheat the outside air during the heating season.

Ventilated Double Wall Energy Savings Per Month

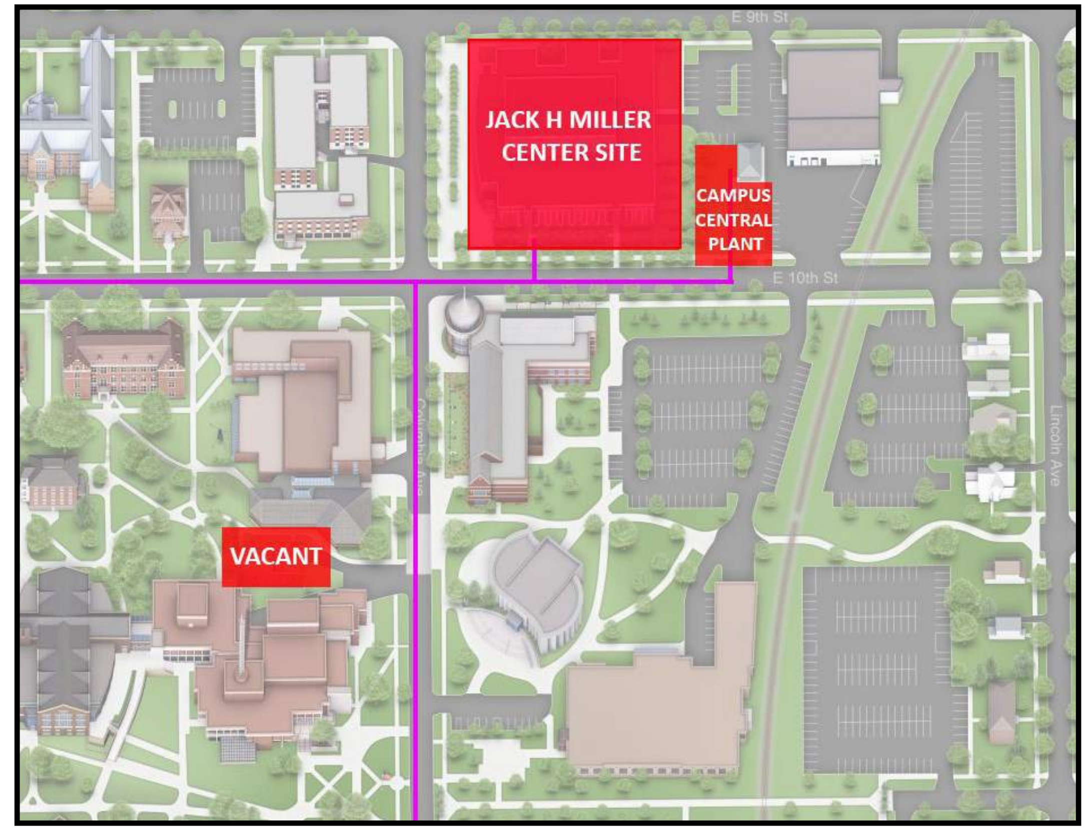


OPTION 1—Connect to Existing Steam Plant

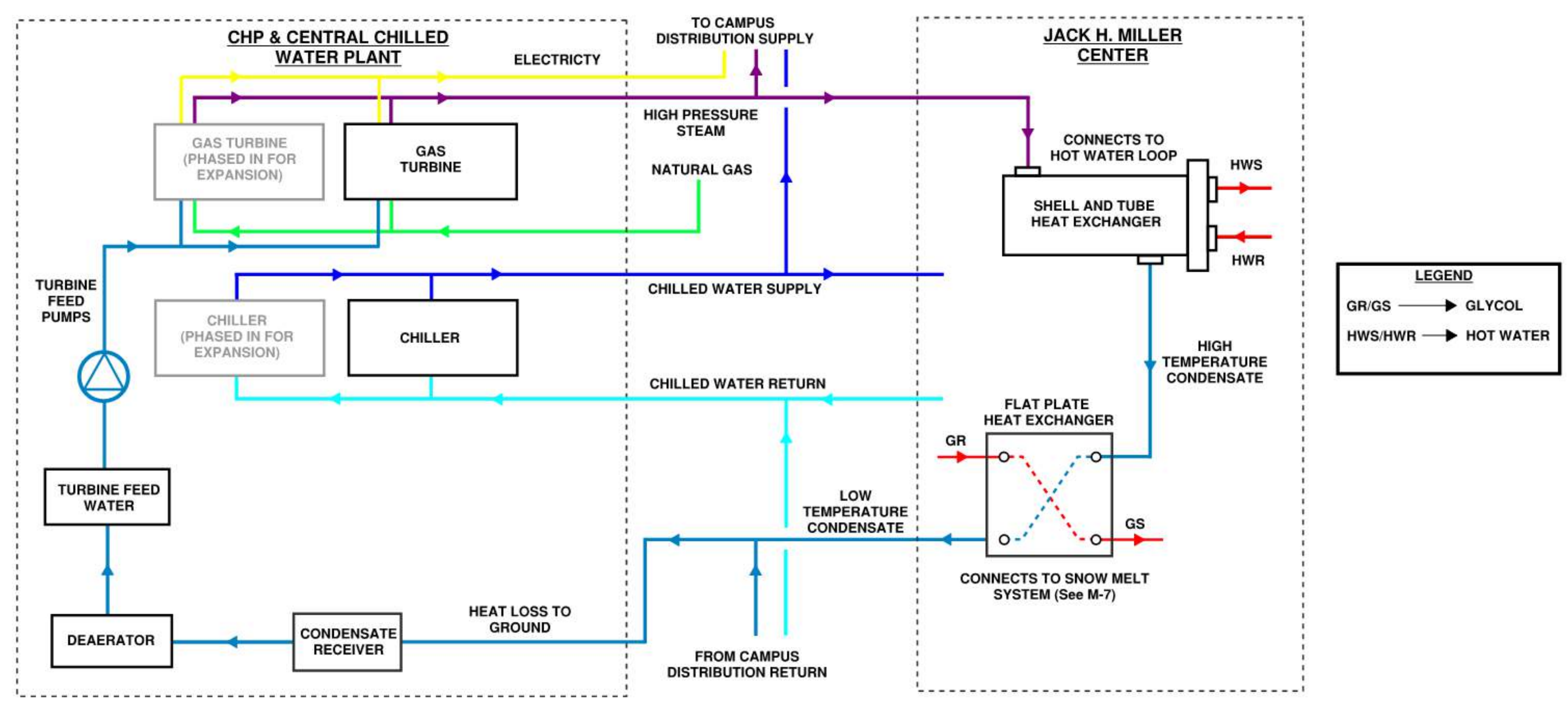


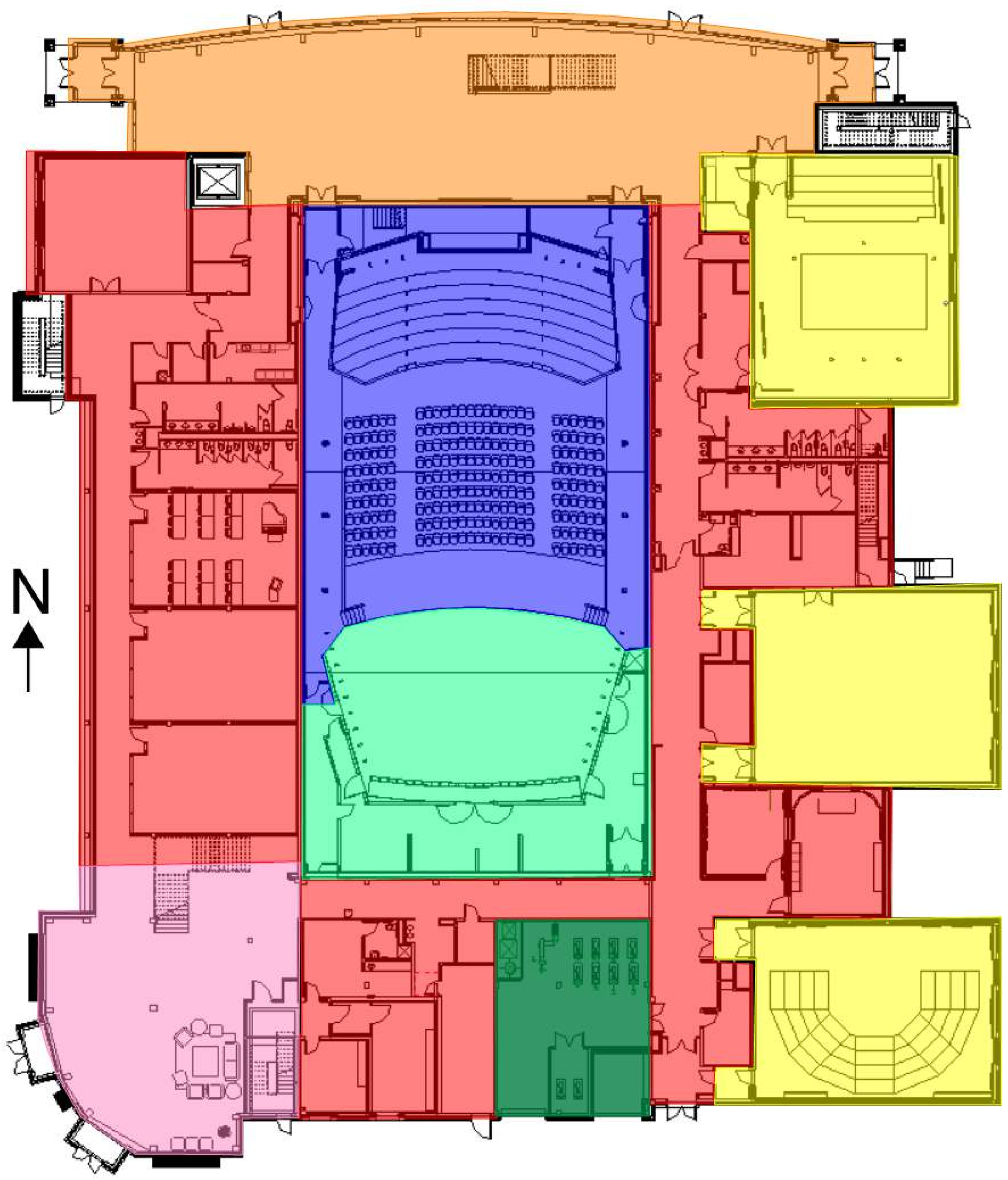


OPTION 2—New Central Plant

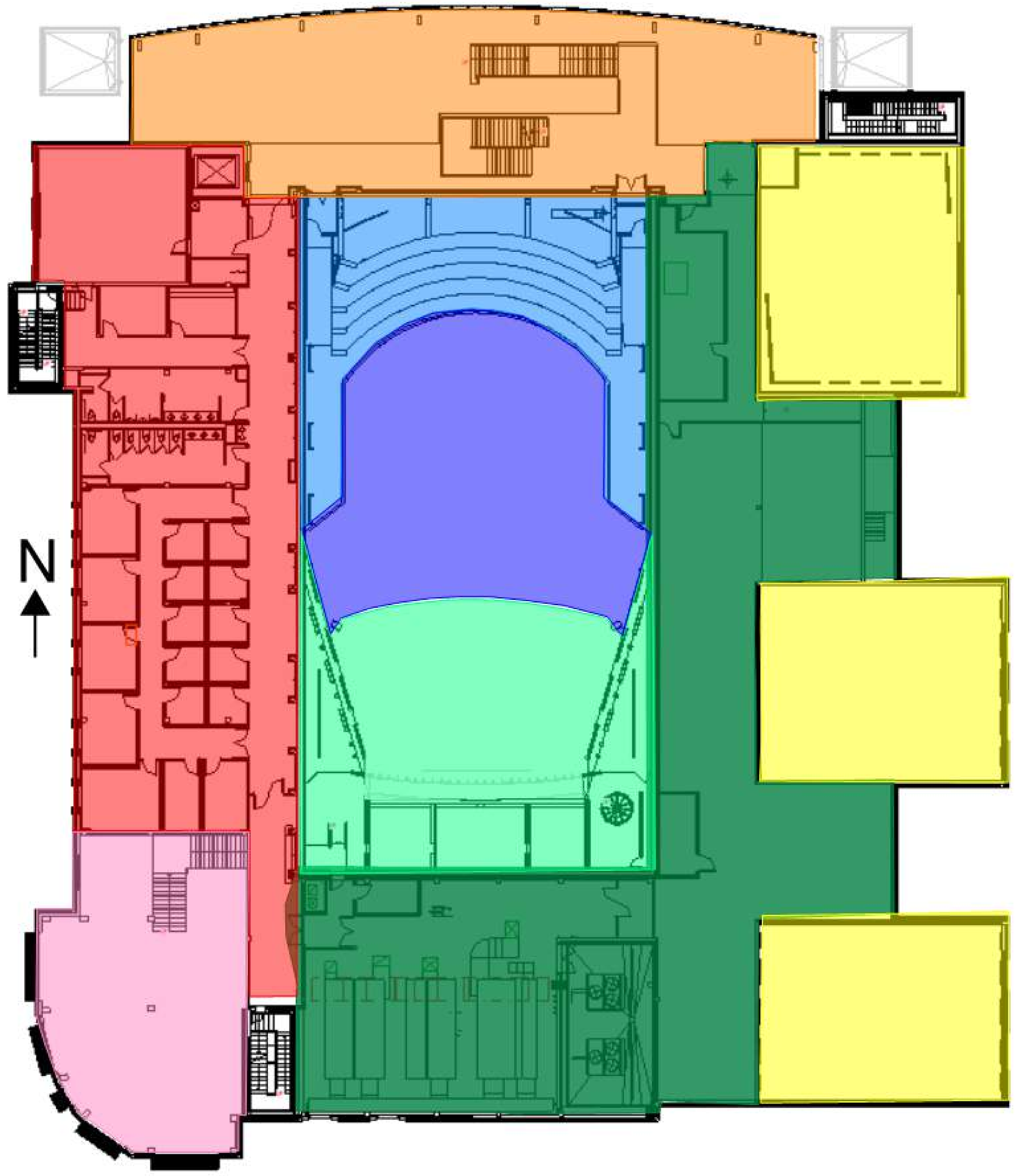


Option 1 is the connection to the existing steam plant that would provide the heat for both the radiant panel and air handling unit hot water loops. Option 2 is an option that lends itself to future expansion a well as generating electricity instead of buying it all from the grid. The new central plant would include a 3 MW gas turbine that would be placed in a open lot adjacent to the Physical Plant Department building next door. This new space would have room for an additional turbine for expansion as well as the new chillers for the proposed central chilled water system as seen below. This new central plant building will account for additional office and storage space that would be needed to manage a central campus plant. This option centralizes the hot and chilled water generation in one building and reduces noisy mechanical equipment and maintenance from each individual building.

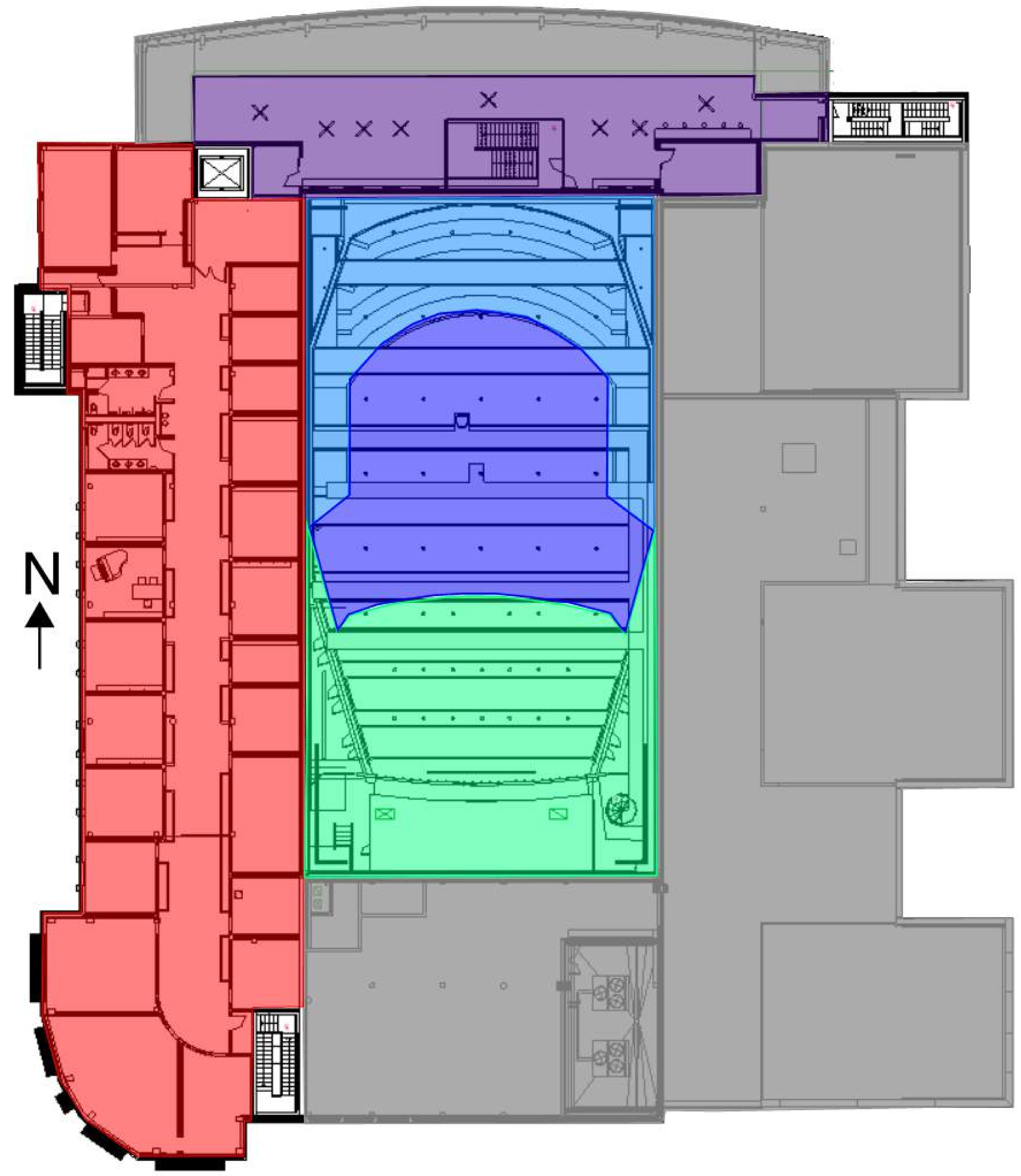




1 FIRST FLOOR AHU ZONING



2 SECOND FLOOR AHU ZONING



3 THIRD FLOOR AHU ZONING

AHU - #	ZONE	DISTRIBUTION	SA SET POINT
AHU - 1	FIRST FLOOR CONCERT HALL	DISPLACEMENT VENTILATION	65F, 45%RH
AHU - 2	STAGE, BOH	CEILING SUPPLIED	55F,95%RH
AHU - 3	NORTH LOBBY	PERIMETER VAV, FLOOR SUPPLIED	55F, 95%RH
AHU - 4	ORCHESTRA, CHOIR REHEARSAL, RECITAL HALL	DISPLACEMENT VENTILATION	65F, 45%RH
AHU - 5	FACULTY STUDIOS, PRACTICE ROOMS	DOAS, CEILING SUPPLIED	60F, 55%RH
AHU - 6	SOUTH LOBBY	PERIMETER VAV, FLOOR SUPPLIED	55F, 95%RH
AHU - 7	BALCONY OF CONCERT HALL	DISPLACEMENT VENTILATION	65F, 45%RH

AHU-1
AHU-2
AHU-3
AHU-4
AHU-5
AHU-6
AHU-7
HV-1
MECH
ROOF

SYNDICATE

PROJECT

JACK H. MILLER CENTER FOR MUSICAL ARTS

HOLLAND, MICHIGAN

SHEET TITLE

AHU ZONING

NOT FOR CONSTRUCTION

AEI TEAM NO.
01-2019

DATE
February 18, 2019

SCALE
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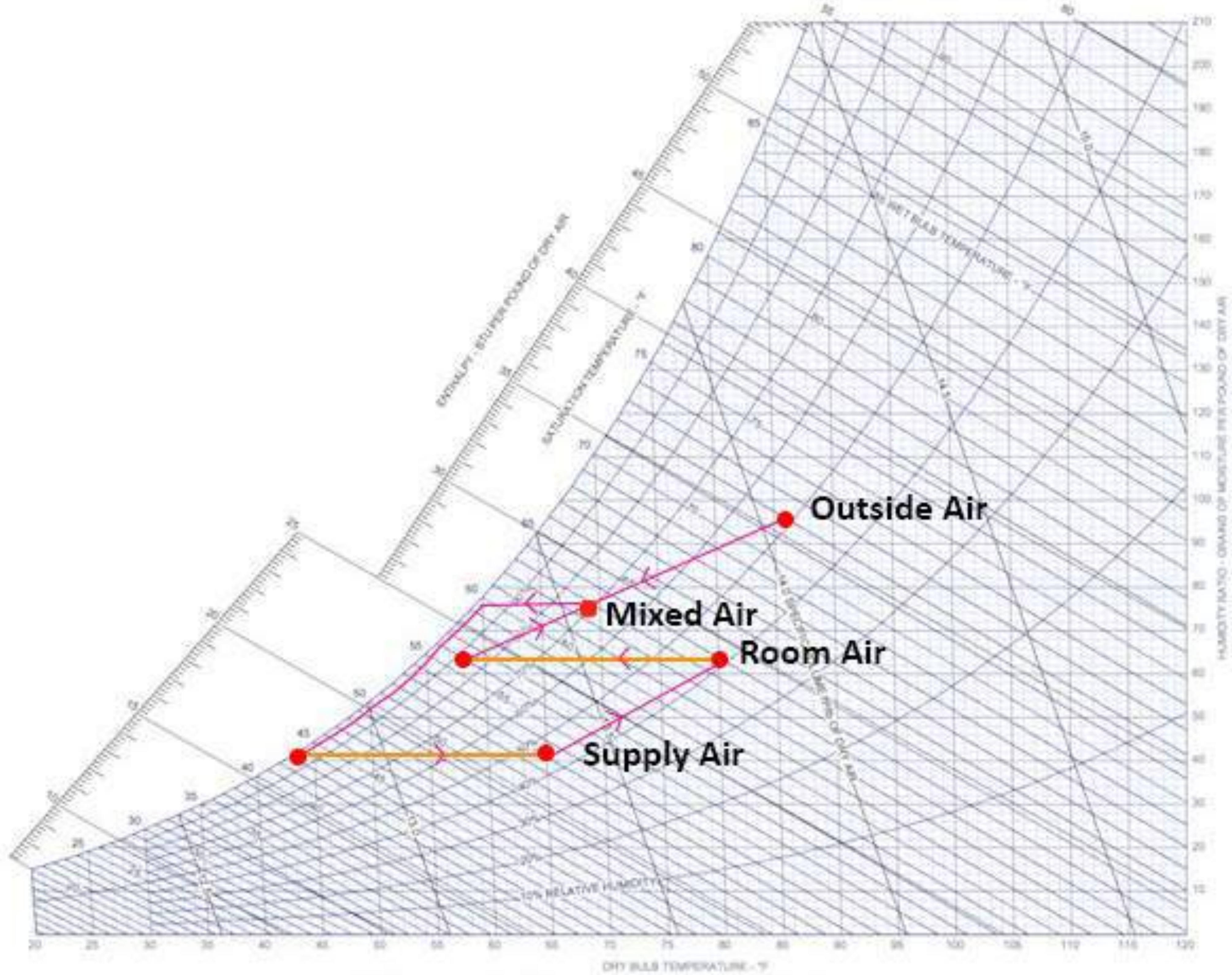
DRAWING NO.
M-1.0

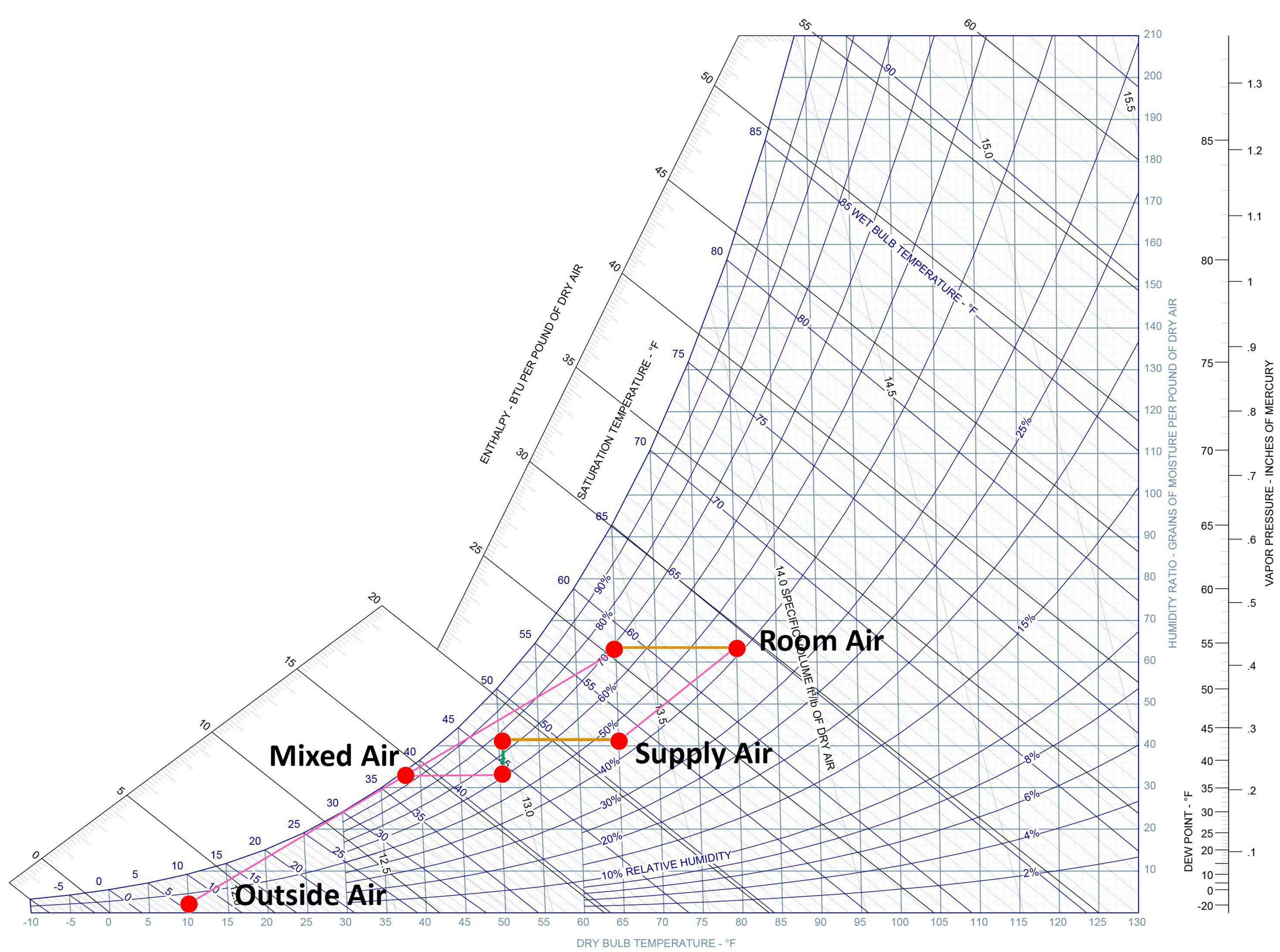
PAGE NO.
81

TYPICAL AIR HANDLING UNIT COOLING PROCESS

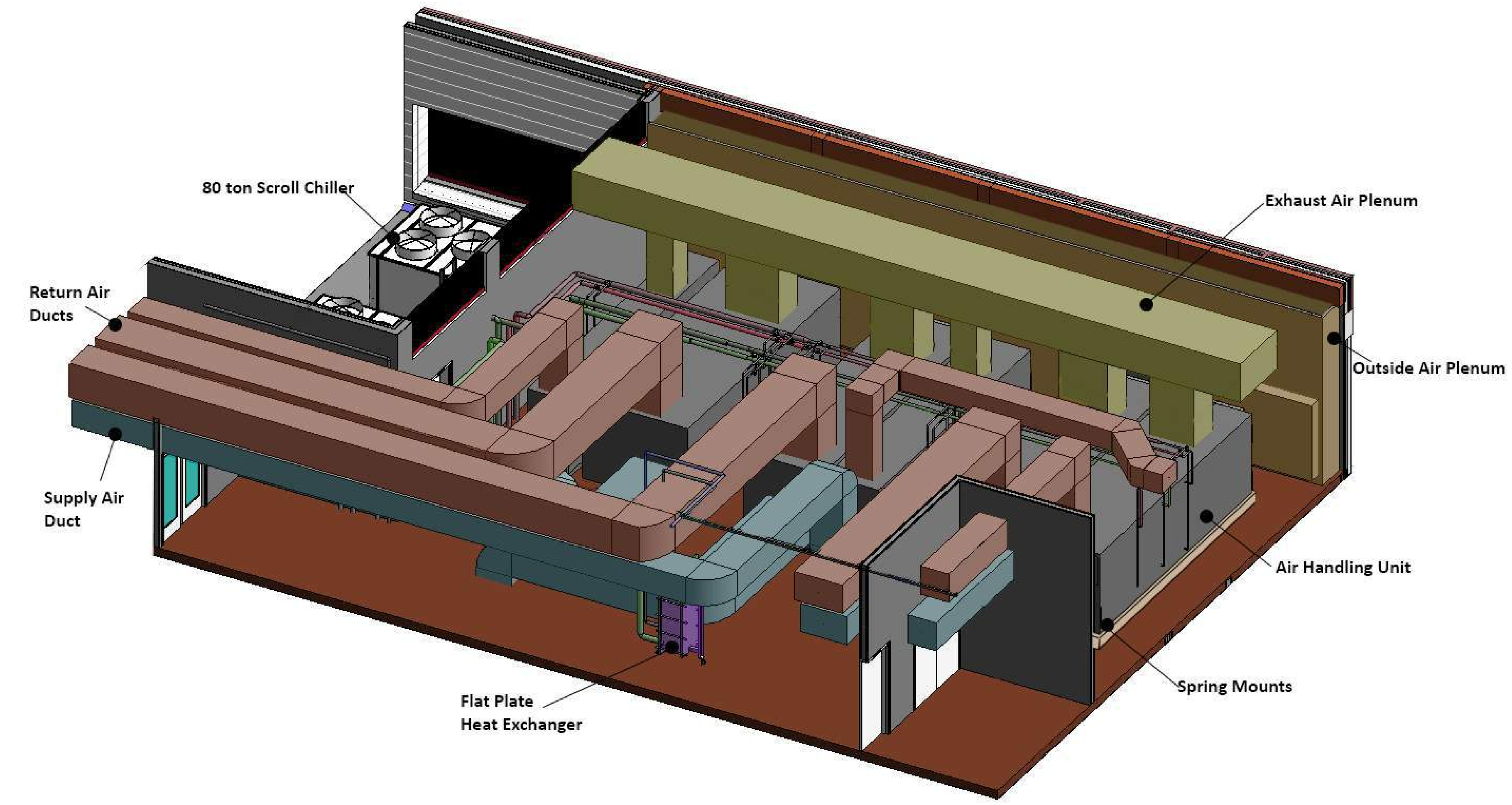


Air Through Flat Plate Heat Exchanger

TYPICAL AIR HANDLING UNIT HEATING PROCESS



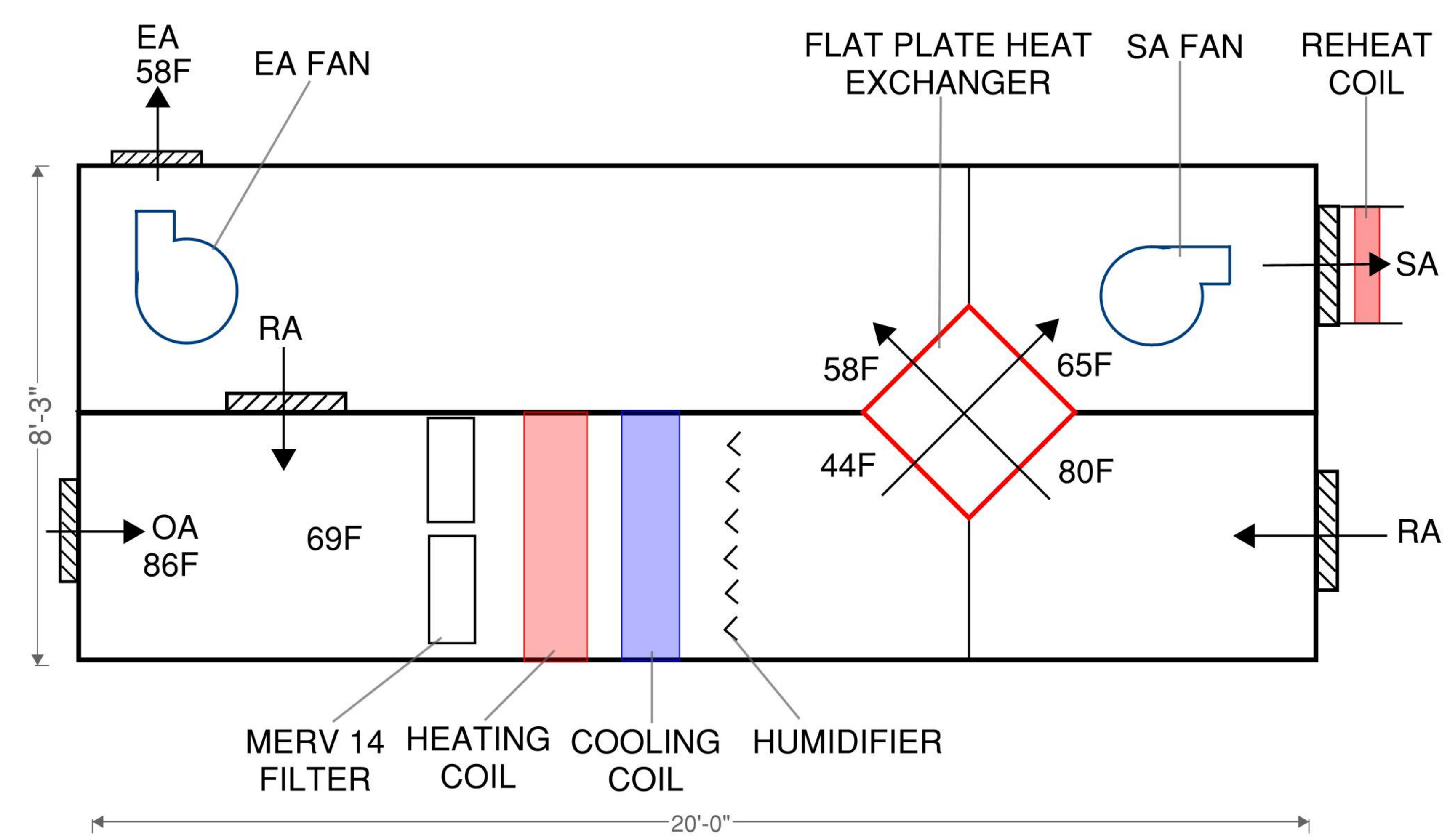
Air Through Flat Plate Heat Exchanger
Air Through Humidifier



SECOND LEVEL MECHANICAL ROOM

Six out of seven air handling units are located in the second level mechanical room. Each unit is equipment spring isolators mounted on a acoustical neoprene pad. The outside air is first mixed with return air and sent through a MERV 14 filter and cooling/heating coils. During the heating season, a humidifier will introduce steam into the airflow to ensure the humidity requirements for the spaces are met. Finally the supply air exchanges heat with return air through a flat plate heat exchanger as the last stage of reheat before entering the designated spaces. In the case that the flat plate heat exchanger does not meet the desired reheat setpoint, a supplemental reheat coil will be placed in the supply ducts. By utilizing the flat plate heat exchanger, *Syndicate* is able to reduce the chiller load by 50 tons since the return air is cooled by the supply air at each unit before mixing with the outside air.

The exhaust air is routed to discharge below the air cooled scroll chillers. Since the air was cooled from the flat plate heat exchanger , it is rejected at a design point of 58F. The air cooled scroll chillers become more efficient with cooler outside air, so by exhausting the cool air above the chillers, *Syndicate* is able to slightly increase the operating efficiency of the chillers during the cooling season.



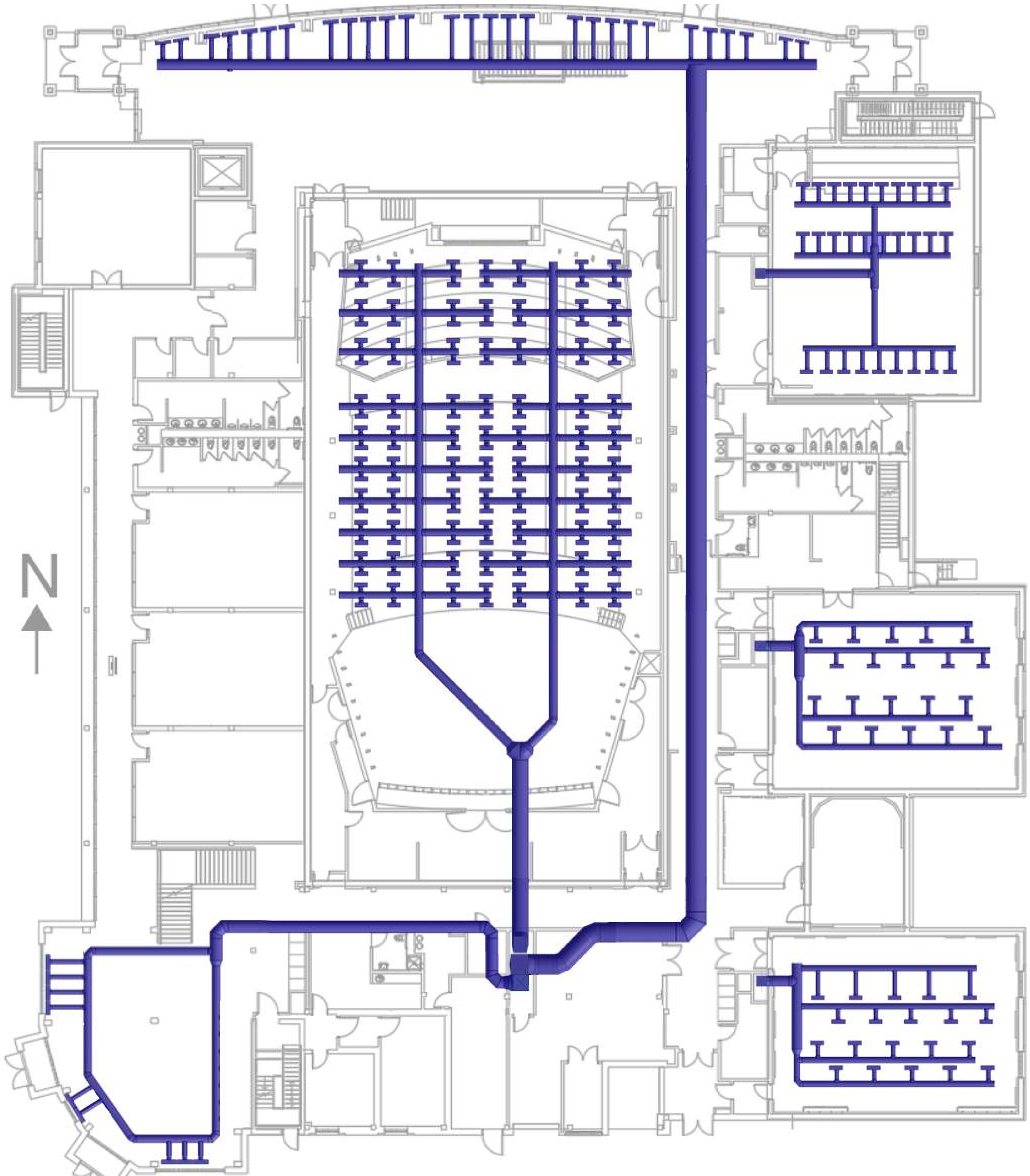
TYPICAL AIR HANDLING UNIT LAYOUT (COOLING CYCLE)

SYNDICATE

PROJECT
JACK H. MILLER CENTER FOR MUSICAL ARTS
HOLLAND, MICHIGAN

SHEET TITLE
Mechanical Room Details

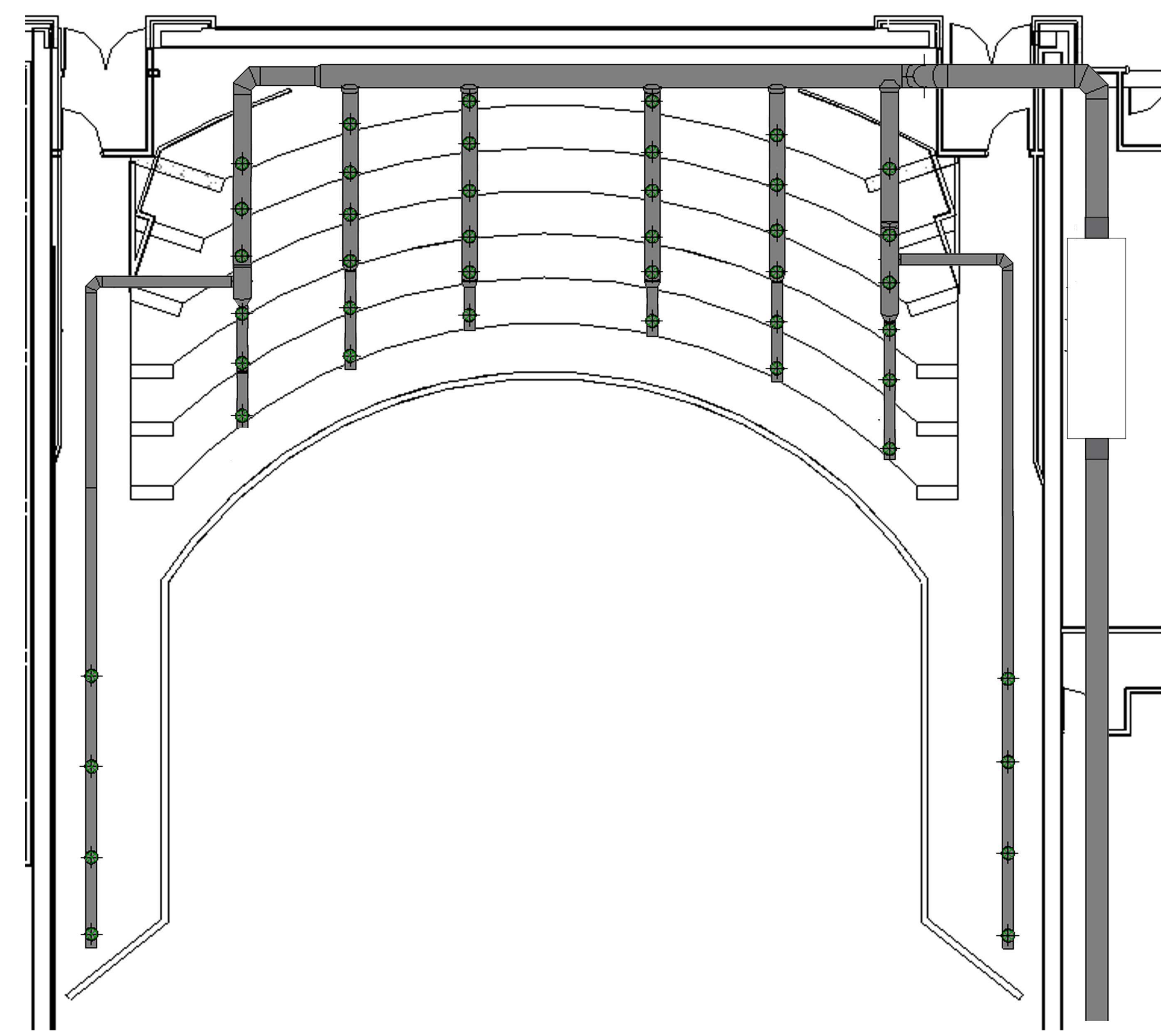
NOT FOR CONSTRUCTION
AEI TEAM NO. 01-2019
DATE February 18, 2019
SCALE NOT TO SCALE
DRAWING NO. M-2.0
PAGE NO. 82



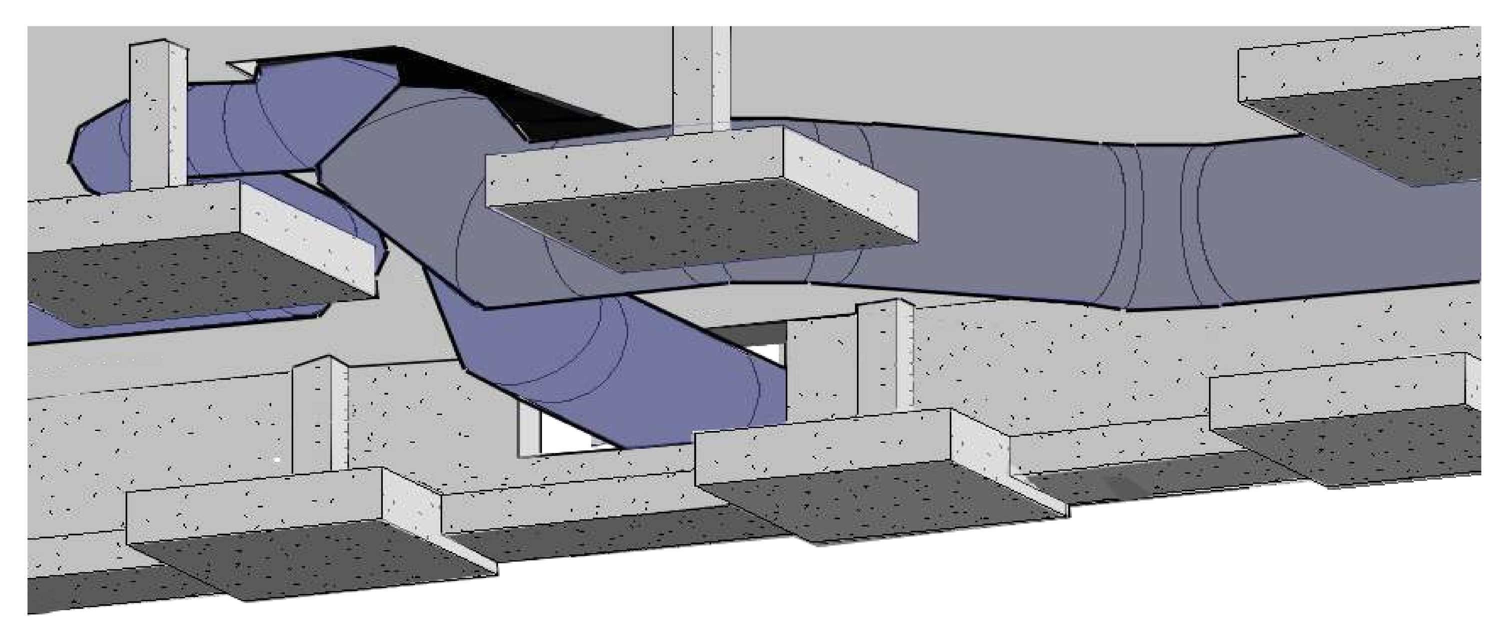
OVERALL BLUE DUCT LAYOUT

BLUE DUCT SYSTEM

The Blue Duct System is provided by *AQC Industries* as a solution to running ducts underground. The duct system is made up of high density polyethylene and can be directly buried underneath the slabs. The Blue Duct is guaranteed and warranted not to rust, mold or crush, and can easily be capped during construction to prevent dust and debris from entering the duct. The system does not require concrete housing, and only needs backfill soil when installing. The blue duct system is long lasting and durable. With built in R-10 insulation and resistance to mildew and corrosion, the cleanable blue duct system will provide clean fresh air to the occupants.



CONCERT HALL BALCONY DISPLACEMENT VENTILATION LAYOUT



BLUE DUCT AND FOUNDATION COORDINATION

DISTRIBUTION TO SPACES

To best supply the large volume spaces throughout The Miller Center, *Syndicate* ensured the concrete footers were 6' below top of slab where needed to allow the blue duct system to maneuver to the designated spaces. This allowed for uniform excavation depth of footers and easier coordination between mechanical and structural elements during the construction process. When ducts penetrate into spaces, the precast panels will be coordinated to have openings to allow the ducts to pass through into the space. To minimize excavation, three main duct runs were used to limit the duct sizes to 48"ø, 40"ø , and 28"ø. To minimize underground duct cost, the recital and rehearsal zone duct run was routed through the mechanical storage space on the second floor before penetrating the precast panels underground. The main duct runs were ensured to allow air to travel at 1200 fpm and then reduce to 500fpm in the duct branches. Directly beneath each diffuser is an acoustically lined plenum to reduce the velocity to 40fpm when entering the space. The concert hall balcony is served by an adjacently located air handling unit to minimize friction loses. The displacement ventilation ductwork in the balcony was coordinated to run between the structural beams to adequately supply the occupants with the appropriate amount of fresh air.

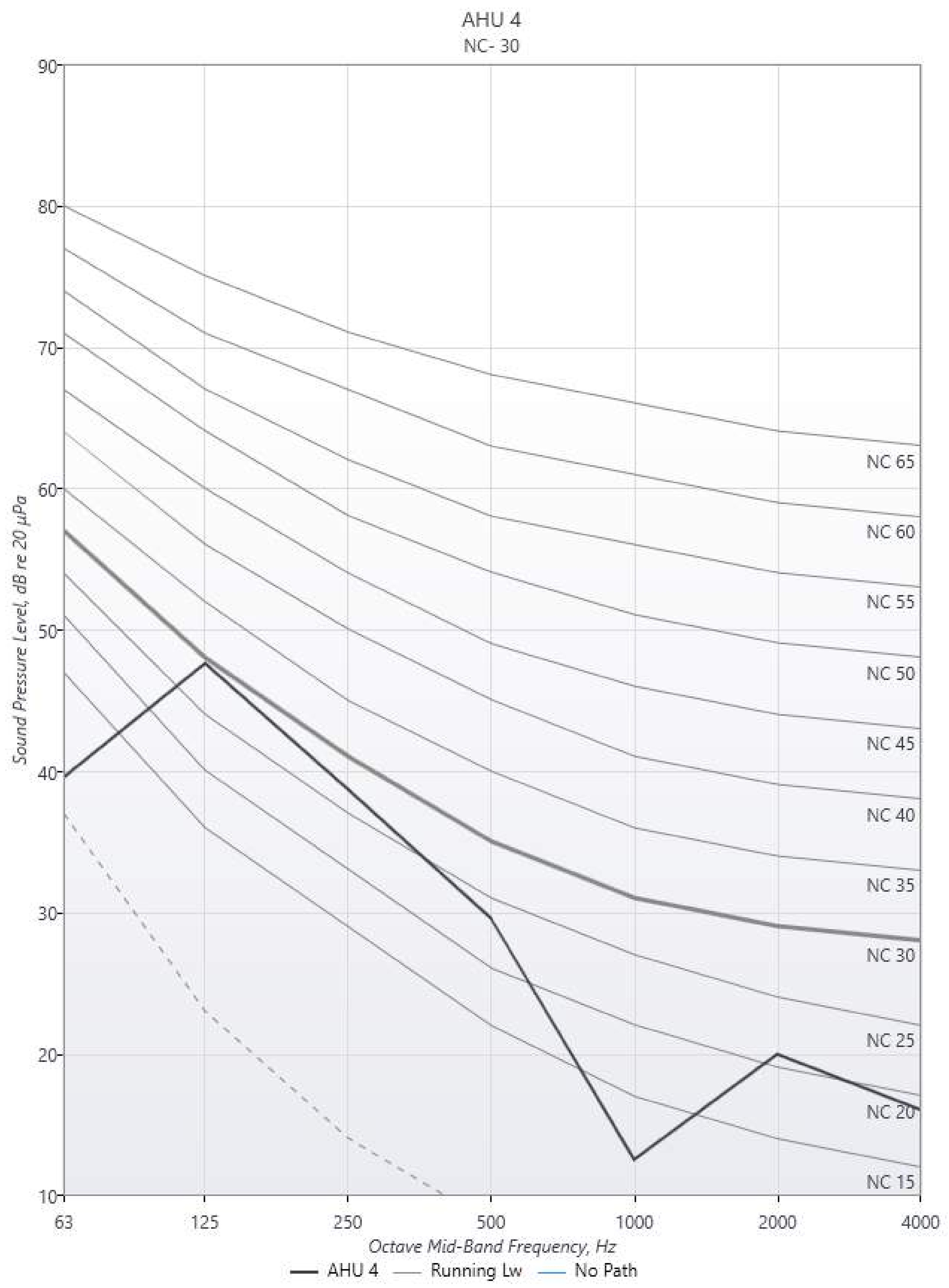
SYNDICATE

PROJECT

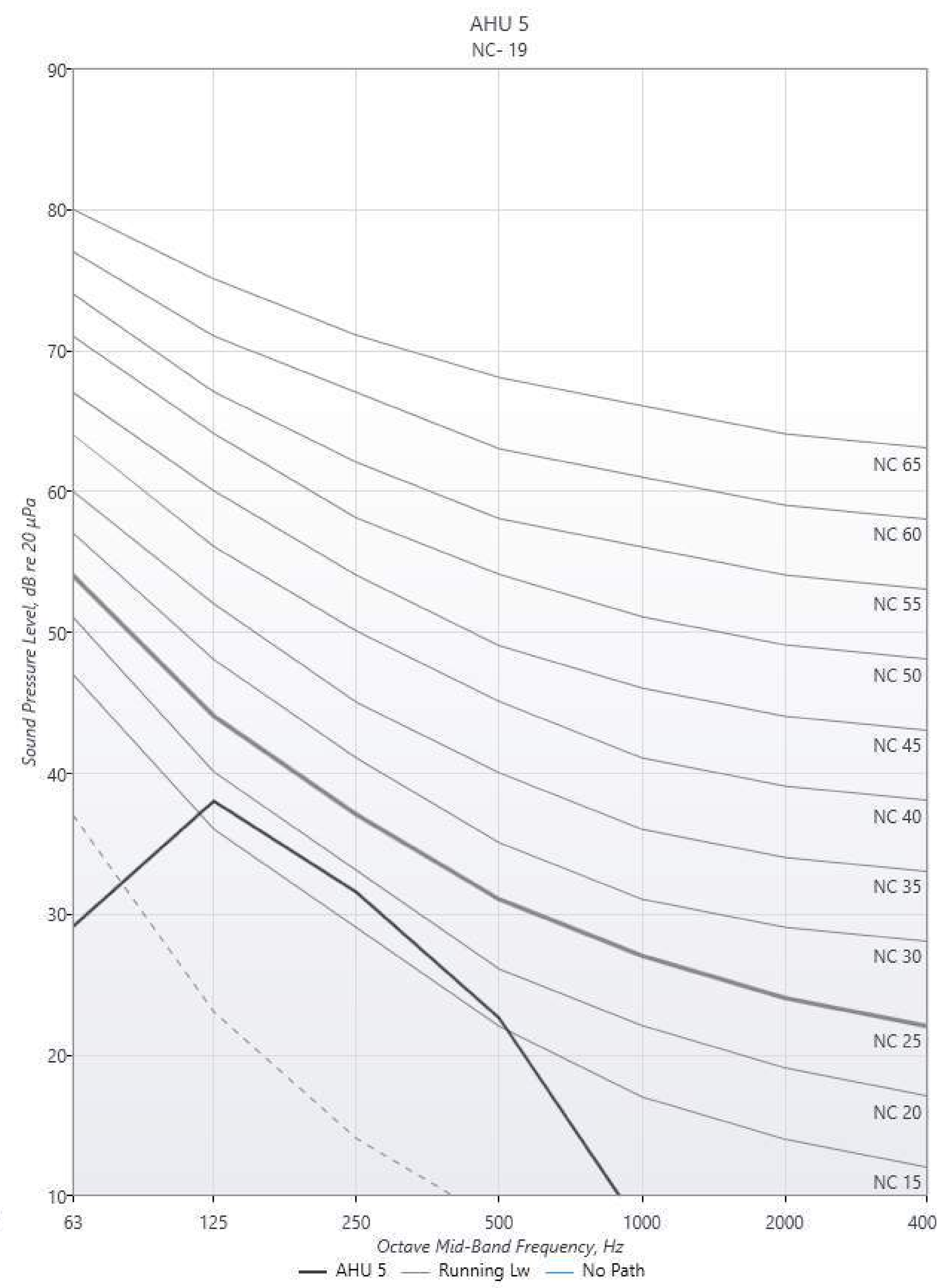
JACK H. MILLER CENTER FOR MUSICAL ARTS

HOLLAND, MICHIGAN

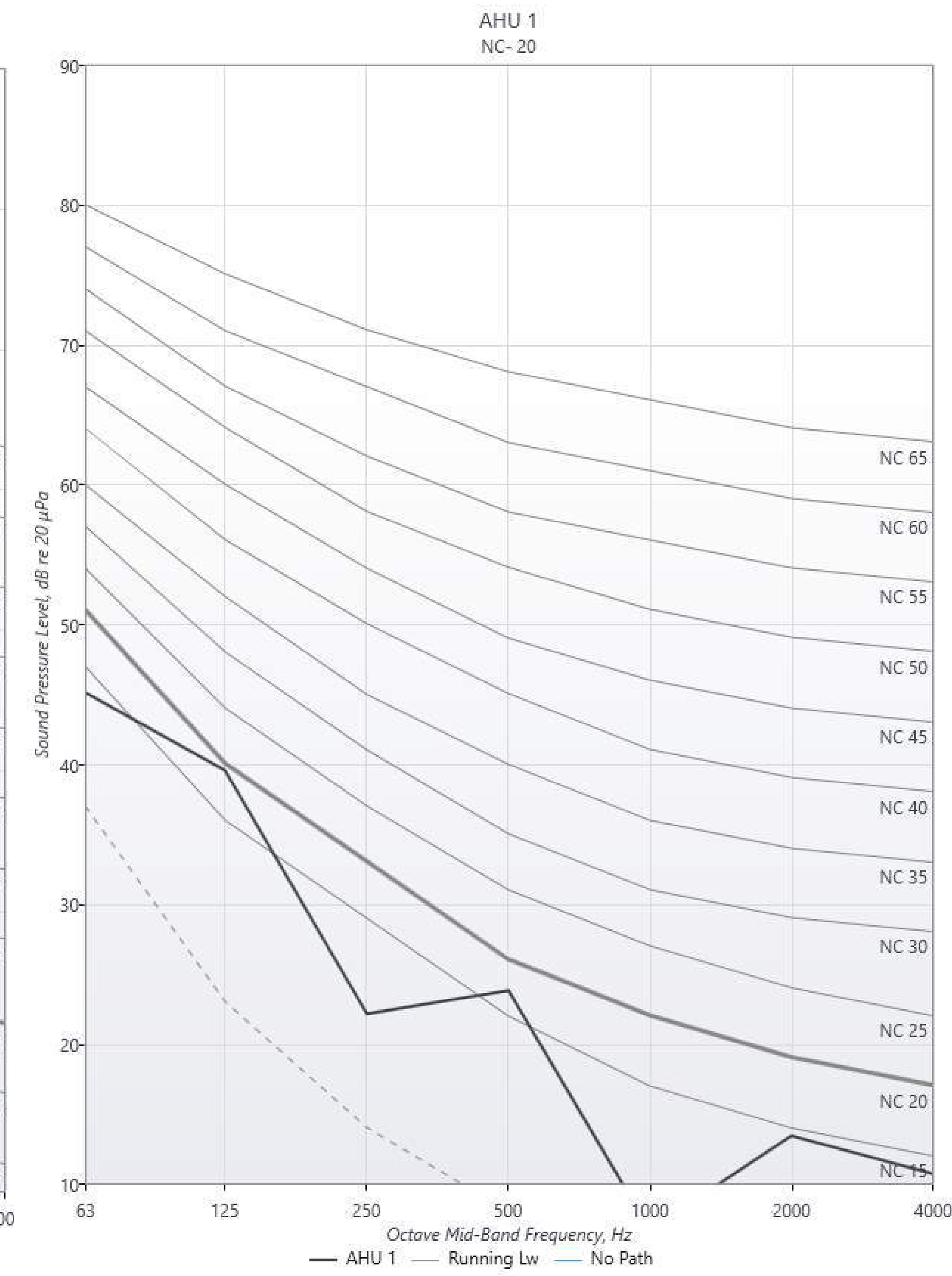
SHEET TITLE	DISPLACEMENT VENTILATION PLANS
NOT FOR CONSTRUCTION	AEI TEAM NO. 01-2019
DATE February 18, 2019	SCALE NOT TO SCALE
DRAWING NO. M-3.0	PAGE NO. 83



REHEARSAL SPACES ,
MEETS NC-30 REQUIREMENT



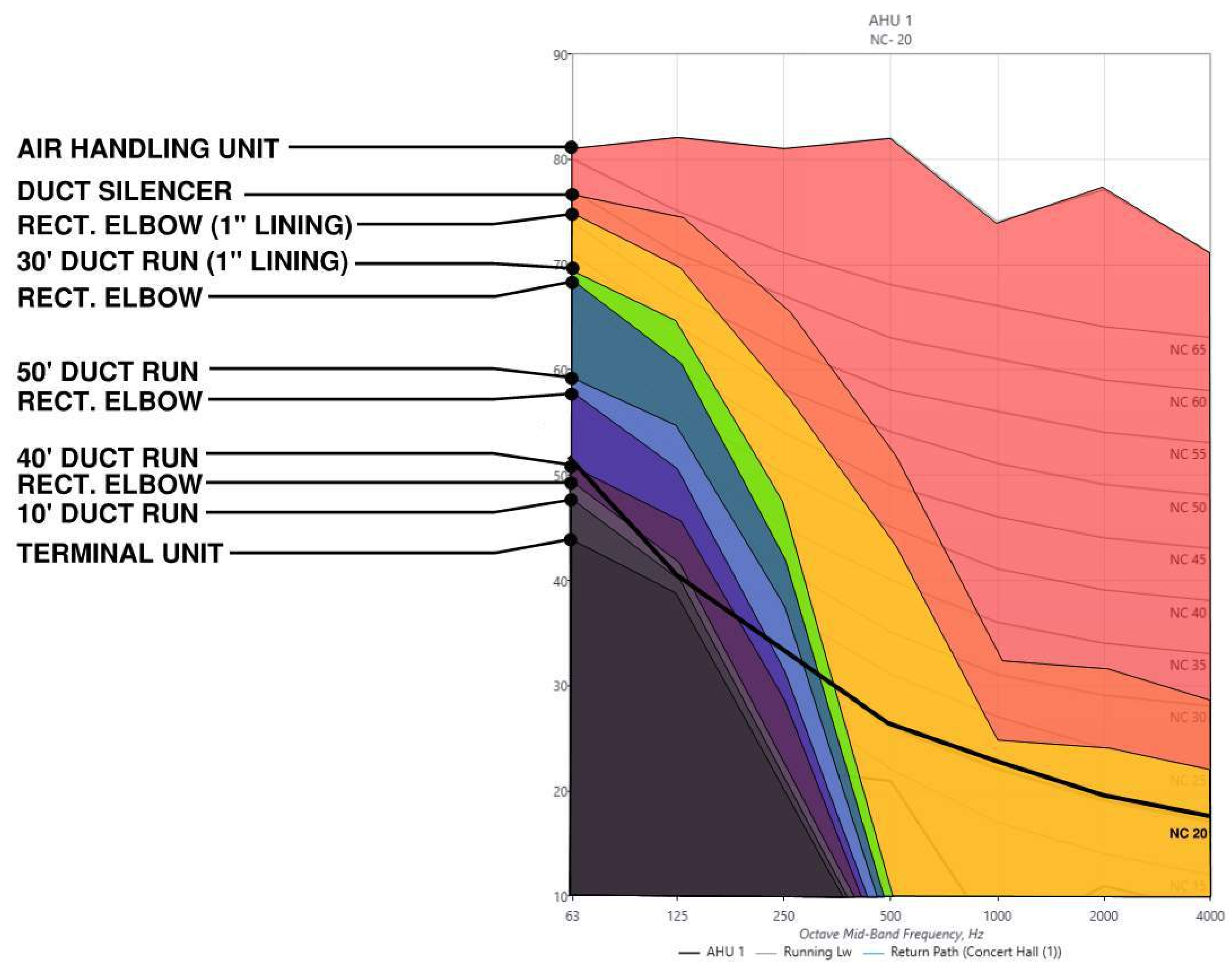
FACULTY STUDIOS,
MEETS NC-25 REQUIREMENT



CONCERT HALL,
MEETS NC-20 REQUIREMENT

The concert hall and the recital hall fall under the category that specifies an NC value of 20. This is a very stringent requirement and is due to the sensitivity of these spaces. The orchestra and choir rehearsal halls do not have live performances in them, so they are slightly less sensitive at an NC rating of 25. Practice rooms and faculty studios have a more lenient rating of NC-30. The long rectangular duct runs worked to allow for much of the sound to be mitigated before reaching the diffusers. When the long duct runs were not sufficient, there was a combination of duct silencers and 1" duct liners added a short distance after the air handling units. The addition of these design features was only needed right after the AHU and not through the entire duct run due to the effective sound mitigation at the different frequencies just a short distance into the duct.

Diffusers were selected to ensure the NC requirement was met in each space. In the area with displacement ventilation 10" floor diffusers from *Price Industries* were selected with a design flow rate of 50CFM, which has a NC Rating below 15. In the office and practice rooms, a ceiling mounted VAV diffuser from *Titus* was selected with an NC rating of 17. Both of these selection meet the NC requirements for the spaces, ensuring the functions of the building will not me disturbed by mechanical background noise.



CONCERT HALL NC GRAPH PROGRESSION

MECHANICAL WALL TRANSMISSION LOSS CALCULATION

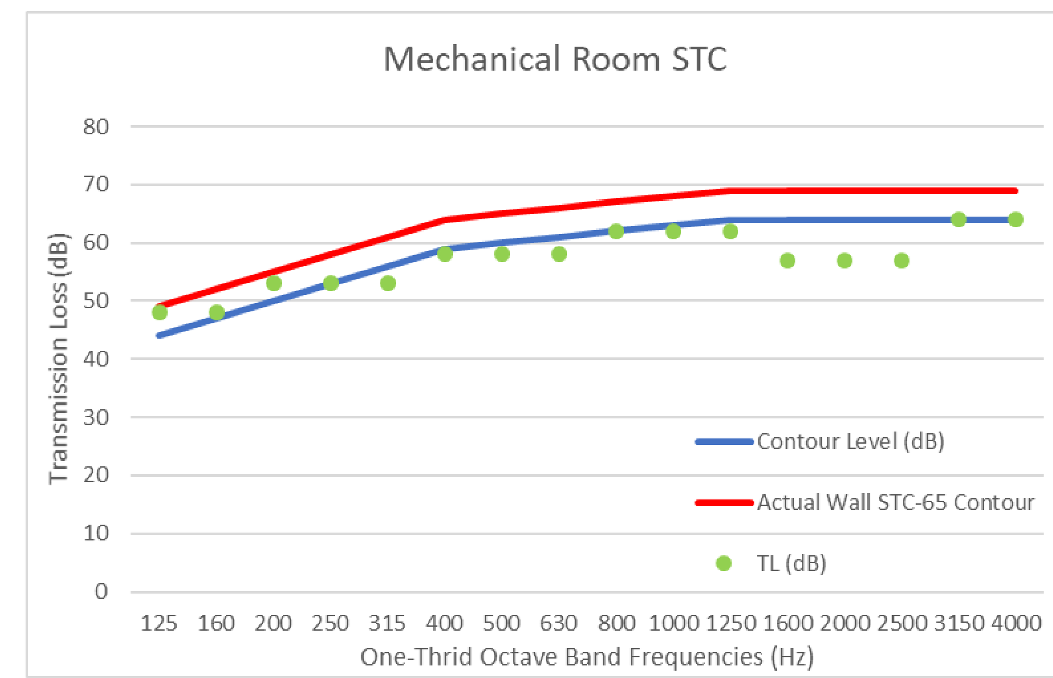
	Frequencies (Hz)															
	125	160	200	250	315	400	500	630	800	1000	1250	1600	2000	2500	3150	4000
Mechanical Room	58	58	51	51	51	48	48	48	47	47	47	41	41	41	47	47
NC-25 Curve	44	44	37	37	37	31	31	31	27	27	27	24	24	24	22	22
Difference (NR)	14	14	14	14	14	17	17	17	20	20	20	17	17	17	25	25
RT	0.54	0.54	1.68	1.68	1.68	3.16	3.16	3.16	3.52	3.52	3.52	2	2	2	1.31	1.31
SW	640	640	640	640	640	640	640	640	640	640	640	640	640	640	640	640
TL	48	48	53	53	53	58	58	58	62	62	62	57	57	57	64	64

MECHANICAL WALL CONTOUR

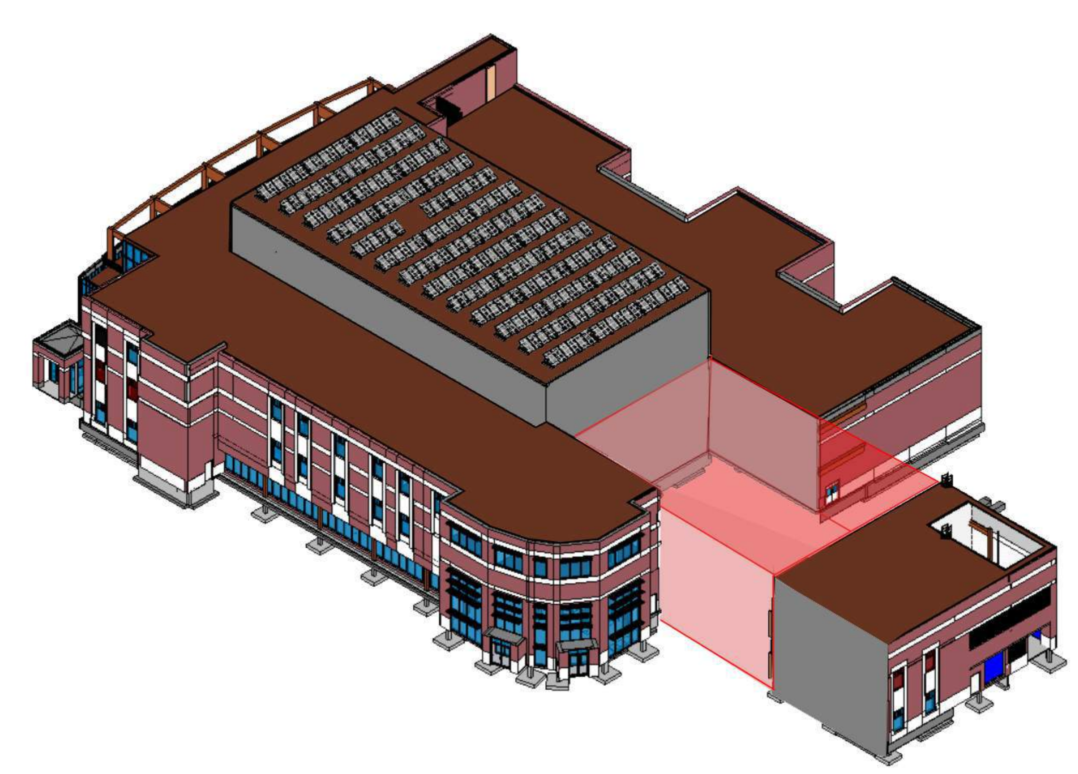
1/3 Octave Band Frequency	Contour Level (dB)	TL (dB)	Deficiency (dB)
125	44	48	0
160	47	48	0
200	50	53	0
250	53	53	0
315	56	53	3
400	59	58	1
500	60	58	2
630	61	58	3
800	62	62	0
1000	63	62	1
1250	64	62	2
1600	64	57	7
2000	64	57	7
2500	64	57	7
3150	64	64	0
4000	64	64	0
TOTAL			25
Assembly STC:	60		

The main mechanical room is located on the second floor adjacent to the concert hall back of house. *Syndicate* wanted to ensure the mechanical equipment operation would not disturb performances or any other functions in The Miller Center. The back of house requires an NC rating of 25 do mitigate background noise disturbances. A wall that provides this needs an STC of 60. *Syndicate* was able to create an assembly that exceeded this requirement with a wall STC of 65 as can be seen by the red line contour below.

MECHANICAL ROOM WALL STC GRAPH



Syndicate was able to stack the first and second floor mechanical rooms and completely isolate the structure shown below. Through this design, the vibrations from the mechanical equipment are greatly mitigated.



SYNDICATE

PROJECT

JACK H. MILLER CENTER FOR MUSICAL ARTS

HOLLAND, MICHIGAN

SHEET TITLE

ACOUSTIC CALCULATIONS

NOT FOR CONSTRUCTION

AEI TEAM NO.
01-2019

DATE
February 18, 2019

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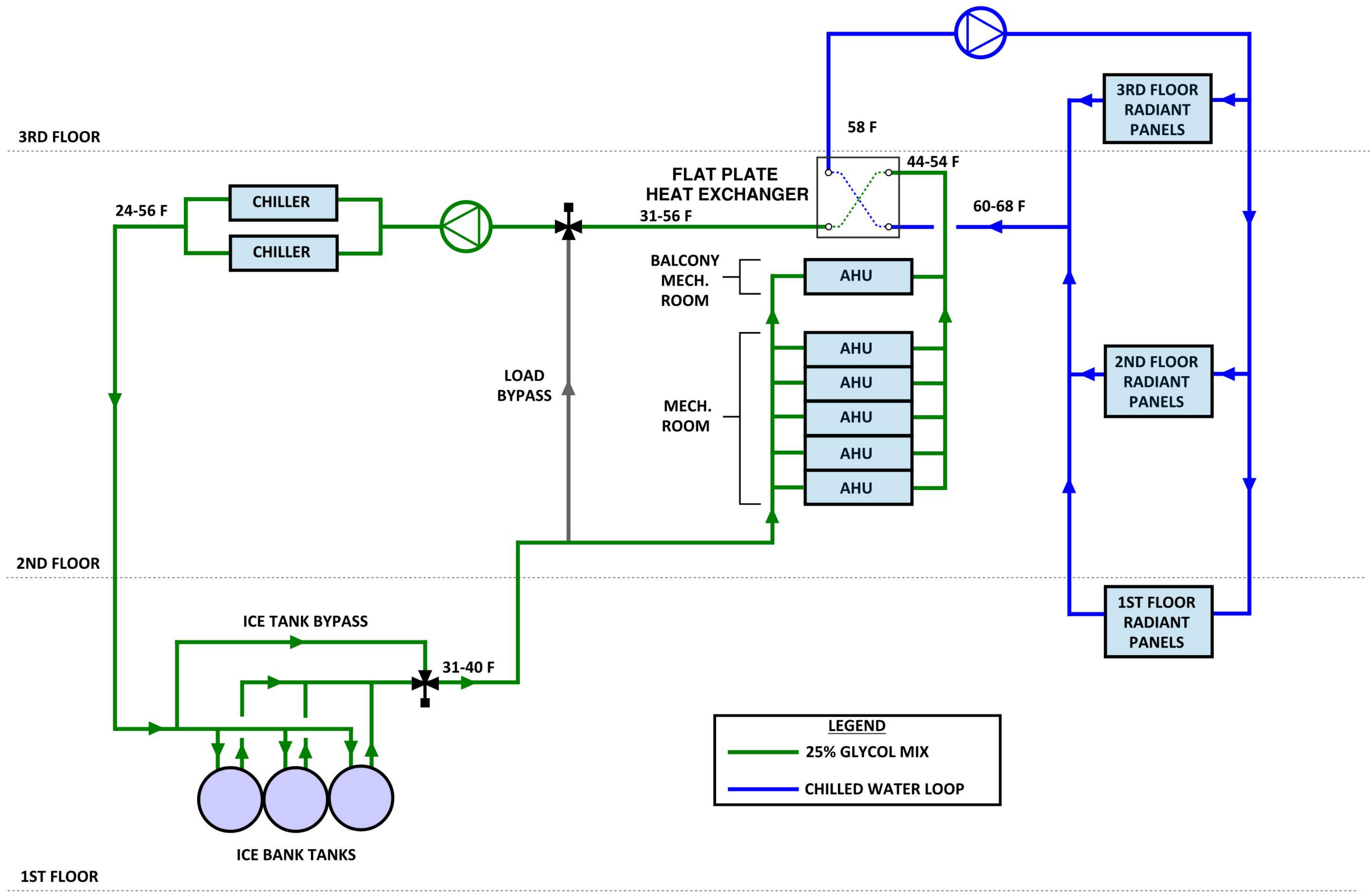
NOT TO SCALE

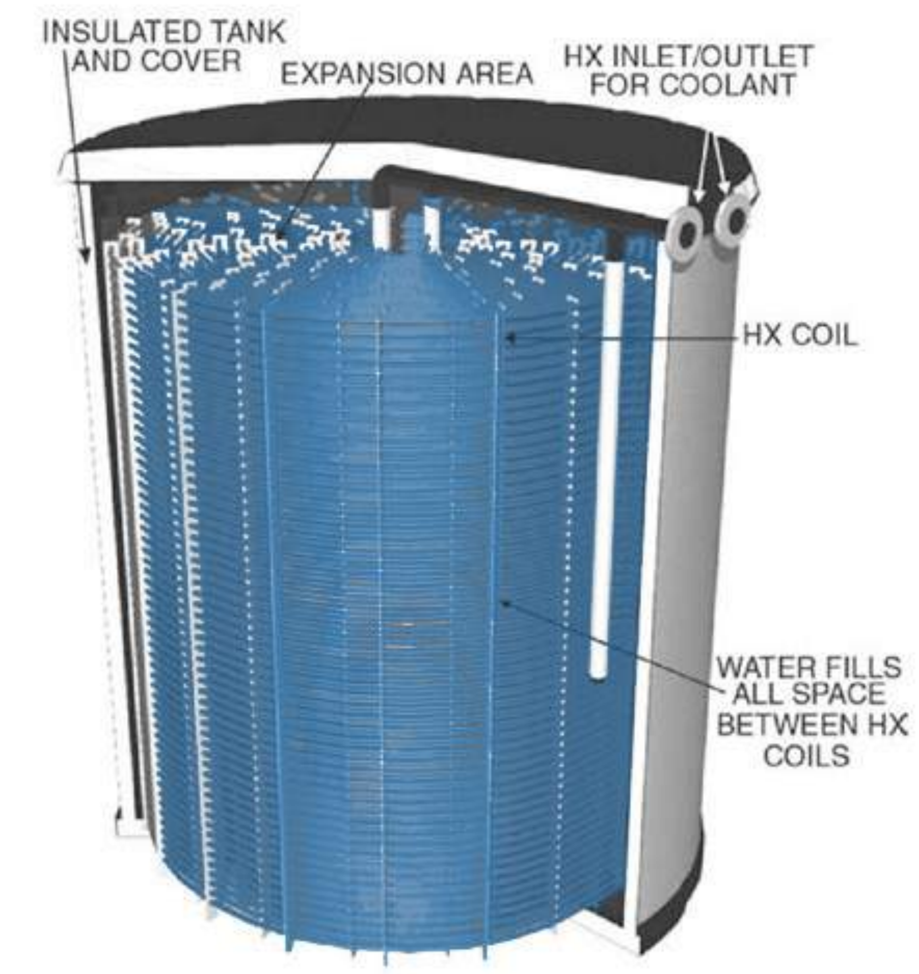
DRAWING NO.
M-4.0

PAGE NO.

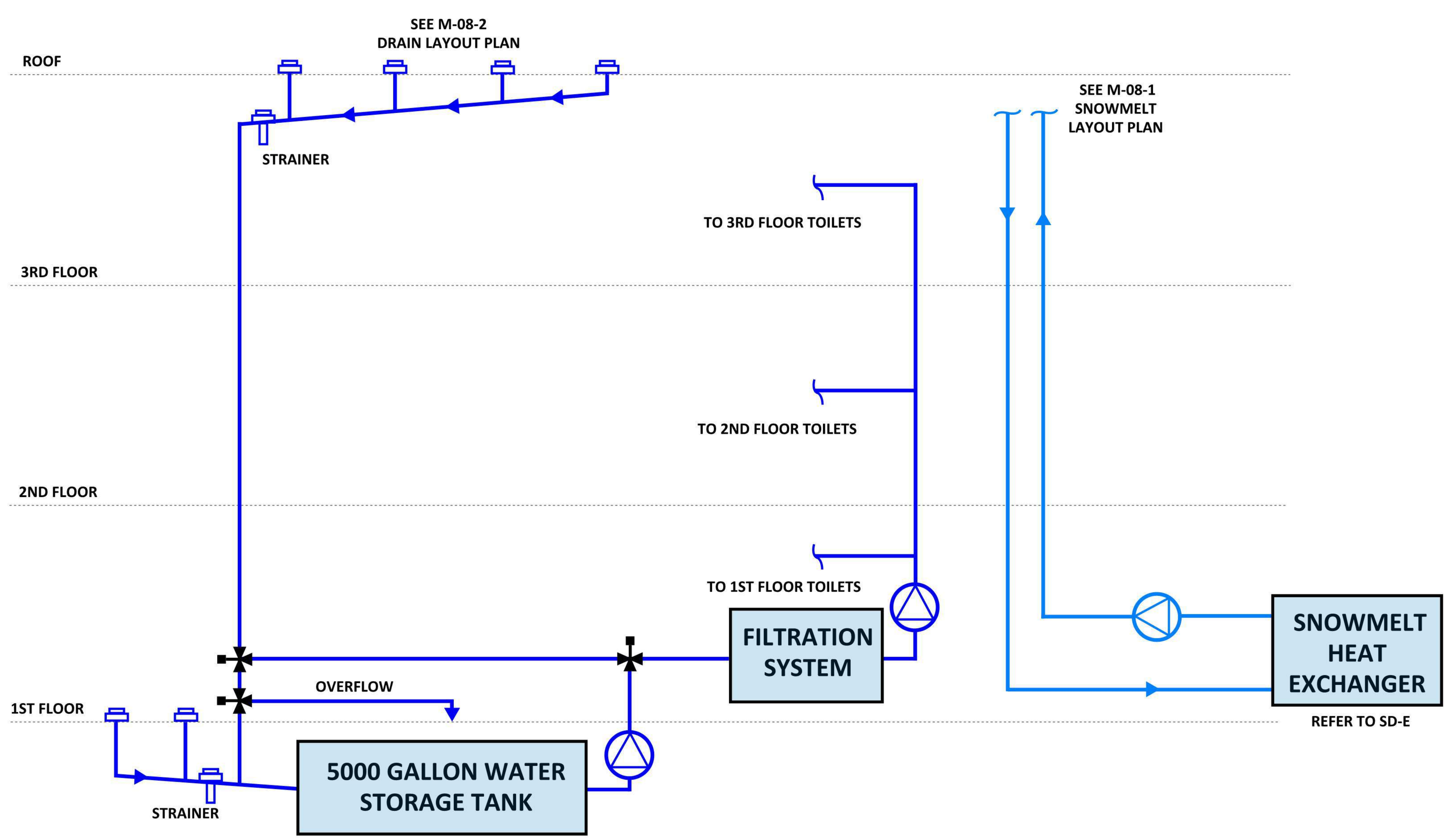


1 CHILLED WATER & GLYCOL LOOPS

Ice is formed and stored on the tube heat exchanger surface while the glycol flows through the tube side. A 25% glycol mixture was used to allow system water to be cooled below the freezing point of water. The chiller is upstream and in series with the thermal storage. This allows the chiller to operate more efficiently when discharging since it will precool the water to 48F instead of 40F.. Thermal storage are easy to maintain and operate, making the system ideal to significantly lower the utility cost at little extra cost. See M-6.0 for specific thermal storage cycles.



INTERNAL FREEZE INTERNAL MELT TANK INTERIOR

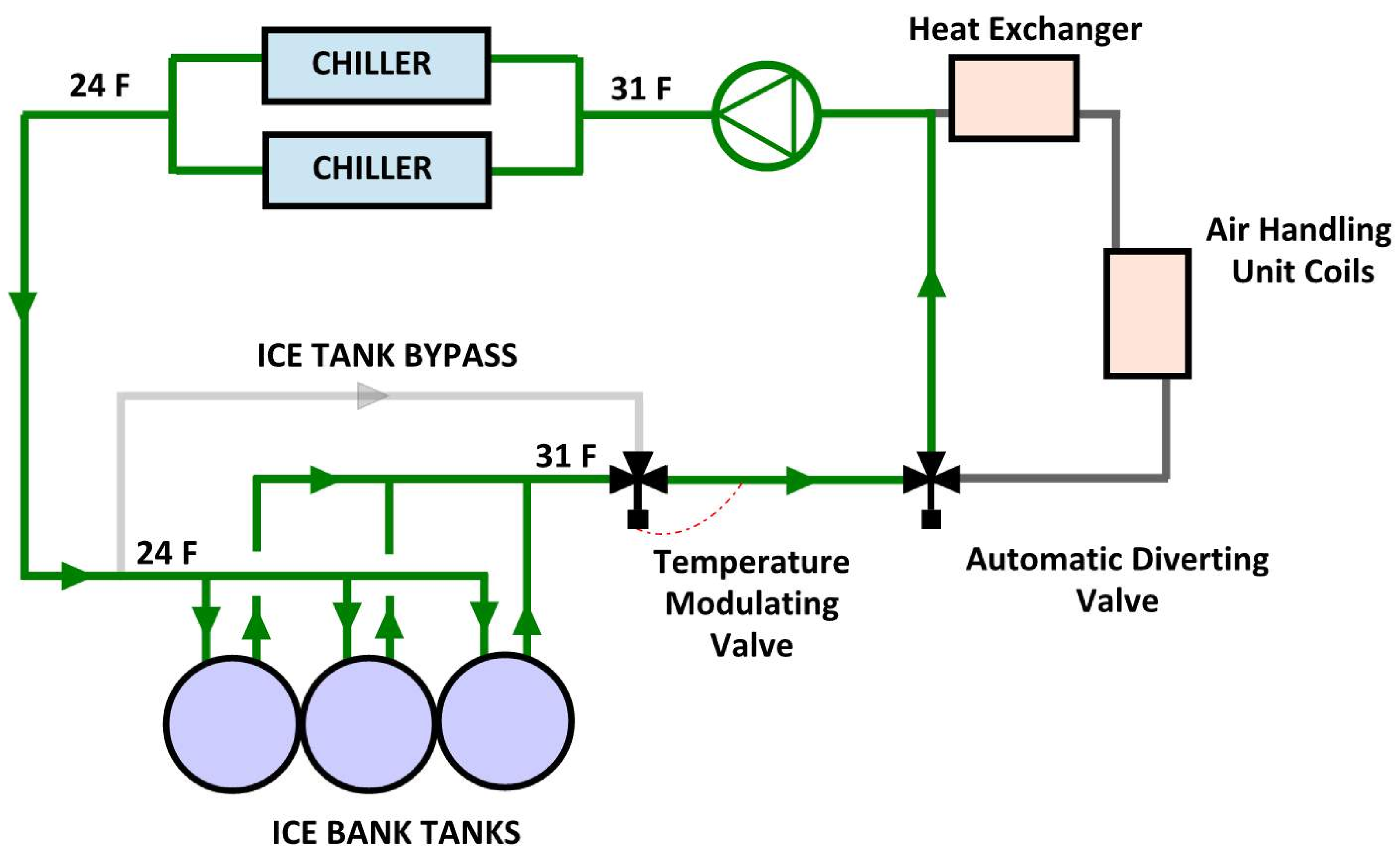


2 PRECIPITATION COLLECTION LINE DIAGRAM

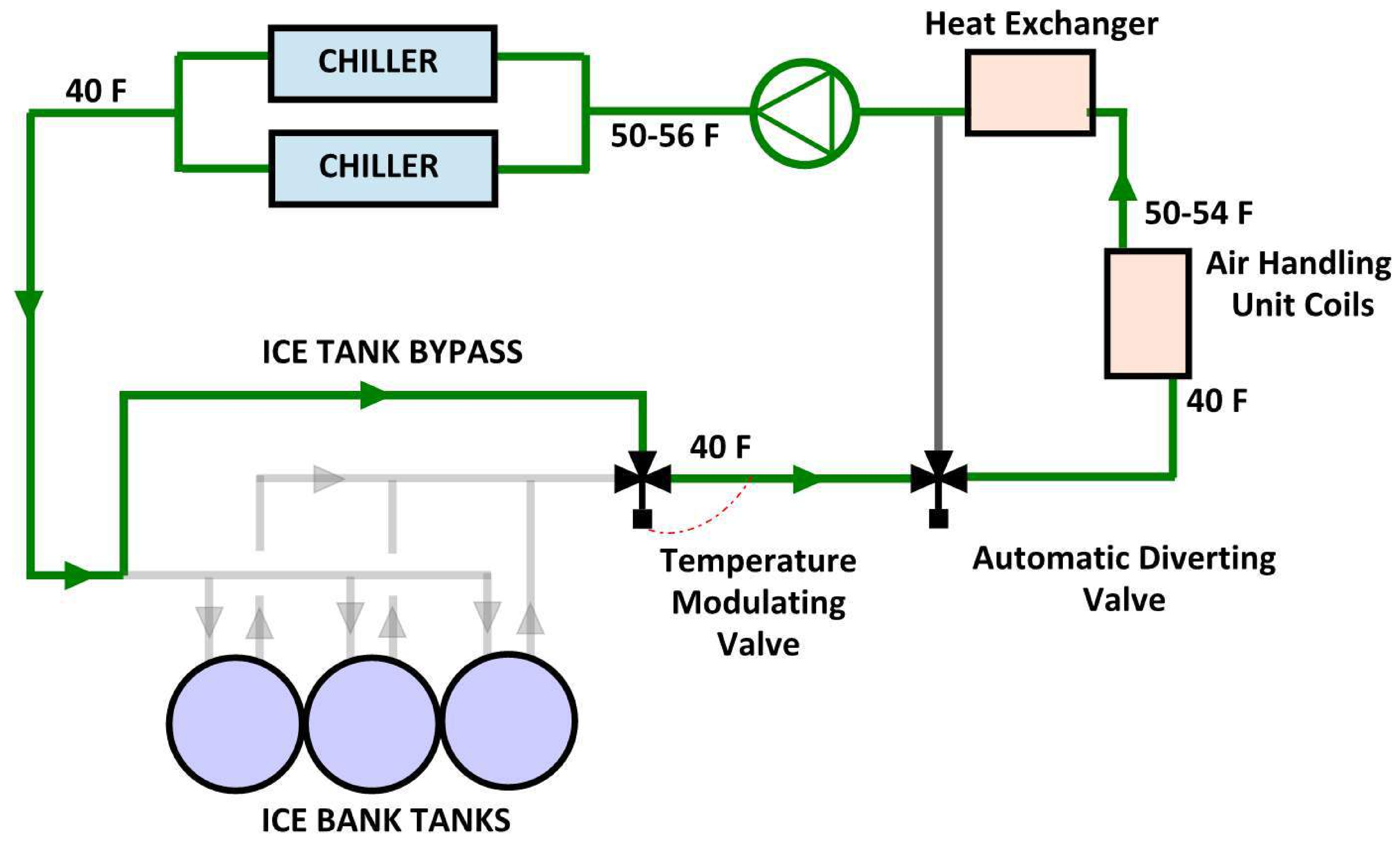
The snowmelt loop consists of a 25% glycol mixture that is sent through a flat plate heat exchanger to be heated from 50F to 80F from the steam condensate. The glycol mixture is then pumped to the roof to melt ice and snow that accumulates during the winter months. The snowmelt is controlled by an automatic sensor on the roof surface that provides feedback of the outdoor temperature, current roof temperature, and detection of moisture. The snowmelt system will be at an idling setpoint of 28-30F, which allows the system respond quicker to a need for snowmelt rather than allowing the slab to get to ambient temperature. For layout and cost analysis see M-7.0.

The precipitation collection system collects water and melted snow from all the roofs and the plazas on the ground level. The water is either sent directly into the filtration system to be used for grey water, sent into the storage tank, or sent into the gravel surrounding the tank during overflow conditions. See M-7.0 for roof drain layout.

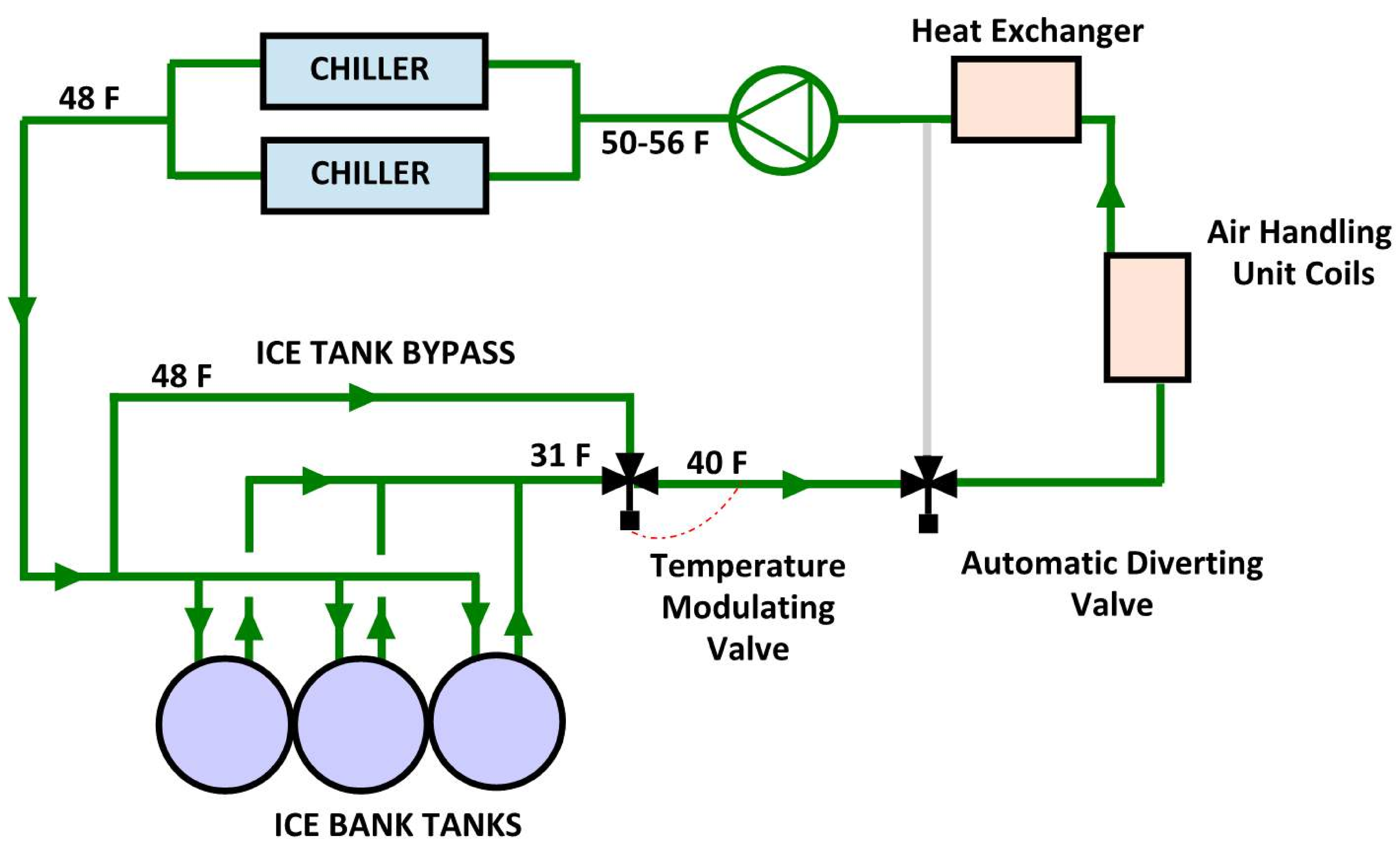
SYNDICATE	
PROJECT **JACK H. MILLER CENTER FOR MUSICAL ARTS** HOLLAND, MICHIGAN	
SHEET TITLE PIPING LINE DIAGRAMS	
NOT FOR CONSTRUCTION	AEI TEAM NO. 01-2019
DATE February 18, 2019	SCALE NOT TO SCALE
DRAWING NO. M-5.0	PAGE NO. 85



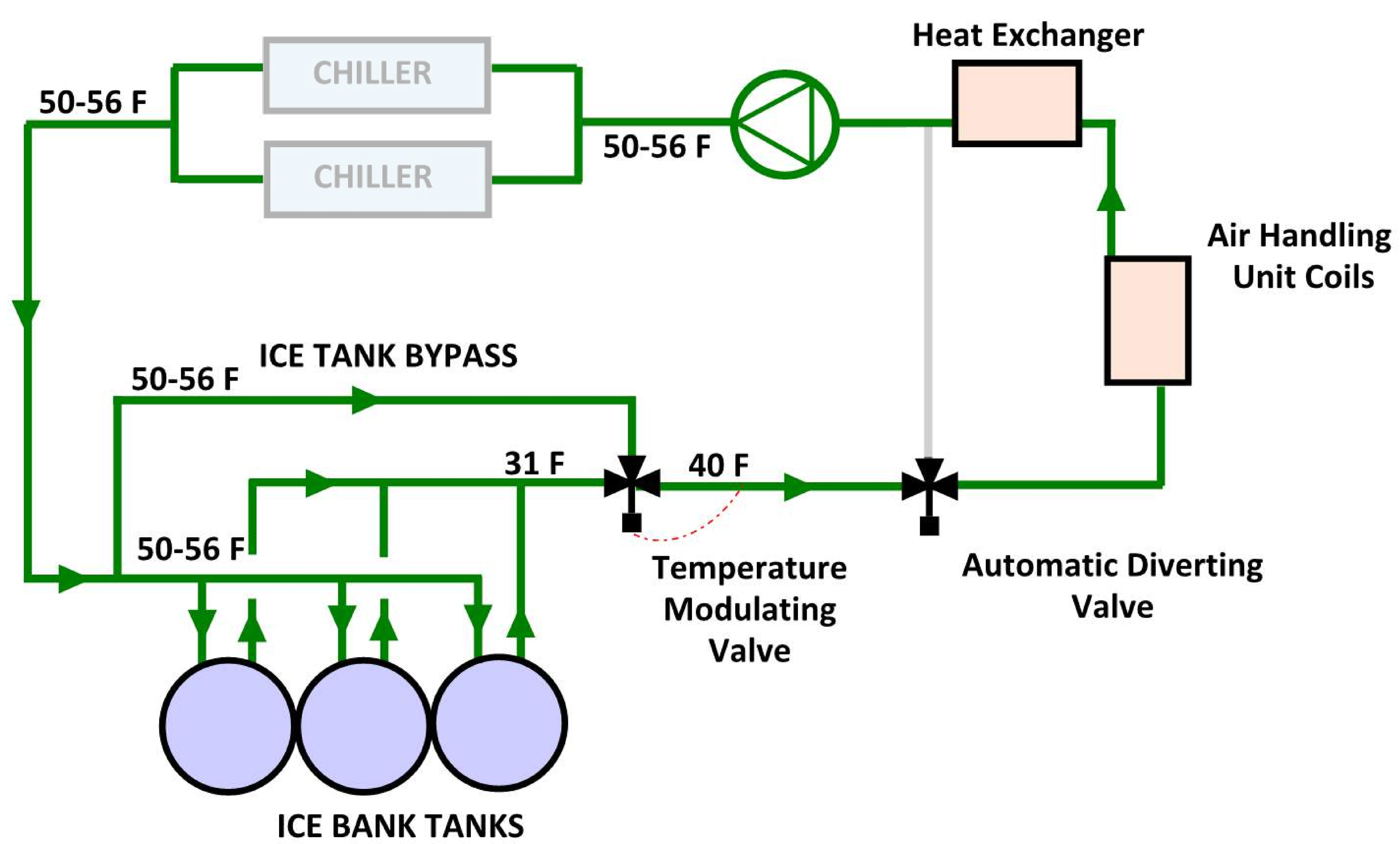
1 THERMAL STORAGE CHARGING CYCLE



2 THERMAL STORAGE BYPASS CYCLE



3 CHILLER AND THERMAL STORAGE DISCHARGING CYCLE

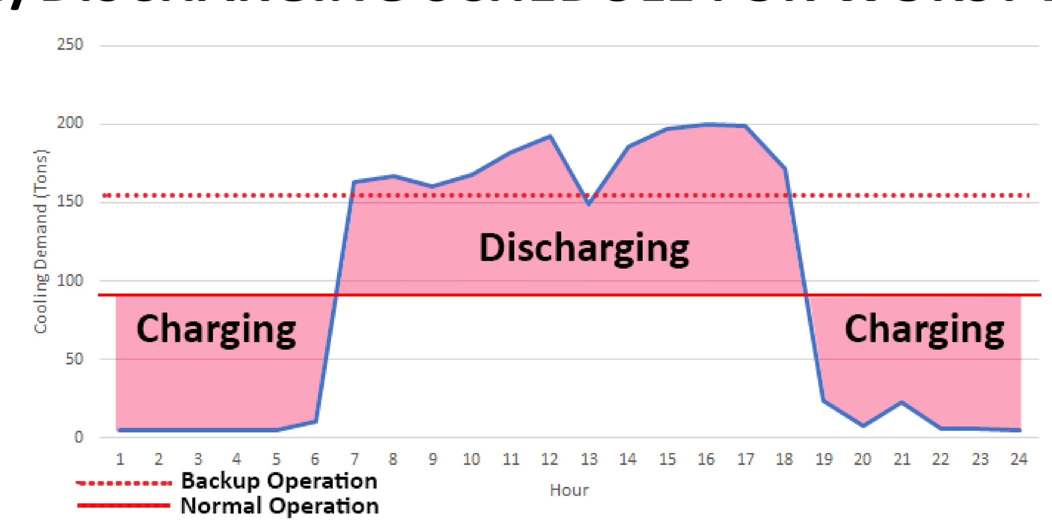


4 THERMAL STORAGE ONLY DISCHARGING CYCLE

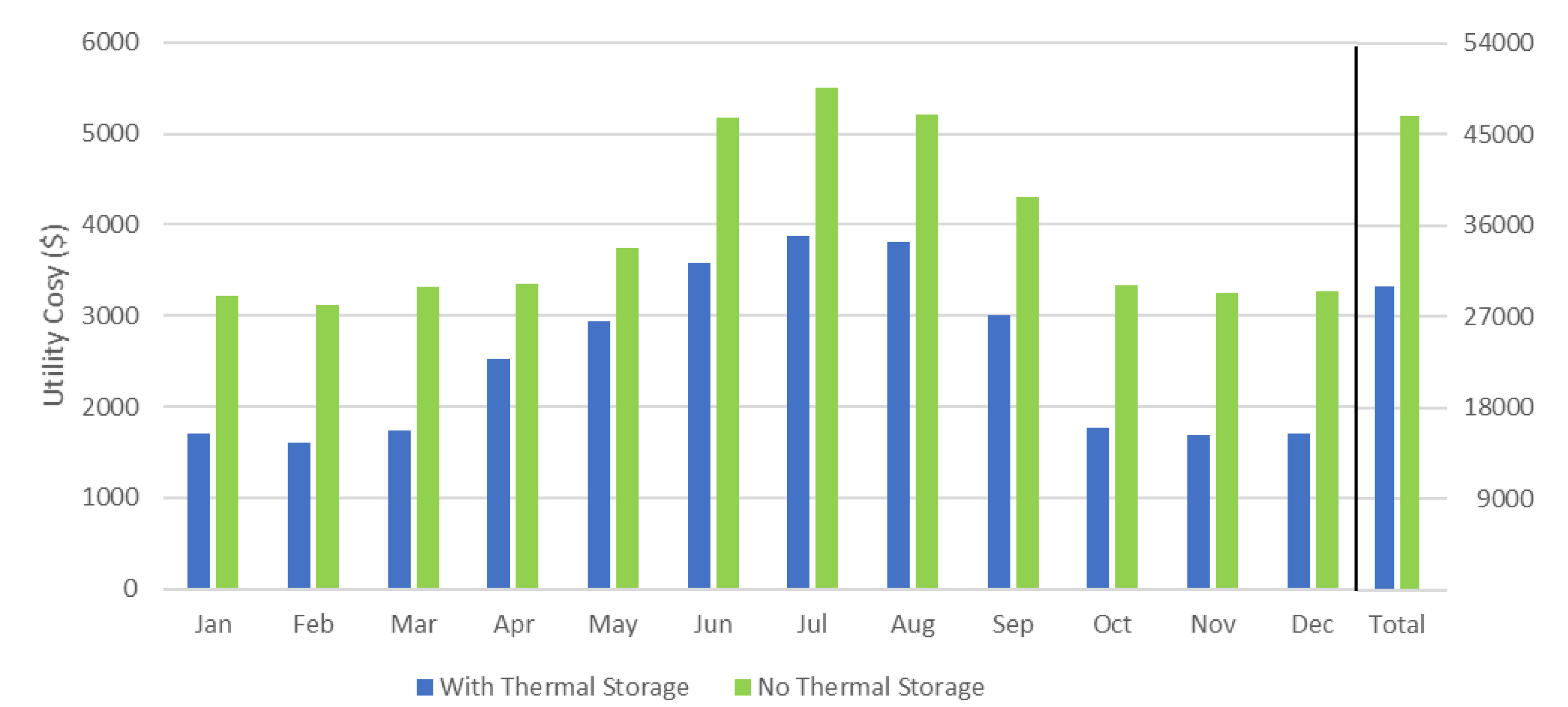
THERMAL STORAGE COST ANALYSIS

	First Cost	Yearly Maintenance Cost	Yearly Utility Savings	Simple Payback
Thermal Storage	$ 122,000	$ 8,100	$ 16,200	1.40
No Thermal Storage	$ 100,000	$ 7,900		

CHARGING/DISCHARGING SCHEDULE FOR WORST LOAD CONDITION



MONTHLY UTILITY COST WITH AND WITHOUT THERMAL STORAGE



SYNDICATE

PROJECT

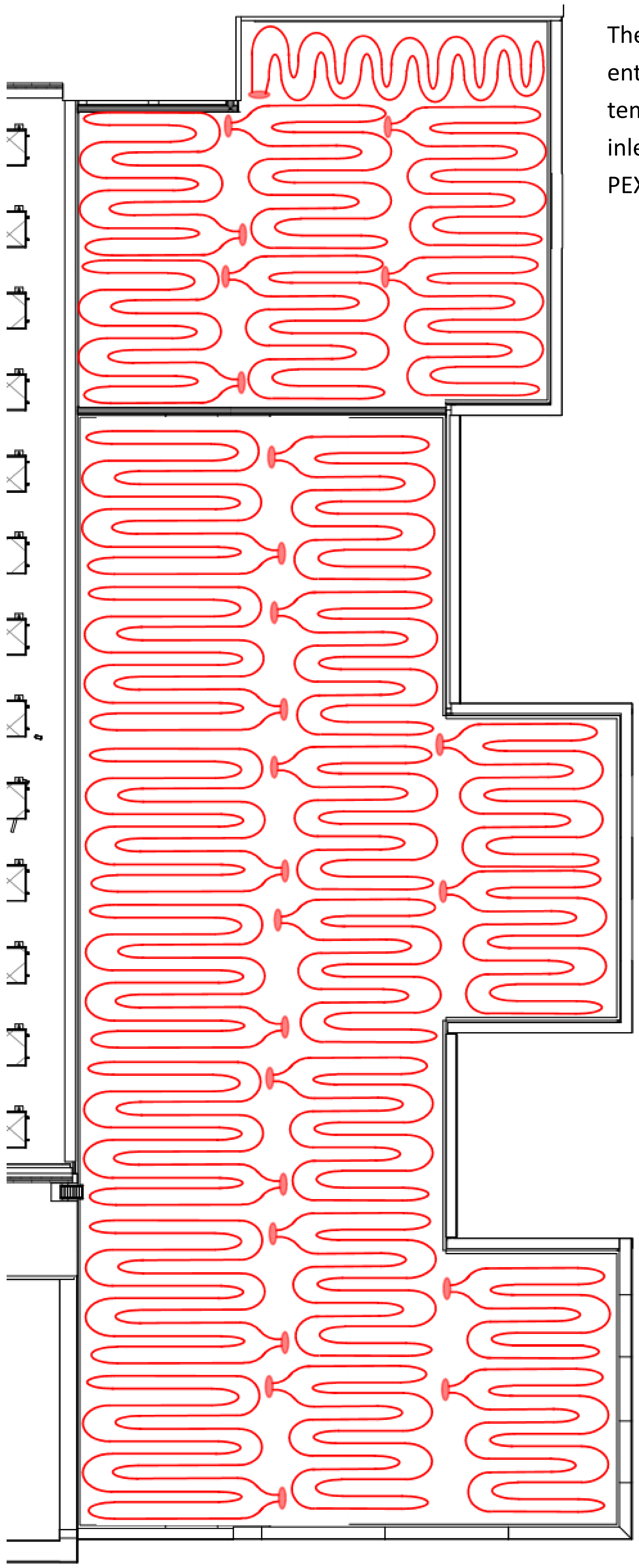
JACK H. MILLER CENTER FOR MUSICAL ARTS

HOLLAND, MICHIGAN

SHEET TITLE

THERMAL STORAGE ANALYSIS

NOT FOR CONSTRUCTION	AEI TEAM NO. 01-2019
DATE February 18, 2019	SCALE NOT TO SCALE
DRAWING NO. M-6.0	PAGE NO. 86



1 TYPICAL SNOWMELT ROOF LAYOUT

**Snowmelt loops located on all horizontal roof surfaces

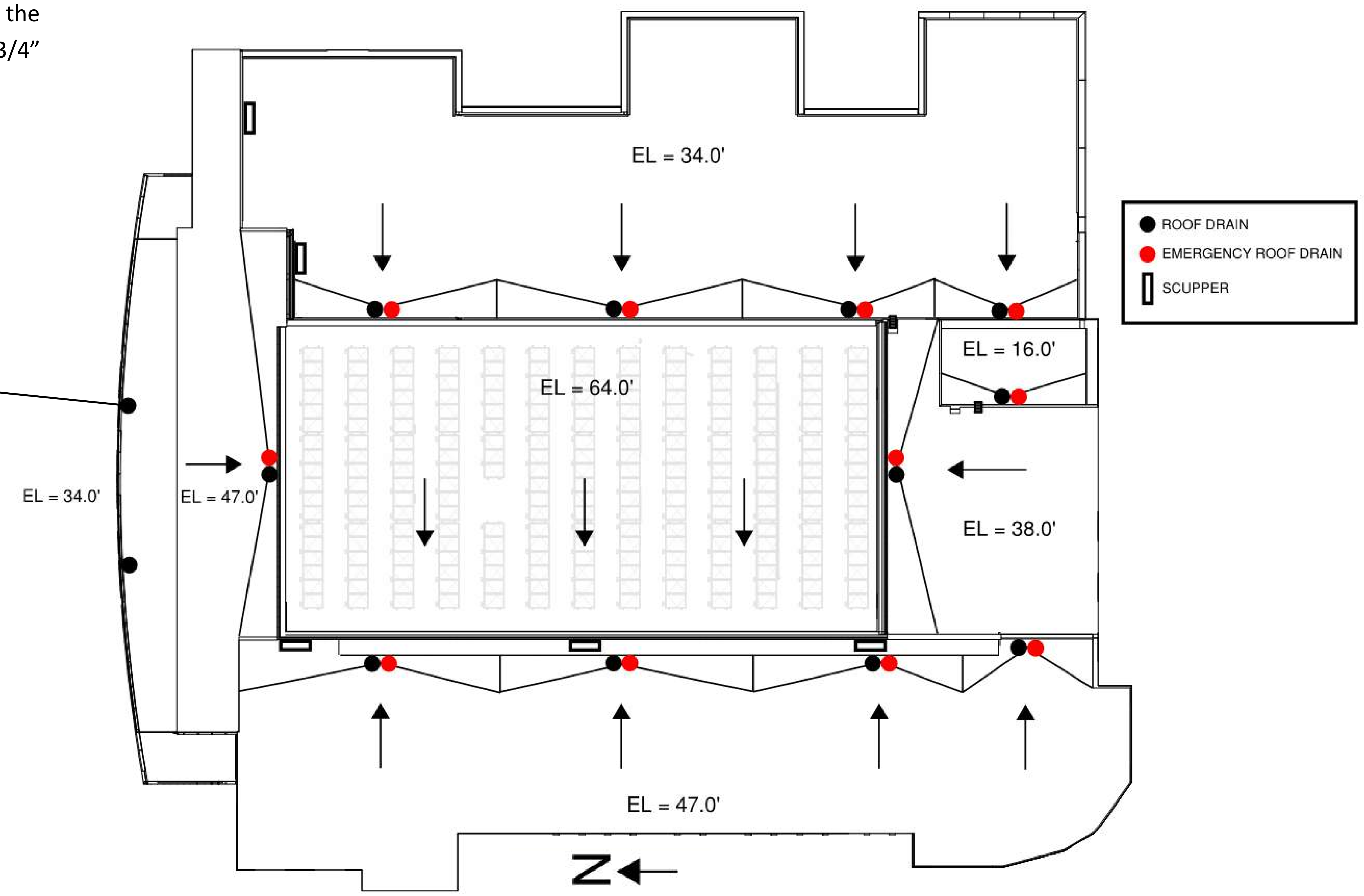
Active loop ends, main headers and control valves mounted centrally at a utility room

The snowmelt on the roof was design in a reverse return layout to allow the entire roof to heat up more evenly. Loops were also ensured to have an inlet temperature of 80F and a maximum temperature difference of 30F between the inlet and outlet of the loops. The roof area requires 44,000 linear feet of 3/4" PEX piping and save $8,500 in annual water/sewer utilities.

Concealed Drainage Pipe

DRAINAGE PIPE AND COLUMN DETAIL

The roof drain layout provides a direct way for storm water and melted snow to be collected in the underground collection tank or into the filtration system. The concert hall roof is sloped to the south were scuppers will drain the water down to the roof below. 4" drains collect the water and are routed down external downspouts against the concert hall walls to reduce disturbing the rooms below. This is especially important when above the concert hall to minimize piping in the concert hall. The water will be sent through the filtration system on the first floor, to be used for grey water. The greywater will be sent to the low flow toilet fixtures installed throughout the building. When the water is not needed it will be sent to an underground storage tank.



2 PRECIPITATION COLLECTION LINE DIAGRAM

SNOWMELT COST ANALYSIS

Water and Sewage Cost ($/ccf)	Water Collected (gal/year)	Yearly Savings	Install Cost	Payback
4.48	1,433,129.66	$8,583.45	$62,064.20	7.23

LOW FLOW FIXTURE IMPROVEMENTS BREAKDOWN

			Baseline	Low Flow Fixtures		Baseline	Low Flow Fixtures
	Flushes/ day	*Number of People*	*Gal/flush*		*Number of fixtures*	*Gallons used/day*	*Gallons used/day*
Toilet female	0.86	165	1.6	1.1	24	5448.96	3746.16
Toilet male	0.55	165	1.6	1.1	7	1016.4	698.775
Urinal	0.31	165	1	1	13	664.95	664.95
						Baseline	Low Flow Fixtures
	Duration (sec)	*Baseline flow gpm*	*Design Flow gpm*	*Uses per day*	*Number of fixtures*	*Gallons used/day*	*Gallons used/day*
Lavatory Facet	60	1.5	0.5	11.15	28	468.27	156.09
Showerhead	300	2.5	2.5	1	1	12.5	12.5
					Total	7611.08	5278.475
					%savings	**30.65%**	
	Toilet Cost	*Number of Toilets*	*Faucet Cost*	*Number of Faucets*	*Install Cost*	*Annual Water/ Sewage Cost*	*Payback*
Baseline	$454.00	31	$301.00	28	$22,502.00	$12,445.64	
Design	$475.00	31	$311.00	28	$23,433.00	$8,631.36	
					$931.00	**$3,814.28**	<1 year

SYNDICATE

PROJECT

JACK H. MILLER CENTER FOR MUSICAL ARTS

HOLLAND, MICHIGAN

SHEET TITLE

SNOWMELT AND DRAINAGE PLANS

NOT FOR CONSTRUCTION

AEI TEAM NO.
01-2019

DATE
February 18, 2019

SCALE
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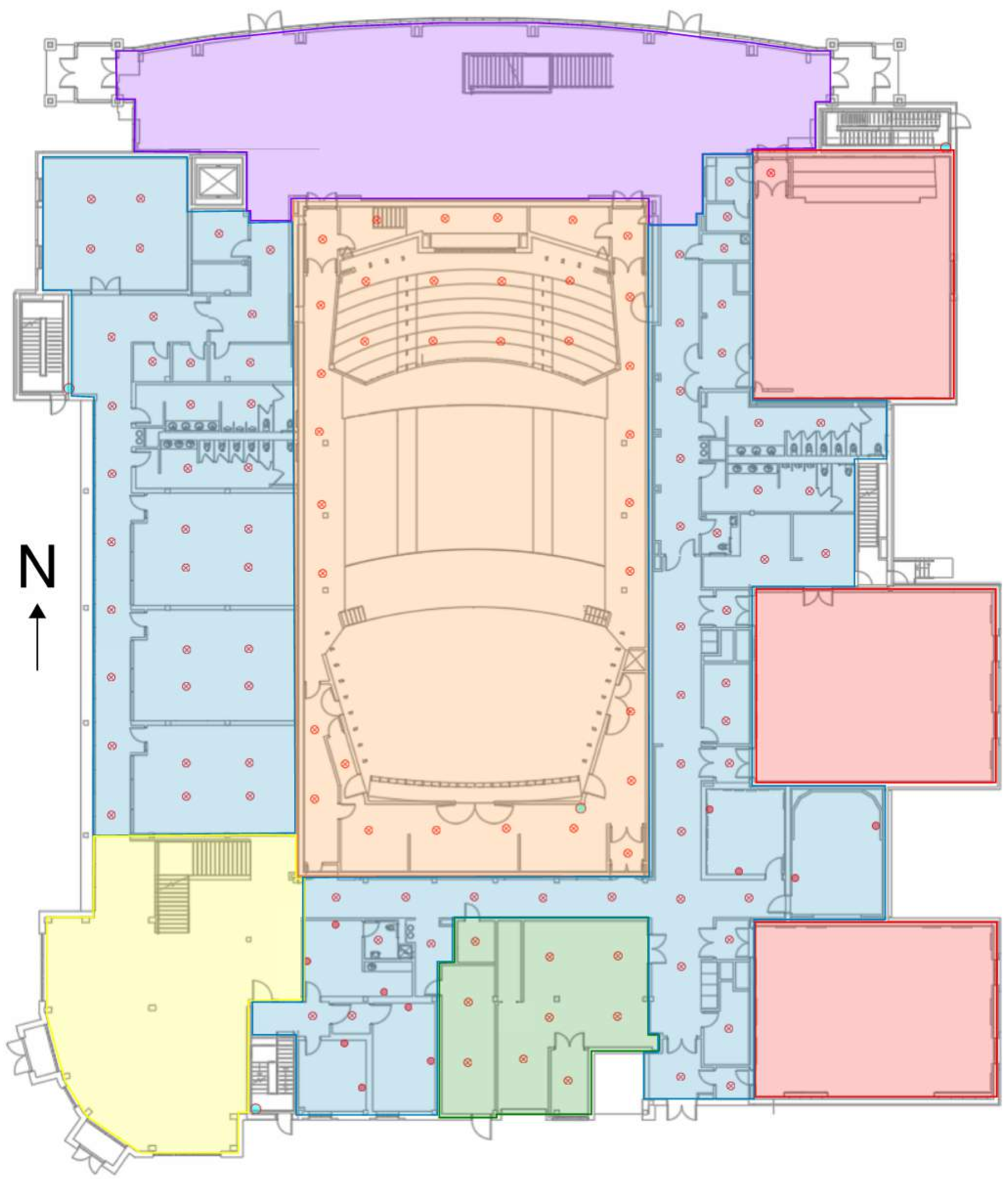
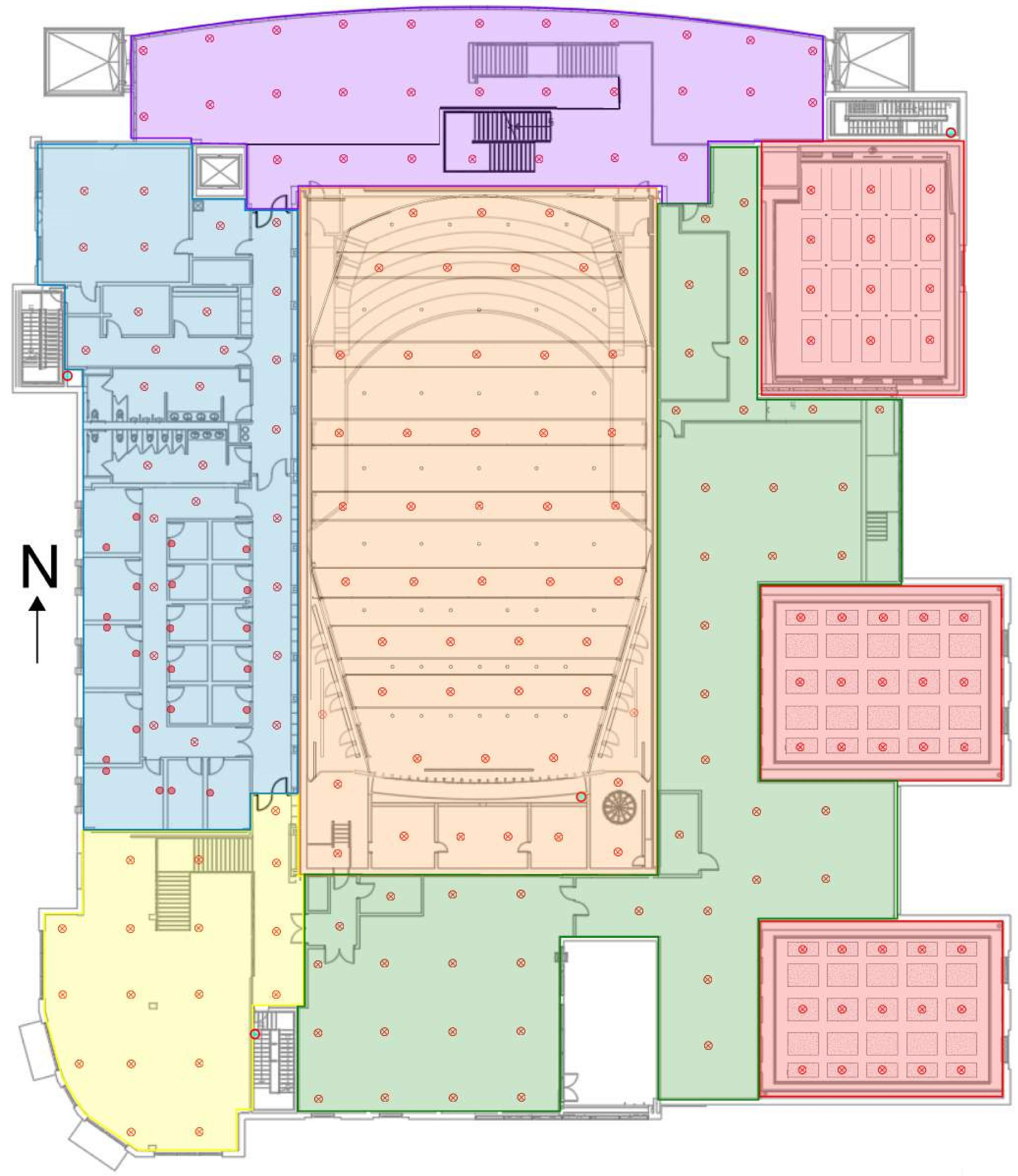
DRAWING NO.
M-7.0

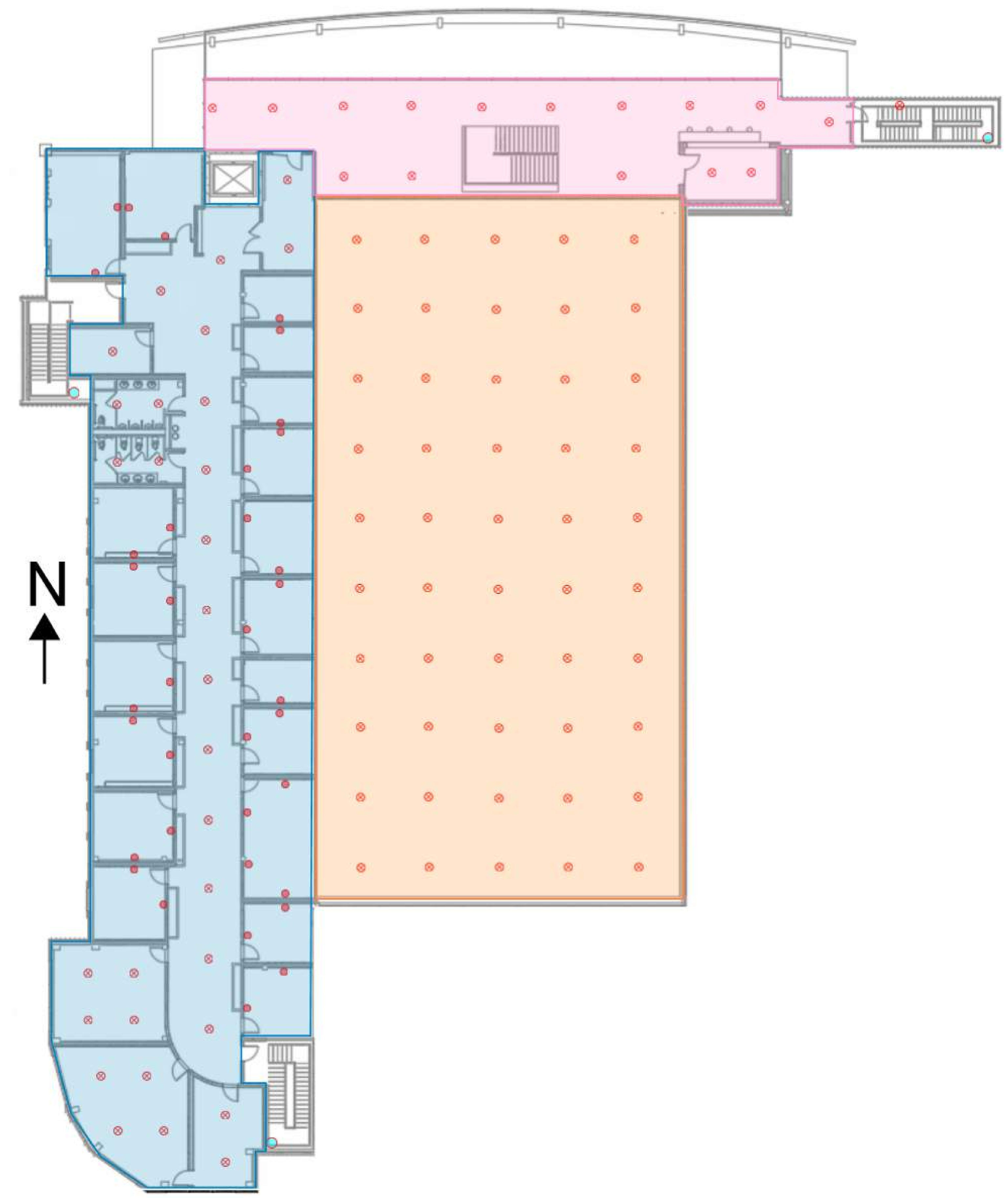
PAGE NO.



1 FIRST FLOOR SPRINKLER PLAN



2 SECOND FLOOR SPRINKLER PLAN



3 THIRD FLOOR SPRINKLER PLAN

Concealed Pendant Sprinkler

Sidewall Sprinkler

Standpipe

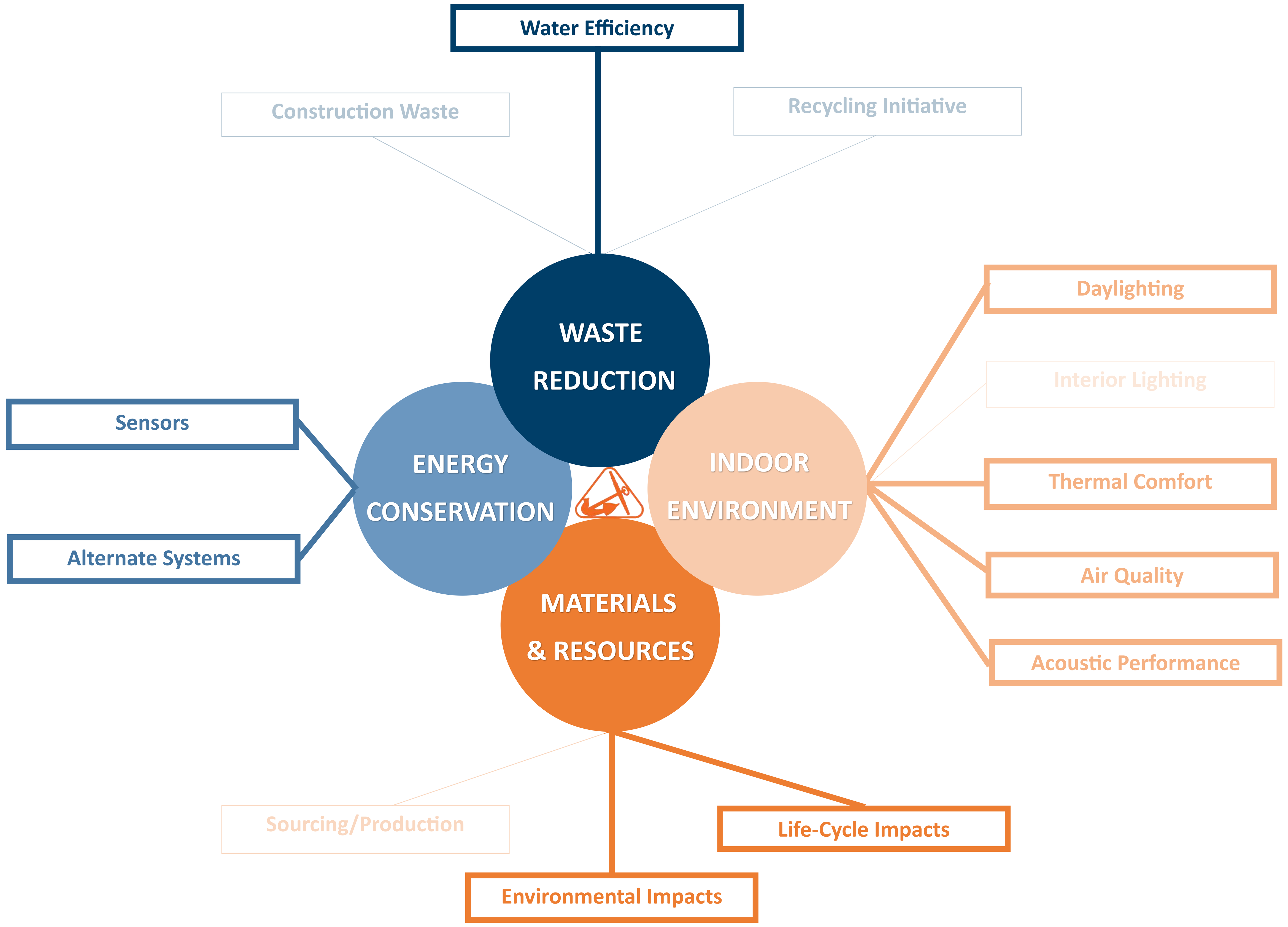
Colors Denote Sprinkler Annunciation Zones

Concealed pendant sprinklers were used throughout the building to maintain a clean aesthetic but still providing adequate protection against fire. For example, in performance spaces, sprinklers will be installed and concealed in acoustical ceiling panels/ribbons. In the faculty studios and practice rooms, two side wall sprinklers were placed based on the requirements for area coverage from NFPA 13. By adding an occupiable roof and third floor, standpipes are now required to be placed in stairwells. In addition, the stage will require a Class III standpipe due to the area of the platform being greater than 1000SF. The fire suppression system utilizes an automatic sprinkler system in accordance with NFPA 14. The system is also equipped with smoke detectors in every room.

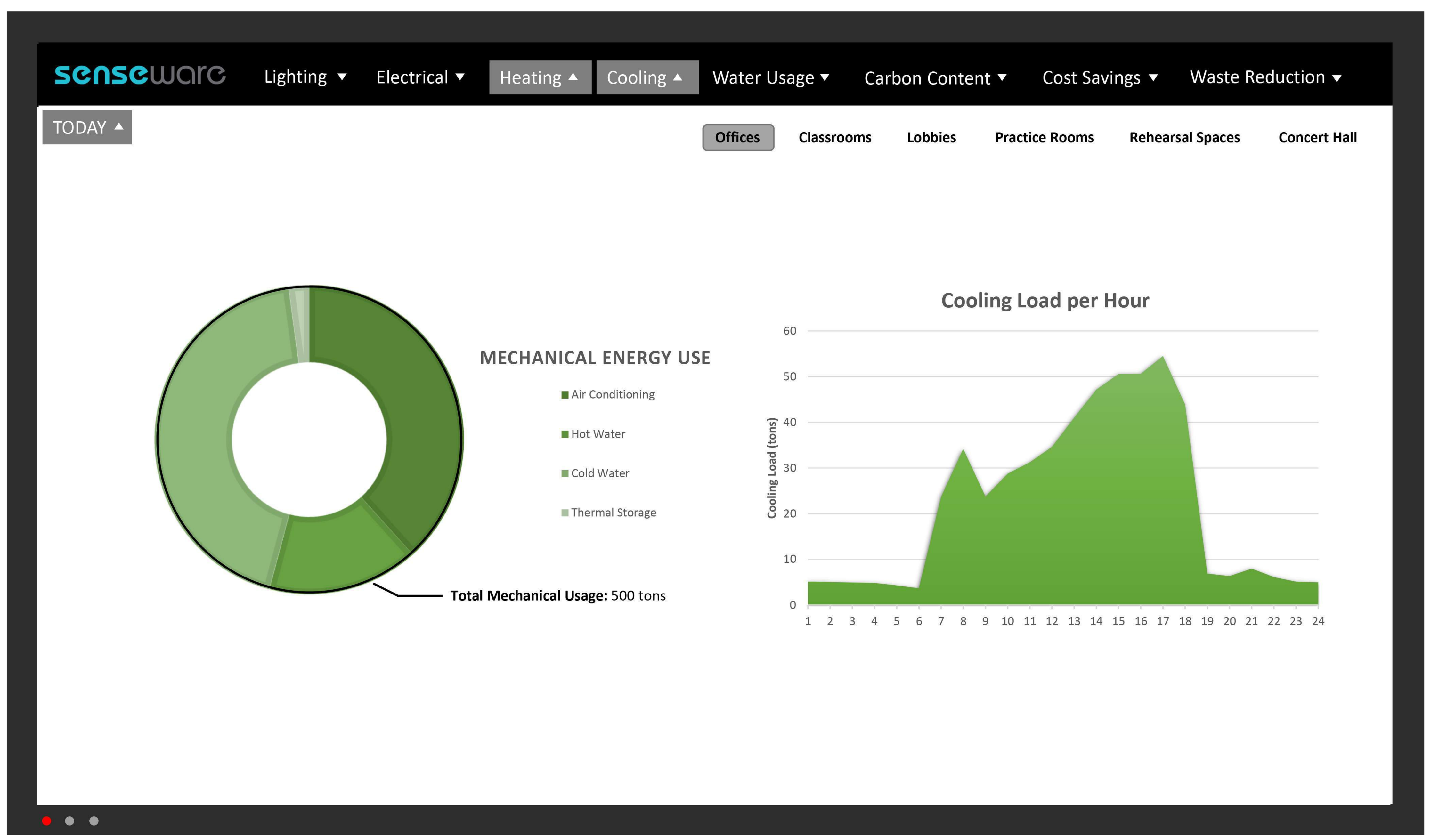
SYNDICATE	
PROJECT **JACK H. MILLER CENTER FOR MUSICAL ARTS** HOLLAND, MICHIGAN	
SHEET TITLE FIRE PROTECTION	
NOT FOR CONSTRUCTION	AEI TEAM NO. 01-2019
DATE February 18, 2019	SCALE NOT TO SCALE
DRAWING NO. M-8.0	PAGE NO. 88

THE HOPE COLLEGE SUSTAINABILITY PLAN

Syndicate, after considering aspects of the LEED and WELL plans and the efforts that Hope College is already making, has created a customized sustainability plan for Hope College. This plan allows Hope to pursue environmentally-minded goals without sacrificing their academic objectives. There are four main canons that encompass large sustainability aspects, and those four are broken down into several implementation categories (shown below). The objectives that were considered during the mechanical design of The Miller Center are highlighted below.



DASHBOARD DISPLAY



JACK H MILLER PILOT PROGRAM

Syndicate has implemented this Sustainability Plan on The Miller Center project. Below are the specific aspects of the plan that are highlighted during the mechanical design, color-coded by the main sustainability categories.

Alternate Systems

The concert hall is currently scheduled for 15 events a year, so to condition the space at the same rate as the rest of the building would be a waste of energy. Therefore, *Syndicate* put the concert hall and stage on three separate air handling units that will only run closer to full capacity when there are performances. The design also allows for the three independent operations of the platform, auditorium, balcony for different occupancy uses.

Sensors

Occupancy sensors will be placed in all rooms and interact with lighting controls as well as air handling unit controls. When the occupancy sensors detect 60% of the faculty studios and practice rooms are unoccupied for more than 1hr, the air handling unit will adjust the setpoint to avoid over cooling/heating unoccupied spaces.

Daylighting

By incorporating the ventilated double wall façade on the west corridor , ample amount of daylight was incorporated in interior spaces will saving heating/cooling energy. In an average year, the ventilated double wall façade will save 83.9MMBTU/hr in heating and cooling loads.

Air Quality

Displacement ventilation through buried ducts was implemented on the Miller Center project. This provides the freshest air to the building occupants because the air is being supplied at floor level. The air will reach the occupants first , ensuring their load is met before the air is exhausted from the ceiling above. The upper zone in large volume spaces is unoccupied, so the level of air quality above the occupants is not a concern. This is implemented and extremely effective in the large volume spaces; the atriums, concert hall, and recital and rehearsal spaces.

Water Efficiency

A snow melt system was installed on the roof of the Miller Center. This system uses waste heat from the condensed water before it is returned to the central steam plant. The water is sent through a heat exchanger that warms a glycol/water solution, which is then sent to the roof on days that ice or snow occur. Year round, precipitation from the roof and plazas are collected , stored, and filtered to use as greywater for toilets throughout the building. This prevents over 1.53million gallons of water every year from being wasted and sent to the sewer. The 1.53million gallons of water will also be reused throughout the building as greywater., doubling the cost savings based on sewer and water utility rates.

Life-Cycle Impacts

The central plant option will provide Hope Campus with a long lasting CHP and chilled water plant that will allow Hope College to expand and grow in the future. A central plant provides higher efficiency and centralized operation and maintenance.

Environmental Impacts

By reorienting the building ninety degrees , going beyond the envelope requirements set by AHRAE 90.1, and by making many other energy conscious decisions during the design phases, *Syndicate* was able to reduce the overall building load by 41% based on the given architecture and ASHRAE 90.1 standards. This reduction in energy demand allows for smaller mechanical equipment and significant reduction in fuel consumption.

Thermal Comfort

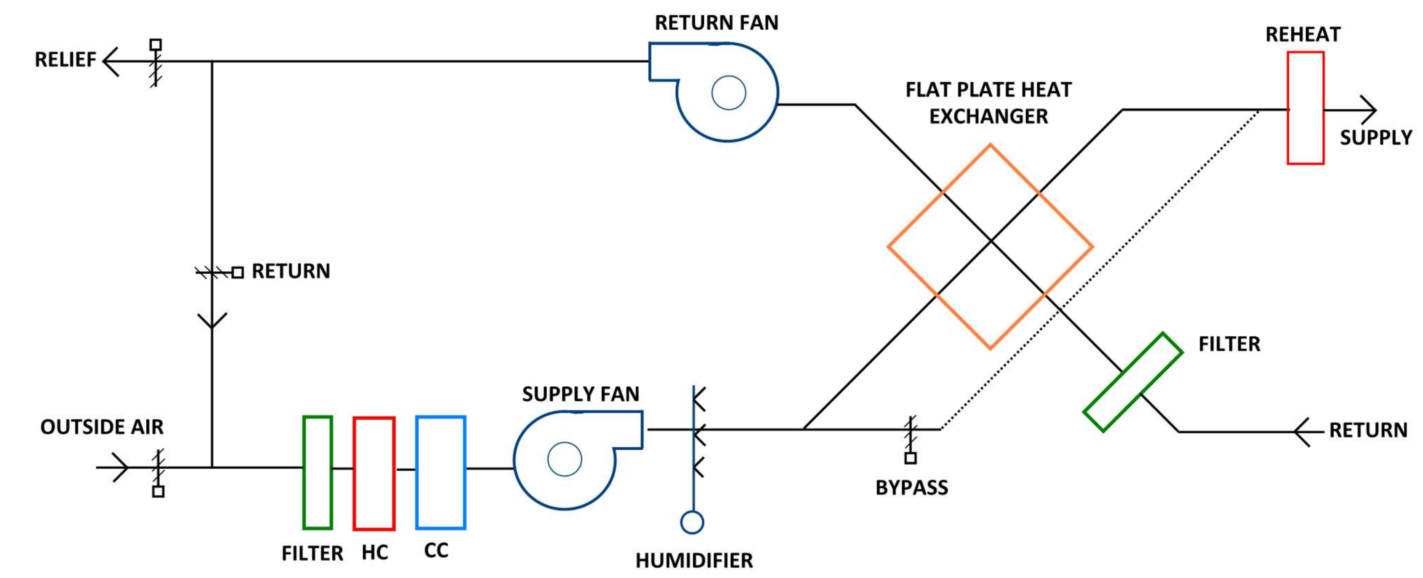
Syndicate chose to reorient the Miller Center so the main atrium faces north in order to decrease the amount of uncomfortable sunlight that it would have originally received when oriented West. Additionally, the curtain glass used in the West façade is ventilated double-wall façade to stabilize thermal levels and repurpose the solar energy. Finally, implementing displacement ventilation in the concert hall will maximize thermal comfort during performances by providing slow, cool air directly to the occupants.

Acoustic Performance

The background noise level of mechanical equipment is a concern when it comes to musical performance spaces. All spaces in the Miller Center were calculated to be below set standard NC and RC levels based on the respective space use. In addition, the mechanical rooms are stacked on top of each other and completely isolated from the rest of the building structure. This ensures the mechanical equipment will not be a disturbance to any performances.

VENTILATION CALCULATIONS

ROOM NAME	OCCUPANCY CATEGORY	NET OCCUPIABLE FLOOR AREA, AZ	RA (CFM/SF)	ZONE POPULATION, PZ (#)	RP (CFM/PERSON)	BREATHING ZONE OA (PEOPLE)	BREATHING ZONE OA (AREA)	BREATHING ZONE OUT-SIDE AIRFLOW, VBZ	ZONE AIR DISTRIBU-TION EFFECTIVENESS	ZONE OUTDOOR AIRFLOW, VOZ (CFM)
100 NORTH LOBBY	LOBBIES	4,398	0.06	800	5.00	4,000	264	4264	1.20	3553
102 STAGE	STAGES, STUDIOS	1,964	0.06	150	10.00	1,500	118	1618	1.00	1618
101 ORCHESTRA LEVEL	AUDITORIUM SEATING AR-	1,235	0.06	285	5.00	1,425	74	1499	1.20	1249
113 CROSSOVER	CORRIDORS	490	0.06	-	0.00	-	29	29	1.20	25
103 PARTERRE	AUDITORIUM SEATING AR-	1,438	0.06	285	5.00	1,425	86	1511	1.20	1259
108 CONTROL ROOM	MEDIA CENTER	196	0.12	2	10.00	20	24	44	1.00	44
121 BOX OFFICE	OFFICE SPACE	83	0.06	1	5.00	5	5	10	1.00	10
120 RECITAL HALL	AUDITORIUM SEATING AR-	1,971	0.06	150	5.00	750	118	868	1.20	724
C-101	CORRIDORS	655	0.06	-	0.00	-	39	39	1.00	39
126 INSTRUMENT ROOM	STORAGE ROOMS	414	0.12	-	5.00	-	50	50	1.00	50
130 ORCHESTRA REHEARSAL	MUSIC/ THEATRE/ DANCE	1,938	0.06	70	10.00	700	116	816	1.20	680
133 JAZZ PRACTICE ROOM	MUSIC/ THEATRE/ DANCE	289	0.06	5	10.00	50	17	67	1.00	67
134 RECORDING STUDIO	MEDIA CENTER	465	0.12	8	10.00	80	56	136	1.00	136
140 CHOIR REHEARSAL	MUSIC/ THEATRE/ DANCE	1,753	0.06	100	10.00	1,000	105	1105	1.20	921
110 BOH	STORAGE ROOMS	1,105	0.12	-	5.00	-	133	133	1.00	133
154 GREEN ROOM	BREAK ROOMS	267	0.06	5	5.00	25	16	41	1.00	41
155 PERCUSSION STUDIO	MUSIC/ THEATRE/ DANCE	260	0.06	5	10.00	50	16	66	1.00	66
156 FACULTY STUDIO	MUSIC/ THEATRE/ DANCE	210	0.06	3	10.00	30	13	43	1.00	43
C-102	CORRIDORS	1,704	0.06	-	0.00	-	102	102	1.00	102
C-103	CORRIDORS	1,134	0.06	-	0.00	-	68	68	1.00	68
109 SOUTH LOBBY	LOBBIES	2,403	0.06	142	5.00	710	144	854	1.20	712
193 KEYBOARD CLASSROOM	LECTURE CLASSROOM	758	0.06	18	7.50	135	45	180	1.00	180
194 CLASSROOM	LECTURE CLASSROOM	778	0.06	25	7.50	188	47	234	1.00	234
192 CLASSROOM	LECTURE CLASSROOM	788	0.06	36	7.50	270	47	317	1.00	317
182 CATERING	COFFEE STATIONS	120	0.06	1	5.00	5	7	12	1.00	12
180 ORGAN FACULTY	MUSIC/ THEATRE/ DANCE	836	0.06	4	10.00	40	50	90	1.00	90
201 MEZZANINE	CORRIDORS	1,350	0.06	-	0.00	-	81	81	1.20	68
253 STORAGE	STORAGE ROOMS	140	0.12	-	5.00	-	17	17	1.00	17
C-206	CORRIDORS	562	0.06	-	0.00	-	34	34	1.00	34
202 BALCONY	AUDITORIUM SEATING AR-	1,970	0.06	230	5.00	1,150	118	1268	1.20	1057
C-202	CORRIDORS	749	0.06	-	0.00	-	45	45	1.00	45
260 PRACTICE ROOM	MUSIC/ THEATRE/ DANCE	61	0.06	1	10.00	10	4	14	1.00	14
261 PRACTICE ROOM	MUSIC/ THEATRE/ DANCE	61	0.06	1	10.00	10	4	14	1.00	14
262 PRACTICE ROOM	MUSIC/ THEATRE/ DANCE	61	0.06	1	10.00	10	4	14	1.00	14
263 PRACTICE ROOM	MUSIC/ THEATRE/ DANCE	61	0.06	1	10.00	10	4	14	1.00	14
264 PRACTICE ROOM	MUSIC/ THEATRE/ DANCE	61	0.06	1	10.00	10	4	14	1.00	14
265 PRACTICE ROOM	MUSIC/ THEATRE/ DANCE	61	0.06	1	10.00	10	4	14	1.00	14
266 PRACTICE ROOM	MUSIC/ THEATRE/ DANCE	61	0.06	1	10.00	10	4	14	1.00	14
267 PRACTICE ROOM	MUSIC/ THEATRE/ DANCE	61	0.06	1	10.00	10	4	14	1.00	14
268 PRACTICE ROOM	MUSIC/ THEATRE/ DANCE	61	0.06	1	10.00	10	4	14	1.00	14
269 PRACTICE ROOM	MUSIC/ THEATRE/ DANCE	61	0.06	1	10.00	10	4	14	1.00	14
270 FACULTY STUDIO	MUSIC/ THEATRE/ DANCE	157	0.06	3	10.00	30	9	39	1.00	39
271 FACULTY STUDIO	MUSIC/ THEATRE/ DANCE	152	0.06	3	10.00	30	9	39	1.00	39
272 FACULTY STUDIO	MUSIC/ THEATRE/ DANCE	152	0.06	3	10.00	30	9	39	1.00	39
273 FACULTY STUDIO	MUSIC/ THEATRE/ DANCE	171	0.06	3	10.00	30	10	40	1.00	40
274 FACULTY STUDIO	MUSIC/ THEATRE/ DANCE	218	0.06	3	10.00	30	13	43	1.00	43
275 PRACTICE ROOM	MUSIC/ THEATRE/ DANCE	106	0.06	2	10.00	20	6	26	1.00	26
276 PRACTICE ROOM	MUSIC/ THEATRE/ DANCE	126	0.06	2	10.00	20	8	28	1.00	28
301 PRACTICE ROOM	MUSIC/ THEATRE/ DANCE	125	0.06	2	10.00	20	8	28	1.00	28
302 PRACTICE ROOM	MUSIC/ THEATRE/ DANCE	122	0.06	2	10.00	20	7	27	1.00	27
303 PRACTICE ROOM	MUSIC/ THEATRE/ DANCE	125	0.06	2	10.00	20	8	28	1.00	28
304 FACULTY STUDIO	MUSIC/ THEATRE/ DANCE	183	0.06	3	10.00	30	11	41	1.00	41
305 FACULTY STUDIO	MUSIC/ THEATRE/ DANCE	199	0.06	3	10.00	30	12	42	1.00	42
306 FACULTY STUDIO	MUSIC/ THEATRE/ DANCE	206	0.06	3	10.00	30	12	42	1.00	42
307 PRACTICE ROOM	MUSIC/ THEATRE/ DANCE	125	0.06	3	10.00	30	8	38	1.00	38
308 PRACTICE ROOM	MUSIC/ THEATRE/ DANCE	189	0.06	3	10.00	30	11	41	1.00	41
309 PRACTICE ROOM	MUSIC/ THEATRE/ DANCE	342	0.06	5	10.00	50	21	71	1.00	71
310 FACULTY STUDIO	MUSIC/ THEATRE/ DANCE	162	0.06	3	10.00	30	10	40	1.00	40
311 FACULTY STUDIO	MUSIC/ THEATRE/ DANCE	194	0.06	3	10.00	30	12	42	1.00	42
312 DEPARTMENT OFFICE	OFFICE SPACE	268	0.06	3	5.00	15	16	31	1.00	31
313 DEPARTMENT CONFERENCE	CONFERENCE/ MEETING	575	0.06	8	5.00	40	35	75	1.00	75
314 SCORE LIBRARY	STORAGE ROOMS	431	0.12	-	5.00	-	52	52	1.00	52
315 FACULTY STUDIO	MUSIC/ THEATRE/ DANCE	209	0.06	3	10.00	30	13	43	1.00	43
316 FACULTY STUDIO	MUSIC/ THEATRE/ DANCE	221	0.06	3	10.00	30	13	43	1.00	43
317 FACULTY STUDIO	MUSIC/ THEATRE/ DANCE	225	0.06	3	10.00	30	14	44	1.00	44
318 FACULTY STUDIO	MUSIC/ THEATRE/ DANCE	225	0.06	3	10.00	30	14	44	1.00	44
319 FACULTY STUDIO	MUSIC/ THEATRE/ DANCE	235	0.06	3	10.00	30	14	44	1.00	44
320 FACULTY STUDIO	MUSIC/ THEATRE/ DANCE	225	0.06	3	10.00	30	14	44	1.00	44
324 FACULTY STUDIO	MUSIC/ THEATRE/ DANCE	246	0.06	3	10.00	30	15	45	1.00	45
325 FACULTY STUDIO	MUSIC/ THEATRE/ DANCE	340	0.06	3	10.00	30	20	50	1.00	50
C-301	CORRIDORS	2,045	0.06	-	0.00	-	123	123	1.00	123
300 OCCUPIABLE ROOF	LOBBIES/ PREFUNCTION	1,938	0.06	100	7.50	750	116	866	1.00	866



AHU-1 SCHEMATIC

AHU-1 SAMPLE SEQUENCE OF OPERATIONS

1. Occupied Cycle

Warm-up cycle – energize system 1 to 3 hours in advance of event

- Open OA, RA, and relief dampers to minimum OA positions
- Energize supply and return fans
- Set points: supply air at 65°F and room temperature at 75°

Temperature control:

- Wall thermostat cooling setpoint will be 75°F and heating setpoint will be 70°F (adjustable)
- When the wall thermostats detects deviation from the setpoint, the supply fan will adjust air flow.
- If the room temperature remains between the occupied heating and cooling setpoints, the controller will index the supply fan to provide conditioned minimum air ventilation to the room.

Humidity control

- The return air humidity setpoint will be between 45-60%
- The humidifier will turn on if the room RH goes below 45%
- When the room RH goes above 60%., the reheat coil will modulate.

2. Enthalpy Cycle

- The economizer mode will be enabled when the outside temperature is between 60°F - 70°F and enthalpy is between 27 BTU/lb and 20 BTU/lb

3. Unoccupied Cycle

- Supply and return fans operate only to maintain temperature and humidity
- Outside air and relief dampers closed
- Return air damper open
- Maintain room temperature at 3 degrees above or below room set point.

4. Fire Alarm

When unit duct smoke detector detect smoke, unit to go into smoke exhaust mode

- Supply and Return fan at 100%
- Outside air and relief air damper open
- Return air damper closed

5. Trouble Alarms

Freeze Protection – When supply air is below 38°F

- Fan to deenergize
- Chilled water valve open to 50%
- Hot water valve open

Abnormal conditions

- Set points deviation >5°
- Fan failure
- Fan VFD fault

EXHAUST CALCULATIONS

ROOM NAME	OCCUPANCY CATEGORY	AIR CLASS	EXHAUST RATE (CFM/ SF OR UNIT)	NUMBER OF FIXTURES	TOTAL EXHAUST (CFM)
123 RESTROOM	TOILET - PUBLIC	2	50	6	300
124 RESTROOM	TOILET - PUBLIC	2	50	5	250
125 RESTROOM	TOILET - PRIVATE	2	70	1	70
154A RE-	TOILET - PRIVATE	2	70	1	70
191 RESTROOM	TOILET - PUBLIC	2	50	5	250
190 RESTROOM	TOILET - PUBLIC	2	50	6	300
184 JANITOR	JANITOR CLOSET	3	1	-	62
252 JANITOR	JANITOR CLOSET	3	1	-	152
255 RESTROOM	TOILET - PUBLIC	2	50	5	250
256 RESTROOM	TOILET - PUBLIC	2	50	6	300
321 RESTROOM	TOILET - PUBLIC	2	50	4	200
322 RESTROOM	TOILET - PUBLIC	2	50	5	250

AIR HANDLING UNIT SCHEDULE

TAG	MAX SUPPLY AIR [CFM]	MIN SUPPLY AIR [CFM]	OA%	NOMI-NAL	SUPPLY FAN [HP]	COOLING		HEATING COIL		VOLTS/PHASE/ HZ	MANUFAC-TURER
						EWT	LAT	EWT	LAT		
AHU-1	10500	4200	40	35	10	40	54	180	160	460/3/60	CARRIER
AHU-2	10500	3000	17	35	10	40	54	180	160	460/3/60	CARRIER
AHU-3	15000	5000	30	60	15	40	54	180	160	460/3/60	CARRIER
AHU-4	7000	4000	54	35	10	40	54	180	160	460/3/60	CARRIER
AHU-5	10500	10500	100	35	10	40	54	180	160	460/3/60	CARRIER
AHU-6	3500	1000	30	15	5	40	54	180	160	460/3/60	CARRIER
AHU-7	3500	800	40	15	5	40	54	180	160	460/3/60	CARRIER

PUMP SCHEDULE

TAG	MOTOR SIZE [HP]	GPM	DUTY POINT [BHP]	MOTOR SPEED [RPM]	DUTY PT PUMP EFF	IMPELLER [IN]	WEIGHT [LB]	MANUFACTURER
HWP-1	40	500	26.2	3600	70%	8.125	465	BELL & GOSSETT
HWP-2	60	300	42.8	3600	70%	9.25	665	BELL & GOSSETT
CHWP-1	30	300	21.7	3600	70%	7.5	470	BELL & GOSSETT
GW-1	25	750	23.8	3600	79%	6.5	350	BELL & GOSSETT

SCROLL CHILLER SCHEDULE

TAG	CLG (TONS)	EVAPORATIVE CONDI-			CONDENSER CONDITIONS			MANUFAC-TURER	MOD-EL
		EWT [F]	LWT [F]	FLOW [GAL]	EAT [F]	NUMBER OF FANS	FLOW [CFM]		
CH-1	50	55	35	90	90	3	30,500	CARRIER	30RAP

VARIABLE AIR VOLUME SCHEDULE

TAG	FLOOR	CFM	HP	VOLT/ PHASE	MANUFACTURER	MODEL
VAV-1	1	3000	1	120V/1	DAIKEN	MQTH-520
VAV-2	2	3000	1	120V/1	DAIKEN	MQTH-516
VAV-3	3	2500	1	120V/1	DAIKEN	MQTH-520

FIRE PUMP SCHEDULE

TAG	LOCATION	GPM	SPEED [RPM]	IMPELLER DIAMETER	MOTOR HP	MAX WP	MANUFACTURER
FP-1	MECH ROOM	1000	3600	DIRECT	50	120	XYLEM

HEAT EXCHANGER SCHEDULE

TAG	LOCATION	TYPE	INLET CONDITION		OUTLET CONDITION		INLET		OUTLET		MANUFACTURER
			MEDI-UM	TEMPERATURE/ PRESSURE	MEDIUM	TEMPERATURE [F]	MEDIUM	TEMPERATURE [F]	MEDIUM	TEMPERATURE [F]	
HX-1	1ST MECH ROOM	STEAM	STEAM	50PSIG	WATER	200	WATER	160	WATER	180	TACO
HX-3	1ST MECH ROOM	WATER	WATER	200F	WATER	150	GLYCOL	50	GLYCOL	80	TACO
HX-3	2ND MECH ROOM	GLYCOL	GLYCOL	51F	GLYCOL	52	WATER	62	WATER	58	TACO

THERMAL STORAGE SCHEDULE

TAG	LOCATION	CAPACITY [TON-HRS]	VOLUME OF WATER [GAL]	DISCHARGING		CHARGING	
				INLET TEMPERATURE	OUTLET TEMPERATURE	INLET TEMPERATURE	OUTLET TEMPERATURE
IS-1	UNDER-	400	4965	52	40	24	31

SYNDICATE

PROJECT

JACK H. MILLER CENTER FOR MUSICAL ARTS

HOLLAND, MICHIGAN

SHEET TITLE

VENTILATION CALCULATIONS, SCHEDULES, CONTROLS

NOT FOR CONSTRUCTION

AEI TEAM NO.
01-2019

DATE
February 18, 2019

SCALE
NOT TO SCALE

DRAWING NO.
M-10.0

PAGE NO.
90

0.0 LIGHTING/ELECTRICAL EXECUTIVE SUMMARY

CONTROLS SYSTEM

- Implementing a *Lutron Vive Wireless Controls System* introduces the opportunity for daylight harvesting, occupancy sensing, vacancy sensing and time scheduling.
- A controls system connects to the building systems to reduce total building energy by 32% when compared to ASHRAE 90.1-2013 standards.

LIGHTING DESIGN

- The lighting design creates a welcoming building environment, highlights important architectural features and memorabilia, and provides a safe and enjoyable experience through innovative technology.
- All lighting fixtures are LED with dimming capabilities and are properly coordinated with the appropriate drivers to mitigate humming.

DAYLIGHTING

- *Syndicate* collaborated to provide several daylighting features within the building:
  - The north lobby
  - The south lobby
  - The west corridor
  - Additional third floor with skylight rooms
- These designs allow daylight into 96% of the commonly occupied spaces while mitigating direct sunlight exposure, providing a healthier environment for occupants, and reducing the electric lighting energy consumption by 48%.

MAIN ELECTRICAL SYSTEM

- The building utilizes Hope College's existing campus utility with an exterior 1000 KVA transformer to step down the voltage to a 480Y/277V.
- *Syndicate* developed two options for power generation:
  - On-site 200-kW fuel cell generator to produce clean energy when needed
  - Introduction of a campus central plant with combined heat and power (CHP) to reduce energy waste and provide power campus-wide

SPECIALTY ELECTRICAL SYSTEMS

- A reduction of the building's carbon footprint was made by providing alternative electric systems that allow for clean energy production through the use of:
  - A photovoltaic array that can generate 93,000 kWh/yr, located on the concert hall roof
  - Vibration Energy Harvesting (VEH) to produce a max of 27.5 mW for powering of all low-voltage systems

ENERGY CERTIFICATION

- A dashboard display is located in both lobbies for occupant observation to showcase the energy conscious design and continuous cost savings.
- Information is gathered through *Lutron's Quantum* energy management system, which speaks directly to the *Lutron Vive* and *Senseware* systems for lighting, electrical and mechanical load information.

Lighting/Electrical Table of Contents

1.0 PROJECT OVERVIEW

The Jack H. Miller Center for Musical Arts (The Miller Center) is a proposed building for Hope College located in Holland, Michigan. *Syndicate* is an integrated design-build team that produced a high-quality design and construction plan for this project. The project site is situated in the northeast corner of campus across from downtown Holland, near Lake Michigan. The Miller Center acts as an investment for the future of Hope College and as a showcase pilot for a new sustainability plan on campus. The addition of an occupiable roof and south lobby allows this building to act as a gateway space for connecting Hope College campus to downtown Holland. The Miller Center can be seen in *Figure 1.*

Figure 1: *Syndicate's Design*

Syndicate's final design is a three-story building designed for serving the educational and performance requirements of Hope College. Totaling 70,000 square feet (SF), The Miller Center includes an 800-seat symphonic concert hall, a smaller recital hall for intimate chamber performances, and two large rehearsal spaces for choirs and orchestras. The building also includes classrooms, faculty studios, and student practice rooms distributed throughout the three stories.

2.0 VISION STATEMENT

Through a multidisciplinary team strategy, Syndicate produced a high-quality center for musical arts that met the goals and mission of Hope College. As a team, Syndicate chose to pursue this project with a vision statement that would contain individualized team and discipline goals. The vision statement is HOPE and the goals are to:

Enhance **H** ope College Campus
Maximize **O** ccupant Experience
Create Premier **P** erformance Spaces
Minimize **E** nergy Impact

Refer to Integration SD-A for details about the vision statement.

3.0 PROJECT GOALS

To achieve HOPE, *Syndicate* created specific integration goals for these four vision statements. Below are the objectives for the lighting/electrical team to meet the integrated team goals.

3.1 Enhance Hope College Campus

Through an interdisciplinary design approach, *Syndicate* wanted to create an addition to the Hope College campus that would have lasting positive impacts. The team collectively understands the budgetary and timeline concerns of the owner, and as a result, set out to:

- Create both lighting and electrical systems that are economical, efficient and accommodating of other building systems
- Provide a building controls system that sets the new standard for sustainability on campus.

- Develop electric lighting schemes that draw occupants towards the building.

3.2 Maximize Occupant Experience

Syndicate's goal is to provide a world-class facility that enhances both the education and entertainment value of the musical arts through the built environment. In addition to enhancing the architecture, the team sought to accomplish this goal by:

- Providing safe, sufficient lighting levels in each space.
- Allowing for a higher degree of occupant control.
- Providing daylight into at least 90% of all commonly occupied spaces.
- Mitigate solar heat gain and reduce uncomfortable glare that may be caused by direct sunlight exposure.

3.3 Create Premier Performance Spaces

The primary purpose of The Miller Center is to provide superior performance spaces, which *Syndicate* held as a priority driving all design decisions. For each performance space, the team aims to provide:

- A unique and visually stunning lighting design.
- Properly coordinated LED fixtures with the appropriate drivers to mitigate potential noise from equipment or flickering from lighting.
- The ability to adapt to any intended experience of the performance type.
- A higher degree of controls flexibility for all present and future performances.
- The appropriate controls to command both the lighting and mechanical systems.

3.4 Minimize Energy Impact

Syndicate recognizes the substantial energy impacts of the built environment and strives to create a building for Hope College that reflects this challenge by:

- Exceeding the ASHRAE 90.1-2013 standard by at least 20%.
- Providing various forms of clean energy generation.
- Coordinating all electric lighting with the proper photocells, occupancy/vacancy sensing, timeclock scheduling, high end trimming, and demand response control where appropriate.
- Integrating mechanical and receptacle loads into the controls system.
- Reducing the need for electric lighting within the building by at least 30%.

4.0 DAYLIGHTING DESIGN

4.1 Solar Considerations

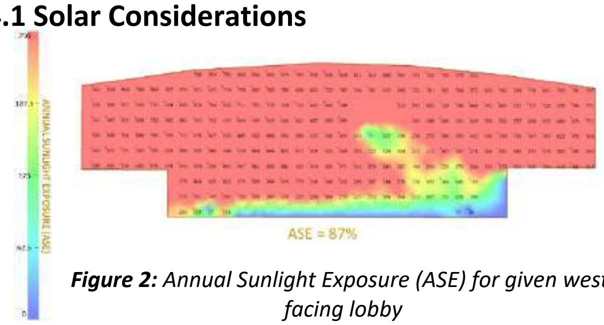


Figure 2: *Annual Sunlight Exposure (ASE) for given west-facing lobby*

Syndicate ran a daylight analysis on the given building layout to identify potential areas of improvement using *Licaso*, an *AGi32* plug-in, as the main software. This helped to visually analyze daylight and sunlight penetration into spaces as well as gather daylighting metrics such as daylight autonomy (DA) and annual sunlight exposure (ASE). Analyses were run using 300 lux as the baseline. Initial modeling demonstrated an uneven distribution of daylight throughout the building, while the given west-facing lobby experienced a large amount of direct sunlight penetration. This resulted in an ASE of 87% for this orientation, which creates an uncomfortable space due to both solar heat gain and direct glare (*Figure 2*). When moving forward with design decisions, *Syndicate* set a goal to increase daylighting and DA values in spaces currently receiving none while decreasing ASE, solar heat gain, and glare in spaces receiving direct exposure. Refer to Mechanical SD-B for a detailed climate analysis.

4.2 Daylighting Performance Benefits

In the conversation of minimizing energy impact with a focus on maximizing occupant experiences, daylighting strategies are an important feature in all building types. Since this building encompasses musicians, students, and faculty, the benefit of natural light can have a significant positive impact on focus and performance. Therefore, it is important for occupants spending more than 4 hours in these spaces to receive ample amounts of daylight for their benefit. Coordination between all disciplines of *Syndicate* began early in conceptual design to ensure that the architectural layout would aid in the delivery of natural light to regularly occupied spaces. The final solution included the following features that improved upon the given design:

- A northern oriented lobby
- An additional southern lobby
- A western corridor
- An additional third floor with skylight rooms

4.3 Daylighting Redesign

4.3.1 North Lobby

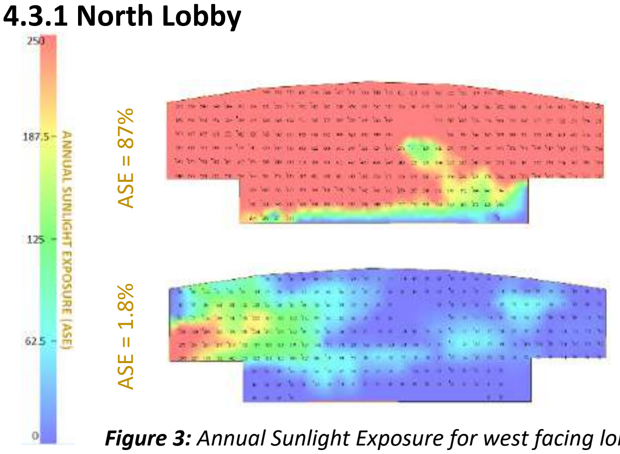


Figure 3: *Annual Sunlight Exposure for west facing lobby (top) vs. north facing lobby (bottom)*

As mentioned in Lighting/Electrical Report Section 4.1, the given west-facing lobby was experiencing an ASE of 87% under this orientation. Through this analysis, *Syndicate* was able to conclude that rotating the building 90 degrees clockwise allowed for maximized comfort by decreasing the ASE to 1.8%, as shown in the comparison in *Figure 3*. Under this new orientation, the north lobby is still achieving 99% DA, meaning it is receiving ample amounts of natural daylight without the negative effects of direct sunlight.

4.3.2 South Lobby

To further improve the new orientation of The Miller Center, *Syndicate* created an additional southern lobby to encourage flow from campus into the building. By adding this lobby, another opportunity to consider the effects of daylighting arose. Horizontal louvers were placed along the exterior façade windows to mitigate the effects of direct sunlight penetration while providing a view to the exterior. Refer to Lighting/Electrical Report Section 4.4.2 within this report for further details on sunlight mitigation. This allows for a DA of 91% with an ASE of 48% for the south lobby.

4.3.3 West Corridor and Classrooms

Figure 4*: 3D section of west corridor and classroom connection detailing daylight penetration into these spaces*

On the first floor, a west corridor joins the two lobbies together and provides a direct connection between Hope College and downtown Holland, which encourages flow through the building. This corridor was relocated to the exterior façade to provide the classrooms with access to daylight. *Syndicate* developed a glass ventilated double wall façade on the exterior and placed large windows adjacent to the classrooms, resulting in an increase in the daylighting in commonly occupied spaces by 10% (*Figure 4*). Refer to Lighting/Electrical Report Section 4.4.1 for further information on the ventilated double wall façade integration. Under this design, the classrooms are reaching a DA of 82% with an ASE of 23%.

4.3.4 Faculty Studios and Practice Skylight Rooms

The team chose to reconfigure the architectural layout of the building to maximize daylight throughout the facility. In order to do this, *Syndicate* created an additional third floor on the western façade. This houses the faculty offices and practice rooms previously not receiving daylight on lower floors, as well as the occupiable roof space.

Figure 5: *Section detail of third-floor and skylights rooms (right)*

For rooms unable to reach the exterior facade, skylights were implemented to admit natural daylight, further increasing the daylighting in commonly occupied spaces by 11% (*Figure 5*). These skylights are providing the faculty offices with a DA of 29% and are providing the practice rooms with a DA of 14%. Both spaces are experiencing an ASE of 0%. A drawback to the design of the skylight was that it added 2,226 kWh/yr to the overall cooling energy. However, *Syndicate* further analyzed this issue and found that the addition of the natural light into the 9 spaces reduced the need for electrical energy usage by 4,955 kWh/yr. This then allowed the skylight to benefit the design through a net reduction in energy of 2,647 kWh/yr.

With these redesigns, *Syndicate* was able to reduce the number of spaces without daylight from 23 (18 practice rooms, 3 classrooms, and 2 faculty studios) to the 12 practice rooms on the second floor. This brings the baseline design of 75% commonly occupied spaces receiving natural daylight to *Syndicate's* design of 96%, exceeding the goal of providing daylighting in at least 90% of commonly occupied spaces. In addition, *Syndicate* was able to mitigate the annual sunlight exposure, solar heat gain, and glare from direct sunlight to provide occupants with a healthier, comfortable environment. Refer to <u>Lighting Drawing L-6.0</u> for all daylighting calculations.

4.4 Integrated Curtain Wall Facades

Investigation into architectural daylighting strategies produced multiple iterations for the curtain wall facade designs. Input from all disciplines shaped these designs, focusing on daylighting benefits, thermal performance, structural stability, and overall cost. Specific glazing and shading devices were selected to improve the overall performance of the curtain wall types. With these designs, the building was able to increase the total amount of glazing on the building's facade, furthering *Syndicate's* goal to maximize occupant experience through added daylight.

4.4.1 Ventilated Double Wall Facade

By adding a glass façade to the west corridor, *Syndicate* worked to ensure solar heat gain will not bring discomfort to the occupants when sunlight is entering the space. The ventilated double wall facade constructed on the exterior of this corridor mitigates this solar heat gain prior to reaching the occupant while still allowing natural daylight to enter this space and the classrooms. This return air travels upwards through the glass between the double wall and is then redirected back to the mechanical room (*Figure 6*). In addition to ensuring comfort, implementing this design also provides occupants in the corridor and classrooms with a view to the exterior. Refer to <u>Mechanical Report Section 7.1</u> for a further explanation on this façade design.

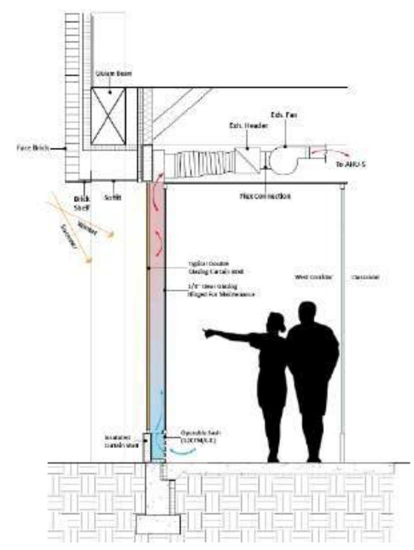


Figure 6: *Ventilated double wall façade detail*

4.4.2 Glazing Selections

Material selection played an integral part in the north and south lobby curtain wall designs. Since 50% of all glazing would be affected by direct sunlight penetration, *Syndicate* sought to maintain a visual transmittance (VT) of 50% for all glazing selections to mitigate this penetration while still providing a view to the exterior.

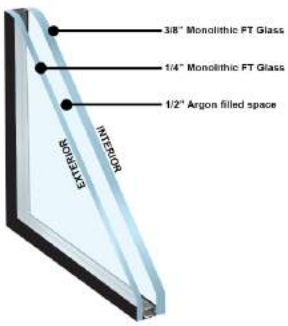


***Figure 7**: Viracon VUE1-40 Insulating Monolithic Glass*

Through collaboration with all disciplines, the glazing selected for the north lobby was *Viracon VUE1-40 Insulating Monolithic Glass* (*Figure 7*). This selection allows for a relative VT of 50% and improves the thermal performance with a winter U-value of 0.25, a summer U-value of 0.21, and a solar heat gain coefficient of 0.21. The south lobby also incorporates the *Viracon VUE1-40* glazing with an additional 70% tint that is added to further block any direct sunlight penetration.

***Figure 8**: Rendered image of a classroom with no Smart Tint Self-Adhesive Film (left) compared to a classroom with the film at 30% transparency (right)*

In the classrooms, a different approach was taken to conserve the view through the large windows. An electronic glazing made by *Smart Tint* that can range from 3% to 97% transparent was chosen. This self-adhesive electronic film is powered by its own external power unit and can be controlled through switching to dim the transparency. This system provides the occupant with a wider range of flexibility over the tinting of the glass and can maintain a view to the exterior when preferred. Refer to <u>Lighting/Electrical SD-E</u> for additional information on the glazing selections.

4.4.3 Shading Selections

***Figure 9:** Dimensioned detail of louvers on the south lobby*

To counteract the comfort issue from the large amount of additional glazing on the southern facade, properly aimed louvers were implemented to omit any direct sunlight as well reduce solar heat gain into the space. These louvers are spaced between 4' and 8' vertically, with 10 "fins" per system at a tilt of 114° from the horizontal (*Figure 9*).

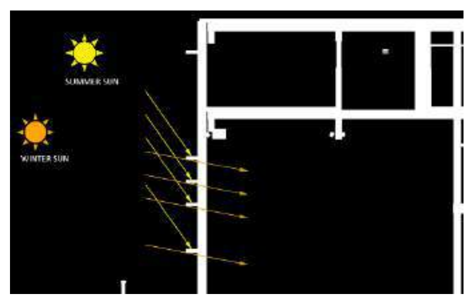


***Figure 10**: Section detail of the south lobby louvers operating during the summer and winter months*

Coupled with the glazing on this façade, *Syndicate* was able to further reduce amounts of direct sunlight and solar heat gain while still allowing for natural daylight to enter (*Figure 10*).

Various spaces require interior shading to properly serve the occupant's needs by adding flexibility. These shades are controlled via the *Lutron Pico Wireless Controller,* which is provided near a main switch in these spaces. All faculty studios located along the west façade on the second floor are equipped with *Lutron's T Screen with KOOLBLACK-THEIA* in charcoal/grey. These shades have a 2.6% openness factor with a VT of 8.1%. With this combination, faculty members can reduce the amount of direct sunlight penetration, solar heat gain, and uncomfortable glare while maintaining a partial view to the exterior. Blackout shades from *Lutron's Serena Shades* are provided for the classrooms, the choral rehearsal space, and the orchestral rehearsal space for situations when the projector is in use. Refer to Lighting/Electrical SD-E for further shading performance and specifications.

5.0 LIGHTING DESIGN

Syndicate developed lighting design criteria and methods to produce a welcoming building environment, to highlight important architectural features and memorabilia, and to provide a safe and enjoyable experience through innovative technology. All of *Syndicate's* lighting designs incorporate LED fixtures and incorporate energy efficient building strategies, such as control methods and dimming capabilities. All fixtures are to be properly coordinated with the appropriate drivers to mitigate potential humming. Refer to Lighting/Electrical SD-E for lighting fixture specifications.

5.1 North Lobby

Figure 11: *Rendered image of the North Lobby*

When arriving in downtown Holland and Hope College, one will first notice The Miller Center as a beacon for the university. By highlighting various structural features and memorabilia within the north lobby space, a captivating aura is created that can be seen through the glass atrium. This draws occupants to the building by:

- Complimenting the CLT structure through a grazing technique, creating a warm glow on the ceiling
- Providing surface mounted track fixtures to satisfy ambient lighting conditions
- Using sconce lighting to enhance the verticality of the wooden columns and provide markers to the concert hall entrance on the first and second floors
- Highlighting important memorabilia located along the wooden feature walls
- Encouraging flow to the second floor and the occupiable roof space using LED tape lighting underneath stair and balcony railings
- Backlighting the box office signage to guide occupants to the ticket purchasing location upon entering the building
- Backlighting two feature clocks to highlight the presence of Jack H. Miller, a clock-maker and collector, and his contributions to the construction of this building

Refer to Lighting Drawing L-3.0 for mounting details and directional output of the north lobby fixtures.

5.2 Concert Hall

Figure 12: *Rendered image of the Concert Hall*

The concert hall encompasses dynamic lighting that can adapt to the intended experience of the musical performance while also providing future flexibility with the implementation of DMX controls. This lighting provides a relaxing performance venue by:

- Creating a "starry night" effect with an LED fiber optic array controlled by DMX to provide irregular shimmers of light to mimic a realistic nighttime sky. Refer to Lighting Drawing L-3.0 for details on the construction of the fiber optic array and mounting details.
- Enhancing the presence of the acoustical ribbon features using wall grazers
- Providing snooted, cylindrical pendant fixtures aligned with the fiber optic array to satisfy ambient lighting conditions and minimize glare visible to the occupants
- Providing recessed downlights along the perimeter walkways to satisfy ambient lighting conditions while entering and exiting the concert hall
- Defining the aisle ways and row markers using LED tape lighting

5.3 Recital Hall

Figure 13: *Rendered image of the Recital Hall*

The Recital Hall is a dynamic, small-scale performance space with a flexible lighting system to complement the range of configurations and concerts. The entire space is treated as a performance area with customizable architectural features, such as a moveable floor in the center of the space and unfixed seating. The flexible space is supported through the lighting design by:

- Providing flexible track lighting to accommodate to the intended performance experience while satisfying ambient lighting conditions
- Complimenting both the upper and lower wooden acoustical panels by recessing grazers in the channels that wrap around the north and south walls
- Highlighting the wooden feature wall to provide a warm glow when first entering the space by recessing wall grazers in the channel located above

5.4 South Lobby

Figure 14: *Rendered image of the South Lobby*

The south lobby is an additional entrance that provides a direct connection to Hope College Campus. This space is to be used primarily by students and faculty but will also be used by the general public during musical performances. Therefore, two lighting schemes are utilized to satisfy the needs of the occupants. One scheme encourages students to sit and study by creating a comfortable lounge space. The other scheme encourages occupants to move through the west corridor to the north lobby and concert hall entrance. These schemes are achieved by:

- Creating a comfortable lounge space by staggering three large ring pendants of various diameters in a clock-like design to lower the visual plane of the space and translate feelings of intimacy
- Providing general ambience in all transient spaces

through sconce lighting and surface mounted track fixtures to encourage flow to the next space

- Encouraging student flow to the second floor and practice rooms using LED tape lighting underneath stair and balcony railings

5.5 Classrooms

Figure 15: *Rendered image of the Classrooms*

The intent behind the classroom lighting design is to create a comfortable learning environment that encourages productivity. Glare is reduced on work surfaces for comfort and the use of electronic devices. This lighting encourages productivity by:

- Reducing the amount of glare on the work plane while satisfying ambient lighting conditions using direct/indirect pendant fixtures
- Highlighting any content that may be displayed on the whiteboard for visual clarity purposes using wall washing fixtures recessed into the channel above

5.6 Faculty Studios

Figure 16: *Rendered image of a Faculty Studio with a punch window.*

The intent behind the faculty studio lighting design is similar to design of the classroom. Each faculty office houses an instrument, which requires ample lighting for visual clarity of sheet music and for collaboration between students and faculty. Acoustically integrated pendant fixtures are used for diffuse lighting that satisfies both ambient lighting and acceptable sound criteria when instruments are played. These fixtures are pendant at higher levels than the radiant panels to ensure the radiant panels have a direct line of sight to the occupant. Refer to Lighting Drawing L-4.0 for mounting details and directional output of the acoustical pendant fixtures in the faculty studios.

5.7 Occupiable Roof Space

Figure 17: *Rendered image of the Occupiable Roof Space.*

The occupiable roof space is an additional feature provided by *Syndicate* at the request of Hope College as a venue space for various events. The lighting design in this space is to provide a private, comfortable aesthetic for occupants and encourage them to spend time here while providing sufficient lighting levels in the event of a performance occurring in this space. This is achieved by:

- Creating 6’ x 16.5’ drop-ceilings, pendant 1’ from the CLT, in three separate bays for drop-ceiling locations with LED tape lighting along the top perimeter to cast a warm glow on the CLT above.
- Recessing linear strip fixtures into the bottom of the drop-ceiling panels to satisfy ambient lighting criteria
- Mimicking the south lobby and creating private lounge areas with circular pendant lighting to lower the visual plane in these areas and translate feelings of intimacy

- Highlighting the texture of the brick features along the wall of the concert hall by placing grazing fixtures behind a 5' partition wall to eliminate any direct glare in occupant eyes

Refer to Lighting Drawing L-4.0 for mounting details and directional output of the occupiable roof fixtures.

6.0 POWER CONSIDERATIONS

Syndicate analyzed various options for the electrical design to generate the best solution for the building and the team's intended goals. Over the course of the design phase, the following alternative energy generation system options were analyzed and researched:

- Photovoltaic Power
    - Rooftop Array
    - Glass Enclosure
- Vibrational Energy Harvesting
- Fuel Cell Generator
- Combined Heat and Power

Syndicate looked at the advantages, disadvantages and associated efficiencies against building operating loads and costs for each system. Refer to Lighting/Electrical Drawings SD-C and SD-D for more information on the electrical equipment analysis.

6.1 Photovoltaic Power

6.1.1 Rooftop Array

Early in the schematic design phase, *Syndicate* considered using photovoltaics to generate electricity. The project's location of Holland, Michigan lends itself to an average of 175 sunny or partly sunny days. The concert hall's height provides an ideal mounting location for a rooftop photovoltaic array with a relatively flat surface and no surrounding shadows to interfere with daylight exposure. Upon running system calculations through both *Helioscope* and *System Advisory Model (SAM),* a rooftop array with a 57.9-kWdc nameplate can generate approximately 93,000-kWh/yr. With Holland's energy and demand charges factored into the potential savings of the system and with an initial cost of $123,000, *Syndicate* has determined the system has an 11-year payback period. This payback is only one year above the recommended 10-year ideal. With the average lifespan of a PV system being 35 years, there will be a net gain of 24 years before a new system is required. Over the entire 35-year period, 3.26 GWh of energy will be generated, resulting in a total net savings of $243,000. Therefore, *Syndicate* recommends a rooftop PV system be implemented for this building.

Figure 18: *Photovoltaic array on the concert hall roof*

The proposed layout of the rooftop PV array is shown in *Figure 18* with the photovoltaic array highlighted in yellow. Refer to Lighting/Electrical SD-D and Integration I-9.0 for further details on the rooftop array.

6.1.2 Glass Enclosure

Figure 19: *Photovoltaic Glass enclosure on the south lobby*

Syndicate also investigated the use of a new photovoltaic system technology referred to as transparent photovoltaic panels (PV glass) on the south lobby (Refer to *Figure 19,* windows highlighted in yellow for placement of glass). Calculations for the PV glass were completed in *SAM* similar to the rooftop PV array. After running these analyses, *Syndicate* determined that the annual generation 2,850 kWh/yr, resulting in a net savings of $298 each year. This provides a 57-year payback period for the glass system. This payback period is about 6-times the recommended period of 10 years. Therefore, the system will fall short of being 100% paid off by its end of life (35 years). As a result, the PV glass is not recommended by *Syndicate* for implementation on this building. Refer to Lighting/Electrical SD-D for further details on the integrated PV glass system.

6.2 Vibration Energy Harvesting

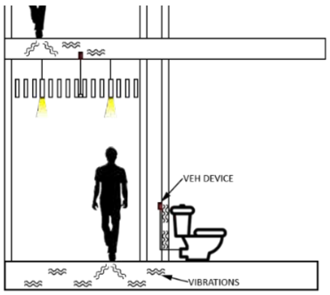


Figure 20: *Detail of the Vibration Energy Harvesting system*

Part of the alternative energy analysis was an evaluation of the vibration energy harvesters (VEH). The purpose of a VEH system is to power low-voltage equipment sensors that can remain self-powered through the conversion of vibrations into energy. *Syndicate's* design approach was to expand the VEH load from low-voltage sensors to a variety of low-voltage equipment, thereby reducing the need for external grid power sources. In coordination with the structural design team, it became apparent that the structure has natural vibrations caused by factors such as wind or occupants walking around. While completely unnoticeable by occupants, the VEH equipment is sensitive enough to pick up the vibrations. At the compact size of a D battery, a VEH can produce a max 27.5 mW to discretely power the sensors from behind the scenes. This will remove the need for lithium batteries, reducing the carbon footprint of the building. *Syndicate* decided to implement these energy harvesters to power all low-voltage sensors in The Miller Center, which includes all 128 wireless lighting control sensors and all 70 automatic lavatory sensors. Refer to Lighting/Electrical SD-D for further details on the VEH system.

6.3 Emergency Power Generation

6.3.1 Fuel Cell Generators

Syndicate implemented an alternative source to emergency power for life safety loads in the event of normal power failure. One of the acceptable options is the utilization of a solid oxide fuel cell system. Through the conversion of chemical energy from natural gases like hydrogen, electricity can be generated with far less emissions than a standard diesel generator or the electric grid. With this knowledge, *Syndicate* proposes the use of the *BloomEnergy Solid Oxide Fuel Cell* to produce energy during a power outage, as well as reduce energy demands during peak times. This will reduce the carbon footprint of the building further by generating cleaner energy than that of Holland's electrical grid. The proposed system will be a 200-kW fuel cell that can service the emergency loads of The Miller Center and off-set grid reliance during normal operations. The fuel cell is located above ground outside the main electrical room and will connect to the natural gas lines running through Holland, Michigan. This option is recommended if Hope College desires to only focus on The Miller Center. The next section covers *Syndicate's* solution to a campus-wide focus. Refer to Lighting/Electrical SD-C for further details on the solid oxide fuel cell system.

6.3.2 Combined Heat and Power

Syndicate analyzed the existing Hope College steam plant and has concluded that it is near capacity. Therefore, a central campus plant including co-generation and chilled water production is being introduced as a viable replacement for the central steam plant. Should Hope College choose this option as proposed by *Syndicate*, it would be provided with an alternative to an on-site generator for production of back-up power, as described in Mechanical Report Section 8.1.2. The plant can provide an estimate 3-MW of electricity and can sync to the switchboard to provide a voltage with phasing identical to the grid. Similar to a fuel cell, the central plant can reduce The Miller Center's dependency on the grid during peak demand periods and the building's carbon emissions.

Refer to Lighting/Electrical SD-C for further information on combined heat and power carbon emissions. Fuel costs for a standard system require the purchase of both natural gas and electric, costing roughly $1.5 million per year. However, the proposed system only requires the cost of the natural gas to power the gas turbine. Therefore, the centralized plant would further contribute to cost savings with a lower up-front cost and by providing independency from Holland's electrical grid.

7.0 BUILDING ELECTRICAL SYSTEMS

7.1 Normal Power

The Miller Center will pull its main source of electricity from the campus utility. At the utility entrance, an exterior 1000 KVA transformer will step down the voltage to a 480Y/277V. This voltage is the main distribution voltage for the building because a higher voltage allows for smaller conductor sizes due to a lower current, resulting in lower material costs. A utility line connects into a 1200 A switchboard that will act as the main fault protection device for the system (*Figure 21)*. Downstream of the switchboard are four lighting panels, three mechanical panels, three normal power panels, two emergency power panels, and one standby power panel. In compliance with ASHRAE 90.1-2013, all panels are metered.

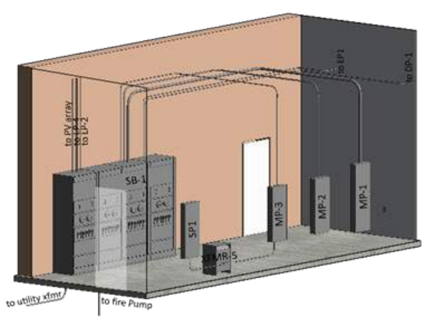


Figure 21: *3D view of Main Electrical Closet*

A central distribution system was chosen to provide consolidated control over the power for this project. This was chosen in place of a distributed system because distributed works best in larger multi-story buildings that have large quantities of varying space types. Therefore, an electrical closet containing both a lighting panel and a normal power panel can be found near the north end of the building on each floor (*Figure 22*). The closets are stacked to provide short runs between the panels, reducing the impact of voltage drop. The second-floor lighting panel acts as a distribution panel feeding both the first and third-floor lighting panels. Each lighting panel will feed their respective floor's normal power panel, connecting through a 45 KVA transformer to step the voltage down to 208Y/120V. A fourth lighting panel is in the second floor dimming room to provide dedicated protection to all lighting and controls within the concert hall. Refer to Electrical Drawings E-1.0, E-2.0 and E-3.0 for a full power plan layout on each floor.

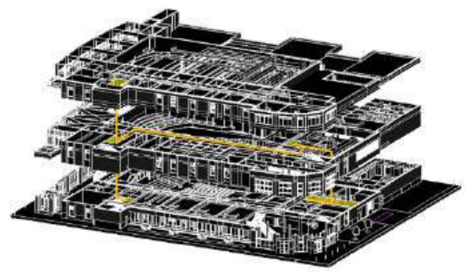


Figure 22: *Electrical Main Conduit Runs*

7.2 Emergency Power

An emergency lighting panel that is fed from the switchboard is located in the emergency electrical room that is adjacent to the main electrical room, per the National Electric Code (*Figure 23*). The emergency power panel will serve all emergency egress lights required to provide the occupants with sufficient light levels to safely evacuate the building. This includes aisle lighting in the concert hall, egress lighting in all large spaces and corridors, and stair corridor lighting. A distribution panel will also be located in the emergency electrical room and will serve both the emergency lighting panel and one mechanical panel on stand-by power. All emergency loads will either be serviced by a 200-kW fuel cell located on-site or from the new proposed campus central plant. Refer to Lighting/Electrical Report

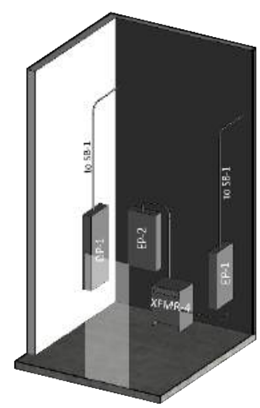


Figure 23: *3D view of Emergency Electrical Closet*

Section 6.3 for more information on the emergency power generation options.

8.0 SUSTAINABLE STRATEGIES

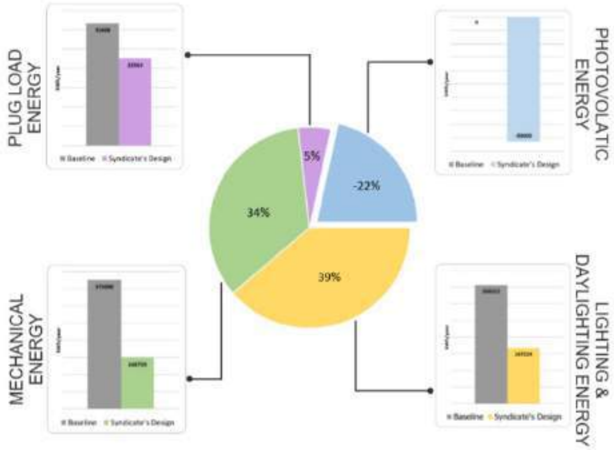


Figure 24: *Energy Savings baseline vs. Syndicate's design*

Syndicate made it a priority to reduce energy consumption through the utilization of a number electrical and lighting systems. This was done to provide Hope College with a new standard of building design to meet their desired green energy mindset. These systems include daylight harvesting, dynamic lighting controls, and sustainable energy generation through photovoltaics and VEH (*Figure 24*).

8.1 Daylight Harvesting

Syndicate placed great value in ensuring that daylight was incorporated in the architectural design based on the many benefits that natural light has for productivity and occupant satisfaction. Refer to Lighting/Electrical Report Section 4.0 for further information on the daylight design. With this integration, *Syndicate* recognized the opportunity to incorporate daylight harvesting to reduce electric lighting loads throughout the building. Spaces that are receiving an ample amount of daylight are equipped with photocells that will automatically dim or shut off the lights when sufficient daylight levels are present. Closed loop sensors is used in faculty studios and practice rooms to capture both electric light and daylight values. Open loop sensors are used in both lobbies to account for the high levels of daylight in these spaces. With these controls implemented, *Syndicate* was able to reduce electric lighting loads by 48%. Refer to Lighting Drawing L-5.0 for further analyses on daylight harvesting and energy savings.

8.2 Lighting Controls

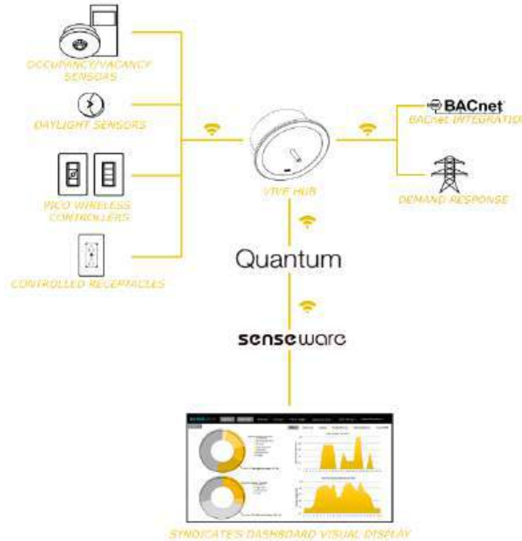


Figure 25: *Integration of Building Controls*

Energy reduction and occupant comfort were the driving factors for *Syndicate* when it came to the implementation of lighting controls. Aside from photocells, ASHRAE 90.1-2013 requires occupancy/vacancy sensing, plug load control and bi-level control. To exceed these standards, *Syndicate* is providing additional controls such as timeclock scheduling, high-end trimming, demand response control, and HVAC integration to further reduce energy loads. Refer to Lighting Drawing L-5.0 for a detailed explanation on all control implementations for the building. The *Lutron Vive* system was chosen for centralized command over these controls because of its wireless flexibility and simple interface (*Figure 25*). One major feature of the *Vive* system is the BACnet protocol and its ability to communicate with *Lutron's Quantum* energy management system. This provides the capability to monitor and record energy usage, contributing to the new sustainability plan that has been designed for Hope College. *Lutron's Radio Powr Savr Sensors* are used for occupancy, vacancy and photocell sensing because of their wireless interface, which reduces wiring costs. These sensors can speak to the dimmers, switches, and *Vive* system using *Clear Connect RF Technology*. The *Vive* wireless hub is installed in four centralized locations per floor

(Refer to Lighting Drawing L-5.0 for these locations) and are powered through *PowPak Modules*. Each hub can speak to all local controls through the same *Clear Connect* technology at a maximum radius of 71'. This system operates through an uncongested radio frequency band, providing reliable communication among all controls. With these controls implemented, *Syndicate* was able to reduce total building energy by 32% compared to ASHRAE 90.1-2013. Refer to Lighting Drawing L-5.0 for further analyses on the controls system and energy savings.

A DMX lighting control system will be used in the concert hall to control both house lighting and performance lighting. With the current lighting design of the concert hall, a DMX system can provide nearly unlimited control over the lights through its 512-channel universe, such as the "starry night" affect through the fiber optics. With the DMX system being implemented early on, an infrastructure is now available should more theatrical performances become common in the future.

9. ENERGY CERTIFICATION

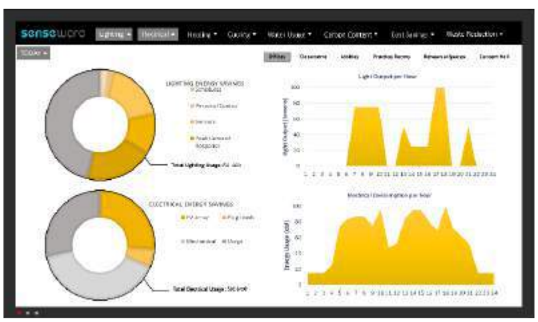


Figure 26: *Lighting/Electrical Dashboard Display*

To further Hope College's notion to become a more sustainable campus, *Syndicate* went above and beyond to implement a sustainability plan for the future of the university. Refer to Construction Report Section 8.0 for a further explanation The Miller Center's sustainability plan.

To bring the certification to an everyday occupant level, *Syndicate* designed a dashboard system to display the various ways the building is improving energy savings daily. The energy display will be present in both lobbies for occupant observation. Behind the scenes, *Senseware* is gathering mechanical load, water consumption, solar payback, structural sustainability and cost information while speaking to the *Vive to* gather lighting load, additional HVAC load, and electrical load information. This system creates a digital display for Hope College to proudly present the ways in which they are embracing a more sustainable community (*Figure 26*).

10. SPECIALTY SYSTEMS

10.1 Fire Alarm System

Figure 27: *Gamewell's Fire Control Instruments from left to right: Fire Alarm Control Panel, Photoelectric Smoke Sensor, Manual Pull Station, and Multi-Criteria Detector for heat detection*

The Miller Center is classified as building type A-2, therefore in accordance with NFPA 72, a manual fire alarm system will be installed. *Gamewell's Fire Control Instruments* by *Honeywell* products are used throughout the building (*Figure 27*).

All smoke detectors shall utilize photoelectric obscuration smoke detection. With these detectors being line-type, all large areas will be secure with a detector having a greater coverage area. As an additional precaution, fire alarms and visual type horns with strobes were also placed throughout the building so that all occupants are aware of an emergency. A fire alarm control panel is in both the north and south lobbies for convenient access in the event of an emergency. Several manual pull stations will be located at the vestibules in both lobbies, corridors, and equipment rooms. Heat detectors will also be installed for the elevator and any activation of this detector will result in a trip of the circuit breaker serving the elevator. Flow switches and tamper switches are also installed for the required sprinkler system to react in the event of a fire.

10.2 Security System

The Miller Center is a hub for faculty, students and expensive musical instruments. Therefore, *Syndicate* implements several security strategies to ensure safety for all visitors.

Honeywell's OMNIPROX card readers are installed at every exterior entrance. These readers are to operate during non-core hours, or between the hours of 7PM and 7AM. During this time, students and faculty are permitted to swipe their university ID card to enter through the two lobbies. All other entrances are accessed by facility managers only. In addition, the concert hall, recital hall, practice rooms, faculty studios, and rehearsal spaces always require *OMNIPROX* swipe access to prevent instrument theft and ensure privacy. Students, faculty, and facility managers always have access to these spaces with their university ID card.

10.3 Telecommunications System

Telephone and data ports are to be installed within all faculty offices, practice rooms, and classrooms for proper connection to internet sources. Cat6 horizontal cabling is used to provide a wider bandwidth at 250 MHz, compared to Cat5's 100 MHz bandwidth. All horizontal cabling imposes a 296-foot length restriction before cabling must be terminated.

11.0 LESSONS LEARNED

The design process of The Miller Center was a series of lessons learned for all disciplines involved. The lighting/electrical team quickly learned that one design can have major impacts on other discipline designs. Therefore, meeting as a team and discussing all design changes helped to mitigate any negative impacts that could occur from improper coordination. By collaborating and communicating together, *Syndicate* was able to create an effective design that fulfilled all goals as a team.

12.0 CONCLUSION

Syndicate was able to enhance Hope College's campus by creating both lighting and electrical systems that are economical, efficient and accommodating of other building systems, as well as develop a controls system that sets a new standard for sustainability on campus.

Syndicate worked together to maximize the occupant experience by enhancing the architecture through the lighting design, providing safe, sufficient light levels in each space, and by implementing a higher degree of occupant control in all faculty studios, classrooms and practice rooms. In addition, the team collaborated closely to incorporate more natural light into the building with the end result of increasing daylight by 96% in all commonly occupied spaces.

The lighting/electrical team provides a unique and visually stunning lighting design in all performance spaces. Controls in these spaces allow for flexibility and the ability to adapt to any intended experience of the performance while automatically commanding the lighting and mechanical systems.

Syndicate strived to minimize energy impacts resulting from the built environment by properly coordinating all electric lighting, receptacle loads, and mechanical loads to the *Lutron Vive System* and by displaying the energy savings resulting from *Syndicate's* design on a dashboard system in the north and south lobbies. In addition, a PV array and VEH system were implemented to provide clean alternatives to energy sources, reducing the building's carbon footprint.

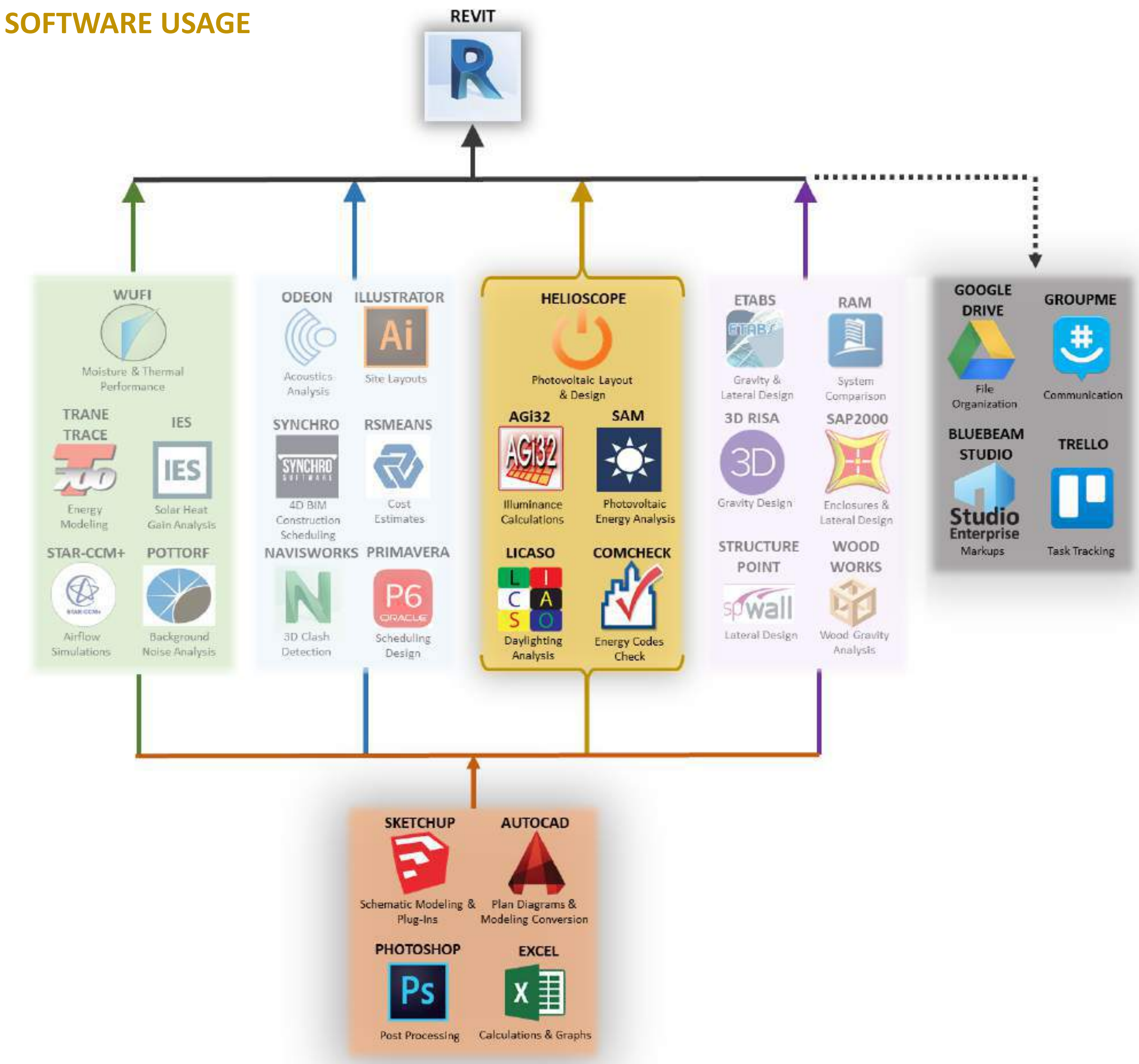
DECISION MATRICES

Syndicate's four project goals drove the ultimate decisions for all final designs. A weight value of 1-3 was assigned to each of the goals for each category to help us select which option was in the team and project's best interest. All end results are checked marked by an X and are thoroughly explained throughout the entirety of the Lighting/Electrical report and throughout the supporting and drawing documents. Further explanation of how the decision matrix operates is explained within Integration SD-A.

SYNDICATE — DECISION MATRIX: Lighting/Electrical Team

Team Goals :	Enhance Hope College Campus			Maximize Occupant Experience			Create Premier Performances			Minimize Energy Impacts						
	Construction Schedule	Aesthetics	Cost	Comfortability	Accessibility	Quality	Reduced disturbances	Sound Quality	Flexibility	Waste Reduction	Carbon Footprint	Life Cycle	Efficiency	Weighted Score	Rank	Final Outcome
ELECTRICAL DISTRIBUTION SYSTEM																
Weights :	1	0	3	0	2	3	1	0	2	2	1	3	3			
Centralized System	1	0	2	0	3	2	1	0	1	3	3	2	3	**46**	1	X
Distributed System	1	0	2	0	2	2	2	0	2	2	2	2	2	**41**	2	
Wireless System	2	0	1	0	2	1	2	0	2	3	3	1	3	**39**	3	
Additional Comments :	A centralized system was selected by *Syndicate* due to the smaller square footage of our building. A wireless or distributed system would result in a higher wiring cost. A centralized system also allows us to send electrical distributions at a higher voltage, simulatenously reducing voltage drop throughout the system.															
PHOTOVOLTAIC TECHNOLOGY																
Weights :	1	2	3	2	0	3	0	0	1	1	3	2	3			
Photovoltaic Rooftop Array	2	1	3	1	0	3	0	0	1	2	3	2	3	**49**	1	X
Photovoltaic Glass	1	2	1	2	0	1	0	0	2	2	1	2	2	**32**	2	
Additional Comments :	A photovoltaic array was selected against the photovoltaic glass due to it's higher annual generation, lower cost, and faster payback period. This sytem will allow for ample savings to reduce the overall buildings energy usage.															
SOUTH LOBBY SHADING METHODS																
Weights :	1	3	3	3	0	2	1	0	2	0	2	2	0			
Vertical Louvers	1	2	2	1	0	1	1	0	1	0	1	2	0	**27**	3	
Horizontal Louvers	1	3	2	2	0	1	1	0	2	0	2	2	0	**37**	1	X
Screen Wall	2	1	1	3	0	1	1	0	3	0	3	2	0	**36**	2	
Additional Comments :	All shading methods were thoroughly analyzed when taken into consideration. Ultimately, horizontal louvers were selected as *Syndicate* felt they were able to block ample amounts of direct sunlight while still allowing for a view to the outside as well as keeping the building's aesthetic cohesive.															
EMERGENCY POWER SUPPLY																
Weights :	1	1	3	0	2	2	2	2	3	3	3	2	3			
On-Site Fuel Cell	3	2	2	0	3	2	2	3	1	2	3	3	3	**64**	1	X
Combined Heat & Power	1	3	2	0	2	3	2	3	3	3	2	2	2	**64**	1	X
Additional Comments :	Due to both emergency power supply options coming out as a tie, *Syndicate* proposes to options for the owner to choose from. Option 1: If the scope only includes the Miller Center, use an on-site fuel cell. Option 2: If the scope includes the Miller Center & other buildings on campus, use the new proposed CHP plant.															

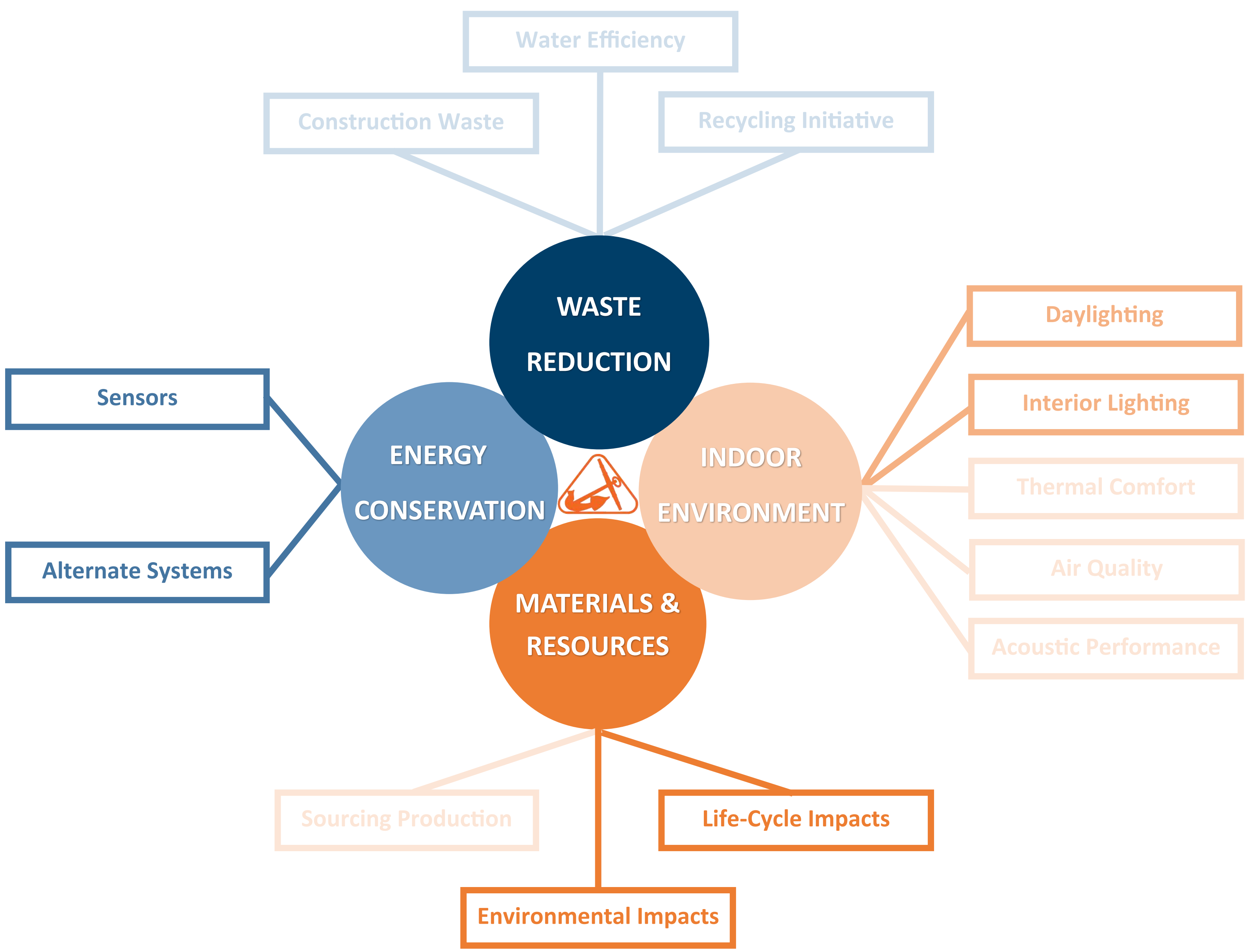
SOFTWARE USAGE



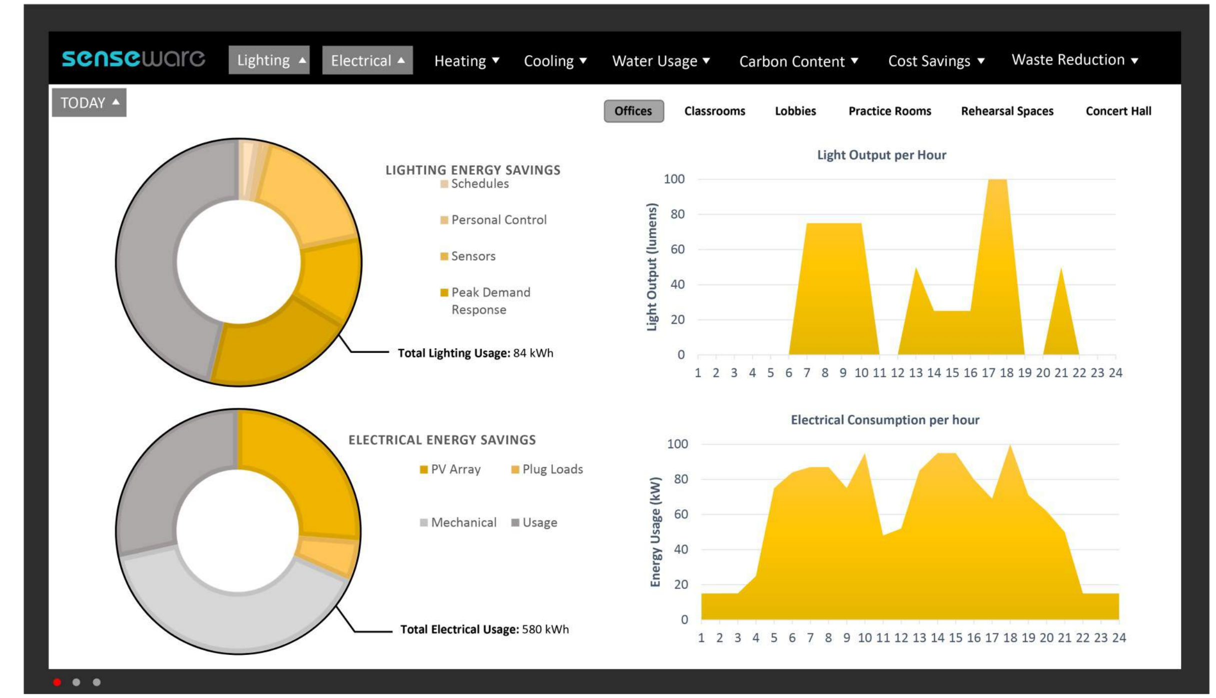
The software usage flowchart above lays out the various applications used in the process of designing The Miller Center. *Syndicate's* lighting/electrical team utilized primarily the programs listed in the yellow section, while the orange section represents the integrative software used by all disciplines. *Revit* stands at the top of the hierarchy to represent where all information culminated for the finalized design. *Syndicate* used 3D exports from *Revit* to bring into *AGi32* to run accurate illuminance calculations. Daylighting analyses were performed in *Licaso*, a plug-in for *AGi32*, to obtain daylight autonomy and annual sunlight exposure metrics. *Comcheck* was implemented to cross check the lighting power densities within the building against those of ASHRAE 90.1-2013. Floor plans were also exported from *Revit* to create lighting and power layouts within *AutoCAD*, as well as to create an overall site model in *Sketchup. SAM, Helioscope,* and *Excel* were used for all photovoltaic calculations. *Photoshop* and *Excel* allowed *Syndicate* to create informational graphics to help the reader along the way.

THE HOPE COLLEGE SUSTAINABILITY PLAN

Syndicate, after considering aspects of the LEED and WELL plans and the efforts that Hope College is already making, has created a customized sustainability plan for Hope College. This plan allows Hope to pursue environmentally-minded goals without sacrificing their academic objectives. There are four main canons that encompass large sustainability aspects, and those four are broken down into several implementation categories (shown below). The objectives that were considered during the lighting/electrical design of The Miller Center are highlighted below.



DASHBOARD DISPLAY



The above figure displays a representation of what the occupants of The Miller Center will see when walking into either the north or south lobby. This display will be interactive for all visitors to observe the real-time energy and cost savings achieved through lighting and electrical design strategies. The user will have the option to explore daily, monthly, and annual energy data to become well acquainted with the positive impact The Miller Center has on the environment. This interaction with the public will help to promote a sustainable way of thinking across the campus and provide a positive influence for Hope College's future.

JACK H MILLER PILOT PROGRAM

Daylighting

The final design of The Miller Center allowed daylighting into 96% of all commonly occupied spaces. Reference Lighting Drawing L-6.0.

Interior Lighting

Light levels were designed to meet IES recommended values. Reference Lighting/Electrical Report Section 5.

Life-Cycle Impacts

High end trimming was enabled for all controlled spaces to extend the life of all LEDs. Reference Lighting Drawing L-5.0.

Environmental Impacts

A natural gas fuel cell and vibration energy harvesters are implemented to emit lower emissions into the environment. Reference Lighting/Electrical SD-C and Lighting/Electrical SD-D.

Sensors

Occupancy, vacancy, and daylight sensors were implemented in all commonly occupied spaces to reduce lighting, HVAC, and plug loads. Reference Lighting Drawing L-5.0.

Alternate Systems

The photovoltaic rooftop array was designed to generate around 93,000 kWh/yr, reducing energy dependency on the electric grid. Reference Lighting/Electrical SD-D.

OPTION #1

SOLID OXIDE FUEL CELL

The *BloomEnergy* Solid Oxide Fuel Cell runs on a variation of natural gas mixed with oxygen to produce electricity. This fuel cell will connect to the natural gas lines running through Holland, Michigan and requires a fraction of the fuel quantity that other back-up energy generation options do. Through the utilization of an anode and cathode, the fuel cell is able to cause a chemical reaction between a mixture of steam and natural gas with oxygen ions from the cathode. This process results in a reformed fuel, which is able to produce electricity. The fuel cell is capable of generating 200 kW, limiting the amount of unneeded energy being produced during an emergency.

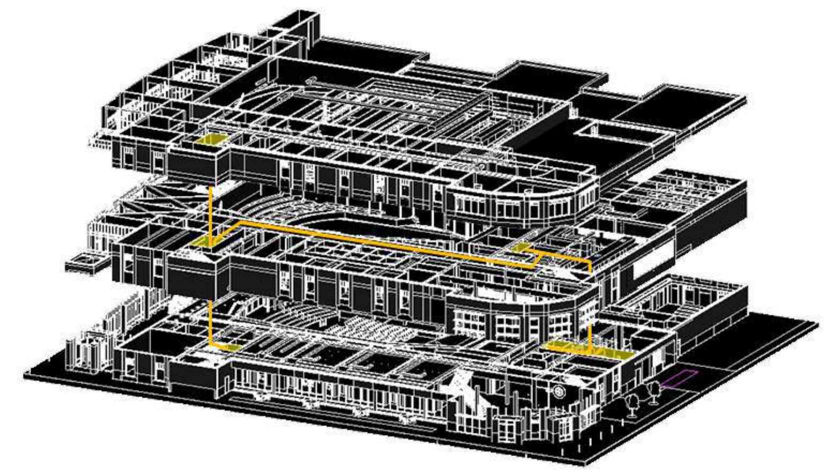
Clean Energy

No combustion is required in the production of energy, therefore emissions to the environment are miniscule.

Smaller Foot Print

With a dedicated natural gas line, the fuel cell does not require on site storage of fuel.

MAIN ELECTRIC CONDUIT



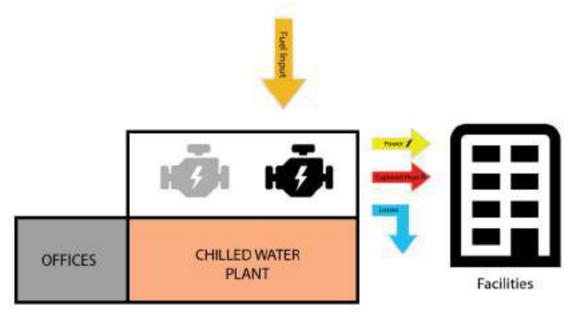
Utility Sizing			
Load Type	Load (VA)	Demand Factor	KVA
Lighting	29120	1.25	36.4
Receptacle (First 10,000)	10000	1	10
Receptacle (Remaining)	77300	0.5	38.7
HVAC	622000	1	622
Elevator	45000	1	45
		Total	752.1
		Amps	905.05 A
		Amps (25% Growth)	1131.32 A
		Standard Breaker Size	1200 A
		Standard Bus Bar Size	1200 A
		Utility Feeder Size	(3) 400 kcmil

VOLTAGE DROP CALCULATION								
UPSTREAM PANEL	DOWNSTREAM PANEL	Amps	Wire / Ground Wire	Feeder Length (FT)	Voltage	Voltage Drop	Allowable Drop Percentage	Drop Percentage
EMERG.	DP1	225	1 SET OF 4#1 + 1#8 G	46	480	2.22	3.00	0.46
SB-1	EP1	70	1 SET OF 4#10 + 1#10 G	17	480	2.06	3.00	0.43
SB-1	LP2	300	1 SET OF 4#4/0 + 1#8 G	200	480	5.09	3.00	1.06
LP2	LP1	225	1 SET OF 4#4 + 1#10 G	16	480	1.55	3.00	0.32
LP2	LP3	225	1 SET OF 4#4 + 1#10 G	16	480	1.55	3.00	0.32
SB-1	LP4	225	1 SET OF 4#10 + 1#14 G	62	480	10.73	3.00	2.23
SB-1	MP1	600	2 SETS OF 4#4/0 + 1#3 G	12	480	1.58	3.00	0.33
SB-1	MP2	400	1 SET OF 4#300 + 1#4 G	15	480	0.36	3.00	0.08
SB-1	MP3	125	1 SET OF 4#3 + 1#8 G	18	480	0.77	3.00	0.16

OPTION #2

COMBINED HEAT AND POWER

Unlike a conventional power plant, combined heat and power is able to generate electricity without wasting energy during the process. A standard power plant will waste as much as 60-70% of the energy generated, while a central plant will only waste around 10%. Using the natural gas pipelines running through Hope College, the central plant will not only produce electricity at a cleaner rate than a standard generator, but will also supply steam and hot water. The proposed plant is able to provide 3 MW of electricity providing general and emergency power to multiple buildings located on campus.



CHP Modularized Unit in New Campus Central Plant Building

Improved Efficiency

CHP ensures that energy typically lost in a standard powerplant is conserved, limiting waste drastically.

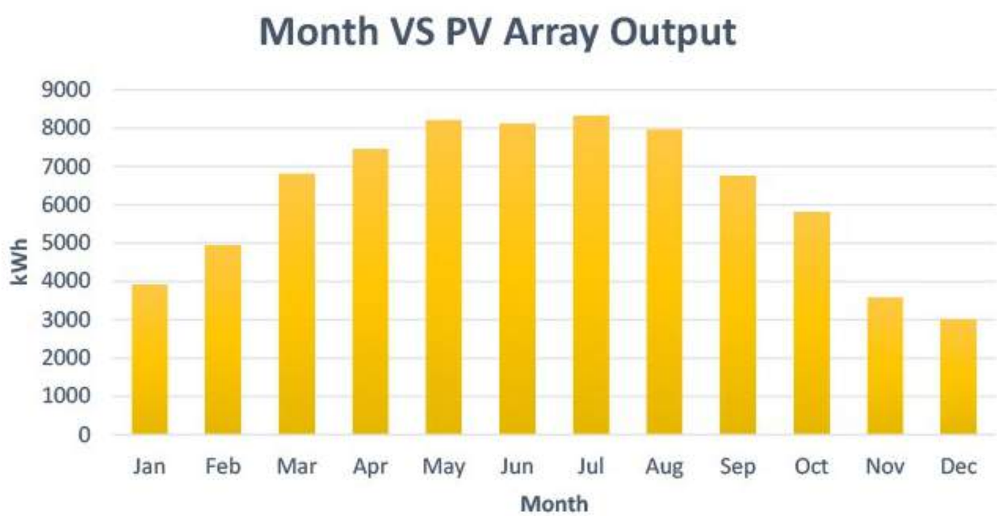
High Redundancy

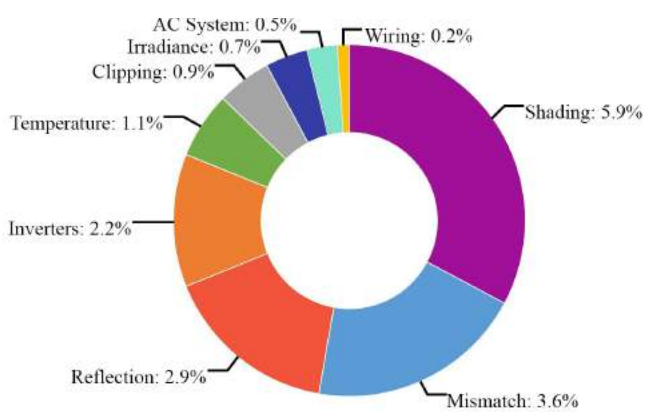
The incorporation of CHP allows for many campus buildings to no longer rely on the temperamental electric grid .

CHP - Emissions Analysis		
	Electric Grid	CHP
CO_2 Emitted (tons/year)	22469.4	14,585
NO_x Emitted (tons/year)	28.91	27.18
CO Emitted (tons/year)	11.9574	0.27
SO_x Emitted (tons/year)	127.458	0.07
Emissions Reduced		
	CO_2 (tons/year)	7884.4
	NO_x (tons/year)	1.73
	CO (tons/year)	11.6847
	SO_x (tons/year)	127.388

Fuel Cell - Emissions Analysis		
	200 KW Bi-Fuel Generator	200 KW Fuel Cell
CO_2 Emitted (lbs/MWh)	1280	679
NO_x Emitted (lbs/MWh)	25.33	<0.01
CO Emitted (lbs/MWh)	42.67	<0.05
SO_x Emitted (lbs/MWh)	0	0
Emissions Reduced		
	CO_2 (lbs/MWh)	601
	NO_x (lbs/MWh)	25.33
	CO (lbs/MWh)	42.62
	SO_x (lbs/MWh)	0

PHOTOVOLTAIC ROOF ARRAY ANALYSIS

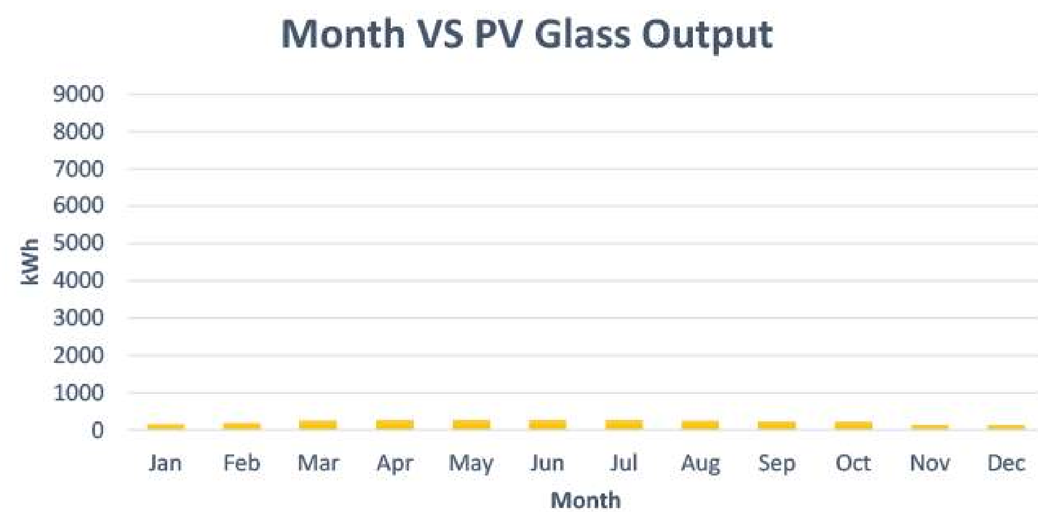


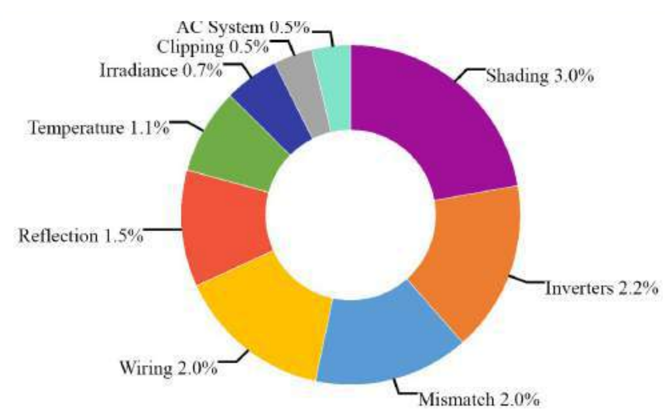


Syndicate used *HelioScope* to design the proposed PV-system and get a detailed analysis of the system's performance. The above graph is a monthly breakdown of the energy potential that the system can generate in kWh. *HelioScope* was also able to analyze potential system losses, shown in the left diagram. Shading is the largest contributor to system loss due to the inclusion of snow fall.

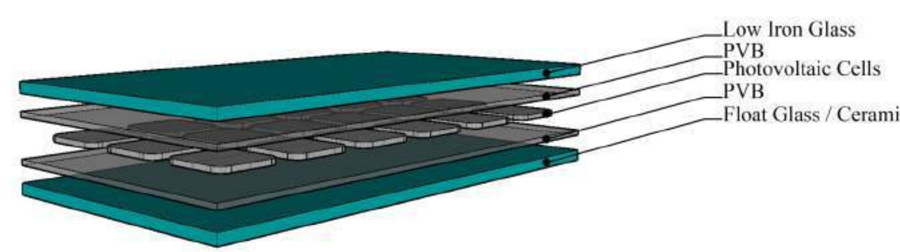
Syndicate understands that sun position and self-shadowing are major factors that must be accounted for when designing a photovoltaic system. The lighting/electrical team researched Michigan's public weather data and found that in the spring and fall seasons the most common solar angle is 47° from the vertical. This meant that *Syndicate's* PV system needed to be angled at 43° from the horizon. The design team chose to recommend *Solar Canada's Hanwha* photovoltaic panels as their robust design, efficient power generation, and manufacturing proximity to Holland made it the optimal choice. With a length and depth of 5-feet and 3-feet respectively the panel is able to withstand snow loads up to 5,400 Pa. These dimensions, along with the design angle, lead to a preferred spacing of 5-feet to avoid any self-shadowing. This spacing was calculated using the sun's position on December 21, at 12:00 PM.

PHOTOVOLTAIC GLASS ANALYSIS



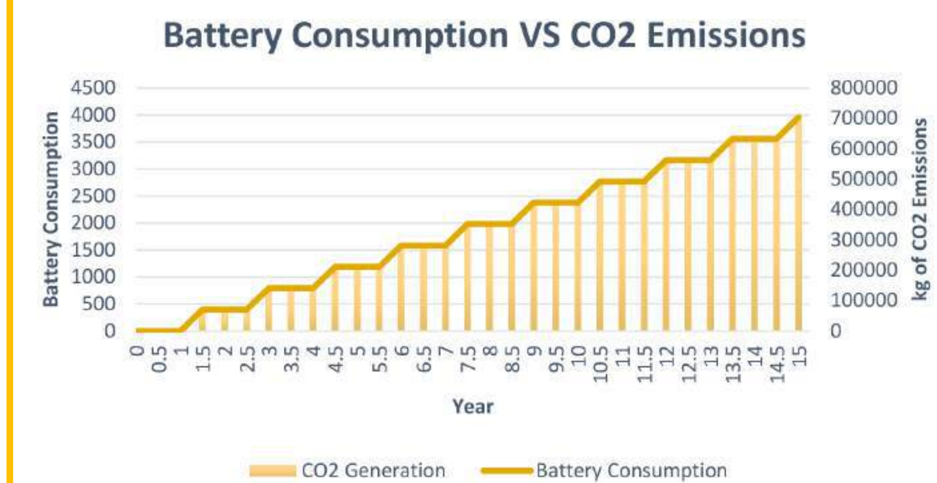


Syndicate used *System Advisory Model (SAM)* to accurately analyze how the PV Glass would perform. Comparatively, the annual energy output of the window system is 0.03% of the total output of the rooftop array. Similar to *HelioScope*, *SAM* was able to produce potential system losses. While not as severe, shadowing is still the largest contributor to shade due to the system spanning from a west to south orientation.



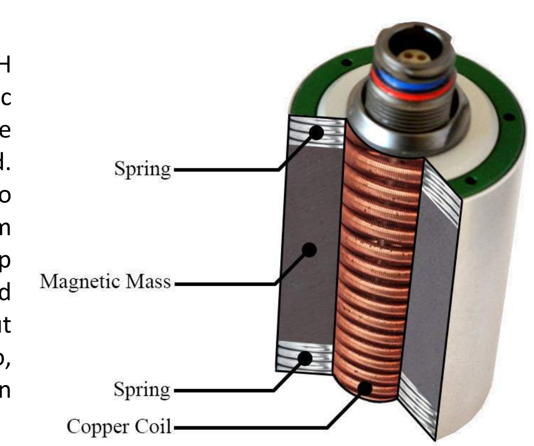
Syndicate was aware that this technology is newer when compared to other PV-systems. With this knowledge, an effort was made to find a PV glass product that balanced cost, energy output, and transparency. The design team ultimately noticed a negative correlation between efficiency and transparency of the glass. *Syndicate* decided to analyze *OnyxSolar* PV-glass as it provided a wide range of system specification options. To analyze a realistic glass transparency, the least efficient of *Onyx's* products had to be chosen. This transparency was 30% with an energy output of 28 W/m^2. The end results of the analysis showed that the PV glass system had an annual energy production-to-system cost ratio of 0.16, almost 5-times smaller than the rooftop array's ratio of 0.76. While an exciting technology, *Syndicate* decided that the system was still too new to fit into the design goal set forward for The Miller Center.

VIBRATION ENERGY HARVESTER ANALYSIS



The replacement of disposable single-use batteries with a renewable and sustainable energy source is a long term opportunity to reduce Hope College's carbon footprint. *Syndicate* found that if every sensor utilized in The Miller Center design used an average of 2 AA batteries with a lifespan of 1.5 years, roughly 400 batteries would be disposed every 1.5 years. This immediate number may not sound large, but over the course of 15-years a total of 4,000 batteries will have been used. The average lifetime carbon footprint for a AA battery is 175kg of CO^2, meaning over a time period of 15-years, 700,000kg of CO^2 emissions could be avoided with the use of VEH technology. This is equivalent to removing 168 passenger vehicles off the road for one year.

ReVibe Energy's Model-D VEH technology induces electromagnetic induction by placing a copper wire in the center of a magnetic field. The magnets are set between two springs to allow for movement from vibrations. As the magnets move up and down, a voltage is generated and fed through the copper coil out to the sensor it is wired to, eliminating the sensors need for an external power source.



FIXTURE SCHEDULE

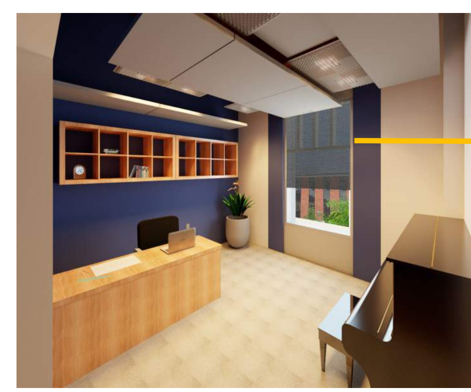
TYPE	DESCRIPTION	MANUFACTURER	CATALOG NUMBER	LAMPS	VOLTAGE	PRODUCT IMAGE	LOCATION
A1	2' X 4' DIRECT PENDANT, SOUND ABSORBING MATERIAL, WHITE FINISH, DIMMABLE 0-10V TO 1%	ARTEMIDE	MEB-SL-MD-835-08-WH	31W, 2626LMS LED (INCLUDED) 80 CRI, 3500K	120-277		FACULTY STUDIO, PRACTICE ROOM
A2	2' X 2' DIRECT PENDANT, SOUND ABSORBING MATERIAL, WHITE FINISH, DIMMABLE 0-10V TO 1%	ARTEMIDE	MEB-SS-MD-835-08-WH	15.5W, 1313LMS LED (INCLUDED) 80 CRI, 3500K	120-277		FACULTY STUDIO, PRACTICE ROOM
D1-D2	2.5" DIAMETER RECESSED DOWNLIGHT, 60 DEGREE DIRECT BEAM, THERMALLY PROTECTED DIE-CAST ALUMINUM FRAME, MATTE BLACK FINISH, DIMMABLE 0-10V TO 1%	FOCAL POINT	FLS2D-RO-VARIES-WFL-120-LU5-T-LS2-RD-35K-DN-WFL-CD-BK	8W, 500-700LMS LED (INCLUDED) 80 CRI, 3500K	120-277		CONCERT HALL/RESTROOMS/NORTH LOBBY
E1	EXTERIOR LED BOLLARD, SYMMETRIC THROW CAST ALUMINUM HOUSING, METALIC FINISH, ACRYLIC LENS, IP66 RATING DIMMABLE DRIVER	EATON - INVUE	ABB-B2-LED-42-D1-S-GM-MS/DIM-2H8-ISHH	32W, 1,276LMS LED (INCLUDED) 80 CRI, 3000K	277		EXTERIOR
E2	EXTERIOR BOLLARD FIXTURE, ASSYMETRIC CAST ALUMINUM HOUSING, METALIC FINISH, ACRYLIC LENS, DIMMABLE DRIVER	EATON - INVUE	ABB-B2-LED-42-D1-A-GM-MS/DIM-2H8-ISHH	23W, 848LMS LED (INCLUDED) 80 CRI, 3000K	277		EXTERIOR
E3	3.5" DIAMETER EXTERIOR DOWNLIGHT, 60 DEGREE BEAM ANGLE SILICON GASKET, STAINLESS STEEL FINISH, IP44 RATING DIMMABLE DRIVER	HALCYON - R642	R642-KSTSL	10W, 800LMS LED (INCLUDED) 80 CRI, 3000K	277		EXTERIOR
E4	13" X 4" DIRECT EXTERIOR WALL MOUNTED FIXTURE, DIE-CAST ALUMINUM HOUSING, BLACK TGIC THERMOSET FINISH, ACRYLIC LENS, MULTI-VOLTAGE DRIVER, IP65 RATED, INTEGRATED MOTION SENSOR	LITHONIA - D-SERIES	DSXW1-LED-10C-530-30K-T2M-MVOLT-PIR-SF-DBLXD	19W, 1950LMS LED (INCLUDED) 70 CRI, 3000K	277		EXTERIOR
E5	3" DIAMETER EXTERIOR INGROUND UPLIGHT, 34 DEGREE BEAM ANGLE, POLISHED ALUMINUM BODY, STAINLESS STEEL, DIMMABLE 0-10V TO 1%, IP67 RATING	TARGETTI - JUPITER	JUP-RP-FL-L1-30-24-1E3175-DEL-X-320-3-4-24-D	15W, 982LMS LED (INCLUDED) 84 CRI, 3000K	120-277		EXTERIOR
E6	1" INGRADE GRAZER, ALUMINUM EXTRUSION, WHITE DIFFUSING LENS, DIMMABLE 0-10V, UL DAMP LOCATION	DALUME	DCR-1-12W-35K-FL-UD-EM	12W, 1090LMS LED (INCLUDED) 80CRI, 3500K	120-277		EXTERIOR
F1	8.7 MM DIAMETER FIBER OPTIC, MEGOLON S530 JACKET, BLACK FINISH, DMX COMPATIBLE	VISUAL LIGHTING TECHNOLOGIES	F-MF-SF-PM-50	N/A	120-277		CONCERT HALL
G1-G2	2' X 4' OR 1'X4' DIRECT RECESSED TROFFER FIXTURE, VARIABLE LENGHTS STEEL FRAME, ACRYLIC DIFFUSE LENS, MATTE WHITE HOUSING, DIMMABLE 0-10V 1%, OPTIONAL EMERGENCY PACK	FOCAL POINT - AERION	FARL-VARIES-AC-4500L-35K-1C-UNV-L3D-G1-WH	43W, 4500LMS LED (INCLUDED) 80 CRI, 3500K	120-277		CORRIDORS/STORAGE
H1	1' HIGH OUTPUT TAPE LIGHT, 1/8" THICK, SILICONE CASED, ADHESIVE, DIMMABLE 0-10V ELV	WAC LIGHTING	LED-TE24535-1-WT	5W, 440LMS LED (INCLUDED) 90 CRI, 3500K	277		NORTH/SOUTH LOBBIES, OCCUPIABLE ROOF
I1	1' X 4' DIRECT LINEAR INDUSTRIAL FIXTURE, STELL FRAME, ACRYLIC FROSTED LENS, ALUMINUM FINISH, DIMMABLE 0-10V	LITHONIA - IBG	IBG-8000LM-SEF-AFL-GND-MVOLT-GZ10-35K-80CRI-DNA	55W, 8000LMS LED (INCLUDED) 80 CRI, 3500K	120-277		MECHANICAL/ELECTRICAL/STORAGE
L1-L2	DIRECT LINEAR LED WALL GRAZER, VARIABLE LENGTHS SATIN BLACK FINISH, DIMMABLE 0-10V	EDGE LIGHTING	C-1RE-JBOX-CC-WG-7WDC-48-35K-BK	28W, 475LMS/FT LED (INCLUDED) 85 CRI, 3500K	120-277		RECITAL/ORCHESTRAL/ CHORAL/CONCERT HALL, NORTH LOBBY, OCCUPIABLE ROOF
L3	4' LINEAR PENDANT LIGHT FIXTURE, 80/20 DIRECT/INDIRECT, METALIC SILVER COAT, CLEAR ACRYLIC LENS, DIMMABLE 0-10V TO 1%	FLUXWERX	VU1-B-B-B-35-S-04-G-L1-M-03	23W, 2222LMS LED (INCLUDED) 83.3 CRI, 3500K	120-277		CLASSROOM
L4	4' DIRECT LINEAR PENDANT LIGHT FIXTURE, DIRECT, ALUMINUM HOUSING, ACRYLIC LENS, HIGH REFLECTANCE WHITE FINISH, DIMMABLE 0-10V TO 1%	AMERLUX	GRUV1.5-J/IS-A16-PL-5-35-HW-120/277-4-IND-HILUME-H-ECO	5W/FT, 3794LMS LED (INCLUDED) 83 CRI, 3500K	120-277		CORRIDORS
L5	3" LINEAR DIRECT RECESSED FIXTURE, O-SHAPE 4' X 10', ALUMINUM HOUSING, ACRYLIC LENS, DIMMABLE 0-10V TO 1%	XAL - BASO	BAS2-G-L-1D-7-2-7-0-H-7-XXXX00-C	19W, 1820LMS, LED (INCLUDED) 80 CRI, 3500K	120-277		OCCUPIABLE ROOF
P1	17.5" DIAMETER SNOOTED HIGH BAY PENDANT, 40 DEGREE DIRECT BEAM, DIE-CAST ALUMINUM FRAME, BLACK FINISH, CLEAR LENS, LUMENTALK COMPATIBLE	LUMENPULSE	LBXP-HO-277-40K-FL-SCAN-48-LSLH-BK-ES-UL	205W, 10,689LMS LED (INCLUDED) 80 CRI, 4000K	120-277		CONCERT HALL
P2-P3-P4	DIRECT/INDIRECT RING PENDANT, VARIABLE DIAMETERS SUSPENDED CABLE, PASSIVE INTERNAL COOLING, SILVER FINISH DIMMABLE 0-10V TO 1%	XAL LIGHTING	MIN2-4-C-2-4-7-2-7-0-O-6-4-D4	221W, 400LMS/FT LED (INCLUDED) 80 CRI, 3500K	277		SOUTH LOBBY
P5	4.5" DIAMETER DIRECT PENDANT FIXTURE, WIDE FLOOD BEAM EXTRUDED ALUMINUM HOUSING, ACRYLIC LENS, WHITE FINISH, DIMMABLE 0-10V TO 1%	FOCAL POINT - ID+	FLCY4-RD-WHR-2500L-35K-1C-UNV-PC-LH1-C72-DNT-WFL-CD-WH	36W,1500-2500LMS LED (INCLUDED) 80 CRI, 3500K	120-277		CHORAL/ORCHESTRAL HALL
P6	3' DIAMETER DIRECT PENDANT FIXTURE, SUSPENDED CABLE, DIFFUSE WHITE ACRYLIC LENS, STEEL HOUSING DIMMABLE 0-10V TO 1%	FOACL POINT - SKYDOME	FSDL-33-CX-4000L-3500K-90CRI-1C-UNV-L11-C96-EM-WH	77W, 4000LMS LED (INCLUDED) 90 CRI, 3500K	120-277		OCCUPIABLE ROOF
S1	22" UP/DOWN WALL SCONCE, SILVER FINISH, ADA COMPLIANT DIMMABLE 0-10V TO 10%	VISA LIGHTING	OW2400-L35K-MVOLT-GSIL-RMB	13W, 410LMS LED (INCLUDED) 93 CRI, 3500K	277		NORTH/SOUTH LOBBIES
S2	25" UP/DOWN WALL SCONCE, ALUMINUM & STEEL FRAM, LINEN SHADE, ACRYLIC LENS, DIMMABLE 0-10V TO 1%	EATON - SHAPER	161-25"-WALL-L3/835-UNV-TC-161-25"-SIW	19W, 2000LMS LED (INCLUDED) 83 CRI, 3500K	120-277		RESTROOMS
S3	4" X 4' DIRECT/INDIRECT WALLL MOUNTED FIXTURE, ALUMINUM FRAMING, ACRYLIC LENS, MATTE WHITE FINISH, DIMMABLE 0-10V 1%	EATON - NEO-RAY	S124-DIW-ULO-1-35-0048-1-E-U-DD-1-5-W	52W, 4526LMS LED (INCLUDED) 85 CRI, 3500K	120-277		FIRE STAIRS
T1	6" DIAMETER TRACK FIXTURE, 18 DEGREE BEAM, BLACK, DIE-CAST ALUMINUM, PROTECTIVE GLASS LENS DIMMABLE ELV	IGUZZINI	IPLCM-930-MD-277-02-LTE	41W, 3080LMS LED (INCLUDED) 90 CRI, 4000K	120-277		RECITAL HALL
T2	5.5" DIAMETER TRACK FIXTURE, 30 DEGREE FLOOD BEAM, SILVER, DIE-CAST ALUMINUM, PROTECTIVE GLASS LENS DIMMABLE ELV	IGUZZINI	I.MK56-277-10	41W, 3080LMS LED (INCLUDED) 90 CRI, 4000K	120-277		NORTH/SOUTH LOBBIES
W1	4' LINEAR DIRECT RECESSED WALL WASHER, EXTRUDED ALUMINUM FRAME, MATTE WHITE FINISH, DIMMABLE 0-10V TO 1%	AMERLUX	FINO-CLG-GB-A16-6-35-HW-120/277-4'-CON-HILUME-5-ECO-CP	6W, 1390LMS LED (INCLUDED) 83 CRI, 3500K	120-277		CLASSROOM
W2	2.5" DIAMETER DIRECT RECESSED WALL WASHER, 30 DEGREE BEAM, DIE-CAST ALUMINUM FRAME, MATTE BLACK FINISH, DIMMABLE 0-10V 1%	FOCAL POINT	FLS2W-RF-500L-FL-120-LH1-T-CP-LS2-RD-35K-WW-FL-BK-BK	9W, 500LMS, LED (INCLUDED) 80 CRI, 3500K	120		NORTH LOBBY
X1	8" EXIT SIGN, RED LETTER COLOR, POWDER COAT FINISH, STEEL HOUSING, SELF-POWERED	FOCAL POINT	XLN1-8-S-R-2U-STW12	N/A	120-277	EXIT	VARIOUS

LIGHTING CRITERIA

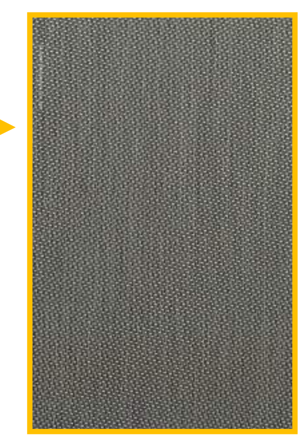
SPACE	ASHRAE 90.1 2013 LPD (W/SF)	ACTUAL LPD (W/SF)	TARGET AVERAGE (FC)	ACTUAL AVERAGE (FC)
North Lobby	2.0	0.92	15	21
South Lobby	0.9	0.48	15	16
Concert Hall (Seating)	2.43	0.97	7.5	36
Recital Hall (Seating)	2.43	0.71	7.5	42
Choral Hall	1.24	0.85	30	20
Orchestral Hall	1.24	1.14	30	22
Occupiable Roof Space	1.23	0.16	10	18
Classrooms	1.24	0.48	40	31
Faculty Studios	1.11	0.54	30	31
Practice Rooms	1.24	0.59	40	37

SHADING SPECIFICATIONS

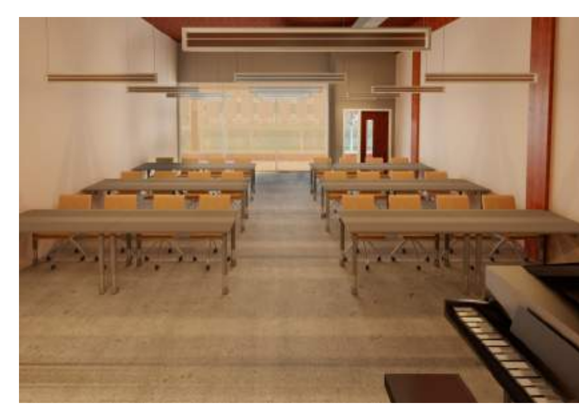
SHADE TYPE	OPENNESS	VISIBLE TRANSMITTANCE	COLOR	LOCATION
T-SCREEN - THEIA	2.6% (+/- 0.75%)	8.1% (+/- 1.7%)	WHITE/CHARCOAL	FACULTY STUDIOS
SERENA	~0%	~0%	BLACKOUT	CLASSROOMS



Rendering of the *T-SCREEN with KOOLBLACK-THEIA* shading device shown in a Faculty Studio with a punch window.



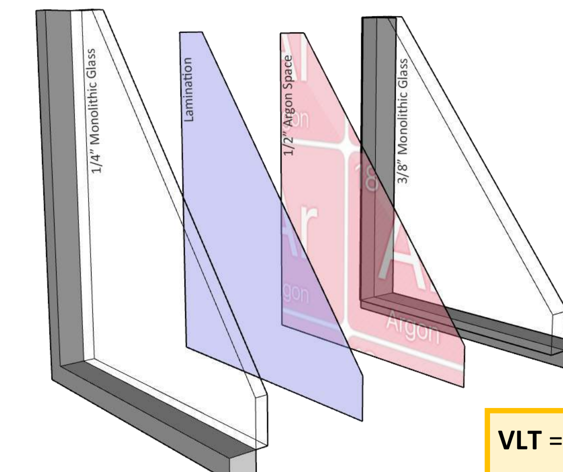
Provided by *Lutron*



Rendering of the *Smart Tint* film shown in a Classroom

GLAZING SELECTIONS

NORTH LOBBY GLAZING

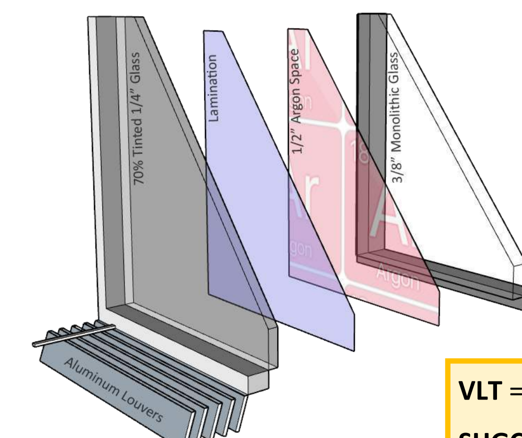


VLT = 44%

SHGC = .58

U-Value = .48

SOUTH LOBBY GLAZING & LOUVERS

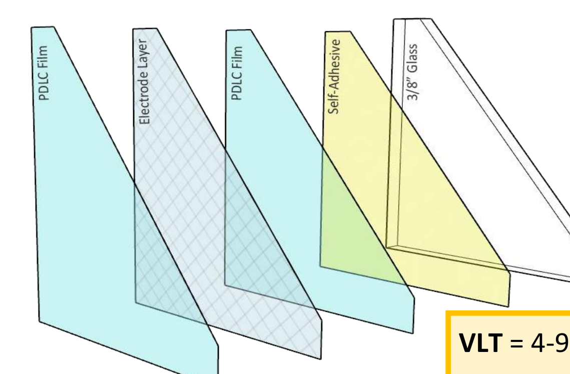


VLT = 44%

SHGC = .70

U-Value = .48

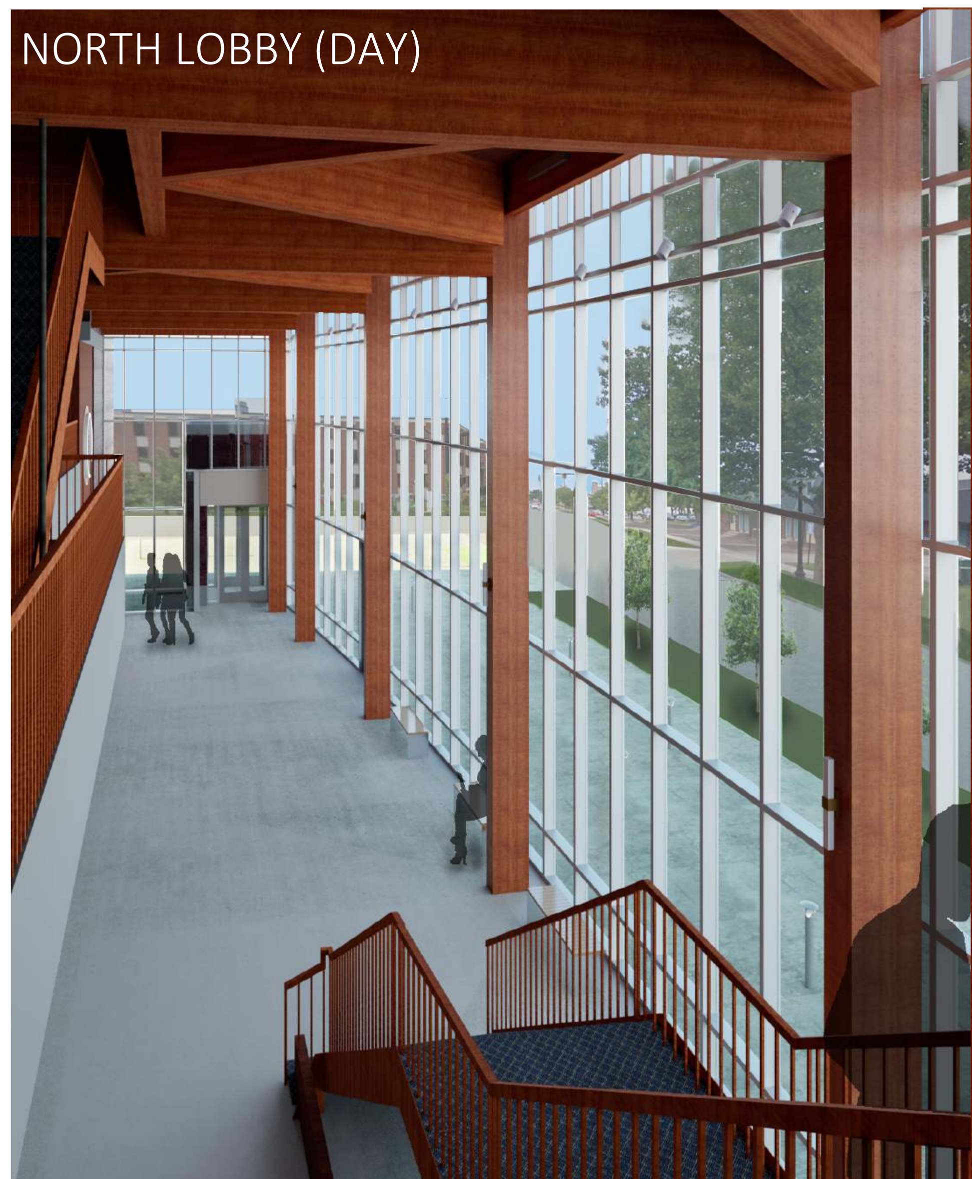
CLASSROOM *SMARTTINT SELF-ADHESIVE FILM*



VLT = 4-98%

SHGC = .71

U-Value = n/a



NORTH LOBBY (DAY)

NORTH LOBBY (NIGHT)

CLASSROOM

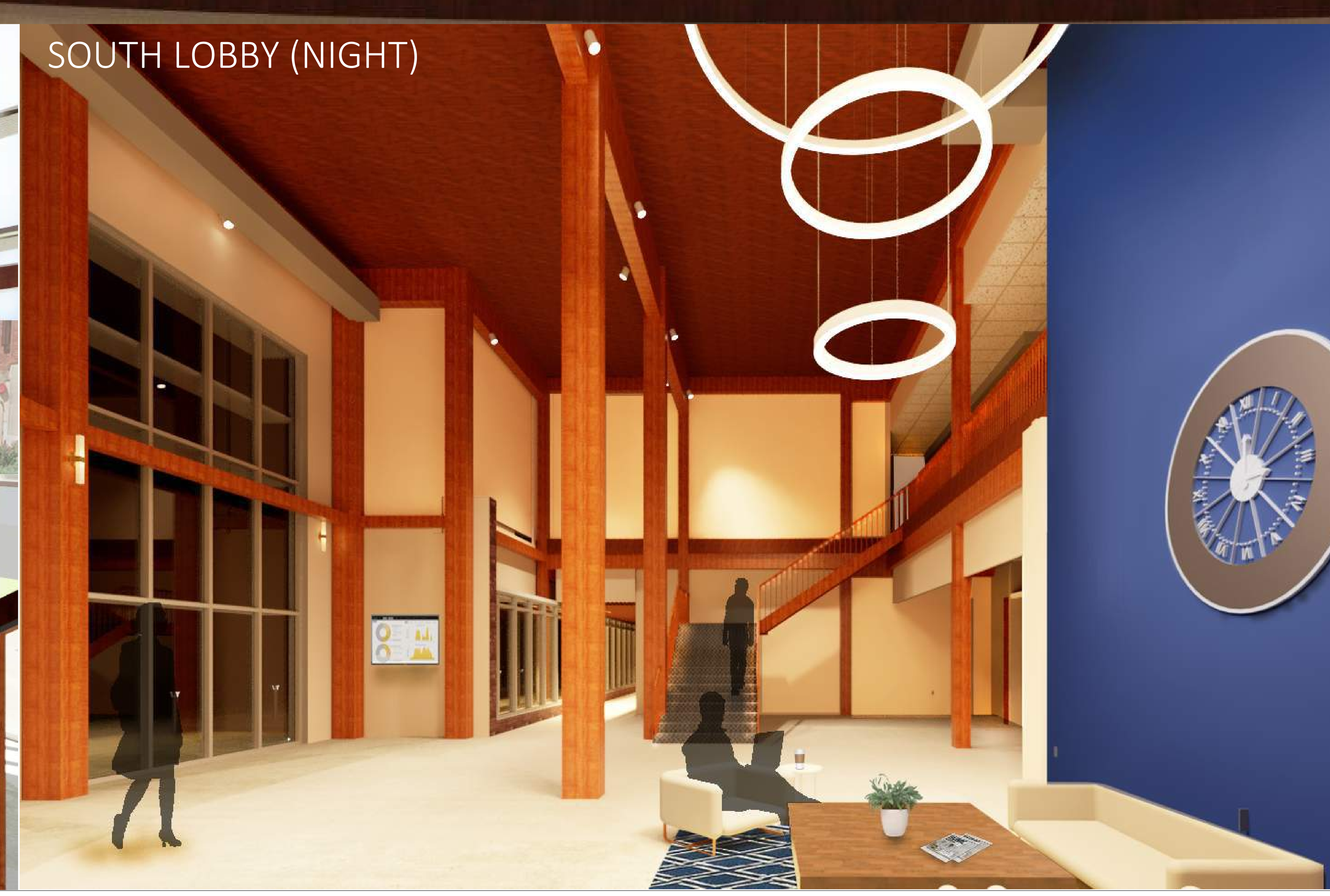
OCCUPIABLE ROOF (DAY)

RECITAL HALL

CONCERT HALL

OCCUPIABLE ROOF (NIGHT)

SOUTH LOBBY (DAY)

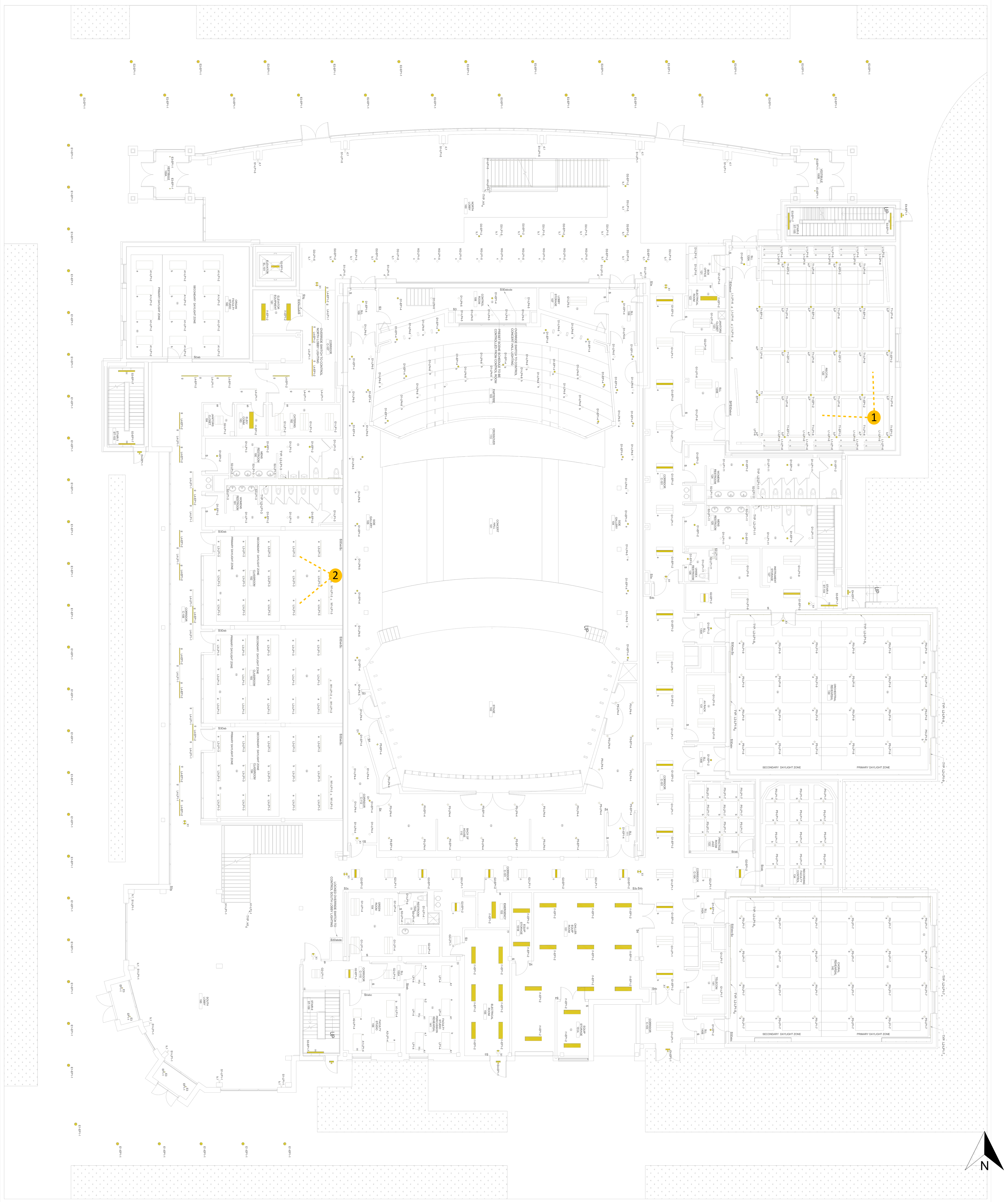


SOUTH LOBBY (NIGHT)

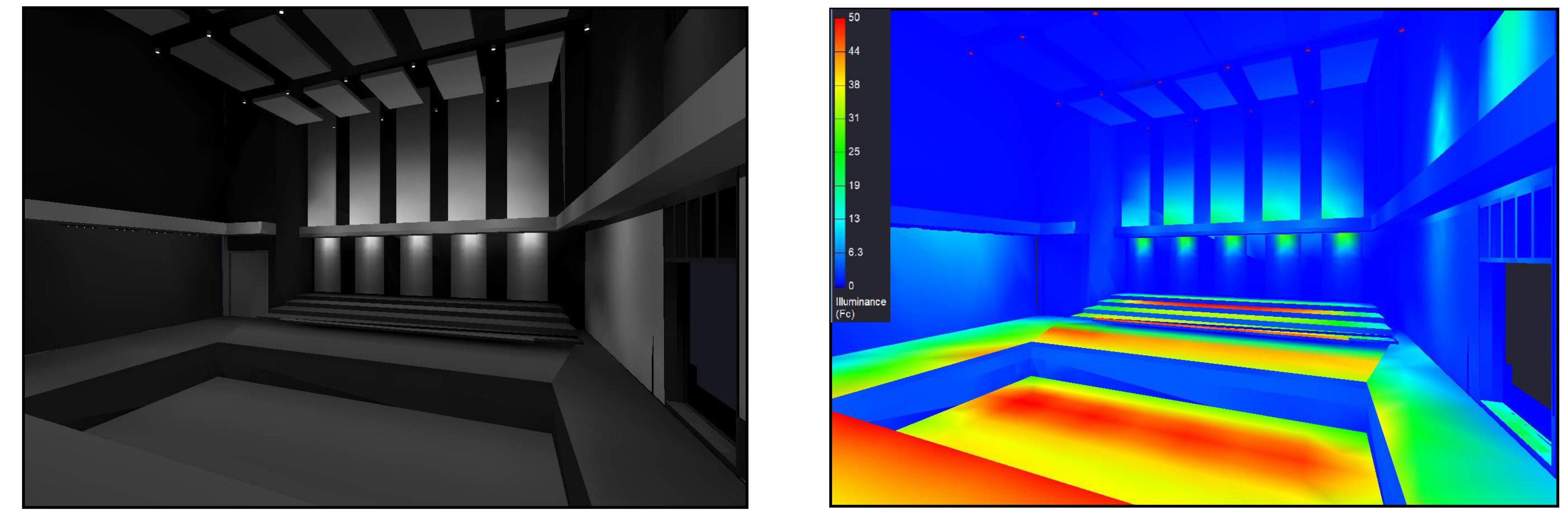
FACULTY STUDIO

SYNDICATE

PROJECT **JACK H. MILLER CENTER FOR MUSICAL ARTS** HOLLAND, MICHIGAN	
SHEET TITLE	
NOT FOR CONSTRUCTION	AEI TEAM NO. 01-2019
DATE February 18, 2019	SCALE NOT TO SCALE
DRAWING NO. L-1.0	PAGE NO. 111

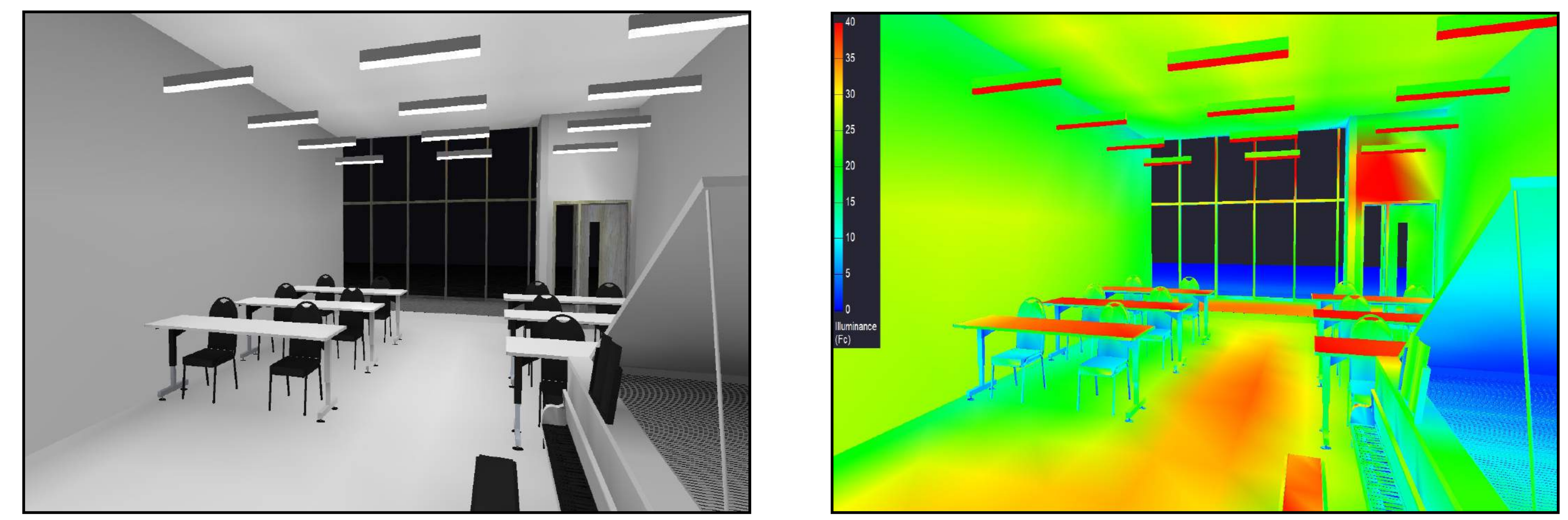


RECITAL HALL



1 Recital Hall Pseudo Black and White & Pseudo Color

CLASSROOM



2 Classroom Black and White & Pseudo Color View

FIXTURE NAMING CONVENTION KEY

XX-PB-#

x,#

Switch Designation, Daylight Zone

Fixture Tag, Panelboard Location, Circuit Designation Number

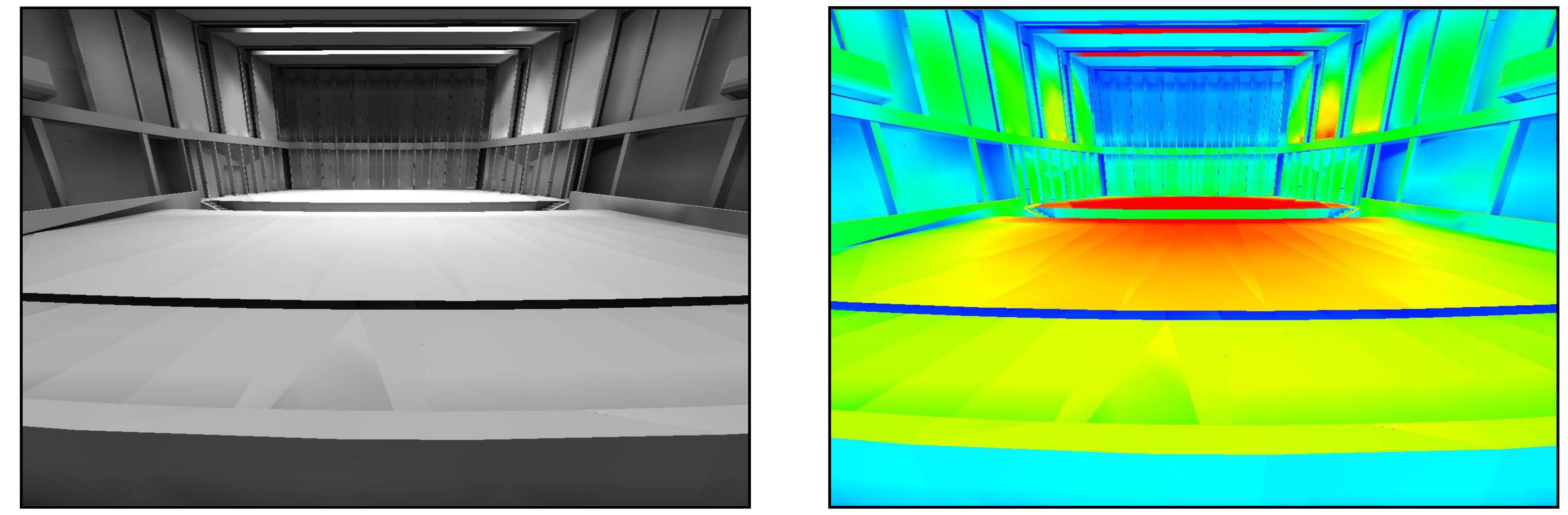
LIGHTING CONTROLS & SYMBOLS

- VIVE — LUTRON VIVE HUB
- OS — CEILING MOUNTED OCCUPANCY SENSOR
- VS — CEILING MOUNTED VACANCY SENSOR
- DS — CEILING MOUNTED DAYLIGHT SENSOR
- OS — WALL MOUNTED OCCUPANCY SENSOR
- VS — WALL MOUNTED VACANCY SENSOR
- OS — INTEGRATED OCCUPANCY SENSOR WITH FIXTURE
- DS — INTEGRATED DAYLIGHT SENSOR WITH FIXTURE
- $D — SWITCH WITH INTEGRATED DIMMER
- $P — SWITCH WITH INTEGRATED PRESET SCENE SCHEDULE CONTROL
- WALL MOUNTED EMERGENCY EXIT SIGN
- CEILING MOUNTED EMERGENCY EXIT SIGN
- TYPICAL SHADED EMERGENCY LIGHT

SYNDICATE

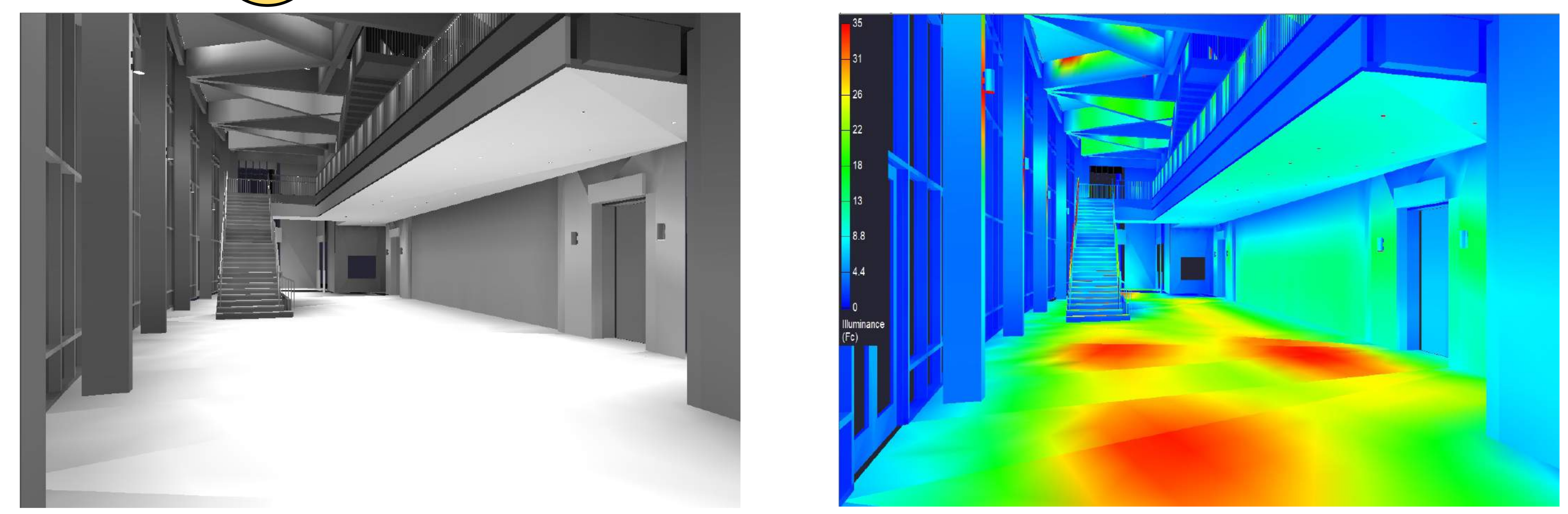
PROJECT **JACK H. MILLER CENTER FOR MUSICAL ARTS** HOLLAND, MICHIGAN	
SHEET TITLE FIRST LEVEL LIGHTING AND CONTROLS PLAN	
NOT FOR CONSTRUCTION	AEI TEAM NO. 01-2019
DATE February 18, 2019	SCALE NOT TO SCALE
DRAWING NO. L-2.0	PAGE NO. 112

CONCERT HALL



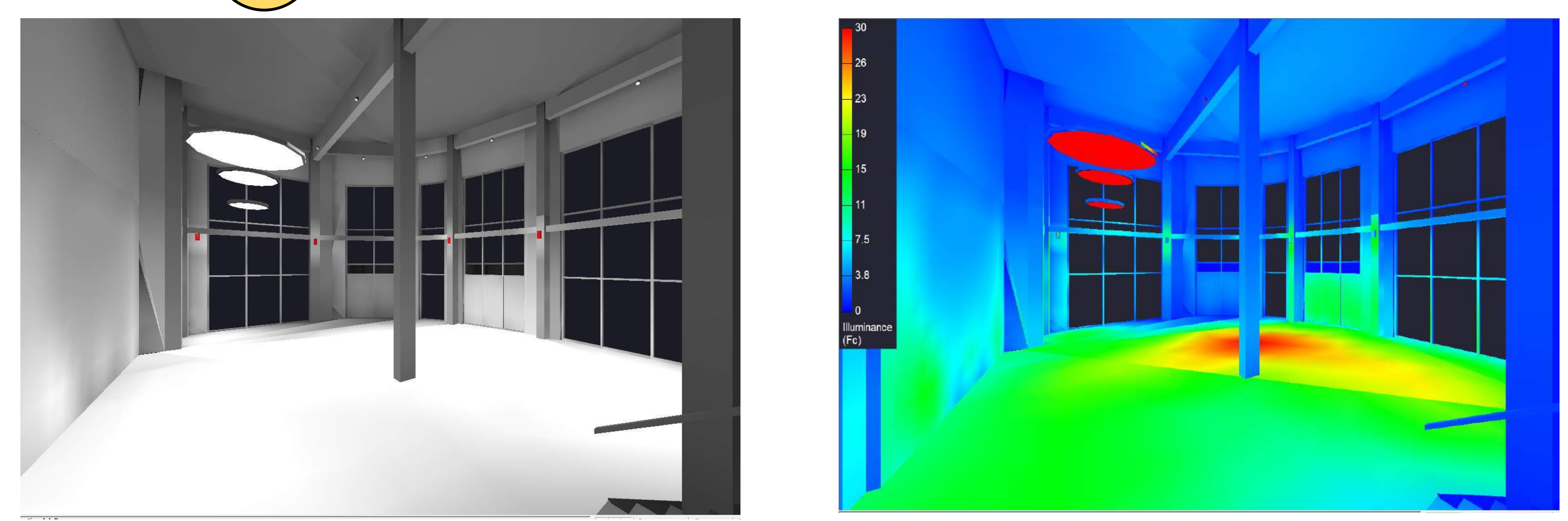
1 Concert Hall Black and White & Pseudo Color View

NORTH LOBBY



2 North Lobby Black and White & Pseudo Color View

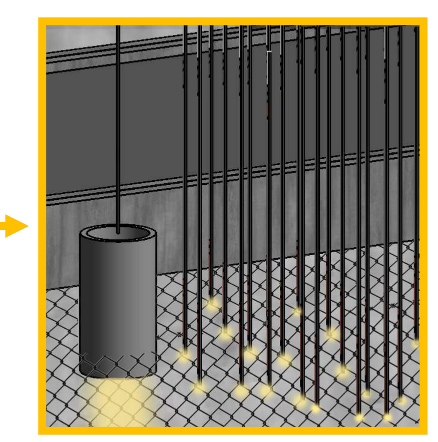
SOUTH LOBBY



3 South Lobby Black and White & Pseudo Color View

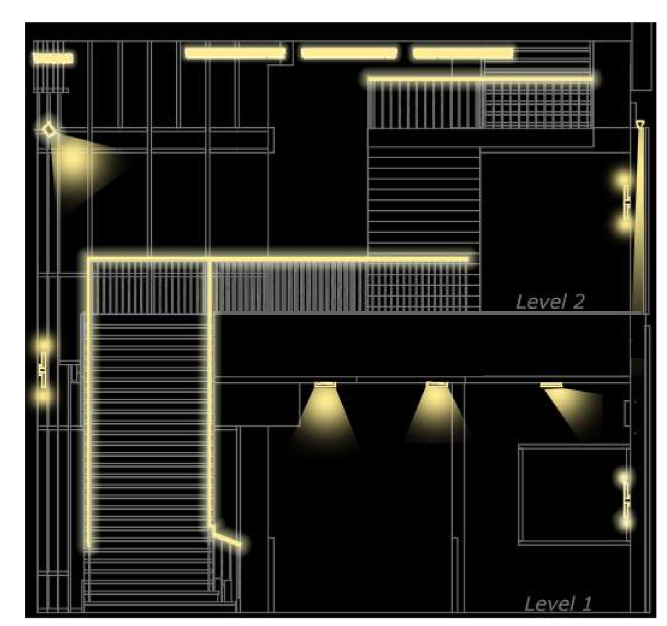
FIXTURE MOUNTING DETAILS

Section A



Schematic detail of the fiber optic lights anchored to the wire mesh, which is flush with the snooted pendant lights.

Schematic detail of the North Lobby lighting design to show mounting and directional output of the fixtures.



Section B

SYNDICATE

PROJECT

JACK H. MILLER CENTER FOR MUSICAL ARTS

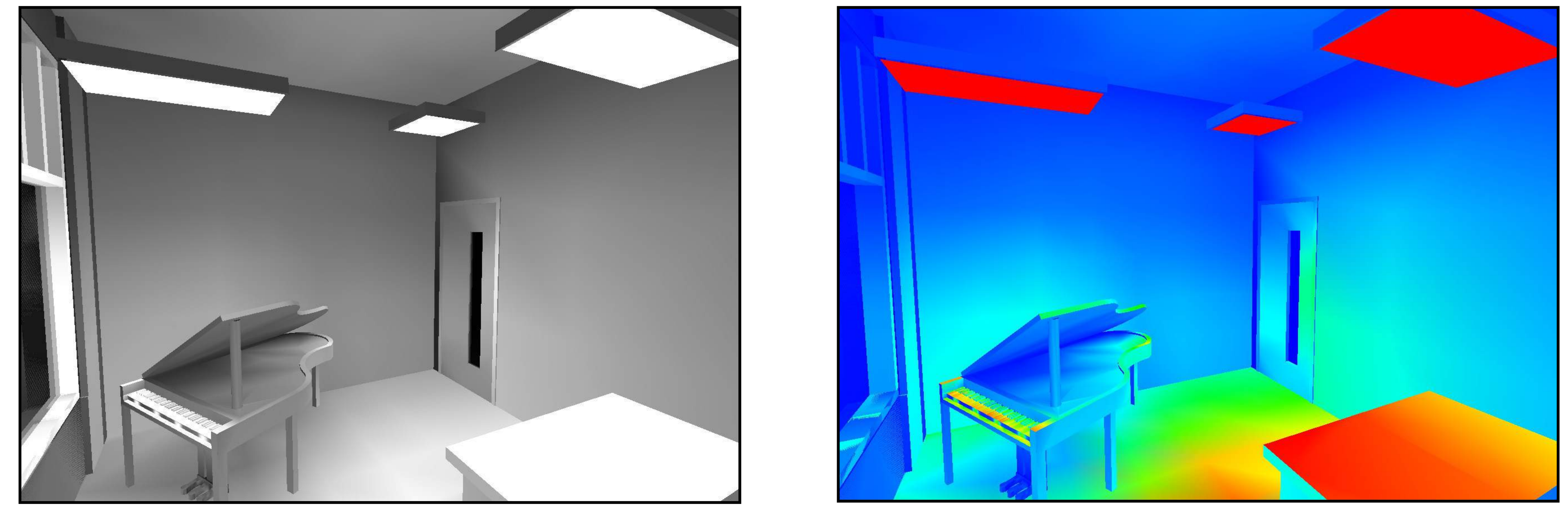
HOLLAND, MICHIGAN

SHEET TITLE

SECOND LEVEL LIGHTING AND CONTROLS PLAN

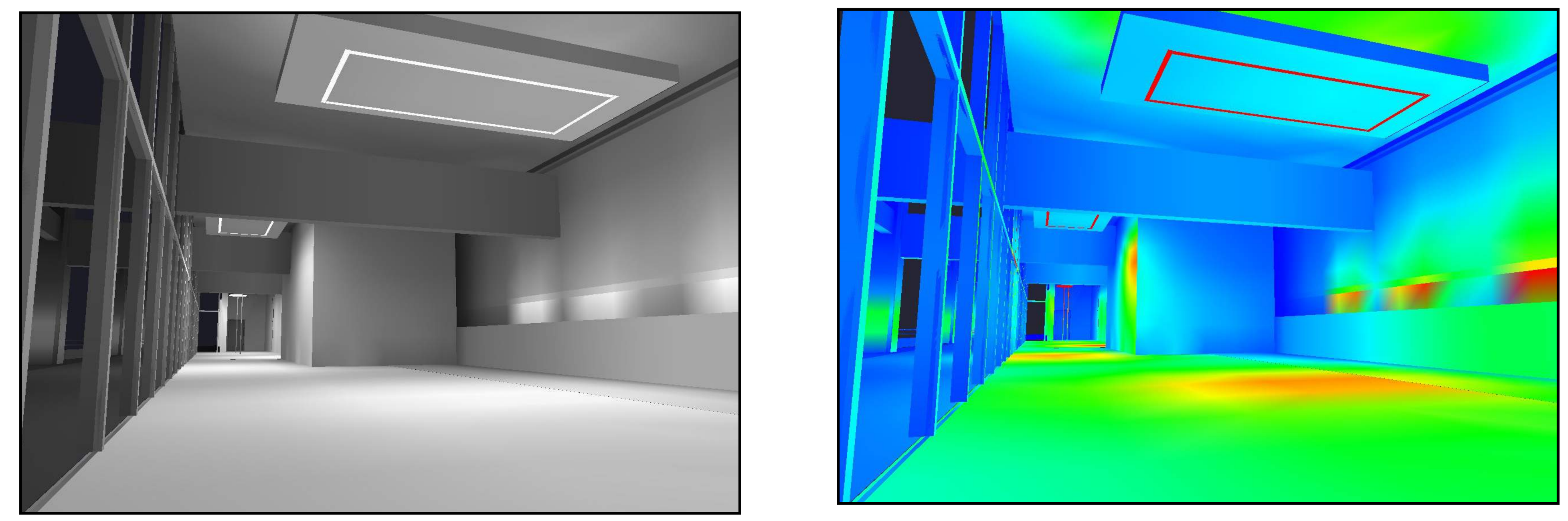
NOT FOR CONSTRUCTION	AEI TEAM NO. 01-2019
DATE February 18, 2019	SCALE NOT TO SCALE
DRAWING NO. L-3.0	PAGE NO. 113

FACULTY STUDIO



1 Faculty Studio Black and White & Pseudo Color View

OCCUPIABLE ROOF

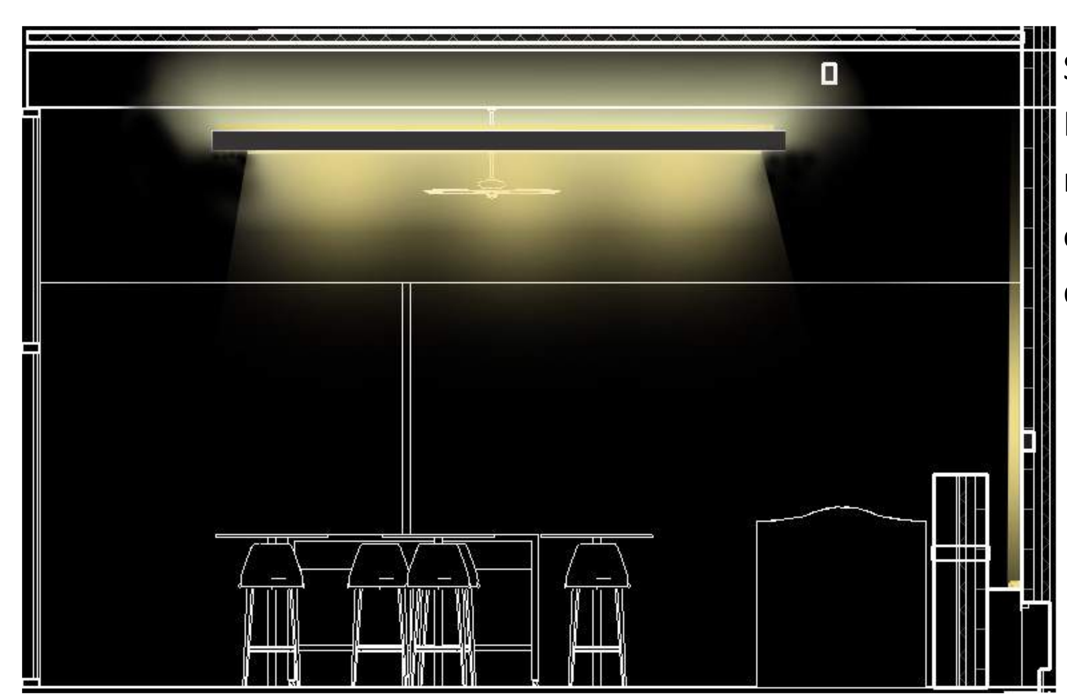


2 Occupiable Roof Black and White & Pseudo Color View

FIXTURE MOUNTING DETAILS

Section A

Schematic detail of a typical Faculty Studio with a punch window and of a typical skylight room to show the directional output of the acoustic fixtures, the mounting relationship between the fixtures and the radiant panels, and the sunlight penetration into each space.



Section B

Schematic detail of the Occupiable Roof lighting design to show mounting and directional output of the fixtures and the customized drop-panel.

SYNDICATE

PROJECT

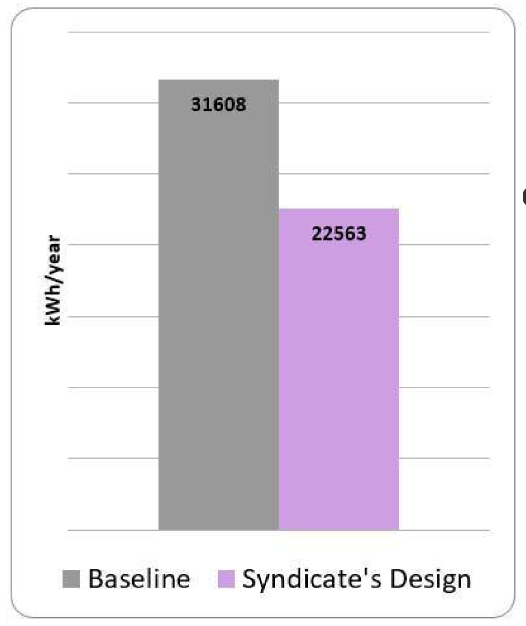
JACK H. MILLER CENTER FOR MUSICAL ARTS

HOLLAND, MICHIGAN

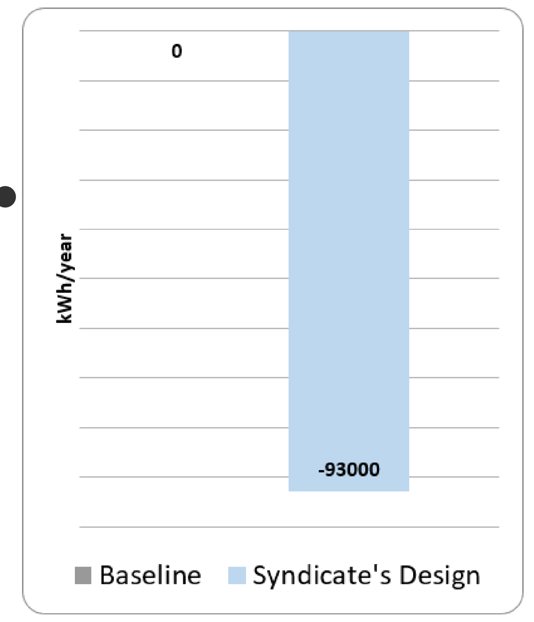
SHEET TITLE THIRD LEVEL LIGHTING AND CONTROLS PLAN	
NOT FOR CONSTRUCTION	AEI TEAM NO. 01-2019
DATE February 18, 2019	SCALE NOT TO SCALE
DRAWING NO. L-4.0	PAGE NO. 114

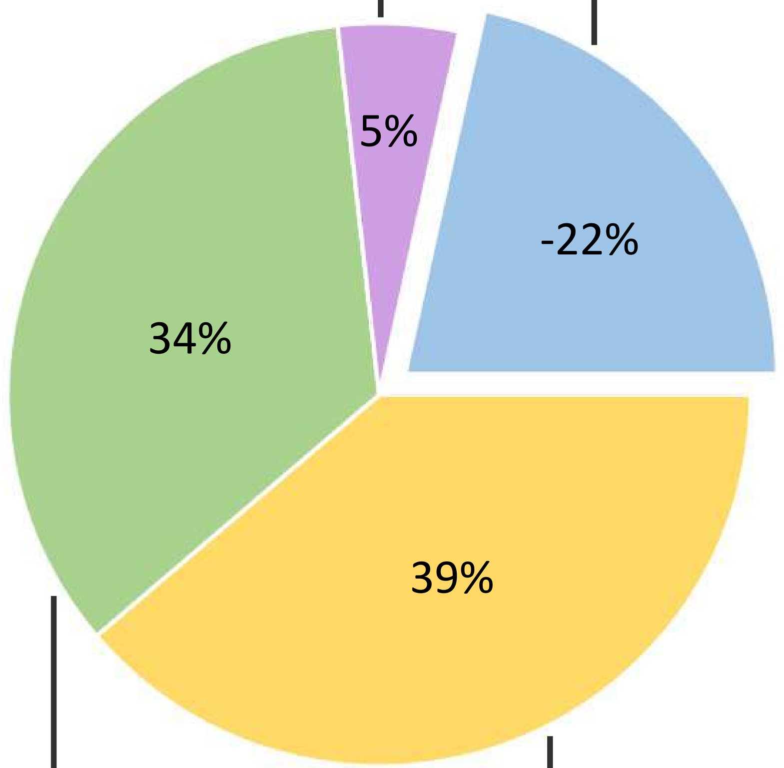
ENERGY SAVINGS

PLUG LOAD ENERGY

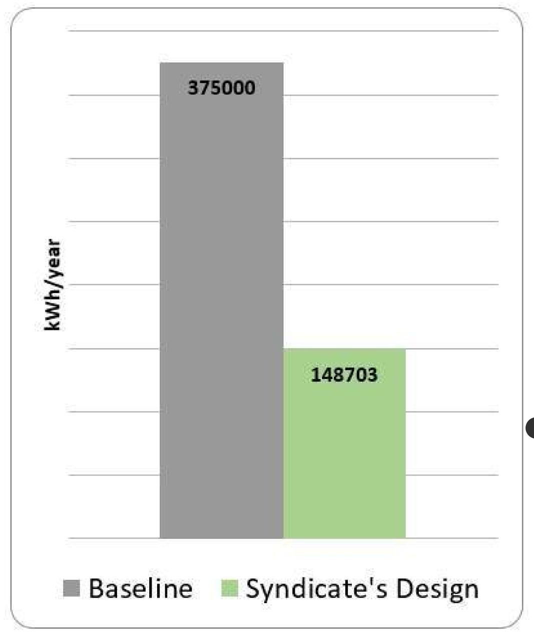


PHOTOVOLATIC ENERGY

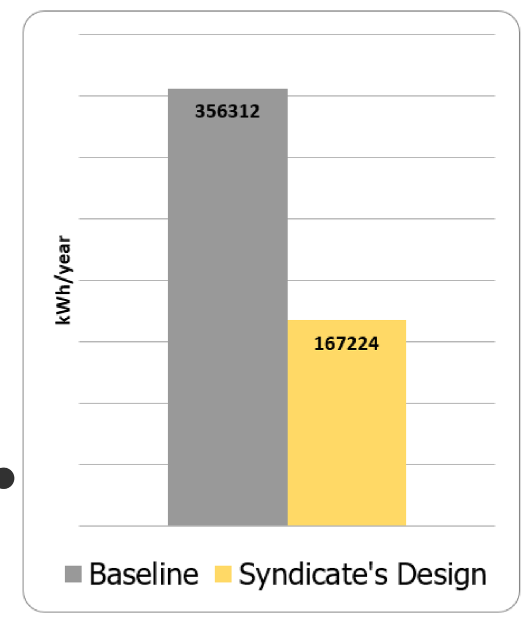




MECHANICAL ENERGY



LIGHTING & DAYLIGHTING ENERGY



TOTAL BASELINE ANNUAL ENERGY USAGE	*SYNDICATE'S* ANNUAL ENERGY USAGE
763 MWh/year	**245 MWh/year**

At 245 MWh/year, *Syndicate's* overall design uses **32.2%** less energy than the ASHRAE 90.1 2013 baseline design.

NOTE:
*Operational hours assumed 14 hrs/day.
**Daylight hours adjustment to account for assumption of 10 out of the 14 hours of operation to be daylight.
***Adjusted for spaces not continuously occupied throughout the year.

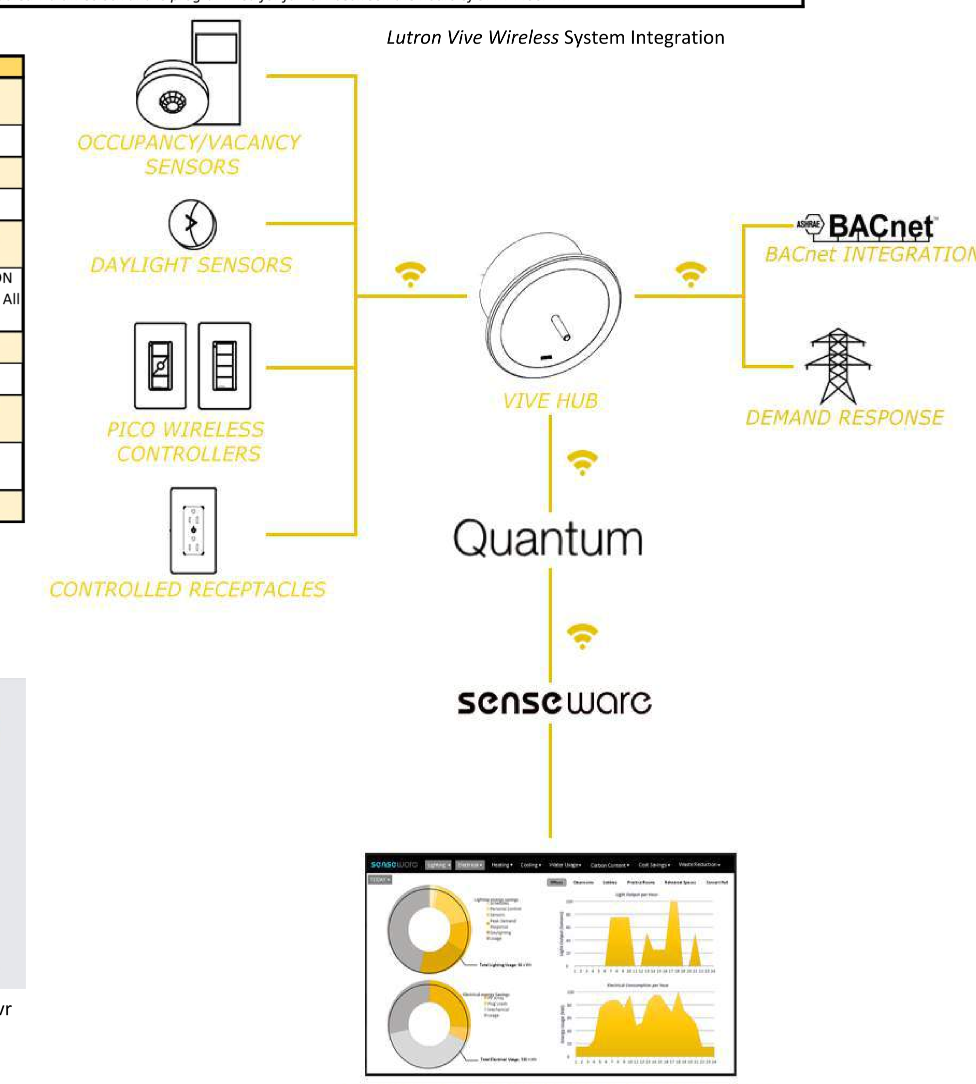
ROOM NAME	ASHRAE 90.1 2013 AREA CATEGORY	AREA (SF)	ASHRAE 90.1 2013 LPD (W/SF)	ASHRAE 90.1 2013 ALLOWED WATTAGE	ASHRAE 90.1 2013 ANNUAL ENERGY (kWh)*	SYNDICATE LPD (W/SF)	SYNDICATE PROPOSED WATTAGE	SYNDICATE INITIAL ANNUAL ENERGY (kWh)*	DAYLIGHT SAVINGS (DA, 300)	DAYLIGHT HOURS ADJUSTMENT**	OPERATIONAL HOURS ADJUSTMENT***	SYNDICATE TOTAL ANNUAL ENERGY (kWh)
North Lobby	Theater Lobby	4398	2	8796	44948	0.92	4039	20639	99%	71%		6050
South Lobby	Typical Lobby	2772	0.9	2495	12749	0.48	1337	6832	91%	65%		2393
Corridors	Corridors <8 ft. wide	8556	0.66	5647	28856	0.69	5874	30016				30016
Sound Locked Lobby		939		620	3167	0.33	312	1594				1594
Restrooms	Restrooms	2125	0.98	2083	10642	1.27	2694	13766				13766
Electrical/Mechanical	Electrical/Mechanical	8749	0.42	3675	18777	0.63	5483	28018				28018
Storage	Storage > 50 sq.ft.	1195	0.63	753	3847	0.67	796	4068				4068
Catering	Food Preperation	140	1.21	169	866	0.92	129	659			50%	330
Faculty Studios	Enclosed offices	5693	1.11	6319	32291	0.54	3064	15657	35%	25%		11744
Box Office		79		88	448	0.75	59	301				301
Choral Hall	Classroom/lecture/training	1684	1.24	2088	10670	1.28	2152	10997				10997
Orchestral Hall		1833		2273	11615	1.14	2096	10711				10711
Classrooms		2220		2753	14067	0.48	1071	5473	82%	59%		2269
Practice Rooms		1797		2228	11387	0.59	1068	5457	14%	10%		4912
Concert Hall (seating)	Audience/Seating area	7266	2.43	17656	90224	0.97	7070	36128			50%	18064
Recital Hall		1873		4551	23258	0.71	1328	6786			75%	5090
Back of House	Dressing/fitting room	2817	0.61	1718	8781	0.63	1769	9040				9040
Green Room		253		154	789	0.78	198	1012				1012
Stairwells	Stairwells	2622	0.69	1809	9245	0.40	1040	5314				5314
Conference	Conference/meeting/multi-purpose	576	1.23	708	3620	0.83	477	2437	91%	65%		854
Occupiable Roof		1957		2407	12300	0.16	308	1574	99%	71%	50%	231
Score Library	Library stacks	431	1.71	737	3766	0.58	252	1288	91%	65%		451
	TOTAL	**59975**		**69728**	**356312**		**42616**	**217768**				**167224**

LIGHTING CONTROLS

ROOM NAME	LOCAL CONTROL 9.4.1.1(a)	MANUAL ON 9.4.1.1(b)	AUTOMATIC FULL ON 9.4.1.1(c)	AUTOMATIC PARTIAL ON 9.4.1.1(c)	BILEVEL CONTROL 9.4.1.1(d)	AUTOMATIC DAYLIGHT RESPONSE CONTROL 9.4.1.1(e)	AUTOMATIC PARTIAL OFF 9.4.1.1(g)	AUTOMATIC FULL OFF 9.4.1.1(h)	TIMECLOCK SCHEDULED	PRESET SCHENE SCHEDULED	RECEPTACLE CONTROL 8.4.2	
North Lobby			●		●		●		●			*Lighting is scheduled via timeclock and is programmed for full ON between the hours of 7:00AM-7:00PM. Automatic partial OFF is implemented all other hours. Automatic photocell dimming is implemented in daylight zones. Override lighting control switch located in nearby Electrical Room (Reference Lighting Drawing L-2.0).*
South Lobby	●		●		●		●		●			*Lighting is scheduled via timeclock and is programmed for full ON between the hours of 7:00AM-7:00PM. Automatic partial OFF is implemented all other hours. Automatic photocell dimming is implemented in daylight zones. Override lighting control switch is located in locked panel within space (Reference Lighting Drawing L-2.0).*
Concert Hall		●	●		●			●		●		*All lighting within space to be controlled via DMX Lighting for advanced programming capability of fiber optics and stage lighting. All HVAC to be controlled via timeclock. General lighting and HVAC are programmed into a preset scene schedule prior to event. Lighting and HVAC are programmed for full ON two hours prior to event and automatic full OFF is implemented two hours post event. Override*
Recital Hall	●	●	●		●			●		●		*Lighting and HVAC are programmed into a preset scene schedule prior to event. Lighting and HVAC are programmed for full ON one hour prior to event. Automatic full OFF is implemented one hour post event. Override lighting control switch located at entryway*
Orchestral Rehearsal	●		●		●	●		●			●	*Lighting is programmed for automatic full ON/full OFF via occupancy sensor. Automatic photocell dimming is implemented in daylight zones. Automatic 50% receptacle load reduction control tied to occupancy sensor.*
Choral Rehearsal	●		●		●	●		●			●	*Lighting is programmed for automatic full ON/full OFF via occupancy sensor. Automatic photocell dimming is implemented in daylight zones. Automatic 50% receptacle load reduction control tied to sensor.*
Faculty Studios	●	●			●	●		●			●	*Lighting is programmed for manual full ON/automatic full OFF via vacancy sensor. Automatic HVAC control tied to vacancy sensor (Reference Mechanical Report 8.2.3). Automatic photocell dimming is implemented in daylight zones. Automatic 50% receptacle load reduction control tied to vacancy sensor.*
Practice Rooms	●	●			●	●		●			●	*Lighting is programmed for manual full ON/automatic full OFF via vacancy sensor. Automatic HVAC control tied to vacancy sensor (Reference Mechanical Report 8.2.3). Automatic photocell dimming is implemented in daylight zones. Automatic 50% receptacle load reduction control tied to vacancy sensor.*
Classrooms	●			●	●	●		●			●	*Lighting is programmed for automatic partial ON/automatic full OFF via occupancy sensor. Automatic HVAC control tied to occupancy sen sor (Reference Mechanical Report 8.2.3). Automatic photocell dimming is implemented in daylight zones. Automatic 50% receptacle load reduction control tied to occupancy sensor.*
Occupiable Roof Space				●	●	●		●		●		*Lighting and HVAC are programmed into a preset scene schedule prior to event. Lighting and HVAC are programmed for full ON one hour prior to event. Automatic full OFF is implemented one hour post event. Automatic photocell dimming is implemented in daylight zones. Override lighting control switch is located in Catering Room (Reference Lighting Drawing L-4.0).*
Restrooms	●			●				●				*Lighting is programmed for automatic partial ON/full OFF via occupancy sensor.*
Corridors			●				●		●			*Lighting is scheduled via timeclock is programmed for full ON between the hours of 7:00AM-7:00PM. Automatic partial OFF is implemented all other hours.*
Stairwells			●				●					*Lighting is programmed for automatic full ON/partial OFF via occupancy sensor.*
Mechanical/Electrical Rooms	●	●						●				*Lighting is programmed for manual full ON/full OFF.*
Storage/Back of House	●	●						●				*Lighting is programmed for manual full ON/automatic full OFF via vacancy sensor.*
Exterior									●			*Lighting is scheduled via timeclock and is programmed for full ON between the hours of 5PM-7:00AM.*

CONTROL TYPE	DESCRIPTION
Local Control	There are one or more manual controls that control all lighting within the space. Each device is readily accessible and located within view of the lights it is controlling.
Manual ON	No lights within the space atuomatically turn ON and are manually controlled by occupants.
Automatic Full ON	All lights within the space automatically turn ON.
Automatic Partial ON	All lights within the space automatically turn ON to no more than 50% light output.
Bilevel Control	All lights shall be controlled with at least one intermediate step or continuous dimming to at least 50% light output. Light level outputs are determined based on fixture capability. Manual override controls are readily accessible for occupant use.
Automatic Daylight Responsive Control	Spaces where lighting is contained completely or partially within daylight areas and is 150W or greater will be controlled by photocontrols. Dimming will have at least two levels between ON and OFF (one between 50%-70% and one between 20%-40% of design lighting power). Primary and secondary lighting zones are assigned for general lighting and are controlled separately. All calibration adjustments are readily accessible.
Automatic Partial OFF	All lights within the space automatically reduce to at least 50% within 20 minutes of vacancy.
Automatic Full OFF	All lights within the space will automatically shut OFF within 20 minutes of vacancy.
Timeclock Scheduled	All lights within the space are scheduled to operate at full ON during typical occupancy use hours and reduce to at least 50% light output when operating outside of typical occupancy use hours. The lights will automatically turn ON, dim, and turn OFF based on the schedule applied.
Preset Scene Scheduled	Lights within the space are to be programmed into presest scenes prior to occupancy. Preset scenes will include automatic full on and full and is based on estimated occupancy. All preset scenes may be modified at any time and will include a maximum of ten preset scenes not includinga automatic full ON and full OFF.
Receptacle Control	All 125V, 15-20A receptacles within the space shall atuomatically shut OFF after 20 minutes of vacancy.

Lutron Vive Wireless System Integration



SYNDICATE'S DASHBOARD VISUAL DISPLAY

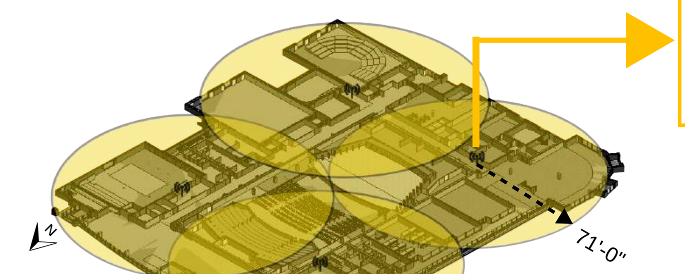
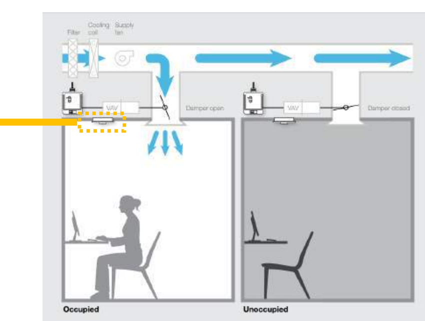


Figure above depicts the typical location of each *Lutron Vive Wireless Hub* per floor. Each Hub encompasses a 71' radius of control. The third-floor Southeast Quadrant does not contain a Hub due to no interior spaces in this quadrant.

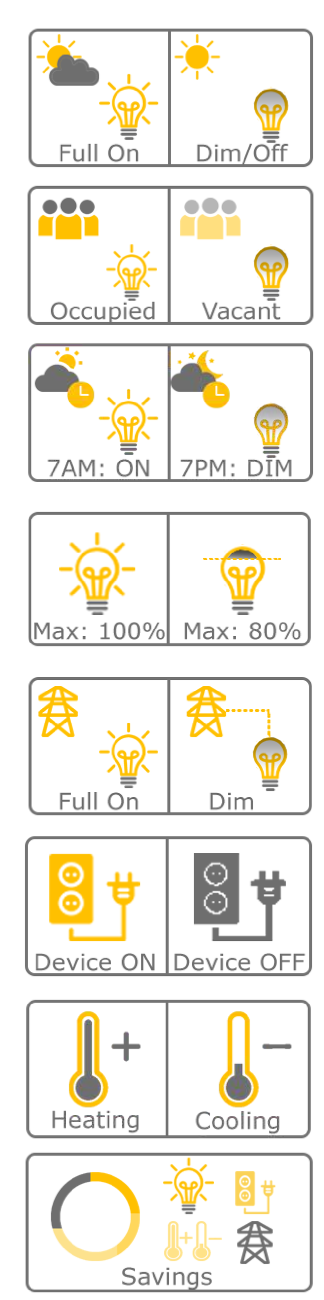
Lutron Vibe Hub

Lutron Radio Powr Savr Sensors



Schematic representation of Radio Powr Savr sensor communication with HVAC system (Provided by Lutron)

Lighting Controls Summary- ***Lutron Vive***



Daylight Harvesting
Dimming of electric lighting when sufficient daylight levels are present, resulting in potential savings of 25-60% in electric lighting costs.

Occupancy/Vacancy Sensing
Sensing occupancy within a space and turning off electric lighting after a period of vacancy, resulting in potential savings of 20-60% in electric lighting costs.

Timeclock Scheduling
Providing programmed changes in the electric lighting levels based on the time of day, resulting in potential savings of 10-20% in electric lighting costs.

High End Trimming
Setting maximum allowed light levels based on each space to reduce the production of excess light, resulting in potential savings of 10-30% in electric lighting costs.

Demand Response
Automatically reducing electric light levels during demand periods, resulting in potential savings of 30-50% in peak period costs.

Plug Load Control
Automatically turning off loads after a period of vacancy, resulting in potential savings of 15-20% in controlled electric load.

HVAC Integration
Controlling the heating, cooling, and ventilation systems through BACnet protocol, resulting in potential savings of 5-15% in HVAC costs.

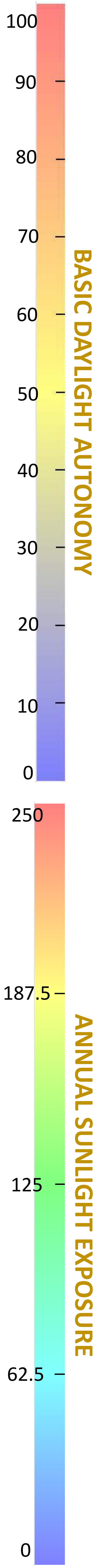
Dashboard System
Identifying important lighting, electrical, and HVAC consumption and coordinating with Lutron's Quantum energy management system to display the energy conscious design.

SYNDICATE

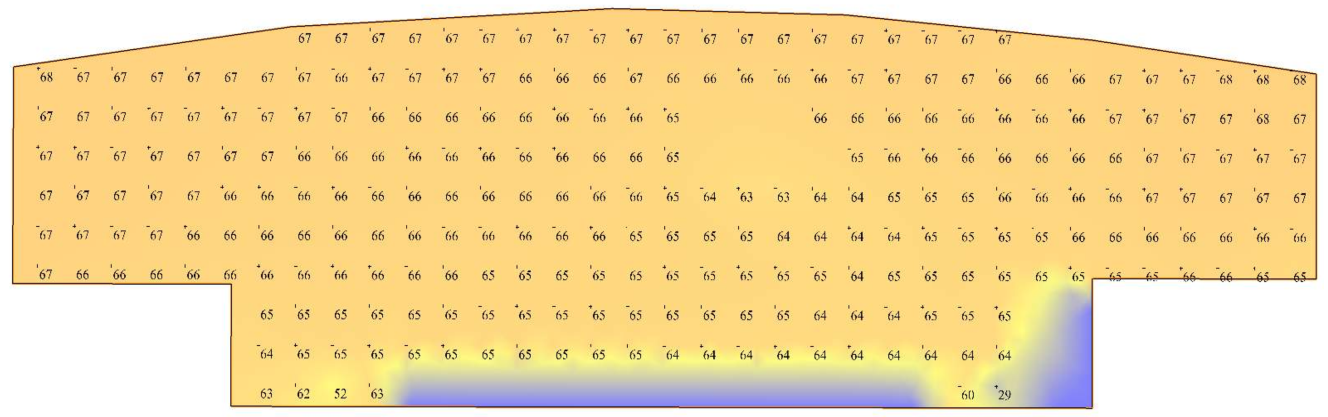
PROJECT
JACK H. MILLER CENTER FOR MUSICAL ARTS
HOLLAND, MICHIGAN

SHEET TITLE
Lighting Controls & Energy Savings

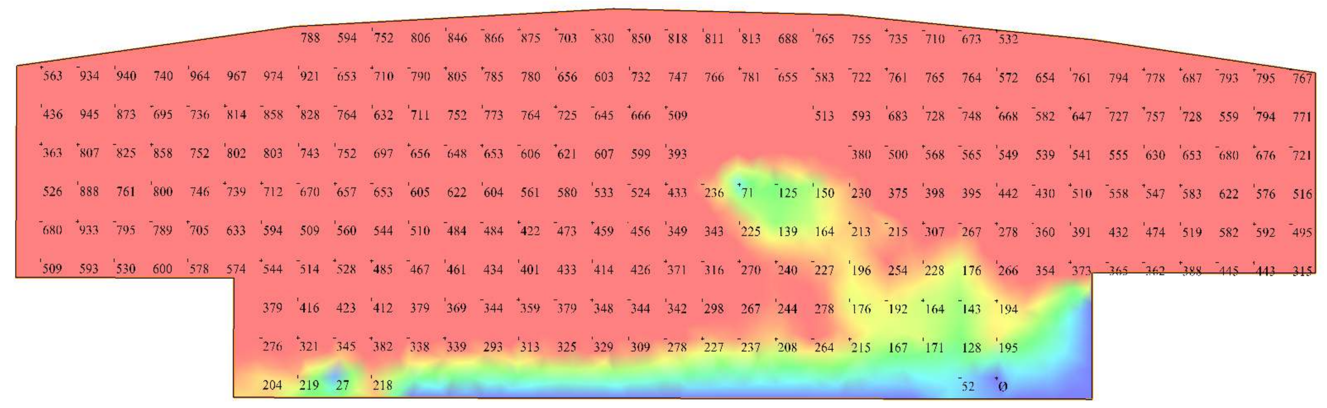
NOT FOR CONSTRUCTION	AEI TEAM NO. 01-2019
DATE February 18, 2019	SCALE NOT TO SCALE
DRAWING NO. L-5.0	PAGE NO. 115



GIVEN ORIENTATION—WEST FACING

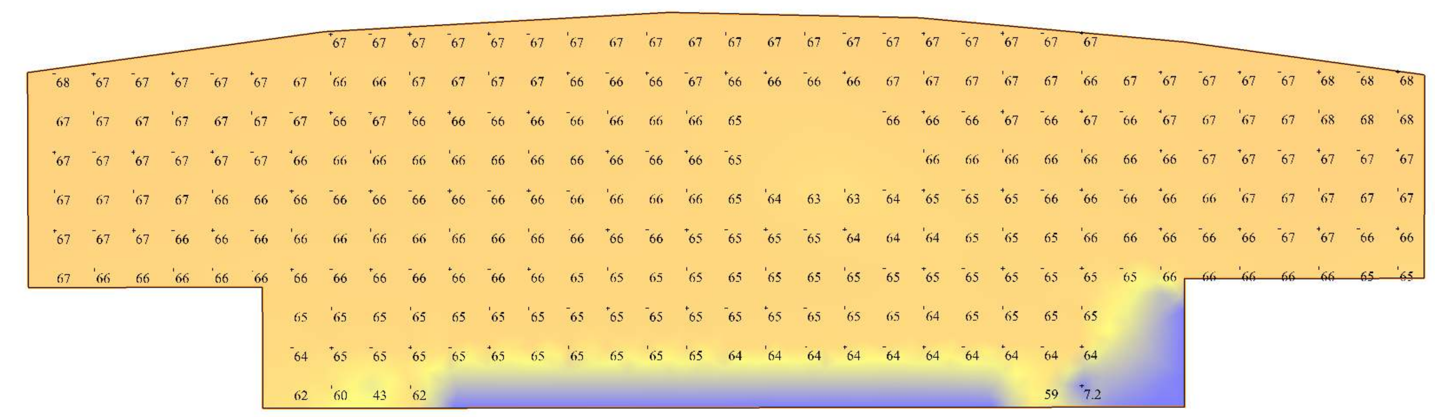


DA_300 = 100%

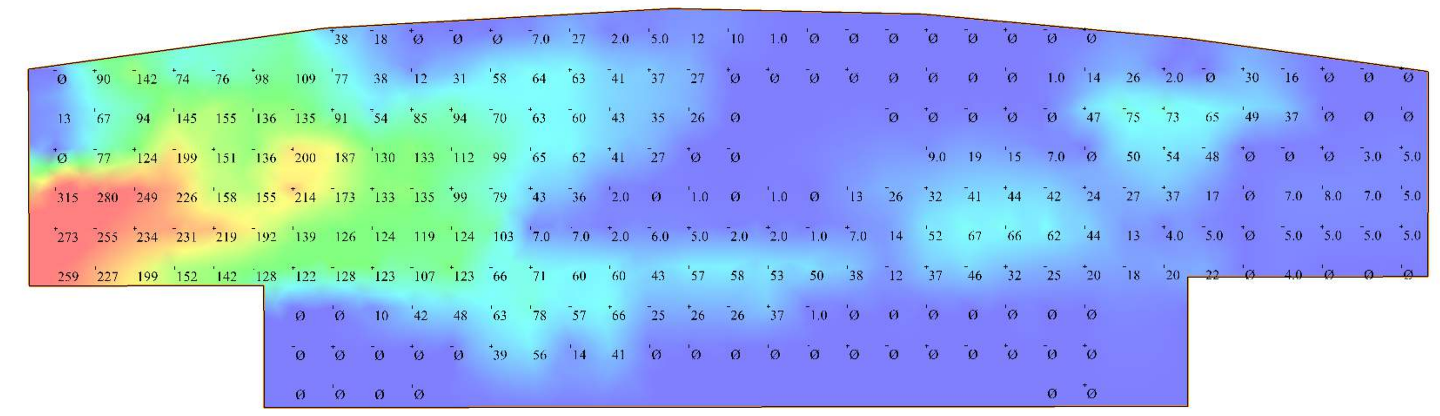


ASE = 87%

SYNDICATE'S ORIENTATION –NORTH FACING



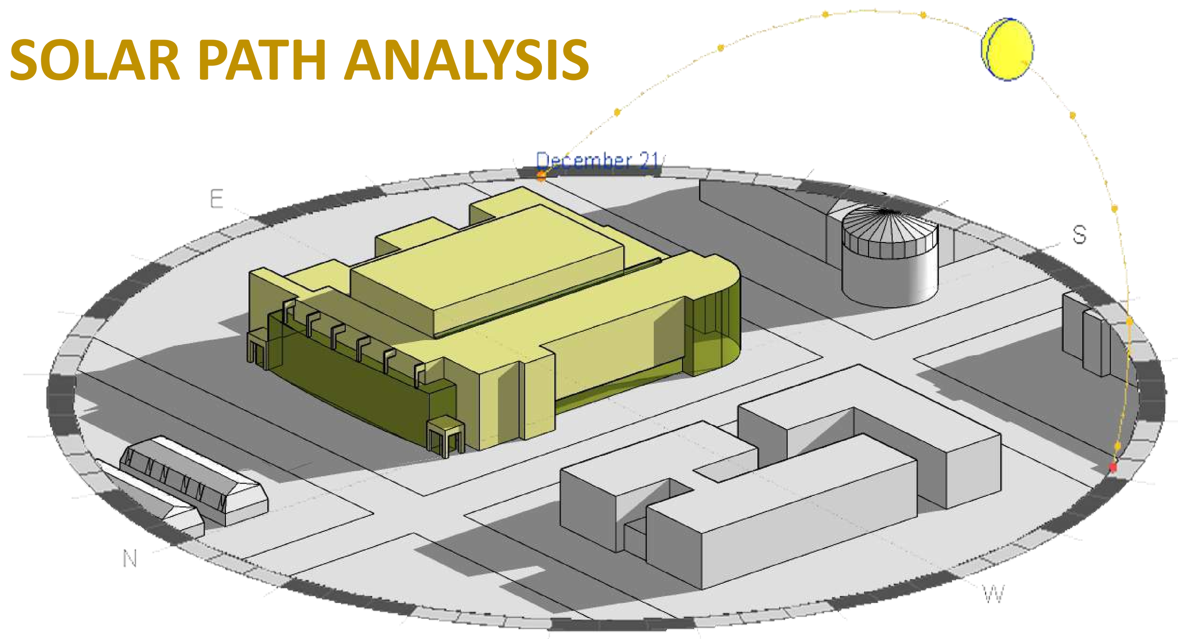
DA_300 = 99%



ASE = 1.8%

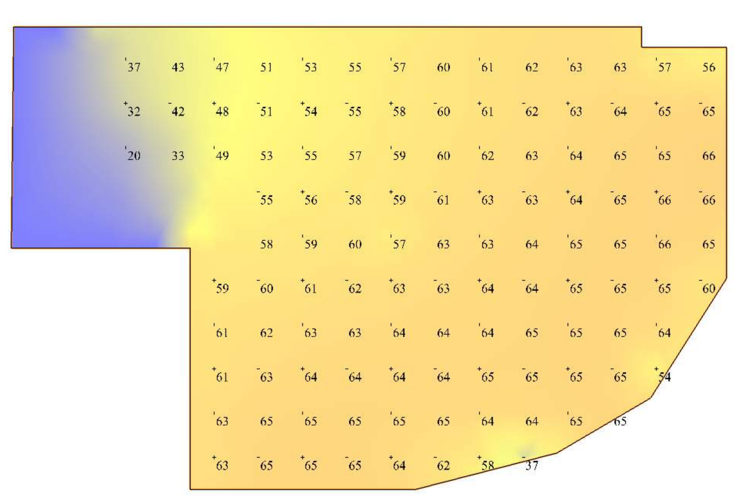
Prior to designing any of the systems of the building, *Syndicate* analyzed the pros and cons of orienting The Miller Center to face north instead of the given west facing façade. Immediately, the team was aware that the west facing atrium would let in ample amounts of direct sunlight, thus causing discomfort and glare for the occupants inside. The analysis was run at 300 lux, following the typical higher educational building criteria for illuminance. *Syndicate's* orientation provides an annual sunlight exposure (ASE) of 1.8% in comparison to the original 87% ASE when faced west. However, a key design to point out is that while *Syndicate* was able to reduce the direct sunlight into the lobby, we were still able to achieve ample amounts of daylight at 99% daylight autonomy (DA), not breaching far from the 100% DA in the given orientation.

SOLAR PATH ANALYSIS

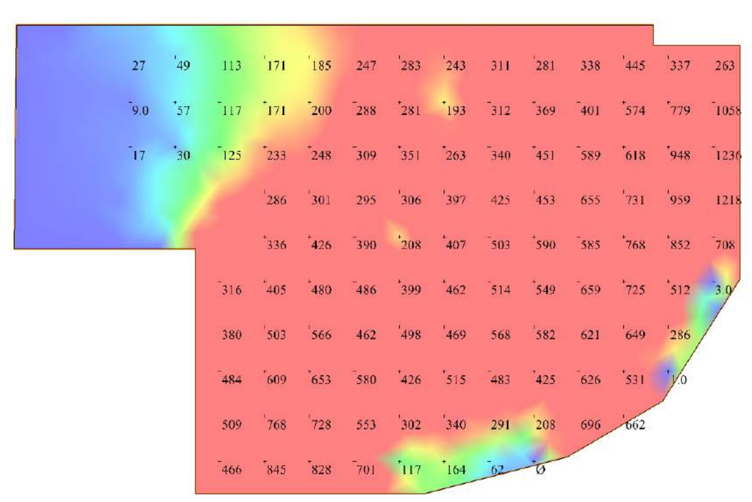


In order to generate a better understanding on the affect of the surrounding buildings on The Miller Center, *Syndicate* analyzed the sun's path on both equinoxes, the summer solstice, and the winter solstice (shown above). The Miller Center stands tallest at 64' to the top of the central concert hall, with surrounding buildings like the Martha Miller Center at 35'. Concluding that shadowing would not be an issue for our building, *Syndicate* furthered the approach to incorporate as much daylight as possible. However, given the original orientation of The Miller Center it was obvious that more direct sunlight was penetrating through our major curtain wall façade, creating discomfort for the occupants. There was also a lack of daylit spaces throughout the entirety of The Miller Center, which *Syndicate* took upon themselves to amend.

SOUTH LOBBY—30% TRANSPARENT WINDOWS



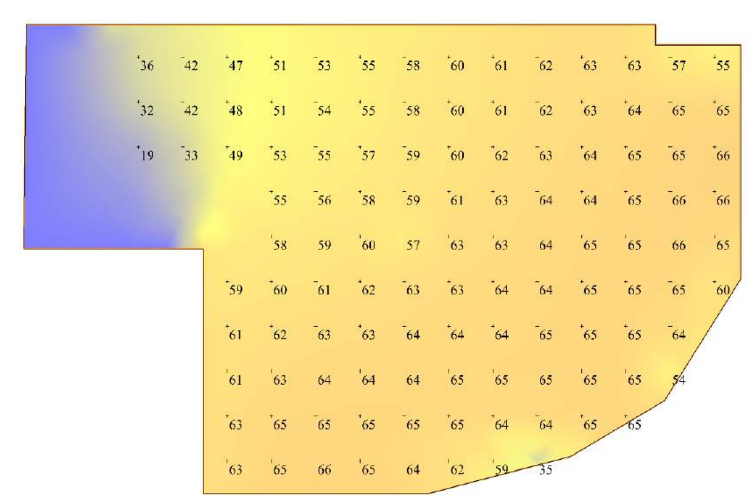
DA_300 = 91%



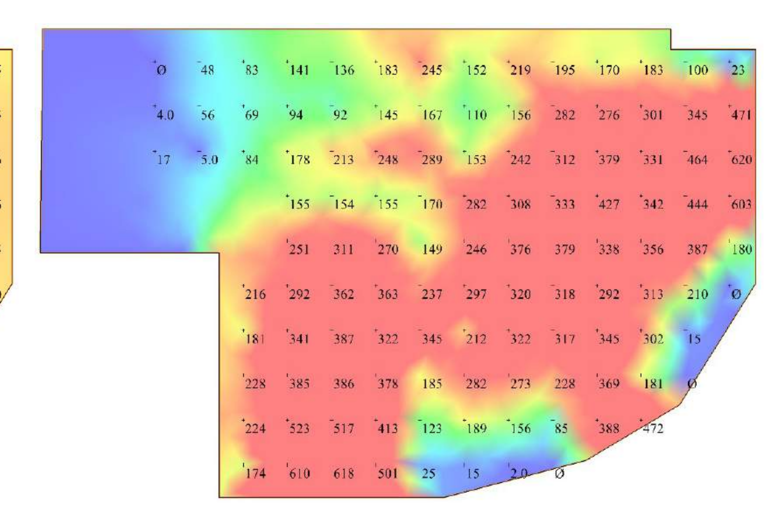
ASE = 78%

ITERATION 1

SOUTH LOBBY— 30% TRANSPARENT WINDOWS & HORIZONTAL LOUVERS



DA_300 = 91%

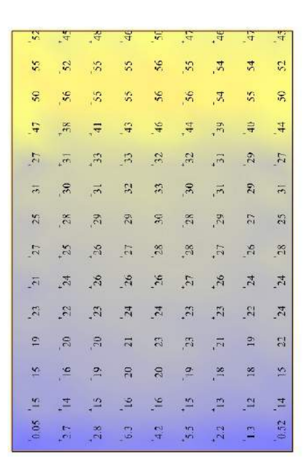


ASE = 48%

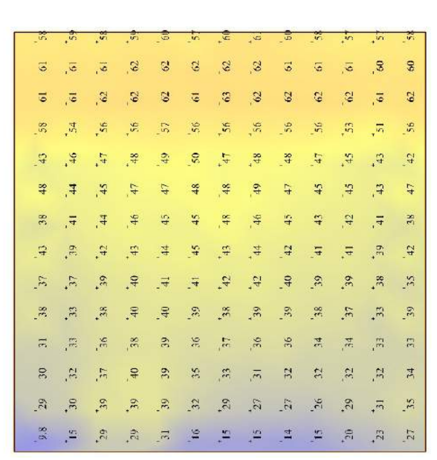
OPTIMIZED ITERATION

The re-orientation of the building provided *Syndicate* with another opportunity to bring daylight into The Miller Center. A second lobby was added to the southwestern side of the building to welcome all students and faculty in a more intimate manner than when entering the building. Taking inspiration from The Martha Miller Center across the street, a glass and brick rotunda was created. However, with a large amount of glazing facing the southwest direction, comes direct solar glare and discomfort. To combat this, *Syndicate* analyzed many iterations (two of which are shown) including combinations of tinted windows and different louver lengths and counts. With four rows of louvers per column of curtain wall and 30% transparent windows, we were able to reduce the ASE to 48% from the original 100% while keeping DA at 91%.

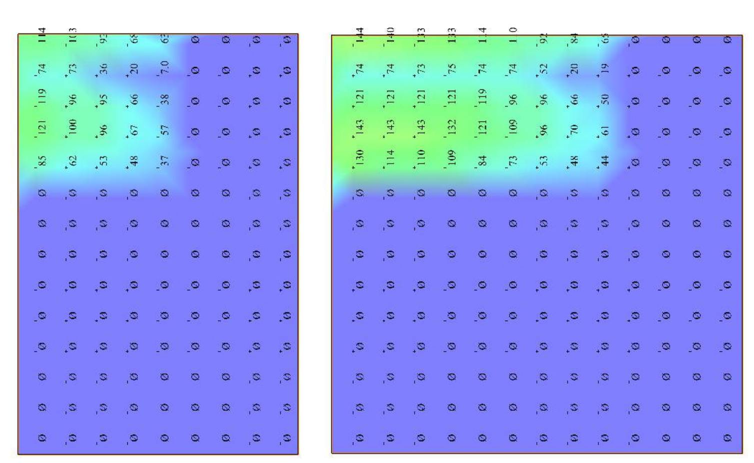
SKYLIGHT ROOMS



DA_300 = 14%



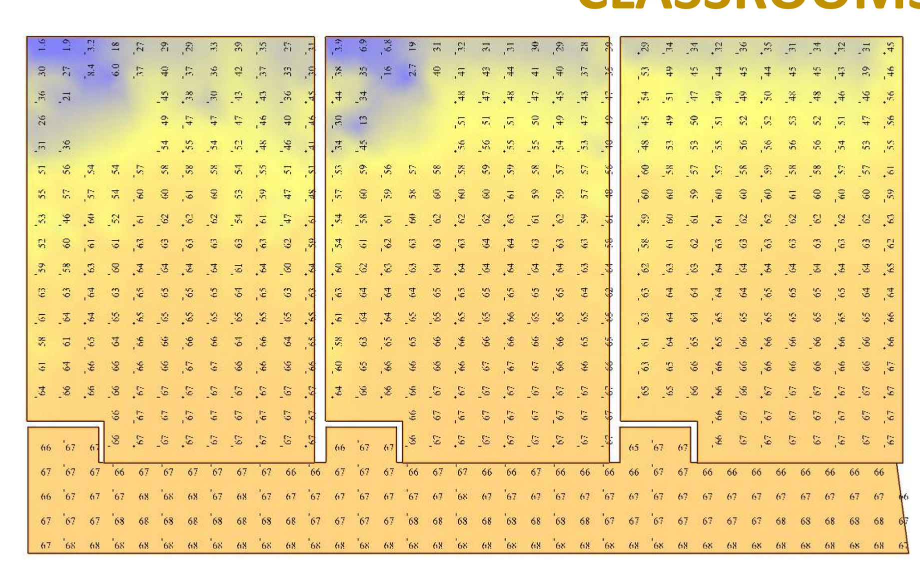
DA_300 = 29%



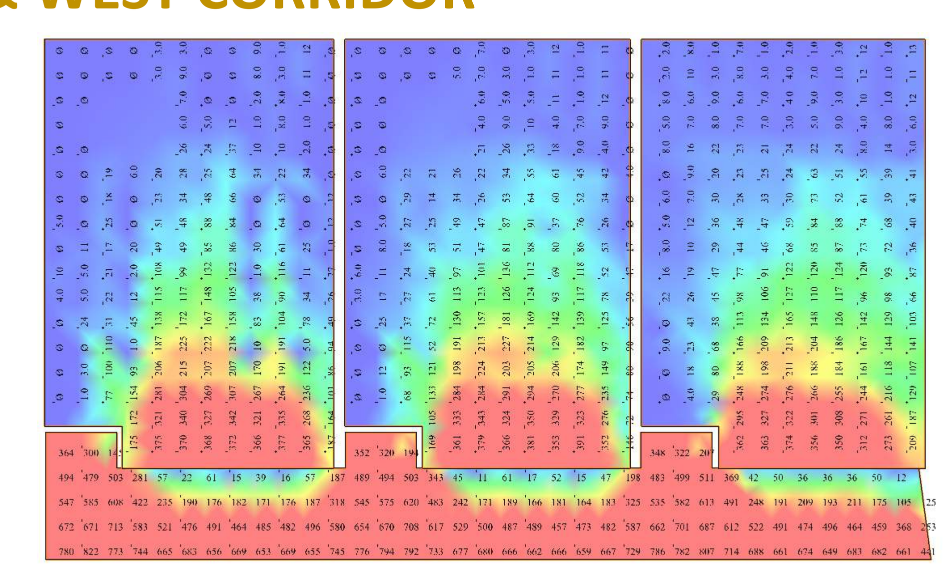
ASE = 0%

In order to successfully implement daylight into most of the spaces, faculty offices (right grid) and practice rooms (left grid) were organized to encompass the second and third floor western facades. For spaces without access to the exterior walls, tilted skylights were incorporated to admit natural daylight. The larger faculty offices allow for more daylight due to the larger span of glass above in comparison to the half-size practice room. Direct sunlight is not an issue because the 64' tall concert hall walls are able to block any direct sunlight until the late afternoon hours.

CLASSROOMS & WEST CORRIDOR



DA_300 = 82%



ASE = 23%

In the given design, the three classrooms within this facility were left dark with no daylight. Quickly, that was able to change when *Syndicate* was given the opportunity to incorporate an accent curtain wall façade corridor that connects the south lobby to the north lobby. Setting the classrooms back into the corridor against the concert hall and implementing large glazing on the entrance wall to the classrooms allowed for daylight to penetrate into the classrooms while minimizing solar heat gain and direct sunlight within the space. While the ASE is only at 23%, *Syndicate* still implemented a *Smart Tint* self-adhesive film on the classrooms to add an extra layer of comfort for the occupant's in times when glare is present.

PROJECT

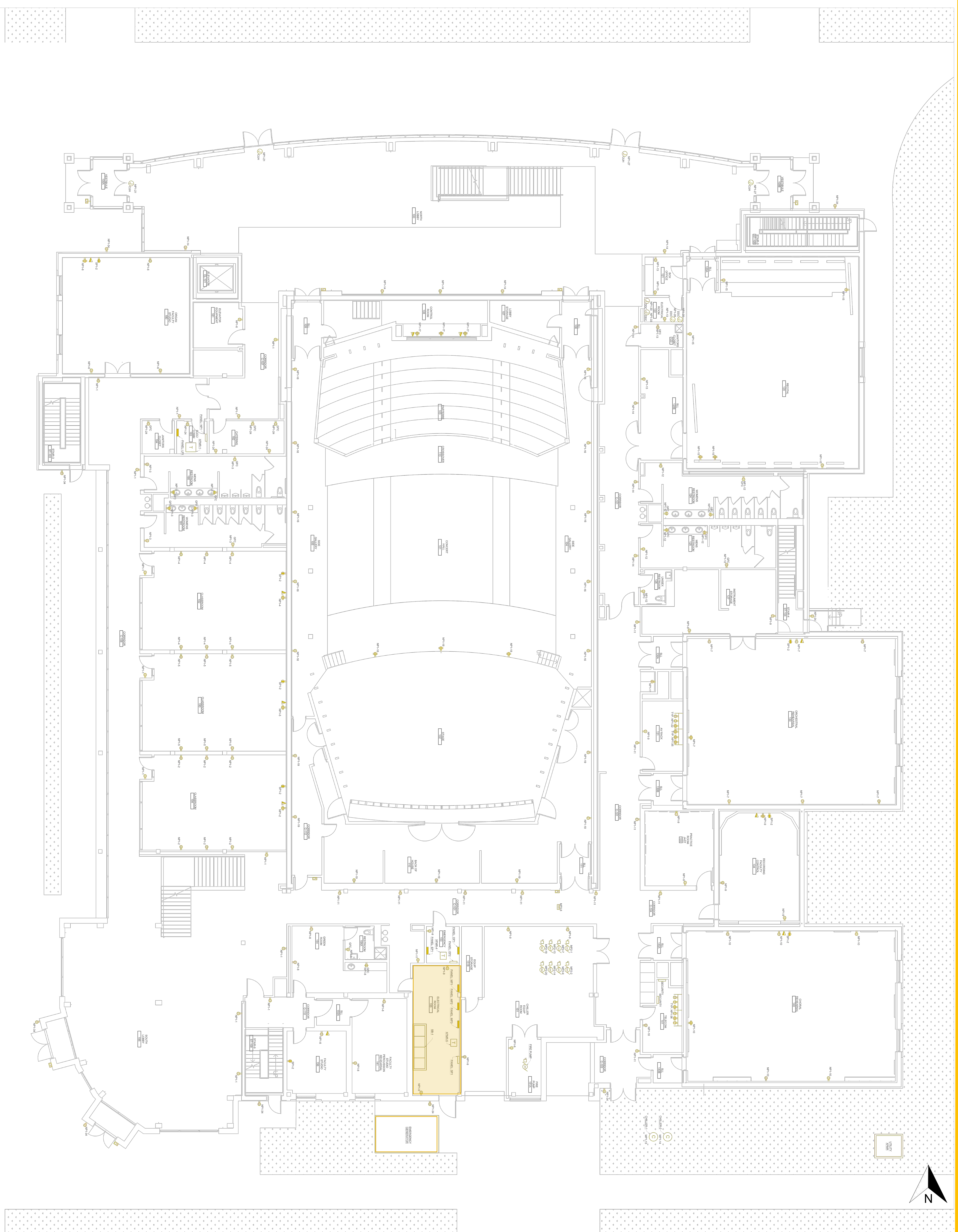
JACK H. MILLER CENTER OF MUSICAL ARTS

HOLLAND, MICHIGAN

SHEET TITLE

Daylighting Analysis Iterations

NOT FOR CONSTRUCTION	AEI TEAM NO. 01-2019
DATE February 18, 2019	SCALE NOT TO SCALE
DRAWING NO. L-6.0	PAGE NO. 116



ELECTRICAL EQUIPMENT ABBREVIATIONS

ABBREVIATION	DESCRIPTION
XFMR	TRANSFORMER
SB	SWITCHBOARD
ATS	AUTOMATIC TRANSFER SWITCH
STS	STANDBY POWER TRANSFER SWITCH
FP	FIRE PUMP
CW	CHILLED WATER PUMP
HW	HOT WATER PUMP
SM	SNOW MELT PUMP
GM	GLYCOL MIX PUMP
VAV	VARIABLE AIR VOLUME
CR	CARD READER
DDC	DEDICATED CONTROLS CIRCUIT
CUH	UNDER CABINET HEATER

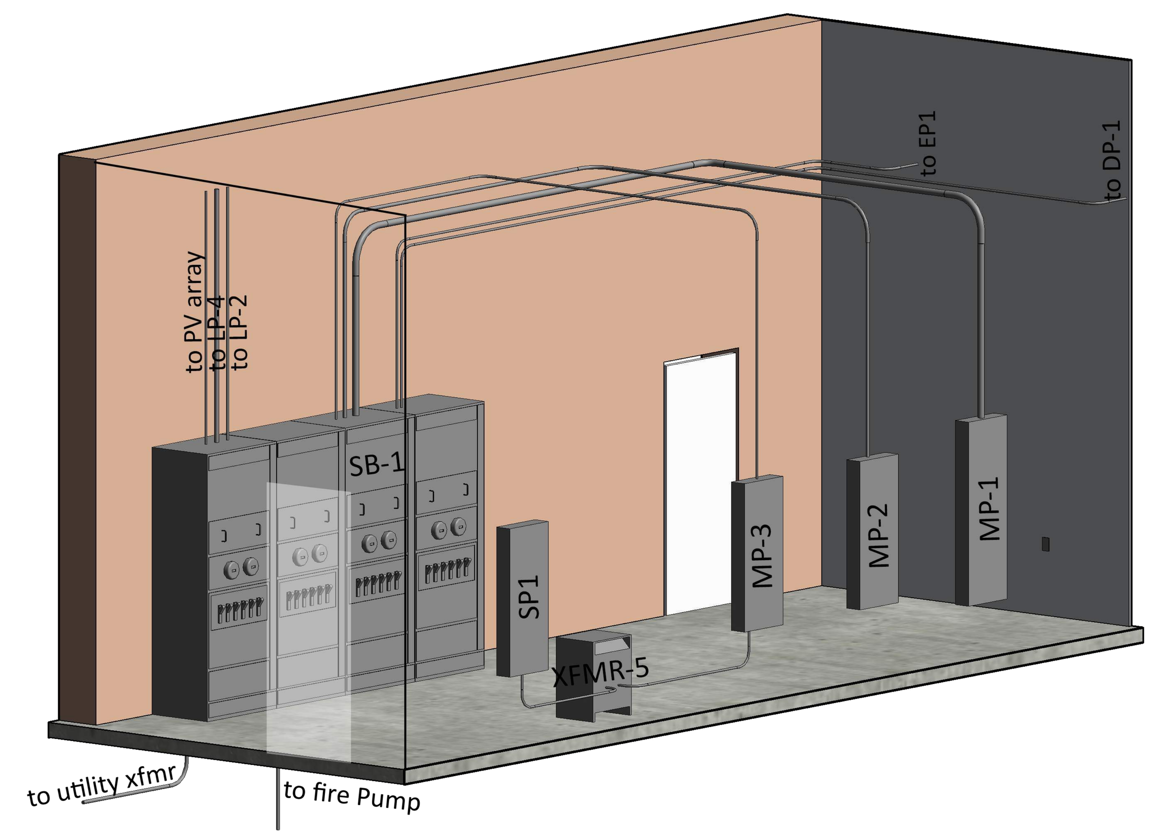
ELECTRICAL NAMING CONVENTION KEY

PB-# → *Panelboard Location, Circuit Designation Number*

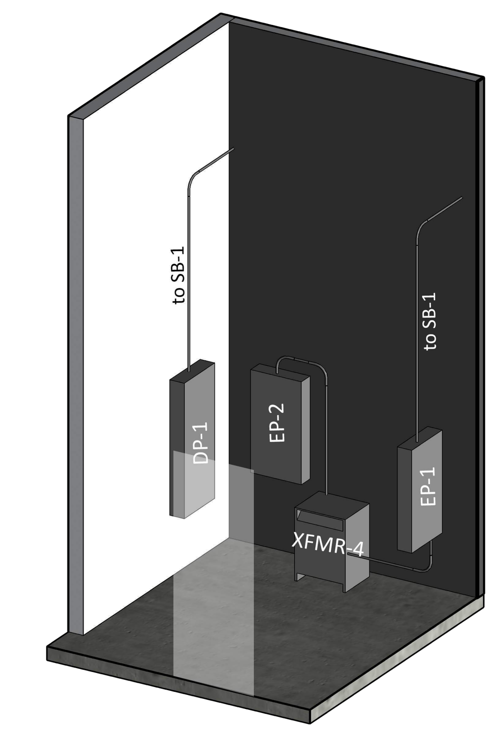
ELECTRICAL POWER & EQUIPMENT SYMBOLS

	DUPLEX RECEPTACLE
	ABOVE COUNTER DUPLEX RECEPTACLE
	QUADPLEX RECEPTACLE
	STANDBY DUPLEX RECEPTACLE
	LOCKING DUPLEX RECEPTACLE
J	JUNCTION BOX
	TELECOMM/DATA PORT
CR	WALL MOUNTED CARD READER
CR	PEDESTAL MOUNTED CARD READER
	480Y/277V SURFACE MOUNTED PANELBOARD
	208Y/120V SURFACE MOUNTED PANELBOARD
T	SECONDARY TRANSFORMER
	MOTOR & CONNECTION
VAV	VAV BOX
C	CHILLER
	DISCONNECT STRESS

MAIN ELECTRICAL ROOM



EMERGENCY ELECTRICAL ROOM



SOLID OXIDE FUEL CELL

The location of the *BloomEnergy* Solid Oxide Fuel Cell power generator is shown to be adjacent to the main electrical room on the exterior side of The Miller Center. This fuel cell will connect to the natural gas lines running through Holland, Michigan.

SYNDICATE

PROJECT

JACK H. MILLER CENTER FOR MUSICAL ARTS

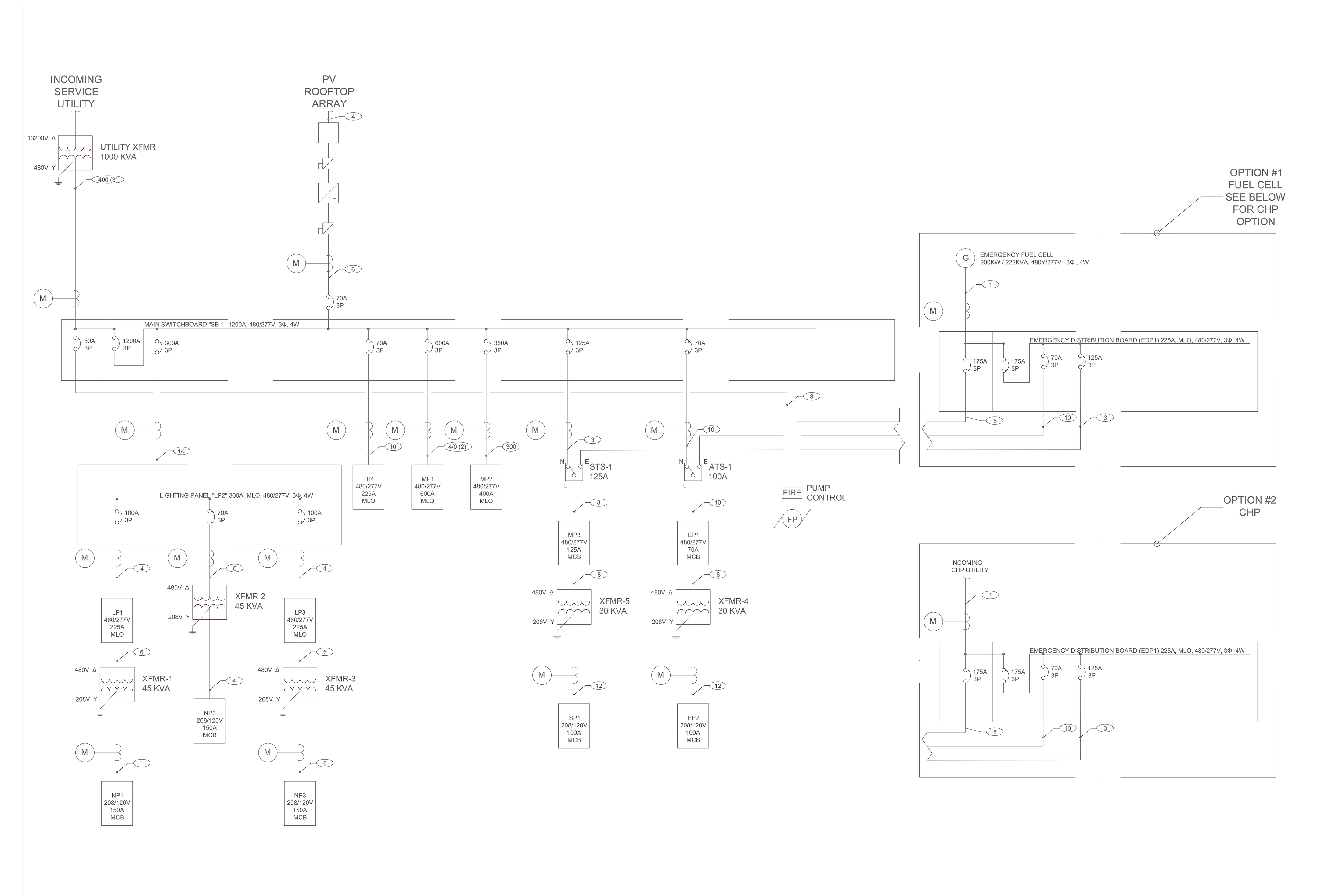
HOLLAND, MICHIGAN

SHEET TITLE

FIRST LEVEL POWER PLAN

NOT FOR CONSTRUCTION	AEI TEAM NO. 01-2019
DATE February 18, 2019	SCALE NOT TO SCALE
DRAWING NO. E-1.0	PAGE NO. 117

SINGLE LINE DIAGRAM



MECHANICAL/ELECTRICAL COORDINATION SCHEDULES

AIR HANDLING UNIT SCHEDULE

Tag	Voltage/Phase/Hz	Supply Fan [hp]	Equivalent Load per Pole [VA]	Return Fan [hp]	Equivalent Load per Pole [VA]
AHU-1	480/3/60	10.0	15541.7	10.0	15541.7
AHU-2	480/3/60	10.0	15541.7	10.0	15541.7
AHU-3	480/3/60	15.0	23312.5	15.0	23312.5
AHU-4	480/3/60	10.0	15541.7	10.0	15541.7
AHU-5	480/3/60	10.0	15541.7	10.0	15541.7
AHU-6	480/3/60	5.0	7770.8	5.0	7770.8
AHU-7	480/3/60	5.0	7770.8	5.0	7770.8

VARIABLE AIR VOLUME SCHEDULE

Tag	Volt / Phase	Horse power [hp]	Equivalent Load [VA]
VAV-1	120 V/ 1	1	745
VAV-2	120 V/ 1	1	745
VAV-3	120 V/ 1	1	745

PUMP SCHEDULE

Tag	Volt / Phase	Horse power [hp]	Equivalent Load per Pole [VA]
HWP-1	480/3	40.0	53285.7
HWP-2	480/3	60.0	79928.7
CHWP-1	480/3	30.0	39964.3
GW-1	480/3	25.0	33303.5

SYNDICATE

PROJECT

JACK H. MILLER CENTER FOR MUSICAL ARTS

HOLLAND, MICHIGAN

SHEET TITLE

SECOND LEVEL POWER PLAN

NOT FOR CONSTRUCTION

AEI TEAM NO. 01-2019

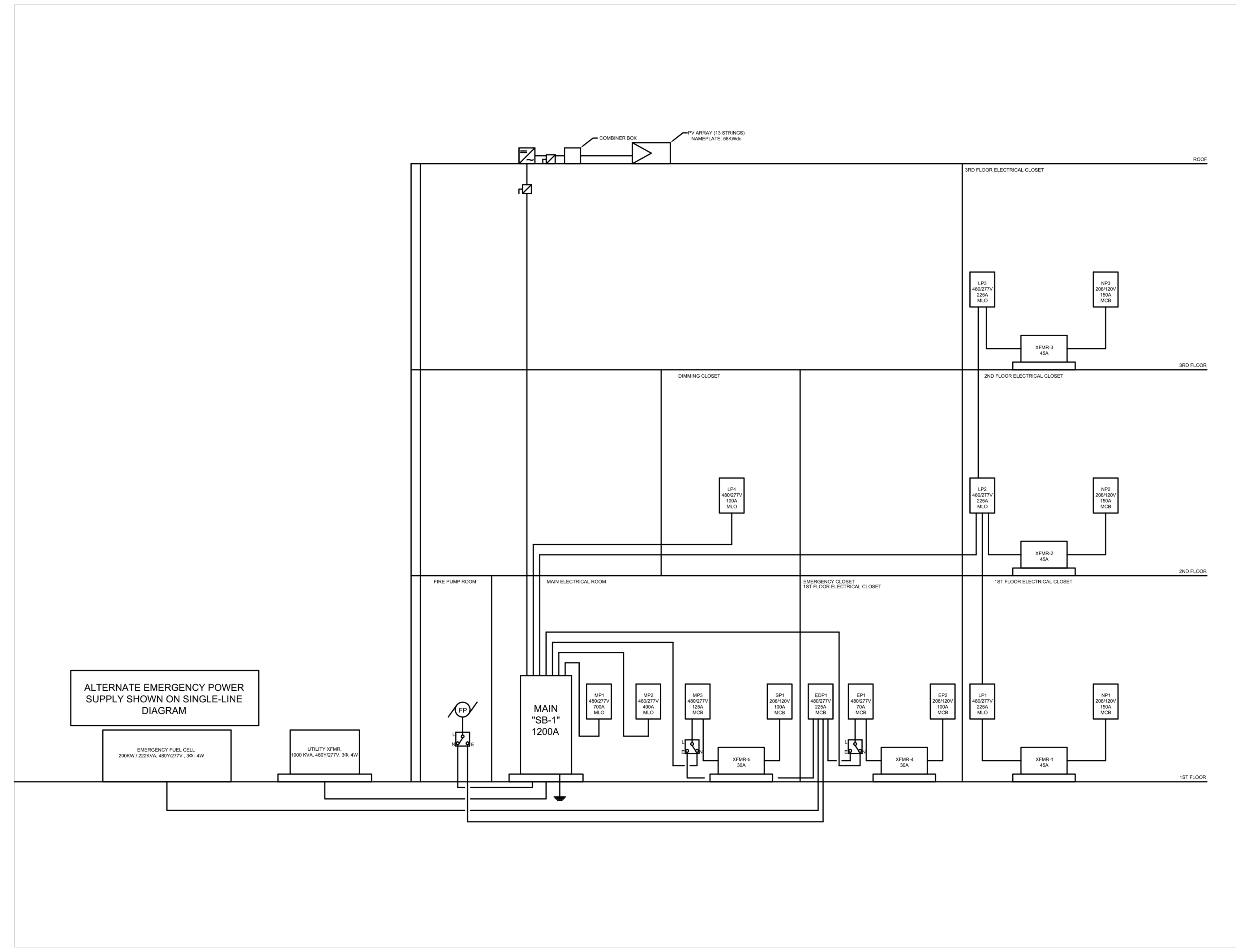
DATE February 18, 2019

SCALE NOT TO SCALE

DRAWING NO. E-2.0

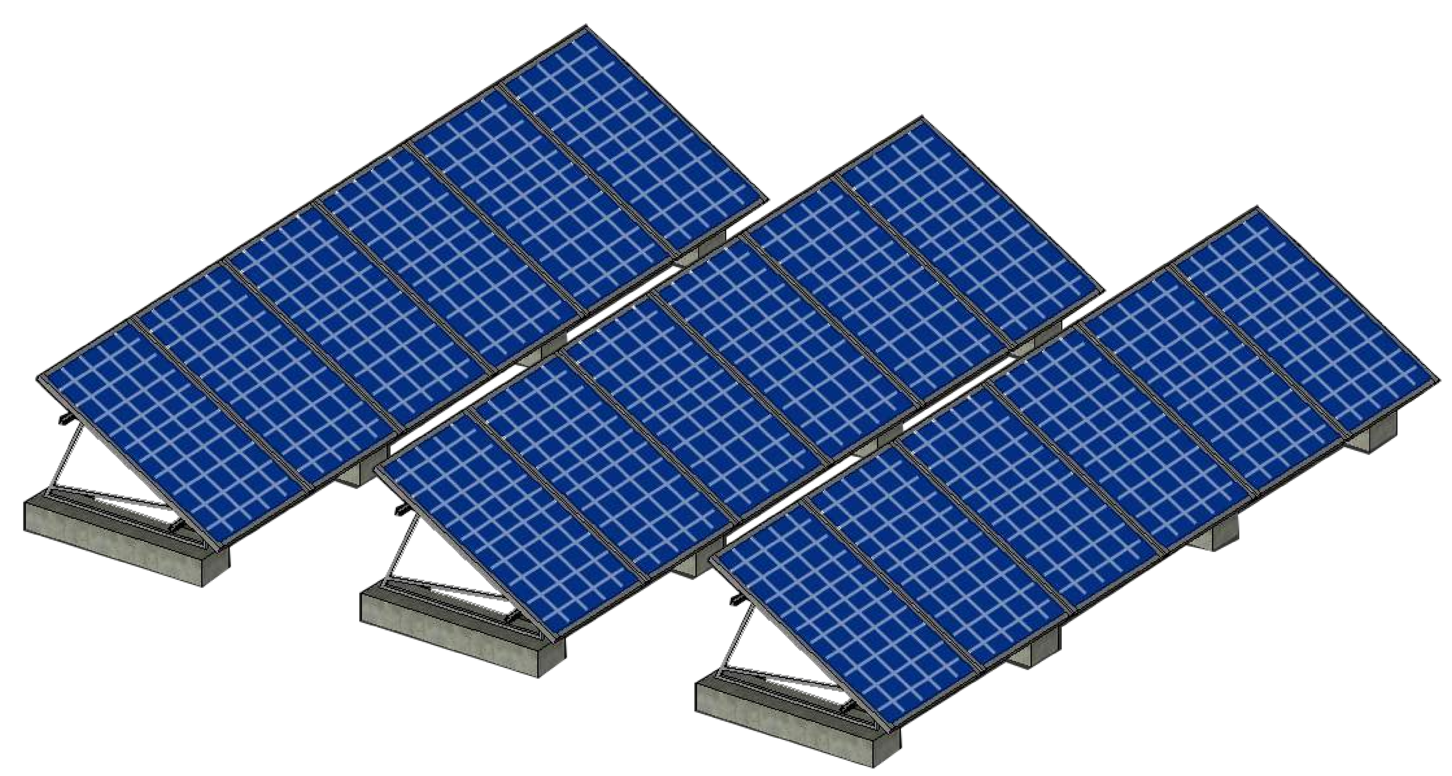
PAGE NO. 118

RISER DIAGRAM



PHOTOVOLTAIC ROOFTOP ARRAY

To achieve the most efficient power production possible *Syndicate* designed the photovoltaic roof top array to have a mounting angle of 43-degrees. With the projects geographic location the electrical design team found a due south orientation allowed for the maximum number of panels to be mounted with the highest power generation. One major challenge in the design of a photovoltaic system is the loss in efficiency due to shadows. For the design of The Miller Center's PV-array the design team did not need to consider shadows from nearby obstructions as the panels are mounted on the rooftop of the 60' concert hall. Self-shadowing was a major concern however, and the design team performed calculations to find a balance between the required spacing to avoid large losses and still have an ample number of panels on the roof. *Syndicate* found that a 5' spacing would accomplish this goal allowing for 13 rows of panels to be installed onto the roof. The final design utilizes a total of 140 photovoltaic panels with a minor 5.9% shadow loss factor.



SYNDICATE

PROJECT

JACK H. MILLER CENTER FOR MUSICAL ARTS

HOLLAND, MICHIGAN

SHEET TITLE

THIRD LEVEL POWER PLAN

NOT FOR CONSTRUCTION	AEI TEAM NO. 01-2019
DATE February 18, 2019	SCALE NOT TO SCALE
DRAWING NO. E-3.0	PAGE NO. 119

Panel Schedules

EDP1, EP1, EP2, MP1, MP2, MP3, LP1, LP2, LP3, LP4, NP1, NP2, NP3, SP1

SWITCHBOARD: SB-1

LOCATION: ELECTRICAL ROOM 155
SUPPLY FROM: ELECTRIC GRID
MOUNTING: FLOOR MOUNTED
ENCLOSURE: -

VOLTAGE: 480/277
PHASE: 3
WIRE: 4

A.I.C. RATING: 42,000A
BUS RATING: 1200A
MAIN TYPE: MCB, BOTTOM ENTRY
MCB RATING: 1200A

CKT	CIRCUIT DESCRIPTION	# OF POLES	FRAME SIZE	TRIP RATING	LOAD
1	LP2	3	400A	300A	103800 VA
4	LP4	3	100A	40A	8300 VA
5	EP1	3	100A	70A	19600 VA
6	MP1	3	700A	600A	360300 VA
7	MP2	3	400A	350A	231000 VA
8	MP3	3	225A	125A	80500 VA
				TOTAL CONN. LOAD:	799000 VA
				TOTAL AMPS:	961 A

SYNDICATE

PROJECT

JACK H. MILLER CENTER OF MUSICAL ARTS

HOLLAND, MICHIGAN

SHEET TITLE

PANELBOARDS

NOT FOR CONSTRUCTION

AEI TEAM NO.
01-2019

DATE
February 18, 2019

SCALE
NOT TO SCALE

DRAWING NO.
E-4.0

PAGE NO.
120

0.0 CONSTRUCTION EXECUTIVE SUMMARY

CONSTRUCTABILITY

- Coordinated underground duct system with structural foundations
- Created BIM plan to enhance total building systems and constructability

DELIVERY METHOD

- Integrated design-build facilitated a multidisciplinary approach
- Minimized amount of contracts for owner
- Full team involved from project conception
- Allowed for faster construction, safer design, and higher quality

SUSTAINABILITY

- Created a new sustainability plan for Hope College
- Encourages environmentally focused design and construction practices
- Incorporates current university efforts

QUALITY

- Developed a robust quality plan for construction of heavy timber and concrete precast panels
- Implemented QR code tracking technology and regular acoustically focused meetings with subcontractors

COST

- Total budget: $23,926,850.00
- Delivered the project $1,073,150.00 under the $25 million budget
- Breakdown:
  - Services: 32%
  - Shell: 23%
  - Interiors: 16%
  - Fee: 12%
  - Equip/Furnishings: 8%
  - GCs: 7%
  - Substructure: 2%

SCHEDULE

- Total construction schedule is 16 months
- Expedited traditional schedule by 3 months through fast-tracking
- Phased to allow for a higher level of control and organization
- Implemented parade of trades to mitigate conflict

Construction Table of Contents

1.0 PROJECT OVERVIEW

The Jack H. Miller Center for Musical Arts (The Miller Center) is a proposed building project for Hope College located in Holland, Michigan. *Syndicate* is an integrated design-build team that produced a high-quality design and construction plan for this project. The project site is situated in the northeast corner of campus across from downtown Holland, near Lake Michigan. The Miller Center acts as an investment for the future of Hope College and as a showcase pilot for a new sustainability plan on campus. The addition of an occupiable roof and south lobby allows this building to act as a gateway space for connecting Hope College campus to downtown Holland. *Syndicat*e's final design is a three-story building designed for serving the educational and performance requirements of Hope College. Totaling 70,000 square feet (SF), The Miller Center includes an 800-seat symphonic concert hall, a smaller recital hall for intimate chamber performances, and two large rehearsal spaces for choirs and orchestras. The building also includes classrooms, faculty studios, and student practice rooms distributed throughout the three stories.

2.0 VISION STATEMENT

Through a multidisciplinary team strategy, *Syndicate* produced a high-quality center for musical arts that met the goals and mission of Hope College. As a team, *Syndicate* chose to pursue this project with a vision statement that would contain individualized team and discipline goals. The vision statement is HOPE and the goals are to:

Enhance **H** ope College Campus

Maximize **O** ccupant Experience

Create Premier **P** erformance Spaces

Minimize **E** nergy Impact

Refer to Integration SD-A for details about the vision statement.

3.0 PROJECT GOALS

To achieve HOPE, *Syndicate* created specific integration goals for these four vision statements. Below are the objectives for the construction team to meet the integrated team goals.

3.1 Enhance Hope College Campus

In order to meet *Syndicate's* goal of enhancing Hope College campus, the construction team developed a schedule and site logistics plan that minimizes campus disturbance and mitigates possible exposure to safety hazards.

3.2 Maximize Occupant Experience

To maximize the occupant experience, *Syndicate's* construction team facilitated open discussions and constant coordination between the design entities to ensure all options were thoroughly considered. *Syndicate* also implemented a parade of trades sequence in the construction schedule to ensure a high focus on finishes and minimize conflicts.

3.3 Create Premier Performance Spaces

Syndicate's construction team has created a rigorous Quality Assurance / Quality Control (QA/QC) system to ensure that all performance spaces are constructed with the utmost attention to acoustic excellence. Various isolation techniques were considered in order to minimize the possibility of sound and vibration mitigation from room to room.

3.4 Minimize Energy Impact

To further the university's sustainability efforts, a new sustainability plan for Hope College was created by *Syndicate* to be implemented campus-wide. This owner-based plan allows the team to minimize the energy impact of their design. It will first be applied to The Miller Center as a pilot to ensure the Hope College Sustainability Plan meets all of the university's environmentally conscious needs before it is applied to any future projects.

4.0 INTEGRATED DESIGN AND DELIVERY

Figure 1: *Delivery Method*

Syndicate offers its services under an integrated design-build delivery method. This delivery method allows streamlined communication between the owner and the project team. *Syndicate* wanted to ensure that Hope College is an integral part of the design and construction process when providing this premier space for its user groups. Through this delivery method, Hope College will only have one contract and one point of contact for the designers and construction professionals. This method ensures that the team is providing the best quality while budgeting reasonably. The designers and construction professionals will be delivering on a fast-tracked timeline because they are under one roof and collaborate from project conception. Refer to *Figure 1* for The Miller Center's organizational chart.

4.1 Stakeholder Analysis

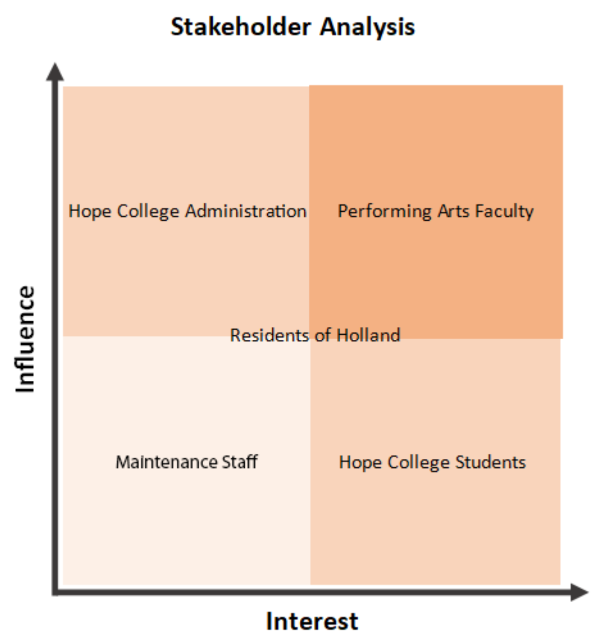


Figure 2: *Stakeholder Analysis*

Syndicate has performed a stakeholder analysis (refer to *Figure 2*) to determine how and when each stakeholder should be incorporated into the project and at what stage. The Hope College Administration has the highest level of influence over this project because they control the funds and programming but will not experience the day-to-day performance of the building like the faculty and students. Therefore, *Syndicate* will include administration heavily at the beginning of the project and keep them informed at a high level, expecting that they provide the project team with a budget and expected schedule. The faculty and students will be involved at a more detailed level, such as classroom layout and storage spaces. They will participate in design reviews with *Syndicate* at various times throughout the design process to ensure the spaces are meeting their needs using both renderings and virtual reality. Another stakeholder that *Syndicate* wants to keep in mind is the maintenance staff and Physical Plant Department. Although they do not have much influence or interest in the project details, they are still affected by the project and play a large role once the project is complete. Therefore, *Syndicate* wants to encourage an open dialogue with these parties to ensure that their needs are being met. Finally, *Syndicate* acknowledges that the residents of Holland will be affected by this project both positively, through the performances provided, and negatively, through any unavoidable inconveniences caused by construction. *Syndicate* will provide a social media page in which all inconveniences caused by construction will be announced with plenty of time for residents to adjust. This page will also provide a public forum in which the residents can express any requests or grievances so that *Syndicate* is aware and can work to accommodate.

4.2 Design/Collaboration Work Space

Syndicate worked in a highly integrated collaborative design space. This space houses individual work stations, a conference area to meet with consultants or advisors, a team meeting space, a virtual reality immersive area, and white boards for visual collaboration. An interactive monitor was utilized in the team meeting space, where the team holds meetings twice a week to discuss the progress in every discipline and make major design/engineering decisions. The layout was chosen by *Syndicate*, fully equipped with updated technology, and outfitted with modular furniture that can adapt should the team decide to change the layout for a special meeting or consulting session. Refer to <u>Construction SD-B</u> for more detail.

4.3 Collaboration Hours

Syndicate had six designated hours throughout the work week in which all ten members were required to be in the collaboration space. This time was used for weekly meetings, consultations, or general work. The team found it useful to keep these hours consistent throughout the project for general collaboration without going out of their way to plan specific meetings. Working in the same room at the same time allowed team members to ask questions real-time and involve everyone in the discussion and decision-making process.

4.4 Multidisciplinary Teams

In addition to the four disciplines and integration, *Syndicate* created three multidisciplinary teams to address certain design/engineering challenges; an architecture team, an acoustics team, and an enclosure team (*Figure 3*). These teams were made up of members from every discipline who worked together to not only improve the overall building performance, but also to improve the total team interdisciplinary collaboration.

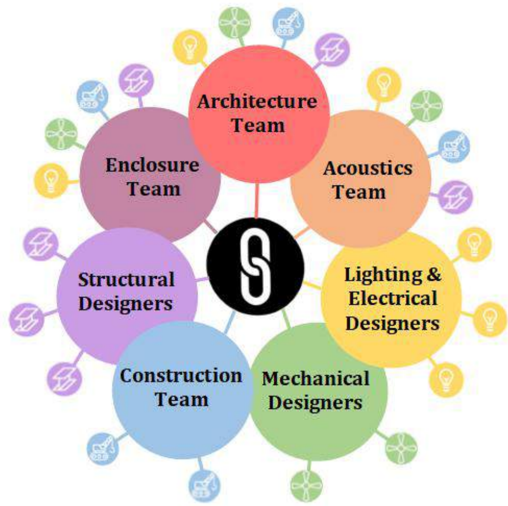


Figure 3: *Team Breakdown*

4.5 Decision Matrix

One aspect that assisted in team integration and design/construction enhancement was the implementation of objective decision matrices. This tool is used to help make unbiased decisions across all disciplines and is weighted to ensure the final outcome benefits the project as a whole, not one specific discipline. *Figure 4* on the next page showcases the important integration decision of which sustainability plan to use on this project and will be discussed further in <u>Construction Report Section 8.0</u>.

SYNDICATE — DECISION MATRIX: CONSTRUCTION

Team Goals :	Enhance Hope College Campus			Maximize Occupant Experience			Create Premier Performances			Minimize Energy Impacts						
	Construction Schedule	Aesthetics	Cost	Comfortability	Accessibility	Quality	Reduced disturbances	Sound Quality	Flexibility	Waste Reduction	Carbon Footprint	Life Cycle	Efficiency	Weighted Score	Rank	Final Outcome
SUSTAINABILITY PLAN																
Weights :	0	0	0	3	3	3	0	2	2	3	3	3	3			
WELL	0	0	0	3	2	3	0	1	1	1	3	1	2	49	3	
LEED	0	0	0	2	1	3	0	1	1	2	2	3	3	52	2	
Hope College Sustainability Plan	0	0	0	2	1	3	0	2	1	3	3	3	3	60	1	X
Additional Comments :	Syndicate has created a sustainability plan specific to Hope College and their priorities by taking into account aspects of other sustainability plan and major sustainability themes. This sustainability plan is intended to be introduced in the early phases of projects so they are designed for sustainability rather than trying to meet criteria once construction is nearly over.															

Figure 4: *Decision Matrix*

4.6 Pull Planning

Pull planning is a collaborative scheduling approach that involves all responsible parties listing the items they need from other parties in order to complete their tasks. This was an important aspect of *Syndicate*'s integration on the project. The team used an online organizational tool called *Trello* to keep track of interdisciplinary deadlines and to encourage transparency between the work each discipline was accomplishing. Refer to *Figure 5*. *Trello* typically consisted of eight sections (four disciplines, integration, and three multidisciplinary teams), in which to-do lists, upcoming deadlines, and completed work were listed. Disciplines would put lists of needed items in the responsible discipline's section. Refer to Construction SD-B for more detail.

Figure 5: *Trello List*

Syndicate also instituted pull planning in their weekly meetings. In the coordinated weekly meetings, the team listed upcoming deadlines and what was needed from each option to meet them. A white board was utilized to list needed items, sketch possible design solutions, or list meeting topics.

Pull planning will be implemented during project construction for the inter-trade coordination. The office trailer will have a full-wall white board and sticky-notes color-coordinated for each trade. The trades will be required to update the pull-plan weekly in the foremen meetings.

5.0 SITE ANALYSIS

Taking into consideration the site location and its influence on the surrounding area was a crucial first step in the planning and design process.

5.1 Existing Conditions

The project site is situated along the northern edge of Hope College's campus at 221 Columbia Avenue. It is surrounded by three streets, with 10th Street to the south, 9th Street to the north, and Columbia Avenue to the west. 9th Street acts as the divider between Hope College campus and the downtown Holland community, so The Miller Center is located near on- and off-campus residential and educational buildings. The Miller Center also shares a plot of land with Hope College's Physical Plant Department to the east, which is mostly utilized for storage of snow removal equipment. Additionally, the site is that it is within close proximity of the Pere Marquette Amtrak transit route, less than 300 feet from the center at its closest point to the east. Refer to *Figure 6* for more information.

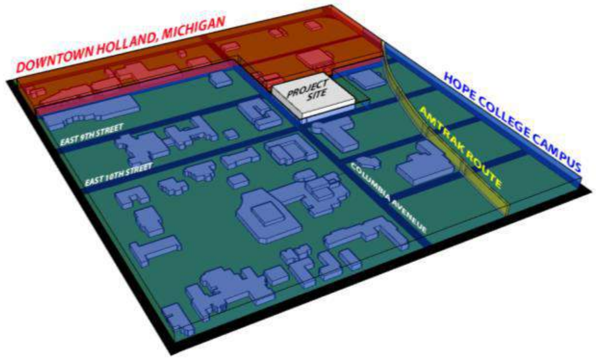


Figure 6: *Existing Conditions*

5.2 Zoning

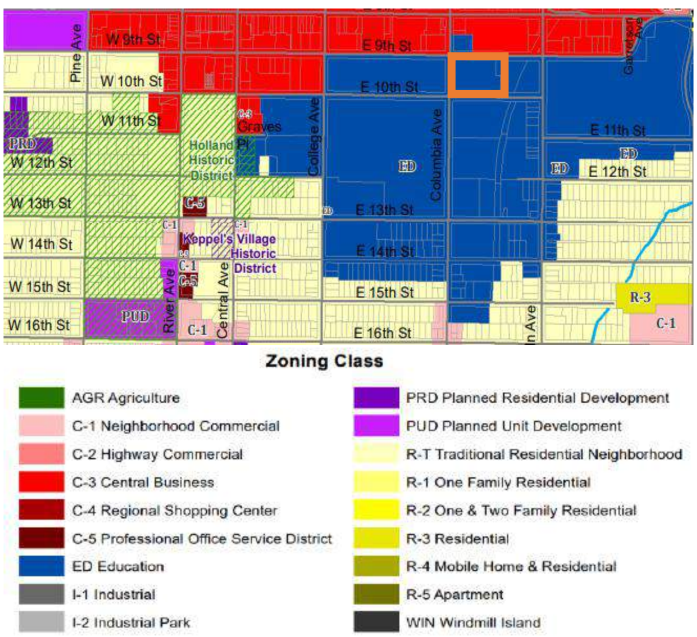


Figure 7: *Holland Zoning*

Given that The Miller Center is located on Hope College's Campus (shown in blue on *Figure 7*), zoning ordinances are compliant with zoning class ED (Education) for the City of Holland. As mentioned, the center lies on the northern boundary between the Hope College campus and the downtown Holland community, with zoning class C-3 (Central Business, shown in red) being the compliance requirements for that portion of downtown. The permit fee for this zone is $125,000 and the plan review fee is $31,000. The project site is outlined in orange on *Figure 7*.

5.3 Site Logistics

With minimal site area and pedestrian safety to keep in mind, site planning and logistics have been carefully considered for the construction of The Miller Center. Throughout the different phases of the project, the site will have to be modified to account for the materials arriving and the means by which they will be installed. Refer to <u>Construction Drawings C-8.0</u>. Due to their direct adjacency to narrow campus streets, the southern and western perimeters of the site present challenges with very limited space for material storage and equipment maneuvering. There is, however, ample space on the east side of the site for laydown, an office trailer for all trades, and other amenities.

Shown in *Figure 8* is the site logistics plan that *Syndicate* will be implementing. 9th Street will be reduced to one lane to allow for deliveries and waste removal to occur in a safe and efficient manner along the north site perimeter when a crane is present on site. The total cost of the road closure, to include permitting and renewal fees, is roughly $500. There is a parking lot south of the site along 10th Street that will be utilized for worker parking.

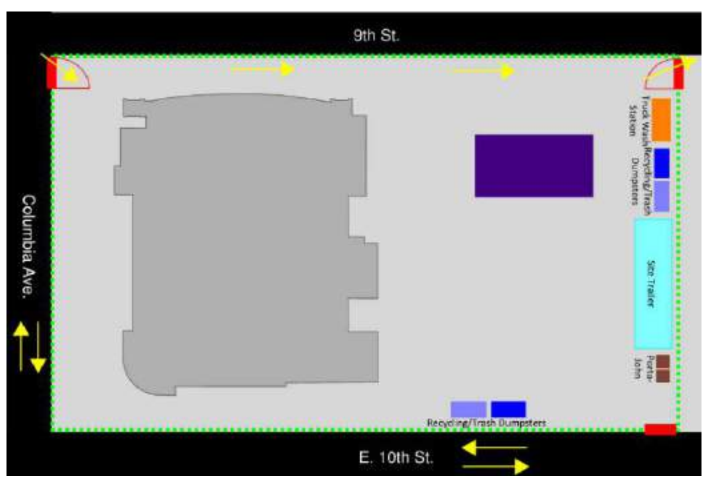


Figure 8: *Site Logistics Plan*

The access points to the site will consist of two gates located on or directly off of 9th Street (depending on whether or not the lane is closed), one for entry and one for exit. A third smaller gate strictly used for foot access at the southeast corner of the site, across from the worker parking lot.

5.4 Phasing

The Miller Center will be constructed in five primary phases: Substructure, Superstructure-1 (lateral systems), Superstructure-2 (non-lateral systems), Enclosure, and MEP / Finishes / Commissioning. Refer to Construction Drawing C-8.0. The Miller Center requires only light excavation as there is no below grade space and relies on a shallow foundation system placed six feet below the top of the slab at its deepest points.

The acoustical criteria for the concert hall, recital hall, choir rehearsal room, and orchestra rehearsal room require these spaces to be isolated from any potential noise disturbance. *Syndicate* has chosen to construct these areas as separate, shelled structures by utilizing concrete precast panels. Superstructure-1 phase includes the erection of these four room shells, as well as the stair towers, elevator shaft, and organ room. These precast walls will make up the lateral system for the building. Work will move left to right to minimize congestion on the eastern side of the site, so the organ room will be completed first, followed by the stair towers and elevator shaft. The concert hall three rehearsal/recital spaces will follow. Refer to *Figure 9* for the phasing plan of Superstructure-1.

Superstructure-2 phase will involve erecting the remaining structural components and placing the concrete cast-in-place floors, following a counterclockwise sequence (refer to Construction Report 10.2).

For the final phase, detailed coordination efforts will be utilized for spaces such as the concert hall that have complicated finish items, and extra precautions have been considered to ensure acoustical performance isn't sacrificed when interior walls and flooring are installed. Refer to Construction Drawing C-2.0 for further details regarding the extra precautions, and Construction Drawing C-8.0 for more phasing information.

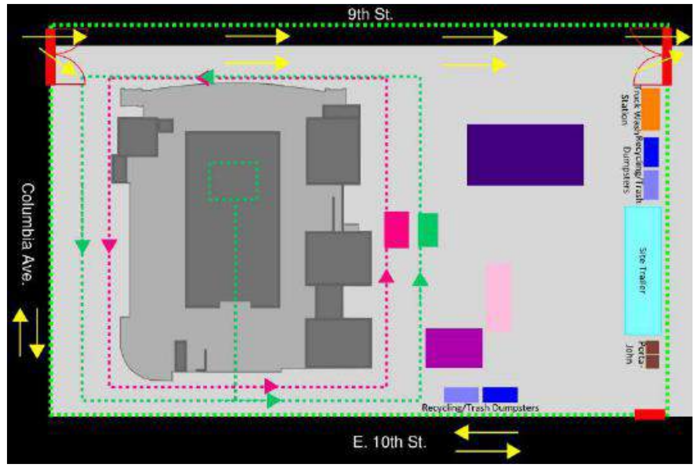


Figure 9: *Phase Two Plan*

5.4.1 Crane Logistics

Syndicate will be using two different cranes during the construction of The Miller Center. The first will be a Manitowoc 2250-Series 3 300-ton crawler crane, used for phase two (Superstructure-1) of the project, a total of 20 weeks. The critical pick for this crane is a 528 SF precast panel weighing 37.8 tons. The second crane is a Manitowoc 8000-1 80-ton crawler crane, used for phases two, three and four (Superstructure-1, Superstructure-2, and Enclosure) of the project, a total of 30 weeks. The critical pick for this crane is a 208 SF cross-laminated timber (CLT) panel weighing 2.9 tons. Refer to Construction SD-E for more details.

5.5 Site Safety

Syndicate is committed to the safety of all workers onsite as well as surrounding communities (faculty/staff/students/public) and will keep a safety professional onsite throughout the duration of the project. University campuses often face the challenge of protecting construction sites from possible student trespassing, and *Syndicate* is prepared to assist in ensuring that all potential hazards are inaccessible at all times. All adjacent sidewalks will be blocked from pedestrian access, with signage expressing the safety risk and alternate routes. Perimeter fencing is fundamental in separating the project activities from its surroundings, and some modifications that exceed the Occupational Safety and Health Administration (OSHA) requirements will be implemented with perimeter fencing as an extra precaution. For example, rather than using the standard eight-foot fence, a ten-foot fence will be installed to reduce the chance of trespassing. Full coverage netting will also be installed on the fence to prevent debris from entering or leaving the project site. As referred to in Construction Report Section 4.1, *Syndicate* will create a Miller Center Construction Facebook page and Twitter account to keep students and local residents up-to-date on safety concerns and any pedestrian or vehicular travel restrictions. There will also be video cameras running on site at all times, indicated by signage around the fence, to increase security and discourage potential trespassing.

All entering employees must be equipped with the appropriate Personal Protection Equipment (PPE). Any employee new to the job will be required to complete *Syndicate's* safety orientation prior to participating in any work on the site. There will be hold daily stretch exercises before the work day begins and organize weekly meetings to discuss potential safety hazards associated with upcoming activities. Failure to comply with these strict safety standards will result in re-training for staff at the cost of the negligent company and/or disciplinary action if the issue persists. Safety of the project employees and the surrounding stakeholders is *Syndicate's* top priority.

5.5.1 Prevention Through Design

The Prevention through Design (PtD) concept, also commonly referred to as Design for Construction Safety or Safety by Design, is an initiative lead by the National Institute for Occupational Safety and Health (NIOSH). It aims to anticipate and design out safety hazards, both during construction and operation of the facility in the early design phases of a project. This initiative requires a highly collaborative approach with an integrated construction team from the project's conception to ensure success. The Miller Center is a good candidate for PtD because it is being delivered through design-build. Although safety was considered a priority throughout the design of this project, *Syndicate* specifically focuses on confined spaces, signage on site, and access/ergonomics for maintenance during operation. Checklists have been created to ensure these safety aspects will also be implemented into the Quick Response (QR) code system. Refer to Construction Report Section 6.2 and Construction SD-C for more information.

5.5.2 Safety During Heavy Timber Construction

Laborers and contractors are expected to understand and abide by OSHA standards and keep an eye out for their fellow workers. This is particularly important as heavy timber is a relatively uncommon system and therefore extra precautions to keep subcontractors safe is needed. Safety-minutes during this part of the project will focus on heavy timber.

5.5.3 Worker Tracking

One of *Syndicate's* safety standards requires all workers onsite to wear a wristband radio frequency identification (RFID) tag. This wristband, paired with software, shows the location of each worker on the project site. *Syndicate* uses this as a medical emergency measure and to track if workers enter an "off-limits" zone while there are safety hazards present. Workers will pick them up from the office trailer at the beginning of each day and leave it on site when they leave to mitigate any concern of privacy interference.

6.0 QUALITY ASSURANCE/QUALITY CONTROL

The Miller Center will be Hope College's first dedicated musical arts building; therefore, *Syndicate* has put a heavy focus on creating premier performance spaces through acoustical excellence. Constructing an acoustically-sensitive area can be extremely difficult. Inconsistencies in construction or any lack of attention to detail can lead to leaks and cause problems for the performances that will take place in those spaces. Therefore, it is important that the laborers and contractors on the project are very knowledgeable about not only the importance of their work quality, but also how to perform the level of work necessary to ensure the best acoustics possible. *Syndicate* has developed several quality assurance and quality control measures to guarantee accurate results throughout the entire building, with a heavy focus on the acoustically critical spaces. The construction team will include acoustic reminders during the weekly foremen meetings with information specific to the areas they are working on at that time. QR code quality checklists (refer to <u>Construction Report Section 6.2</u>) will have information about the large spaces, and the workers will need to be sensitive about even the most minute detail. Refer to <u>Construction Drawings C-2.0</u> for more information.

6.1 Structural Systems

The structural materials being used have also been included in *Syndicate's* quality control research. Given that many laborers and contractors are not familiar with glued-laminated timber (glulam) and CLT, the quality control plan emphasizes the importance of construction methods. It also emphasizes expected results related to the structure, as well as potentially harmful factors that could affect quality. Damages to the wood structure would be detrimental to the project budget and schedule, so proper training and quality measures are extremely important to successful installation.

Syndicate's structural system also includes concrete precast walls that make up the lateral system for the building. These concrete walls act as a natural sound isolator and are a large aspect of *Syndicate's* goal of Creating Premier Performance Spaces in The Miller Center. These panels will be pre-installed with embed plates to allow for the heavy timber structural members to be connected to the concrete shells. *Syndicate* has carefully analyzed the sizes and shapes of the panels, optimizing the layout to ensure there are as many duplicate panels as possible to reduce customization costs. There are a total of 168 panels in The Miller Center. Any openings or variations in the panels have been specifically and accurately called out for the manufacturer to form them correctly. Ultimately, it is the manufacturer's responsibility to ensure the panels are created to meet *Syndicate's* stringent quality requirements, but it is *Syndicate's* responsibility to ensure thorough and effective coordination, and that the manufacturer receives accurate shop drawings. Any error or defects in these panels would prove extremely costly in terms of budget and project schedule. Refer to *Figure 10* for the precast panel plan.

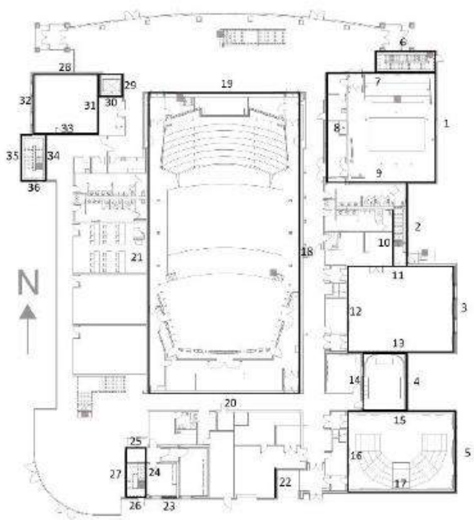


Figure 10: *Precast Wall Plan*

6.2 QR Code Tracking

In order to ensure that quality control measures are precisely followed, a QR code tracking system will be implemented in select spaces throughout the project. QR codes will be placed in the door frames of the selected spaces using phones or iPads. The QR codes will contain quality checklists, safety reminders, and punchlist items. They will track who scanned them and when.

For the quality aspect of this system, QR codes will be placed in the door frames of acoustically sensitive spaces. These include the concert hall, the recital hall, the choir rehearsal room, the orchestra rehearsal room, the faculty studios, and the individual practice rooms. Once scanned, the worker(s) will be able to access the specific quality control checklist for that space. This checklist will enable them to leave comments about certain aspects, upload pictures of any concerns, and contains contact information for the quality control representative on site.

Another advantage of utilizing a QR code tracking system is that *Syndicate* will be able to monitor which subcontractors are entering and working on a space and at what time. This will pinpoint the source of any errors that are encountered through the work progression.

Syndicate will perform their punchlist in the online database called *Procore*. This allows them to continue to use the QR code system in a similar capacity to the quality checklists. For this aspect, QR codes will be placed in all door frames and will be scanned using the *Procore* app to access the specific punchlist items for that space.

Checklist

Figure 11: *Quality QR Code*

An example quality control checklist for the Choir Rehearsal Room can be found on Construction Drawing C-2.0, or you can scan the QR code in Figure 11 (or visit http://l.ead.me/Syndicate).

6.3 Virtual Reality

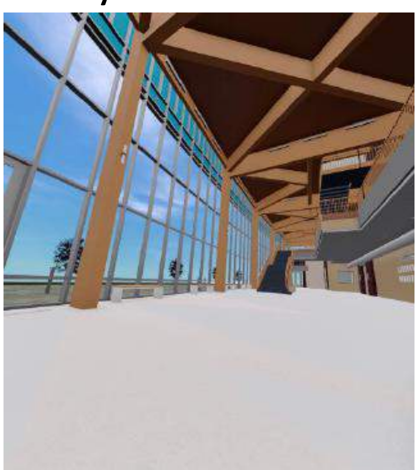


Figure 12: *VR Model of North Lobby*

Syndicate will use virtual reality (VR) throughout the project. The stakeholders will be invited during the design phase of the project to experience VR of their future space to make decisions or suggestions. VR will also be available in the job trailer in the form of virtual mock-ups for all job-site workers to use. This allows workers to consult the model (in the form of virtual mock-ups) if there are any questions about how something should be constructed or what it should look like. Refer to *Figure 12* for an example of VR for the north lobby.

7.0 CONSTRUCTABILITY

Syndicate's construction team aimed to increase constructability in order to maximize the efficiency of the schedule and minimize construction waste. The mechanical system's constructability was a focal point due to the level of coordination and collaboration required. The construction team also implemented Building Information Modeling (BIM) to further improve the overall constructability of the project.

7.1 Underground Ducts

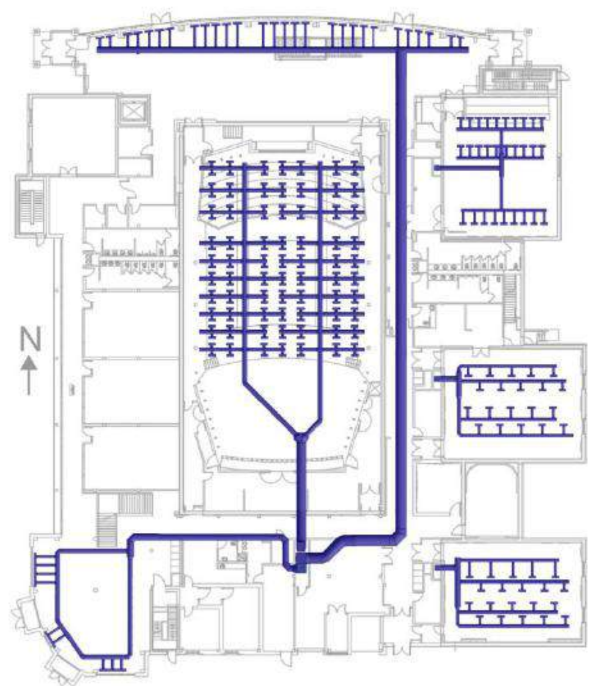


Figure 13: *Underground Duct Plan*

Displacement ventilation requires a significant amount of ducts in overhead spaces to properly move air in a building. To reduce the number of ducts in the ceiling space, *Syndicate* utilized AQC Industries Blue Duct underground preinsulated duct system. Refer to *Figure 13* above for the underground duct plan, and to Mechanical Drawing M-3.0 for more information about these ducts. The ducts will run under the hallways and penetrate the large spaces up through the slab on grade (SOG). The ducts that supply the concert hall and recital/rehearsal spaces must pass through the concrete precast panels at the subgrade level first before they penetrate the SOG. Refer to *Figure 14* for that detail. There was a considerable amount of interdisciplinary collaboration, facilitated by the construction team, that was necessary to ensure that the footings and underground ducts did not clash.

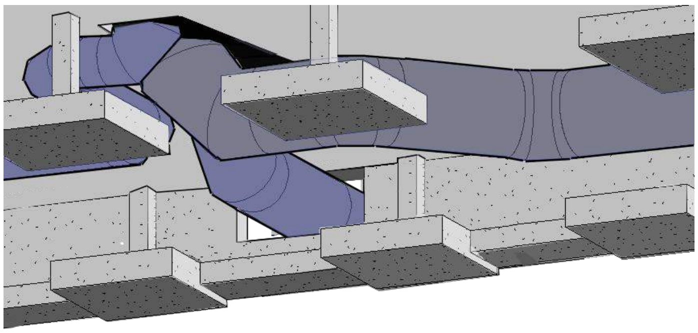


Figure 14: *Underground Duct Penetrating Strip Footer*

These ducts will be placed and tested immediately before the SOG is poured. Extensive commissioning and inspections will be necessary to avoid any demolition and rework after the concrete slabs are placed and cured. The counterclockwise pattern of the project (refer to Construction Report Section 10.2) allows the SOG to start at a different part of the project while the ducts are being placed. By the time the testing is finished, the SOG sequence will reach that area. It is important that the slab gets poured as soon as testing is done because the longer the ducts are exposed, the higher risk they incur of being damaged.

When the decision was made to go with the underground duct system, there was some concern about keeping the ducts clean during construction, considering the amount of dust, dirt, and debris that usually occurs on project sites. *Syndicate* reached out to several construction managers working in the local area that were also installing underground ducts, and they assured the team that as long as the standard cap is placed on the duct opening, they had never experienced any issues with keeping them clean.

7.1.1 Underground Duct Coordination

The installation of the underground ducts and the erection of the precast panels is a detail that required a significant amount of coordination between the construction, structural, and mechanical teams, especially for the concert hall. The three main problems that caused a schedule clash are:

1. The precast panels require bracing until their roof system is installed.
2. The balcony in the concert hall requires a crane to build.
3. The underground ducts cannot be installed until the slab is ready to be placed.

After deliberation, the three teams came to the decision that 25 feet of concrete precast panels would be left out of the south end of the concert hall until the balcony is built and the slab is placed. Refer to Construction Drawing C-1.0 for more information and refer to *Figure 15* for an exploded view of some of the key factors for this space.

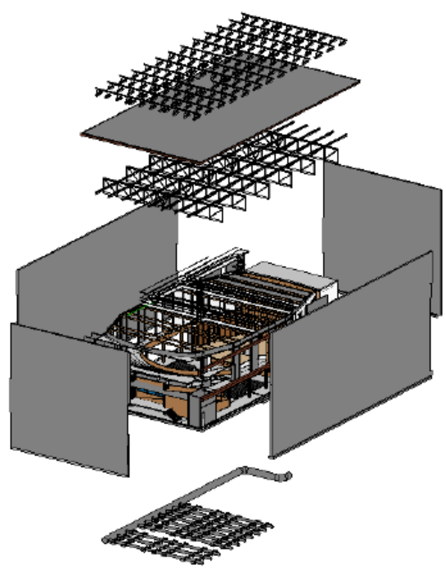


Figure 15: *Exploded View of Concert Hall*

7.2 Building Information Modeling

Building Information Modeling (BIM) is a “digital representation of physical and functional characteristics of a facility that serve as a shared knowledge resource” according to the National BIM Standard. It can be implemented to improve the design, construction, and/or operations of a project. *Syndicate*, an integrated design-build team, has the capability to implement several different types of software on projects without the concern of turning models over to other designers/construction professionals because everyone is in-house. This saves time and effort, which can be spent on implementing more software that further improves projects. *Syndicate* used these constructability challenges, along with the construction team's project goals, as an opportunity to utilize several BIM uses. The BIM implementation plan was split into seven major areas: schedule/site logistics, budget, safety, QA/QC, coordination/waste minimization, prefabrication, and sustainability. Potential BIM uses for each of those areas were listed at the beginning of the project, and those uses were reevaluated to show the ones that were implemented and feasible. Refer to Construction Drawing C-9.0 for the full implementation plan.

8.0 SUSTAINABILITY PLAN

Syndicate believes that sustainability should be an integral part of design, rather than an add-on to be pursued once design is complete. That is why, in lieu of pursuing LEED or Building WELL, *Syndicate* decided to assist Hope College in their goal to be a more sustainable campus by developing a custom plan that focuses on general sustainable aspects that they find the most valuable. These include indoor environment, materials and resources, energy conservation, and waste reduction (refer to *Figure 16*). By doing this, *Syndicate* is building with a focus on the long-term impacts this project has on its occupants and environment, rather than simply aiming to finish a checklist. Once this pilot project proves the value of this new sustainability plan, *Syndicate* encourages Hope College to adopt this policy as their official campus sustainability plan and apply it to any future building projects.

8.1 Dashboard

A proud integration feature of *Syndicate's* green initiative for this project is a digital dashboard, using *Lutron Quantum* and *Senseware* software, that will be located in the north and south lobbies of The Miller Center, where there is the highest amount of foot traffic. This dashboard will talk to a *Senseware* system, that tracks the real-time savings with regard to HVAC and plumbing, and *Lutron Quantum*, that tracks real-time lighting, and electrical controls. It will also display static contributions such as structural system sustainability, lifecycle impacts, air quality efforts, and construction waste reduction. Refer to Integration Drawing I-10.0 for the full Hope College Sustainability Plan and Construction Drawing C-10.0 for the construction team's specific sustainable contributions to this effort.

Figure 16: *Hope College Sustainability Plan*

9.0 COST MANAGEMENT

Syndicate was challenged with completing The Miller Center within a building cost budget of \$25 million, which equates to a baseline of approximately \$360 per SF. During the early design phase, *Syndicate's* estimating team calculated an initial building cost of \$26,092,102.00. The design entities then collaborated with both the construction team and the owner to discuss where costs could be reduced. After those discussions, *Syndicate* has achieved an estimated cost of \$23,926,850.00**.** Details as to how the budget is distributed amongst the project can be found in Construction Drawing C-7.0.

9.1 Budget Tracking

Once the initial $25 million budget was provided, *Syndicate* utilized *RSMeans* Square Footage Cost Data 2018 to determine approximately how much funding was available for each of the main building systems according to Uniformat II Classification, an elemental classification for building specifications, cost estimating, and cost analysis. Given that the scope of The Miller Center is a combination of "auditorium" and "college classroom building" according to *RSMeans*, the concert hall was priced as an auditorium whereas the remainder of the building was priced as an educational building. *Syndicate's* Optimized Design is estimated at $23,926,850.00, $1,073,150.00 below the given budget (a 4.3% savings). The following chart in *Figure 17* displays the progress of *Syndicate's* budget and the relative cost of each building system and general conditions.

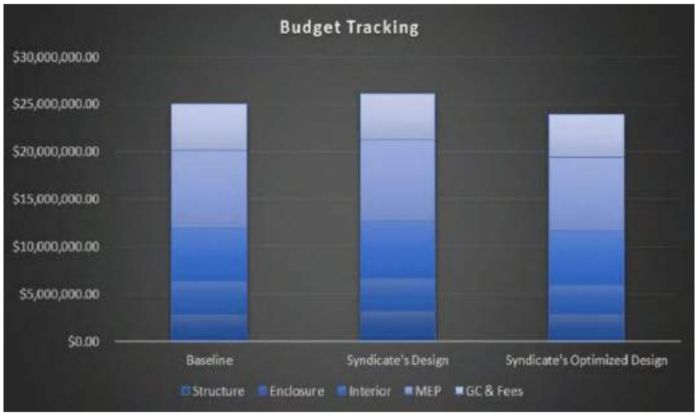


Figure 17: *Budget Tracking*

9.2 Cost Breakdown Structure

As previously mentioned, Uniformat II Classification was used to deconstruct the overall budget for The Miller Center. The categories used can be seen in *Figure 18*, with the associated cost for *Syndicate's* Optimized Design. The construction team achieved level two detailed estimates in the initial design, as well as level three estimates for the final design. Some detailed comparison costs between *Syndicate's* iterations can be seen in Construction Drawing C-7.0.

9.3 Life-Cycle Analysis

Syndicate has designed innovative systems that require life-cycle analyses to be considered.

The mechanical cooling system utilizes thermal storage buried outside in a 400 ton-hour tank. The simple payback period is roughly a year. The stormwater management system, a 5000 gallon storage tank that will be used for greywater, has a payback period of roughly seven years.

Syndicate has also chosen to utilize a 52 kilowatt-hour photovoltaic array upon the concert hall roof in order to generate solar energy, and the payback period of 11 years can be seen further explained in Lighting/Electrical SD-D.

An alternative mechanical design that *Syndicate* considered included the use of cogeneration through the installation of a combined heat and power (CHP) plant on campus. This, of course, would require the coordination of the entire Hope College campus in order to connect said CHP Plant to all new construction. The CHP plant would be housed in a structure on The Miller Center site (between The Miller Center and the Physical Plant Department). It would cost about $500,000 not including the equipment. *Syndicate* has decided that if Hope College proceeds with this option, the team would only be financially responsible for the percentage of energy output expected from The Miller Center. *Syndicate* would design, plan, and construct the plant with proper additional funding.

Uniformat II Breakdown		Syndicate's Optimized Design	Syndicate's Optimized Design
A	Substructure	$424,616.00	1.8%
B10	Superstructure	$2,366,072.00	9.9%
B20	Exterior Enclosure	$2,916,352.00	12.2%
B30	Roofing	$219,107.00	0.9%
C	Interiors	$3,909,687.00	16.3%
D10	Conveying	$1,200,275.00	5.0%
D20	Plumbing	$725,652.00	3.0%
D30	HVAC	$2,224,318.00	9.3%
D40	Fire Protection	$549,645.00	2.3%
D50	Electrical	$2,976,080.00	12.4%
E	Equipment & Furnishings	$1,865,000.00	7.8%
F	Special Construction	-	-
	Subtotal	**$19,376,804.00**	
G	General Conditions	$1,700,000.00	7.1%
H	Syndicate's Fee	$2,850,046.00	11.9%
	TOTAL:	**$23,926,850.00**	

Figure 18: *Estimate*

10.0 SCHEDULE

Syndicate, while also holding student and local resident safety paramount, recognizes the importance of a timely project delivery. To address both aspects of the project, *Syndicate's* construction team developed a 24-month total project schedule, sixteen of those months being construction, that will minimize student exposure to the project. Design and planning will begin in August of 2019 and the Notice to Proceed will be in April of 2020, which will allow site demolition to start as soon as the spring semester ends. Substantial Completion will be in June of 2021 and Full Occupancy in August of 2021, which will not only allow the performing arts faculty plenty of time to move in and adjust to their new space before the fall 2021 semester begins, but will also facilitate any sort of "Open House" for The Miller Center that Hope College wants to host. A total of seven of the sixteen total construction months will happen during the summer semester when student residency is at a minimum.

10.1 Fast-Tracking

Delivering The Miller Center through design-build grants *Syndicate* the flexibility to fast-track the construction process, because the designer and construction teams are integrated in their work and both have a full understanding of the project. While the design team finishes the building design, the construction team will begin on the site demolition, excavation, and foundations. This expedites the full project schedule by three months.

10.2 Parade of Trades

A parade of trades sequence is one in which activities are stacked to follow one another in order to decrease the amount of time necessary and to minimize conflicts between those trades. This acts as a quality assurance measure and schedule buffer. The more the trades repeat the same work, the faster and higher quality their work becomes. Each activity is matched with a weekend to allow time for a trade to work overtime to recover from any problems, should they arise. *Syndicate* will not tolerate delays in the overall schedule once the parade of trades has been reached. The construction schedule reflects a specific amount of time for each activity, but the team recognizes that the first few times performing the activity may be slower. Trades are expected to reach their stride by the time they hit the second floor (area E). The time reflected on the schedule is expected to be the average amount of time needed.

Syndicate is using a counterclockwise sequencing pattern to keep the site as organized as possible. In phase three (Superstructure-2) and phase five (MEP / Finishes / Commissioning), trades follow this pattern. They start in the north lobby (area A) and proceed clockwise through the 3 floors. The four main lateral spaces (the concert hall and recital/rehearsal spaces, shaded in grey in the figure) will come after the four lettered spaces, working from darkest to lightest (shown in *Figure 19*). Refer to Construction Drawings C-6.0 for more information.

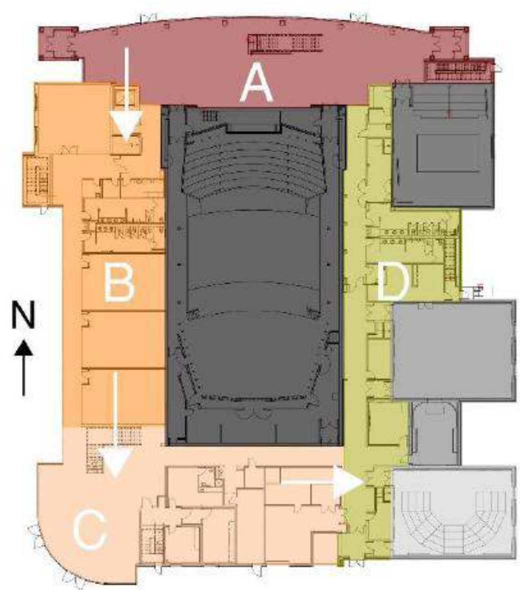


Figure 19: *First Floor Parade of Trades*

10.3 Transition Plan

As previously stated, the building turnover is intended to offer the faculty the summer to get accustomed to their space before the students arrive for the fall 2021 semester. The transition plan is 6 weeks in total. The occupancy date is June 28, 2021, meaning the faculty can move in at that time as the finishing touches are put onto the building. Full occupancy is on August 12, 2021, also allowing the students to get accustomed to their new space and allow for any events that Hope College wants to host.

11.0 OCCUPIABLE ROOF FUNDRAISING

Syndicate has included the occupiable roof in their Optimized Design but would like to offer Hope College an alternate way to cover the cost. The construction team suggests that the college pursues a fundraising strategy for this feature. By doing so, the college could save approximately $700,000.00 from The Miller Center budget. Some options for this could include program advertising for local business sponsorship, a "Patron Levels" program with incentives for donors, a performance gala for school of music students, or naming opportunities for the rooftop space. As the design-build team, *Syndicate's* role would be to donate the following for potential donors:

- a free design of the roof
- models
- renderings
- virtual reality walkthroughs for the potential donors

Figure 20: *Occupiable Roof Rendering*

12.0 LESSONS LEARNED

Throughout this process, the construction team learned that because construction is the last step, it is important that the construction professionals are apart of the process at every step prior. While the design is being developed, it can be easy to take a step back and wait for the design to be finished. However, being involved in every phase to facilitate discussions between disciplines and develop iterations of the schedule and budget is an extremely valuable way to help the team be prepared when the time comes to work solely on construction.

13.0 CONCLUSION

The construction schedule and site logistics plan developed for The Miller Center minimize campus disturbances and safety risks to ensure the students and faculty of Hope College are the top priority by:

- Maximizing the amount of construction happening over the summer when student attendance is low
- Turning over the building in enough time for faculty and students to adjust to their new space before the fall 2021 semester begins
- Installing a ten-foot fence and video-cameras on the site
- Closing a lane on 9th Street during craned phases

By working with the design disciplines to increase daylighting and improve thermal comfort, along with organizing the schedule with a focus on high quality finishes, *Syndicate's* construction team has ensured a space with maximum occupant experience.

Through iterations of prefabricated systems to minimize sound mitigation and working with innovative technology to improve construction quality, *Syndicate* has created a world-class acoustical space to facilitate premier performances.

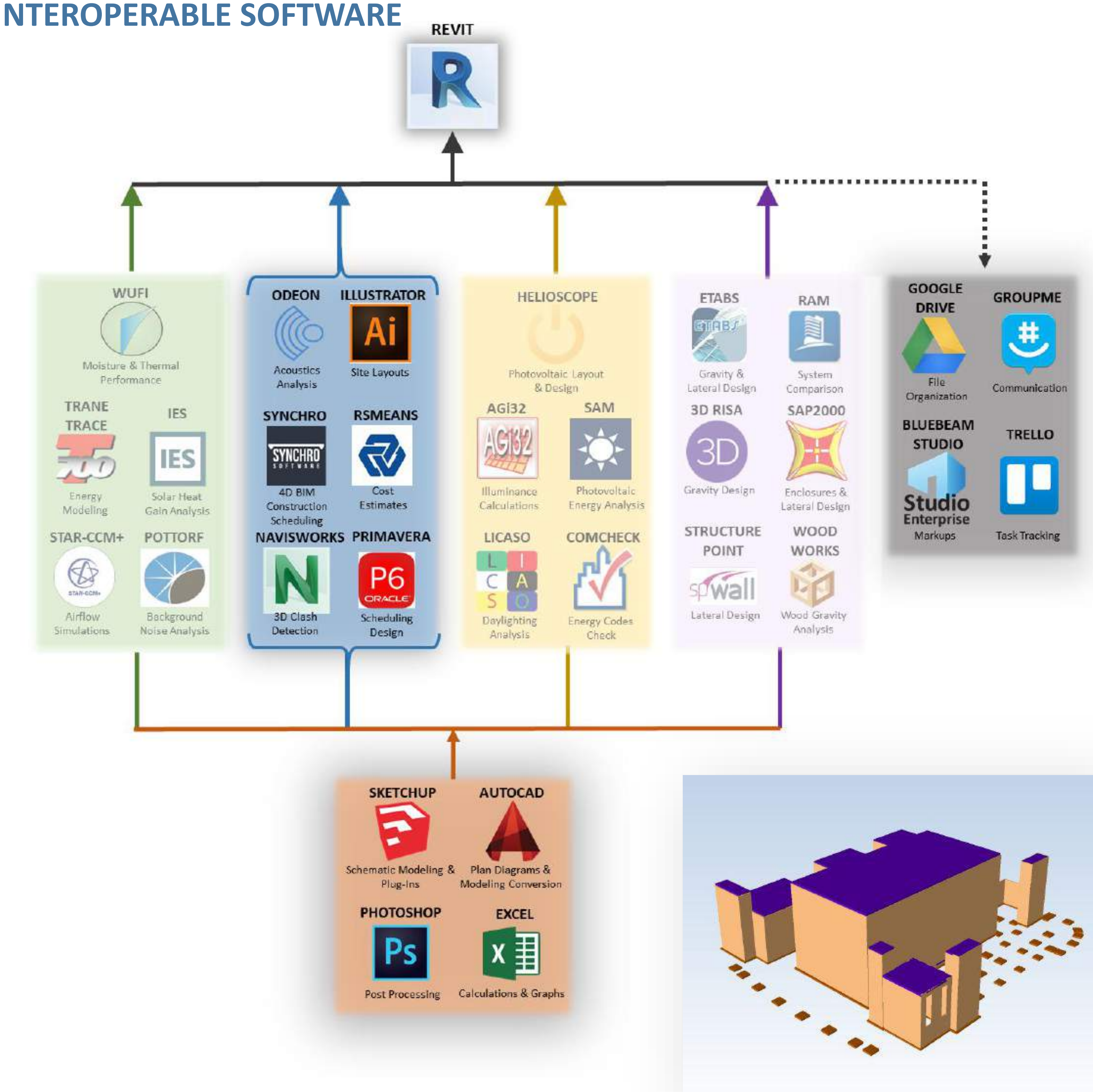
Syndicate has developed a custom sustainability plan for Hope College to encourage and supplement their environmentally-conscious efforts and to minimize the energy impact of this project.

DECISION MATRIX

Syndicate implemented a decision matrix to ease the burden of making multidisciplinary decisions, where it is often difficult to compare criterion. The overarching decision-making themes are the team project goals, and are broken up into smaller components that are given a weight for each decision. For construction, the most important decisions made that required a matrix were the sustainability plan, the mechanical equipment isolation system, and the lateral system. These three decisions are perfect examples of the amount of integration that this project required, because although these three were not specific to construction, the construction team had a lot to offer in terms of cost benefits, schedule impacts, and overall benefit to the project.

SYNDICATE	DECISION MATRIX: CONSTRUCTION															
Team Goals :	Enhance Hope College Campus			Maximize Occupant Experience			Create Premier Performances			Minimize Energy Impacts				Weighted Score	Rank	Final Outcome
	Construction Schedule	Aesthetics	Cost	Comfortability	Accessibility	Quality	Reduced disturbancec	Sound Quality	Flexibility	Waste Reduction	Carbon Footprint	Life Cycle	Efficiency			
SUSTAINABILITY PLAN																
Weights :	0	0	0	3	3	3	0	2	2	3	3	3	3			
WELL	0	0	0	3	2	3	0	1	1	1	3	1	2	49	3	
LEED	0	0	0	2	1	3	0	1	1	2	2	3	3	52	2	
Hope College Sustainability Plan	0	0	0	2	1	3	0	2	1	3	3	3	3	60	1	X
Additional Comments :	Syndicate has created a sustainability plan specific to Hope College and their priorities by taking into account aspects of other sustainability plan and major sustainability themes. This sustainability plan is intended to be introduced in the early phases of projects so they are designed for sustainability rather than trying to meet criteria once construction is nearly over.															
MECHANICAL EQUIPMENT ISOLATION																
Weights :	2	2	2	3	1	2	3	3	1	0	3	0	1			
Basement Addition	3	2	3	2	2	2	2	2	3	0	1	0	0	46	3	
Detached Structure	2	1	2	3	1	3	3	3	3	0	2	0	0	53	2	
Isolated Structure within Building	1	2	2	3	3	3	3	3	2	0	2	0	0	54	1	X
Additional Comments :	The location of the mechanical equipment was considered for not only how the mechanical equipment itself impacts the building, but also how the space acts as a buffer zone from the sound transmitted from the train. Syndicate's design incorporated an isolated structure within the building.															
LATERAL SYSTEM																
Weights :	2	0	3	0	0	0	2	3	3	2	3	0	0			
Precast	3	0	2	0	0	0	3	2	3	3	1	0	0	42	1	X
CIP Concrete	1	0	2	0	0	0	2	2	2	2	1	0	0	31	3	
CMU	1	0	3	0	0	0	2	3	1	2	1	0	0	34	2	
Additional Comments :	The increased speed of construction was crucial for the construction schedule since the gravity system tied into the lateral. Due to this, the lateral system has to be up in a timely manner to continue with construction. The shear quanitity of walls reduced the need for a high strength material, however, thickness was needed for acoustical performance which could be achieved with all systems. Furthermore, the system would not be exposed so the effect on the occupants was not considered.															

INTEROPERABLE SOFTWARE



Syndicate utilized interoperable software to facilitate interdisciplinary communication. All disciplines used *Revit*, *Sketchup*, *Autocad*, *Photoshop*, and *Excel* at various stages of the project. Specifically, the construction team also utilized *Primavera* for scheduling, *Navisworks* for clash detection, *RS Means* for estimating, *Synchro* for 4D modeling, *Illustrator* for site layouts, and *Odeon* for acoustic analysis.

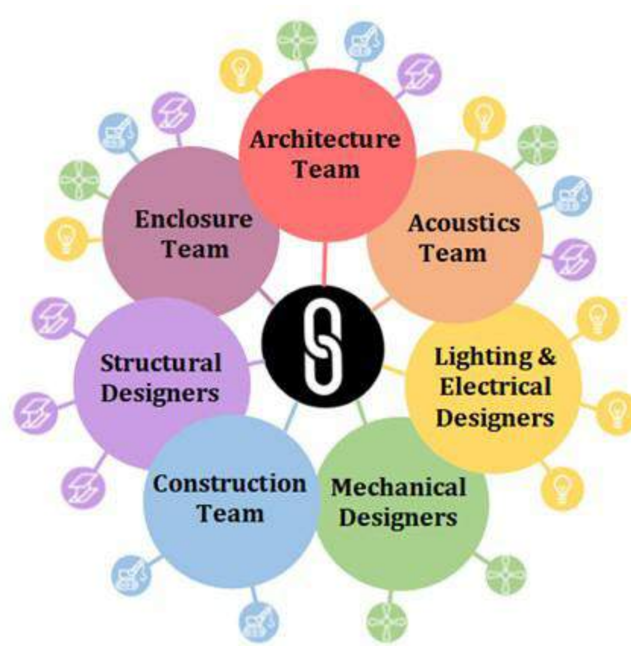
PROJECT DELIVERY

Syndicate will be utilizing an integrated design-build delivery method throughout The Miller Center project. The method lends itself to a high level of integration between the owner, design team, and construction team. This method also decreases the number of contracts from a traditional project delivery method.

Integrated Design-Build Organizational Structure

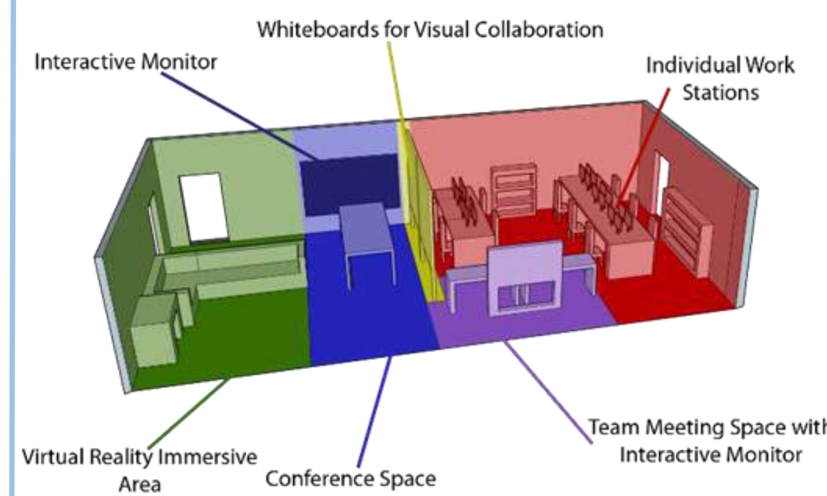
Syndicate as a Design-Build Firm

Syndicate offers a unique opportunity to owners by housing their designers and construction team together. This allows collaboration from the early design stages, ensuring maximum constructability review through the entire project. *Syndicate* also established three multidisciplinary teams to address issues or main are as of focus as the owner defines them. In the case of The Miller Center, *Syndicate* created an architectural team to address changes to the original architecture, and acoustics team to focus on the acoustic challenge of the project and ensure every option was acoustically -focused, and an enclosure team to ensure The Miller Center enclosure offers innovative solutions to the team's project goals.



TEAM DYNAMIC, COLLABORATION, AND PLANNING

The members of *Syndicate* took a personality test before the project started called "The Personality Matrix" which categorized each member into four dominant personalities; a lion ("the doer"), a peacock ("the communicator"), a koala ("the listener"), and an owl ("the thinker"). The team had members in three of the four categories , and for the most part, there were no repeat categories in any option. The team used this information to mitigate conflicts before they arose by learning the communication techniques for the other dominant personalities. Refer to Integration SD-D for more information



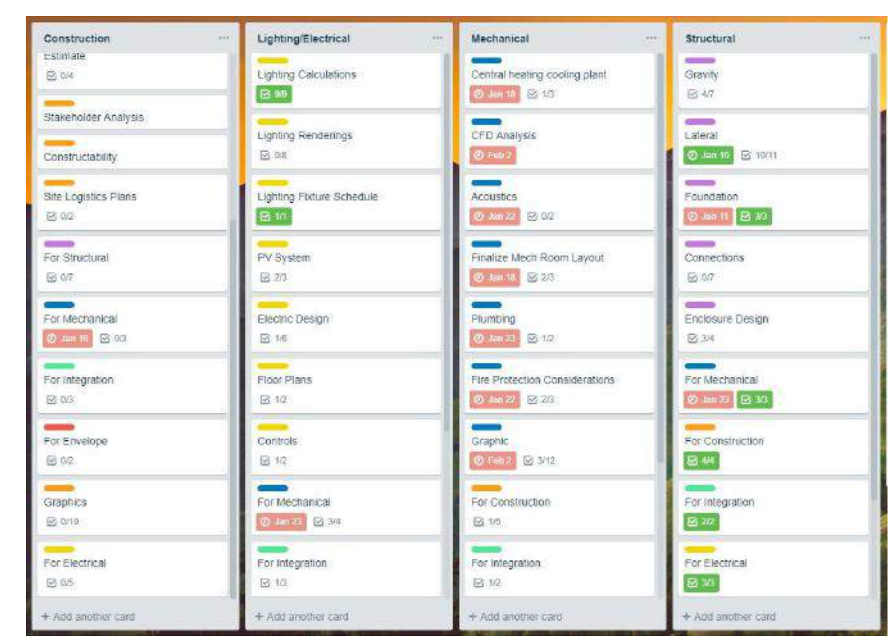
Collaboration Space

Syndicate worked in a highly collaborative area to encourage constant interdisciplinary interaction. The red area indicates the individual workspaces, each equipped with 2 monitors, organized by discipline. The purple area indicates a large interactive monitor that the team could project their work onto simultaneously. The yellow area indicates two white boards that were used to work out design discrepancies and create to-do lists. The blue area indicates a conference space that the team used to meet and discuss group decisions. The green area shows the designated rest space for the team.

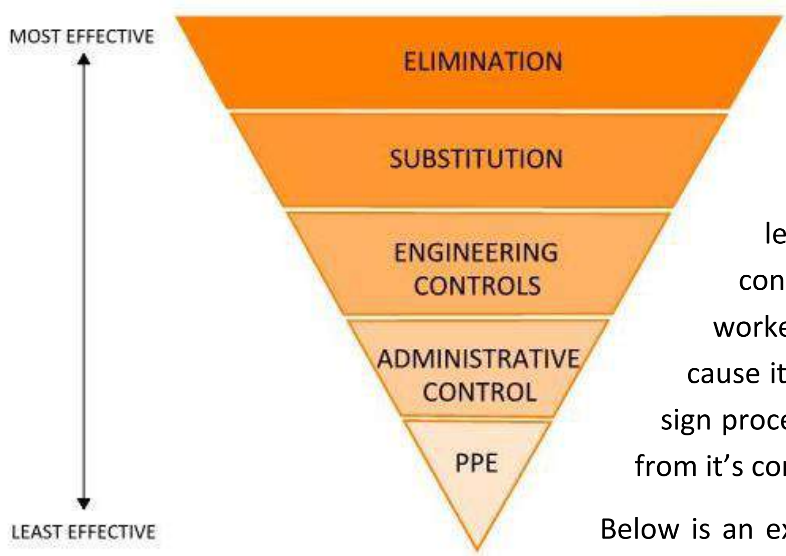
Team Meetings and Task Organization

Syndicate held full-team meetings twice a week. Prior to the meeting, each discipline was required to enter the talking points into a shared document that the construction team used as the meeting agenda. One member of the construction team would take notes in the meetings and organize them into meeting minutes that were made available to everyone. These minutes proved useful when the team needed to reference decisions made weeks later.

Syndicate used an online organizational tool called *Trello* to organize items for which each discipline was responsible . This tool became the team's form of pull planning throughout the project. Each discipline was assigned a color, and whenever a task was created, the responsible discipline's color was added. Whenever one discipline needed an item from another, they would create a task with the corresponding color. The tasks could be assigned a deadline, and the online tool also has a corresponding app for added convenience to the team.



PREVENTION THROUGH DESIGN (PTD)



PtD is a concept in which safety during the construction and operation phases is considered during the design phase. Although PPE is rightfully required on all jobs sites, in terms of hazard elimination, it is the least effective tactic in the industry. In the hierarchy of controls, elimination (PtD) is the most effective in keeping workers safe onsite. It is often considered difficult to do because it requires including the construction team early in the design process. *Syndicate's* construction team is apart of the project from it's conception, allowing them to implement this initiative.

Below is an example of a checklist used when designing for safe construction.

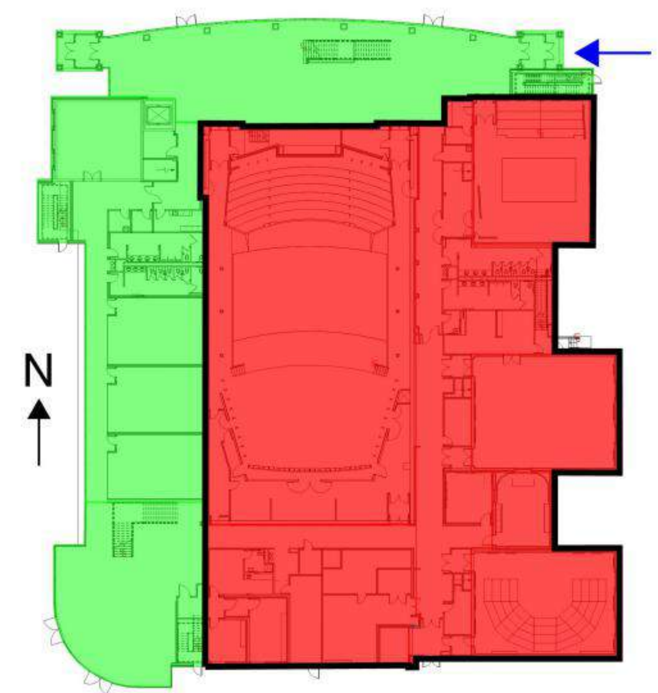
Syndicate's Prevention through Design Checklist			
Design Consideration	**Requirements**	**Meets?**	**Comments**
Confined Space	Avoid designing-in confined spaces	Yes	There are no accessible confined spaces per *Syndicate's* design
	Confined space egress/access unobstructed	N/A	
	Proper signage is in place for the confined space	N/A	
Access/Ergonomics	Is there suitable access to equipment?	Yes	Both during construction and operations, equipment access was considered.
	Will there be enough room to maneuver equipment?	Yes	Any areas in the building that require large maneuvering (pianos) has been sized appropriately
	Will the traveling surface be suitable?	Yes	The safety officer onsite will ensure that all paths are safe and accessible
	Has ergonomics been considered for the workers and end-users?	Yes	The maintenance staff will be involved in design to ensure all areas meet their needs
Signage	PPE	Yes	Provided in the trailer and around site
	Gate Signage includes project name and contact information	Yes	Safety officer, project manager, and superintendent will be listed
	Restricted access/security signage	Yes	Video camera signage on fence, restricted access listed in trailer for workers

WORKER TRACKING (RFID)

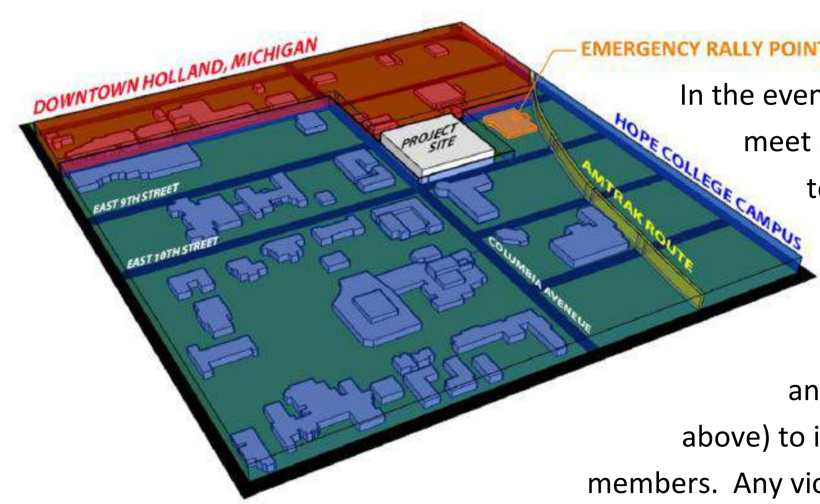
Radio Frequency Identification (RFID) uses electromagnetic fields to automatically identify specific pieces of technology called "tags". RFID tags and tracking is used in many industries to improve efficiency or accuracy. In construction, they are often used for safety and time-tracking.

Worker tracking with RFID tags is a *Syndicate* standard for safety on the job site. All workers pick theirs up at the beginning of the work day and return it at the end. These tags allow the project team to be able to see where the workers are in the case of a medical emergency, or to track workers during special hazardous conditions onsite.

To the right is the hazard zoning for Superstructure-1 when the roofing system for the concert hall and recital/rehearsal spaces are being placed. The green shows the areas workers are allowed to access and red shows restricted areas. The blue arrow is the worker access to the project during this time. RFID allows the project team to ensure no one is in the restricted area during this activity.



SITE SAFETY

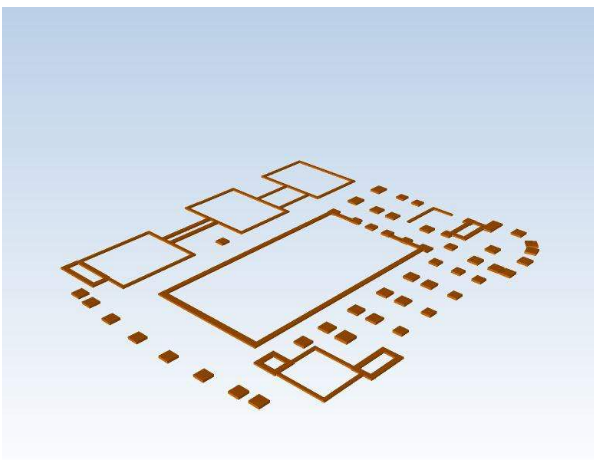


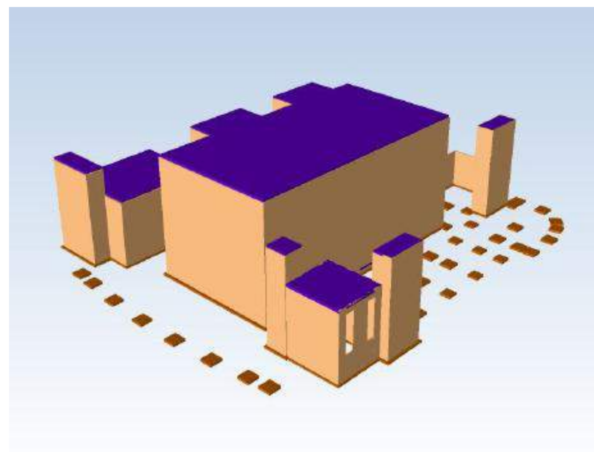
In the event of an emergency onsite, everyone is expected to meet at the Physical Plant Department building adjacent to the site (highlighted in orange).

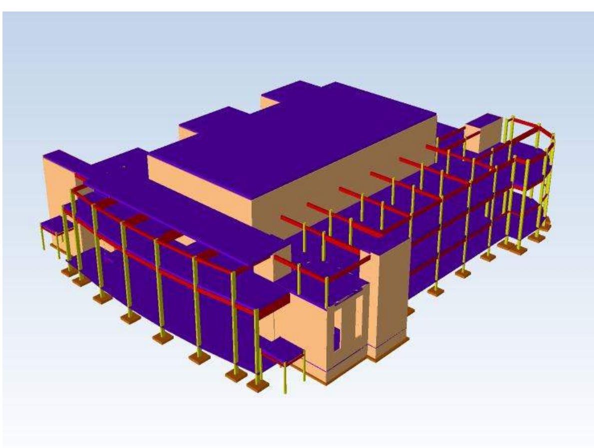
Syndicate has implemented a zero tolerance policy onsite. This includes substance abuse, personal protective equipment (PPE), and any main hazards that require a zoning map (see above) to include precast installation and all heavy timber members. Any violations of this policy will result in re-training at the cost of the negligent company.

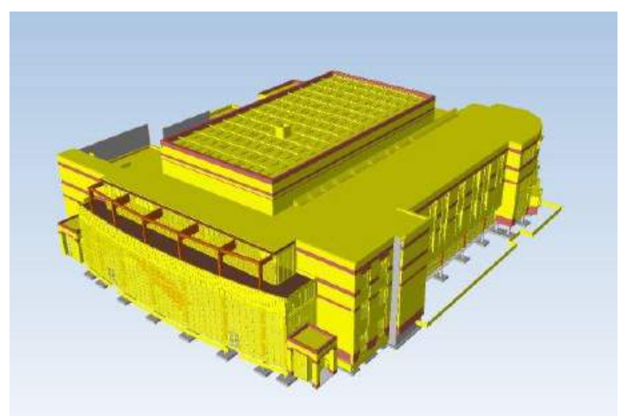
SYNCHRO

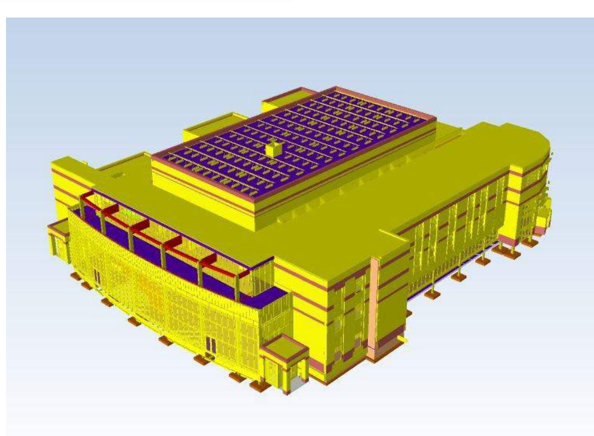
The construction team used *Synchro* as a 4D phasing model. Using a schedule from *Primavera*, a model was built to help the team visualize the construction schedule and sequencing between disciplines. This became particularly helpful during the underground duct and structural system coordination. Below are images from *Syndicate's* five primary phases.



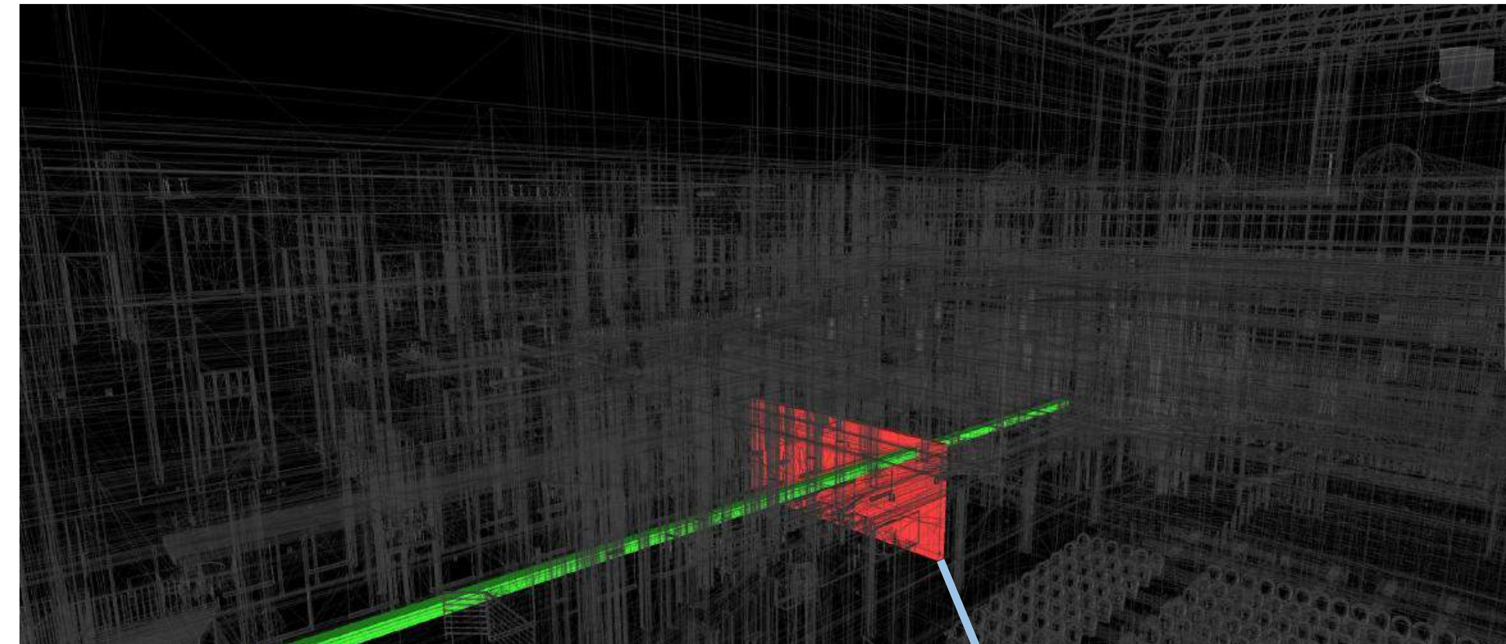




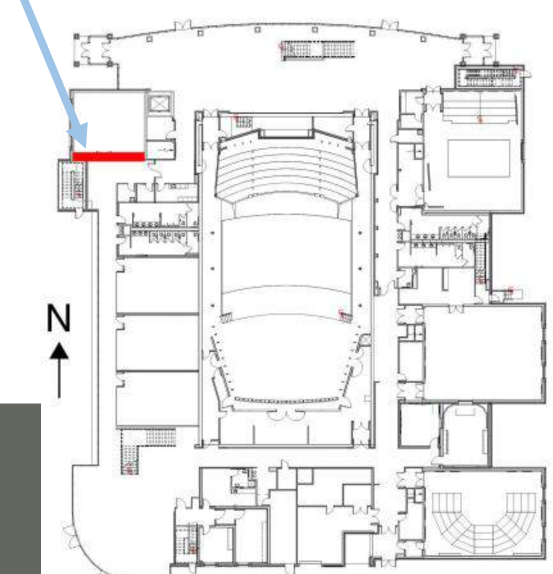




NAVISWORKS



The construction team used *Navisworks* to determine if there were any clashes in the project design. The *Revit* model was uploaded and a clash detection was run. This step of the construction team's analysis was extremely important because the disciplines typically worked in discipline-specific models within *Revit*, so performing a clash detection was a way to check the design progress periodically and recover from any interferences.



The top image shows a mechanical duct running into the concrete precast panel of the organ room (shown in red on the plan).

Liftcrane boom capacities - 2250 Series 3
Boom No. 44 with heavy lift top

113 040 kg (249,200 lb) Crane counterweight 54 430 kg (120,000 lb) Carbody counterweight
360° Rating kg (lb) x 1 000

Boom m (ft) / Radius	21,3 (70)	27,4 (90)	33,5 (110)	39,6 (130)	45,7 (150)	51,8 (170)	57,9 (190)	67,1 (220)	73,2 (240)	79,2 (260)	85,3 (280)	91,4 (300)
5,5 (18)	272,1 (600.0)											
7,0 (22)	239,3 (541.5)	223,4 (495.6)	169,8 —									
8,0 (26)	210,8 (469.1)	210,4 (468.1)	166,2 (367.0)	158,8 (350.7)								
9,0 (30)	188,2 (408.7)	187,8 (407.7)	162,9 (358.2)	155,9 (343.0)	135,8 (298.6)	— (284.1)						
11,0 (36)	154,1 (340.9)	154,2 (340.9)	153,8 (339.8)	150,9 (333.2)	130,7 (288.3)	124,9 (275.6)	108,2 (238.8)					
12,0 (40)	135,9 (293.0)	140,7 (304.2)	140,4 (303.9)	138,0 (298.3)	128,4 (282.3)	123,1 (270.7)	106,5 (234.2)	97,7 (214.8)	— (185.8)			
14,0 (46)	109,0 (239.8)	113,0 (248.7)	112,8 (248.3)	112,6 (247.9)	110,9 (244.2)	107,4 (236.4)	103,1 (227.2)	90,8 (200.2)	80,9 (178.4)	73,8 (162.8)	64,4 (142.0)	55,9 (123.3)
15,0 (50)	98,6 (212.6)	102,5 (221.2)	102,3 (220.8)	102,2 (220.4)	101,9 (219.6)	99,1 (214.7)	96,1 (207.8)	87,5 (191.2)	78,3 (171.3)	71,5 (156.5)	63,4 (138.6)	55,6 (122.6)
18,0 (60)	74,7 (160.4)	79,8 (172.4)	79,5 (171.8)	79,4 (171.4)	78,9 (170.5)	78,8 (169.8)	77,7 (168.3)	74,4 (160.5)	70,5 (153.9)	64,4 (140.7)	58,5 (129.1)	53,0 (116.0)
22,0 (70)	— (110.2)	59,4 (137.4)	60,7 (139.5)	60,4 (139.0)	60,0 (138.1)	59,7 (137.4)	59,2 (136.4)	58,4 (133.8)	56,5 (129.5)	55,4 (125.9)	55,0 (125.0)	48,4 (108.3)
24,0 (80)		51,6 (110.7)	54,0 (116.6)	53,8 (116.1)	53,3 (115.1)	53,0 (114.5)	52,5 (113.4)	51,9 (112.0)	50,9 (110.2)	50,1 (108.3)	48,9 (105.8)	46,4 (101.7)
28,0 (90)			42,8 (97.6)	43,6 (99.0)	43,2 (98.0)	42,8 (97.3)	42,3 (96.2)	41,7 (94.8)	41,2 (93.7)	41,3 (93.6)	40,2 (91.1)	38,8 (88.0)
30,0 (100)			37,8 (80.9)	39,6 (85.6)	39,2 (84.7)	38,9 (84.0)	38,4 (82.9)	37,8 (81.5)	37,2 (80.3)	37,3 (80.5)	36,7 (79.5)	35,4 (76.6)
34,0 (110)				32,1 (72.7)	32,9 (74.1)	32,6 (73.4)	32,1 (72.3)	31,4 (70.8)	30,9 (69.6)	30,9 (69.8)	30,7 (69.2)	29,8 (67.2)
36,0 (120)				28,7 (61.1)	29,9 (64.1)	30,0 (64.7)	29,5 (63.6)	28,8 (62.1)	28,3 (60.9)	28,4 (61.1)	28,1 (60.5)	27,5 (59.4)
42,0 (140)					21,9 (46.3)	22,9 (49.1)	23,2 (49.5)	22,6 (48.8)	22,1 (47.6)	22,2 (47.8)	21,9 (47.1)	21,3 (45.4)

MANITOWOC 2250—SERIES 3 SELECTION CRITERIA

To order to determine the type of crane required to completed construction of The Miller Center, *Syndicate* had to calculate which building component would be the critical pick. After analyzing the weight of each of the structural members, it was found that many of the concrete precast panels were significantly heavier than any of the other members, with the 48'x11' size weighing in at 75,600 pounds (37.8 tons). The site location of those panel sizes was also observed to determine the boom radius required to safely and efficiently install them. Referring to the precast plan on Structural Drawing S-9.0, the critical picks comprise the west stairwell at wall 36, as well as the south stairwell at walls 24 and 27. The required boom radius was measured using the planned crane path along the site, and was found to be 100 feet at a maximum. A boom length of 170 feet was assumed based on the 48 foot height of the panel, along with the height of the rigging. Utilizing these values within load charts for various crane sizes, it was found that a 300 ton crawler crane (Manitowoc 2250 - Series 3) could withstand the critical pick with a capacity of 84,000 pounds at the desired radius and length.

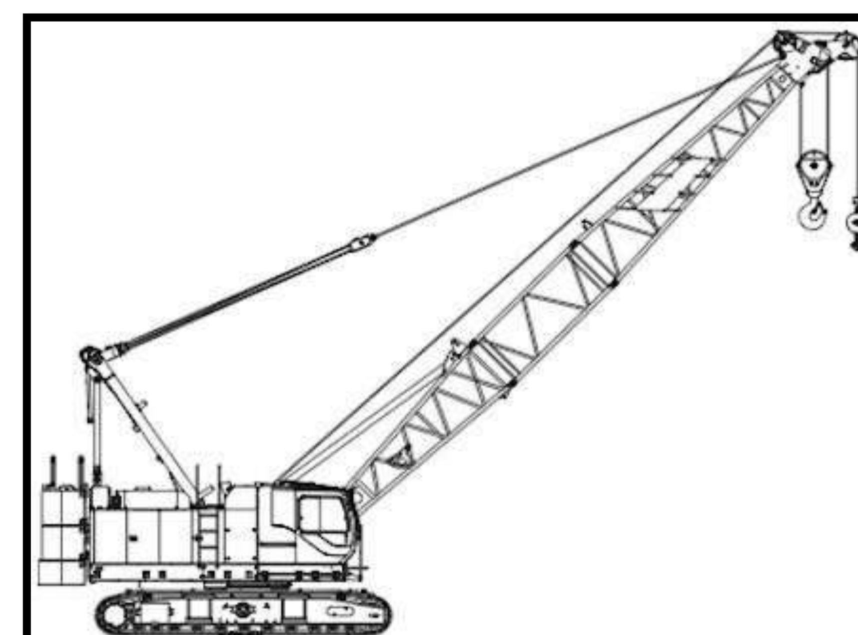
MANITOWOC 8000-1 SELECTION CRITERIA

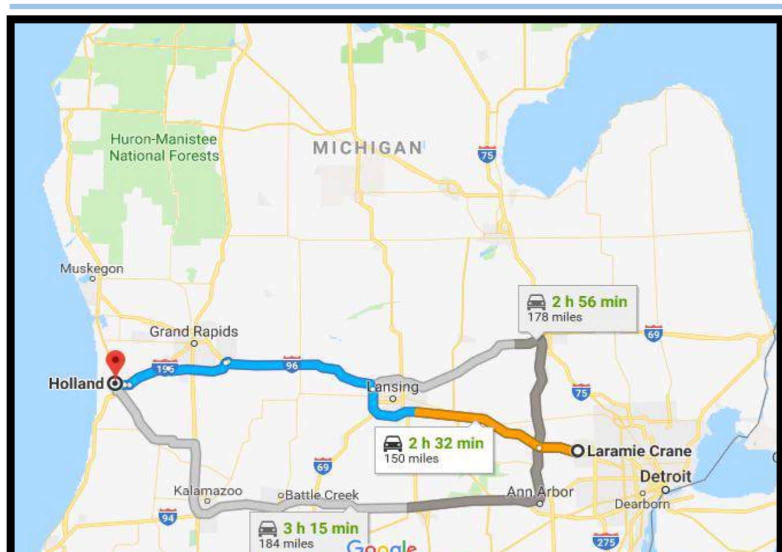
Given that the remaining structural members weigh significantly less than the precast concrete, *Syndicate* chose to de-mobilize the 300-ton crane and mobilize a smaller 80-ton crane once the precast members have all been erected. By analyzing the other structural components, it was found that the next critical pick will be a group of 24.42'x8.5'x10.5" CLT panels located in the 2nd floor mechanical room. With a weight of 5,832 pounds (2.9 tons) and a boom radius of 150 feet, *Syndicate* decided that it was an unnecessary expenditure to keep the 300-ton crane on site and chose an 80-ton crawler crane (Manitowoc 8000-1) for the remainder of construction. The selection criteria can be shown below, where the crane capacity is 3.3 tons versus the 2.9 ton critical pick.

Model 8000-1 liftcrane boom capacities - 8000-1 main boom

57,584 lb crane counterweight
14,330 lb carbody counterweight crawler extended
360° Rating lb x 1 000

Boom ft / Radius	50	60	80	100	120	140	160	180	190	200
12	160.0*									
14	144.0*	143.8*								
16	126.9*	126.7	126.3*							
18	113.2*	113.0	112.6*							
20	97.4	97.1	96.9	96.8*						
24	73.8	73.6	73.3	73.1	73.0*	61.7*				
28	59.2	58.9	58.7	58.4	58.3	57.9	44.0*			
34	45.5	45.2	44.8	44.5	44.3	44.0	42.1*	32.6*	28.8*	25.7*
40	36.8	36.4	36.0	35.7	35.4	35.1	34.9	31.0*	27.5*	24.4*
45	31.6*	31.2	30.8	30.5	30.2	29.9	29.7	29.2	26.4*	23.3*
55		24.2	23.7	23.3	23.0	22.6	22.4	22.0	22.1	21.3*
75			15.9	15.4	15.0	14.6	14.3	13.9	13.9	13.7
95				11.2	10.7	10.2	10.0	9.5	9.5	9.3
105					9.2	8.7	8.5	8.0	8.0	7.8
115					8.1	7.6	7.2	6.7	6.8	6.5
125						6.6	6.2	5.7	5.7	5.4
135						5.9	5.4	4.7	4.8	4.5
145							4.7	4.0	4.0	3.7
155								3.3	3.3	3.0
170								2.6	2.5	



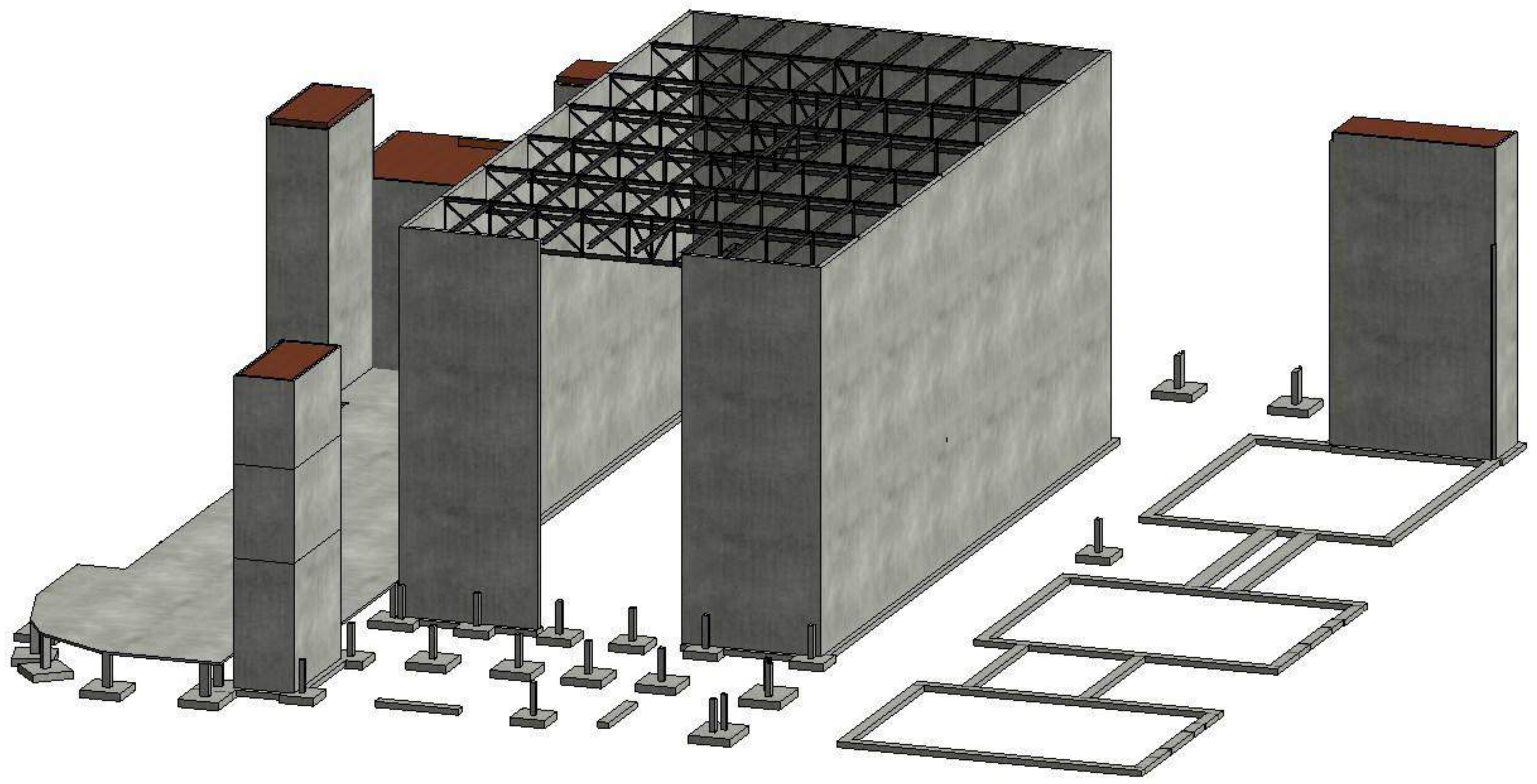


Crane Size	300 Ton	80 Ton
Time Used	20 Weeks	30 Weeks
Operating Cost	$146,000.00	$91,200.00
Rental Cost	$197,875.00	$115,500.00
Daily Equipment	$393,500.00	$256,200.00
Total	$737,375.00	$462,900.00
	$1,200,275.00	

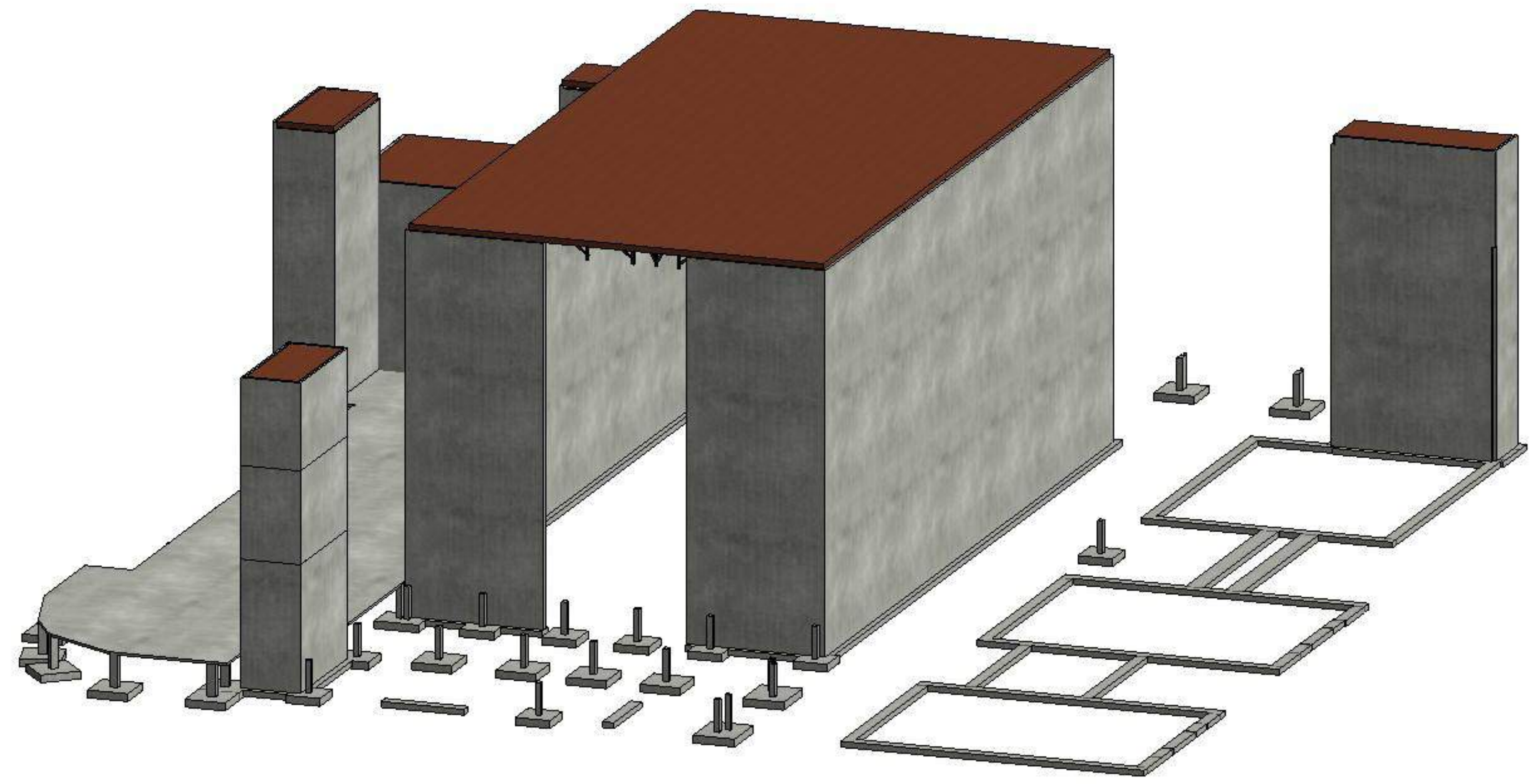
CRANE RENTAL AND ASSEMBLY

Both cranes will be rented from Laramie Crane in Wixom, MI, about 2.5 hours away from the Miller Center site. According to *Syndicate's* schedule, the 300-ton crane will be needed for 20 weeks and the 80-ton crane will be needed for 30 weeks. Assuming a daily operator cost of $182 for the 300-ton crane and $76 for the 80-ton crane, the total rental and operating cost for both cranes will be $1,200,275.00.

LATERAL SYSTEM AND UNDERGROUND DUCT COORDINATION



Concert Hall Truss

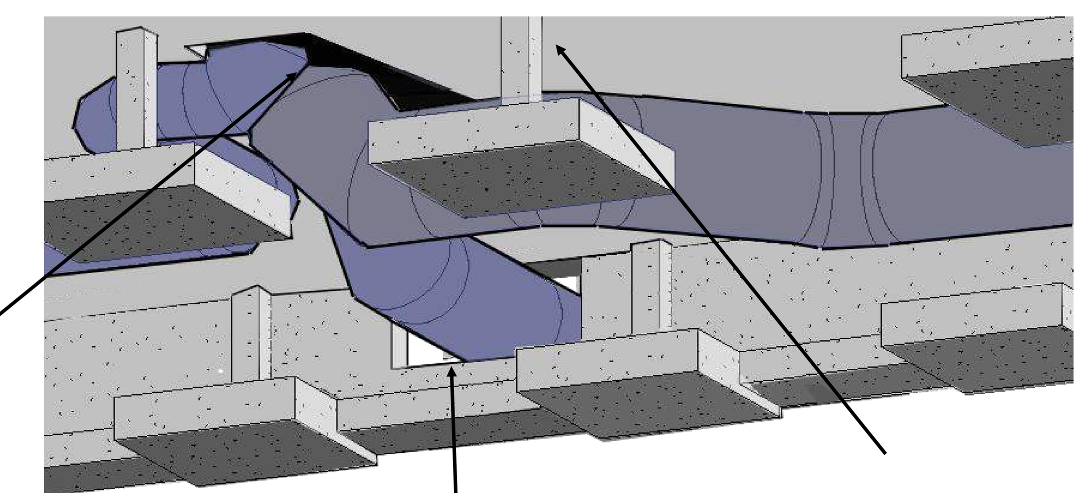


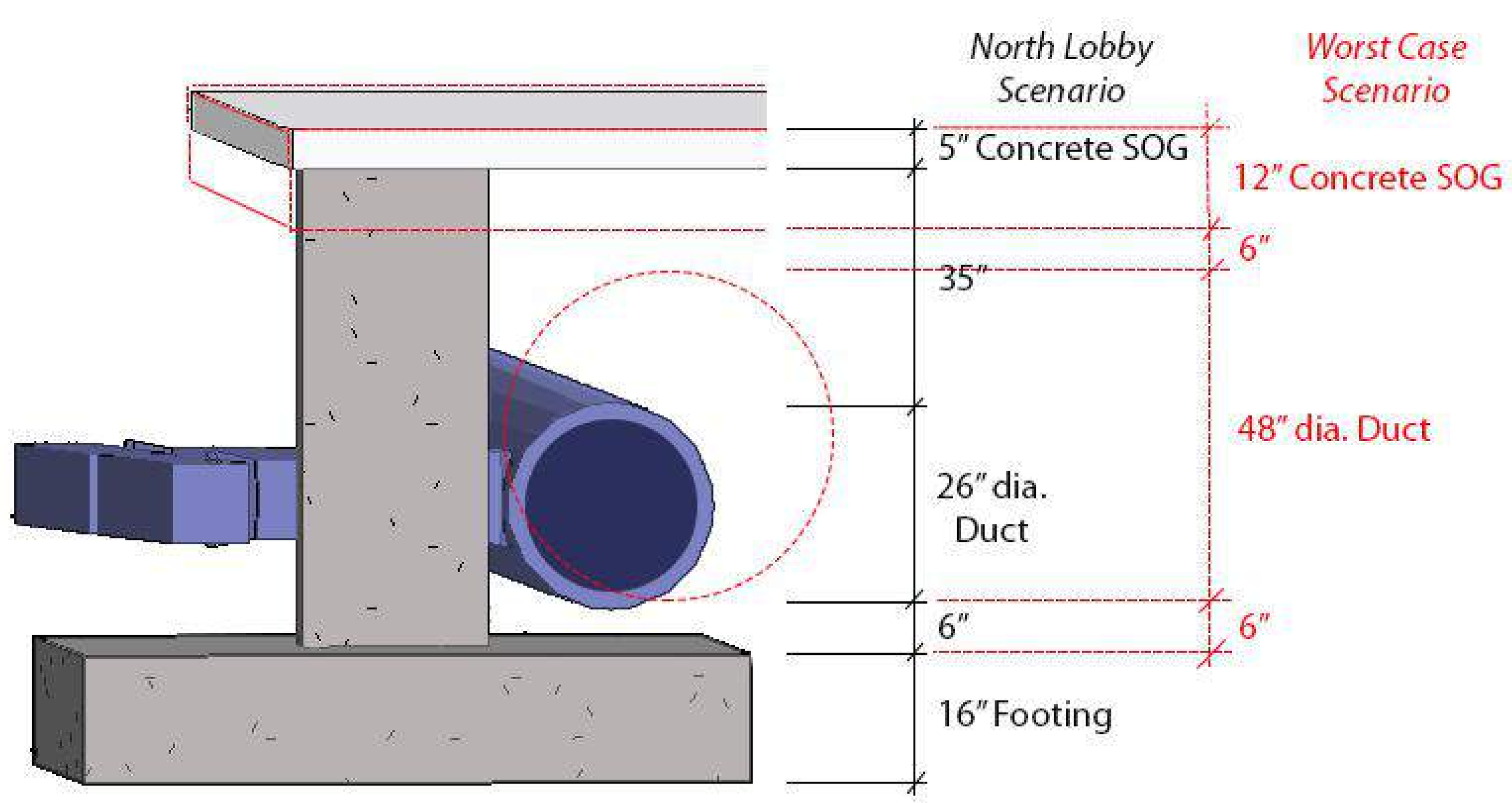
Concert Hall Truss and CLT

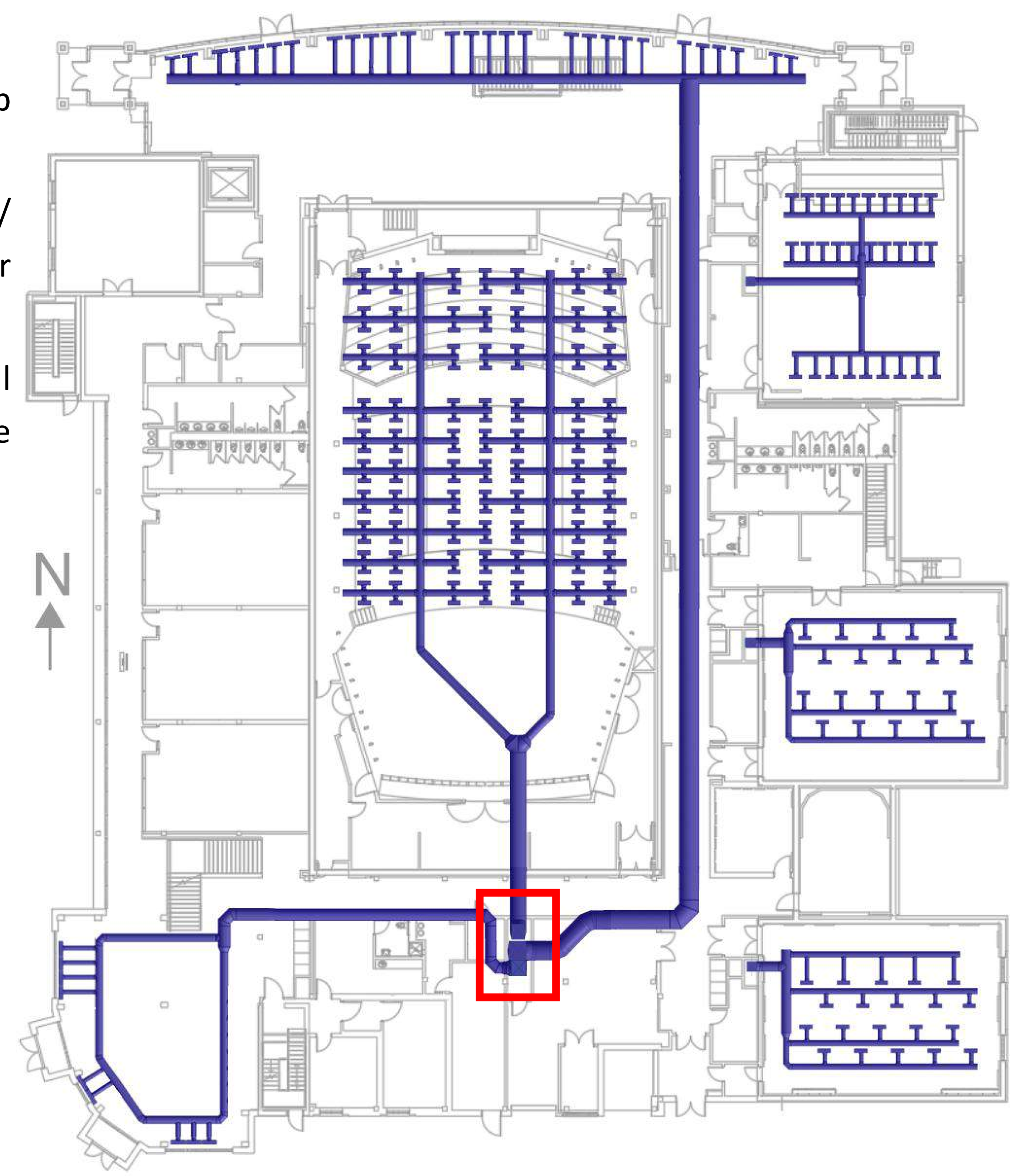
Constructability of the underground ducts proved to be one of *Syndicate's* major integration and coordination aspects. The foundations had already been designed and laid out when the decision was made to use the Blue Duct system for displacement ventilation. The construction team held several meetings to facilitate discussion between the structural and mechanical teams. The following are the steps *Syndicate* took to reach a solution:

1. Ensure that the concrete piers and the duct runs did not clash.
   - There was a clash under the mechanical room where the ducts penetrate the slab. The mechanical team was able to move the ducts and the mechanical equipment they connect to in order to avoid the clash.
2. Ensure the depths of the footers and ducts did not clash.
   - The largest underground duct is 48 inches in diameter, and originally the footers were three and a half feet deep. In order to leave six inches above and below for the underground ducts, the structural team decided to drop the footers to six feet below the top of the slab (see the figure below).
3. The last step in this collaboration was to determine how the underground ducts would penetrate the strip footers that support the lateral system.
   - The duct that supplies the concert hall is 40 inches in diameter and the ducts that supply the recital/rehearsal spaces are 24 inches in diameter. The structural team created a detail that shows a cut out for the suppling duct to enter each space (shown in the far right figure).

Finally, the construction team worked with the two teams to determine the sequence of construction. The panels will be placed and braced, the roofing system will be installed, the bracing will be removed, the underground ducts will be installed, and the slab will be poured. Refer to Construction Drawings C-5.0 for more information.







SYNDICATE	
PROJECT **JACK H. MILLER CENTER FOR MUSICAL ARTS** HOLLAND, MICHIGAN	
SHEET TITLE **Substructure/Superstructure Coordination**	
NOT FOR CONSTRUCTION	AEI TEAM NO. 01-2019
DATE February 18, 2019	SCALE NOT TO SCALE
DRAWING NO. C-1.0	PAGE NO. 141

QR CODE TRACKING

QR Codes will be used in the acoustically sensitive spaces as a quality assurance measure. When scanned, they will show any critical information needed including a checklist to ensure that worker knows exactly what is expected for that space. Every time the code is scanned, it logs which device was used, so if there are any quality issues, it is easy to determine the responsible contractor. Scan the QR code to the right to view the editable pdf quality checklist for the Choir Rehearsal Room.

Checklist

JACK H MILLER CENTER FOR MUSICAL ARTS

CHOIR REHEARSAL ROOM

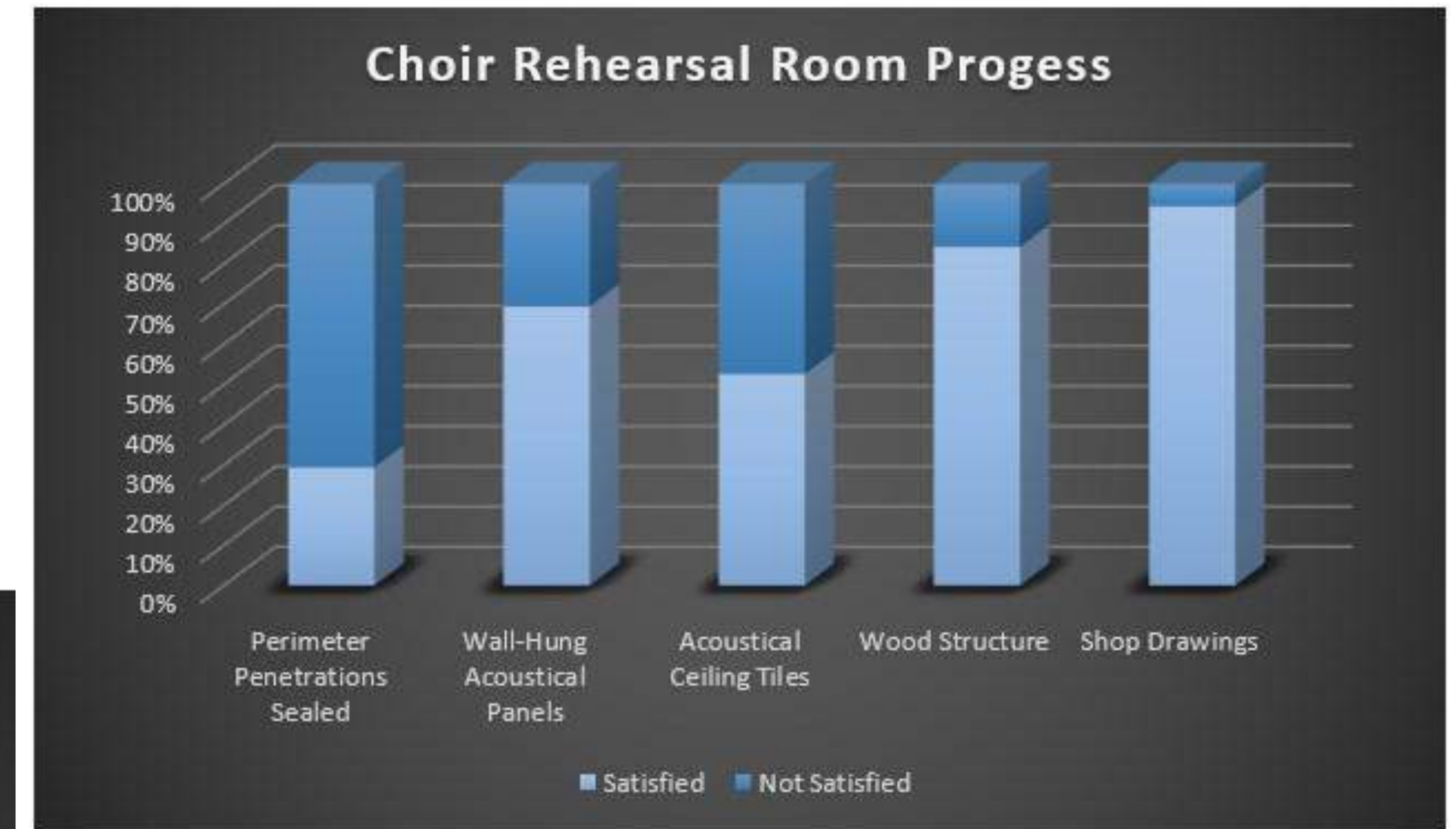
QUALITY

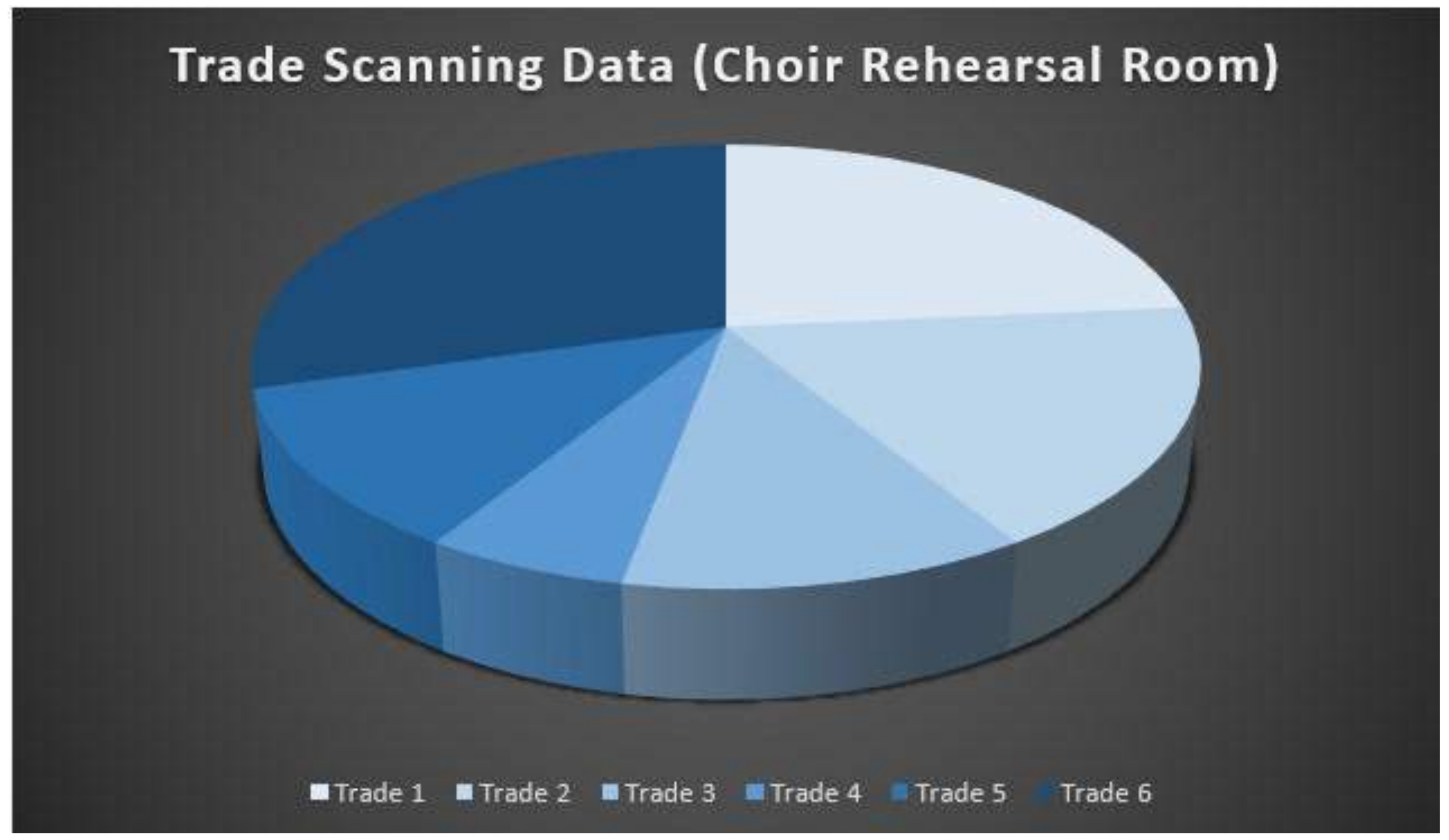
DATE: __/__/____

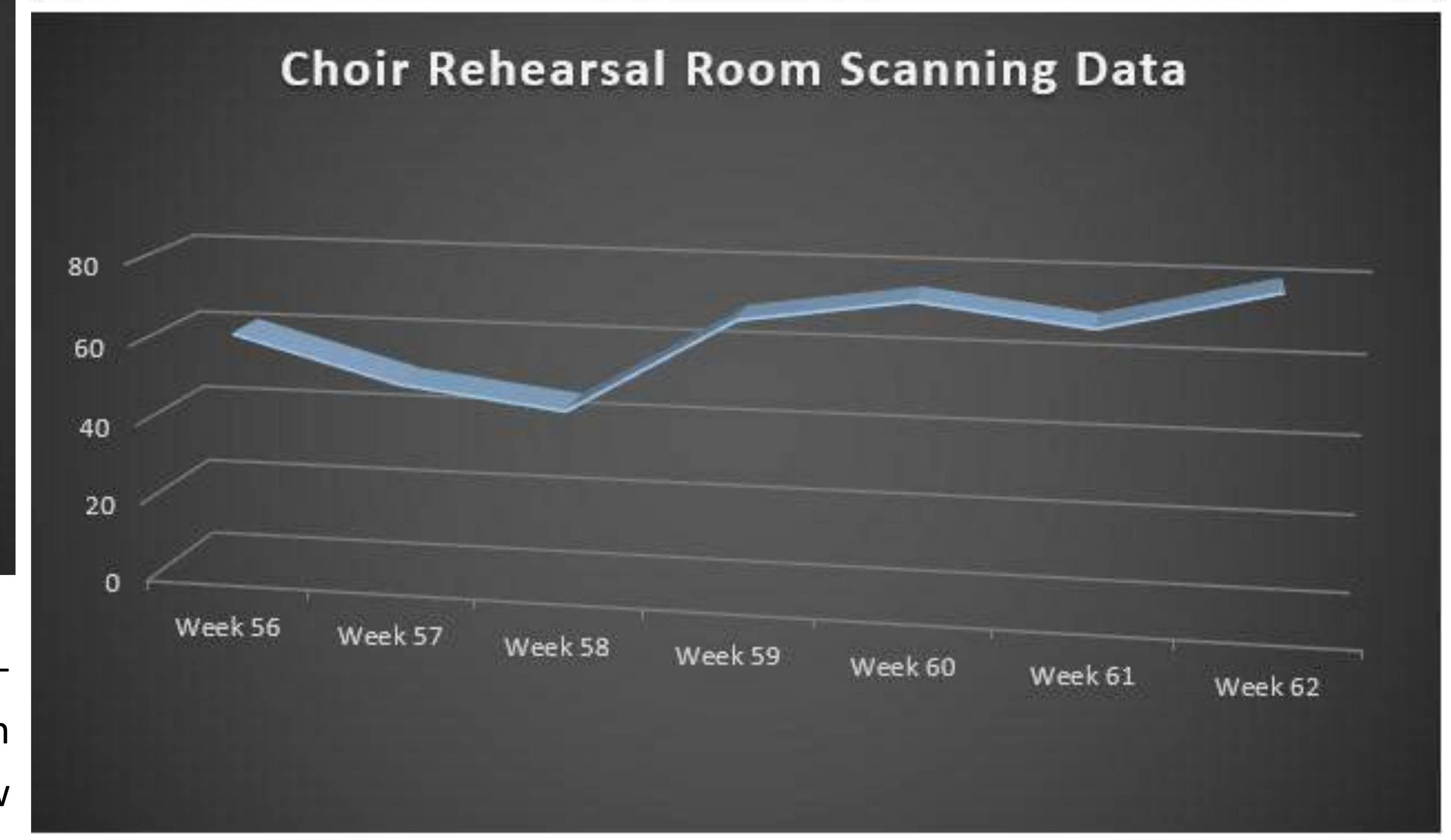
SATISFIED	NOT SATISFIED	
☐	☐	Make sure all perimeter penetrations are sealed (i.e. electrical outlets, door frames, window, drywall)
COMMENTS:		
☐	☐	Check if any of the wall-hung acoustical panels are dented/scuffed
COMMENTS:		
☐	☐	Check if any of the acoustical ceiling tiles are dented/scuffed
COMMENTS:		
☐	☐	Check if any of the exposed wood structure has any damage
COMMENTS:		
☐	☐	Are all items installed according to shop drawings?
COMMENTS:		

If you run into any problems, contact Syndicate's quality control rep: (123) 456-7890

SYNDICATE







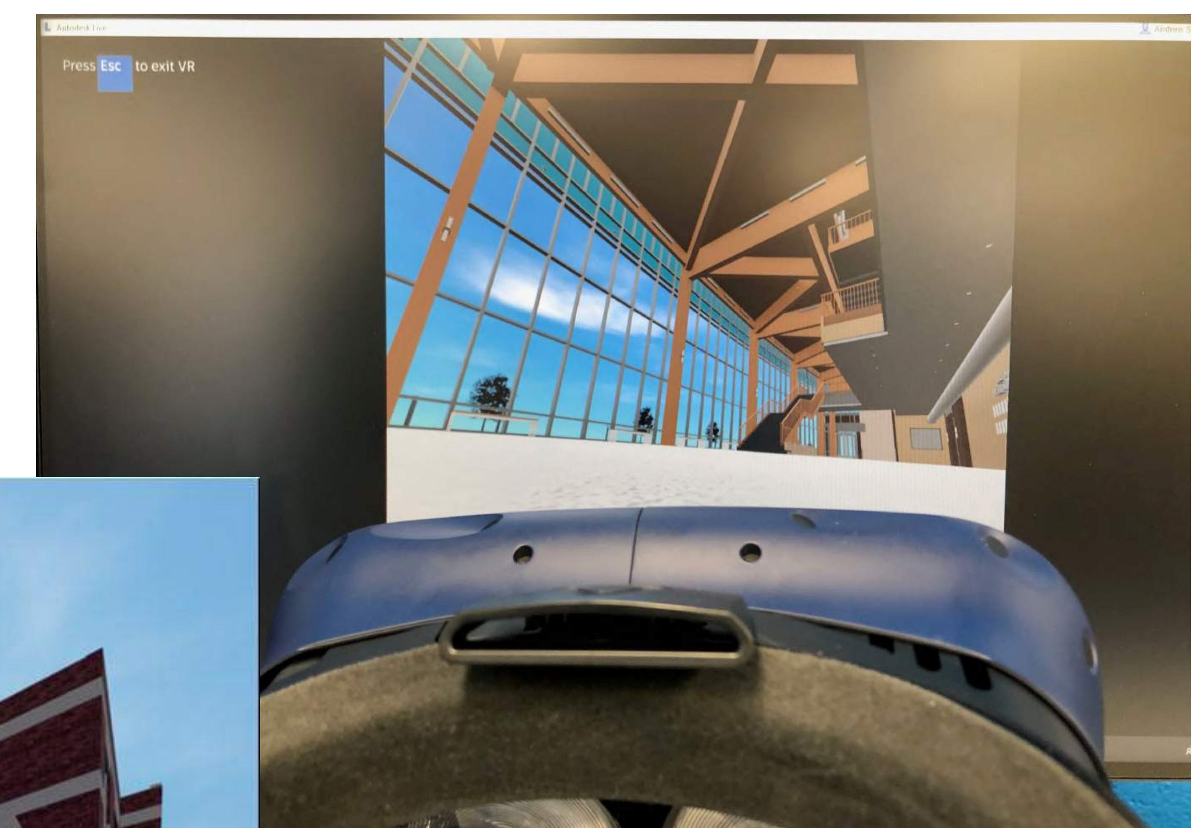
The QR code checklists will be linked to Google to compile the information supplied by workers. In the top right chart, the items from the checklist are shown as percentage satisfied versus not satisfied. The bottom right chart show how many times the QR code was scanned per week. The chart above shows the amount of times the QR code was scan broken down by trade.

VIRTUAL REALITY

Syndicate used VR throughout their project to verify their design and layout was optimal.

Syndicate will use VR as a design tool to keep their stakeholders involved at every major decision point throughout the project. By providing the stakeholders with a way to put themselves in the space before it has been built, it allows them to understand how the space will feel, make decisions or suggestions before the design or construction is too far along, and keep them invested.

VR will be in the office trailer, and will also be used by the workers on site to clarify how an item is to be built or what it should look like.



SYNDICATE

PROJECT

JACK H. MILLER CENTER FOR MUSICAL ARTS

HOLLAND, MICHIGAN

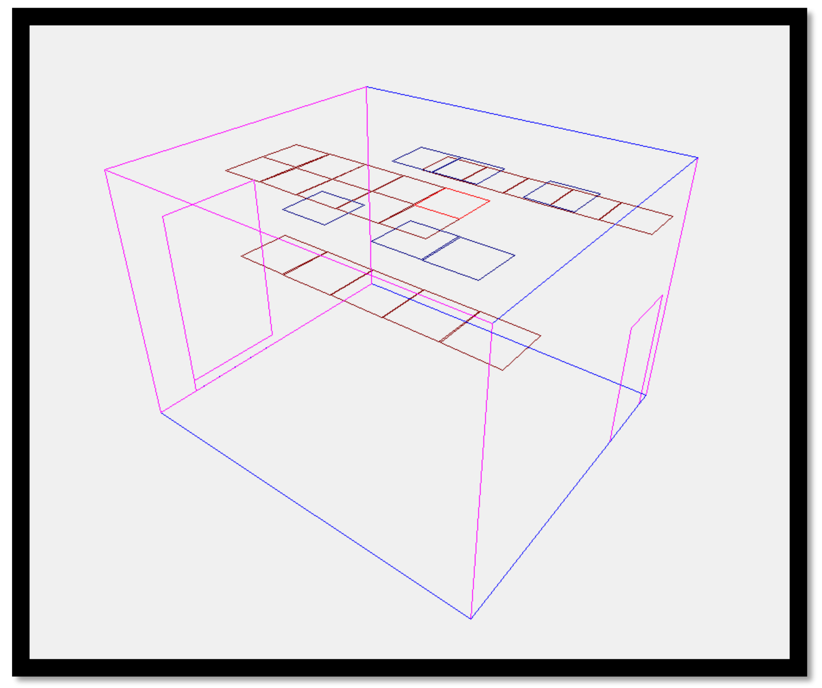
SHEET TITLE

Quality Assurance/Quality Control

NOT FOR CONSTRUCTION	AEI TEAM NO. 01-2019
DATE February 18, 2019	SCALE NOT TO SCALE
DRAWING NO. C-2.0	PAGE NO. 142

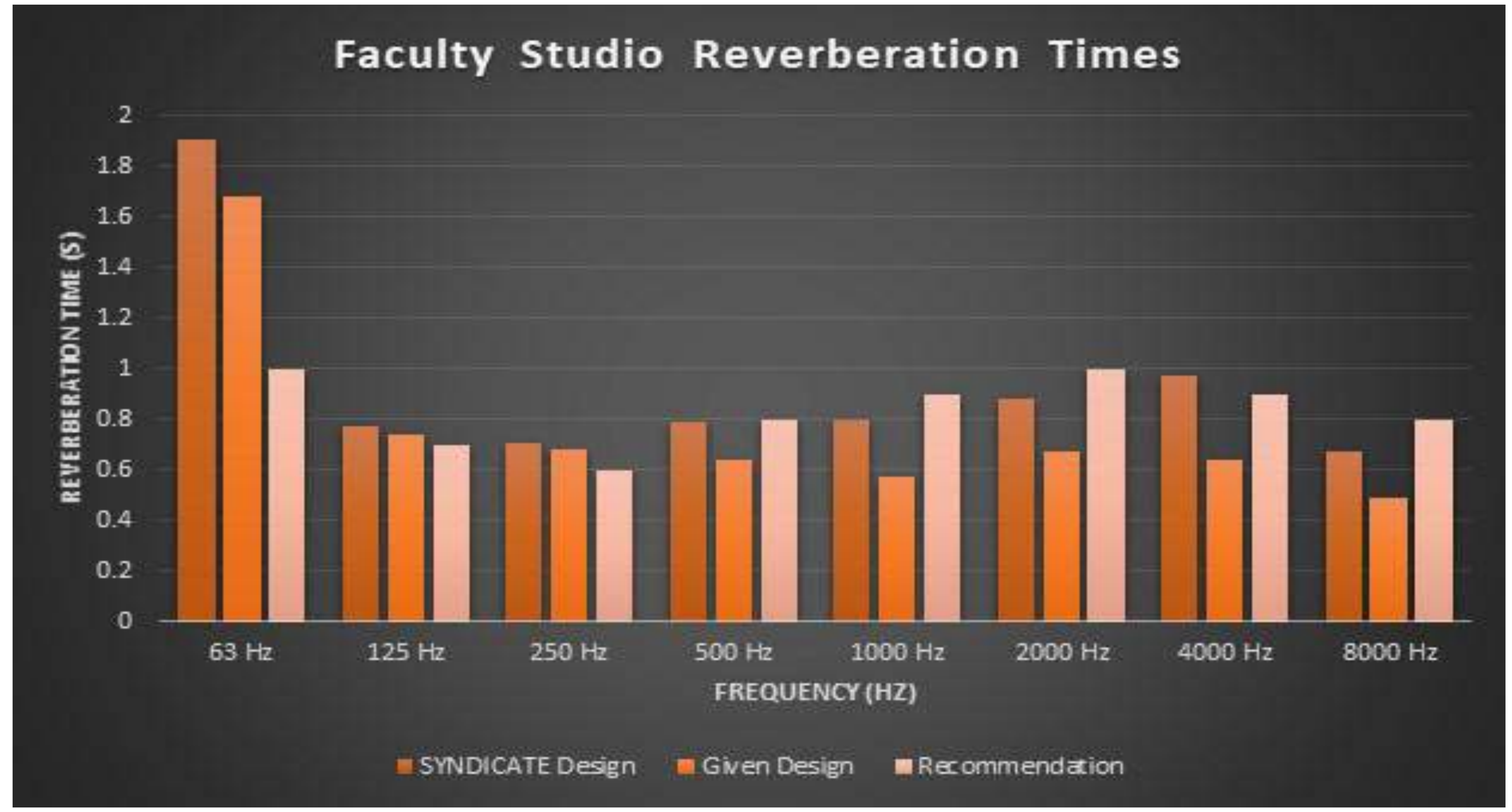
FACULTY STUDIO

Faculty studio rendering



Faculty studio modeled in ODEON

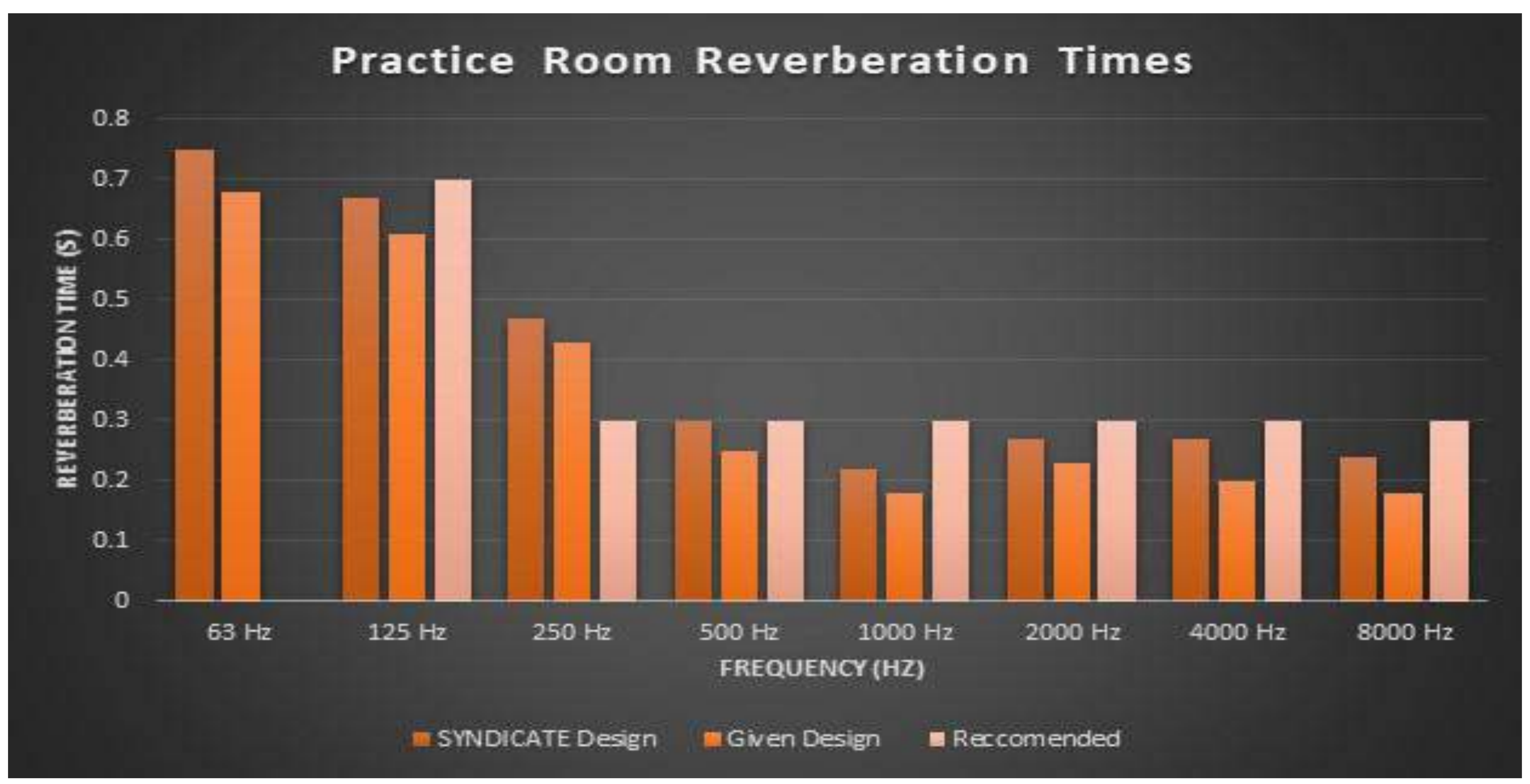
Given Design		Syndicate Design	
Item	**Cost**	**Item**	**Cost**
Faculty Studios			
AST-2 Acoustic Wall Panel	$35,105.00	Acoustical Light Fixtures	$75,990.00
Fluorescent Lighting	$13,974.00		
		Delta	**-$26,911.00**



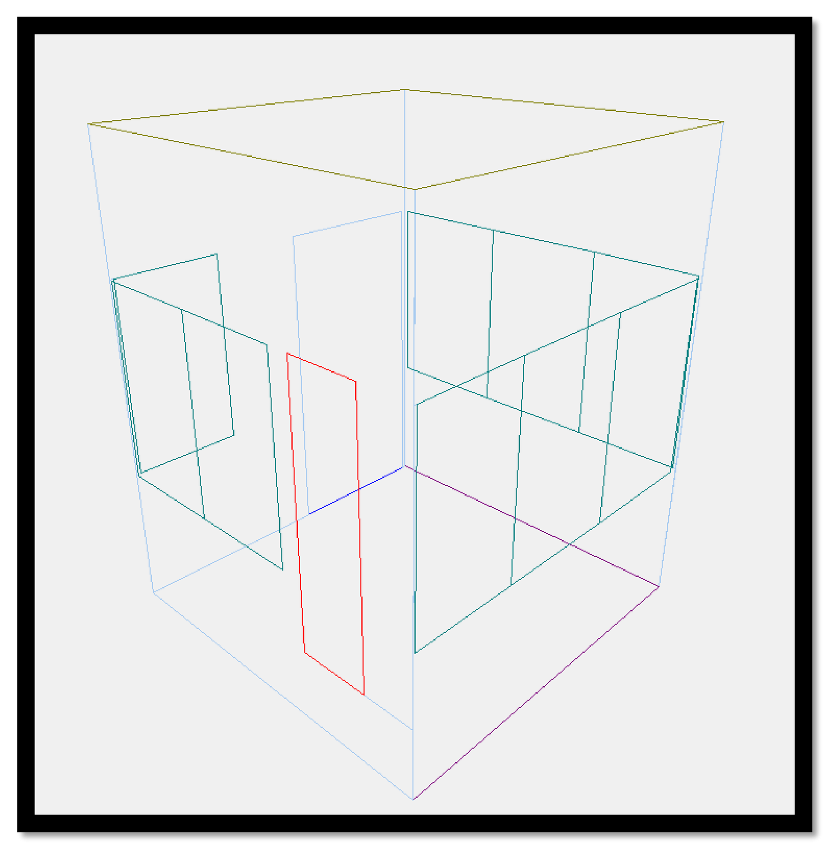
Faculty studio ODEON results

Syndicate incorporated a grid consisting of 2'x2' acoustic lighting fixtures and 2'x2' radiant panels into the *Faculty Studios*. Upon analysis in ODEON it was found that there were too many sound absorbing materials in the space. This allowed *Syndicate* to remove the acoustic wall panels from the given design, reducing some of the additional cost brought on by the advanced equipment. A detailed cost comparison breakdown for the 17 studios can be seen in the table below.

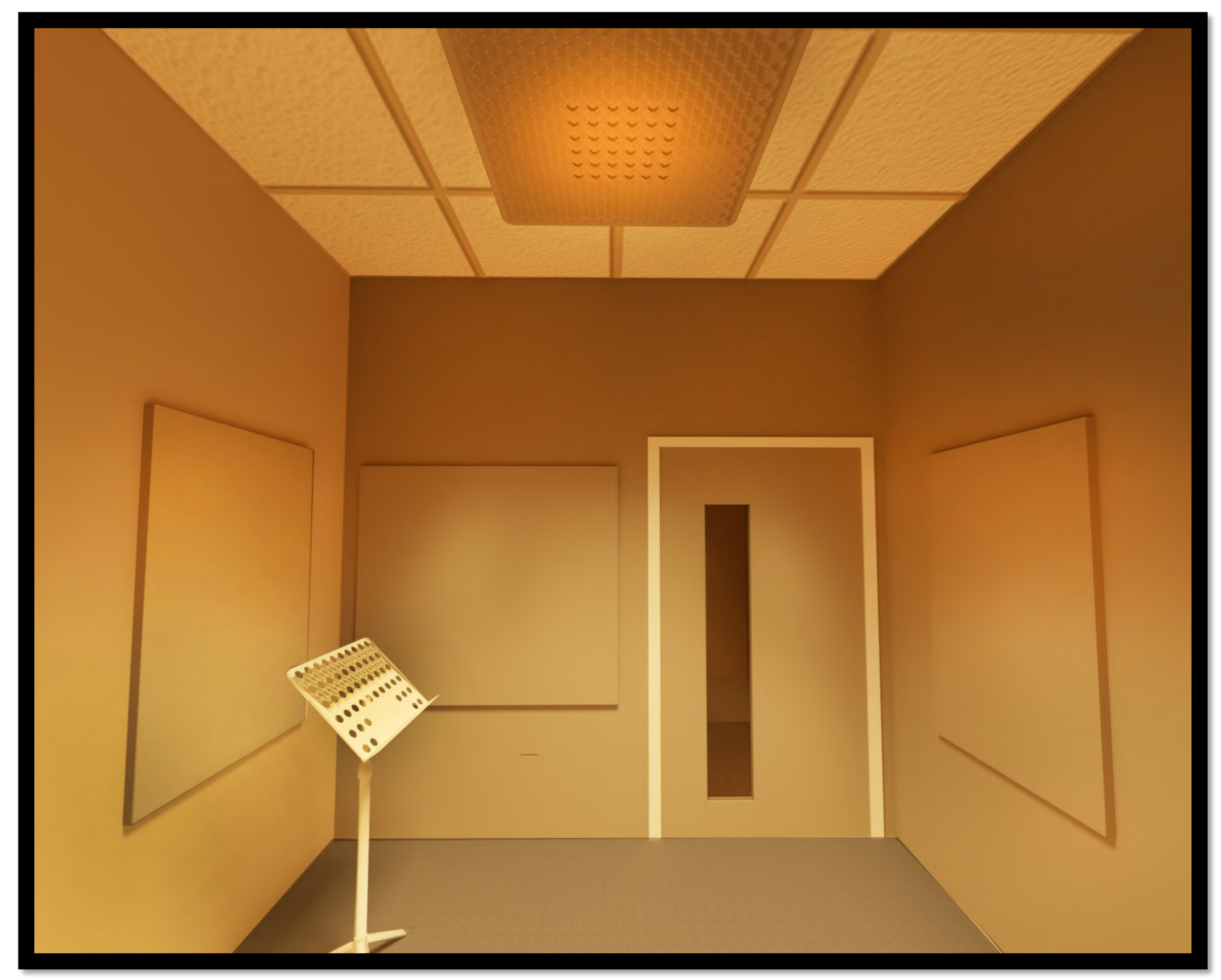
PRACTICE ROOM



Individual practice room ODEON Results



Individual practice room modeled in ODEON



Individual practice room rendering

Syndicate modeled the *Individual Practice Rooms* in ODEON and discovered that the reverberation time values were below the desired range, calling for a removal of sound absorbing materials, The given design provided 9 acoustic wall panels measuring 4'x4'2", and removing 5 of those provided the desired RT values. With 19 rooms, this resulted in 95 panels able to be removed overall. A cost breakdown comparison can be seen in the table to the left.

Given Design		Syndicate Design	
Item	**Cost**	**Item**	**Cost**
Individual Practice Rooms			
AST-2 Acoustic Wall Panel	$35,311.50	AST-2 Acoustic Wall Panel	$15,964.00
		Delta	**$19,347.50**

SYNDICATE

PROJECT

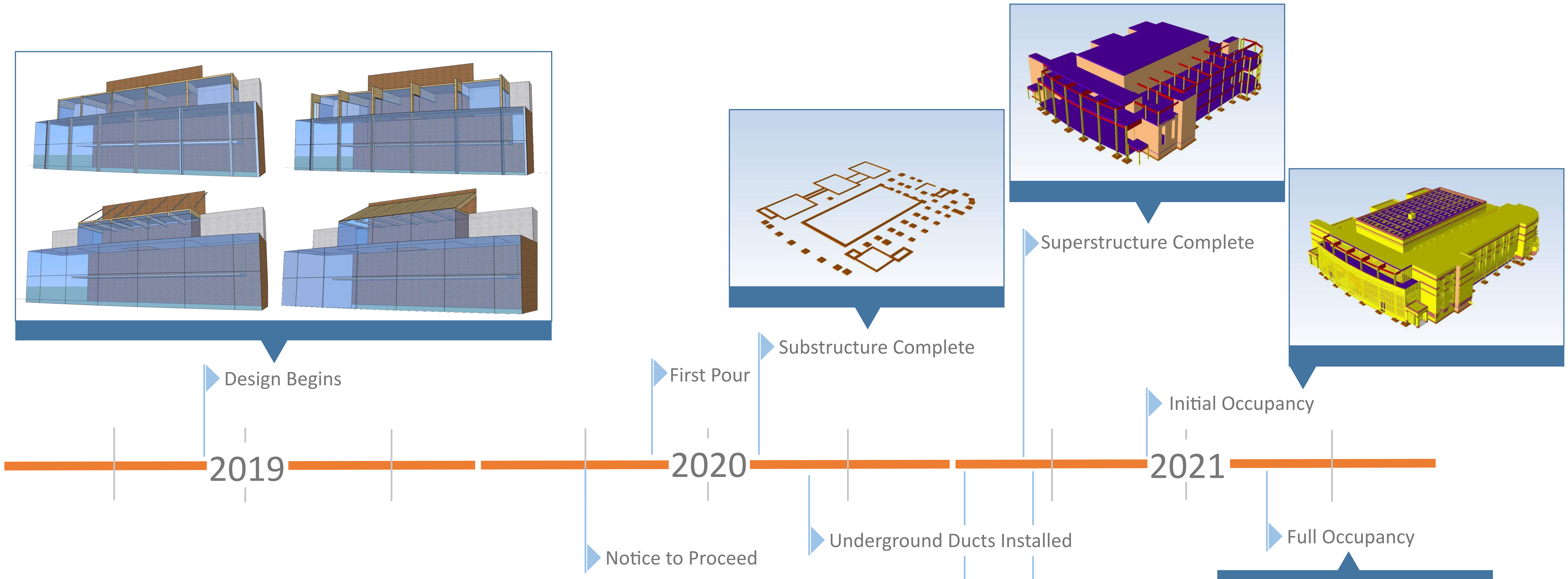
JACK H. MILLER CENTER FOR MUSICAL ARTS

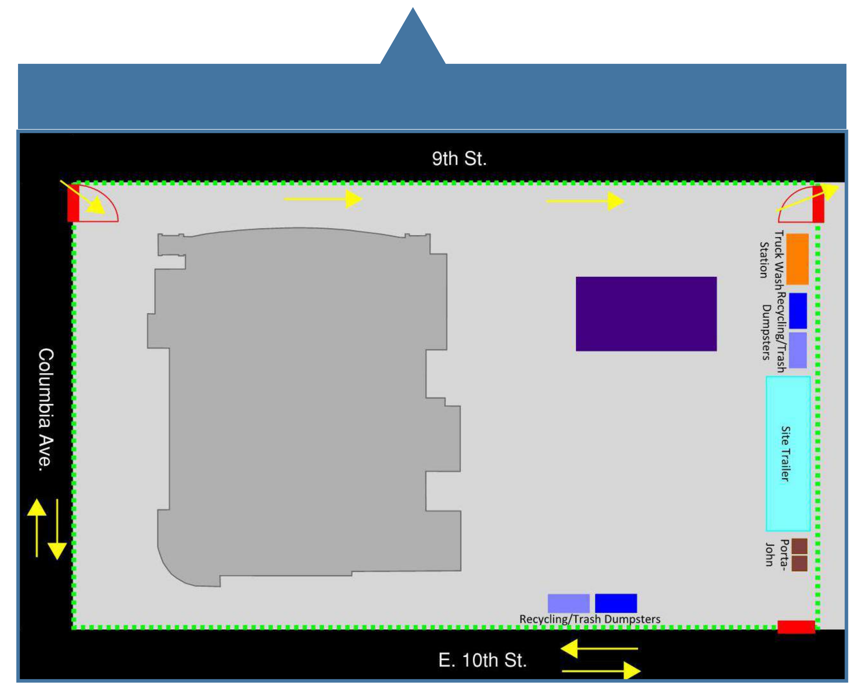
HOLLAND, MICHIGAN

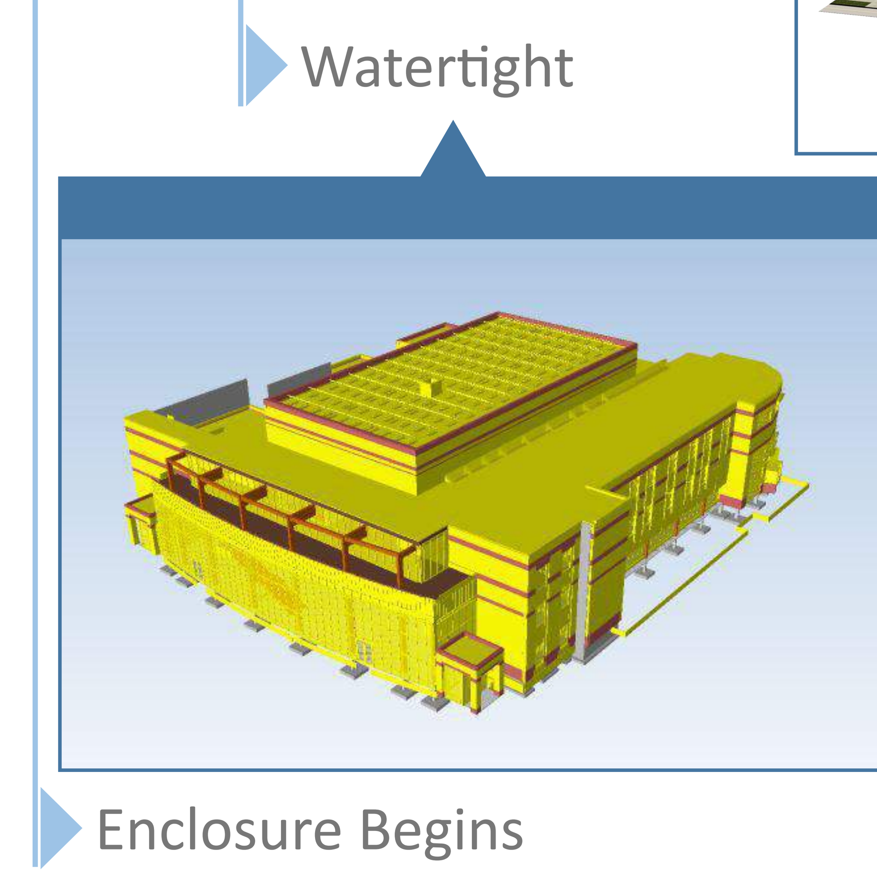
SHEET TITLE

Acoustic Improvements Cost Analysis

NOT FOR CONSTRUCTION	AEI TEAM NO. 01-2019
DATE February 18, 2019	SCALE NOT TO SCALE
DRAWING NO. C-3.0	PAGE NO. 143







MILESTONE SCHEDULE

Syndicate's construction team has created a 24-month total design and construction schedule for The Jack H Miller Center for Musical Arts, sixteen of those months being the construction phase of the project. Shown above is the milestone schedule for the project that was created to give the owner a high-level summary of the project activities and total duration and to ensure any major conflicts with campus events are mitigated. The following are the exact dates of the project's major milestones:

- Design Begins: August 1, 2019
- Notice to Proceed: April 2, 2020
- First Pour: June 4, 2020
- Substructure Complete: July 8, 2020
- Underground Ducts Installed: September 24, 2020
- Enclosure Begins: January 21, 2021
- Superstructure Complete: February 22, 2021
- Watertight: March 4, 2021
- Initial Occupancy: June 28, 2021
- Full Occupancy: August 12, 2021

Further schedule detail can be found on <u>Construction Drawing C-5.0</u> and <u>Construction Drawing C-6.0</u>.

SYNDICATE

PROJECT

JACK H. MILLER CENTER FOR MUSICAL ARTS

HOLLAND, MICHIGAN

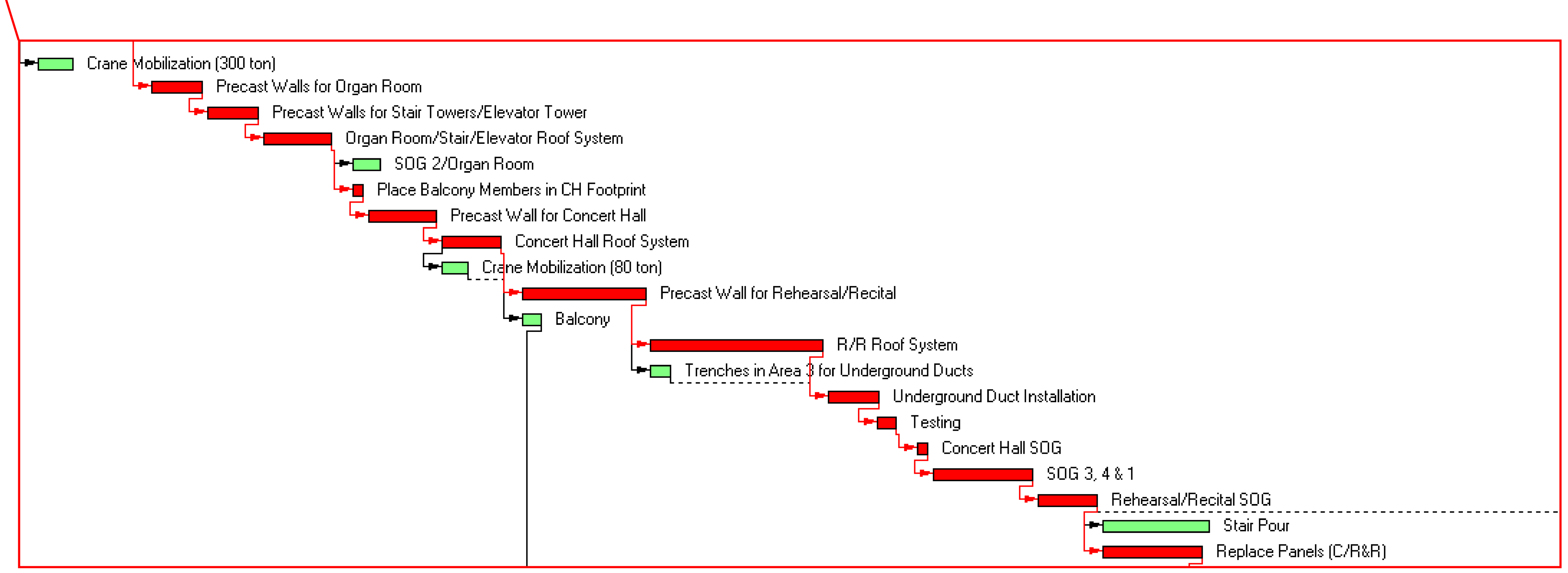
SHEET TITLE

Milestone Schedule

NOT FOR CONSTRUCTION	AEI TEAM NO. 01-2019
DATE February 18, 2019	SCALE NOT TO SCALE
DRAWING NO. C-4.0	PAGE NO. 144

Long Lead Times

Identifier	Item	Lead Time (wks)	Procure By
	Radiant Panels	10	March 12, 2021
	Acoustic Panels	12	January 13, 2021
	Concert Hall Seating	16	December 28, 2020
	Heat Exchanger	16	August 21, 2020
	Heavy Timber	16	March 20, 2020
	Precast Panels	16	March 12, 2020
	Chillers	20	July 24, 2020



SCHEDULE DETAILS

The total construction schedule for the Miller Center is centered around ensuring it is ready for the Fall 2021 semester. Delivering through a design-build approach allows *Syndicate* to fast-track the beginning of the project, so the design will be finalized through the foundation installation and placement of the construction process. Construction will start immediately after the Spring 2019 Commencement, so some of the most interfering activities are happening when most students are home for the summer. The precast and heavy timber construction facilitate an expedited superstructure construction, allowing the project team to spend a significant amount of time on the interiors. This is especially important for this project, as one of *Syndicate's* main goals is to maximize occupant experience.

SYNDICATE

PROJECT

JACK H. MILLER CENTER FOR MUSICAL ARTS

HOLLAND, MICHIGAN

SHEET TITLE

Detailed Schedule

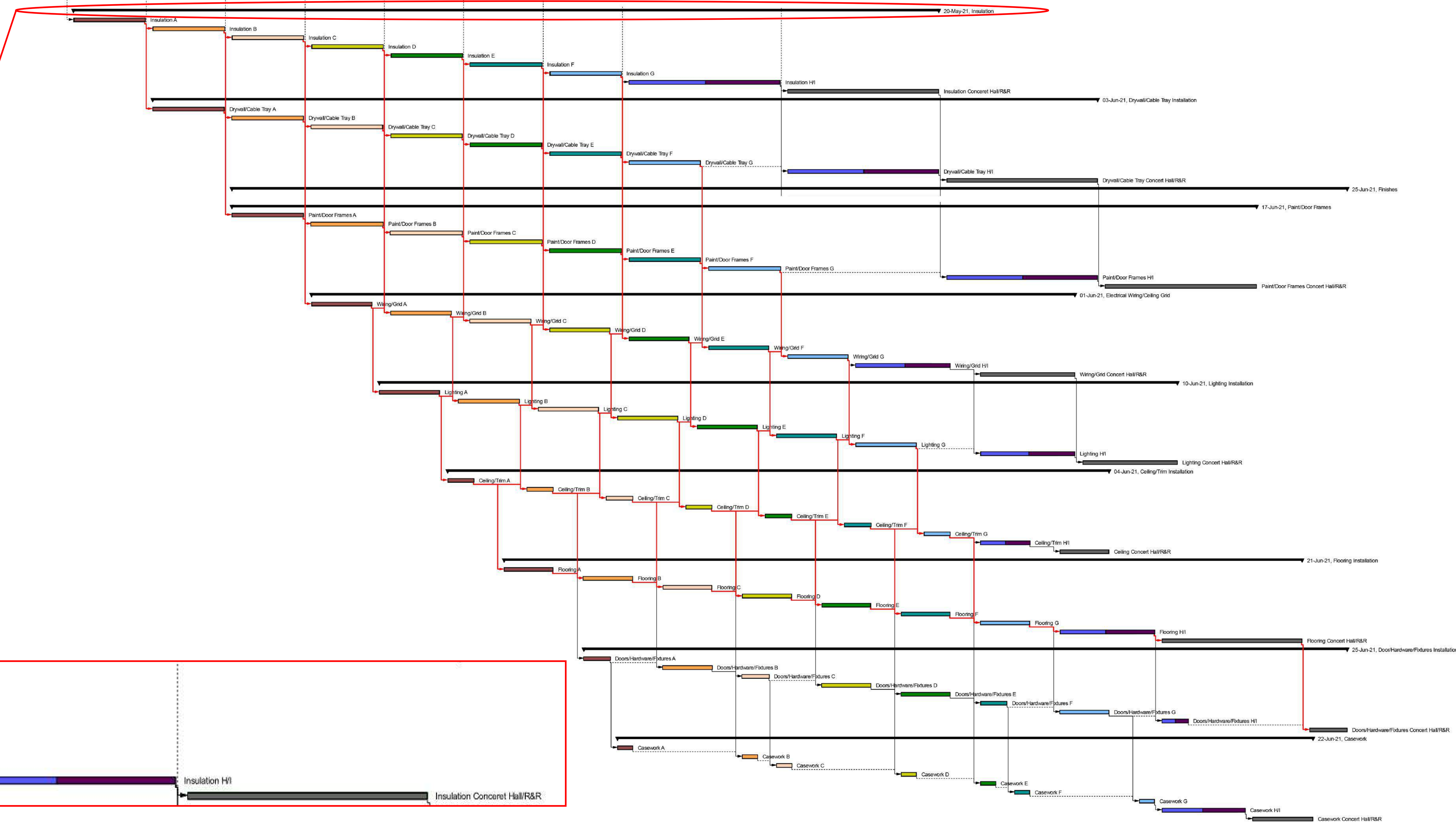
NOT FOR CONSTRUCTION	AEI TEAM NO. 01-2019
DATE February 18, 2019	SCALE NOT TO SCALE
DRAWING NO. C-5.0	PAGE NO. 145

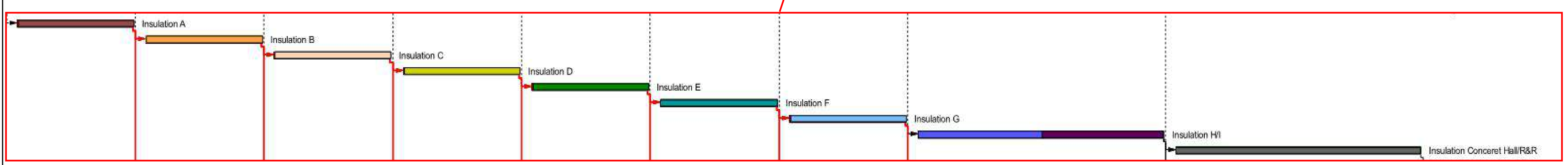
PARADE OF TRADES SEQUENCING

Parade of trades is a highly efficient way of scheduling trades back to back in a certain space, and following a pattern through a project. This tactic is similar to Short Interval Production Scheduling (SIPS), the difference being SIPS is used for highlight repeatable tasks. When one trade follows another consistently, they become accustomed to the way in which the trade ahead of them works and shortens the total time for equipment or material installation. The Miller Center project has four very distinct areas and therefore lends itself to a sequenced schedule. Implementing this sequence will ensure efficiency and high quality of the finishes.

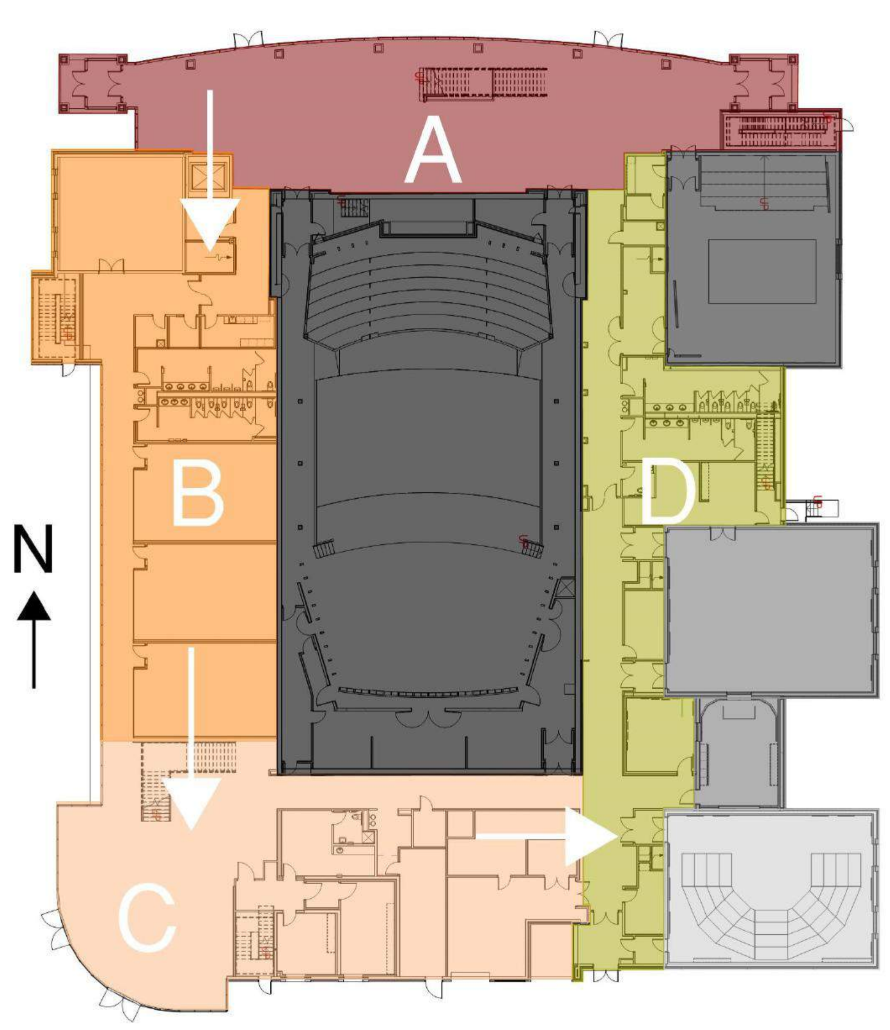
The parade of trades sequencing starts with the framework and includes the MEP, insulation, drywall and cable tray installation, paint and door frames, electrical wiring and ceiling grid, lighting installation, ceiling installation, flooring installation, doors, hardware, and fixtures installation, and casework aspects of the project. This sequencing begins in **December of 2020** and goes through **June of 2021**.

The sequence moves counterclockwise, starting in the north lobby, moves to the west side, then the south lobby and the rest of the south side, and then the east side. The concert hall and recital/rehearsal spaces follow.

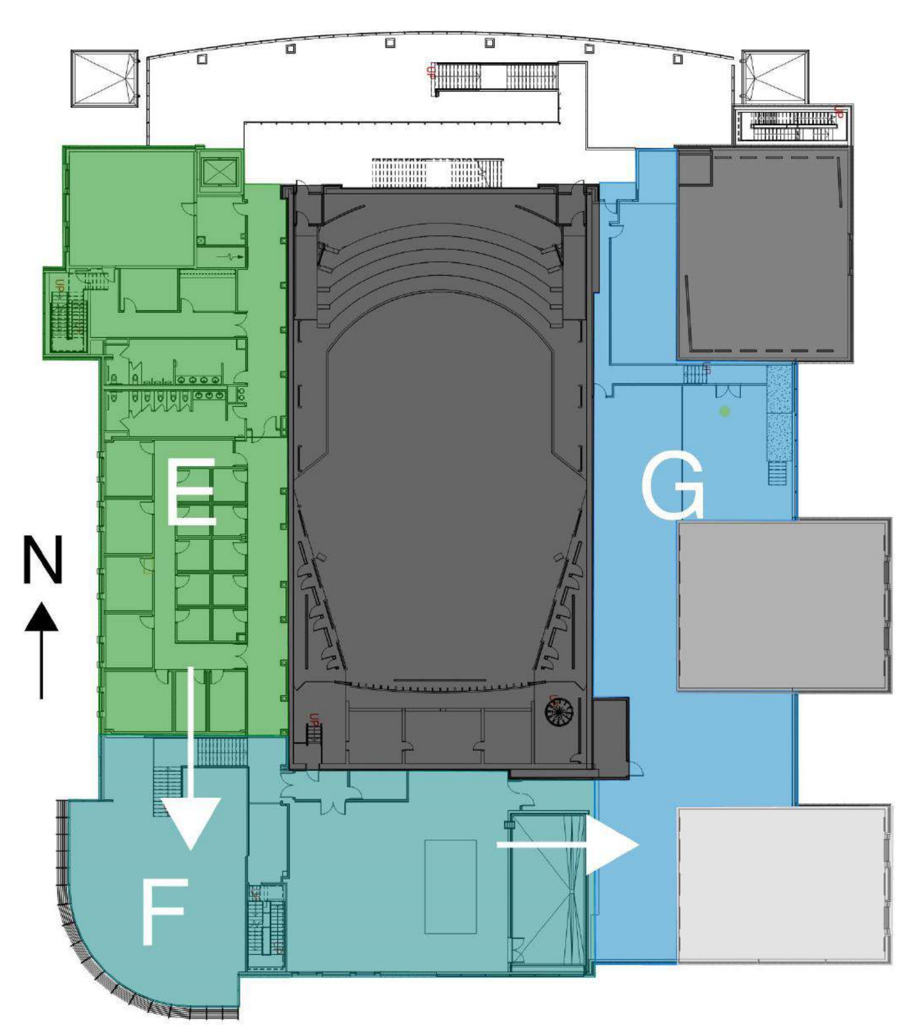




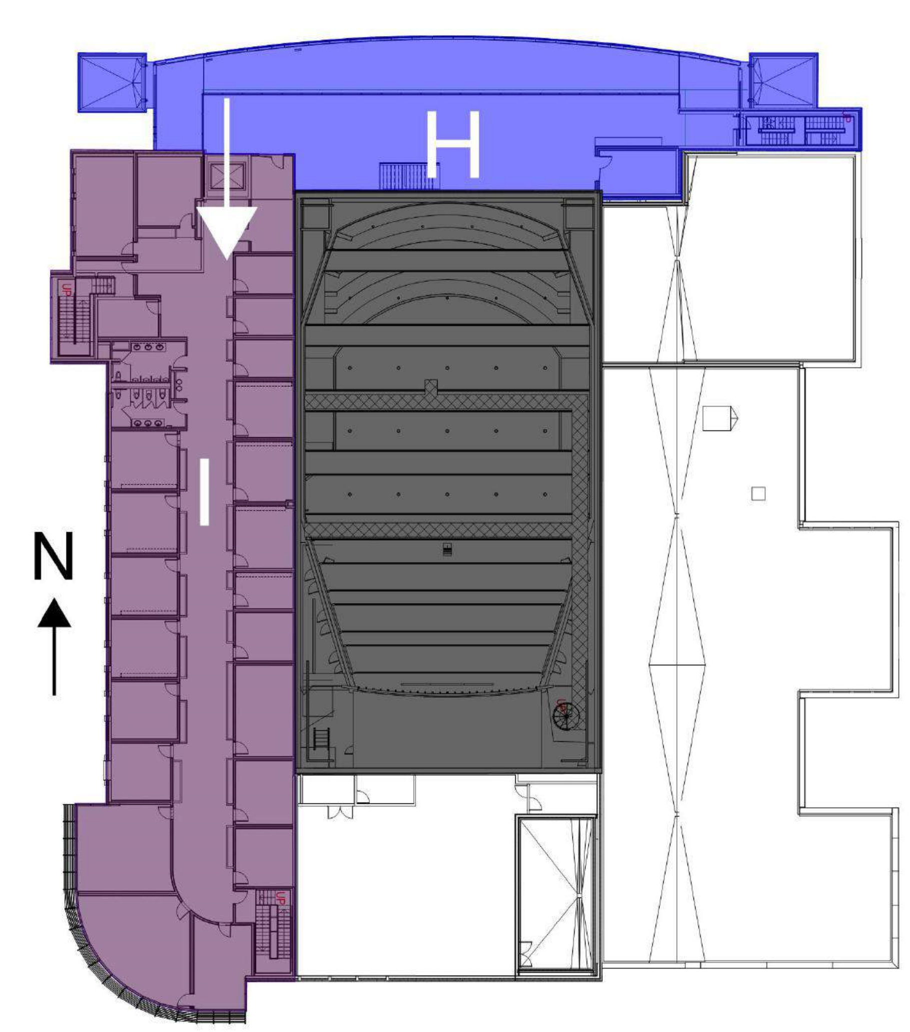
Floor 1



Floor 2



Floor 3



SYNDICATE

PROJECT

JACK H. MILLER CENTER FOR MUSICAL ARTS

HOLLAND, MICHIGAN

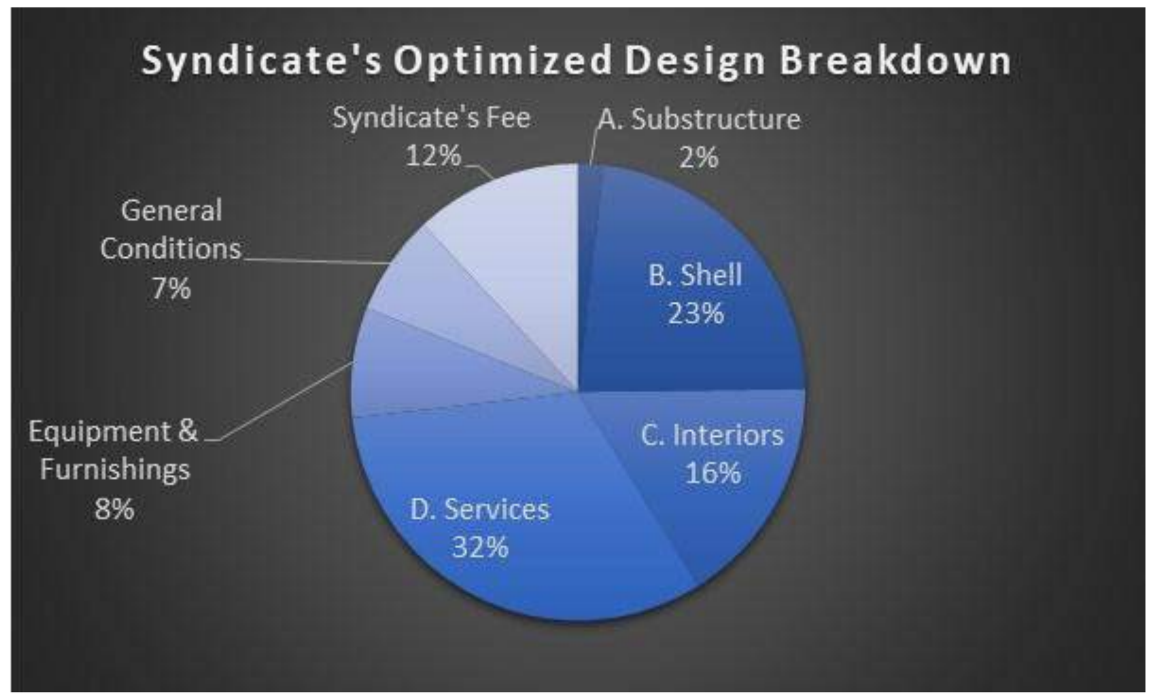
SHEET TITLE

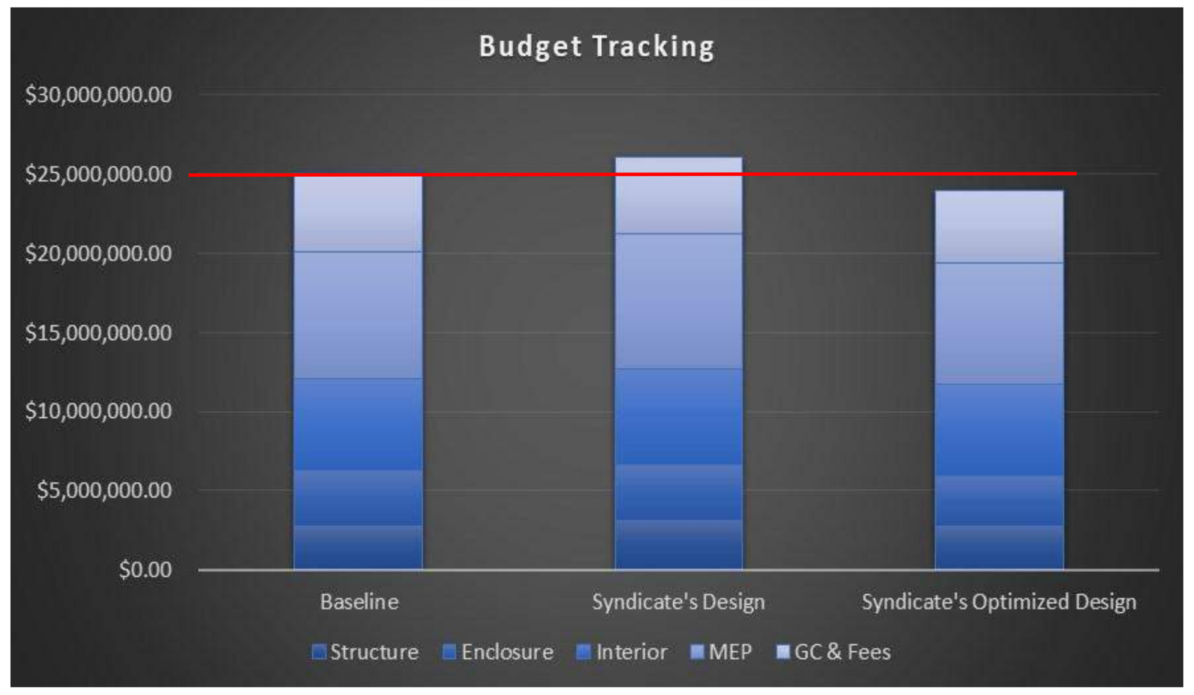
Parade of Trades

NOT FOR CONSTRUCTION	AEI TEAM NO. 01-2019
DATE February 18, 2019	SCALE NOT TO SCALE
DRAWING NO. C-6.0	PAGE NO. 146

UNIFORMAT II COST BREAKDOWN

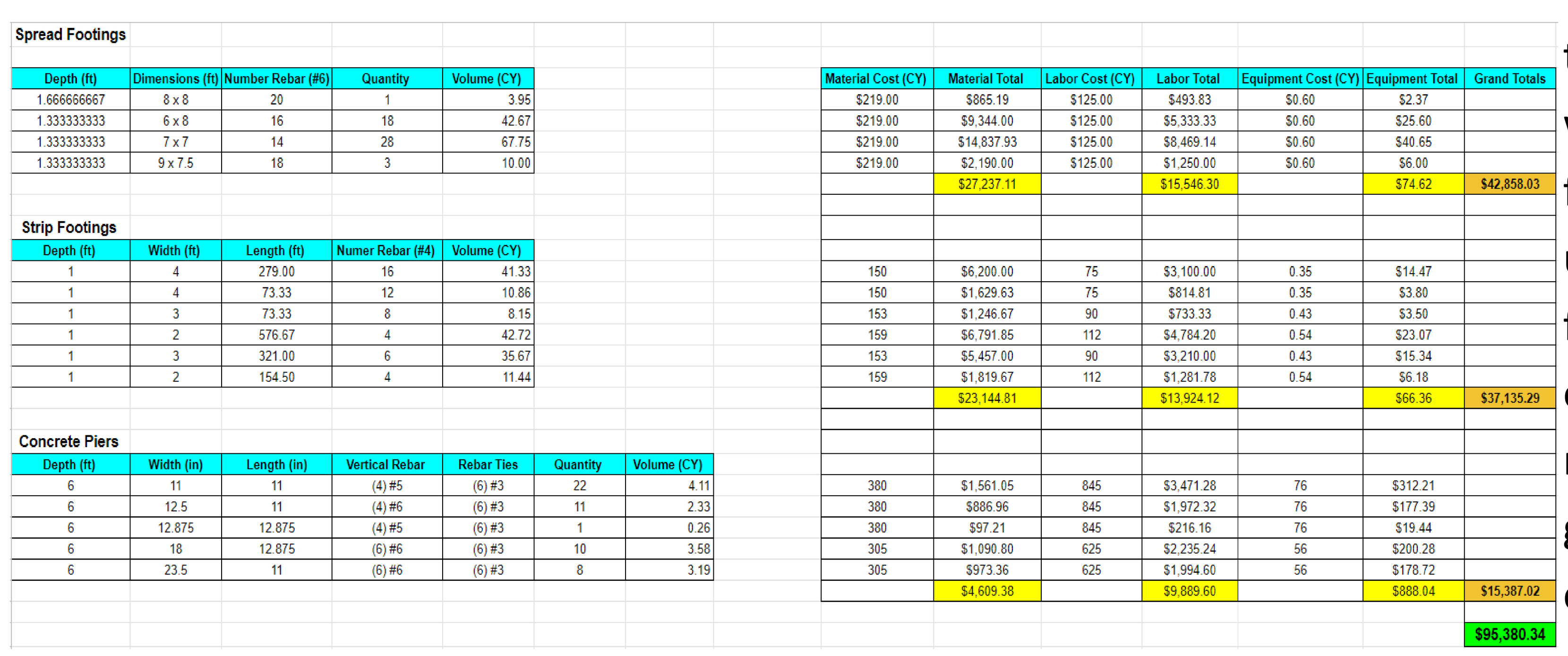
Uniformat II Breakdown		Baseline	Syndicate's Design	Syndicate's Optimized Design	Syndicate's Optimized Design
A	Substructure	$990,000.00	$475,186.00	$424,616.00	*1.8%*
B10	Superstructure	$1,800,000.00	$2,661,831.00	$2,366,072.00	*9.9%*
B20	Exterior Enclosure	$2,860,000.00	$3,210,469.00	$2,916,352.00	*12.2%*
B30	Roofing	$640,000.00	243839	$219,107.00	*0.9%*
C	Interiors	$3,890,000.00	$4,219,151.00	$3,909,687.00	*16.3%*
D10	Conveying	$580,000.00	$1,200,275.00	$1,200,275.00	*5.0%*
D20	Plumbing	$1,583,000.00	$764,435.00	$725,652.00	*3.0%*
D30	HVAC	$2,532,000.00	$2,847,657.00	$2,224,318.00	*9.3%*
D40	Fire Protection	$540,000.00	$605,391.00	$549,645.00	*2.3%*
D50	Electrical	$2,810,000.00	$3,138,811.00	$2,976,080.00	*12.4%*
E	Equipment & Furnishings	$1,865,000.00	$1,865,000.00	$1,865,000.00	*7.8%*
F	Special Construction	-	-	-	-
	Subtotal	**$20,090,000.00**	**$21,232,045.00**	**$19,376,804.00**	-
G	General Conditions	$1,660,000.00	$1,700,000.00	$1,700,000.00	*7.1%*
H	Syndicate's Fee	$3,250,000.00	$3,160,057.00	$2,850,046.00	*11.9%*
	TOTAL:	**$25,000,000.00**	**$26,092,102.00**	**$23,926,850.00**	





The Uniformat II table above details the design phases of *Syndicate's* cost estimate. The program-set target cost of **$25 million** was referenced as the baseline, with RS Means SF Estimate Data 2018 being used to divide the overall cost into Uniformat II categories. Given that the Miller Center is both a college classroom building and an auditorium, the data percentage values for both were combined based on the area ratio of the concert hall to the rest of the building. *Syndicate's* first design included assembly estimates along with some detailed estimates for fully-designed items, and was found to be **$1,092,102** over budget. Following thorough design meetings with the entire team, various changes were made to lower *Syndicate's* final **Optimized Design** estimate of **$23,926,850** and consisted of a fully detailed estimate. The final estimate resulted in a 4.3% savings in relation to the given budget of **$25 million.**

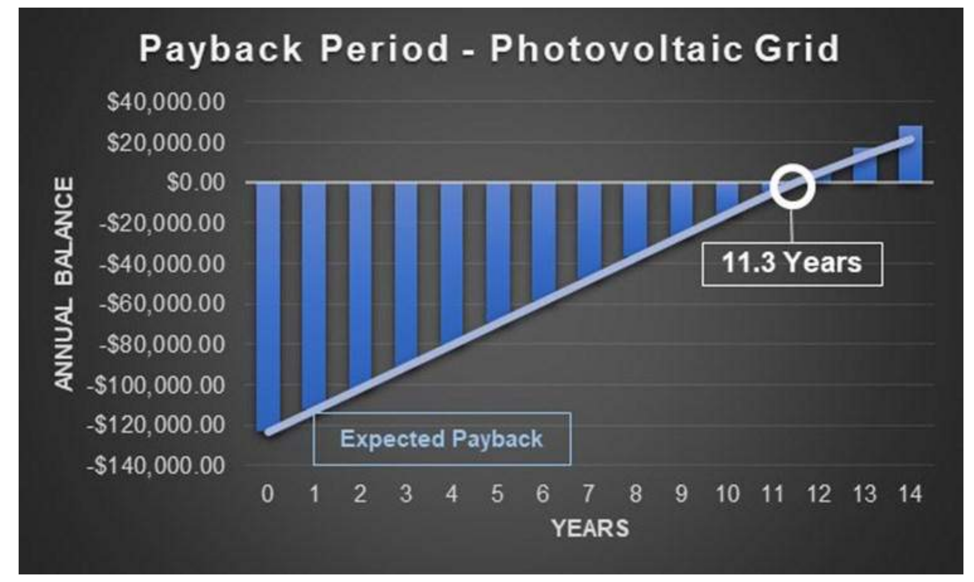
ESTIMATING METHODS



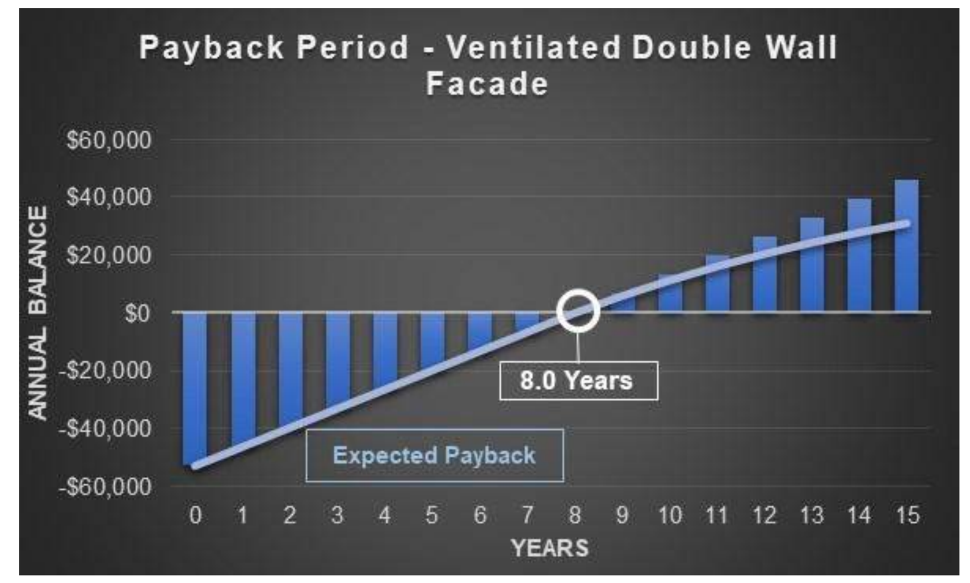
Syndicate strived to produce an estimate that provided the owner with detailed and accurate cost information. The construction team used various RS Means 2018 books for cost data, along with reaching out to manufacturers for less common items. Google sheets were organized by Uniformat in order to compile all of the various estimate components.

LIFE-CYCLE AND PAYBACK PERIOD ANALYSIS

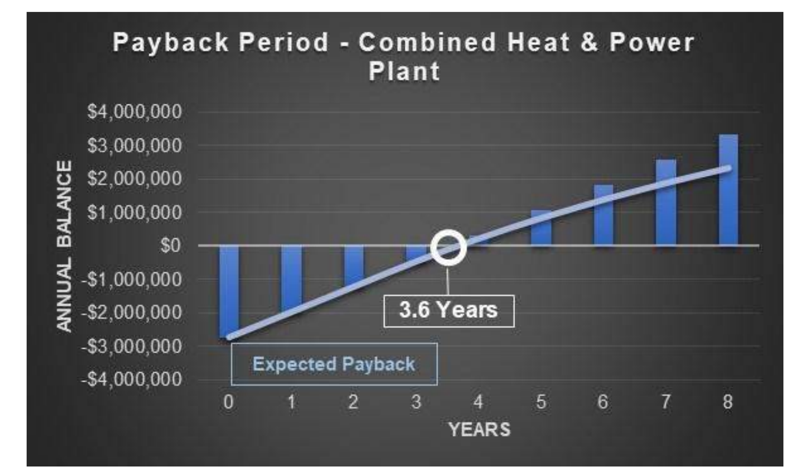
By using integrative design approaches *Syndicate* achieved an overall energy savings of **44%**, exceeding the team's goal of 40%. A life-cycle analysis was performed on the various mechanical and electrical design decisions to determine how economically feasible they will be to the owner. The photovoltaic system that *Syndicate* installed on the concert hall roof added **$123,173** to the electrical systems cost while providing a payback period of **about 11 years**, which *Syndicate* deemed an appropriate amount of time. The radiant panels and the ventilated double wall façade added **$227,872** to the mechanical systems cost, with the ventilated façade providing a payback period of **8 years**. For detailed energy cost and savings data, see Electrical Drawing L-5.0.

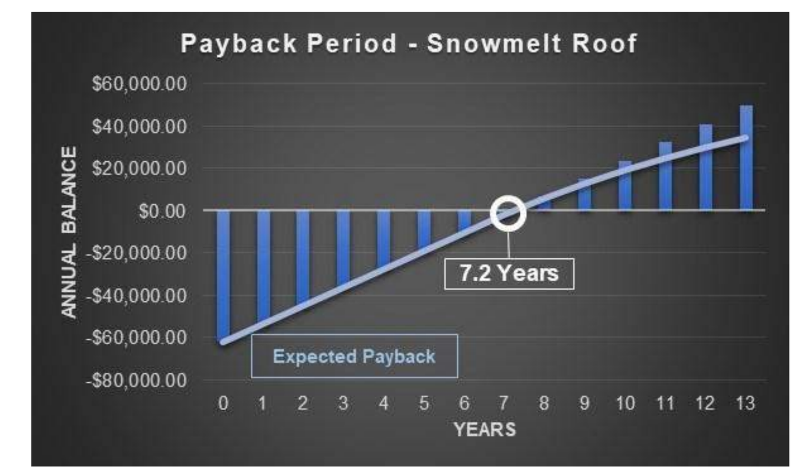


Life-Cycle Analysis: Electrical		
	Baseline Energy	Syndicate's Optimized Energy
Annual Energy Consumption (kWh)	356312.0	167224.0
Energy Cost ($/kWh)	$0.05	$0.05
Annual Energy Cost	$17,815.60	$8,361.20
Added Cost		$123,173.00
	Yearly Energy Savings	**$9,454.40**



Life-Cycle Analysis: Mechanical		
	Baseline Energy	Syndicate's Optimized Energy
Annual Energy Consumption (kWh)	375000.0	148703.0
Energy Cost ($/kWh)	$0.05	$0.05
Annual Energy Cost	$18,750.00	$7,435.15
Added Cost		$227,872.00
	Yearly Energy Savings	**$11,314.85**





STRUCTURAL SYSTEM COMPARISON

Superstructure		
Wood	$	2,046,031.17
Steel	$	1,318,233.96

As part of the program challenges, *Syndicate* was prompted to design the Miller Center with 25% wood. The team exceeded this goal by implementing a structural system that was 86% engineered wood by volume. As heavy timber structures are still a developing concept, there are higher costs associated with the manufacturing and delivery of the wood members. In order to compare the cost and schedule impacts associated with wood structures, *Syndicate* also designed the Miller Center with a steel structure. Detailed takeoffs were extracted from each design in order to provide an accurate estimate, and it was found that the wooden structure was about **$700,000** more expensive than the steel structure. These costs did include, however, the manufacturing and shipping costs associated with the wood structure. The steel system designed consists of a standard concrete on metal deck floor system on top of steel beams and columns. If the owner would become interested in pursuing a more economical option, the steel structure provides a cheaper alternative up-front at **$1,318,233.96**.

SYNDICATE

PROJECT

JACK H. MILLER CENTER FOR MUSICAL ARTS

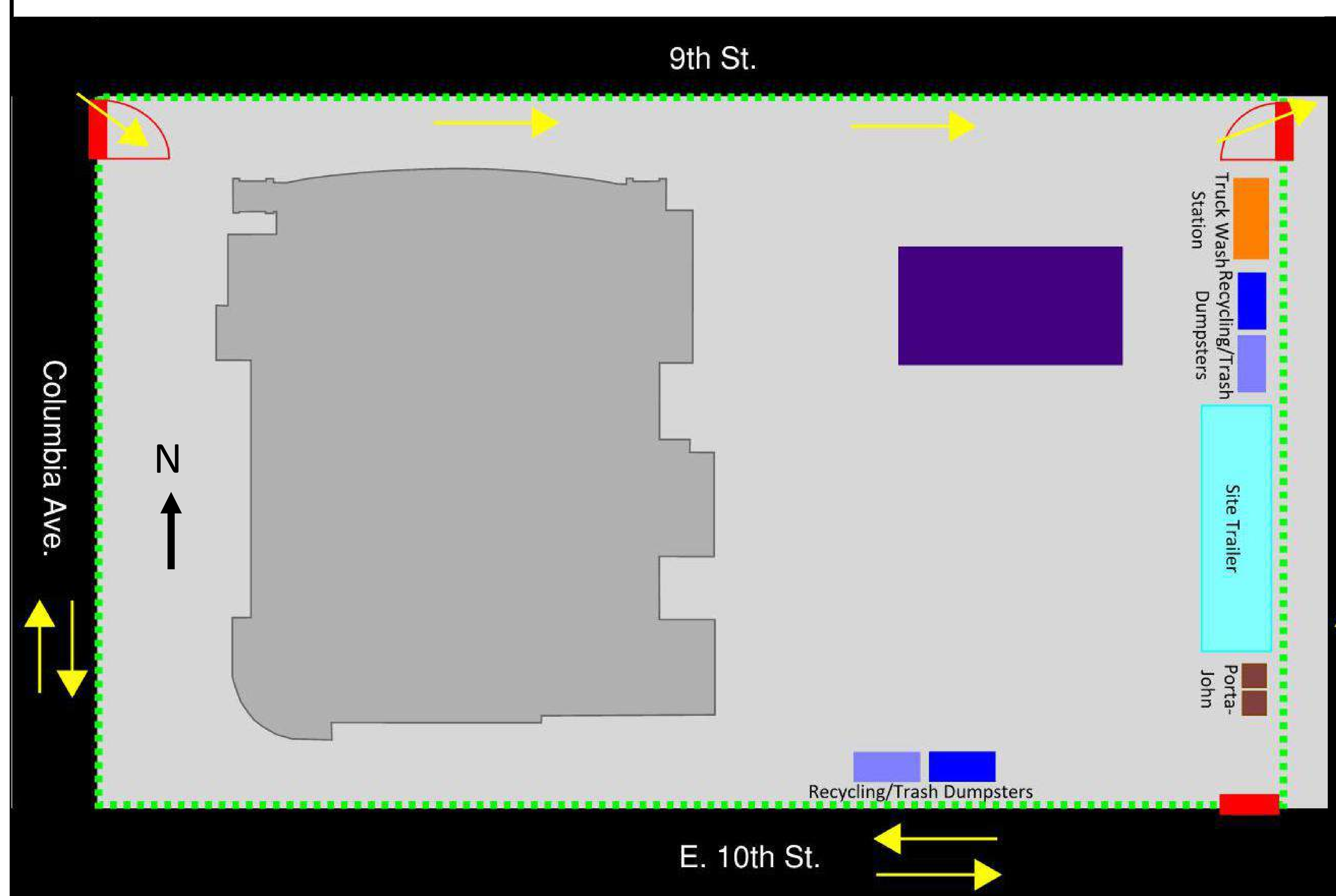
HOLLAND, MICHIGAN

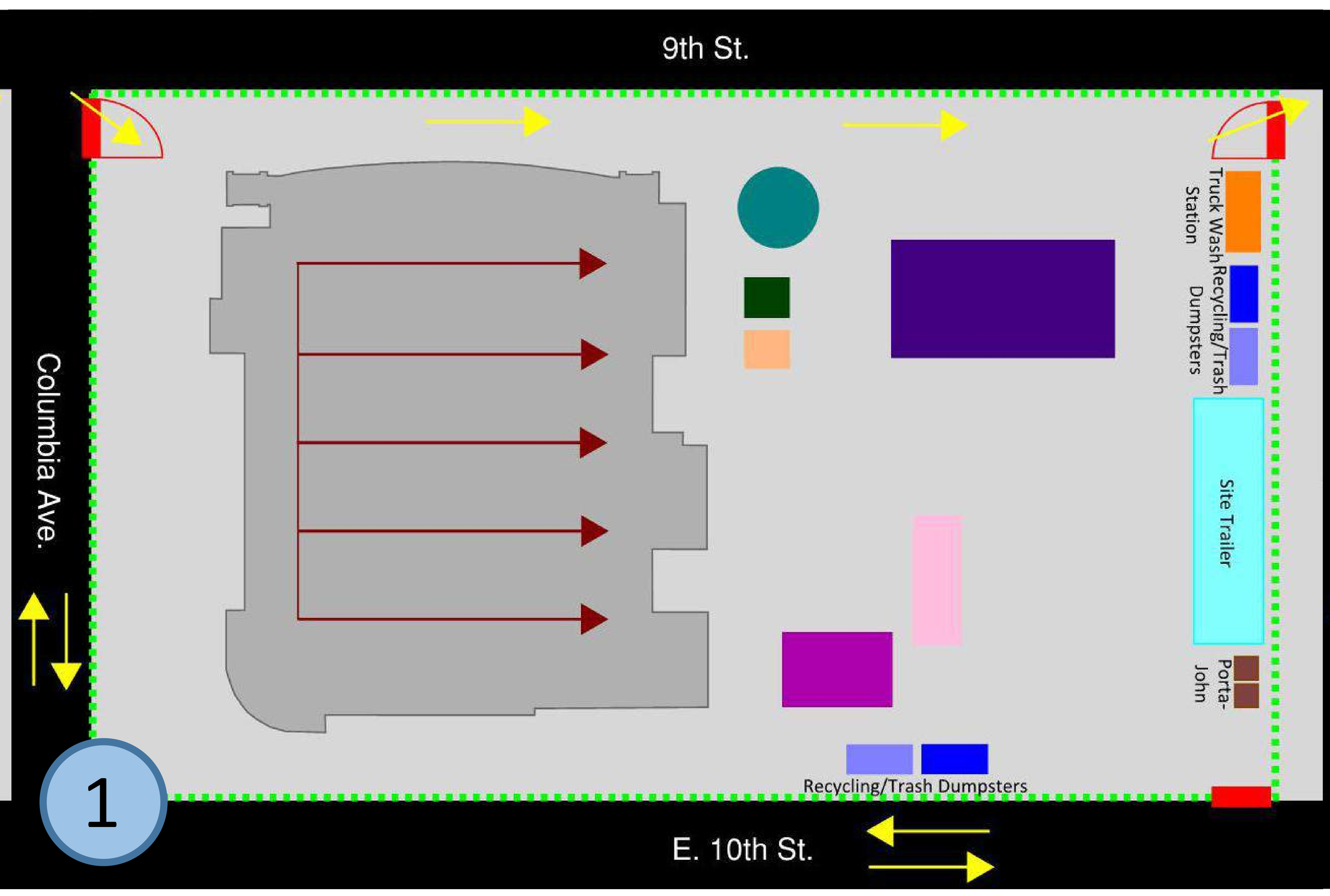
SHEET TITLE

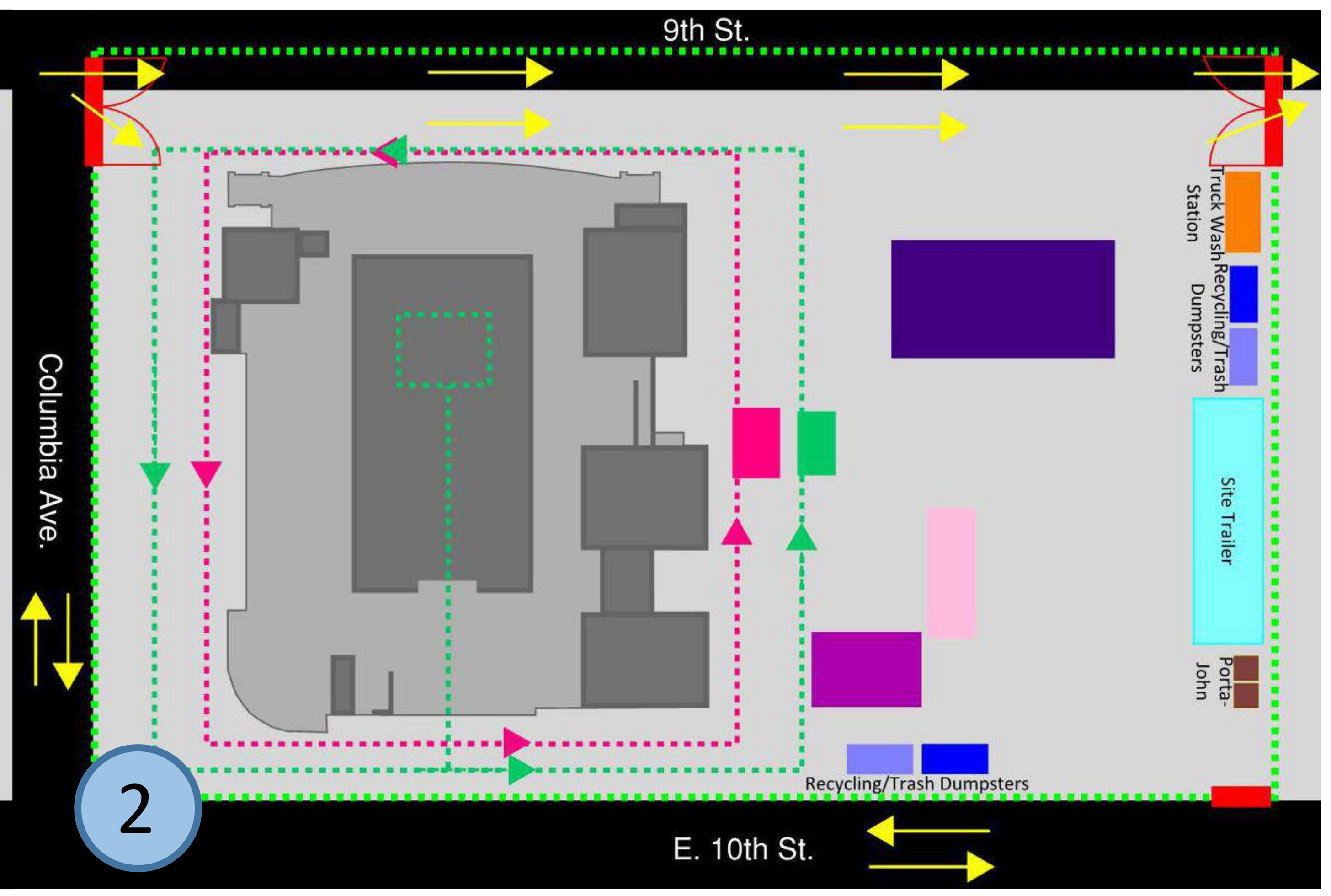
Cost Estimate

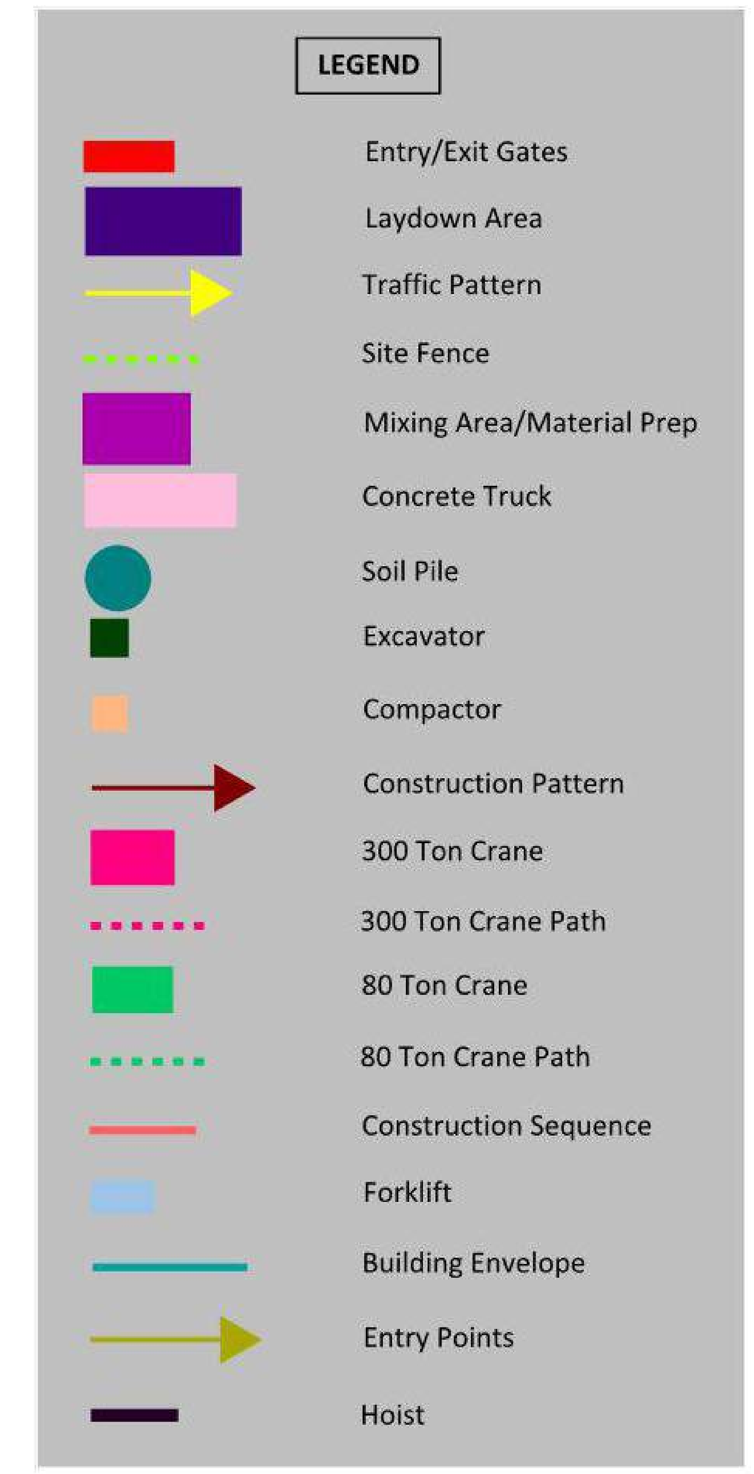
NOT FOR CONSTRUCTION	AEI TEAM NO. 01-2019
DATE February 18, 2019	SCALE NOT TO SCALE
DRAWING NO. C-7.0	PAGE NO. 147

SITE LOGISTICS AND PHASING





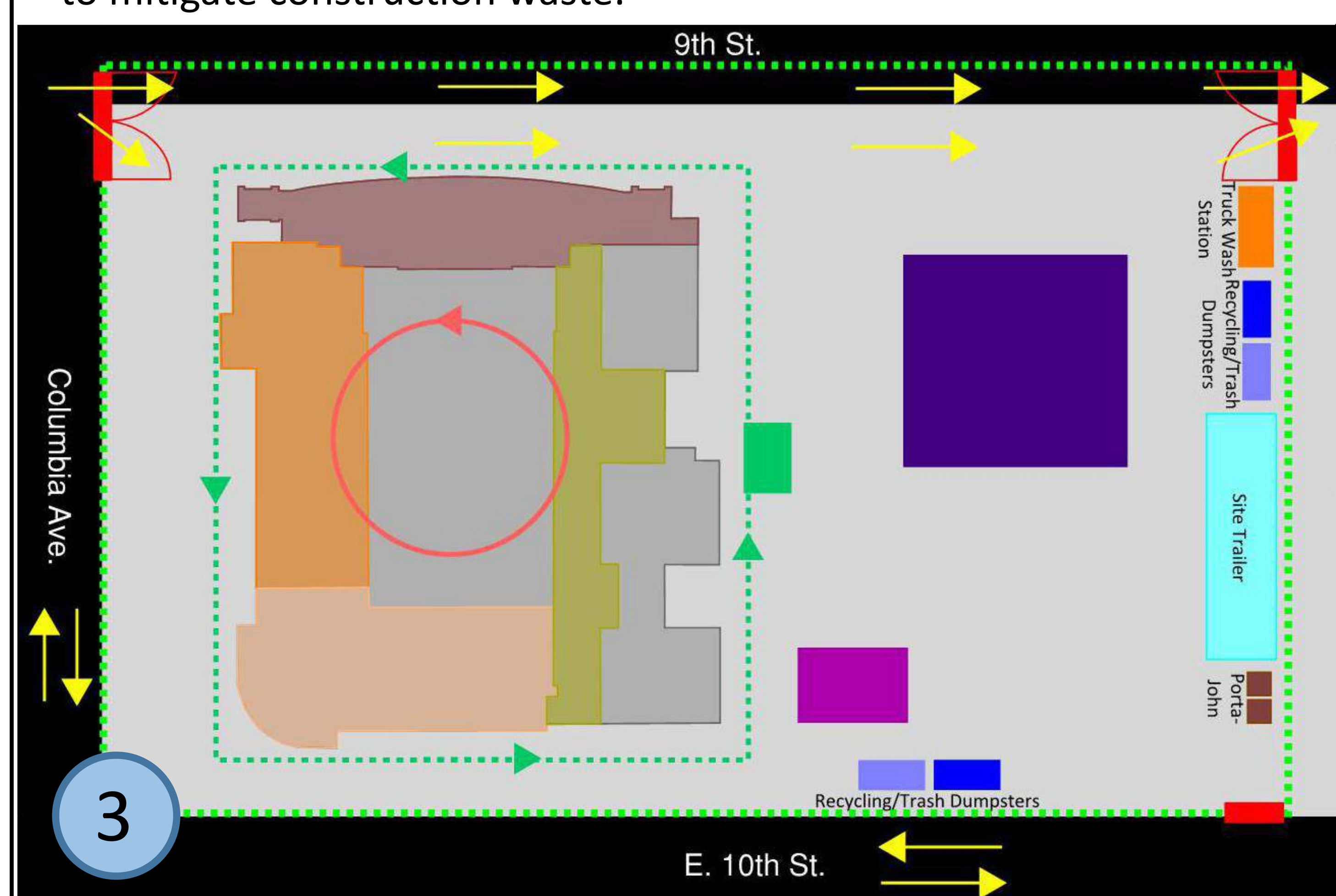


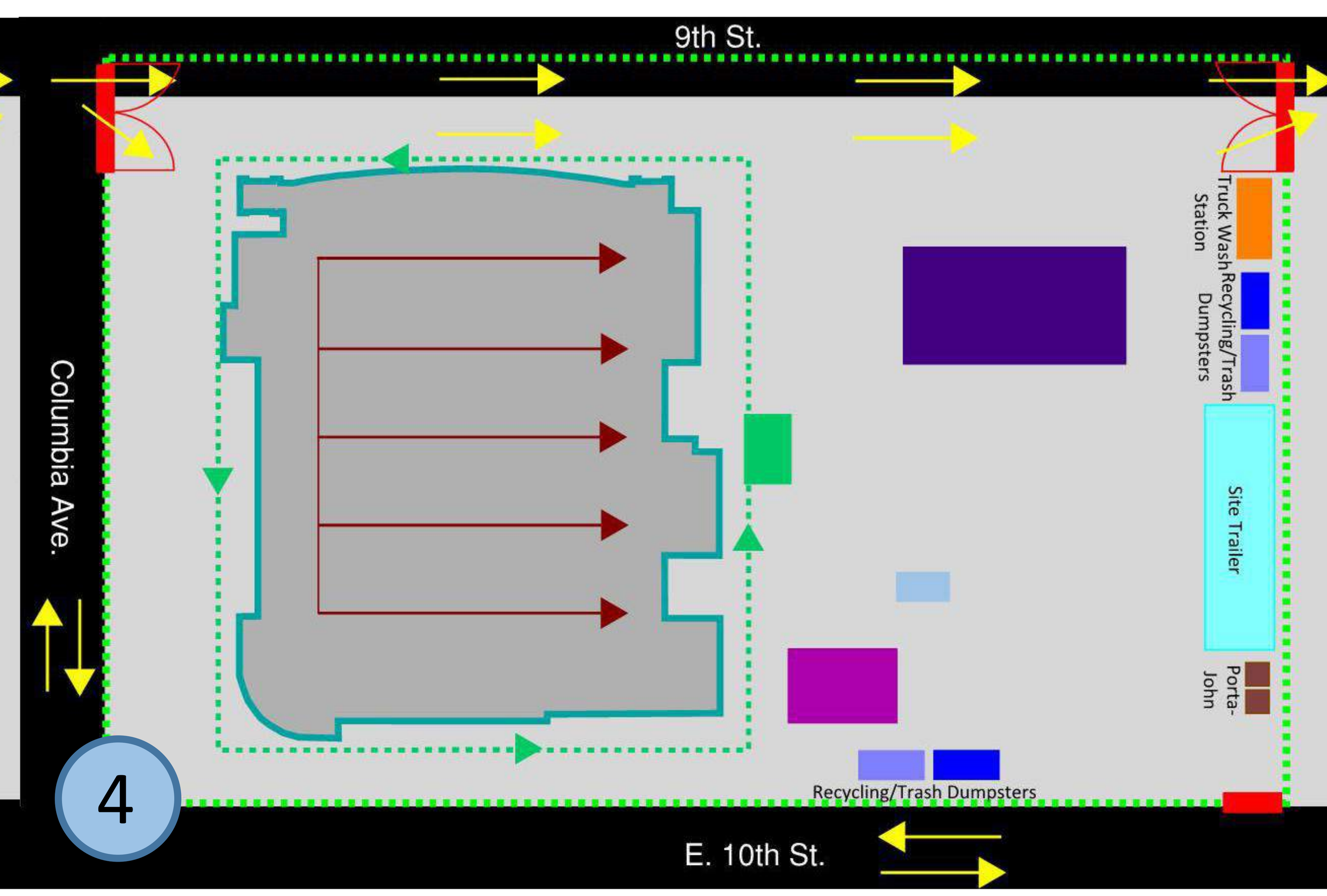


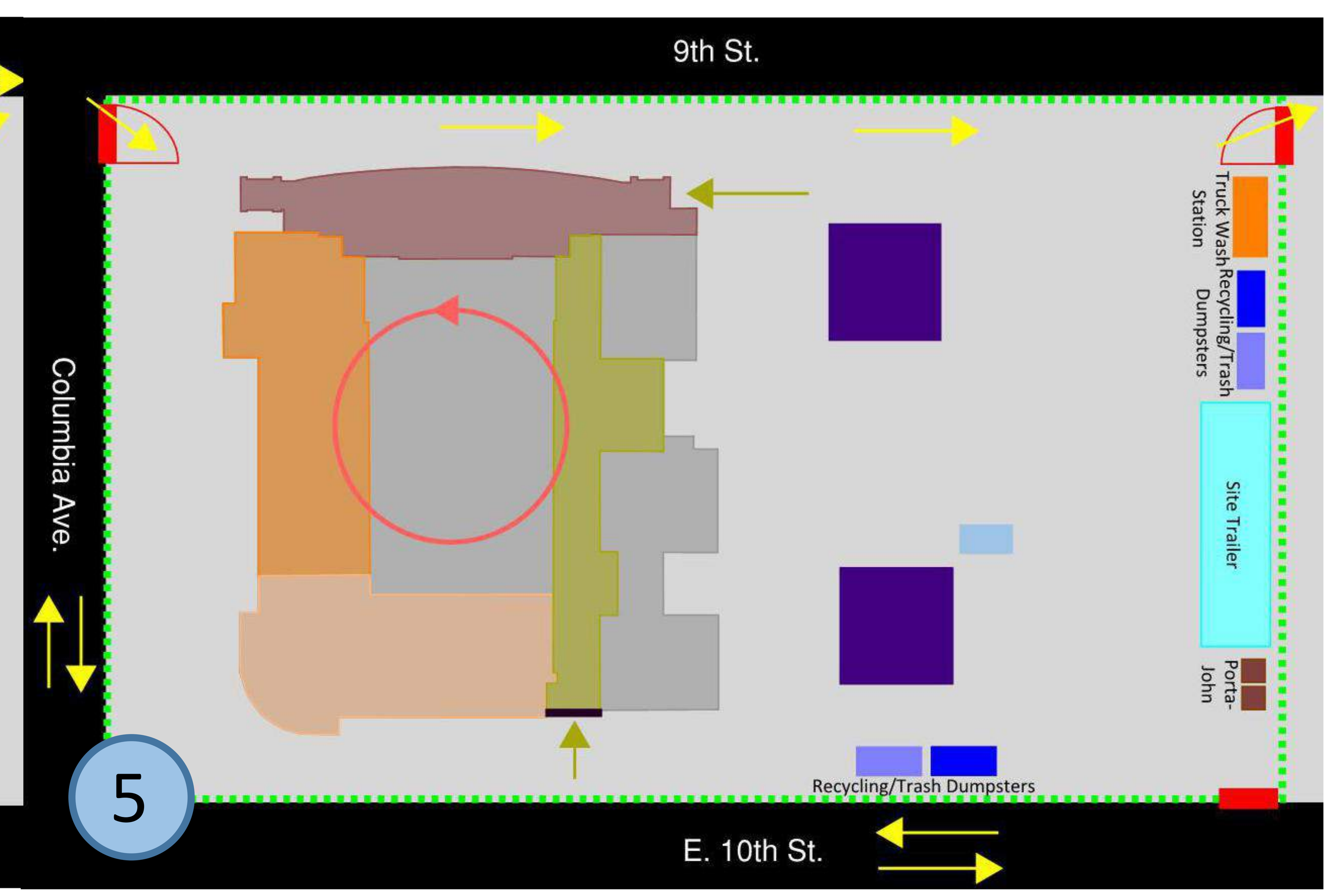
Site Layout - The Miller Center site will be secured with a 10' fence. One of the lanes of 9th St. will be closed during several phases of the construction process. There are delivery entry and exit gates in the northwest and northeast corners of the site, respectively. The gate in the southeast corner of the site is for pedestrian entry/exit. There are 2 standard dumpsters and 2 recycling dumpsters to mitigate construction waste.

Substructure - This phase consists of excavation and placing strip footings and spread footings. The footings will be placed from east to west. This phase will require an excavator and compactor, as well as a concrete truck.

Superstructure 1 - This phase consists of erecting the precast lateral systems (shown in dark grey), the roof on those spaces, the underground ducts, and the SOG. A 300-ton crawler crane is required to place the precast panels. 25' of the precast panels for the Concert Hall lateral system will be placed at the very end, leaving a hole for the crane to enter the space to build the balcony.







Superstructure 2 - This phase consists of placing Glulam beams and CLT, placing the CIP floors on the CLT structure, and framing. An 80-ton crawler crane is required to place these items. This phase will follow a counterclockwise sequence, starting at the north, then the west, then the south, and finally the east. The laydown area of this phase is larger to account for the timber, and will have stilts and tarp to protect the wood from weather.

Enclosure - This phase consists of completing the façade on all sides of the building and placing the roof on the non-lateral areas. It will be finished from west to east to mitigate issues with a crowded site on the west and south sides. This phase will also require the 80-ton crawler crane, along with a forklift.

MEP/Finishes/Commissioning - This phase consists of installation and start-up of all MEP equipment, all finishes, initial occupancy, and turnover. This phase will also follow a counterclockwise sequence (refer to phase 3). The material hoist will be located at the end of the southeast hallway, and the main entrances for workers will be there and the north lobby.

SYNDICATE

PROJECT

JACK H. MILLER CENTER FOR MUSICAL ARTS

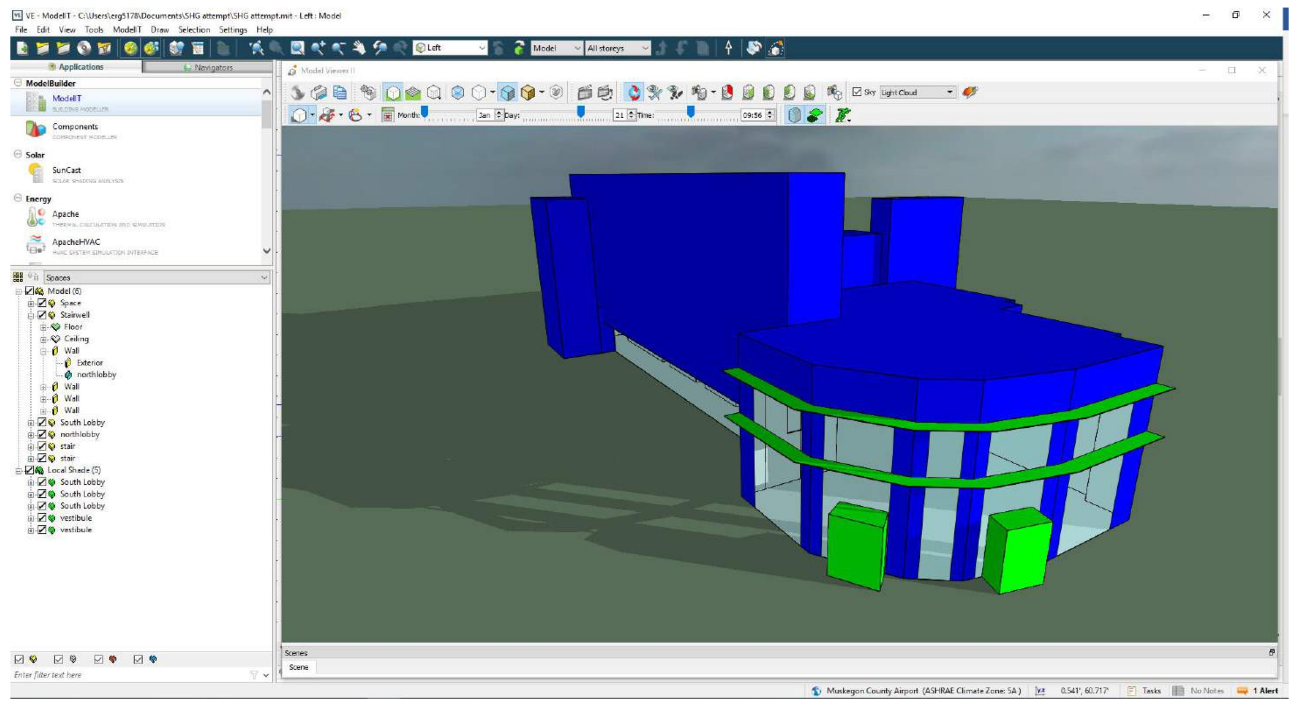
HOLLAND, MICHIGAN

SHEET TITLE

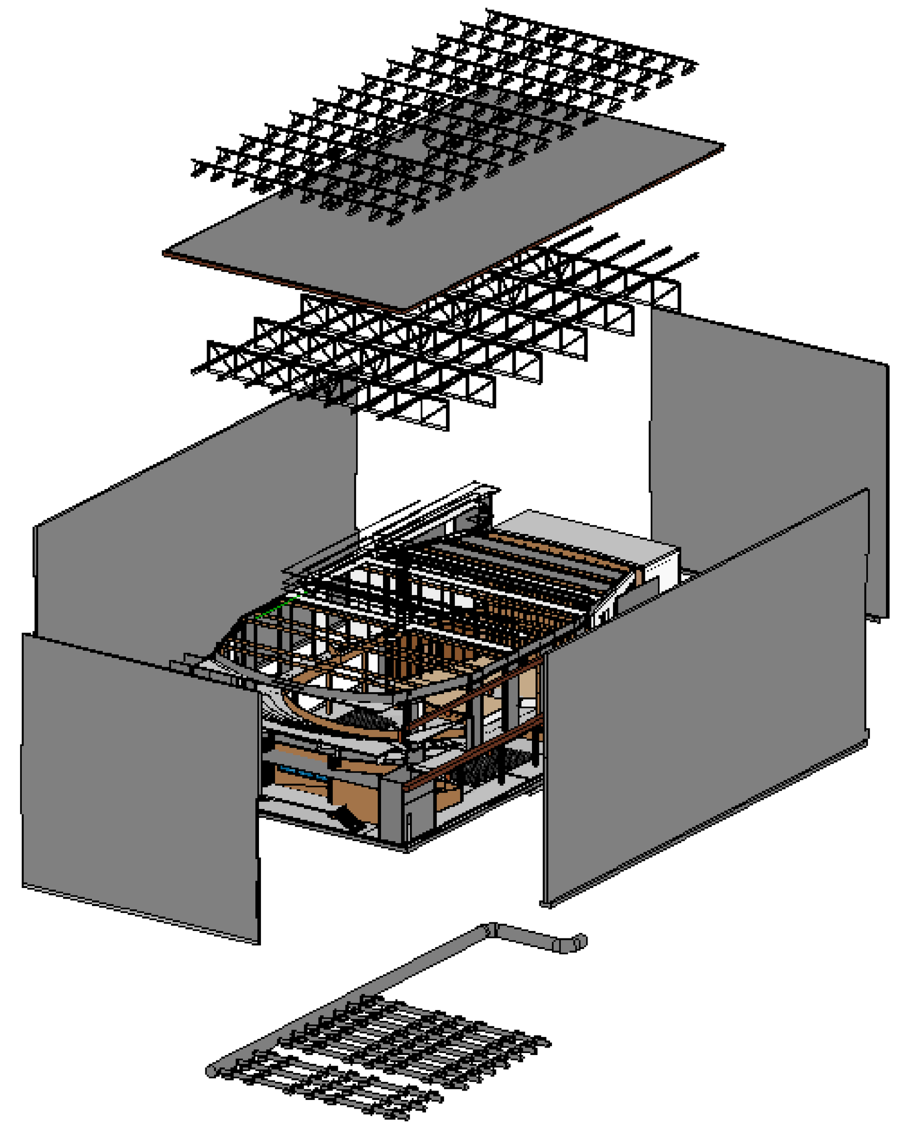
Phasing/Site Logistics

NOT FOR CONSTRUCTION	AEI TEAM NO. 01-2019
DATE February 18, 2019	SCALE NOT TO SCALE
DRAWING NO. C-8.0	PAGE NO. 148

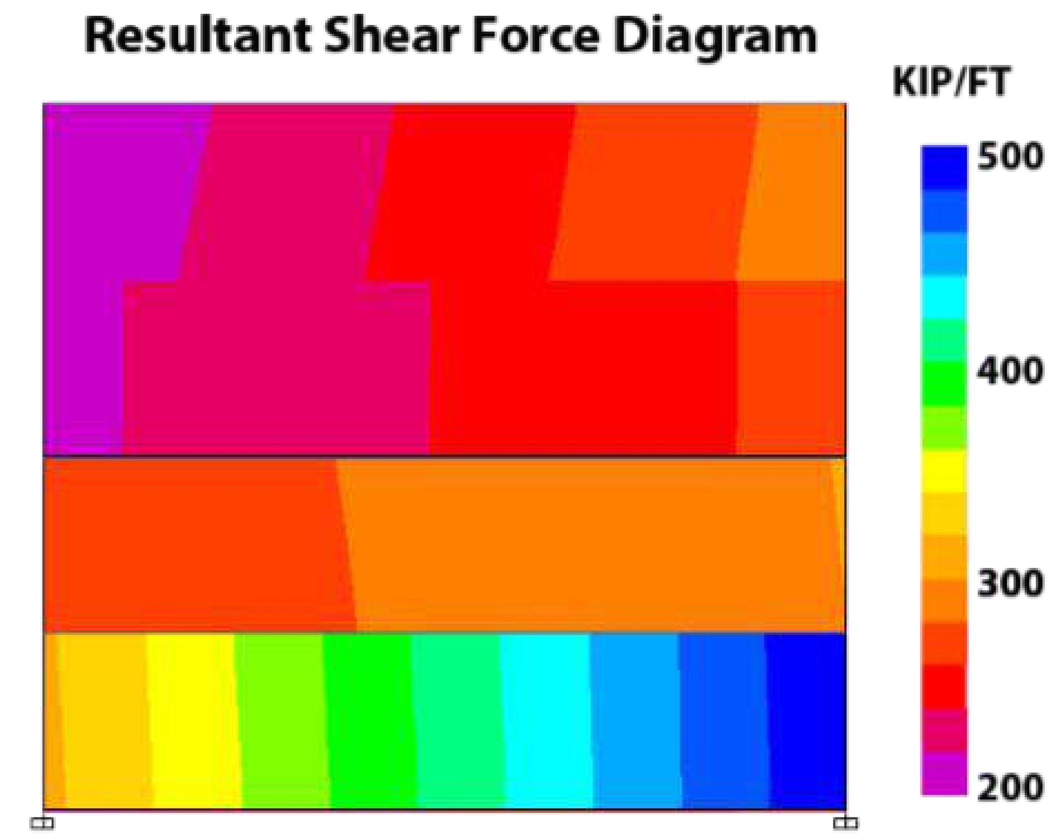
BUILDING INFORMATION MODELING (BIM)



IES Virtual Environment (Mechanical)



Revit (All disciplines and integration)



eTabs (Structural)

COMcheck Software Version COMcheck-Web

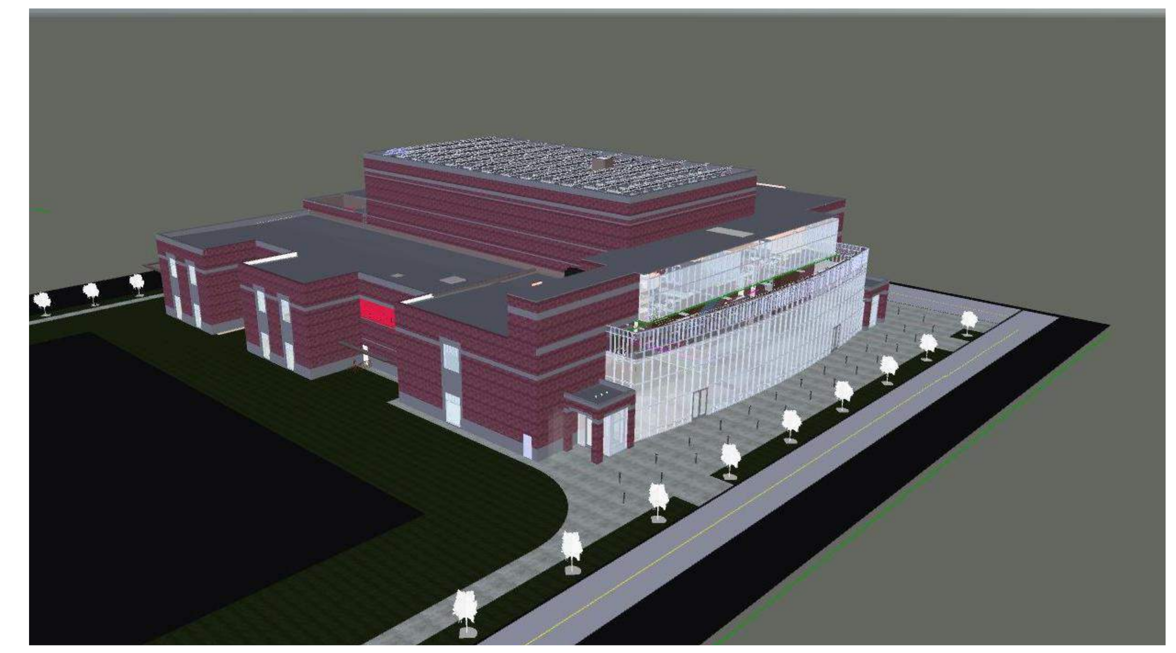
Interior Lighting Compliance Certificate

Project Information

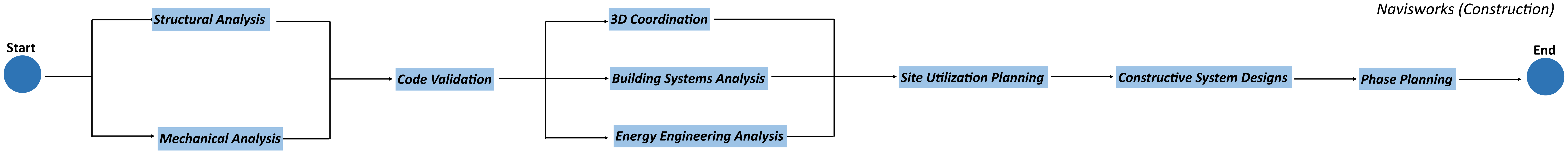
Energy Code:	90.1 (2013) Standard
Project Title:	Hope College
Project Type:	New Construction

Interior Lighting PASSES: Design 39% better than code

CoMcheck (Lighting/Electrical)



Navisworks (Construction)



Syndicate decided to implement BIM on the Jack H. Miller Center for Performing Arts project to improve quality of design and to increase constructability by creating an enhanced technology plan of action.

The first step in the BIM execution was to list the aspects of the project that would benefit from increased technology implementation. The construction team decided to use their main goals throughout the project; schedule/site logistics, budget, safety, QAQC, coordination/waste minimization, prefabrication, and sustainability. Next, *Syndicate* assigned each of those goals a priority. It is important to note that this priority level only applies to how important it is to use BIM for that goal, not the priority of the goal in the overall project. The next step in *Syndicate's* BIM execution was to determine which BIM uses they could implement for each goal. All potential uses were listed for each goal and the entire team got together to discuss which uses were feasible and would benefit the Miller Center. The team set out to implement as many of those feasible uses as possible.

The table to the right is the graphic *Syndicate* used to organize the BIM goals and uses. The BIM uses bolded and italicized are the ones that were successfully implemented in the Miller Center project. The graphic above is a modified level one BIM process map that shows the order in which the BIM uses were implemented throughout the project.

Syndicate found that implementing engineering software to control quality, plan the site logistics, and enhance multidisciplinary coordination proved the most useful in its goal to improve constructability on the Miller Center project.

Above are pictures from the main software utilized by each discipline.

Priority	Construction Team Goals	Potential BIM Uses
Low	Schedule/Site Logistics	Site Analysis ***Phase Planning*** Existing Conditions Modeling Site Utilization Planning
Low	Budget	***Cost Estimation***
Medium	Safety	Disaster Planning ***Site Utilization Planning***
High	QAQC	***Code Validation*** ***3D Coordination*** ***Constructive System Designs*** Maintenance Scheduling
Medium	Coordination/Waste Minimization	***3D Coordination*** Construction Systems Designs
Medium	Precast	***Structural Analysis*** ***Mechanical Analysis*** Construction Systems Designs Digital Fabrication
High	Sustainability	Sustainability Evaluation ***Building Systems Analysis*** ***Energy Engineering Analysis***

SYNDICATE

PROJECT

JACK H. MILLER CENTER FOR MUSICAL ARTS

HOLLAND, MICHIGAN

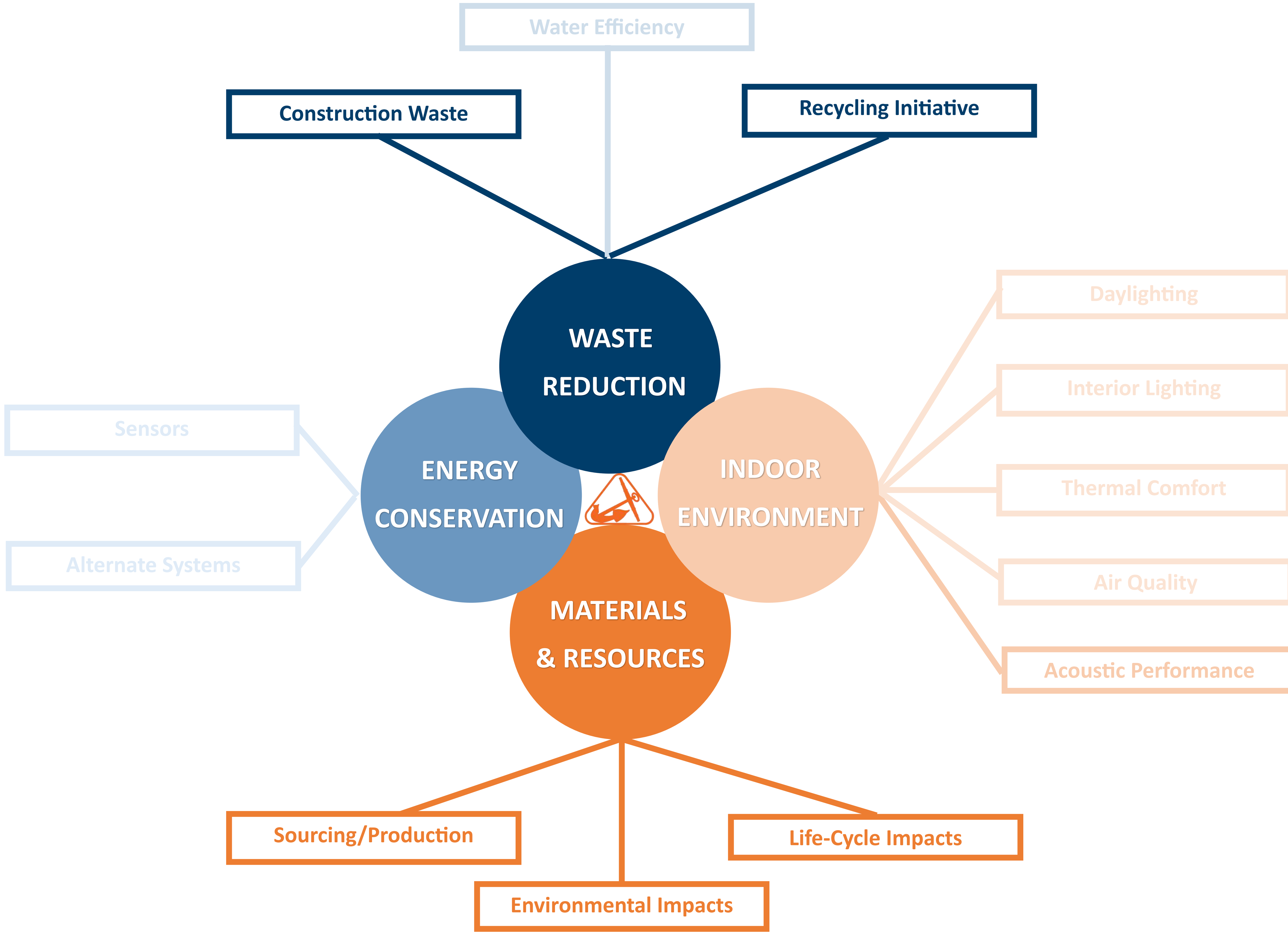
SHEET TITLE

Building Information Modeling

NOT FOR CONSTRUCTION	AEI TEAM NO. 01-2019
DATE February 18, 2019	SCALE NOT TO SCALE
DRAWING NO. C-9.0	PAGE NO. 149

THE HOPE COLLEGE SUSTAINABILITY PLAN

Syndicate, after considering aspects of the LEED and WELL plans and the efforts that Hope College is already making, has created a customized sustainability plan for Hope College. This plan allows Hope to pursue environmentally-minded goals without sacrificing their academic objectives. There are four main canons that encompass large sustainability aspects, and those four are broken down into several implementation categories (shown below). The objectives that were considered during the construction design of The Miller Center are highlighted below.



JACK H MILLER PILOT PROGRAM

Syndicate has implemented this Sustainability Plan on the Miller Center project. Below are the specific aspects of the plan that are highlighted in the construction period of this project.

Construction Waste

There was a site wide effort on the Miller Center project to minimize waste. Prefabrication was heavily utilized to minimize the amount of formwork needed, QR code checklists were implemented to reduce rework and wasted materials, materials that could be reused were held in a specific area on site that was available to all workers to pull from, and any materials that could be recycled were thrown in separate dumpsters.

Recycling Initiative

Syndicate admires Hope College's recycling initiative that has already been implemented on campus and wants to ensure that it is achieving its maximum effectiveness. While recycling is not a perfect system, separating the types of recyclables decreases the possible waste that still remains from a single-stream recycling system.

Sourcing/Production

The manufacturer providing the precast concrete panels for the lateral system, Kerkstra, is located 12 miles away from site. This allowed Syndicate to ship the panels as full 64 foot pieces, reducing the need for additional materials and labor.

The manufacturer for the heavy timber, Nordic Structures, ensures all the trees used for their material are immediately replanted to keep the forest integrity in tact.

Life-Cycle Impacts

Systems were chosen for the Miller Center project that will last a long time, decreased the cost and production requirements of replacing the systems, and will improve the longevity of the building itself. The five main systems implemented in The Miller Center are photovoltaic, thermal storage, ventilated double-wall façade, snowmelt, and CHP.

Environmental Impacts

By building with heavy timber, the project acts as a carbon sink, absorbing carbon that is released into the atmosphere by other products.

Acoustic Performance

By implementing the QR code tracking system and checklists, the construction team was able to ensure that the workers onsite are keeping quality at the forefront of their focus, especially during the finishes phase of the project.

DASHBOARD DISPLAY

In lieu of a plaque or certificate for the achieving the desired level of sustainability on a project, the Hope College Sustainability Plan, calls for the installation of a dashboard display to show off their environmentally conscious decisions and progress. This display will act as a interactive connection point in each lobby to showcase Hope College's energy conservation efforts for the occupants of the building. The user will have the option to explore daily , monthly, and even annual energy usages to fully understand how they too can make an impact on the future of Hope College. With this display, the sustainability plan initiative will further be pursued and hopefully encourage students and faculty to carry this throughout the rest of the campus.

The main hub receives data from various system sensors and meters, interprets the input, and produces a visual display for aspects of sustainability like saved electricity, saved water, and carbon reduction. It can also display static numbers or facts that were achieved through the construction process, like air quality information, construction waste reduction, and materials that were chosen for environmental reasons.

SYNDICATE

PROJECT	
JACK H. MILLER CENTER FOR MUSICAL ARTS HOLLAND, MICHIGAN	
SHEET TITLE **The Hope College Sustainability Plan**	
NOT FOR CONSTRUCTION	AEI TEAM NO. 01-2019
DATE February 18, 2019	SCALE NOT TO SCALE
DRAWING NO. C-10.0	PAGE NO. 150