2019 AEI STUDENT DESIGN COMPETITION

The Jack H. Miller Center for Musical Arts

Holland, Michigan

ATUNE

Structural

Mechanical

Electrical Lighting

Construction

2019 AEI STUDENT DESIGN COMPETITION

INTEGRATION
Incorporated code from other disciplines

STRUCTURAL
ACI 318-08
AISC Manual 13th Addition
ASCE 7-05
ASCE 7-10
CLT Design Manual
IBC 2009 (with Holland, MI ammendments)
NDS 2015

MECHANICAL
2009 Michigan Building Code (IBC 2009)
2009 Michigan Mechanical Code (IMC 2009)
2009 Michigan Plumbing Code (IPC 2009)
Michigan Fire Provention Code
Michigan Uniform Energy Code - 2009 (Based on ASHRAE 90.1 - 2007 Energy Standard for Buildings Except Low-Rise Residential Buildings
2004 ANSI A117.1/ADAAG
ASHRAE Standard 62.1 - 2007 Ventilation for Acceptable Indoor Air Quality
ASHRAE Standard 55 - 2007 Thermal Environmental Conditions for Human Occupancy
NFPA Standards 13, 20, 25 and 90a

ELECTRICAL
2015 International Energy Conservation Code
2015 International Mechanical Code
2015 International Building Code
Illuminating Engineering Society Lighting Handbook
Institute of Electrical and Electronics Engineers - 802.3at
NFPA 70 - 2016 National Fire and Signaling Code
NFPA 72 - 2014 National Electric Code
NFPA 101 - 2015 Life Safety Code
NFPA 111 - Standard on Stored Electrical Energy Emergency and Standby Power Systems

CONSTRUCTION
Occupational Safety and Health Administration (OSHA)

INTEGRATION EXECUTIVE SUMMARY

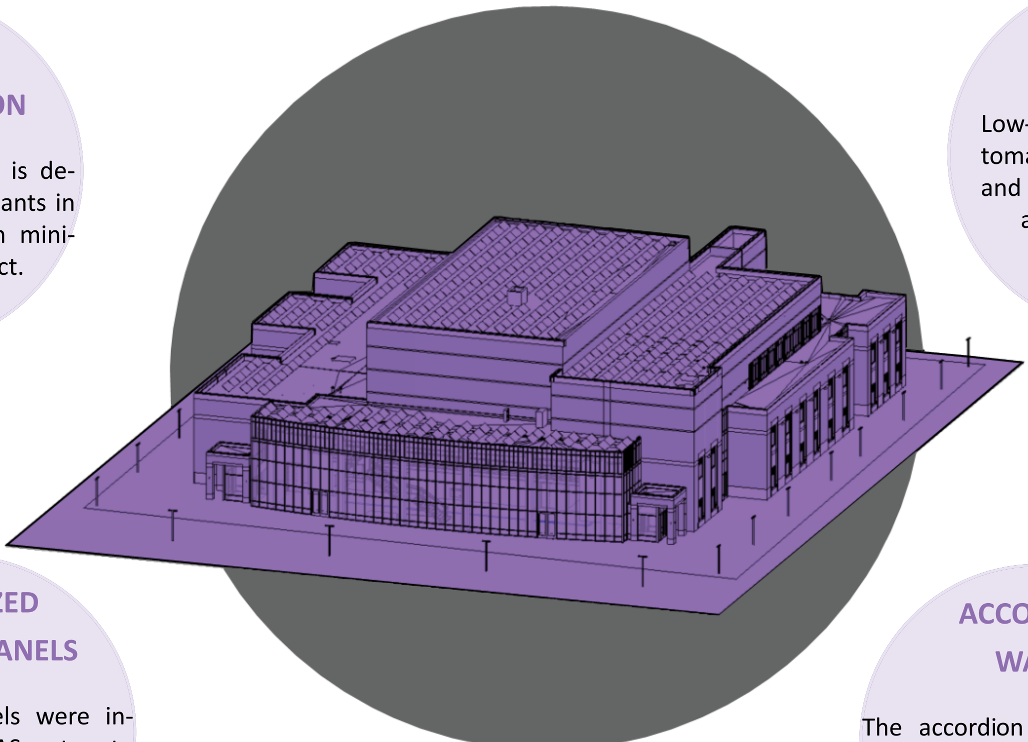
Atune worked in an Integrated Project Delivery method to design and build the Jack H. Miller Center for Musical Arts. This process enabled the entire design team to create a versitile, sustainable building working in harmony. The team focused on innovative and integrated solutions to the buildings's needs and challenges in acoustical design, performance versatility and community servicability.

CLT PANELS

CLT tilt-up panels form the LFRS system, located around the concert hall and recital spaces.

ROOFTOP AMENITY SPACE

The amenity space was design for the south side of the Jack H. Miller Center for Musical Arts to optimize the use of the space year round.



UNDERFLOOR AIR DISTRIBUTION

Conditioned outside air is delivered directly to occupants in voluminous spaces with minimal acoustical impact.

DYNAMIC VIEW GLASS

Low-voltage charge automatically reduces glare and solar heat gain in the artium curtain wall.

MOTORIZED ACOUSTIC PANELS

Reverberation panels were integrated with the BAS system to improve the tranisition of the panels between concerts.

ACCORDION WALLS

The accordion walls were designed with glass panels to optimize natural light in the space. This design integrates with the atrium space.

SNOW MELT/ RAINWATER COLLECTION

Decreases structural loading and provides potable greywater.

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1.0 PROJECT INTRODUCTION

The Jack H. Miller Center for Musical Arts is part of the Hope College campus in Holland, Michigan. This 64,000-square-foot building is to serve as the home for Hope College's Department of Music. It houses an 800-seat concert hall, a recital venue, instructional spaces, practice areas, faculty studios, recording rooms, and computer and piano labs. The building is situated along Columbia Avenue between 9th and 10th street and is adjacent to railroad tracks running on the east side of campus. A total budget of $25 million was targeted for the entire project. Atune has worked to design a solution that exceeds the expectations for the Hope College Community to promote a campus culture where each person can flourish.

2.0 ATUNE'S MISSION

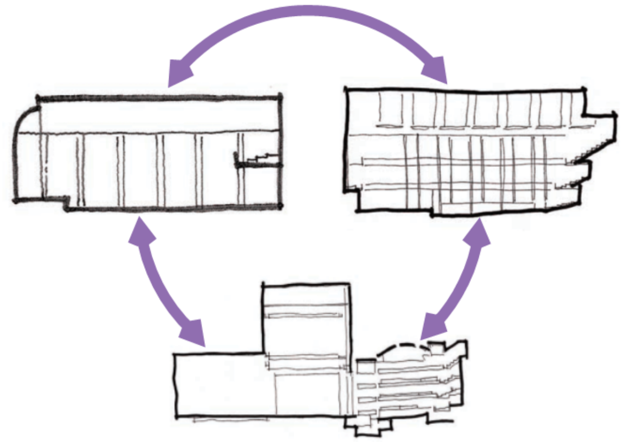
Atune set out to generate a facility design that is not only optimal for music instruction and performance, but also a design that falls in line with the Hope College strategic plan. With a multi-disciplinary approach, the team was able to create an environment for curricular and co-curricular learning opportunities that advance cross-cultural learning and global engagement. The design of the different spaces will allow the student's programs to include relevant and customized experiences. Atune strives to achieve a long-life span while promoting programmatic elements in a way that enhance the public's understanding and appreciation of sustainability within the building. While pursuing goals of the college, Atune weighed different options that allow the faculty and staff to pursue excellence in their work and service to the students. Using Integrated Project Delivery, the Team was able to aid in Hope College's mission while addressing building challenges.

3.0 PROJECT INTEGRATION GOALS

When the team members came together to accomplish a design fit for the Jack H. Miller Center for Musical Arts, they saw that versatility, sustainability and harmony would be focal points during the process.

3.1 Versatility

The team aims to create a space that is able to change feel, sound and appearance for the appropriate performance type within the atrium, concert hall, and proposed amenities space.



Above is an example of the space change Atune plans to apply to the concert hall (Refer to I3.2). With the future in mind, the building is designed to allow for growth in different systems to accommodate expansion on and around the building.

3.2 Sustainability

By using cost effective choices in the design process to lengthen lifespan of equipment in hopes of reducing maintenance costs Atune was able to reduce the environmental impact from transportation of materials. The collaboration between the structural and electrical teams helped to showcase the use of timber through an interactive screen in the atrium to educate occupants about the cost and environmentally friendly decisions made.

3.3 Harmony

Each discipline worked to provide solutions to their focus while assisting in another discipline if feasible. A graph showing these relationships is shown in I2.3. This made for fewer questions between team members and created more opportunity for collaboration and creativity within the team. Scheduling the time frame for the variety of plans set forth was critical to allow for a building that has limitations of space for work and storage. The construction team worked hand in hand with each discipline to assure that innovative ideas would be an option financially and when it comes time for construction. Since the Jack H. Miller Center for Musical Arts is on the perimeter of campus, Atune saw that the façade should be a focus to embrace the essence of the college.

4.0 PROJECT DESIGN CHALLENGES

The Atune team was presented with the main design challenges for this project being: high acoustical performance, timber and engineered wood structural design, and a versatile roof-top amenity space.

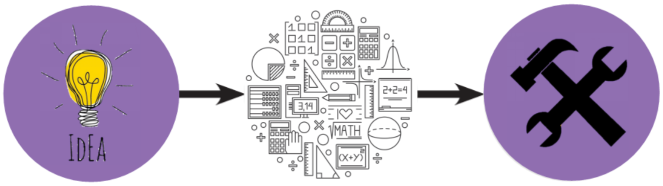
4.1 Acoustics

The most important design challenge across all of the design disciplines was the attention to acoustics. The Jack H. Miller Center for Musical Arts is designed around the performers and audiences that will experience the musical concerts that Hope College has to offer. The design is focused on improving acoustical quality within the concert halls and providing quiet practices spaces for both students and professors.

To exceed the acoustical requirements for this project it was key for Atune's team to collaborate on finding creative solutions that provide the acoustical performance without limiting the functionality of the buildings systems. Each discipline within the Atune team was able to integrate into this overall team goal through material selections, system optimizations and addressing it at every team integration meeting.

4.1.1 Reasons to Address Acoustics

Controlling sound emphasizes the ability to comprehend what is being communicated. In the Jack H. Miller Center for Musical Arts the communication we are focused on is the music being played and the receiving component whether that be a recording device, microphone, or audience. The variance of frequencies being played, spoken, and sung throughout the building need to be addressed in design through all disciplines, then with additional equipment, the sound can be enhanced. Atune's goal within this design was to lay out a plan and general calculations to provide an innovative solution to providing acoustic equipment for the building. Respective disciplines have accounted for these plans throughout the process of design by addressing the overall ideas and principles, the next step will be to hire a sound consultant. Sections 7.1.1 and 8.2.2 further discuss the methods Atune used to adress this challenge.



4.1.2 Separation

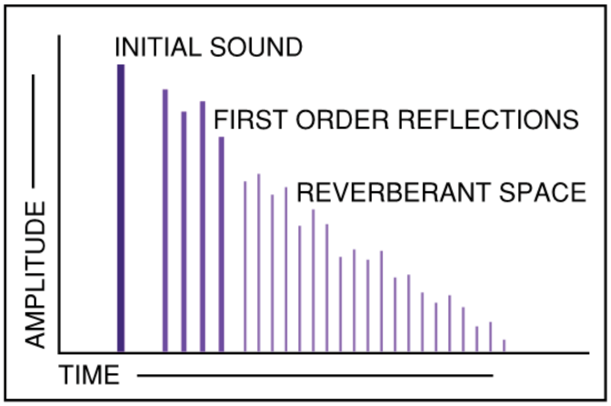
Since there is more than one performance room, separation in both the plan and section view is required. Spaces requiring a higher acoustical performance level should not be adjacent to each other on the same floor nor should they sit on top of one another. The addition of the amenity space also plays a factor in this with its placement above the faculty studios on the south side of the building. The placement was chosen instead of on the north, above the rehearsal rooms, or above the atrium on the west side of the roof.

In certain areas separation was achieved through wall and ceiling assembly. This is especially important for the Organ Faculty Studio that is below Mechanical Room 250 and the Rehearsal rooms on the North side of the building that share a wall with Mechanical Room 224. Even though not all rooms are used for performance, to an extent this treatment is required because separation is still important for practicing instruments in the classrooms, faculty studios, and practice rooms.

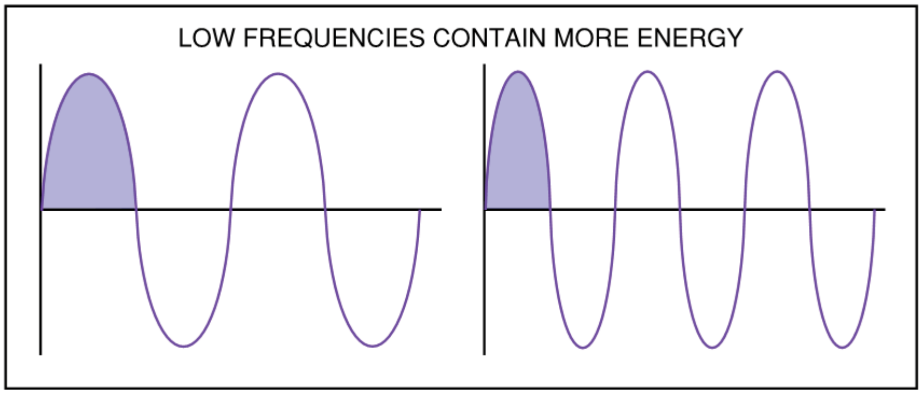
4.1.3 Flexibility

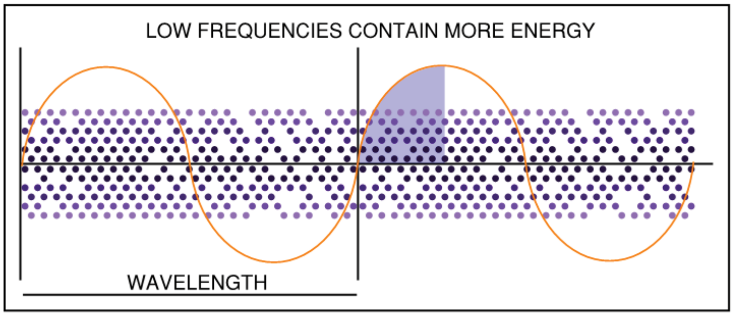
To account for the varied type of performances in the Concert Hall, Atune plans to use technology to change the space shape and size. The team will utilize motorized panels to accomplish this task in accordance with curtains that are used to absorb sound in certain situations. The panels will assist in making the room adapt acoustically to the type of music being performed. This feature will provide Hope College with the ability to account for a variety of performances to present to the community and students.

In acoustics, bass or low frequencies are difficult to control due to their long wavelengths. With enough power, bass will pass through just about anything. This means that it not only requires more energy to generate bass, it is a lot tougher to stop it once it gets going. High frequencies are much less of a problem as the shorter wavelength is much less powerful. The easiest way to absorb low frequencies is to increase the thickness of the panel. This will be implemented in rooms like the faculty studio percussion rehearsal. By calculating quarter wavelength calculations, predicting the required thickness of an acoustic panel becomes much easier. The density of panels also plays a part in the ability for a panel to absorb bass. On the other hand, if the panel is too dense; the high frequencies will simply bounce off and reflect into the room. Broadway panels are designed to do both; they provide balanced absorption.



The two graphs below compare low and high frequencies at the same amplitude. Notice that the longer the bass frequency contains more energy as depicted by the yellow area. Since more energy is in the sound wave, bass will be more difficult to contain.





The math used to predict the low frequency performance of an acoustic panel is known as the 'quarter wavelength calculation' whereby the thickness of the panel is equal to 1/4 the wavelength of the lowest frequency plus a factor for the angle of incidence. The panel density plays an important role.

4.2 Wood, Timber, & Engineered Wood

Timber is a less common commercial building material in the United States despite its nature as a sustainable material. While the challenge only requested a 25% swap in structural material to wood, timber or engineered wood, Atune's structural team in coordination and collaboration came up with an almost 90% engineered wood building. The IPD construction approach used by the Atune team was key in this integration challenge.

Coordination between the mechanical, construction, and structural teams ensured that the use of a timber structure in Michigan would be possible through pre-fabrication processes and HVAC humidity control. An additional concern that was brought up and addressed in integration team meetings was a dry-type sprinkler system to prevent potential structural damage.

This challenge also provided a unique architectural consideration in design as well due to the request for timber from Hope College to promote sustainability in construction and commercial buildings. Collaboration with the electrical team allowed the Atune team to showcase certain aspects of the timber structure to be highlighted as a lesson in sustainability for the public.

4.2.1 Reasons to Address Timber Design

Timber construction is one of the most renewable construction materials in use today. However certain design challenges are presented when using this material such as deflections, minor and major strength axis', as well as additional design checks.

Despite all the challenges that timber construction can present, the entire Atune team recognized the advantages that timber provides. Additionally, proving sustainability and carbon footprint was important to Hope College. The nearly 90% timber construction that Atune is presenting prevents 1,023 metric tons of carbon dioxide from emitting into the air, and is renewable in 8 minutes from the forests in the U.S. and Canada. This is the equivalent of 775 cars off the road for a year or operating 387 homes for a year.

4.2.2 Advantages

Full timber construction provides an improved construction timeline once the materials arrive on-site. This is possible since most of the timber that is called out in Atune's structural design is prefabricated and brought to site.

Another opportunity that the Atune team found for improved system integration using timber construction is to utilize 2x8 dimensional lumber as the framing for all partition walls. Since almost all partition walls are roughly 14" thick due to acoustical insulation, using 2x8 dimensional will not impact the wall dimensions. However, the main decision driver for changing to dimensional lumber was the ability to use the scraps for the recycled timber acoustical panels in the recital spaces, faculty offices, classrooms, and practice rooms. This has allowed Atune to successfully implement a design element that helps achieve two of the design challenges.

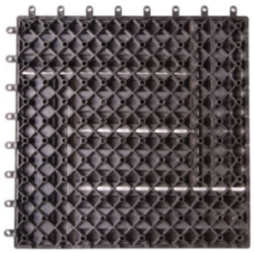
4.3 Roof Top Amenity Space

Since the Jack H. Miller Center for Musical Arts is to be used by Hope College as a multipurpose building, the roof-top amenity space provides the college with a year-round versatile space. This space was a major area of collaboration throughout the design process to ensure the needs of Hope College were met. The roof top amenity space is on the south side of the building and consists of three main areas: a fully enclosed and climate-controlled area with basic amenities, a dynamic enclosure space (can be climate-controlled or open), and a dedicated outdoor roof top amenity area.

To ensure the space can be used year-round in Michigan it was decided by the team that a viable option for enclosing the space in the winter was needed while also matching aesthetically with the space in the summer. This particular challenge was achieved through the coordination of systems selected for the space among all of the disciplines and the inclusion of the construction team on the final decisions to ensure that this part of the project could be achieved with the expectations of Hope College for the construction schedule and budget. (Refer to I3.5)

4.3.1 Weather Challenge

To ensure the space can be used year-round in Michigan, it was decided by the team that a viable option for enclosing the space in the winter was needed while also matching aesthetically with the space in the summer. The Atune team decided that accordion glass doors would provide the amenity space with the dynamic solution needed to keep the roof-top space usable in the winter. In addition to the accordion glass doors, the Atune team worked to implement a composite deck tile for the portion of the roof-top amenity space that will always be outdoors. These roof/deck tiles easily interlock creating a uniform floor, while also improving all future maintenance of the roof structure and the slab-melt system in the amenity space.



4.3.2 Open Area Designs

Based on Hope Colleges' goal of the roof-top space to be used for a variety of social events, fundraisers, and receptions for both the college and the city, Atune incorporated several key items in the design of the space. In the fully enclosed area, the design team focused on basic amenities and services that could be provided during events/receptions. The first focus was continuing the bathrooms and chases up from the 2nd floor to reduce the complexity of the mechanical systems. Secondly, a catering kitchen was added on the southwest corner of the space to allow for the option to serve a full meal, offer cocktails and hor d'oeuvres, or anything in-between.

In the dynamic enclosure space (the area that is separated by the accordion glass doors) there is a built-in serving area that can be used in conjunction with the catering kitchen. This space is also where any tables and chairs would be setup. Additionally, there is space if there was ever a need to setup a mini-stage if there is a fundraising event or other form of a function that requires live music.

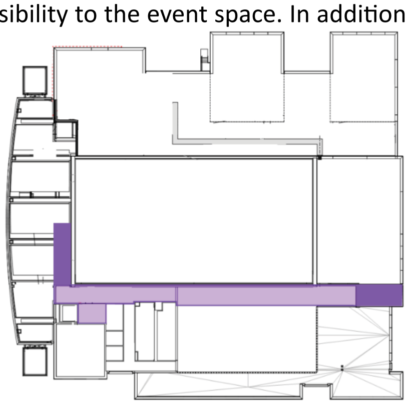
The final area is the dedicated roof top space. This outdoor area is sectioned off from the rest of the roof, which sets the space apart as a stand-alone area. To help improve the architectural design as well as provide the best view the surrounding area, a 4' glass wall parapet was included on the exterior of the roof top amenity area.

4.3.3 Egress

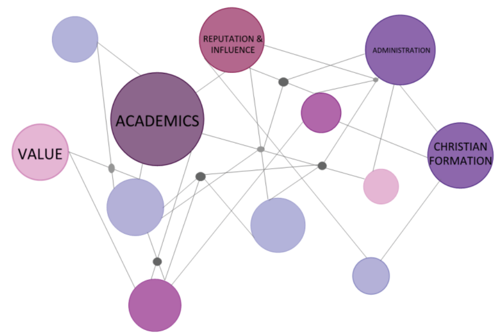
Since the roof top amenity space is to be used for events and receptions it was crucial for the Atune team to ensure the space was easily accessible and had plenty of exits for life safety. Egress and accessibility were a key aspect of the decision to place the amenity space on the south side of the building.

The elevator in the lobby that continues to the second floor was easily incorporated with the amenity space and was extended up one more floor to allow ADA accessibility to the event space. In addition to the elevator a second stairway was added on the east side of the elevator to connect the amenity space to the second floor.

For proper egress, a second stairway was needed on the far east side of the amenity space. Since there was already a stairway located from the first floor to the second floor on the east side of the building, the Atune team chose to continue the stairway up one more story to also serve the amenity space.



5.0 DESIGN INFLUENCES



The design presented by Atune is focused on the needs of Hope College. It was important for the Atune team to understand the expectations and goals of both Hope College and Holland, MI. I3.1

5.1 Owner and Stakeholders

The Hope College community of students, faculty and staff, administration, alumni, parents and trustees have a strategic plan for the college that we considered when designing the Jack H. Miller Center for the Musical Arts.

Academics, Christian formation, global engagement, community, reputation and influence, and value were the key goals associated with the strategic plan. Since the Jack H. Miller Center is to be used for classes as well as performances, we kept the goals of the college in mind.

Value, reputation and influence, and academics were strongly considered in the solutions presented for the timber and roof-top amenity space design challenges. These innovative and quality solutions help set Hope College apart and achieve the 2025 strategic mission.

5.2 Community

Hope College is highly involved with community of Holland, MI and therefore it was key for Atune's team to take the community's influence into consideration as well. Since the Jack H. Miller Center is a building that will be used for the community as well as the college, the timber construction and the roof-top amenity spaces are features that will showcase the Hope College and Holland communities as well as provide a useful space for them to use for years to come.

6.0 DESIGN FACILITATION & COMMUNICATION

To improve the quality of communication and coordination within the team, Atune utilized available time and technology to effectively plan out the work load.

6.1 Decision Making

Atune focused on making decisions for each discipline that took our three team goals into consideration: versatility, sustainability, and harmony. Each integrated piece was chosen while comparing options we researched looking for the big ideas we wanted to focus on for mechanical, electrical, structural, and construction design. A decision matrix assisted in this process and brought the team together early on to choose sub categories that were used for each discipline's choices throughout the development of ideas. The decision matrix was often referenced to confirm that design was moving in the correct direction that aligned with our original goals. Refer to I2.1

INTEGRATION DECISION MATRIX

ATRIUM	VERSATILITY				SUSTAINABLILITY				HARMONY				
	FLEXIBILITY IN USE	ROOM FOR GROWTH	ACOUSTICALLY ADAPTABILITY	AESTHETIC EFFECTIVENESS	LONG LIFESPAN	MAINTNANCE COST	ENVIRONMENTAL IMPACT	EDUCATION TO PUBLIC	MULTIPURPOSE DESIGN	SCHEDULE	BUILDING FACADE	CONSTRUCTABILITY	
WEIGHT	4	2	5	3	5	3	4	4	3	4	1	5	
RAISED FLOOR	16	10	10	6	15	12	12	16	15	8	1	10	131
STANDARD FLOOR	8	4	15	9	20	6	12	8	3	16	1	20	122
WOOD PANELING	12	6	20	3	10	9	16	8	9	8	2	20	123
WOOD STRUCTURE	12	6	15	12	15	9	16	8	9	12	3	10	127

One aspect that was talked about early on was the relevance of LEED and WELL Standards. It was decided that certification was not necessary for our design to exemplify sustainability. Refer to I2.2

6.2 Collaborative Environment / Team Building

The success of this project was dependent on the collaboration amongst our team. That is why Atune chose to form under the IPD design and construction approach.

6.2.1 Inter-Disciplinary Collaboration

Due to the nature of this design challenge and IPD approach, the Atune team met twice a week for integration team meetings. These team meetings discussed overall system integration as well as design decisions that needed full team approval.

In addition to the set integration meetings, the Atune team also met with inter-discipline meetings that did not include the full team when specific system design highly effected multiple disciplines. Examples of this can be found with the placement of the under-floor air distribution and Pavegen tiles.

6.2.2 Intra-Disciplinary Collaboration

The disciplines all meet at least twice a week for focused meetings on their specific system designs as well as to determine what decisions and information were needed from other disciplines.

6.3 Communication

A key part to success in every team setting is establishing effective means for communication. This helped each team member to know their role and foster trust for a positive environment.

6.3.1 Team Planning

From the beginning of the project, forming deadlines was a priority for Atune. Each month, the team went back to evaluate progress and make changes to the schedule in the efforts to assist in moving deadlines forward. By defining short- and long-term goals for the project, each discipline was able to take overall goals into consideration when achieving their own objectives.

Monthly presentations were given to the advisors and other team members to keep all parties up to date on the progress being made and to re-evaluate upcoming tasks. These gave the students the opportunity to receive immediate feedback on the decisions they were making.

6.3.2 Digital Communication

The team looked at long term and short-term planning when it came to be accommodating each member's schedule. To manage each member's availability, class and work schedules were shared in a team calendar early on to prevent unnecessary confusion. The university email accounts made coordination through Outlook Calendar readily available to the team. This way, prior meetings and commitments for school notified members when certain times would be unavailable.

Microsoft OneDrive was used as a data base for the team to store files and share ideas throughout the project. A file naming convention was established and set up for each team so that members from other disciplines would easily be able to navigate through folders to find information in an efficient manner. Refer to the Digital Communication Graphic.

7.0 VERSATILITY WITHIN THE BUILDING

Atune focused on collaboration between disciplines to broaden the functionality of spaces throughout the design process.

7.1 Space Use

The challenge to allow spaces to be used for a multitude of performance types stressed the importance of creative ideas being implemented into the design of large areas of the building.

7.1.1 Motorized Panels

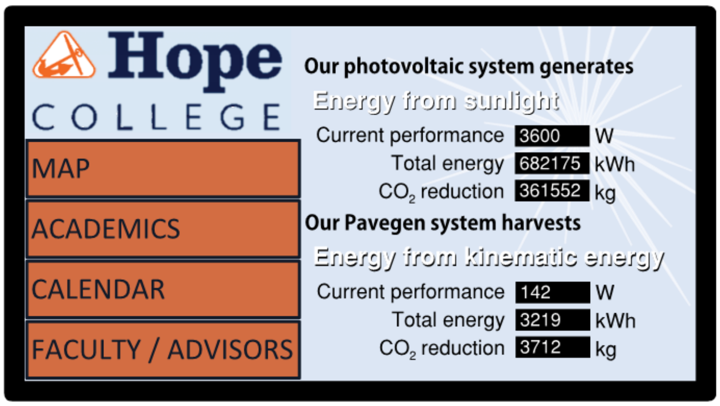
Hope college asked for a versatile concert hall to entertain multiple different performance types, therefore Atune decided to use motorized acoustical panels. The panels will be made of sound reflective fabric contrary to the sound absorbent material used for the curtains. The panels will be located on the wall behind the sound absorbent curtains and will move into the space to reduce the volume of the room. Reflective fabric panels will also be located on the ceiling and drop down to help reduce the volume of the space and decrease the reverberation time of the space. Atune is choosing to decrease the volume and decrease the absorption coefficient of the space to adjust reverberation times. Thus, enabling the concert hall to be adjusted for amplified concerts that require absorbent surfaces to private ensembles that require reflective surfaces for a higher quality of sound. Please refer to the supporting document for detailed calculations and information.

The motorized curtains and panels will have five preprogrammed settings, controllable through a password protected control panel in the control room. These settings will be preset by the acoustic consultant. The system will have an override function for more customizable performances but will require an additional password to minimize user malfunctions. The control panel schematic is pictured below. Refer to the supporting documents for an in-depth description of the five available settings. (I3.2)

7.1.2 Educational Spaces

Although the design of the building primarily focuses on the musical accommodations, the use of the building will mainly be for educational purposes. Seating in the corridors will serve as collaboration spaces for the students. The lockers that line the halls will be used to store instruments when they are not in use. Since there will always be instruments in the building, keeping humidification levels between 45 and 55% is of high importance (see M3.5). Each room has been designed to meet acoustical standards outlined on I3.2.

Another aspect that Atune focused on was educating the public on the sustainable attributes of the Jack H. Miller Center for Musical Arts. People are more likely to practice sustainability if they are educated about the subject. The electrical team worked closely with each discipline to display the information relevant to these sustainable efforts. The decision was made to place an educational display in the atrium, centered on the west wall of the performance hall. This centralized location will allow the building occupants to see the display while traveling through the building. The display will have a live feed from the building's servers; displaying precisely how much energy is being saved by the efficient mechanical design and how much energy is being produced by the renewable sources on site. Also incorporated in this display will be the benefits of sustainable structural design and how the construction of the building benefited from use of local materials to decrease the overall transportation of materials for the project. In addition, the display will offer relevant information to upcoming shows and events that the occupants can refer to.

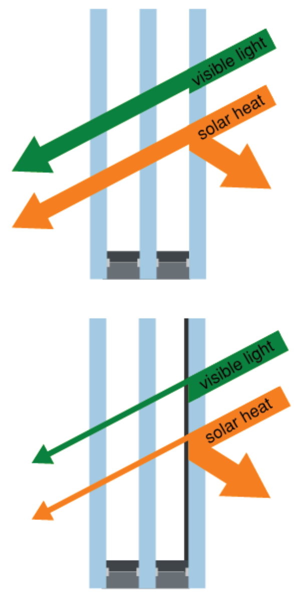


7.2 Cross Discipline Benefit

Atune made an effort to ensure that each expertise benefitted the others in at least one way. The early formation of ideas helped the teams to check in with each other and reference team goals.

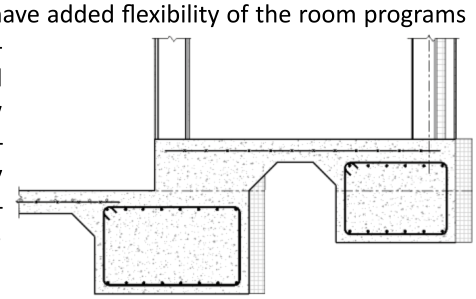
7.2.1 Façade Hydronic Mullions

The mechanical team chose hydronic mullions when entertaining system types that would address the large envelope load of the curtain wall in the atrium. The acoustic and aesthetic benefits (refer to Mechanical Section 7.5) of the system proved more applicable to the space than other options (refer to Mechanical Matrix M2.1). The hydronic mullion piping assists in reducing the envelope load that enters the space by absorbing or delivering heat at the façade. The mullions provide 1/3 of the total sensible load to the space. In addition, the view glass chosen by the electrical team showcases the front of the building by reducing glare while also reducing the mechanical load in the Atrium (7.4.4). The electrical and mechanical teams coordinated closely with each other to integrate the view glass, which requires a low voltage connection to each pane, with the hydronic piping concealed in the mullions, which requires a pipe in the mullion as well as a layer of insulation between the pipe and the building's interior portion of the mullion. This design decision, in conjunction with the radiant slab being implemented in the atrium, allowed for the team to be able to only have to implement forced air via the underfloor ventilation air. The UFAD system itself is quieter than traditional forced air systems, therefore combining the UFAD and the silent slab and mullion hydronic conditioning lead to very advantageous acoustical benefits for the atrium space that will make it more adaptable for a variety of possible uses. This design decision also integrates very well with the curtain wall architectural feature as it is visually concealed within the mullions, but still functions mechanically to help condition the envelope load at the source.



7.2.2 Lowering the Slab

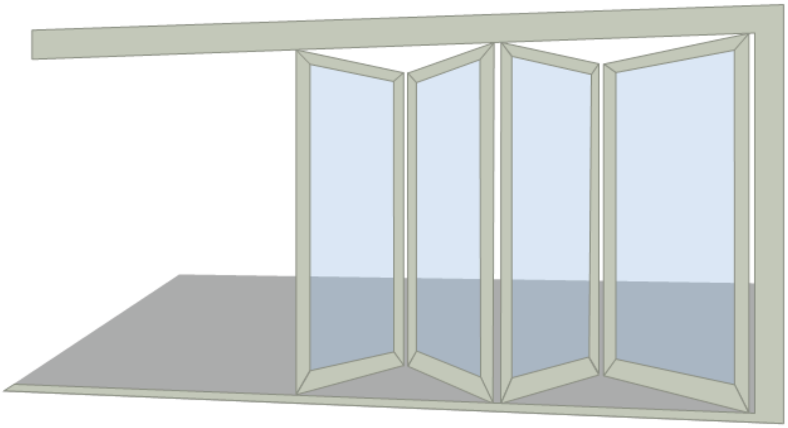
Early coordination allowed Atune to lower the buildng slab in areas that assisted the Electrical and Mechanical systems distribution. Electrical conduit and floor boxes are easily routed beneath the raised floor. Rooms AV Rack 131 and Telecom 141 benefit from a lowered slab and raised floor system for organized cable management around the equipment present. The electrical team was also able to implement their kinematic power generation technology, Pavegen, (reference electrical 6.1.2) easily into the lowered slab section in the corridors near the atrium. Ductwork was granted ample clearance for underfloor air distribution below the raisedfloor, allowing more effective delivery of ventilation air. By lowering the slab in the Recital, Orchestral Rehearsal, and Choral Rehearsal areas Hope College will have added flexibility of the room programs in the future. The electrical and mechanical infrastructure below the floor can be reconfigured more readily than a more conventional scheme in the ceiling plenum.



7.3 Amenity Space

As an additional element, Atune prioritized innovation in the amenity space to account for the year-round use while still utilizing architectural elements and system choices for the rest of the building.

7.3.1 Accordion Walls



An accordion wall made from glass panels were chosen to allow natural light in the space to mimic the architecture in the atrium. This will also allow for the feel and look of the space to remain constant throughout the course of the year when the weather will not allow for an open floorplan to the outside. Having the wall will prevent precipitation from disrupting the underfloor air distribution system and allow for the snowmelt system to still be used outside. (refer to M3.5)

7.3.2 Location

The Southern location allowed for use on the roof of the amenity space to be used for more solar panels. The south facing windows on the exterior face of the amenity space will allow for natural daylight throughout the whole year. The other locations that were discussed was the space above the atrium on the west side of the buildingand on the north side of the building above the rehearsal spaces and Mechanical Room 224. A visual is provided to see the comparison of these areas on I3.2. We compared the area of each space and decided that having a larger area was more important and avoiding the space above rehearsal rooms would have less acoustic concern. Spanning two existing staircases to be used as means of egress proved to be a better option instead of additional design and construction costs for a new stair case. The latter option would result in taking away space from the building owner that was already in use.

8.0 SUSTAINABILITY ACROSS DESIGN

Atune was focused on providing a sustainable design for the Hope College and Holland community. The design selections disscussed in this section cover that.

8.1 Façade

The exterior of the building implements innovation from each discipline while avoiding interruption in the aesthetic elements that exist within the architectural design.

8.1.1 View Glass

View Dynamic Glass was selected to be the glazing system for the curtain wall in the Atrium. This low-voltage system consists of connectors that charge an electrochromic coating on the interior surface of the outermost pane of glass. When charged, the coating can tint to four distinct levels, drastically reducing the glare and the amount of solar heat gain to the west facing curtain wall. In addition, the View Dynamic Glass selected consists of a triple pane construction, with a U-value of 0.14, reducing the amount of heat gain in the system. (Electrical Section 7.2) As a result of this system, the HVAC load was reduced 49%, allowing the mechanical team to decrease their DOAS unit serving the area.

In order to connect each section, a 15" pigtail connector will be routed around through the mullions, avoiding direct contact with the piping for the hydronic system. In order to ensure a long-life, these connections shall be weatherproofed, in the event of a pipe burst within the mullions.

8.1.2 Roof Space Utilization

Atune saw opportunity to utilize the available roof area to aid in sustainability, in addition to the roof's function of providing the area for an amenity space for events and gatherings. The mechanical and structural teams worked together to design a system within the roof slab that will melt the snow for easier drainage to the rainwater collection system while also supporting the solar panels used by the electrical team. For the snow melt slab, coordination was required between the mechanical, structural, and construction teams to route glycol piping through the concrete roof slabs (see Mechanical 7.4.7). This will be achieved by utilizing prefabricated sections of pipe that can be placed and set before the concrete slab is poured. The mechanical team coordinated with the construction team to ensure that the construction was viable (see Construction 7.3) and coordinated with the structural team to ensure the roof slab depth was structurally adequate despite the volume of space the piping occupies (see Structural 6.7). This coordination provided ease of drainage of the melted snow, which will reduce the wear on and increase the lifespan of the structural roof assembly while enabling more rainwater to be collected via the roof drains and used in the building (See Plumbing 8.5). In addition to housing the glycol piping, the roof slab will also support the solar array occupying most of the roof. The PV panel locations were coordinated as to not interfere with the amenity space while still achieving the desired solar capture, which will supply about 20% of the building's electrical needs (refer to Electrical 6.1.1). The inter-workings of the solar panels, roof slab, and snow melt/rainwater collection system required early attention to coordination, but each proved to benefit the final design as they enabled the building to consume less electricity and water long term, thereby reducing long term utility costs and environmental impact.

8.2 Timber Use

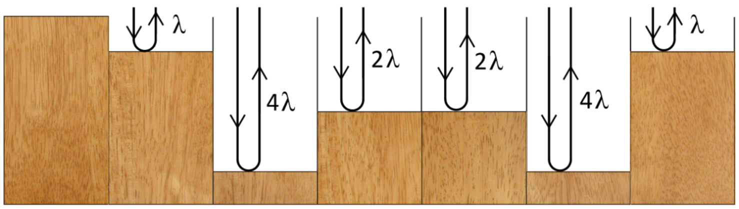
The structural team played the largest role while tackling the challenge for construction with timber. Coordination with other disciplines allowed for further use and implementation of the material.

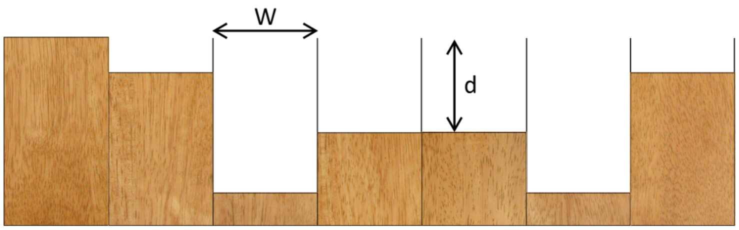
8.2.1 Atrium Structure

Instead of showcasing timber use in the architectural component through wood paneling, the team has decided to expose the zipper truss aspect of the structural design. The zipper truss also provides acoustic insulation for the building. This aspect will also help educate the occupants of the building about the structure's make-up as soon as they enter.

8.2.2 Recycled Acoustic Panels

Since the building is approximately 90% timber, the team wanted to showcase the utilization to occupants by incorporating the timber into the finishes of the building. Atune will use the scrap material from the construction site to design quadratic residue diffusers (QRD) in the faculty studios and classrooms to prevent sound from leaking into adjacent rooms. The frequency that the panels are designed to correlates with the dimensions of the space and what the space is being used for. Since each of the faculty studios have roughly the same dimension, the same panel design will be implemented into each of the rooms. The classrooms will have a different design made





with the same method used for the faculty studios. The design and calculations for the panels can be found (I3.3). The basic idea is that wavelegths are calculated and QRD are designed to allow octaves to meet eachother when they are reflected. Below is a section of a QRD. The contractors will implement a dedicated waste wood bucket while cutting interior non-structural members that are being constructed on-site. The structural team debated changing the original decision of using cold form steel for the stud walls in the building to timber. Research proved that it would be possible to keep the same wall thickness while being able to further improve the carbon footprint, therefore allowing the acoustic panels to be made from on-site scraps. The recycled pieces of wood will be shipped off-site for manufacturing at the end of each week during the construction period.

A majority of the building will utilize QRD to attenuate sound. In a studio it is essential to balance the absorption throughout the audio range so that the recording will translate well onto other audio systems. In this case, the goal is to create a neutral listening environment. The faculty studios will be used to primarily practice with professors in a small reserved space. QRD panels will be placed so that they are able to reduce the amount of echo in the room. Flutter echo is mostly cause by reflective parallel surfaces that allow the echo to sustain itself. Reducing flutter echo is easily done by placing panels on opposing parallel walls in such a way that the echo cannot sustain itself. A mixture of lecture and practice / demonstration will be in the classrooms and attenuation between the adjacent rooms is desired to keep from distracting students and instructors. Each of these rooms require absorption of sound to be fully taken advantage of.

9.0 HARMONY ACROSS DISCIPLINES

Team meetings and technology allowed for ongoing collaboration. Some elements the team emphasized in are in the following text.

9.1 Floor Construction

The high ceilings throughout the building foreshadowed high maintenance costs and construction complications. Making additional space within the floor to house systems that would typically lie within the ceiling proved to be beneficial for multiple disciplines. The structural team was able to assist the mechanical and electrical disciplines with a more dynamic design.

9.1.1 Under floor Air Distribution

Structural SIP walls do not allow for electrical penetrations larger than 1 ½" and the raised floor. A benefit of a raised floor is it will act as a chase for not only mechanical distribution means but also allow for electrical and plumbing runs underneath the floor. Low velocity air at occupant level that addresses the acoustical performance in the space.

9.1.2 Frost Protection

Atune's structural team identified the opportunity to employ frost protected shallow footings around the perimeter of the building. The use of frost-protected footings has reduced the required depth of the grade beam foundation design by 6", which reduces the amount of concrete needed for the building.

In addition to the reduction in the volume of required concrete, the use of frost-protected foundation reduces the amount of formwork used by the construction team. The connection of the concrete to the rigid insulation occurs from the concrete bonding to the insulation during the curing process. This requires the rigid insulation on the exterior face of the grade beam or footing to be used as the formwork.

Finally, the use of frost protected footings reduces the amount of heat lost from the building through the ground and foundations. This thermal efficiency results in a reduction of the sensible loads on the mechanical systems. For more information on the design of the frost-protected shallow footings see SXXX.

9.2 Prefabrication

Due to a series of complex systems, prefabrication efforts will be implemented for a variety of mechanical, structural and electrical systems. Prefabricating some of the elements of the Jack H. Miller Center for Musical Arts will allow the construction team to spend less time on site, with improved efficiency and safety ratings. Constructing elements off site allows the laborers working to focus on fewer tasks which makes them more productive, effectively helping to reduce costs. (refer to Construction 7.3) The same can be said for those employees installing the elements on site. Tasks that were completed off site are tasks that do not need to be worried about on site which means the laborers on site can focus on a smaller number of tasks which in turn, improves productivity and reduces cost.

9.2.1 Structural Systems
The majority of our structure is made from wood which provides a significant opportunity for off-site prefabrication. Elements of the trusses and the carbon fiber wrapped columns can be prefabricated. In addition, the cross laminated timber panels that will make up the walls and floors of the building can be built before they arrive to the site.

9.2.2 Mechanical Systems
The variety of innovative mechanical components allows for a decent amount of integration between the construction and mechanical teams. We have plans to prefabricate the hydronic runs that will be servicing the radiant slab, active chilled beams, and the hydronic mullions. The piping runs for the rooftop snow melt system can be constructed off site as well as piping runs for the standard plumbing system. Additionally, sections of the ductwork and sprinkler pipe will be prefabricated.

9.2.3 Electrical Systems
Typically, electrical panels and conduit runs will be prefabricated however, the use of ethernet cable in our design eliminates the need for approximately 50% of the conduit runs and significantly reduces the number of panels required. There are only 6 panels throughout the building which the construction and electrical teams decided was not enough to worry about prefabricating. However, the solar panel racks can and will be prefabricated to help reduce the large number of manhours the installation of the solar panels will take. We also intend to prefabricate the conduit runs used in the building.

9.3 BAS
Atune decided to implement an artificial intelligent building automation system to unite all the systems. Electrical engineers estimated the cost to build an onsite artificial intelligent system at Hope College. With a projected 90 servers each costing roughly $34,500 the baseline estimate would quickly approach three million dollars. This estimate did not include the space and equipment needed to maintain the system that would have additional cost. Consequently, Atune decided to explore external and established systems. This decision led to finding IBM's Watson. Watson is a combination artificial intelligent (AI) system and machine learning (ML) system. It analyses masses of data and uses the information to answer questions.

The Jack H. Miller Center for Musical Arts will be one of the first buildings to implement a combination AI and ML platform to manage the building. Data will be retrieved from sensors across all disciplines including, occupancy sensors, photocells, temperature sensors, humidistat and duct pressure sensors. More data will be collected using occupant inputs from room schedulers and the buildings IoT platform. Watson will analyze data in real time and seek answers to predetermined functions such as system efficiency and occupant comfort. Atune engineers will work closely with IBM engineers and Hope college representatives to ensure effective commissioning. (refer to Electrical 8.3.2)

An example of Watson's multi-disciplinary integration are the room schedulers to be implemented in all occupied spaces. The room schedulers will be used to reserve rooms in advance through the building's IoT platform. Upon reserving the room, the occupant will be asked for a desired temperature and the estimated occupant load during the reservation. Watson will take this data and compare the set point, occupant loads, utility rates and expected weather for the reserved day and time. It will then analyze the best time to start precooling or heating the room to provide the most efficient and cost-effective scenario. Additionally, the system will use the occupancy controls in the room to determine if the room is in use at the time of the reservation. Once the room establishes vacancy, the room will end the reservation and prepare for the next reservation or close the dampers and valves serving the radiant and latent loads in the room. This enables for faster and more efficient room reservations and building productivity. This is a critical issue for the Jack H. Miller Center because an estimated 127 performances are anticipated a year.

10.0 LESSONS LEARNED
While in school, the team has been taught the importance of designing affordable, sustainable, and efficient systems for owners. This project has given us the realization that innovative design can be produced without the extra cost that it always seems to associate with. Planning ahead with each party involved (electrical, mechanical, structural, construction, and owner) can help push the innovation towards success, even though it may be an iterative process. The team made changes to calculations on multiple counts after going through integration meetings and re-evaluating prior choices made. In the beginning it felt repetitive and unnecessary but being able to confidently present aspects of findings to the rest of the group was worth having to overcome complications.

Over the past few months the team has learned a lot about the industry, but more about how to overcome obstacles and complete tasks while working with and helping each other along the way. Communication was an important aspect of success throughout the journey. Trial and error using different technology to weigh decision making occurred early on. Learning about each other's planning methods helped when it came to team collaboration meetings to efficiently come to agreement. One of the hardest lessons to learn was that it's okay to fail. The important thing for the team was to find the mistakes in previous decisions made, fix them and move forward to find a solution.

11.0 CONCLUSION
Atune was able to design a building with innovative, sustainable systems to satisfy the necessities of the College and Community. In the end, Atune was able to reduce the energy consumption of the building by 25% at a final cost just over 25 million including the add-alternatives to satisfy the project challenges in 30 weeks.

DECISION MATRIX & SYSTEM SELECTIONS

INTEGRATED DECISION MATRIX

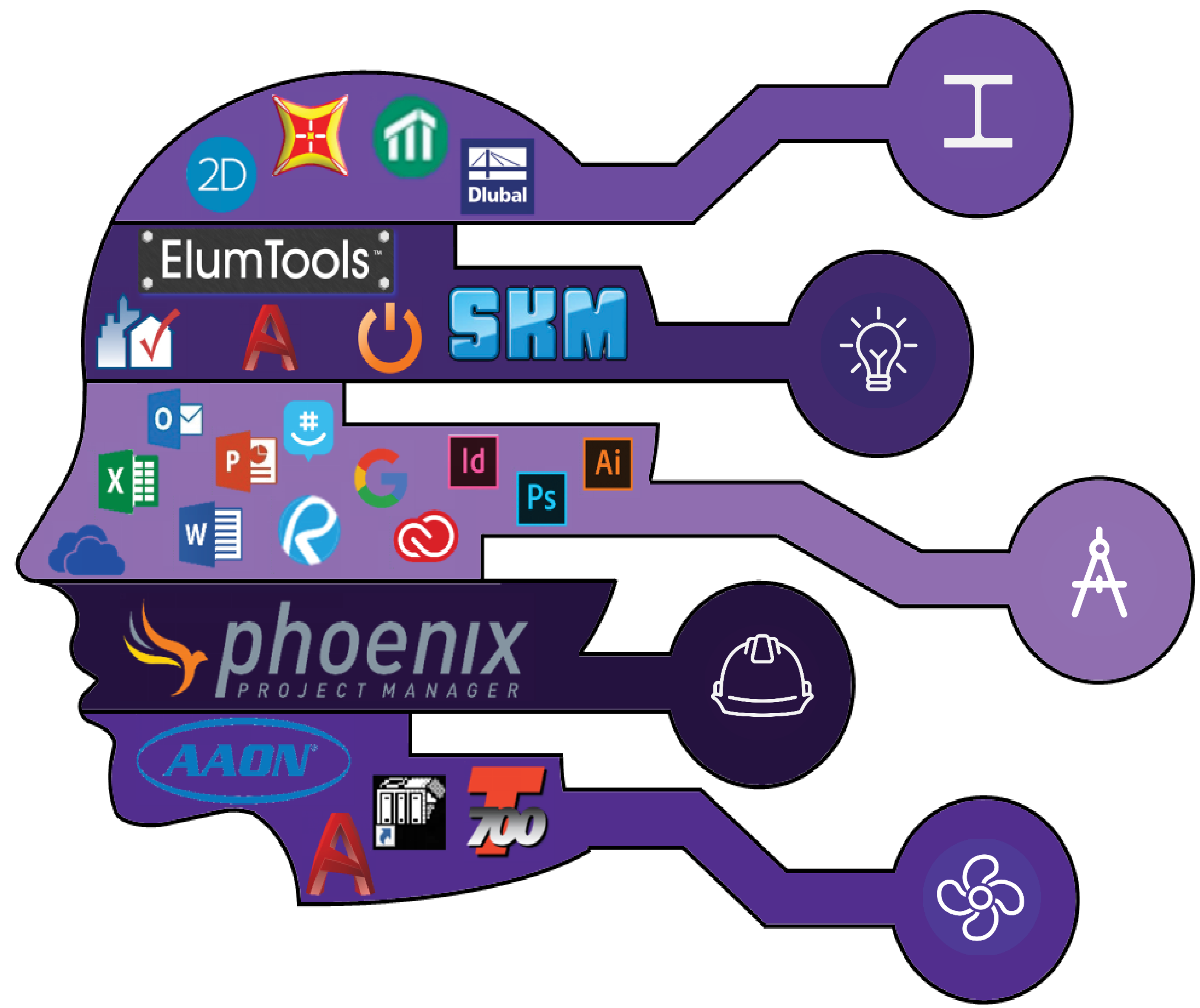
Atune began the design process by selecting three design drivers: harmony, sustainability, and versatility. The team created a decision matrix to ensure that the design drivers were considered in every design decision made. The decision matrix below was used to select systems that optimized integration throughout the Jack H. Miller Center for Musical Arts.

INTEGRATION DECISION MATRIX

	VERSATILITY				SUSTAINABLIITY				HARMONY				
	FLEXIBILITY IN USE	ROOM FOR GROWTH	ACOUSTICALLY ADAPTABILITY	AESTHETIC EFFECTIVENESS	LONG LIFESPAN	MAINTNANCE COST	ENVIRONMENTAL IMPACT	EDUCATION TO PUBLIC	MULTIPURPOSE DESIGN	SCHEDULE	BUILDING FACADE	CONSTRUCTABILITY	
ATRIUM													
WEIGHT	4	2	5	3	5	3	4	4	3	4	1	5	
RAISED FLOOR	16	10	10	6	15	12	12	16	15	8	1	10	131
STANDARD FLOOR	8	4	15	9	20	6	12	8	3	16	1	20	122
WOOD PANELING	12	6	20	3	10	9	16	8	9	8	2	20	123
WOOD STRUCTURE	12	6	15	12	15	9	16	8	9	12	3	10	127
CONCERT HALL													
WEIGHT	4	2	5	3	5	3	4	4	3	4	1	5	
RAISED FLOOR	16	8	15	6	15	12	12	16	15	8	1	10	134
STANDARD FLOOR	8	4	15	9	20	6	12	8	9	12	3	10	116
REVERBERATION PANELS	20	4	25	15	10	3	4	12	12	8	1	5	119
CURTAINS	12	6	10	3	20	12	4	8	6	16	1	20	118
AMENITY SPACE													
WEIGHT	4	2	5	3	5	3	4	4	3	4	1	5	
ROLL-UP WALLS	16	4	5	3	15	9	4	4	3	12	2	15	92
ACCORDION WALLS	16	4	5	15	15	9	4	4	3	12	3	10	100
WEST LOCATION	8	4	5	6	15	9	12	12	9	8	3	10	101
SOUTH LOCATION	16	6	5	9	15	9	8	12	9	16	2	20	127
FACADE													
WEIGHT	4	2	5	3	5	3	4	4	3	4	1	5	
HYDRONIC MULLIONS	12	6	10	9	10	6	16	12	12	8	5	10	116
WOOD MULLIONS	12	6	15	9	10	6	16	8	3	8	3	15	111
VIEW GLASS	16	6	15	12	10	9	16	12	12	12	4	15	139
SOLAR HARVESTING	12	6	15	9	10	9	16	16	9	12	3	15	132
ROOF SPACE													
WEIGHT	4	2	5	3	5	3	4	4	3	4	1	5	
RIAN WATER HARVESTING & SNOW MELT	20	6	5	6	10	6	20	16	15	8	1	10	123
CONVENTIONAL ROOF	12	4	5	9	20	12	4	4	3	16	3	25	117

COLLABORATIVE SOFTWARE

Atune began the design process by selecting three design drivers: harmony, sustainability, and versatility. The below software was utilized for modeling and collaborating design ideas within the Atune team. Bluebeam and Revit were essential in visually conveying the final developed design. This graphic shows the key softwares that each discipline individually used to create the final unified design.



LEED DESIGN GOALS

LEED Design

The Atune team has decided to not pursue LEED Platinum accreditation at the time of construction. Accredidation costs can add up quickly, therefore instead of removing sustainable aspects of the system designs, Atune is providing all of the documentation from the engineers and contractors to Hope College at time of building completion. This documentation will allow Hope College to more easily purchase accreditation in the future if they choose.

Atune designed the Jack H. Miller to achieve LEED Platinum. Since sustainability is important to Hope College, the Atune team focused on engineering green system designs and evaluating how the design and construction process could reduce the carbon footprint of the building.

Holland, MI, has the opportunity for regional credits for aspects of design that incorporate on-site renewable energy, stormwater design (quality control), light pollution reduction and innovative wastewater technologies. Atune's engineering design team achieved these four regional credits through the photovoltaic array on the roof, greywater collection, and mesopic multipliers in lighting design.

For detailed information on all of Atune's sustainable design systems, refer to the structural, mechanical, and electrical narratives.

LEED v4 for BD+C: New Construction and Major Renovation
Project Checklist

Project Name: ATUNE Design - Jack H. Miller Center for Musical Arts

Y	?	N			
1			Credit	Integrative Process	1

Y	?	N		Location and Transportation	16
13	3	0			
1			Credit	LEED for Neighborhood Development Location	16
	1		Credit	Sensitive Land Protection	1
	1		Credit	High Priority Site	2
5			Credit	Surrounding Density and Diverse Uses	5
5			Credit	Access to Quality Transit	5
1			Credit	Bicycle Facilities	1
1			Credit	Reduced Parking Footprint	1
	1		Credit	Green Vehicles	1

Y	?	N		Sustainable Sites	10
8	1	0			
Y			Prereq	Construction Activity Pollution Prevention	Required
1			Credit	Site Assessment	1
1	1		Credit	Site Development - Protect or Restore Habitat	2
			Credit	Open Space	1
3			Credit	Rainwater Management	3
2			Credit	Heat Island Reduction	2
1			Credit	Light Pollution Reduction	1

Y	?	N		Water Efficiency	11
7	2	0			
Y			Prereq	Outdoor Water Use Reduction	Required
Y			Prereq	Indoor Water Use Reduction	Required
Y			Prereq	Building-Level Water Metering	Required
	1		Credit	Outdoor Water Use Reduction	2
6			Credit	Indoor Water Use Reduction	6
	1		Credit	Cooling Tower Water Use	2
1			Credit	Water Metering	1

Y	?	N		Energy and Atmosphere	33
24	0	0			
Y			Prereq	Fundamental Commissioning and Verification	Required
Y			Prereq	Minimum Energy Performance	Required
Y			Prereq	Building-Level Energy Metering	Required
Y			Prereq	Fundamental Refrigerant Management	Required
4			Credit	Enhanced Commissioning	6
11			Credit	Optimize Energy Performance	18
1			Credit	Advanced Energy Metering	1
2			Credit	Demand Response	2
3			Credit	Renewable Energy Production	3
1			Credit	Enhanced Refrigerant Management	1
2			Credit	Green Power and Carbon Offsets	2

Y	?	N		Materials and Resources	13
8	3	0			
Y			Prereq	Storage and Collection of Recyclables	Required
Y			Prereq	Construction and Demolition Waste Management Planning	Required
	3		Credit	Building Life-Cycle Impact Reduction	5
2			Credit	Building Product Disclosure and Optimization - Environmental Product Declarations	2
2			Credit	Building Product Disclosure and Optimization - Sourcing of Raw Materials	2
2			Credit	Building Product Disclosure and Optimization - Material Ingredients	2
2			Credit	Construction and Demolition Waste Management	2

Y	?	N		Indoor Environmental Quality	16
12	2	1			
Y			Prereq	Minimum Indoor Air Quality Performance	Required
Y			Prereq	Environmental Tobacco Smoke Control	Required
2			Credit	Enhanced Indoor Air Quality Strategies	2
3			Credit	Low-Emitting Materials	3
1			Credit	Construction Indoor Air Quality Management Plan	1
2			Credit	Indoor Air Quality Assessment	2
1			Credit	Thermal Comfort	1
2			Credit	Interior Lighting	2
	2		Credit	Daylight	3
		1	Credit	Quality Views	1
1			Credit	Acoustic Performance	1

Y	?	N		Innovation	6
4	0	0			
3			Credit	Innovation	5
1			Credit	LEED Accredited Professional	1

Y	?	N		Regional Priority	4
4	0	0			
1			Credit	Regional Priority: Specific Credit	1
1			Credit	Regional Priority: Specific Credit	1
1			Credit	Regional Priority: Specific Credit	1
1			Credit	Regional Priority: Specific Credit	1

Y	?	N			
81	11	1		TOTALS	Possible Points: 110

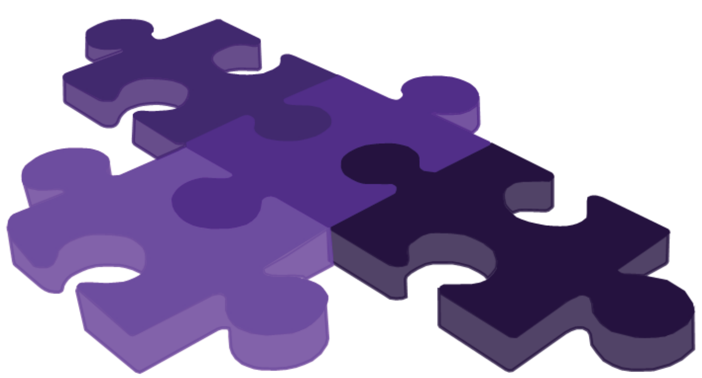
Certified: 40 to 49 points, **Silver:** 50 to 59 points, **Gold:** 60 to 79 points, **Platinum:** 80 to 110

INTEGRATED SYSTEM DECISION FLOWCHART

The team developed a system selection flowchart to justify system selection choices based on the added value for another system of the trade off of integration between the disciplines.

The first column established the systems that required specific design coordination with 2 disciplines. The circular arrows indicated both disciplines benefit while the set of 3 nested arrows indicate only one discipline saw added benefit.

Columns 2 and 3 show the 2 disciplines involved based on color with a brief description of the involved systems. The arrows in between show which discipline is providing the additional coordination for the other disciplines benefit. Arrows in both directions indicates both systems benefitting as well.



Communication was vital to the IPD approach and successful integration of the Atune team. The system integration flowchart was very helpful for the team to have a complete comprehension of the full project.

SYSTEM INTEGRATION DECISION FLOWCHART

SYSTEM AND ASSOCIATED DISCIPLE INTERACTION

SYSTEM INTEGRATION	INVOLVED DISCIPLINE	INVOLVED DISCIPLINE
RADIANT SLAB & SNOW COLLECTION; RAISED FLOOR; HYDRONIC MULLIONS	RAISED FLOOR IN THE CONCERT HALL AND HYDRONIC MULLIONS IN THE ATRIUM. IMPROVES MECHANICAL SYSTEM PERFORMANCE, REQUIRED SPECIFIC COORDINATION WITH STRUCTURAL	RADIANT SLAB & SNOW MELT SYSTEM AID BOTH MECHANICAL AND STRUCTURAL DESIGN
SELF- ADJUSTING PANELS; EMERGENCY POWER FOR HEATING	CONCERT HALL ACOUSTICAL PANELS ARE POWERED TO MOVE BASED ON PERFORMANCE TYPE. MOVING CANTILEVER LOAD HAD TO BE DESIGNED BY STRUCTURAL TEAM.	DUE TO THE QUANTITY OF THE TIMBER IN THE STRUCTURAL SYSTEM, HUMIDITY CONTROL NEEDED TO BE PLACED ON THE EMERGENCY POWER SYSTEM. COORDINATION WITH ELECTRICAL.
SOUND ISOLATION SLABS; RECYCLED WOOD ACOUSTIC PANELS	INCREASED ACOUSTICAL REQUIREMENTS, ADDITIONAL SOUND ATTENUATION IS REQUIRED. STRUCTURAL INCLUDED ADDITIONAL SOUND ISOLATION IN SLABS. RECYCLED TIMBER FROM SITE WILL BE USED TO MAKE ACOUSTICAL PANELS IN CERTAIN AREAS OF BUILDING.	MODIFIED SLAB DESIGN OF FLOOR SYSTEMS TO ADD ADDITIONAL SOUND ISOLATION.
HYDRONICS; SYSTEM SELECTION	INCREASED ACOUSTICAL REQUIREMENTS, SOUND MUST BE CONSIDERED IN ALL DESIGNS.	SYSTEMS SELECTED REDUCE BACKGROUND NOISE FROM MECHANICAL IMPROVING THE OVERALL ACOUSTICAL PERFORMANCE.
SELF-ADJUSTING PANELS	CONCERT HALL REQUIRES ADAPTABLE ACOUSTICAL EFFICIENY BASED ON THE MUSICAL PERFORMANCE.	ADDITIONAL POWER AND DISTRIBUTION REQUIRED.
CLT PREFAB PANELS; CARBON-FIBER WRAPPED COLUMNS	PREFAB HAS POSITIVE EFFECTS ON SCHEDULE IF COMMUNICATED.	CLT SYSTEMS ARE PREFAB PANELS.
UNDERFLOOR PIPING; PREFAB DUCT & PIPING; BOREFIELD	UNDERFLOOR AIR DISTRIBUTION REQUIRES COORDINATION WITH THE CONSTRUCTION TEAM DUE TO FOUNDATION DROPS. PREFAB PIPING AND DUCTS IMPROVE CONSTRUCTION SCHEDULE.	BOREFIELD FOR MECHANICAL SYSTEM RESULTS IN INCREASED COORDINATION AND SCHEDULE TIME FOR CONSTRUCTION.

COLLABORATION MODEL - PROJECT CHALLENGES

ACOUSTICAL CHALLENGE

TIMBER CHALLENGE

ROOFTOP AMENITY CHALLENGE

TIMBER FOR ACOUSTICS

The use of CLT walls, CLT composite floors and glulam framing members improve the overall acoustical attenuation of the building.

IBM WATSON

Utilizing building monitoring and room requests, the building monitoring system can precondition the amenity space. This increases the versatility of the space.

AIR DISTRIBUTION/ HYDRONICS

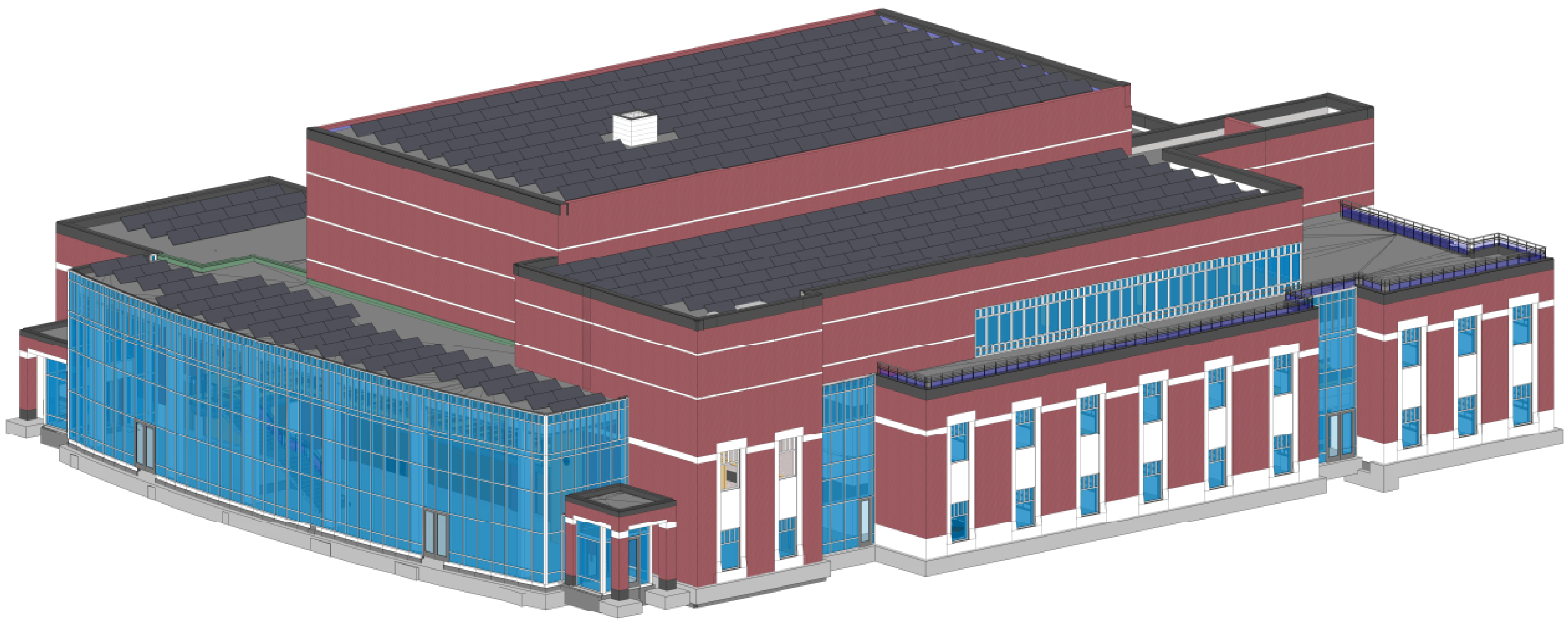
Underfloor air distribution is a quiter system, which is ideal in the concert hall and recital spaces.

COMPOSITE FLOOR SYSTEM

The implementation of a composite CLT and concrete floor system achieves the spans in the Jack H. Miller Center for Musical Arts.

CATERING SPACE

A catering kitchen equipped with the essentials was located above the second floor mechanical room. This feature increases the variety of events the amenity space can entertain.



MOTORIZED PANELS

In the concert hall, the use of motorized panels improves the versatility of the space. These panels improve the acoustical perfomance in the concert hall.

CATERING SPACE

A catering kitchen equipped with the essentials was located above the second floor mechanical room. This feature increases the variety of events the amenity space can entertain.

CARBON FIBER WRAPPED GLULAM COLUMNS

Utilizing the composite action between timber and carbon fiber,reduces the required column size in the atrium. This maintains the openess of the space.

POE

Power over ethernet reduces the penetrations needed by the electrical team. By utilizing fewer wall penetrations for conduit the acoustical performance is improved.

ACCORDION WALLS

The glass accordion wall increases the versatility of the rooftop space during the warmer months. The adaptability of the wall allows the rooftop amenity space to vary.

QRD PANELS

Acousitcal panels for the faculty offices and student classrooms.

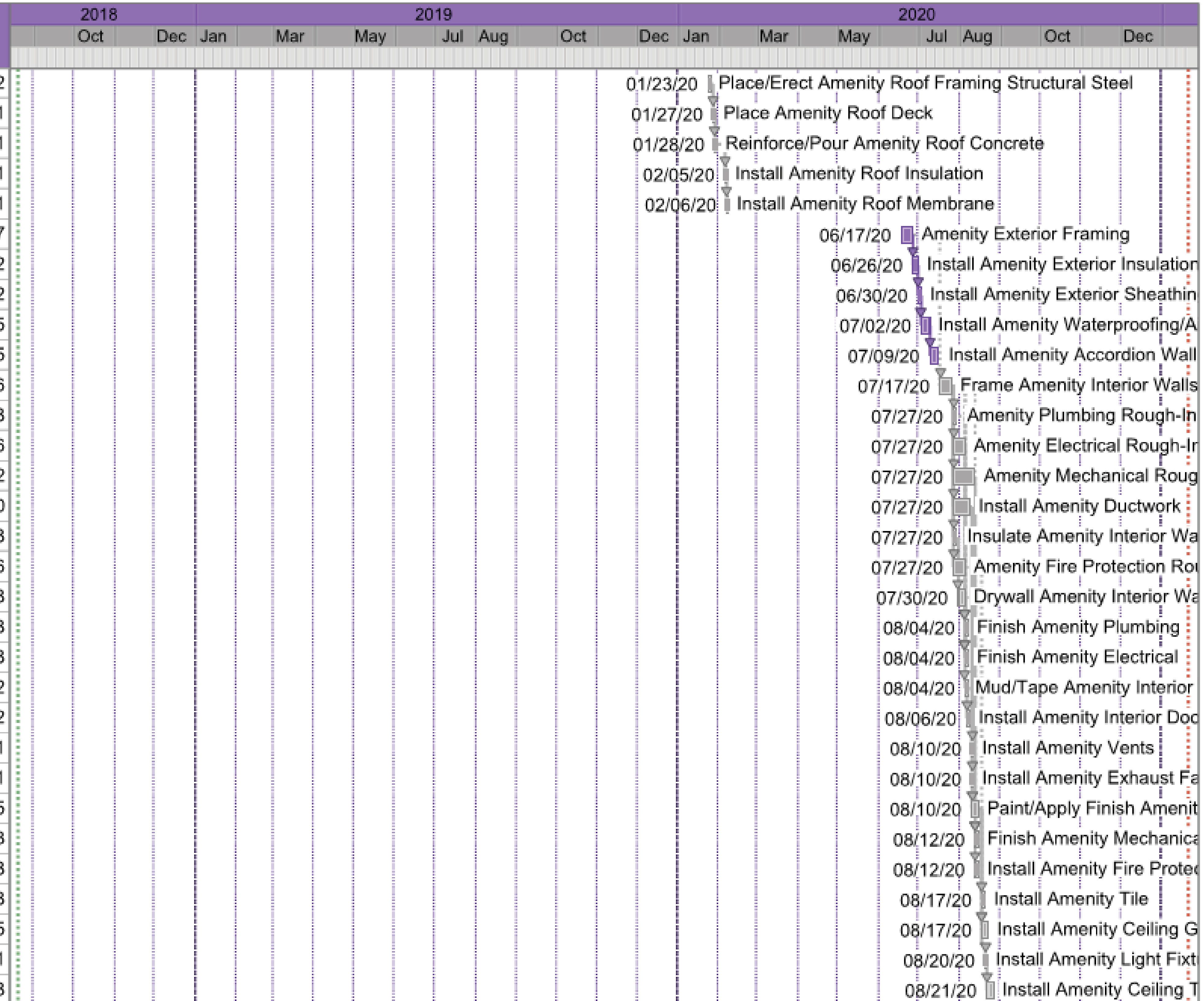
CLT WALLS

Cross laminated timber tilt-up walls improves the constructability of Atune's structural system. The CLT wall design optimizes the CLT capacity to act as the lateral and gravity systems.

PROJECT SUMMARY AND SCHEDULE

PROJECT CHALLENGES SCHEDULE

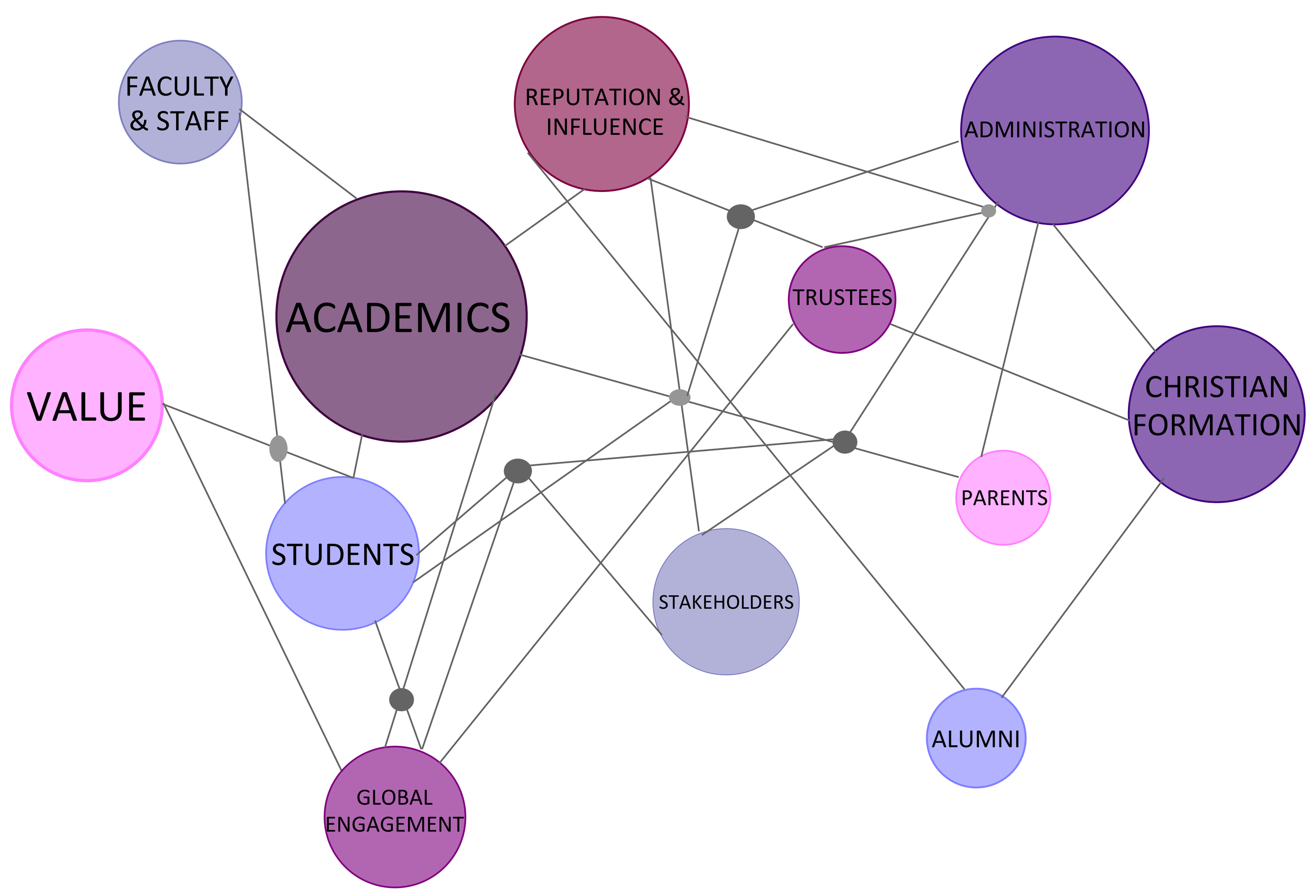
ID	Description	Original Duration
360	Place/Erect Amenity Roof Framing Stru	2
365	Place Amenity Roof Deck	1
370	Reinforce/Pour Amenity Roof Concrete	1
380	Install Amenity Roof Insulation	1
385	Install Amenity Roof Membrane	1
480	Amenity Exterior Framing	7
485	Install Amenity Exterior Insulation	2
495	Install Amenity Exterior Sheathing	2
500	Install Amenity Waterproofing/Air Barrie	5
605	Install Amenity Accordion Wall	5
520	Frame Amenity Interior Walls	6
525	Amenity Plumbing Rough-In	3
530	Amenity Electrical Rough-In	6
535	Amenity Mechanical Rough-In	12
540	Install Amenity Ductwork	10
545	Insulate Amenity Interior Walls	3
550	Amenity Fire Protection Rough-In	6
555	Drywall Amenity Interior Walls	3
560	Finish Amenity Plumbing	3
565	Finish Amenity Electrical	3
570	Mud/Tape Amenity Interior Walls	2
575	Install Amenity Interior Doors/Frames	2
580	Install Amenity Vents	1
585	Install Amenity Exhaust Fans	1
590	Paint/Apply Finish Amenity Interior Wall	5
595	Finish Amenity Mechanical	3
600	Install Amenity Fire Protection System	3
610	Install Amenity Tile	3
615	Install Amenity Ceiling Grid	5
640	Install Amenity Light Fixtures	1
645	Install Amenity Ceiling Tile	3



DESIGN INFLUENCES

Atune kept the focus of the design on the needs of Hope College. Atune worked with Hope College to define the long term goals of the college for the students, faculty, and other stakeholders in Hope College's success. The 2025 goals of Hope College are focused around academics, community, and global engagement.

After conversations with Hope College, Atune made a word cloud to serve as a visual reminder for the team as they went through the design processes.



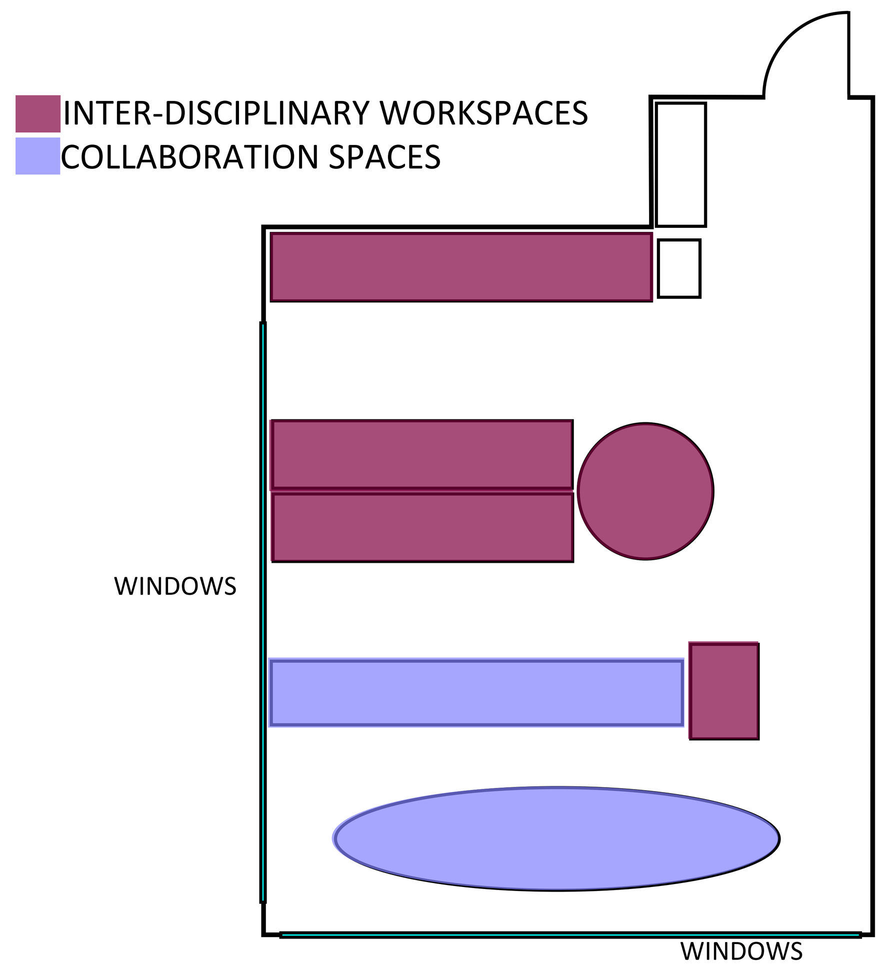
The community involvement is important to Hope College, which is why the roof top amenity area is designed to provide a space the college and community for a variety of events.

Hope COLLEGE

ATUNE DESIGN & COLLABORATION ROOM

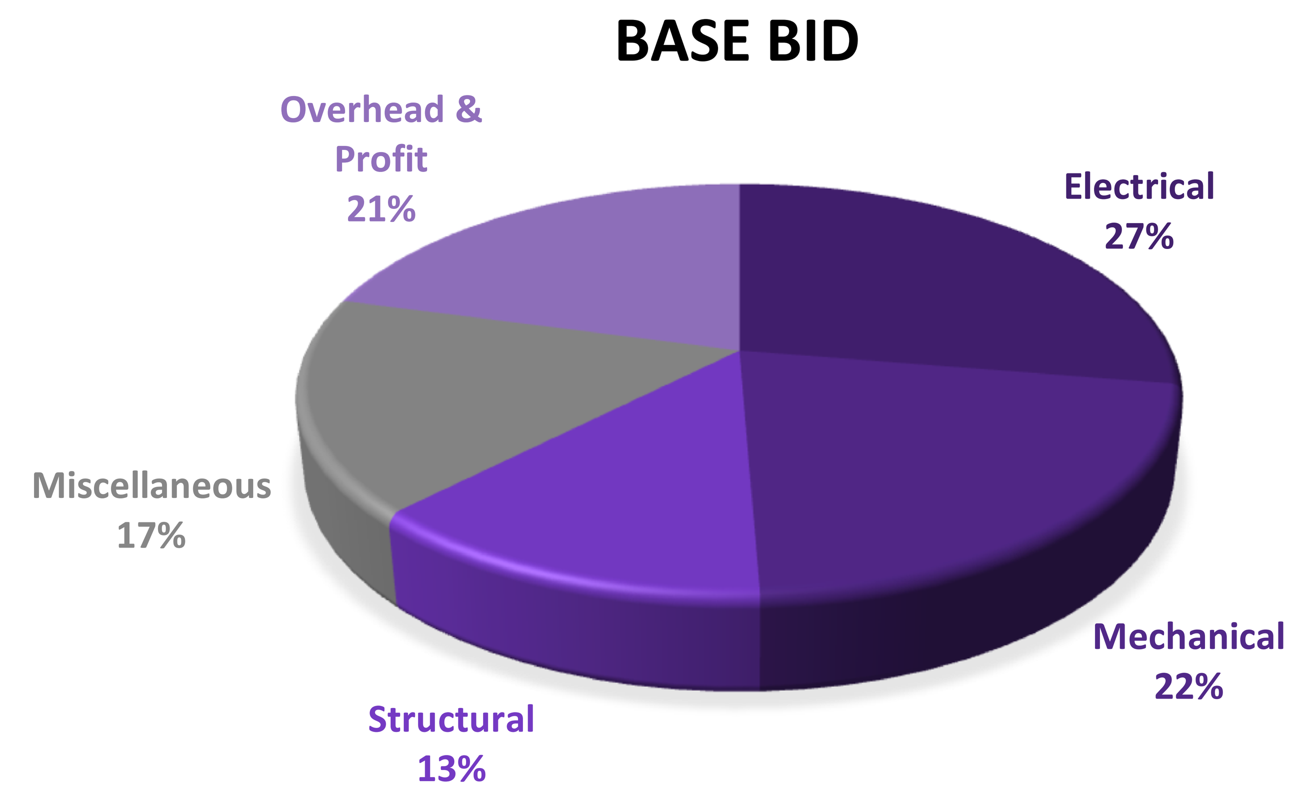
The Atune team worked from a single office space to ensure that design and construction questions could be quickly answered. A total of 11 workstations were available to the team. Each of the workstations came equipped with all of the software programs used by the entire team. This allowed for individual team members to move around the room and sit next to the disciplines that they needed to collaborate with that day.

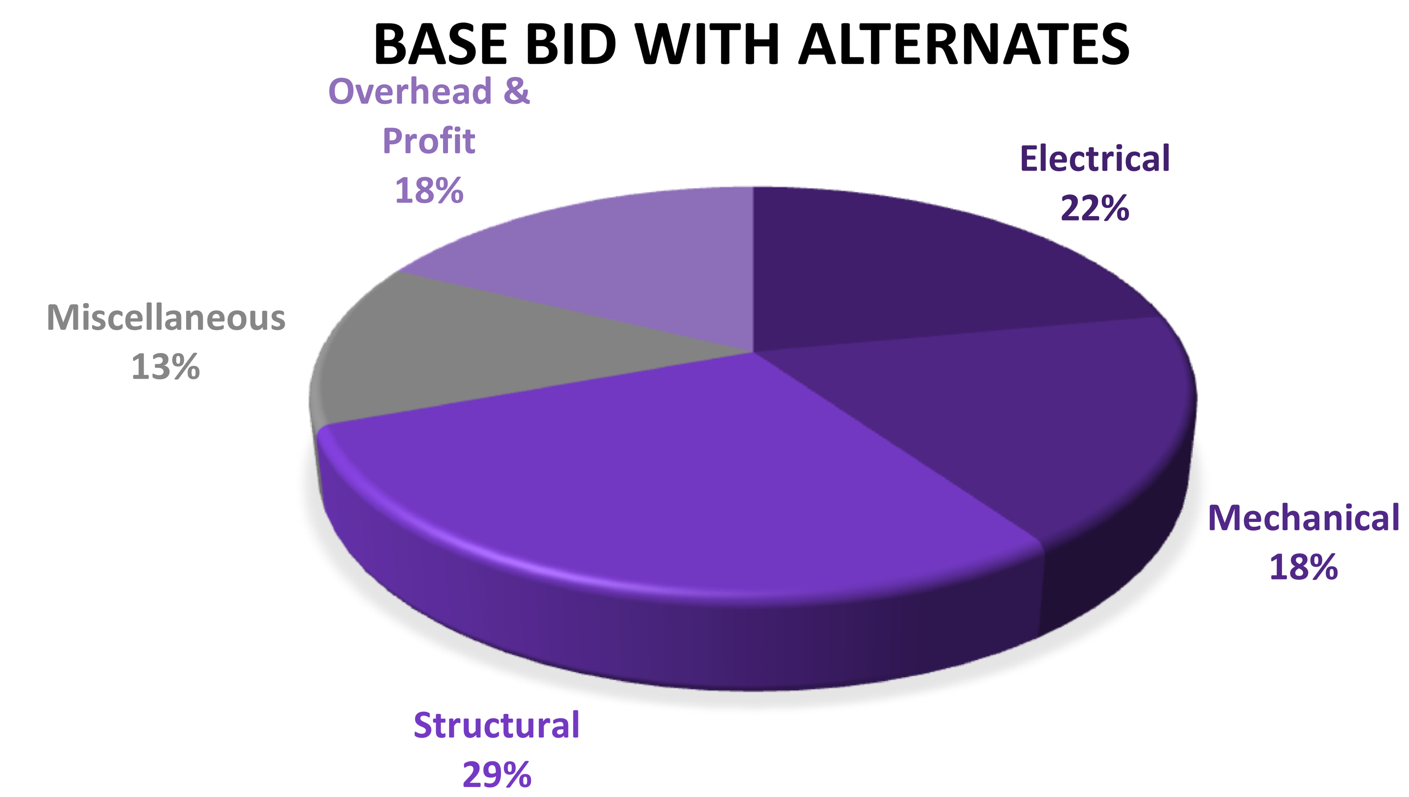
The office space was selected because of the available workstations and collaboration space. Additionally, this workroom had two walls of windows which increased the amount of natural light that entered the space. Based on studies done and the team's experience, the addition of windows to the workspace improved overall team productivity by up to 50%.



DESIGN BUDGET

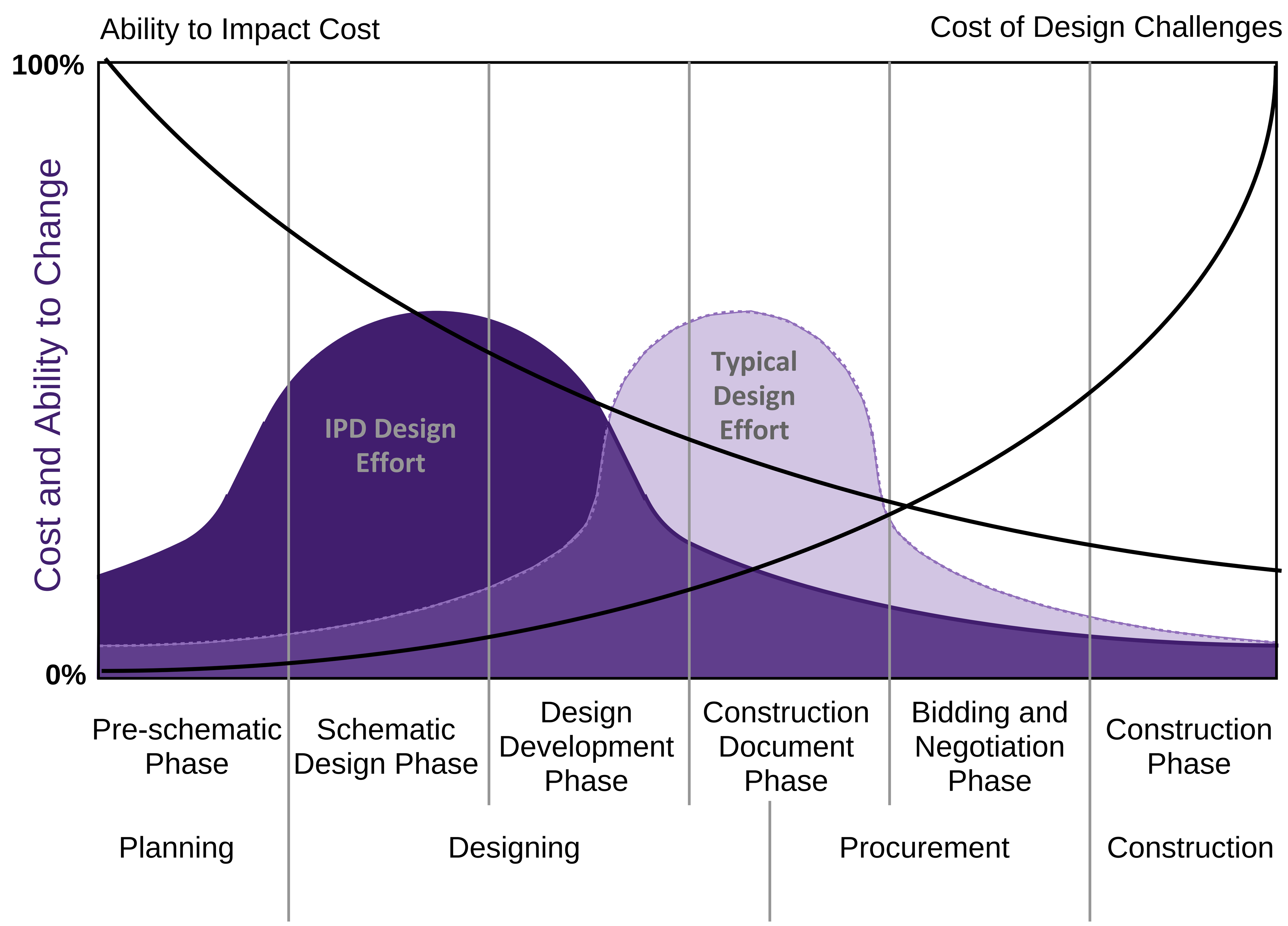
The budget was evaluated on scales with and without the project challenges considered. The Base Bid is $19,367,030 total. The Base Bid with Alternates is $25,080,063.





IPD Design Benefits

The collaborative efforts from the owner, engineers, and contractors in IPD allows for optimization of the project results. The sooner designers and contractors are involved in the planning process allows for a higher chance of benefiting the overall project cost while intercepting the issues early on. The graph below shows that the Integrated Project Delivery method allows for more issues to be addressed early, before the project cost is solidified.



ATUNE

Jack H. Miller Center for Musical Arts

ATUNE INTEGRATION

AEI Team No. 7

Scale

I3.1

DESIGN GUIDELINES FOR HVAC RELATED BACKGROUND SOUND ROOMS				
ROOM TYP.	CLASSIFICATION	OCTAVE BAND ANALYSIS	APPROXIMATE OVERALL SOUND PRESSURE LEVEL	
		NC/ RCb	dBA	dBC
CLASSROOMS	MUSIC TEACHING STUDIO	25	30	55
REHEARSAL	RECITAL HALL	20	25	50
CONCERT	CONCERT HALL	20	25	50
FACULTY STUDIO	MUSIC PRACTICE ROOM	30	35	60
ATRIUM	LOBBY	40	45	65

These design guidelines were used to model spaces to fit sound constraints for different space classifications. Atune used this data to give spaces the ability to transform and provide optimal space form for a performance.

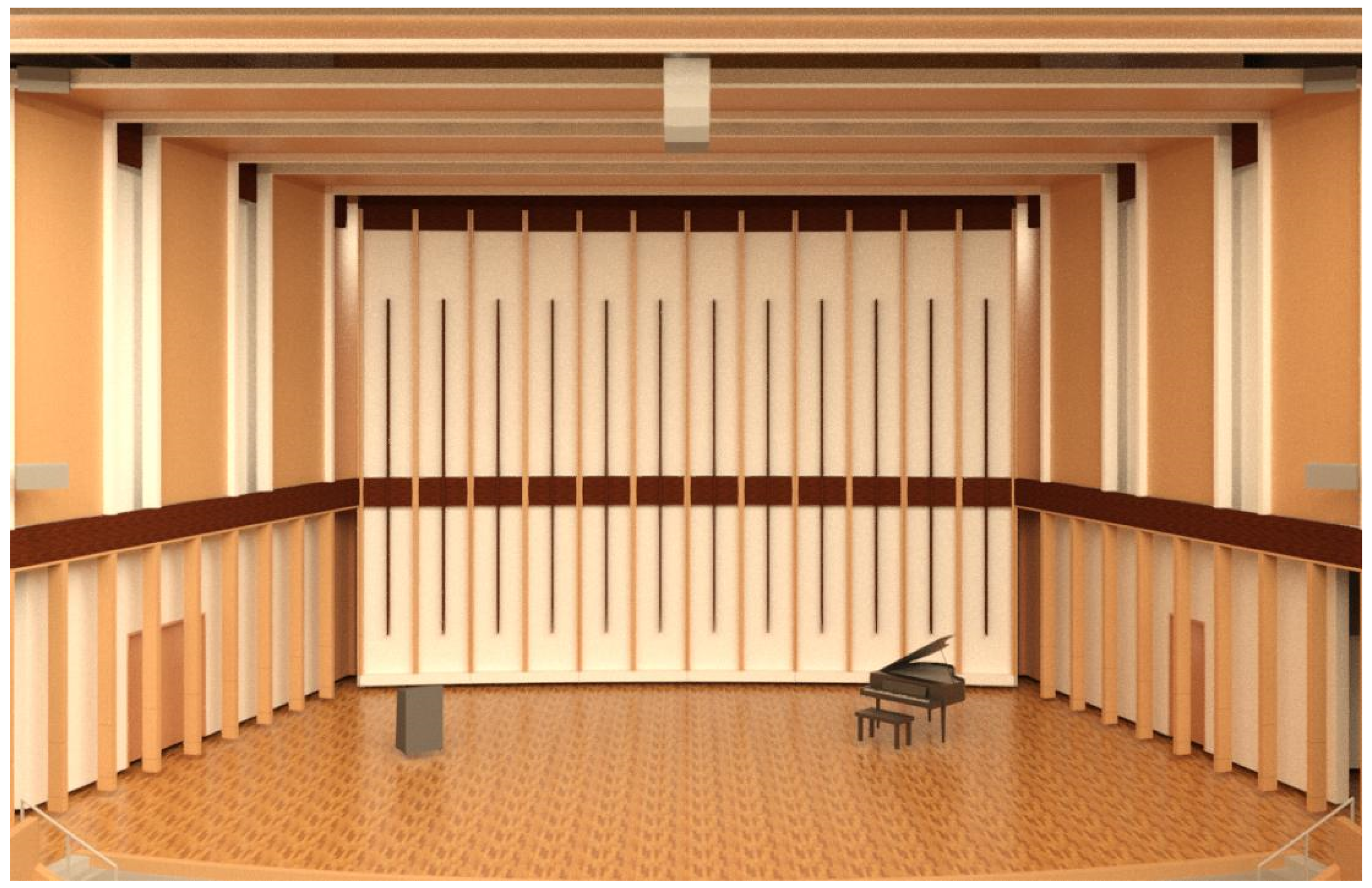
Frequency Ranges of Instruments [Hz]		
Instrument	Lower Limit	Upper Limit
Violin	196	2637
Viola	130.8	1046.5
Cello	65.4	659.3
Double Bass	41.2	246.9
Flute	261.6	2093
Oboe	233	1396.9
English Horn	155.6	932.3
Clarinet(Bb)	146.8	1864.7
Bass Clarinet(Bb)	73.4	698.5
Bassoon	58.3	932.3
Contrabassoon	29.1	155.6
Horn(double, F & Bb)	61.7	698.5
Trumpet (Bb)	164.8	932.3
Trombone(tenor)	82.4	466.2
Trombone(bass)	61.7	466.2
Timpani	87.3	349.2
Harp	30.9	3322.4
Average	110.6	1111.6

Reverberation Calculation Equation

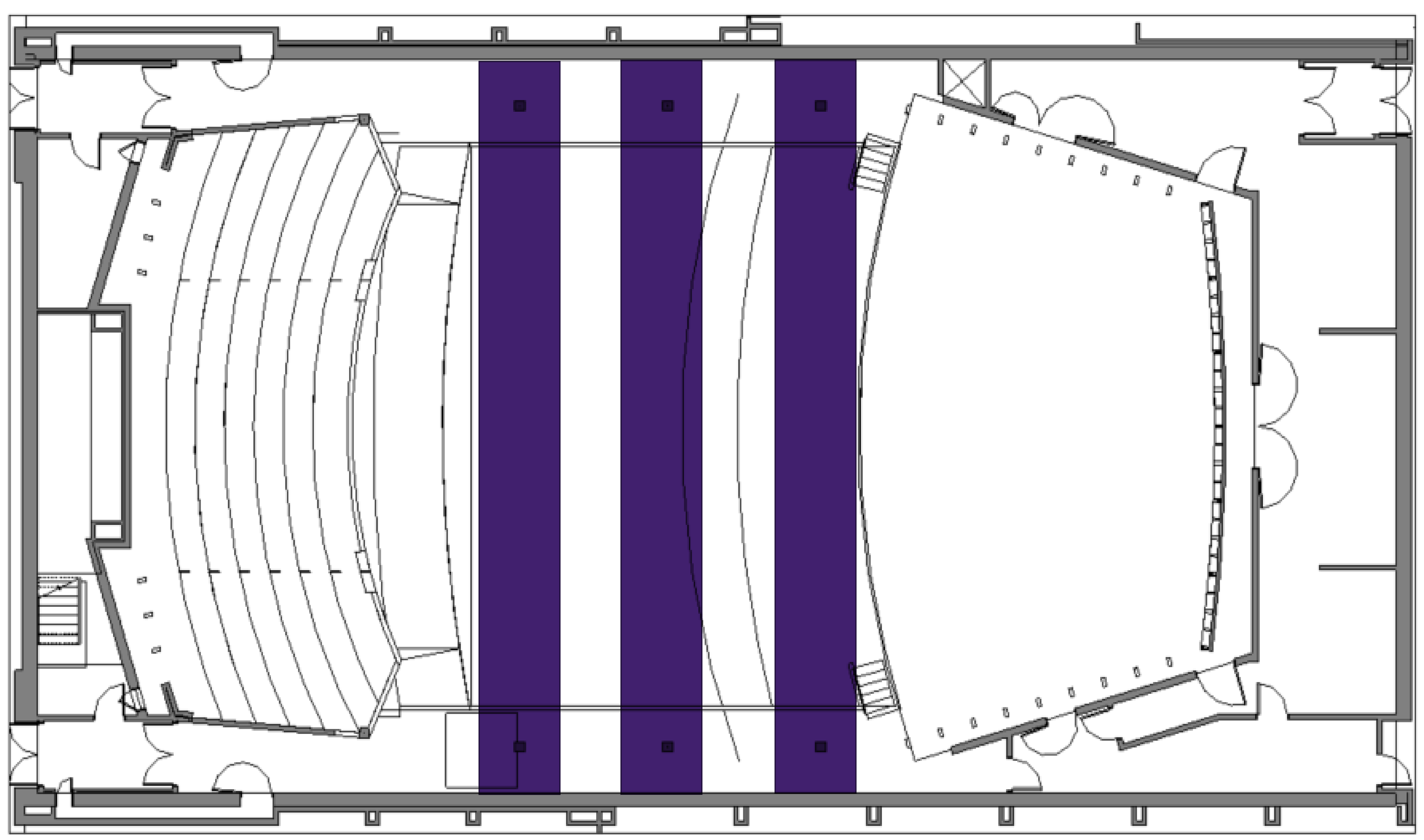
$$RT_{60} = 0.049 * \frac{V}{S_e}$$

Absorption Coefficients @ 500HZ	
Material	Coefficient
Wood on Joist	0.1
Fully Occupied - Fabric	0.88
Empty - Fabric	0.8
Curtian: Reflective	0.15
Curtian: Heavyweight	0.55
Sheetrock 1/2"	0.05

CONCERT HALL SPACE MOTORIZED PANEL LAYOUT AND DESIGN



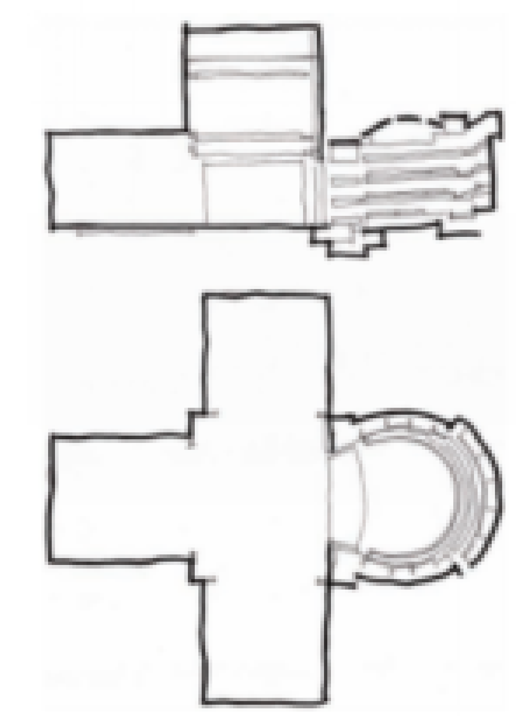
Atune proposed the idea to install motorized acoustical panels in the concert hall to allow the space to adapt to different acoustical performances. The panels are highlighted purple in the figures below. Reverberation time can be adjusted in two ways: volume reduction and coefficient of absorption. With the mechanical panels on the ceiling the volume of the space can be reduced by lowering the panels. The mechanical panels behind the acoustical curtains have a different coefficient of absorption to be able to change the reverberation time even more. Final reverberation ranges are to be calculated in future design with a specialty consultant. Atune anticipates reberberation times from 4 to .3 seconds.



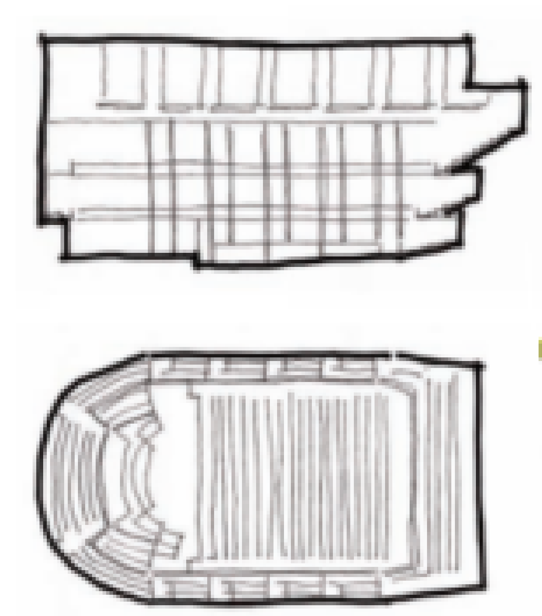
CONCERT HALL SPACE CONSIDERATIONS

Research was conducted for various performance spaces. These show examples of the different room configurations required for a concert hall, recital room and opera house. Atune used these room forms and attempted to create a space that can transform; providing an optimal space form for multiple performance types. There are considerable variations for an opera house. Though there audience size usually ranges from 1,800 to 2,200, Atune wants to provide a similar space on a smaller scale for Jack H. Miller Center for Musical Arts. Concert halls provide a home for classical music and accommodate a wider range of amplified and contemporary music. The typical approaches to concert hall design are 'shoebox' and 'vineyard'. Atune has chosen 'shoebox' to focus on in the design. A recital space has a typical audience of 200 to 600 for classical music.

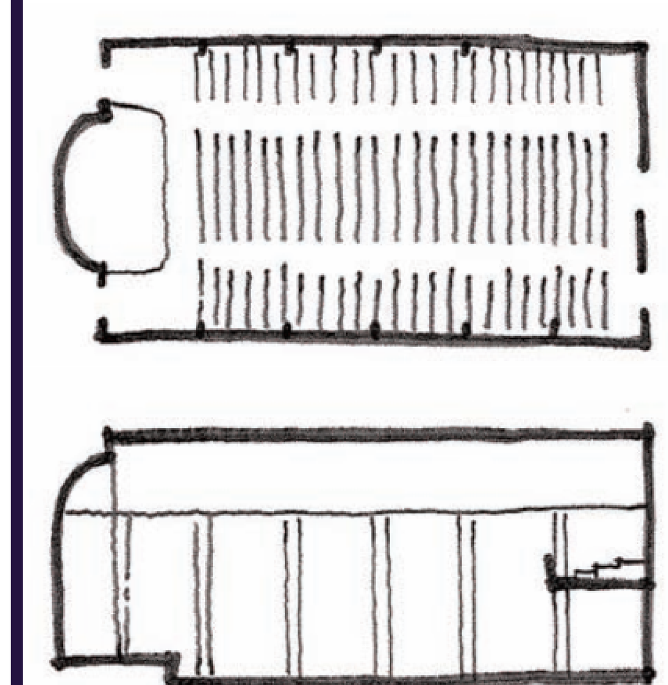
OPERA HOUSE



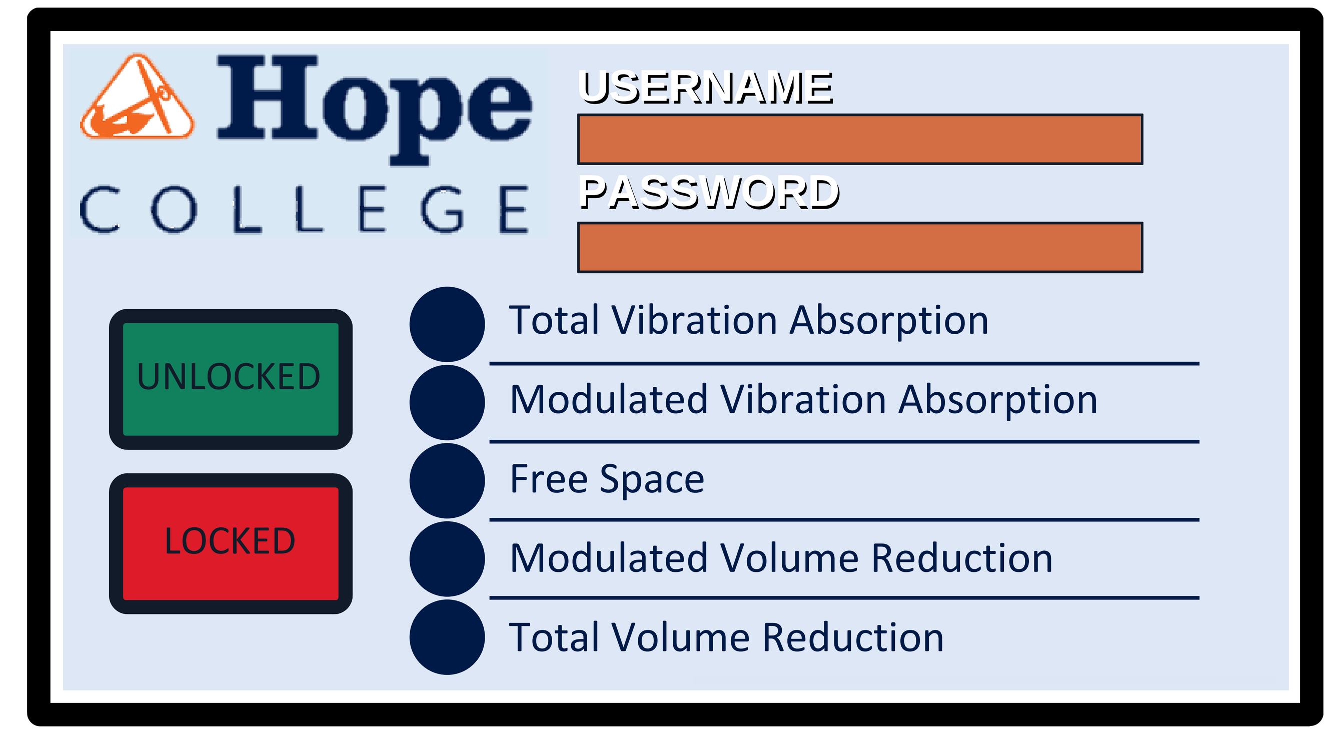
CONCERT HALL



RECITAL ROOMS



CONCERT HALL ACOUSTIC SETTINGS



Depicted above is the user interface to be used for the motorized acoustical panels in the concert hall. The panel is purposely locked to prevent user error from occurring to the preset options determined by the acoustic consultant. This device will keep records of users in the building and how often to relate back to the AIBAS. The different settings will be explained to the user upon selection and ask for confirmation, they are explained below:

Total Vibration Absorption - To be used for electronically enhanced shows such as amplified music concerts.

Modulated Vibration Absorption - To be used for less amplified performances or ceremonies such as public speakers and graduations.

Free Space - To be used by for most common performances such as orchestra and opera shows.

Modulated Volume Reduction - To be used for smaller than normal shows that are purely musical instruments.

Total Volume Reduction - To be used for very small performance types such as private ensemble performances.

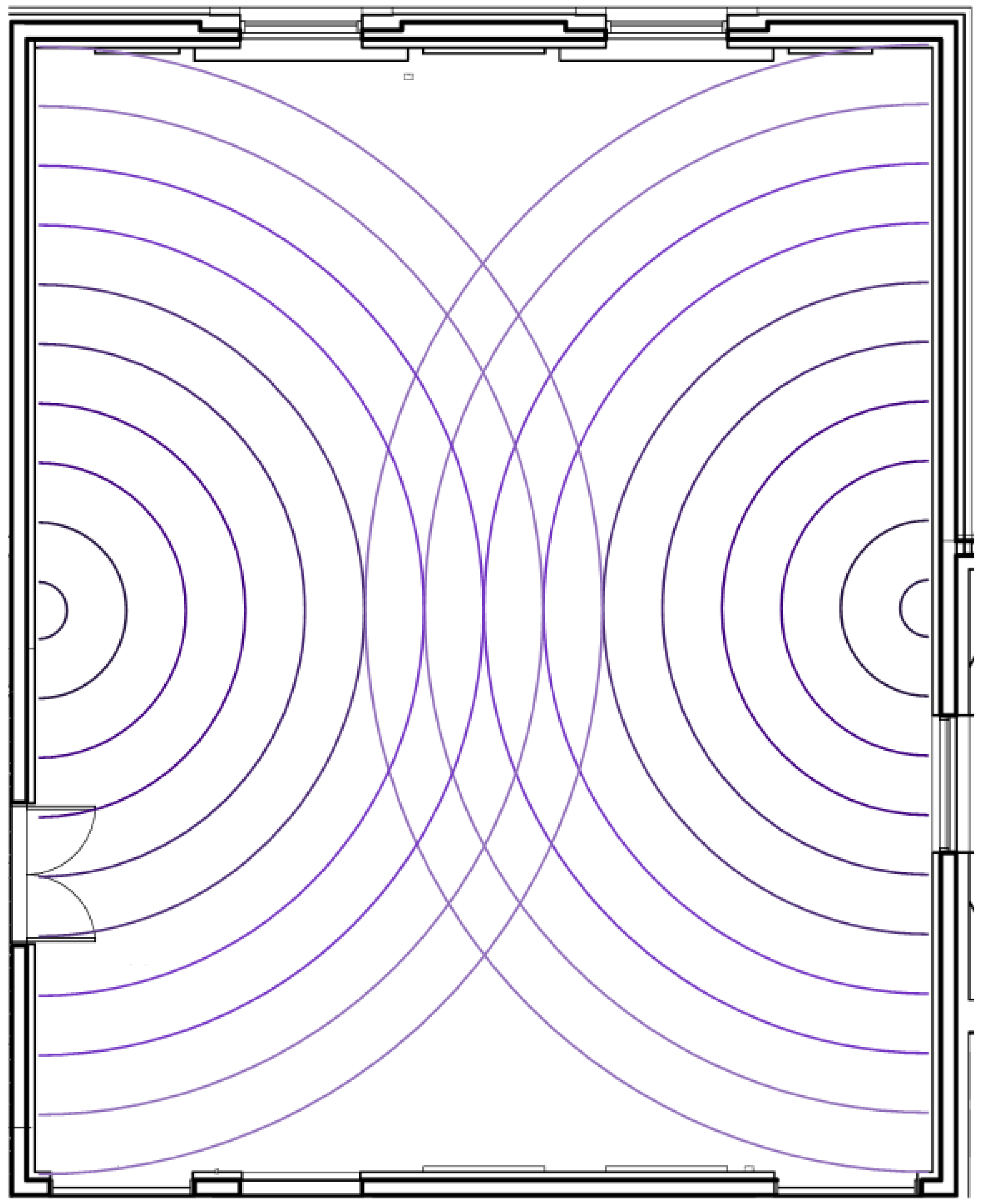
ATUNE

Jack H. Miller Center for Musical Arts

Acoustics

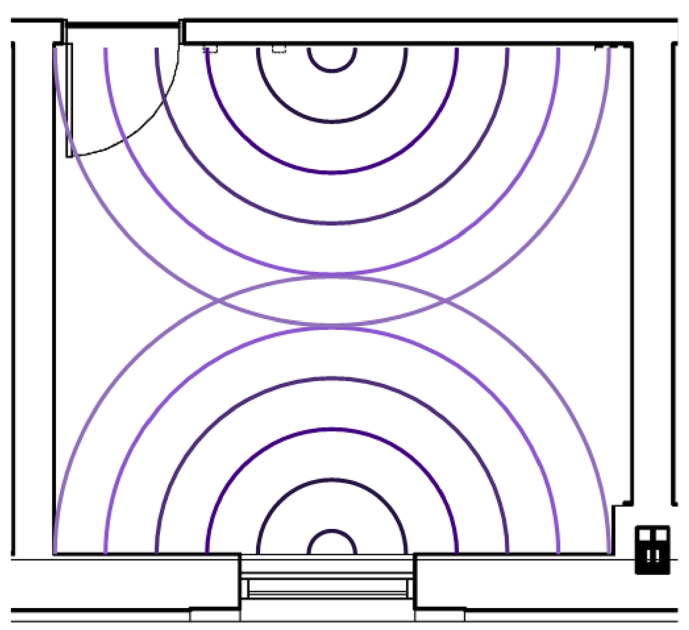
AEI Team No.	7-2019
Date	02/18/2019
Scale	NO SCALE

I3.2

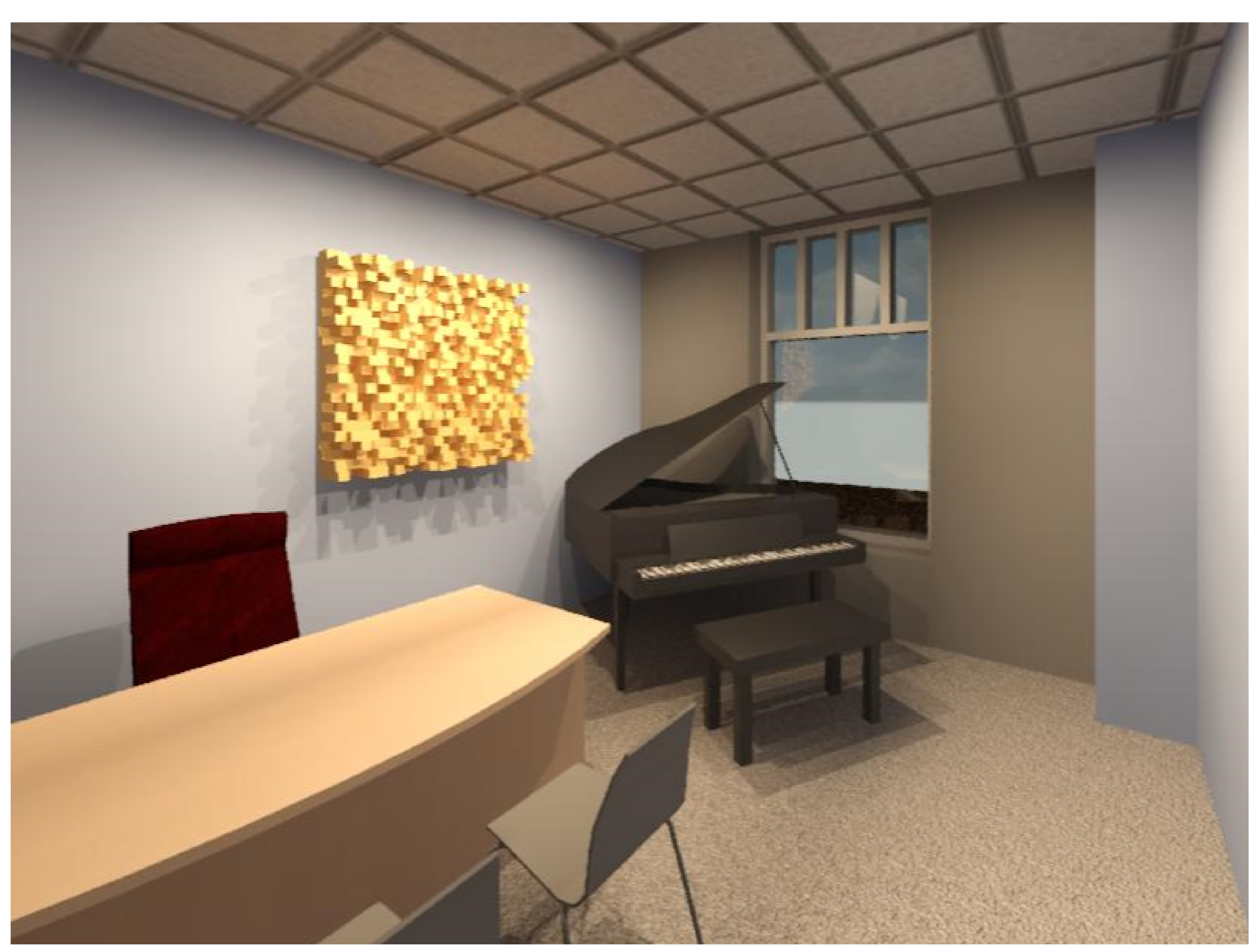


1 TYPICAL REHEARSAL SPACE OCTAVE ISO LINES

The layouts of typical spaces show the octaves of sound waves meeting each other from parallel walls after the respective QRDs designed for the specific room have been placed to provide an acoustically appealing experience for each occupant.

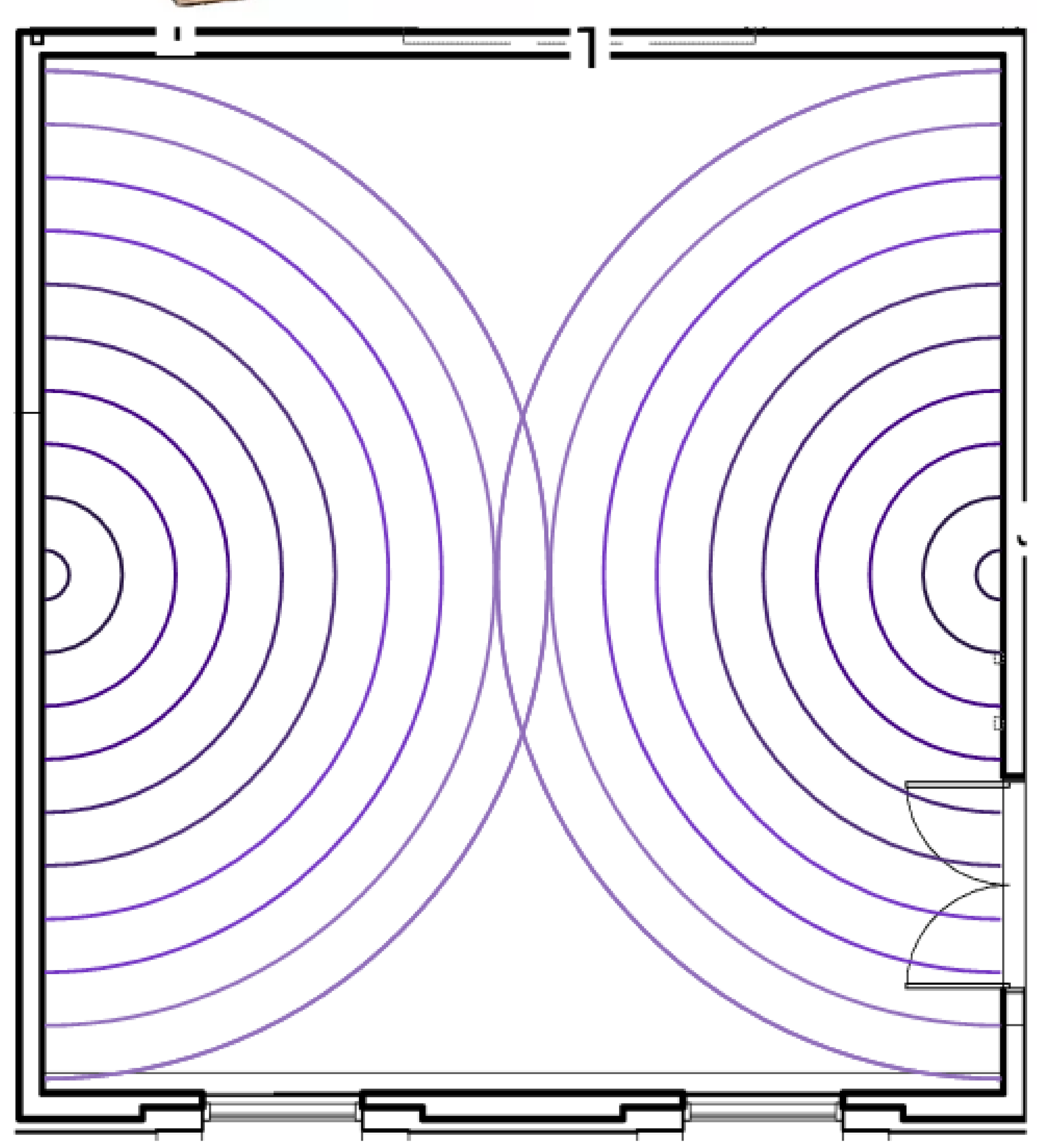


4 TYPICAL FACULTY STUDIO OCTAVE ISO LINES



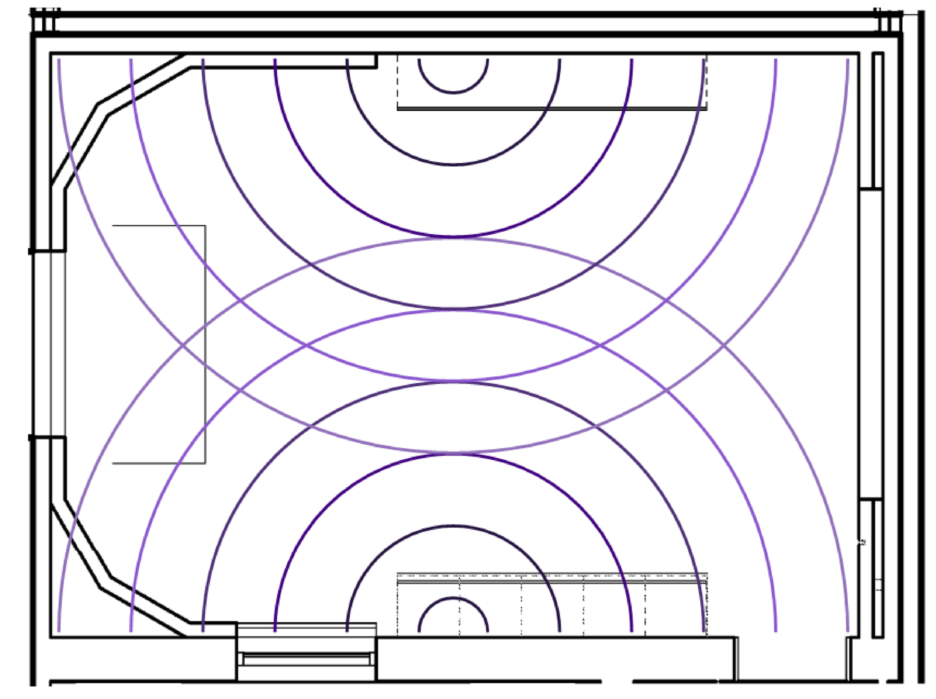
FREQUENCY CALCULATION			
$v = \frac{V(speed\ of\ sound)}{X(room\ length)}(2)(2)$			
TYP. ROOM	LENGTH (m)	WIDTH (m)	FREQUENCY (Hz)
FACULTY STUDIO	4.5	5.1	306
CLASSROOM	6.3	8.6	219
PRACTICE ROOM	3	2.8	492
REHEARSAL	16.3	13	106
ORGAN STUDIO	10	9.3	148
RECORDING	6.3	8.6	219

OCTAVE RANGES FOR PANELS (Hz)							
FACULTY STUDIO	306	612	1224	2448	4896	9792	19584
CLASSROOM	219	438	876	1752	3504	7008	14016
PRACTICE ROOM	492	984	1968	3936	7872	15744	31488
REHEARSAL	106	212	424	848	1696	3392	6784
ORGAN STUDIO	148	296	592	1184	2368	4736	9472
RECORDING	219	438	876	1752	3504	7008	14016

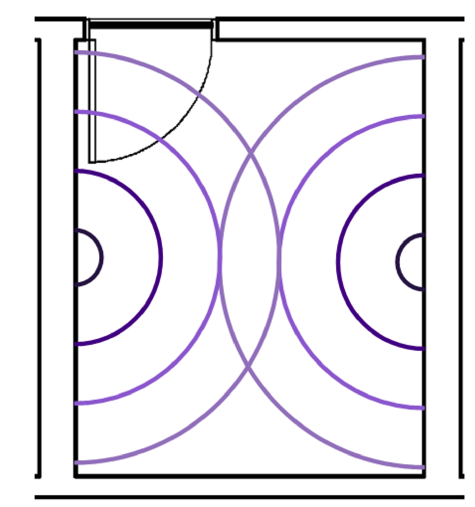


5 TYPICAL ORGAN STUDIO OCTAVE ISO LINES

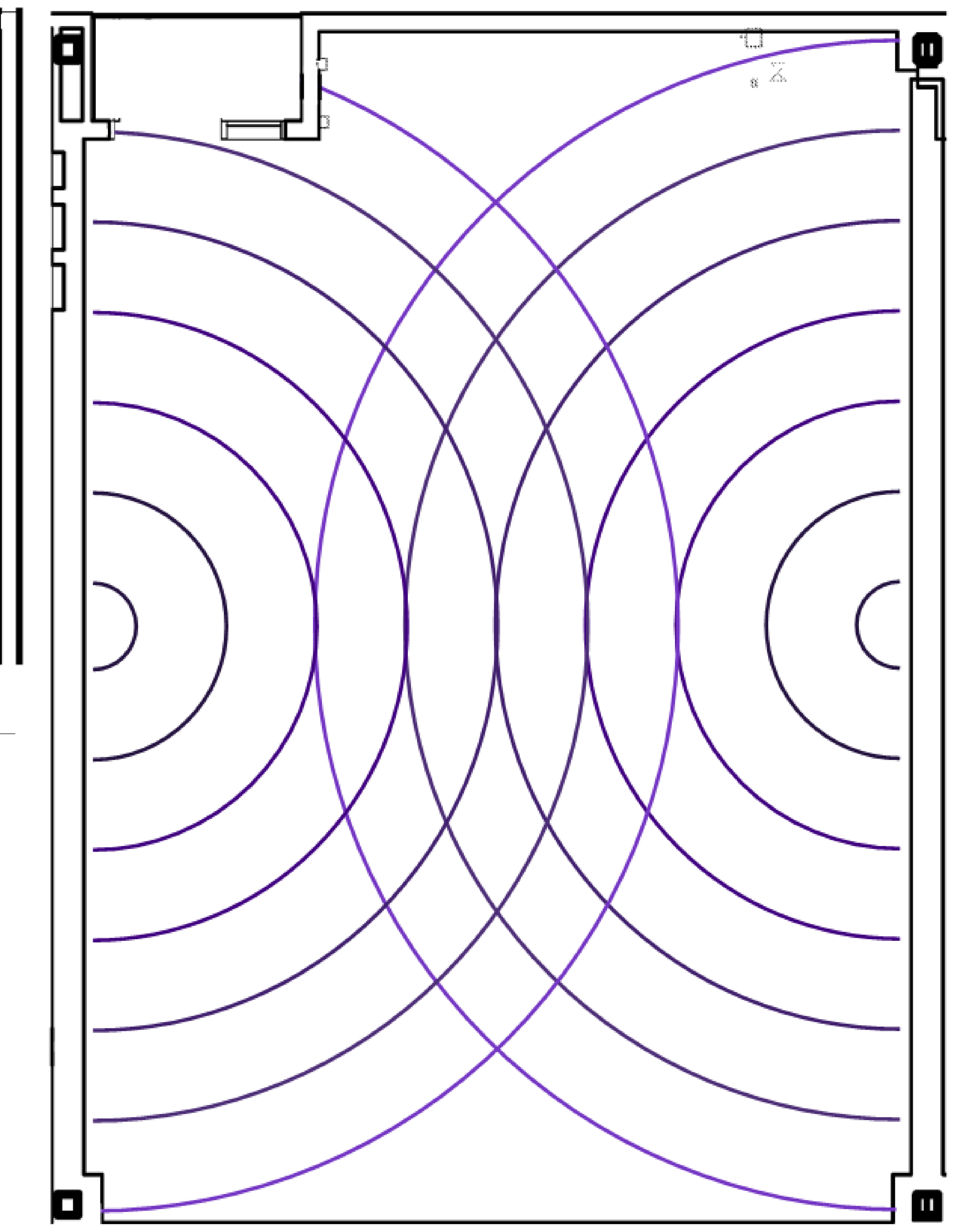
In order to conform to each of the room types and sizes, calculations were made to find the frequencies each room would experience when music is played. Each QRD is designed in accordance with the dimensions of the room to account for the sound waves that bounce from parallel walls. The calculations are done using the walls that are the shortest distance from each other in each room. This is because vibration will occur on these walls first when music is played. Atune wanted to make sure that the panels had a maximum eight inch column depth to reduce the amount of volume taken in the room. This objective was met by increasing the three octaves from the lowest to highest frequency for the sizing calculations.



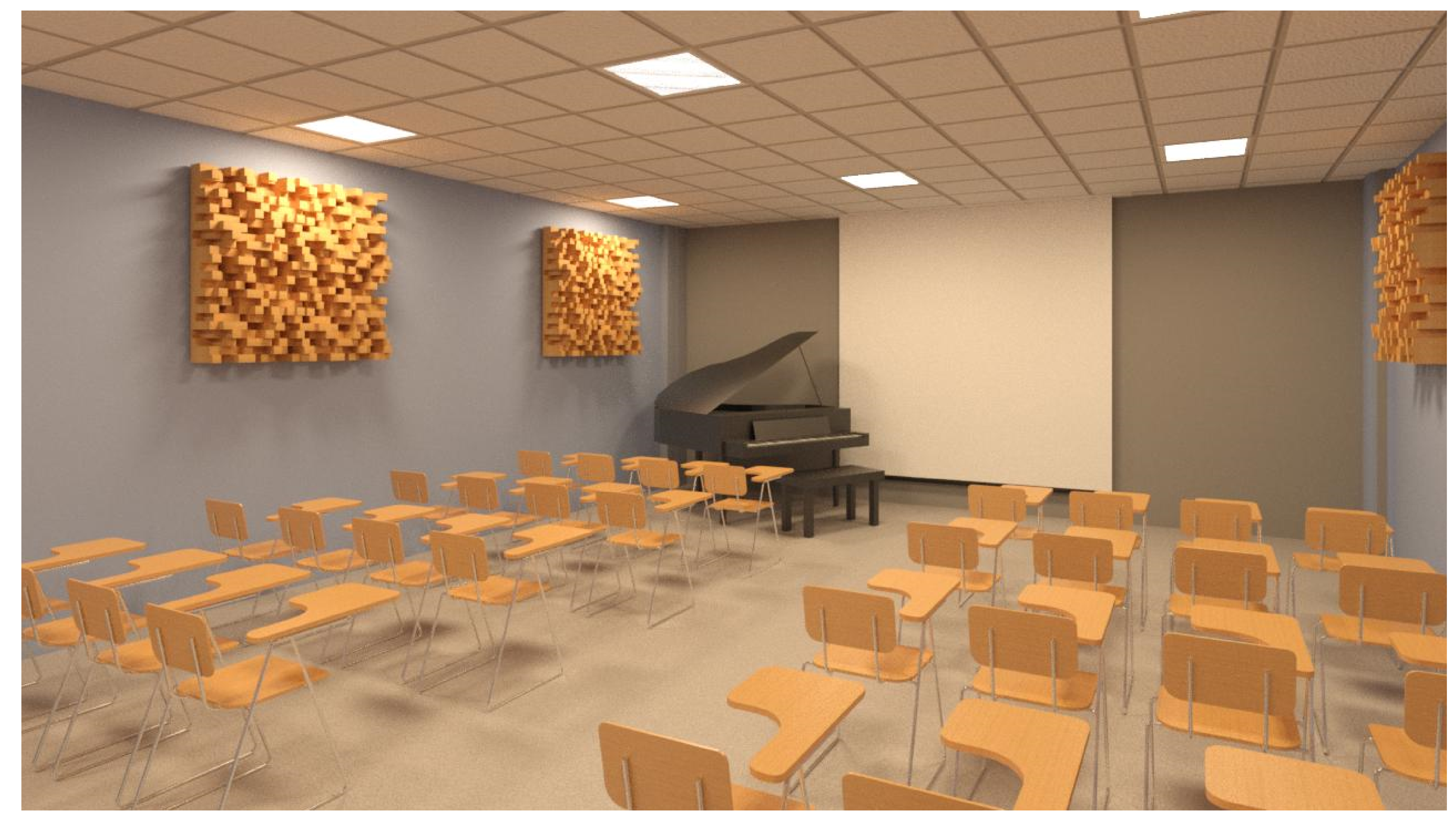
2 TYPICAL RECORDING SPACE OCTAVE ISO LINES

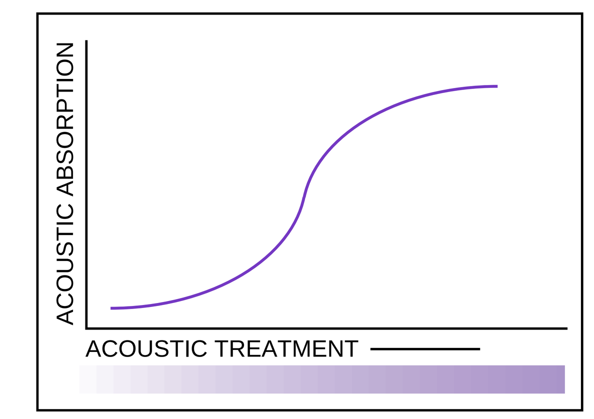


6 TYPICAL PRACTICE ROOM OCTAVE ISO LINES



3 TYPICAL CLASSROOM SPACE OCTAVE ISO LINES





Application is very important when it comes to the amount of coverage in a room. The type of space relies on the preference of the user. Therefore each room will have a distinct spacing criteria that will depend on the conversation with faculty and maintenance.

0	3	4	1	2	3	3	1	4	2	3	3
3	0	1	4	2	1	1	3	3	2	1	1
3	1	1	3	1	3	2	2	1	0	2	2
2	2	2	2	0	4	3	2	3	2	1	1
3	3	1	1	3	1	1	3	4	3	1	3
2	3	2	1	2	0	3	2	4	2	1	0
2	3	2	1	3	1	2	2	3	1	3	4
2	0	2	4	4	0	1	2	1	4	2	2
3	4	1	0	1	3	3	1	0	2	3	3
1	3	3	1	2	4	1	2	0	1	3	1
2	1	2	3	1	3	3	2	4	2	3	4
2	4	2	3	3	1	1	2	0	3	1	0

This formation is used for each of the panel designs for the different room types. By referencing the Acoustic Panel Design table, visualizing the difference in QRD between the rooms becomes more apparent. The layout is used across most design of QRD for optimal function. Deeper columns allow for lower frequencies, which means that the more column sizes that are used results in a larger frequency range.

ACOUSTIC PANEL DESIGN										
TYP. ROOM	FREQUENCY (Hz)		PANEL DIMENSIONS	COLUMN DIMENSIONS						TOTAL LENGTH NEEDED (in)
				COLUMN WIDTH (in)	COLUMN LENGTH (in)					
	LOW	HIGH	SQUARE (in)		0	1	2	3	4	
FACULTY STUDIO	1224	9792	8 1/4	3/4	0	1 3/8	2 3/4	4 1/8	5 1/2	13 7/8
CLASSROOM	876	7008	11 5/8	1	0	2	3 7/8	5 3/4	7 3/4	19 3/8
PRACTICE ROOM	984	7872	10 3/8	7/8	0	1 6/8	3 4/8	5 1/8	6 7/8	17 1/4
REHEARSAL	848	6784	12	1	0	2	4	6	8	20
ORGAN STUDIO	1184	9472	8 5/8	3/4	0	1 3/8	2 7/8	4 1/4	5 3/4	14 1/4
RECORDING	876	7008	11 5/8	1	0	2	3 7/8	5 3/4	7 3/4	19 3/8

ATUNE

Jack H. Miller Center for Musical Arts

Acoustics

AEI Team No.	7-2019
Date	02/18/2019
Scale	NO SCALE

I3.3

TIMBER CONSTRUCTION

The main goal for the Atune structural team was to supersede the 25% timber construction, that was set forth by Hope College. Atune has surpassed the 25% as well as the 80% internal goal set by the structural team. Through coordination with the rest of the team, Atune's structural team has created a 90% timber and engineered wood structural system for the Jack H. Miller Center for Musical Arts.

To continue to strive towards Hope College's goal for sustainability, Atune's structural and construction team have worked to ensure that all of the wood products used in the Jack H. Miller Center for the Musical Arts are Forest Stewardship Council approved.

CO_2 REDUCTION

By utilizing 90% timber in the structural systems, Atune's team has achieved a substantial effort towards the goal of sustainability. Through the CLT walls, composite floor system, glulam columns, timber trusses and LVL partition wall studs, the Jack H. Miller Center for Musical Arts uses approximately 104,000 cubic feet of wood products.

The components of the structural systems store 2643 metric tons of CO_2 which is the equivalent of 775 cars of the road for a year and 387 homes powered for a year. Between the U.S. and Canadian forests, the timber used in the Jack H. Miller Center for Musical Arts could be cumulatively replenished in 8 minutes.

Results

Volume of wood products used (m^3):
2940 m^3 (103819 ft^3) of lumber and sheathing

U.S. and Canadians forests grow this much wood in:
8 minutes

Carbon stored in the wood:
2643 metric tons of CO_2

Avoided greenhouse gas emissions:
1023 metric tons of CO_2

Total potential carbon benefit:
3666 metric tons of CO_2

Equivalent to:

775 cars off the road for a year

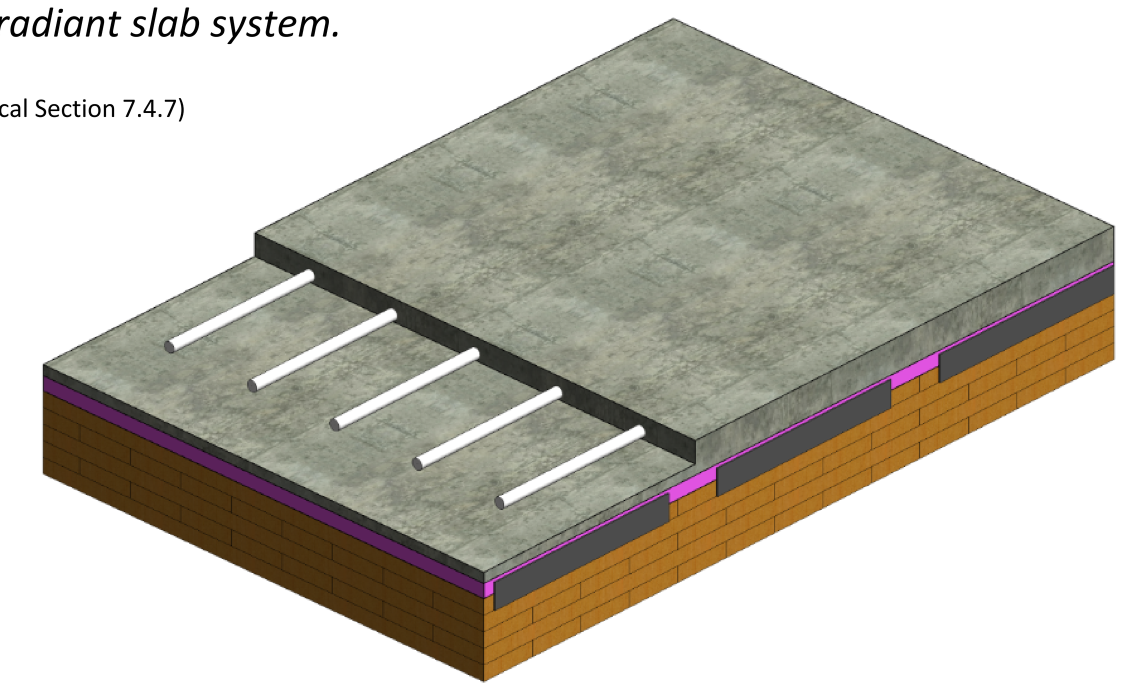
Energy to operate **387** homes for a year

IPD INTEGRATION FOR TIMBER DESIGN

MECHANICAL - STRUCTURAL INTEGRATION

Radiant Slab System
The radiant slab aids in decreasing the amount of snow melt that is sitting on the roof. The water collection is used as greywater throughout the building. The below graphic shows a detail of the radiant slab system.

(Refer to Mechanical Section 7.4.7)



MECHANICAL - STRUCTURAL INTEGRATION

DOAS System
Humidity is being controlled through the DOAS systems being used by the mechanical design. Humidity control was key for the long-term success of the timber structural system, especially in Holland, MI.

(Refer to Mechanical Section 7.4.3)

CONSTRUCTION - STRUCTURAL INTEGRATION

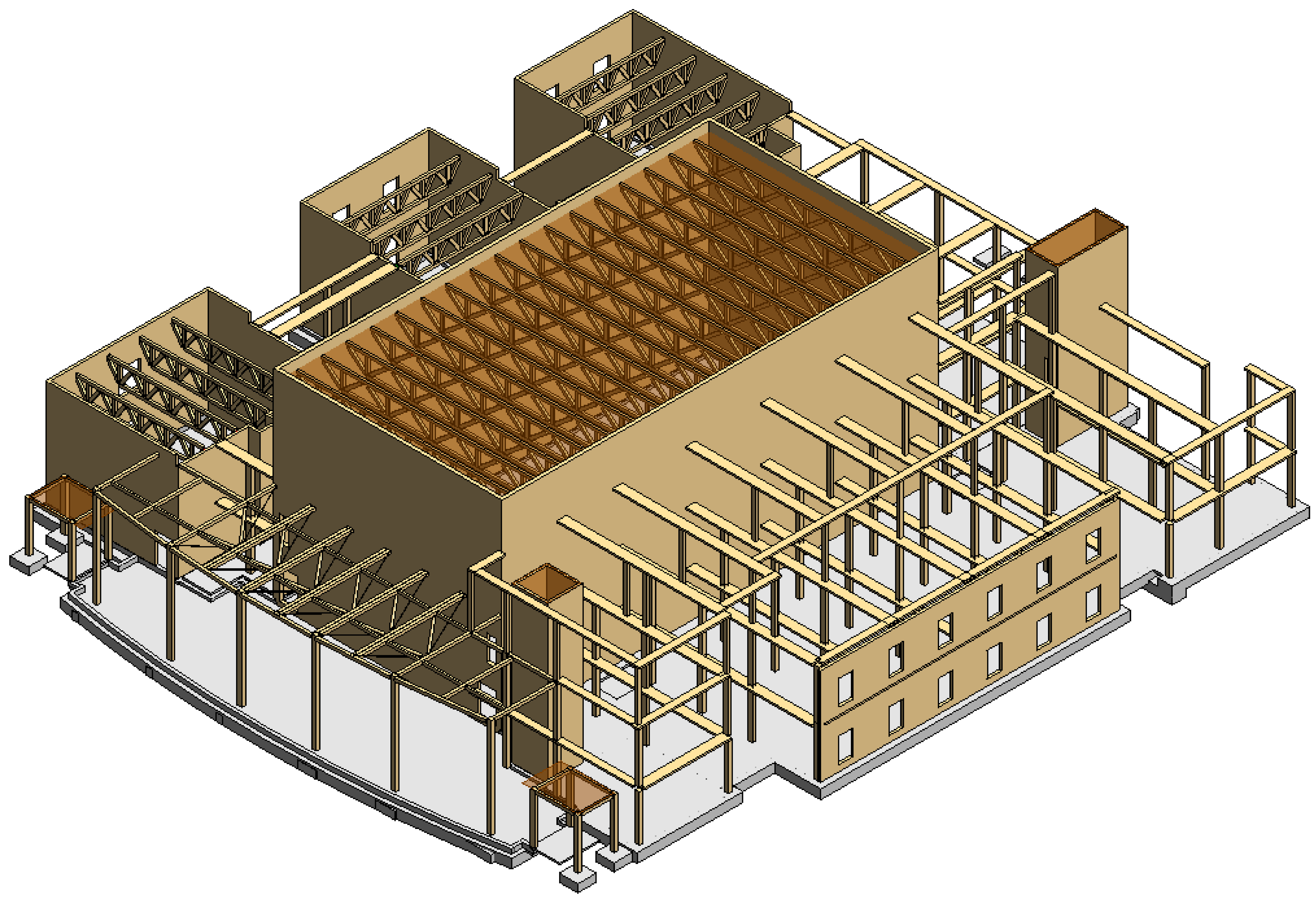
Prefabrication of CLT Panels
Managing weather protection prior to building dry-in is critical for uncompromised structural members

(Refer to Construction Section 7.3)

CONSTRUCTION - STRUCTURAL INTEGRATION

Capacity of the Crane
The CLT panels were the driving factor in determining the tonnage capability of the crane

(Refer to Construction Section 7.2)



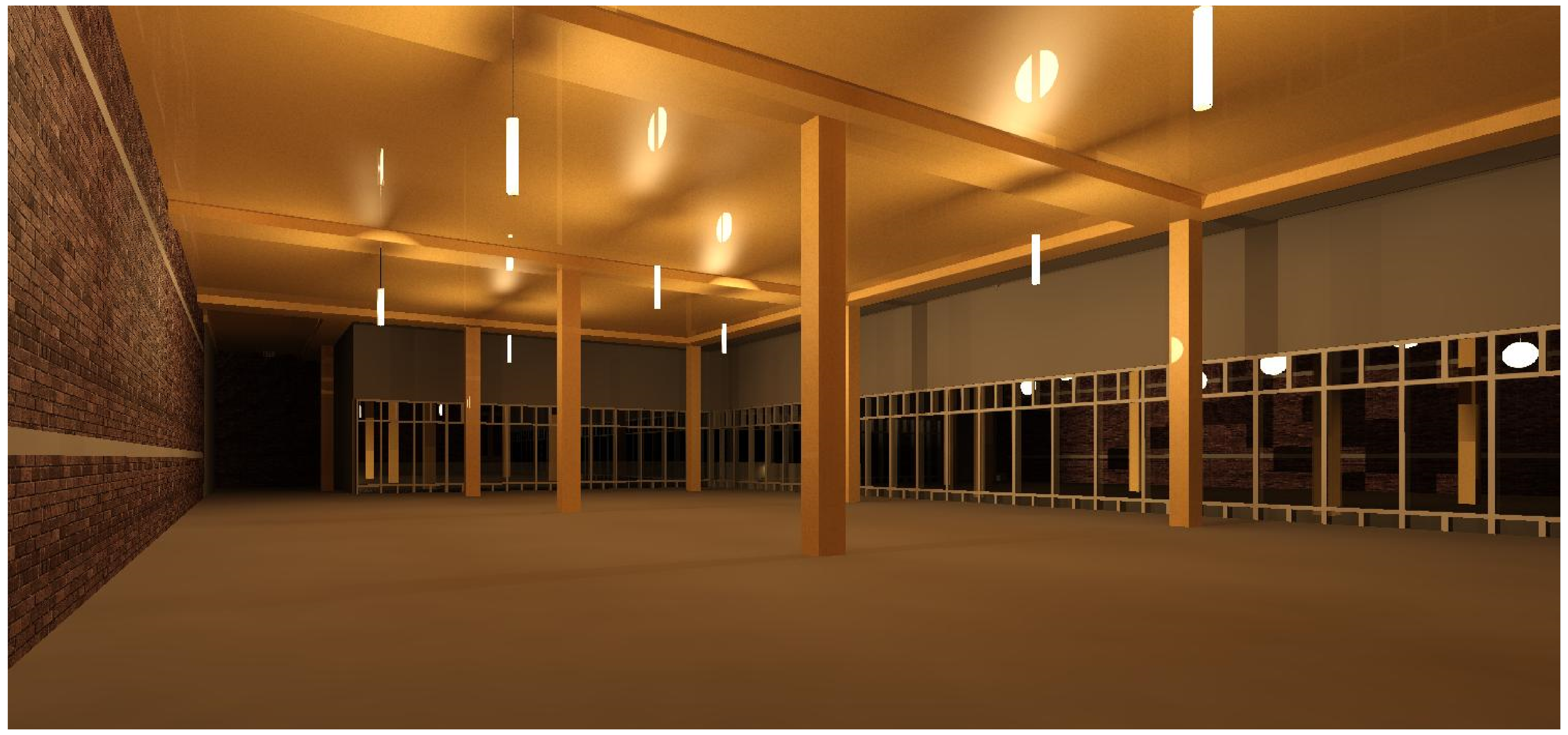
ATUNE

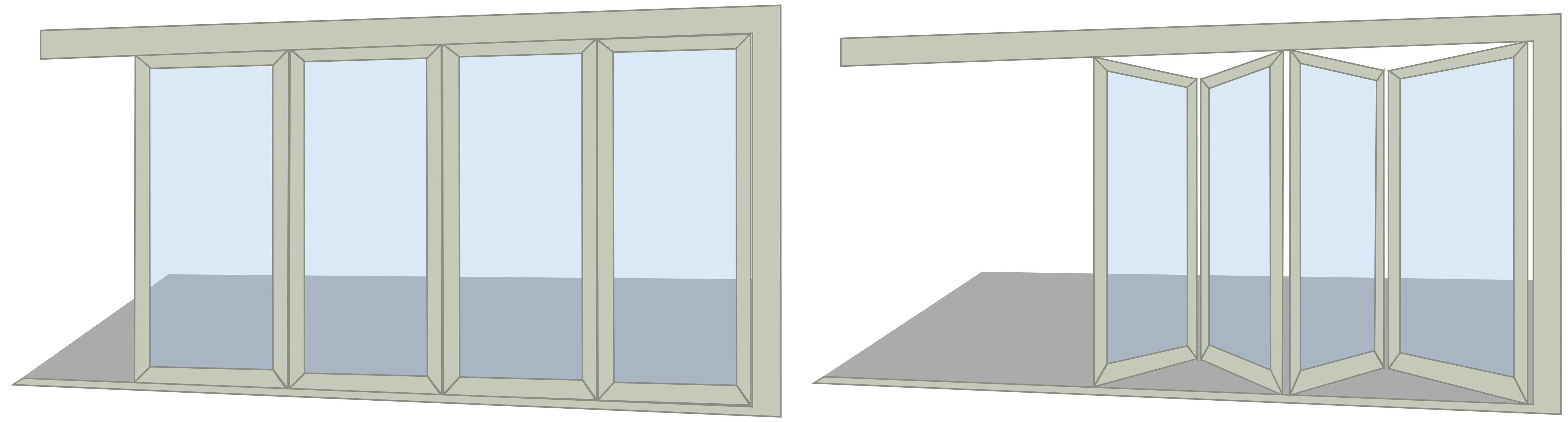
Jack H. Miller Center for Musical Arts

Timber Integration

AEI Team No.	7-2019
Date	02/18/2019
Scale	NO SCALE

I3.4





ACCORDION ENCLOSURE WALLS & CONTSTRUCTABILITY

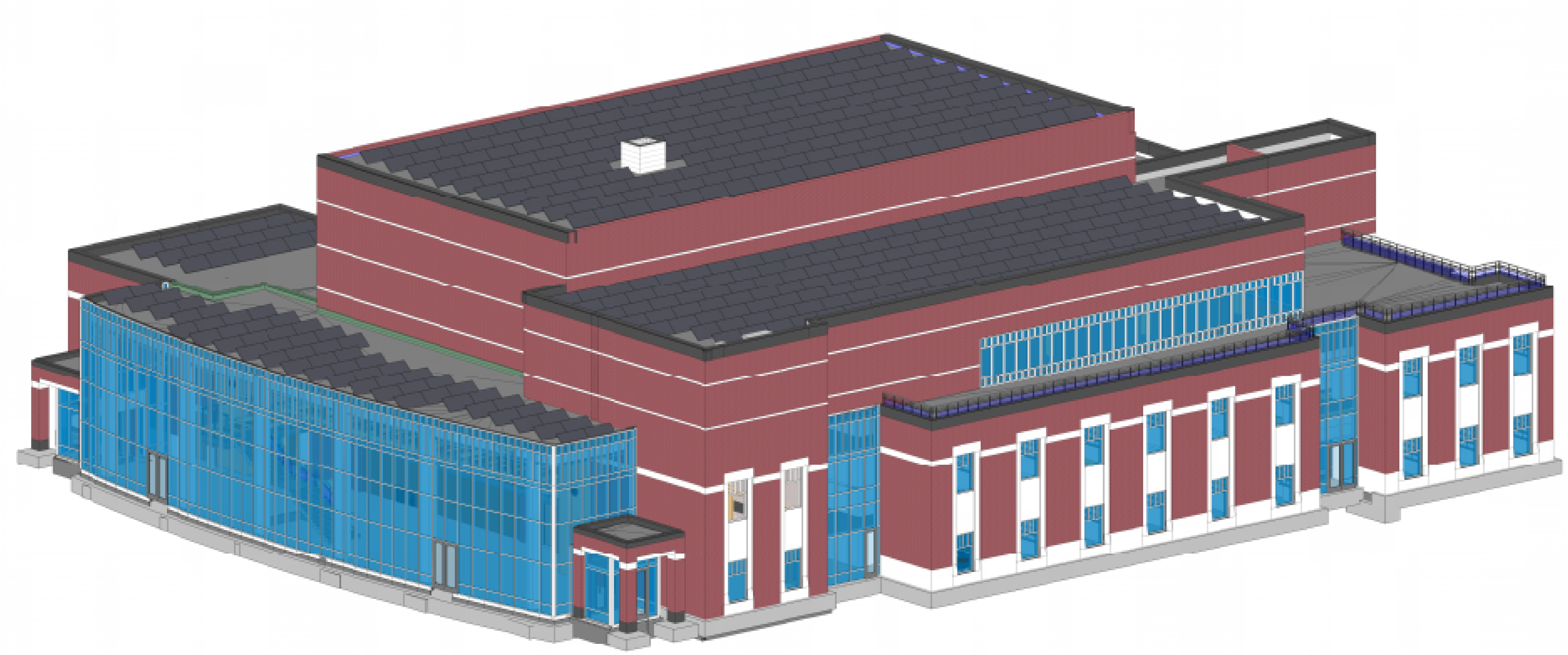
The construction team is anticipating improved safety and reduced risk when it comes to the shipping and delivery of the accordion wall. The modular nature of the wall allows it to be shipped in a more compact package which will greatly reduce the risk of breaking panels in transit.

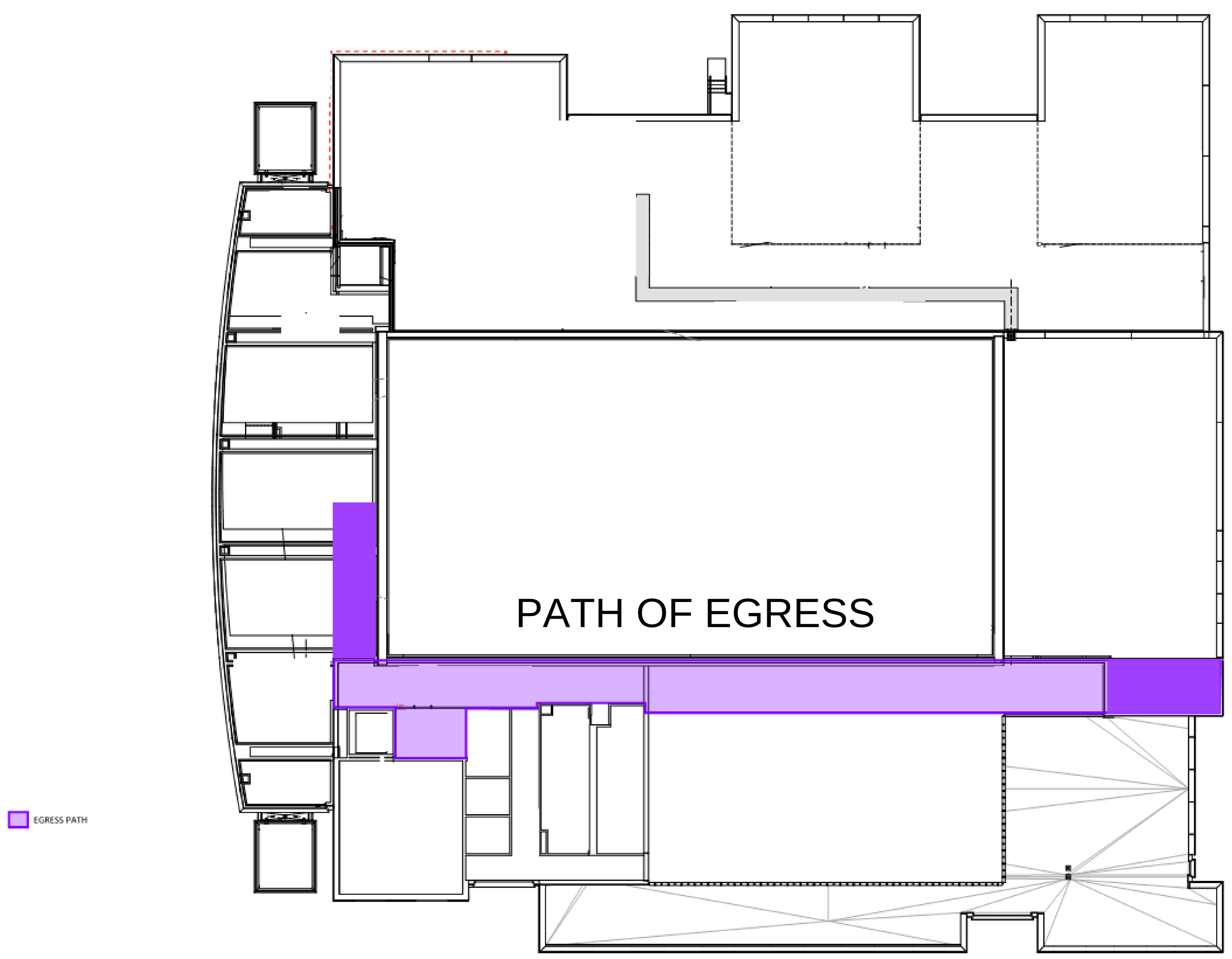
ROOFTOP AMENITY DESIGN

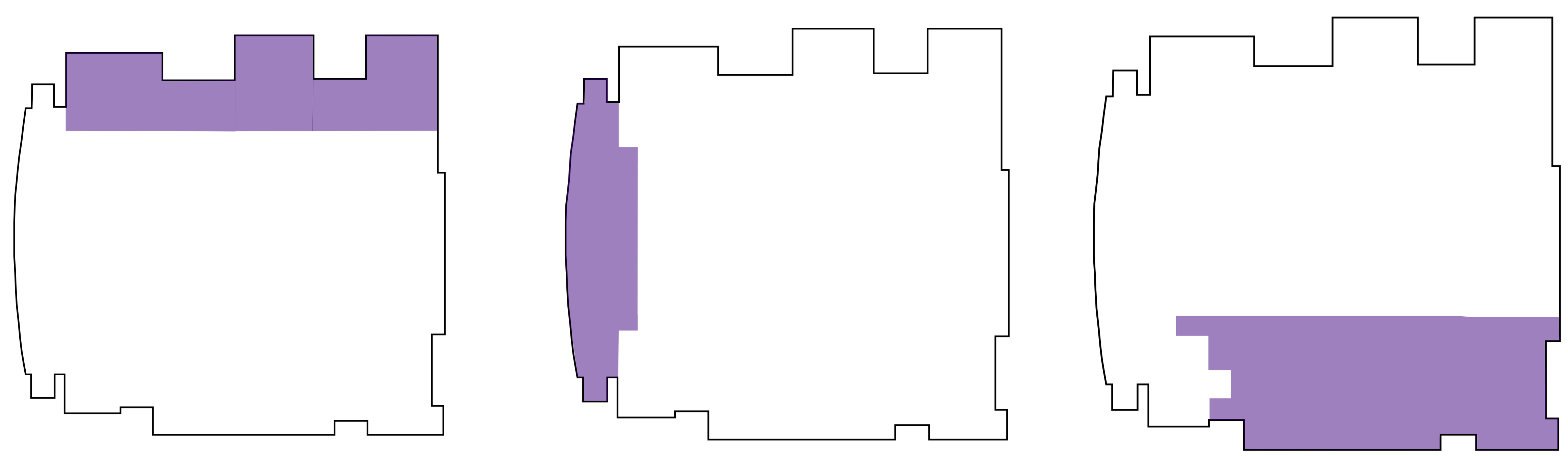
The open floor plan of the rooftop amenity space will allow for a variety of uses both indoors and outdoors for Hope College and the community. It provides the ability to host over 100 people with adequate spaces, restroom requirements, and egress requirements. In addition, the support spaces provided include Catering, Janitor, Elec, Storage, Restrooms, Elevators and 2 Stairs.

This outdoor space was still considered with occupant safety in mind. As can be seen in the figure to the right, a glass railing/parapet is being implemented to allow an open, safe space to the occupants.

The cost to include the amenity space would be an additional $925,000 for Hope College, however the space will provide a return on investment as the college hosts events for various organizations and community members.







AMENITY SPACE LOCATION SELECTION

The three graphics above display the possible roof areas considered for the rooftop amenity space. The south location was decided after multiple design iterations involving the entire Atune team. This location choice provides the ability to egress the rooftop space per life safety standards, and additionally will not distract from the front building facade.

ATUNE

Jack H. Miller Center for Musical Arts

ROOFTOP AMENITY DESIGN

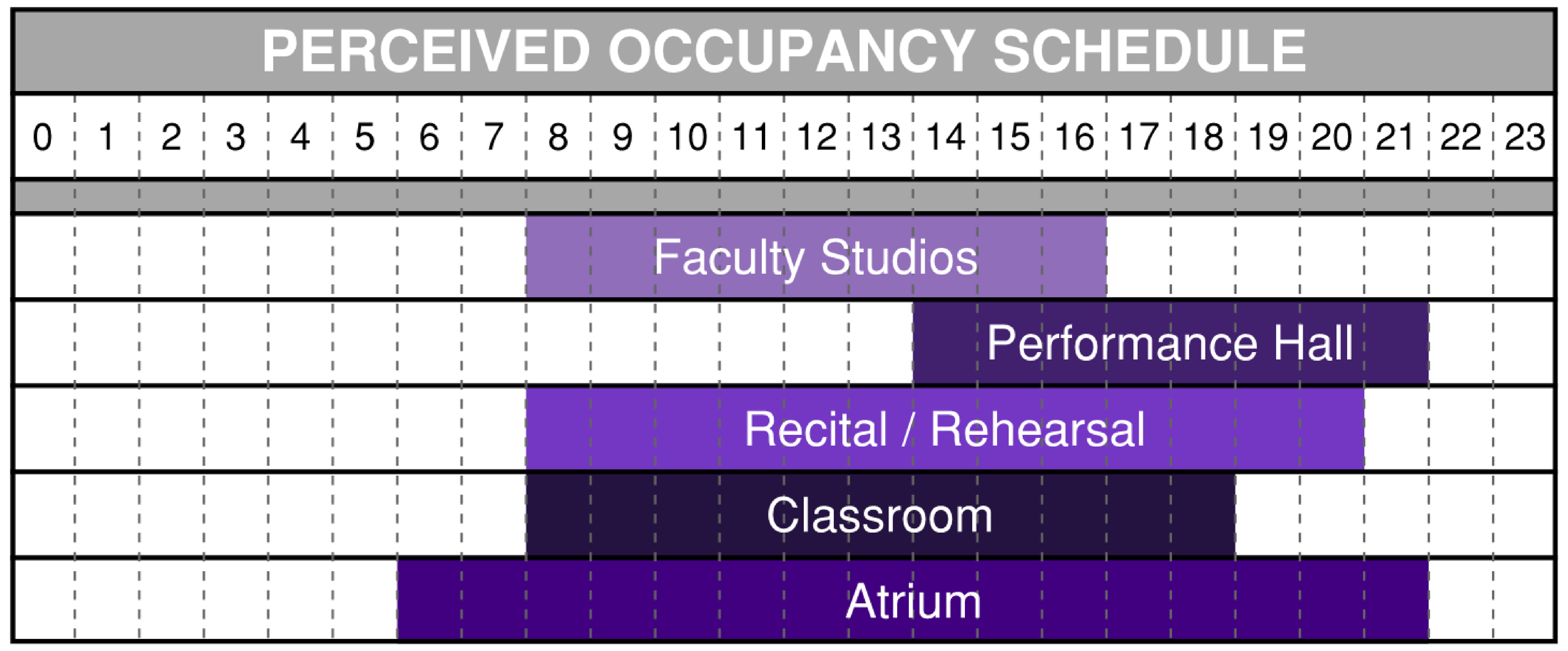
AEI Team No.	7-2019
Date	02/18/2019
Scale	

I3.5

ROOM SCHEDULERS

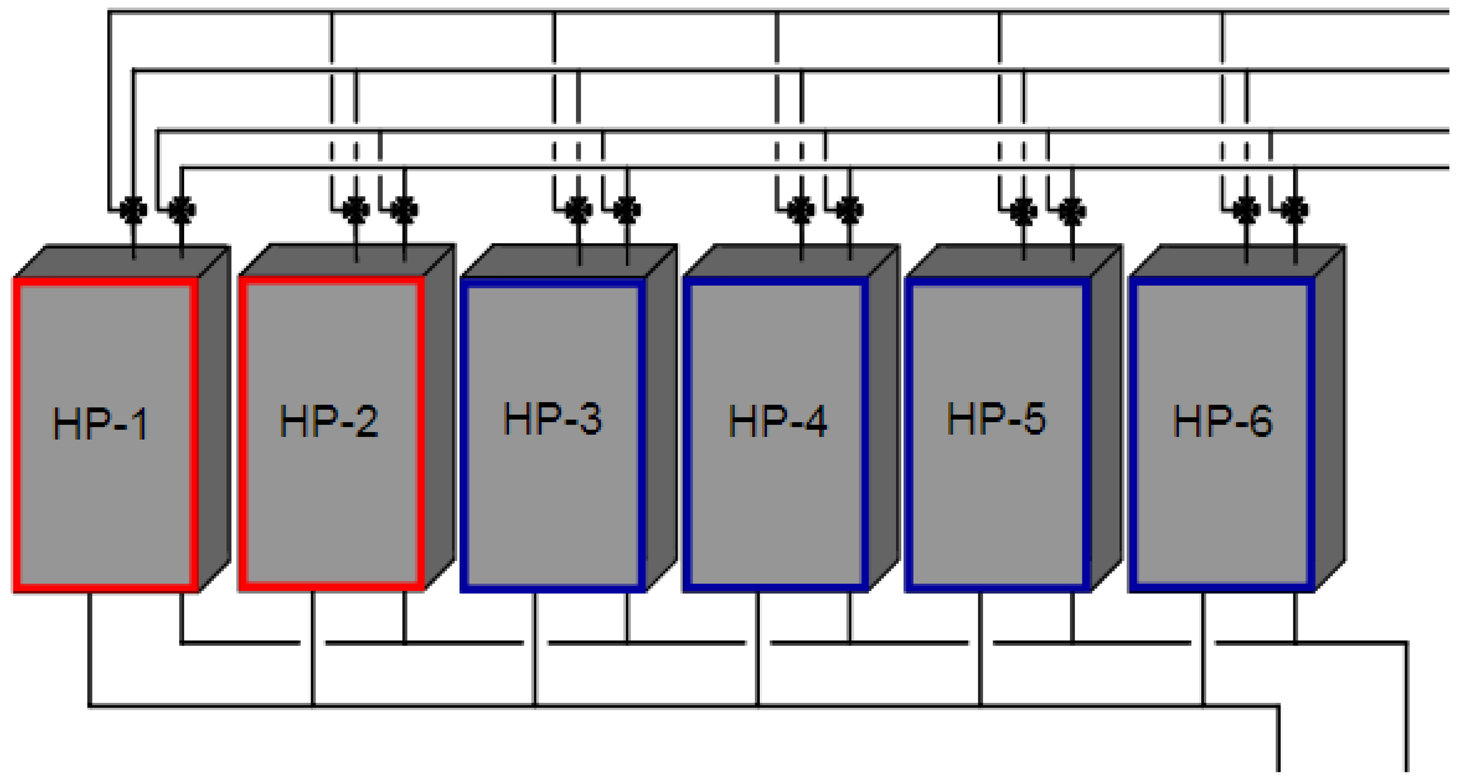
Atune understood the hectic and ever-changing schedules that result from a college campus atmosphere; even more so for a college building with 127 rehearsals and performances anticipated on a yearly basis. In order to address the busy schedules, Atune proposes a design solution to aid in the organization and scheduling of room functions. All rooms will have a 7" digital room scheduler located outside that will display the information relevant to the room's use and serve as an emergency notification device. Following is an example of what the room schedulers will look like.

Initially, the room schedulers will work with the Perceived Occupancy Schedule to assist in the conditioning of spaces, prior to occupancy. After a regular schedule is determined, the Watson Building Automation System will use the room occupancy sensors to continuously update the online room schedule. The Watson BAS will compare room schedule to inactivity in the room. If inactivity is detected during the first five minutes of the scheduled time, Watson will cancel the reservation allowing others to reserve the room instantly. Watson will also continuously look at scheduled time and alert any occupant who is trying to reserve a room that conflicts with already existing room schedules. In the meantime an output to the corresponding ventilation air VAV box will enable a reduction in DOAS usage, saving energy.



WATER TO WATER HEAT PUMPS

Heating and cooling are both possible in one water to water heat pump via the integral refrigeration cycle reversing valve. When implemented with multiple heat pumps, a flexible system for producing heating and chilled water for a multitude of hydronic and radiant elements. The hydronic infrastructure prescribed for the Jack H. Miller Center for Musical Arts can be easily modified in the future should the building program shift.

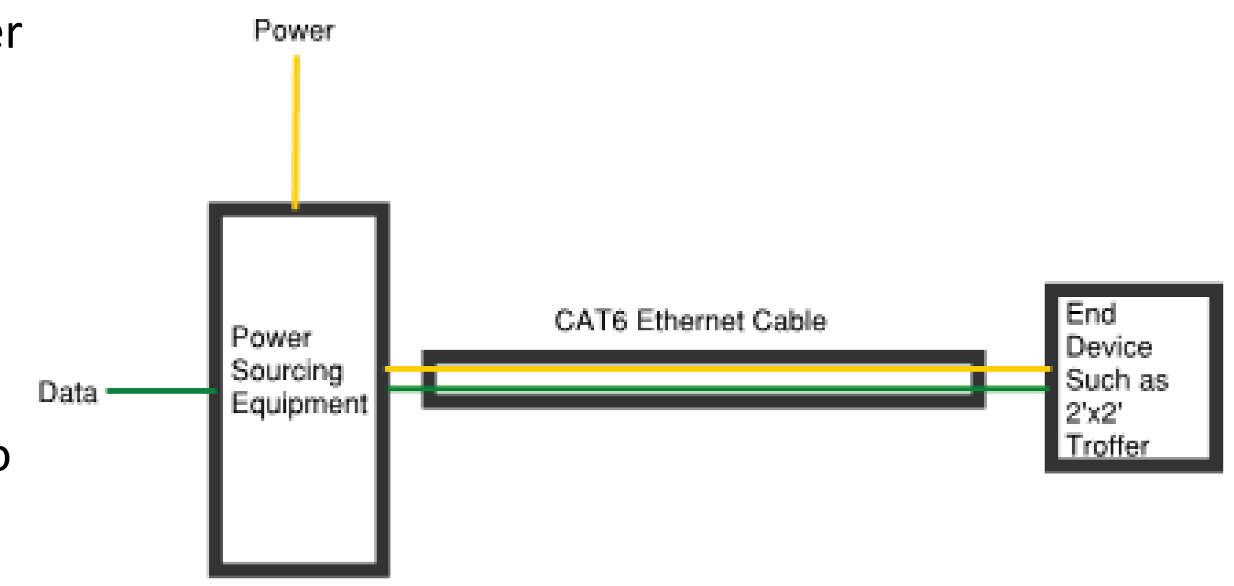


ZIPPER TRUSS

The Atune team implemented a multi-purpose zipper truss in the building atrium. The truss system supports a large dead load from the above roof while also suspending the walkway and stairs below. The trusses' ability to support the walkway was vital in keeping the atrium an open circulation space. The primarily wood system doubles as an architectural piece as well as an educational component. The zipper truss is a focal point that the electrical team highlights through their lighting design for the purpose of education. The lighting design shadows the zipper truss by using recessed cans in the bottom of the structure.

POWER OVER ETHERNET (PoE) LIGHTING

Atune decided to implement the PoE system in order increase the versatility of the building as a whole. This innovative system reduces the constraints that typical conduit runs might have, which limit the clashes that would inevitably occur between the systems that the mechanical and structural designers have chosen. This system, which combines power and data, provides the capability to adapt to unpredicted future uses, as any university building might require. The intuitive plug and play mechanism of the system also allows for the interchanging of lighting schemes throughout the building.



ATUNE

Jack H. Miller Center for Musical Arts

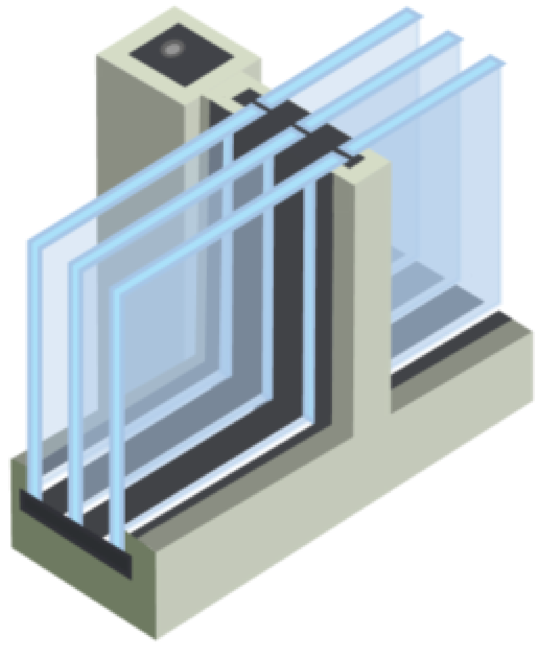
VERSATILITY

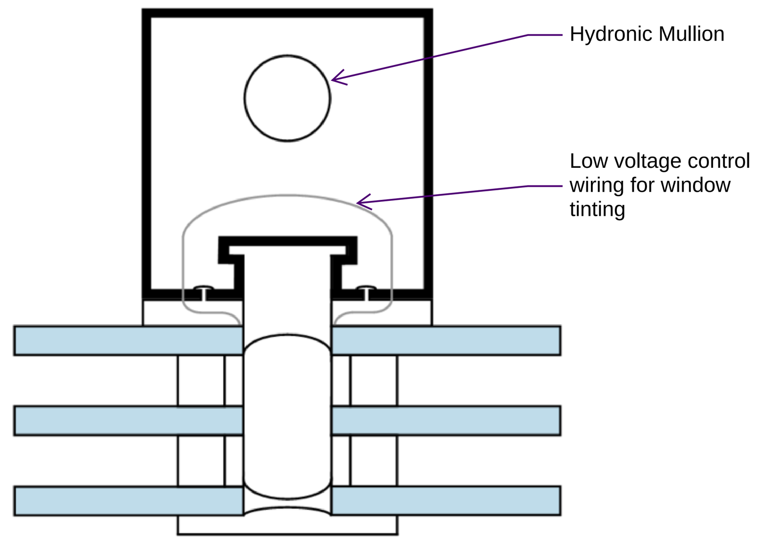
AEI Team No.	7
Date	
Scale	

I3.6

DYNAMIC VIEW GLASS

Dynamic View Glass was implemented on the western facing facade in the atrium. The purpose of implementing view glass was to reduce the solar heat gain in the atrium during cooling season. The three-pane-glass has 4 tint settings, pictured below. The use of view glass reduced the solar load by 49%. Additionally, hydronic mullions routed in the curtain wall helps to reduce heating and cooling loads. The pictures on the right graphically display the arrangement of these two unique technologies that required integration between each discipline.





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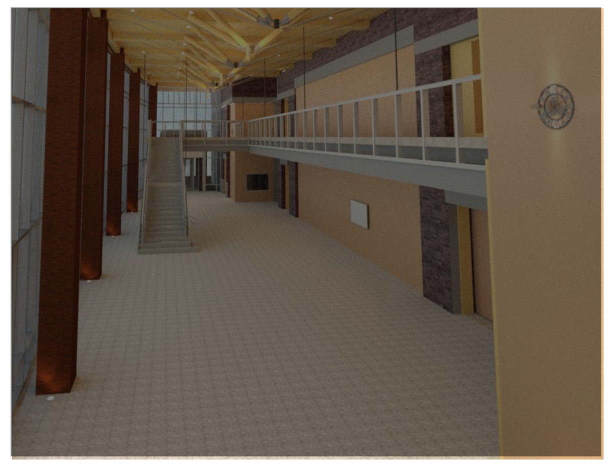

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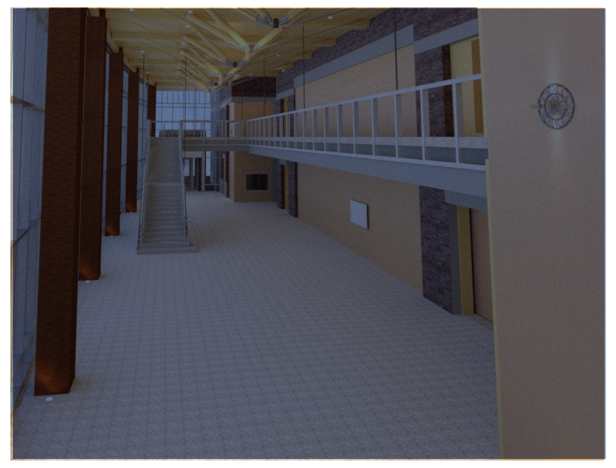
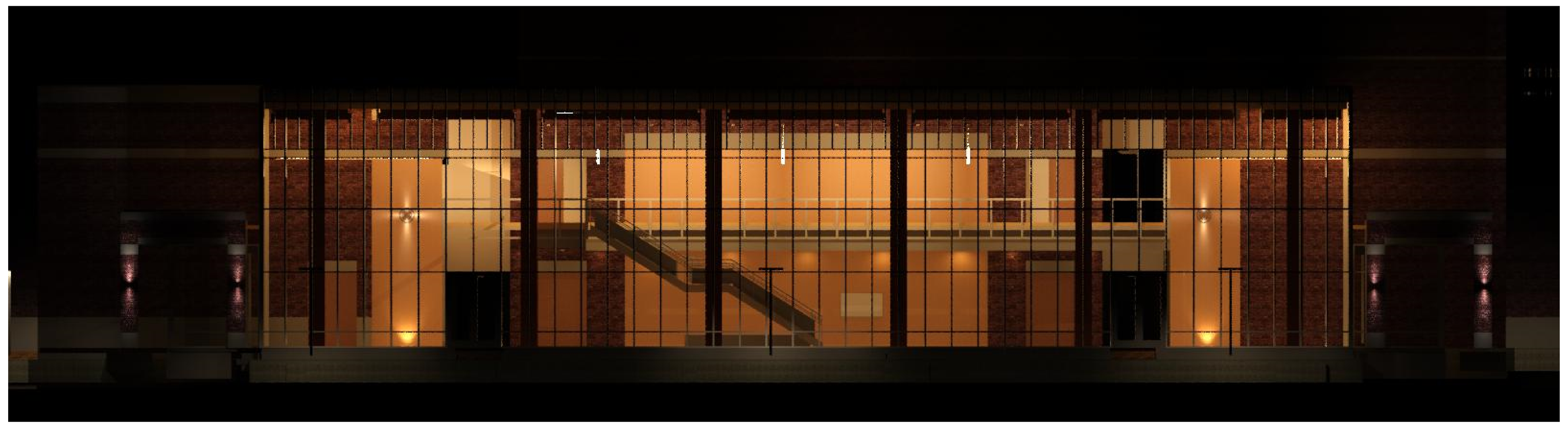
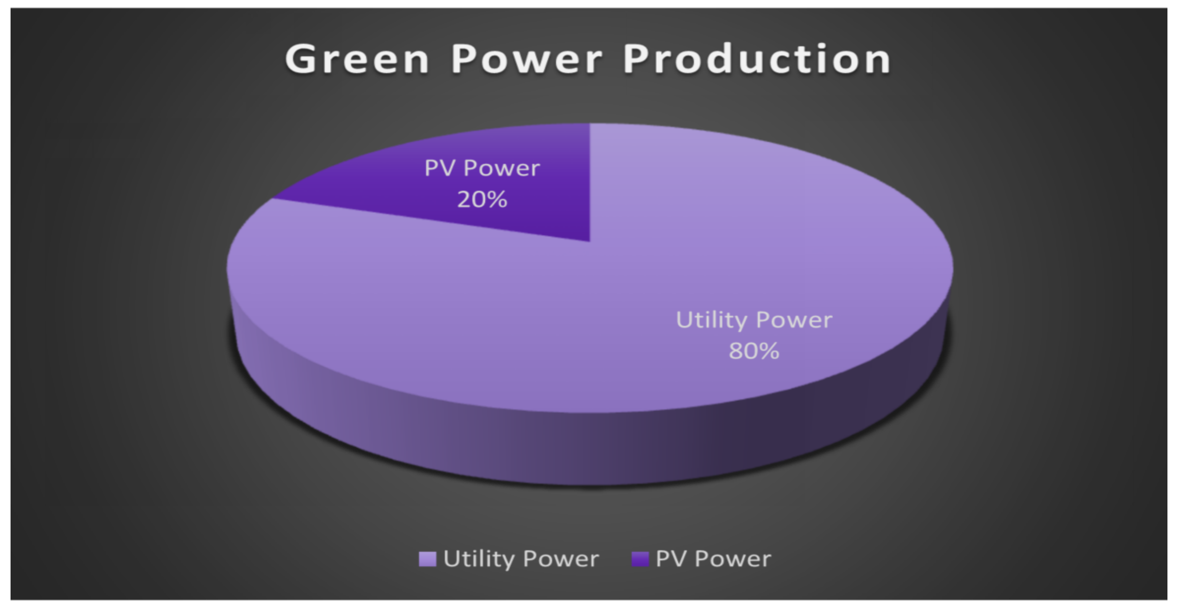
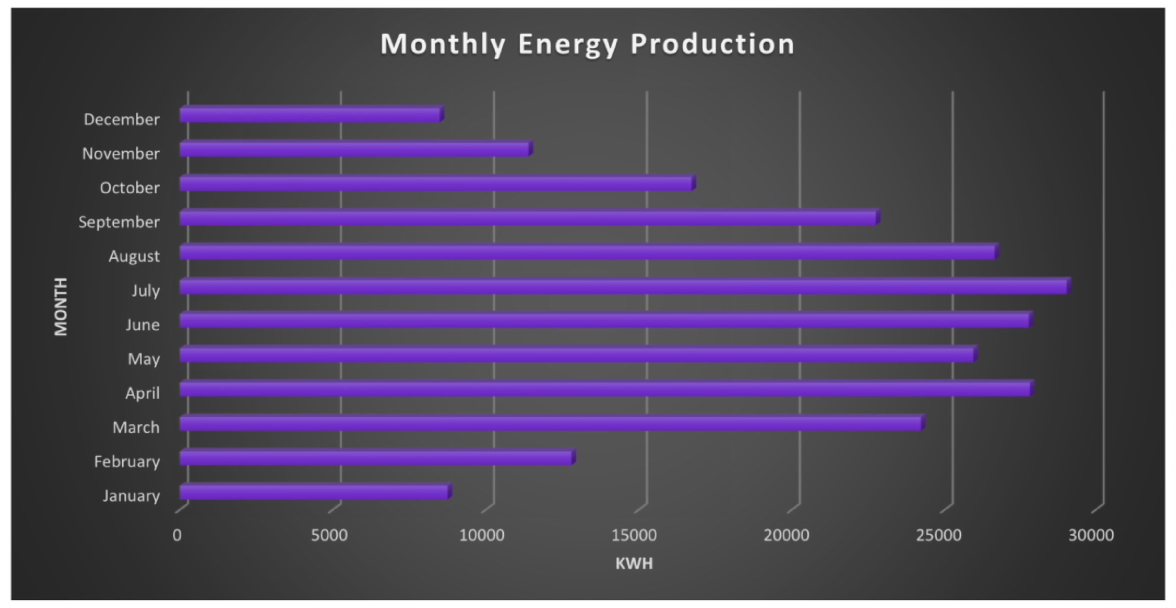


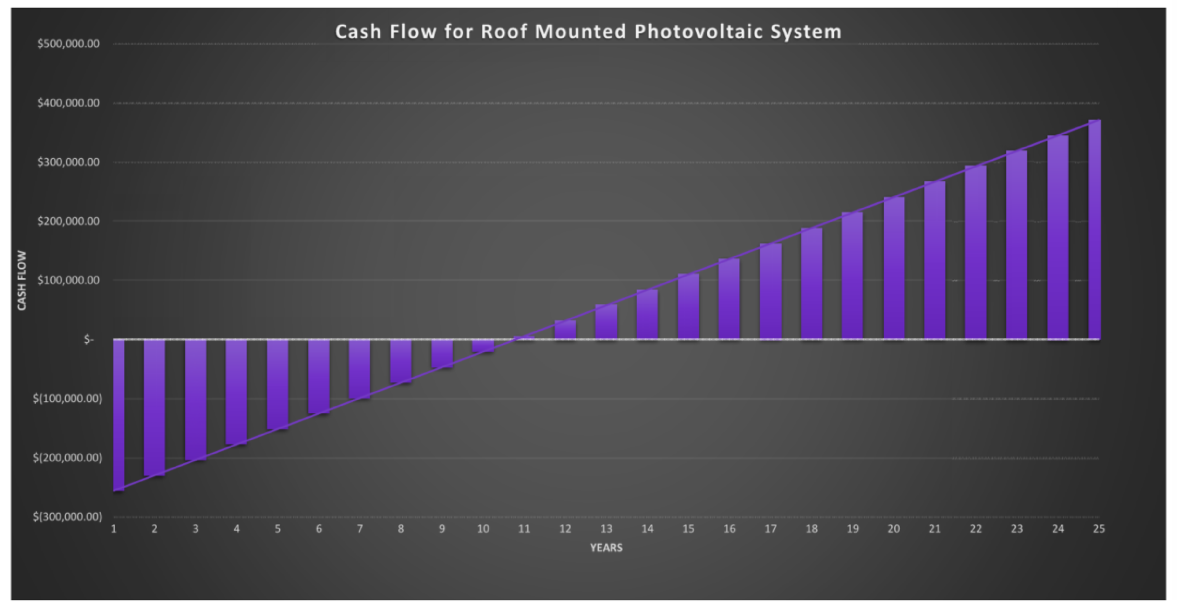


LIGHT POLLUTION

Atune lighting designers used 2800-3000 CCT layered light to create dynamic lighting that attracts occupants to enter the Jack H. Miller Center for Musical Arts. The use of warm light sources in the interior gives the building a welcoming feeling. The cooler 4000-4500 CCT luminaires on the exterior enabled the use of mesopic multipliers to lower recommended illumination levels and ultimately reducing light pollution to nearby spaces. Less than five percent of the total delivered lumens by exterior luminaires are higher than 90 degrees to the horizontal plane. This design choice was made to raise awareness to light pollution of dark skies.

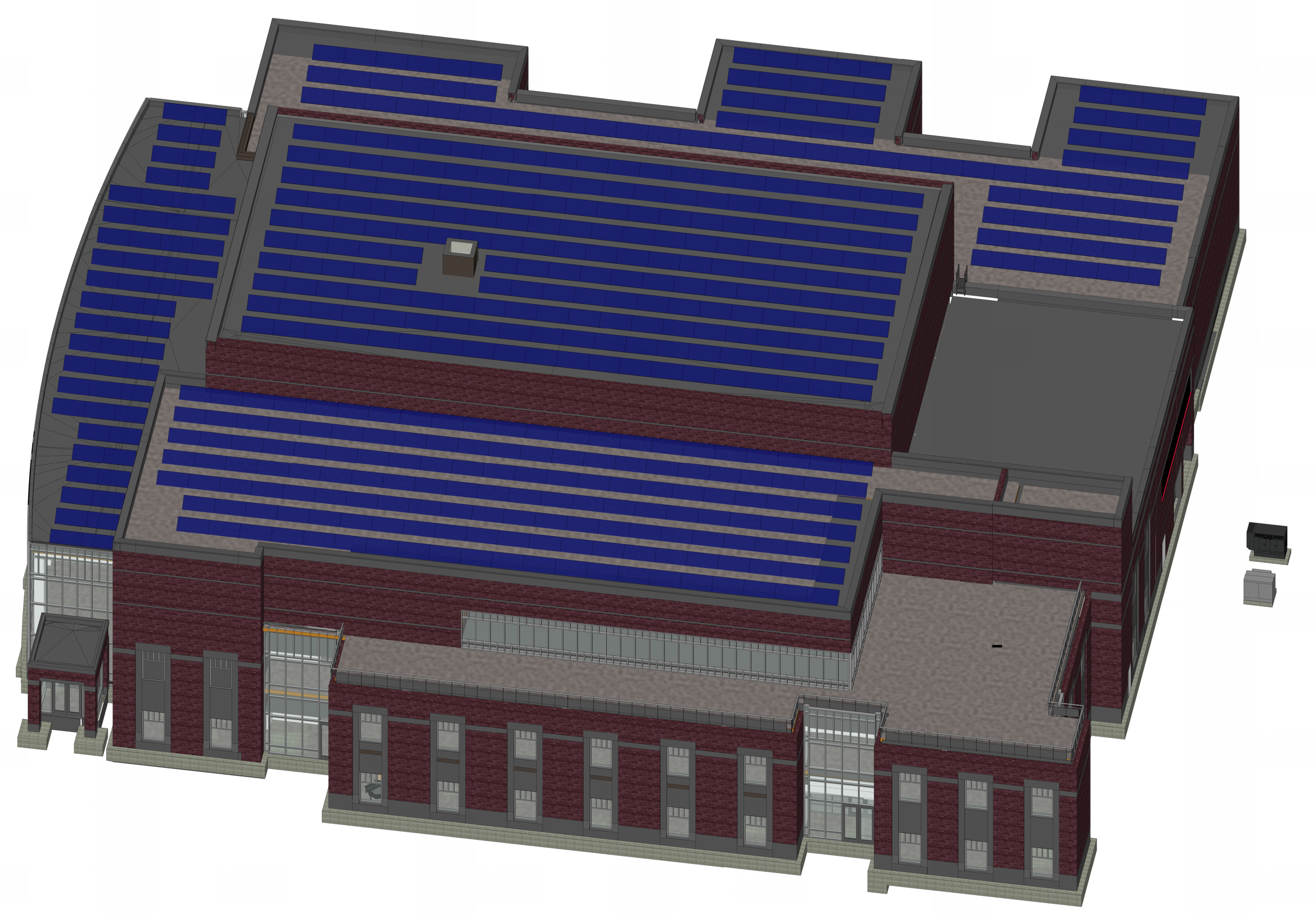






PHOTOVOLTAIC POWER GENERATION

Working with the rest of the design team, Atune's electrical designers conducted research to see if solar panels would be a wise implementation for the project. The electrical team found that Michigan has been steadily increasing the use of solar panels throughout the state. This is due largely to recent increases in solar panel technology, allowing them to capture nearly 20% of the radiated energy. As demonstrated in the electrical section, the system proved viable, with an impressive payback period of less



CONSTRUCTION RESPONSE

VIEW GLASS

The view glass will be treated as any large window package would be with the additional consideration of the electrical hookups that will require coordination between the glazers and the electrical subcontractor. The construction team will have to take into consideration that a large portion of the shell of the building will be missing until the glass in installed and plan their protective measures accordingly.

HYDRONIC MULLIONS

In order to install the hydronic mullions, the construction team will need to make sure the mechanical subcontractor coordinates with the team installing the view glass who is already coordinating with the electrical subcontractor due to the electrical hookups in the glass.

SOLAR PANELS

Constructing the solar panel racks off site will increase the productivity of the installation of the solar panels. The racks themselves will be light enough to lift to the corner of the roof with the crane on site and then they can be carried to the correct spot by the men on the roof.

ATUNE

Jack H. Miller Center for Musical Arts

SUSTAINABILITY

AEI Team No.	7-2019
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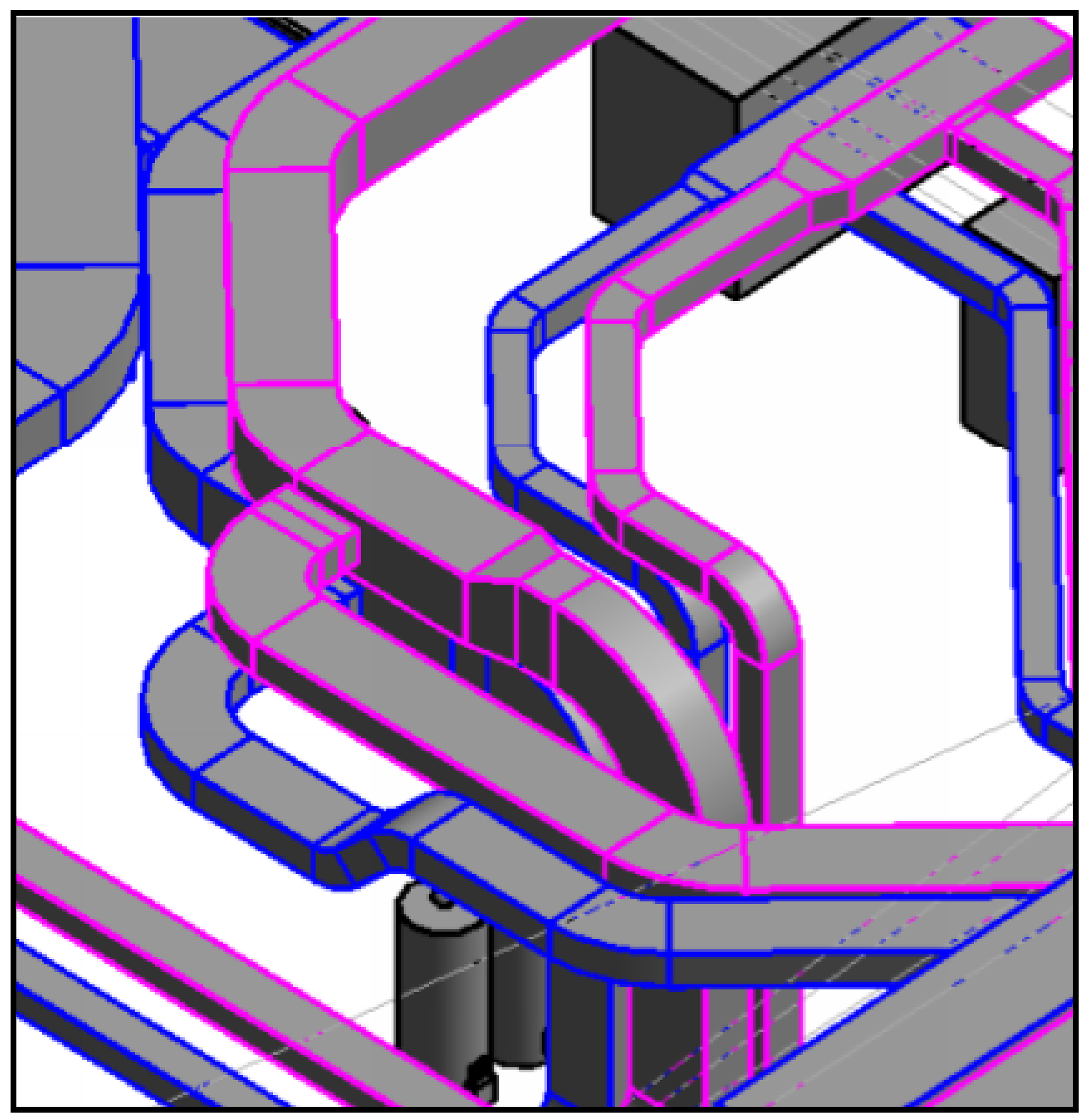
Scale	

I3.7

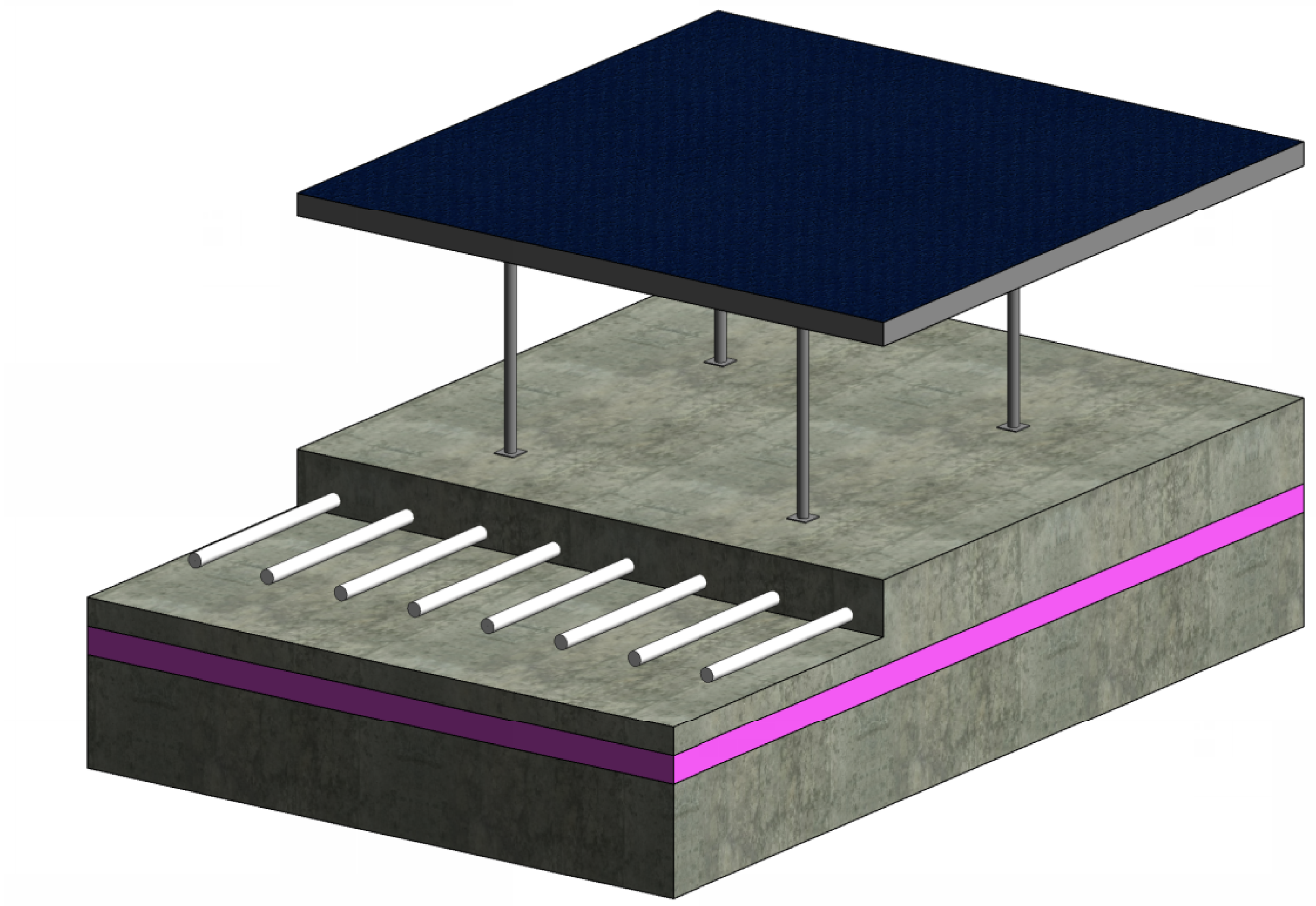
BUILDING AUTOMATION SYSTEM

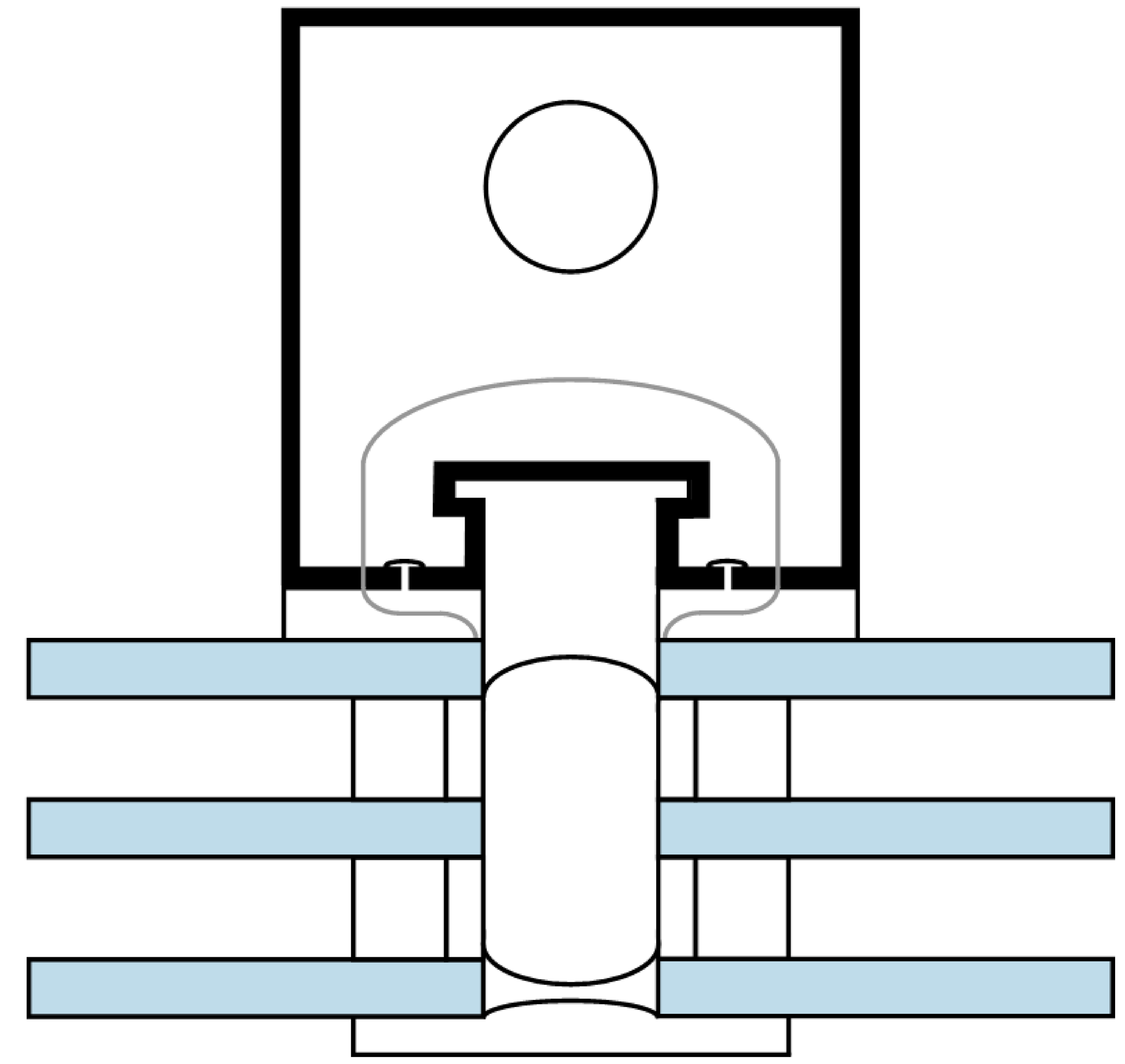
The IBM's Watson AI Building Automation System is a pinnacle demonstration of harmony as it unites all the building systems. Watson is a combination artificial intelligent and machine learning system. It will retrieve data from sensors across disciplines including occupancy sensors, photocells, thermostats, humidistats, and pressure sensors to continually improve efficiency and performance over the life of the building.



PREFABRICATION

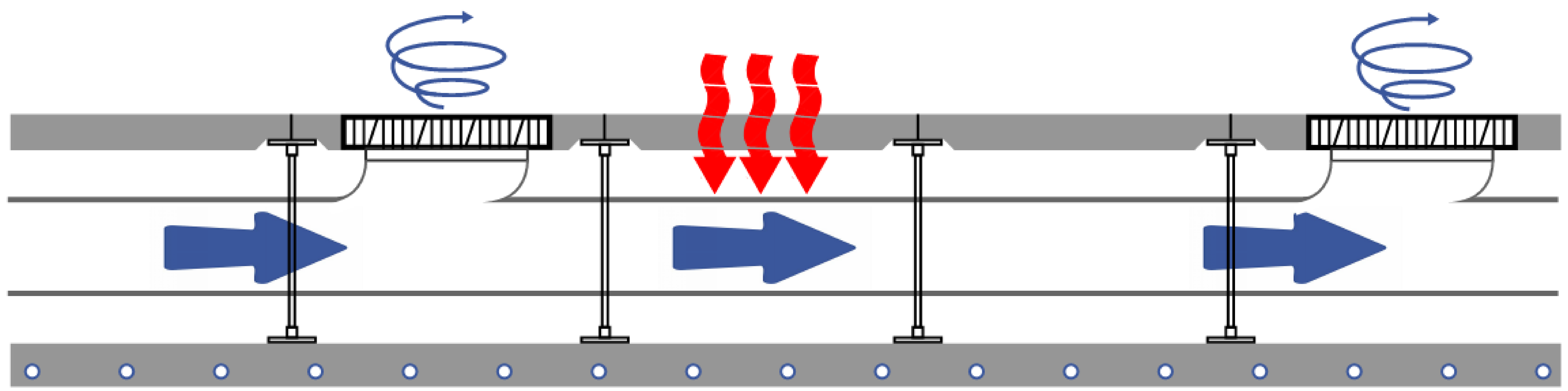
Through Integrated Project Delivery, the Atune designers were able to collaborate with the construction team to implement prefabrication for many system components in the Center for Musical Arts. The example above shows straight duct lengths as well as fittings that can be prefabricated off site to reduce the amount of man hours spent in the field. The mechanical designers have already laid out all high and medium pressure ductwork so logistics can begin for prefabrication. Similar prefabrication techniques will be used for all HVAC and plumbing piping on the projects, and also for electrical conduit. In addition, the structural team has coordinated with the construction team with regard to the components of the design that will be prefabricated by a manufacturer.





ATRIUM AND RAISED FLOOR

The Atrium features many of the collaborated items accomplished by Atune. In addition to the facade integration with the view glass and hydronic mullions being implemented in the curtain wall, there is major coordination taking place under the floor. The floor construction consists of a floor slab with radiant slab piping running throughout, underfloor air distribution, and electrical routing through the floor. This is all accomplished via the raised floor configuration shown.



UNDERFLOOR AIR DISTRIBUTION AND CONSTRUCTABILITY

The underfloor air system presents the construction team with a few design challenges but also provides an opportunity for safer work practices. A dropped slab requires increased attention to detail when framing and pouring the slab on grade. Additionally, raising the floor to accommodate the underfloor air system will increase the schedule slightly. However, running a large amount of ductwork on the floor significantly reduces the time laborers spend with their feet off the ground in scissor lifts and on ladders.

FROST PROTECTION

Providing frost protection along the foundations not only decreases the transfer of heat across the surface but also improves the ease of constructibility of the foundation. The construction team will excavate additional soil to make space for the insulation boards and then they will be able to use the insulation as formwork for the exterior of the foundation.

This design required intercommunication between all disciplines to implement the system. Though this design requires special attention by the team versus a traditional shallow footings, it provides tremendous benefit to the design overall. As stated, the construction team will benefit by being able to use less formwork as the insulation will be partially serving as formwork. The structural team benefits by being able to reduce the volume of concrete for the footings. Additionally, the mechanical team benefits as the insulation reduces the heat loss and heat gain through the building as mentioned above.

ATUNE

Jack H. Miller Center for Musical Arts

HARMONY

AEI Team No.	7-2019
Date	02/18/2019
Scale	

I3.8

STRUCTURAL EXECUTIVE SUMMARY

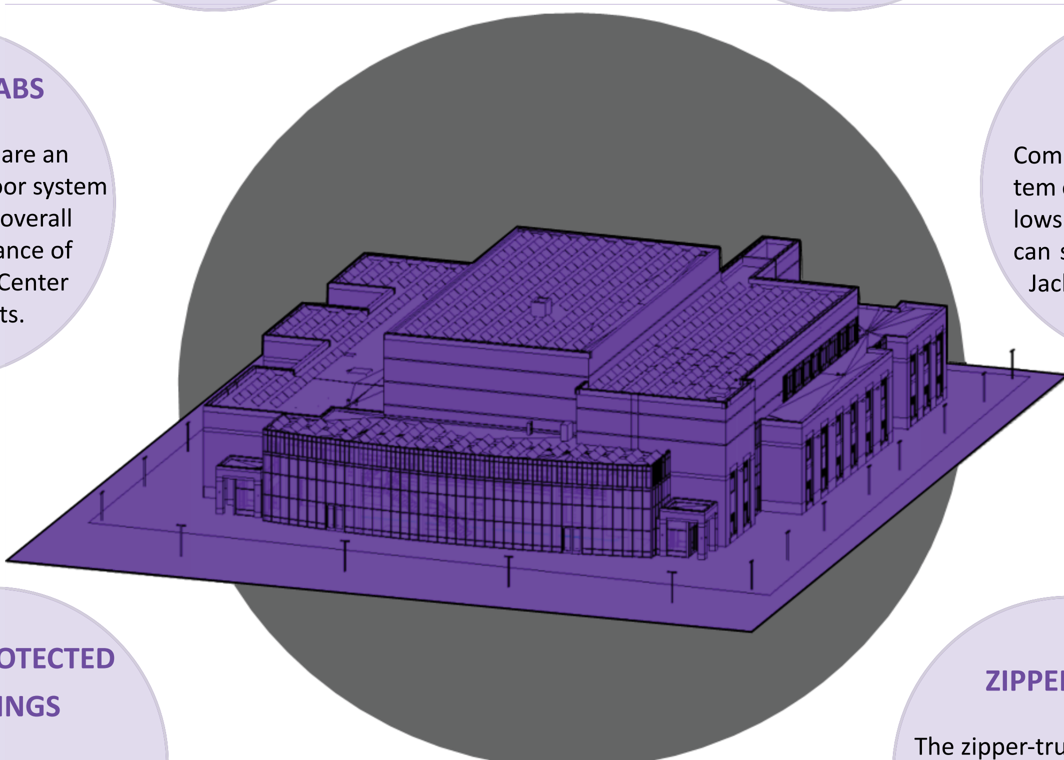
Atune utilized the Integrated Project Delivery method to design the Jack H. Miller Center for Musical Arts. This process enabled the design team to create a versatile and sustainable building with all its systems working in harmony. The structural team aimed to create a high performance building while not exceeding the project budget. In doing so, the team considered many innovative and integrated solutions to meet the building's needs. These solutions address the building's capability to perform efficiently, adapt under varying conditions and serve as a safe environment. Through this design process, the structural team has achieved a structural system that is 90% timber.

CLT PANELS

CLT tilt-up panels form the LFRS system, located around the concert hall and recital spaces.

ROOFTOP AMENITY SPACE

The design of the rooftop amenity space continued the timber construction allowing for multidisciple integration to provide a year round space for the college.



ISOLATED SLABS

The isolated slabs are an integral part of the floor system that increases the overall acoustical perfomance of the Jack H. Miller Center for Musical Arts.

COMPOSITE FLOOR

Composite action floor system of CLT and concrete allows for timber design that can span large bays in the Jack H. Miller Center for Musical Arts.

FROST PROTECTED FOOTINGS

Improve thermal performance of the building while reducing formwork and concrete needed in construction.

ZIPPER TRUSS

The zipper-truss is a strucutral system that highlights the sustainability and use of timber in construction.

CARBON FIBER WRAPPED COLUMNS

Carbon fiber wrapped columns are utilized in the atrium to reduce the column sizes and maintain the openess of the atrium.

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1.0	INTRODUCTION
2.0	ATUNE'S MISSION
3.0	PROJECT STRUCTURAL GOALS
4.0	STRUCTURE & INNOVATIONS OVERVIEW
5.0	DESIGN METHODOLOGY
6.0	GRAVITY SYSTEM DESIGN
7.0	LATERAL SYSTEM DESIGN
8.0	FOUNDATION SYSTEM DESIGN
9.0	BUILDING ENCLOSURE DESIGN
10.0	PROJECT BUDGET & CONSTRUCTABILITY
11.0	PROJECT CHALLENGES
12.0	LESSONS LEARNED
13.0	CONCLUSION

1.0 PROJECT INTRODUCTION

The Jack H. Miller Center for Musical Arts is located at Hope College in Holland, Michigan. The 64,00 square-foot building includes multiple performance venues, classrooms, practice rooms, faculty studios and office spaces for Hope College's Music Department. The building is situated along Columbia Avenue between 9th and 10th street and is adjacent to railroad tracks running by the campus. Atune has worked to design a solution that exceeds the needs and expectations for the Hope College community and the surrounding Holland, Michigan area.

2.0 ATUNE'S MISSION

The design intentions that the Atune team has set forth for the Jack H. Miller Center for Musical Arts are sustainability, harmony, and versatility. The structural system design was centered around these three intentions to provide Hope College with the best building possible. Atune's overall design of the Jack H. Miller Center for Musical Arts was approached through an Integrated Project Delivery (IPD) method enhanced through using Building Information Modeling (BIM). Although IPD is a more demanding and strenuous process, the work that was achieved through this process would not be possible without the IPD method.

3.0 PROJECT STRUCTURAL GOALS

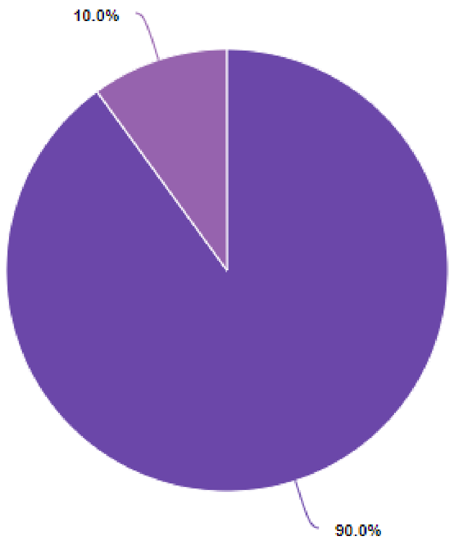
The following reflects how the structural team helped reach the goals Atune set forth for Hope College's Jack H. Miller Center for Musical Arts.

3.1 Versatility

Atune wanted to create a versatile building for Hope College to utilize for years to come. The building is not only an important component to the college, but to the Holland community. Atune felt it was important to make a building that was adequate for the needs of both parties. The building will be used for many different purposes and events, so the systems must be able to adapt in order to accommodate those needs. The structural team contributed to the versatility of the Jack H. Miller Center for Musical Arts by selecting and designing systems that have multiple uses and purposes. One example of this would be the versatile use of CLT panels for both a lateral and gravity system. Another example of structural versatility can be seen in the rooftop amenity space. There, the structural team designed a roof system that implements removable floor tiles which allow for maintenance during certain times of the year while serving occupants other times of the year. This is just a few of many areas where versatility can be seen throughout the structural systems design.

3.2 Sustainability

The structural system displays sustainability through every facet of the design by utilizing wood construction. The design competition challenges each team to utilize a minimum of 25% wood construction throughout the structural design. As sustainability is one of the team's primary goals, Atune decided to go above and beyond this challenge by designing a structure composed of 90% wood construction. The team used Forest Stewardship Council (FSC) approved wood throughout the entire project in order to ensure the design sustainability. Every major structural member composing the gravity and lateral system is engineered wood-- either glulam or cross-laminated timber (CLT).



3.3 Harmony

Atune's goal was to create a building that displays harmony at every level, with every discipline and every component working together to create one collective building. Harmony can be seen throughout the entire structural design, but it is most evident in the foundation design. The mechanical team utilized an underfloor air distribution system while the electrical team implemented Pavegen in the floors. Both OF THESE components had a large impact on the building foundation. Through much collaboration, the team was able to reach a design that worked well for every party. The structural team decided to create a dropped slab in necessary locations. The team then worked closely with the construction team to make sure implementation of all designs would be possible. Utilizing the IPD method made harmony throughout design possible.

4.0 BUILDING STRUCTURE & INNOVATIONS OVERVIEW

The structural systems selected for the Jack H. Miller Center for Musical Arts consists of more than 80% of engineered timber construction. The Atune team is utilizing a combination of cross-laminated timber (CLT), glulam, and glulam with carbon-fiber reinforcement. Though the use of 90% wood construction for this application was innovative in and of itself, the team decided to take the design even farther by implementing unique wood structural systems. Atune designed the concert hall as a "building within a building" to ensure the concert hall remained acoustically isolated from the rest of the building and the nearby train track. The team implemented carbon fiber wrapped columns and a zipper truss in the atrium in order to provide structural stability and maintain architectural effectiveness. The standard floor framing utilizes and inventive composite wood and concrete floors with dropped beams. Innovation is on display throughout the entire structural system of the Jack H. Miller Center for Musical Arts. The implemented innovations will be furthered highlighted in Structural Sections 6, 7, 8, and 9.

5.0 DESIGN METHODOLOGY

The design process used by the structural team focused on providing an exemplary building that would exceed Hope College's wants and needs. The following methodologies stated were used in order to provide a resilient building with a long lifespan. Atune utilized design codes and standards in a way that exceeds industry norms.

5.1 Design Codes and Standards

The design of all structural systems proposed for the Jack H. Miller Center for Musical Arts followed all codes currently adopted by Ottawa County and the Holland Municipal Code (including all amendments). Refer to page ii for a list of all relevant codes and standards used for design and construction of the Jack H. Miller Center for Musical Arts.

Portions of the structural system were designed using more stringent code to achieve higher building integrity. The primary area where this was done is discussed in the Section 7.2.

5.2 Fire Protection

Prior to design of the structural system, Atune determined the occupancy to be mixed use of type A-1, A-3, B, and S-2 in accordance with IBC 2009. The construction type was then determined to be type IV HT. The design meets all other requirements for height and area of the space that is dictated by the construction type. The primary structural system is required to have a 3-hour fire rating, while the floor is required to have a 2-hour fire rating. The team kept these fire ratings in consideration during design, but in the end the requirements for acoustics and design strength for timber dictated the thickness of all structural components.All required fire ratings were met through these thicker members.

5.3 Design and Analysis Software

Atune's structural design team utilized hand calculations and commercially available structural software. A variety of computer software was used to check hand calculations and optimize various components of the building. The primary software used for structural calculations was RISA, SAP 2000, Excel, and Dlubal. In addition to calculations and structural analysis software, Atune utilized REVIT and Adobe Creative Cloud to produce models and design documents. A summary of all software used by Atune can be found on I2.1.

6.0 GRAVITY SYSTEM DESIGN

Atune's structural team designed a floor system composed of a concrete-CLT composite slab that acts as the diaphragm, with incorporated sound isolation floor slabs for acoustical integration. The CLT floor is designed as an integrated floor and beam system. The floor system is supported by glulam columns. In the atrium where extra strength is required due to the unbraced length, the columns are wrapped with carbon fiber to act as reinforcement. The atrium roof is home to a zipper truss that will be discussed in depth in Section 6.4.4. The concert hall and recital/rehearsal spaces have a roof system composed of specialty wood trusses. The following sections provide a detailed explanation of the gravity design.

6.1 Gravity System Goals

Atune set the strength design criteria for the gravity system that would meet and exceed code. The purpose of this is to allow the Jack H. Miller facility to evolve as the college grows. These goals matched the rest of the Atune team's focus being on Hope College. The final design achieves sustainability through wood construction, which doubles as an acoustical attenuation component to the building. Structural sheet S3.2 highlights the integration of Atune's goals with the gravity system.

6.2 Gravity Loads

Gravity Loads were determined based on the use, construction, and location of the Jack H. Miller Center for Musical Arts. The loads were calculated according to the IBC 2009 and ASCE 7-05/10. The building was classified as Risk Category III.

6.2.1 Dead

Dead loads were calculated for the building roof & floor systems as well as the walls. The dead loads were primarily used to design gravity framing and to calculate the building seismic weight. The electrical and mechanical teams implemented solar panels and a slab melt system on the roof that resulted in an additional dead load of 4psf, for the structural team to account for in designing the roof. For the detailed dead load calculations refer to S2.2.

6.2.2 Live

The diversity of the building use and occupancy resulted in live loads ranging from 40 psf to 150 psf. Live load reduction was used where applicable. It is important to note that the lower roof on the south side of the building changed from a 20 psf live load to a 100 psf live load to accommodate the rooftop amenity space. For a full live load map of the facility refer to sheet S3.3.

6.2.3 Snow

According to local code the ground snow load in Holland, Michigan is 50 psf. The roof design snow load was calculated to be 34.7 psf. Although a slab melt system was implemented on the roof, the structural team designed the roof to withstand snow loads dictated by code. The reason for this is system redundancy and occupant safety in case the slab melt system were to fail. Due to the changes in roof heights the lower roofs experience a larger snow drift. One of the major areas of concern for the snow load was the possibility for large amounts of dumping between the rooftop amenity space roof and the open area of the amenity space. For the detailed snow load calculations refer to S2.2.

6.3 Alternate Systems Evaluation

The following systems were evaluated for the Jack H. Miller Center for Musical Arts, but not selected in the final structural design. The team used a decision matrix to choose systems that would help the team accomplish the desired goals. Please see S2.1 for the matrix used to make the gravity system decisions for each space. The table below shows the alternate systems considered and how they addressed Atune's team goals.

Heavy Timber Beams & Columns		
Benefits	**Trade Offs**	**Goals**
Conventional design. Easily constructable.	Basic construction type, not innovative.	Flexibility in Use Long Life Span Environmental Impact Integration Capable IPD Constructability
Composite Wood/Concrete Floor w/ Heavy Timber Framing		
Benefits	**Trade Offs**	**Goals**
Composite material properties. Higher acoustical values.	Material creep. Increased design time for shear connectors. Uncommon construction.	Acoustical Adaptability Flexibility in Use Long Life Span Environmental Impact Integration Capable
CLT w/ Heavy Topping		
Benefits	**Trade Offs**	**Goals**
Composite material properties. Higher acoustical values. Innovative.	Material creep. Uncommon construction.	Acoustical Adaptability Flexibility in Use Long Life Span Environmental Impact Integration Capable
Column Framing w/ Carbon Fiber		
Benefits	**Trade Offs**	**Goals**
Innovative. Composite material properties.	Expensive material. Long lead time for construction.	Flexibility in Use Long Life Span Environmental Impact

6.3.1 Sawn Lumber Beams & Columns

Originally sawn lumber framing was considered due to the familiarity and finish of the product. Although the cost of solid sawn lumber is initially lower than engineered wood products, it has many downfalls such as quality control issues and limited sizes. Sawn lumber will be utilized in some areas but was ultimately not implemented as the primary gravity system for the building due to the large loads, height of building, and large spans of the building.

6.3.2 Engineered Wood Beams & Columns

Engineered Wood beams and columns are very common in industry for large-scale timber structures. The advantage to a system such as this is that it provides sustainable design that is also easily constructible. However, this system has limited capacity compared to other options the team considered. The system is not uncommon, so it leaves little room for the level of innovation Atune desires to achieve. When utilizing the decision matrix, some of this system's biggest fallbacks for the Jack H. Miller building were the lack of acoustical adaptability and the inability to add much to the architectural aesthetics. Atune decided this system did not offer enough to implement in the building.

6.3.3 Composite Timber & Reinforced Concrete Floor with Steel Transfer Girders

Atune's structural team turned to inspiration from the John W. Oliver Building at the University of Massachusetts Amherst. One of the first mass timber buildings in the United States that incorporated a variety of European timber technology. The building's gravity system is comprised of timber-concrete composite floor system, glulam beams, and glulam columns. The transfer girders however are made of steel and wrapped in wood. Keeping true to the ideas that Atune set forward to create a sustainable all wood design ultimately lead the team to a different design without the use of the steel girders.

6.4 Gravity Design Progression

For the primary gravity system, Atune selected composite CLT floor panels, reinforced concrete spandrels, and reinforced concrete joints that serve to connect glulam columns. The concert hall and performance spaces utilize CLT wall panels and wood joists. The atrium design was heavily influenced by integration with electrical and mechanical to keep the floor plan as open as possible. Ultimately glulam columns wrapped in carbon fiber reinforcement and a zipper truss with integral glulam beams. This design will be discussed in more detail to follow.

6.4.1 Floor System

The structural team was inspired by SOM's Concrete Jointed Timber Frame (CJTF) System. SOM has put out two detailed reports regarding high-rise timber buildings. Glulam columns and exterior CLT walls connected with interior and perimeter precast concrete beams and spandrels that support the composite concrete-CLT floors. SOM, with the help of Oregon State University, conducted a large study on the CJTF floor system. The purpose of testing was to research CLT floor systems with a composite concrete topping slab, which are often designed like a concrete flat slab system. The program researched the effectiveness of composite action, two-way bending stiffness, and continuous beam behavior for the CJTF system. The shear connectors that the Atune team chose were HBV steel mesh connectors manufactured and developed in Germany. The connector plates are approximately 40 inches long and 2 9/16 inches tall with a 1.25 embed into the CLT with epoxy manufactured specifically for the grooves in the CLT Panel.

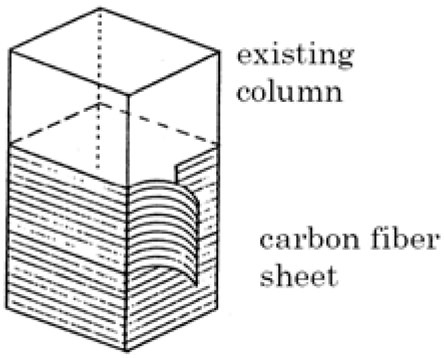
Another system we evaluated was sound isolation floor slabs. There are several types that could be utilized in the building based on location and acoustical concerns. The two main concerns were sound and vibration isolation. The major advantages to integrating these with our design is

the acoustical advantages and they are easy to install/implement with floor systems that use concrete. Since two variations of isolation slabs were considered, additional construction coordination was needed to ensure it would be feasible.

6.4.2 Column Framing

Standard column framing throughout the building is made up of glulam columns. The glulam columns were chosen due to their sustainability and capacity. An additional advantage is the integration with the CLT-Concrete composite floor.

Glulam columns were a viable option for the standard framing throughout the building, but they were not adequate to support the mechanical tower or to support the load at the front of the atrium. Sustainability was a design driver, so the team decided switching the columns to a different material was not an option. Instead, the team looked for innovative solutions to increase column capacity. Atune decided to wrap the columns in SikaWrap, which is a bi-axial carbon fiber fabric with an epoxy coating that is used for structural strengthening. This design technique not only increased the capacity of the wood columns, but it allowed the team to use smaller columns in the necessary areas. The structural team worked closely with the construction team to make sure that wrapping the wood columns in carbon fiber could be done without having a major impact on the project schedule. A SikaWrap distributor, Ridgemoor Supply, is located 25 miles away from the project site in Kentwood Michigan. Ridgemoor Supply was able to provide a pricing quote along with information on wrapping and expoxy coating the columns upon erection. In the end, after research and collaboration, the team decided wrapping the columns in carbon fiber fabric was the best option.



6.4.3 Specialty Concert Hall Design

The main concert hall has been treated as a building within a building due to the very different use and makeup of the space as well as the location. The roof will be comparable in structural design to the rest of the building, except for the additional loads due to the catwalks and stage lighting that will be supported from the roof. The balcony structure will also have similar structural floors, but the balcony seating will also contain an under-floor air distribution system like the rest of the main level of the concert hall. This results in an increased design load and additional coordination for potential penetrations through the slab.

On the ground level, Atune is implementing sound isolation floor slabs. The primary reason is to aid in the acoustic design/performance of the building. Rather than using glulam columns in this area of the building, Atune has decided to utilized CLT tilt-up wall panels. CLT tilt-up wall panels provide the strength and capacity to vertically span the 32’ 0” unbraced length required for the upper portion of the building as well as provide acoustical isolation from the surrounding spaces. These panels also double as both the gravity and lateral system for the concert hall design.

6.4.4 Zipper Truss

The atrium is a major architectural component to the Jack H. Miller Center for Musical Arts. The structural team wanted to create a design that added to the architectural aesthetic of the atrium in a way that showcased sustainability. The atrium has a high ceiling and a 35’ 0” span in the east-west direction. The roof of the atrium supports 58 solar panels and a large snow load. The atrium is also home to a 10’ 0” wide walkway and stairs that are suspended from the atrium roof by steel tension rods. The structural team selected a system that addressed these structural loads and supplemented the architecture, while also accomplishing the team goals. The typical floor/roof system that was used throughout the building was lacking in capacity and architectural effectiveness in the atrium. After looking for unique and effective solutions, the team decided on the use of a zipper truss in the atrium. The truss is perfect for carrying the roof load across the 35’ 0” atrium span, and the 32’ 0” ceiling allows the truss to avoid looking intrusive. In conjunction with Hope College’s goals, Atune decided to use the building to educate occupants about sustainability. The zipper truss accomplishes this by a bold display of wood construction and innovation. See the graphic below for a better understanding of the zipper truss implemented in the atrium of the Jack H. Miller Center for Musical Arts.

6.5 Design Optimization

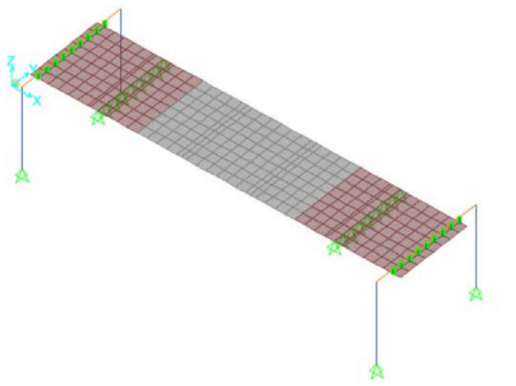
Once the above gravity systems were selected, the structural team focused on improving the design to perform at required ASD load combinations.

6.5.1 Composite Floor System

The CLT with reinforced concrete floor system was designed for the worst case loading seen by the system. Once general sizes were designed, coordination with the mechanical team was needed to integrate the radiant floor HVAC with the concrete slab size. The floor analysis utilizes the most common analytical approach for calculating the stiffness and strength properties of CLT floor systems with composite concrete slabs. The “gamma method” from Annex B of the Eurocode 5, Design of Timber Structures, was developed in order to calculate the effective stiffness of two timber elements connected with mechanical fasteners with a known slip modulus. This calculation dates back to the derivations of Mohler, involving basic engineering mechanics. The US CLT Handbook references the Gamma Method and has been evaluated for timber-concrete composite floor systems two different times by Gerber (2015) and Manaridis (2010). An eight-step approach was used for the analysis method.

- Determine the CLT properties for the floor system considered per APA-PRG 320.
- Calculate the effective cross-sectional properties of the CLT floor from US CLT Handbook.
- Determine the composite fastener type and associated slip modulus (Ks) per manufacture's technical report.
- Calculate the effective composite stiffness properties per Annex B.
- Calculate the apparent stiffness of the floor system per the US CLT handbook.
- Evaluate the floor system for deflections and vibrations per rational analysis.
- Calculate the normal stresses due to bending moments, shear stresses, fastener loads of composite floor system per Annex B.
- Compare the calculated stressed to allowable limits by NSD.

Sound isolation floor slabs can either be a mat underlay of the finished floor that is on top of the concrete slab or it can be a variation of a floating floor system for sound and vibration isolations. Due to the variety of performance and practice spaces in the Jack H. Miller Center for Musical Arts, the mat underlay will be implemented throughout the building. In areas of higher acoustical concerns, the mat underlay will be used in conjunction with the underfloor air distribution system, which acts similar to an elevated vibration isolation system. The use of the mat slab with the underfloor air distribution system ensures the isolation of the concert hall from any external noise and vibration disturbances. Refer to S3.4 for details of the sound isolationsa systems.



6.5.2 Glulam Column Framing

Glulam columns were sized for a variety of cases and determined worst case for different areas while still maintaining constructability. The design of the glulam column system went through several design iterations to ensure that carbon fiber wrapped columns were only needed in the atrium space and below the cooling tower. Atune designed the typical gravity columns in the building. The structural team evaluated the atrium, concert hall/recital halls, and the offices/classrooms. For detailed sizes refer to S2.3.

The use of carbon fiber fabric as a structural strengthening material is generally implemented as concrete reinforcement where structural repair or renovation is needed. The use of carbon fiber reinforcement in initial construction, on wood columns, is a huge advancement in industry. After research and design iterations, the team was able to design the wrapped columns using strain compatibility. The stress, strain, and elastic modulus of each material were combined based on the area of each material, to determine an elastic modulus for the composite column (Ecomp = 2550 ksi). The composite elastic modulus was then used to calculate a maximum design stress of 66 ksi, governed by the glulam core. It is important to note that this is a conservative calculation because the use of carbon fiber would increase the capacity of the wood and result in a higher maximum stress value. Testing of the composite columns is recommended to quantify a more adequate maximum stress. The glulam columns selected were 10.5x11" (nominal). Without the carbon fiber wrapping, the columns failed by almost 400% when checked for combined axial and bending. After wrapping the columns in 1/8" of SikaWrap, the columns were at 85% combined axial and bending capacity. This innovative solution guarantees a sustainable system with the capacity to support large loads while maintaining open spaces.

6.5.3 Specialty Concert Hall Design

CLT panels were chosen because they are similar in application to concrete tilt-up panels. This material/system choice will allow the optimization of the "building within a building" design with constructability focus. The panels were sized using the worst loading case expected to be seen by the panels and are designed to meet NDS-2015 code.

The design process to size CLT wall panels an iterative stepped approach based on the load conditions seen and the axial/flexural design strength of the panels. Due to the humidity and climate in Holland, MI, all panels were conservatively designed with a wet service factor. The first iteration evaluated the Structurlam 245V, 7-ply CLT panel. Design checks showed that the panel could not support the axial load seen on the first floor. The panel didn't have the capacity to support the unbraced length of the concert hall. Based on product capacity tables from Structurlam, the next iteration checked the 315E, 9-ply CLT panel. The design checks passed for axial loading, shear, bending and combined bending and axial. For detailed calculations and drawings, refer to S2.4.

6.5.4 Roof Design

Atune's structural team evaluated the roof framing systems to produce the most effective design to optimize the large spans and the use of the roof space on the south side of the building. The loads calculated for the roof include snow, wind uplift, gravity, live loads, and the specialty cases of the solar panels integrated by the electrical team and the slab-melt technology, mechanical units integrated with the mechanical team.

Roof snow loads were calculated according to ASCE 7-05. A 35 psf flat roof snow load controlled over the roof. The design also considers worst case parapet snow drift loads of 100 psf. For the detailed calculations see S2.2.

The wind uplift pressures seen on the roof were determined in accordance with ASCE 7-10, Components & Cladding. Wind speed seen in Holland, MI is 120 mph, and the uplift seen on the roof averaged to 80 psf. For the detailed calculations see S2.2.

When we compared the other loads seen on the roof, including the solar panels and slab-melt system, the snow loads governed the design of the roof. Atune's structural team evaluated standard joist framing, timber framing and the composite CLT with reinforced concrete for roof framing. The roof system is 2-hr fire rated per IBC 2009, and therefore the roof framing will be of the composite CLT with reinforced concrete construction, for the lower structure. In addition to the increased loads seen on the upper and lower roofs, the integration of the slab-melt system with mechanical required a thicker concrete slab on the roof to account for the ¾" piping.

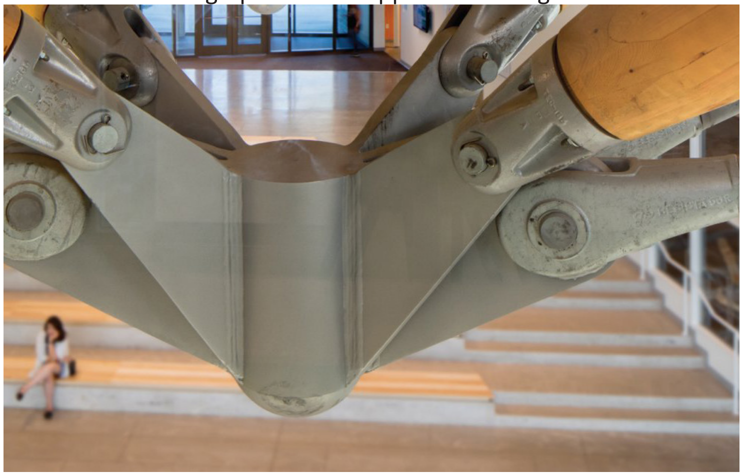
The roof structure of the main concert hall and the three recital spaces are specialty wood trusses. The upper roof has naturally longer spans. In addition to the weight that it supports from above, it also supports the weight of the catwalks and other stage equipment that hangs below. The concert hall trusses are 28x12 FS web members with two nailed 36x14 top and bottom chords, these trusses are spaced at 8'0" on center. For the smaller recital halls, the 12x6 web members are connected by 12x12 top and bottom chords, these are spaced at 12'0" on center. See structural sheets for the roof framing plans, and S3.3 for specific point loads from maintenance walkways.

Location of the solar panels was coordinated with Atune's electrical team to optimize the energy gain while minimizing structural deflections and loads. For more detailed information on the selection of the solar panels refer to Electrical Narrative Section 6.1.1. The slab-melt was integrated with Atune's mechanical team to help minimize the continued snow loads seen on the roof. The snow melt gained through this system is advantageous for the mechanical team to utilize rainwater collection. The rainwater collected will be used as potable grey water. More detailed information regarding the slab-melt system can be found in Mechanical Narrative Section 7.4.7.

6.5.5 Zipper Truss

The structural team utilized Dlubal's RFEM software to aid in the design of the zipper truss. After several design iterations, the structural team reached a final design for the atrium zipper truss system. The truss system consists of 6 trusses in total, each 12'0" on center and 6'0" deep. The trusses span the width of the atrium at 35'0". Each truss includes an 18" deep glulam top chord compression member which spans the width of the atrium. The individual trusses also consist of four 9" diameter compression glulam struts and four 1.5" diameter steel rods. The glulam compression members transfer the load to the central point of the zipper truss, called the bullet connector, picture below.

Upon transferring the load to the bullet connector, the tension rods then transfer the load to the 18" glulam beams. The beams frame into the carbon fiber fabric wrapped columns and the performance hall CLT panels, which then transfer the roof load to the ground. See S3.8 for a detailed graphic of the zipper truss design.



6.7 Gravity Connection Design

The gravity connections were designed using NDS 2015, and design guides. The connection designs were optimized for the specified systems.

6.7.1 Glulam to Foundation Connection

The glulam columns will be connected to the foundation by steel angles with hooked anchor bolt holes into the slab. The column will sit on a ¾" steel plate in order to help keep moisture out of the column. Extra cocking can be applied near the steel plate to help with acoustical performance between spaces. See S3.10 for connection detail.

6.7.2 Panel-to-Panel Connections

The panels will be interconnected using internal structurally composite lumber (SCL) internal splines connected with self-tapping screws. The splines should also include a structural adhesive complying with ANSI 405 to increase the strength and stiffness of the connection. See S3.10 for connection detail.

6.7.3 Panel-to-Foundation Connections

The CLT walls connect to the shallow foundations using a 3/4" steel plate and 3/4" steel angle connecting the wall to the slab. The angle is connected to the CLT using self-tapping screws and an anchor bolt connecting into the slab. The plate is connected using self-tapping screws into the CLT, similar to the angle, and self-tapping masonry screws connecting into the foundation. The CLT wall is separated from the foundation with a 3/4" sill plate and thermal insulation. See S3.10 for connection detail.

6.7.4 Framing-to-CLT Wall Connections

Connections from framing to the CLT panels will be a combination of metal brackets and kickers connected using 1" lag-screws. Typical 90° angle metal brackets will connect the member to the CLT wall at the joining point. Additional angles will connect the SCL kicker to the CLT wall and the framing member, generally a beam. See S3.10 for connection detail.

6.8 Gravity System Summary

As a result of the structural decision matrix, the selection of gravity systems was driven by the project goals of versatility, sustainability, and harmony. The main gravity systems, including the roof, are as follows: composite CLT with reinforced concrete, glulam column framing, specialty wood trusses, and CLT wall panels. The gravity systems all enhance the structural stability of the building and assist the acoustical performance of the music center. The integration of the slab-melt and solar panels with the structural roof system for both the upper and lower roofs was a major integration opportunity for the Atune team. Refer to the table below to see how the structural system met Atune's goals.

Team Goals	Structural Design Criteria	Goals Met/Exceeded
VERSATILITY	Make material and system selections that increase the acoustical performance of the structure.	✓
	Design the gravity systems to minimize the members that intrude into the space while still allowing for future growth.	✓
SUSTAINABILITY	Material and system selection that allows for longevity of the structural systems and ease of maintenance in future.	✓
	Focus on material selection local to the region and environmentally sustainable.	✓
HARMONY	Eliminate design clashes with MEP. Focus on systems that provide opportunities to integrate with MEP.	✓
	Decrease the schedule for structural system by increasing design of prefab members.	✓

7.0 LATERAL SYSTEM DESIGN

Atune's structural team designed the lateral system by the major areas of the music center. The main concert hall, the three smaller recital halls on the north side, and the longer of the walls on the south side will all be constructed of large CLT tilt-up panels. The entrance atrium lateral forces are transferred through the diaphragm to the CLT walls of the concert hall.

7.1 Lateral System Goals

Atune set the strength design criteria for the lateral system that would meet and exceed code. These goals matched those of the rest of the Atune team with the focus being on Hope College. The final design shows sustainability through wood construction, which doubles as an acoustical component to the building. See S3.1 for highlights of the integration of Atune's goals with the lateral system.

7.2 Lateral Loads

Atune evaluated both the seismic and wind conditions expected to be seen on the Jack H. Miller Center for Musical Arts. Atune designed the lateral systems according to ASCE 7-10. The loads were determined using the newer code due to more conservative values calculated over those in the ASCE 7-05. Prior to design, the building was determined to have a Risk Category, III, and an Exposure Category, C.

7.2.1 Wind

The Jack H. Miller Center for Musical Arts was designed as an enclosed building. The height of the building was assumed to be the average height between the concert hall core and the exterior building, at 42'0". Additionally, the structure was treated as rigid when calculating the applied wind loads. The total wind base shear was calculated to be 436.5 kips. See S2.2 for the detailed wind calculations.

7.2.2 Seismic

Holland, Michigan, is located in a low seismic region, therefore seismic loads were checked but do not govern for lateral loads. The seismic loads were calculated using site class D, per the geotechnical report. See S2.2 for the detailed seismic load calculations.

7.3 Alternate Systems Evaluation

The following systems were evaluated for the Jack H. Miller Center for Musical Arts, but not selected for the final structural design. The team used a decision matrix to choose systems that would help the team accomplish the desired lateral system goals. Please see S2.1 to see the matrix used to make the lateral system decisions for each space. See the table below to see how the considered sytems were considered in regard to Atune's goals.

7.3.1 Heavy Timber Braced Frames

The advantages to using heavy timber braced frames on this project would be the high strength-to-weight ratio that they provide. Additionally, the braced frames would give a high short-term load strength. However, due to the material properties of heavy timber braced frames they have a naturally low response modification factor which requires either more heavy timber members or more robust members. Either option to increase the lateral strength resulted in an increase in cost, affecting the schedule and budget. Therefore, this lateral force resisting system was not selected for the final design.

7.3.2 Timber Moment Frames

This system is an innovative response to lateral loading seen by the building while increasing the use of timber in the structural systems. Timber moment frames are not common due to the lack of ductility in the members. Since timber moment frames are still under research as an effective lateral system, there are several drawbacks including but not limited to the lack of design guides and codes. In addition to the draw backs in design, the construction of timber moment frames would have an impact on the construction schedule and budget due to the slower speed to erect the members and the need for specialty connections.

7.3.3 Wood Shear Wall

The sheathing materials used in timber frame building diaphragms can economically be upgraded to resist shear loading. This allows a timber frame design to take horizontal and vertical loads. Several of the advantages to timber shear walls include lighter weight construction (compared to similar systems), resilient system and faster conventional construction. Due to the material properties of timber shear walls special considerations need to be taken when designing the sheathing thickness, nailing pattern, chord/strut design, and support connections. The structural team did not select this system in the end because it did not achieve all of Atune's design goals.

7.3.4 SIP Walls

SIP walls are not ideal for long-spans and large unobstructed spaces but are a great shear wall alternative in buildings four stories or shorter, like the Jack H. Miller Center for Musical Arts. Additionally, SIP walls provide better acoustical insulation than traditional timber shear walls. In addition to the large acoustical advantages the SIP walls can be replaced to maintain building occupancy if they were ever to experience structural damage. However due to the restrictions of SIP walls with any mechanical chases and only permitting electrical runs that are 1-½ inch or smaller, careful integration would be needed in choosing the placement of SIP walls in the building. Due to the lack of integration this LFRS system was not selected.

7.3.5 Alternate Systems Overview

Refer to the table for an overview of why the team ultimately decided not to implement the discussed lateral systems.

Shear Wall		
Benefits	**Trade Offs**	**Goals**
Faster and lighter construction. More architectural freedom.	Smaller room openings.	Flexibility in Use Aesthetic Effectivness Long Lifespan Education to Public Constructability
Structural Insulated Panels		
Benefits	**Trade Offs**	**Goals**
Improved R-values. Easy to maintain/replace. Shear wall design advantages.	Smaller room openings. No plumbing or piping chases. Limited electrical chases.	Flexibility in Use Aesthetic Effectivness Long Lifespan Education to Public Constructability
Heavy Timber Braced Frames		
Benefits	**Trade Offs**	**Goals**
High wood to weight ratio. High short term load strength.	Lower response modification factor. More members. Increased Cost. Brittle Failure Mode.	Flexibility in Use Aesthetic Effectivness Long Lifespan Education to Public Mulipurpose Design
Timber Moment Frames		
Benefits	**Trade Offs**	**Goals**
Composite material properties. Innovative.	Low tensile strength. Not practical for construction.	Aesthetic Effectivness Long Lifespan Education to Public Multipurpose Design

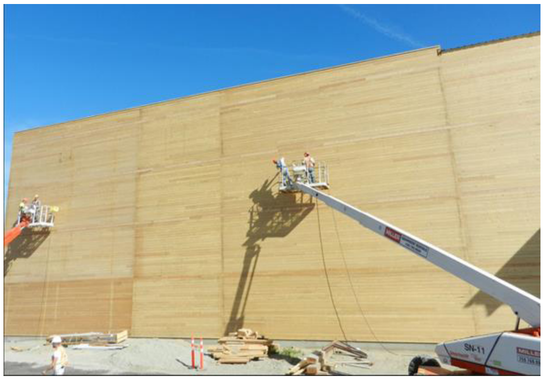
7.4 Lateral Design Progression

The use of the structural decision matrix made the CLT Panels an obvious choice for the lateral system, as it scored high in versatility, sustainability and harmony. The panels are cross-laminated which means the strong axis is alternating within the wood. As a result, these panels act as both the gravity system and the lateral system. Also, the panels are very easy to construct and will result in a shorter construction schedule. The panels help accomplish the team's sustainability goal through the use of timber. Last, the panels provide acoustical isolation to the concert and recital halls.

The panels will be placed around the concert hall and the recital/rehearsal areas. In order to combat the torsional effect this placement will have on the building, a CLT panel was added on the south wall as seen on S3.4. The stairs and elevator shaft will also be encased in CLT panels, primarily for structural support and to meet fire ratings on the egress routes. The atrium has little room to implement a lateral system due to the glass façade, so the performance hall CLT panels will provide the needed lateral stability for the atrium through a cantilevered diaphragm.

7.5 Design Optimization

Once the above lateral system was selected, the structural team focused on improving the design to perform at required loading combinations. In addition to the strength requirements, the structural team worked on designing the lateral systems to meet the drift limitation of 0.01H.



The CLT panels for the main concert hall, the 3 smaller recital halls on the north side, and the longer of the walls on the south side were all checked using the NDS-2015 and CLT Handbook design guides. Coordination with the construction team ensured the panels were designed within standard sizes of manufactures, such as Structurlam, allowing for pre-fabrication of the panels. Prefabrication can economically be done off site and brought to site, positively impacting the construction schedule and limiting the material that is stored on-site for long periods of time. Since tilt-up panels require additional design and construction coordination up front, Atune's IPD approach has ensured that errors on the pre-fabricated elements of the Jack H. Miller Center for Musical Arts are minimized.

Initial sizing of the CLT panels had been taken from manufacturer data sheets to ensure that a typical sized panel would be able to withstand and transfer the building loads. The structural team went through a series of iterative design checks to optimize the panel sizes. The first iteration checked a Structurlam 191E, 7-ply CLT panel. The design checks evaluated the worst-case loads and unbraced length of the panels in each of the 3 main locations in the building. While the panel was adequate in shear strength it did not meet the axial strength requirements in all the panel locations.

The second iteration checked a Structurlam 243E, 9-ply CLT panel. In the 3 smaller recital halls and the south wall, the design checks passed for axial, shear, bending, and combined bending and axial loading. The maximum wall deflections were less than 0.2 inches. The second iteration for the concert hall panels checked a Structurlam 315E, 9-ply CLT panel. In addition to the gravity checks passing, as mentioned in Section 6.5, the lateral design checks for this panel also passed and the maximum wall deflections were less than 0.2 inches. See S2.4 for panel locations and sizes.

7.6 Lateral Connection Design

The lateral connections were designed using the CLT Handbook US 2013 Edition. There were several key CLT panel connections that were designed including panel-to-panel, panel-to-foundation, and framing-to-CLT panels/walls. All CLT connections will have structural adhesives included in addition to the mechanical connectors. All connections that have a material connection point need to have an acoustic membrane/sealant separating the materials except the panel-to-panel connections.

7.6.1 Panel-to-Panel Connections

The panels will be interconnected using internal structurally composite lumber (SCL) internal splines connected with self-tapping screws. The splines should also include a structural adhesive complying with ANSI 405 to increase the strength and stiffness of the connection. See S3.10 for connection detail.

7.6.2 Panel-to-Foundation Connections

The CLT walls connect to the shallow foundations using a 3/4" steel plate and 3/4" steel angle connecting the wall to the slab. The angle is connected to the CLT using self-tapping screws and an anchor bolt connecting into the slab. The plate is connected using self-tapping screws into the CLT, similar to the angle, and self-tapping masonry screws connecting into the foundation. The CLT wall is separated from the foundation with a 3/4" sill plate and thermal insulation. See S3.10 for connection detail.

7.6.3 Framing-to-CLT Wall Connections

Connections from framing to the CLT panels will be a combination of metal brackets and kickers connected using 1" lag-screws. Typical 90° angle metal brackets will connect the member to the CLT wall at the joining point. Additional angles will connect the SCL kicker to the CLT wall and the framing member, generally a beam. See S3.10 for connection detail.

Team Goals	Structural Design Criteria	Goals Met/Exceeded
VERSATILITY	Growth Potential	✓
	Architecural Congruity	✓
SUSTAINABILITY	Material Performance	✓
	Environmental Accountabilit	✓
HARMONY	Integration Capable	✓
	IPD Constructability	✓

7.7 Lateral System Summary

An integrated selection and design of the lateral systems was the driver in achieving and exceeding the project goals of versatility, sustainability and harmony. Utilizing CLT panel walls throughout the building optimizes acoustical performance of the structural system and contributes to the construction schedule aiding in the IPD approach that Atune is using for the Jack H. Miller Center for Musical Arts. Atune designed a lateral system that will provide the building a resilient design that contributes to the life of the building.

8.0 FOUNDATION SYSTEM DESIGN

Due to the large soil bearing pressure in Holland, MI, and the frost depth of 42", Atune's structural team selected frost protected spread footings to reduce the volume of concrete needed in the foundations.

8.1 Foundation Design Goals

Atune's foundation goals were driven heavily by the desire to continue to integrate within the disciplines and to exceed industry standards. Preliminary designs were performed, and all alternate systems were compared using a decision matrix which was governed by Atune's goals and project themes. Refer to the decision matrix on S2.1.

8.2 Site Analysis

Atune utilized the geotechnical report recommendations for convectional spread footings provided by Driesenga & Associates, Inc. The general soil profile was topsoil, sand with trace silt, fine to medium sand, and still grey silt. The grey silt was encountered at depth of 50 feet. Due to the soil profile in order to achieve the required depth of existing soil densification, vibro-compaction is recommended over surface-only methods of compaction.

The large trees in the project area will be addressed by complete removal of the tree roots. The demolition of the existing garage structure and other previous structures' foundations, floor slabs, utilities, and other below-grade structures will be removed from the proposed building's footprint. For all pavement areas leading up to the building's footprint all existing utilities and below grade structures will be removed at least 2.5 feet below the final subgrade.

Recommended depth for all perimeter footings is at least 42" below finished grade in order to protect against frost. The footings should be designed for a maximum net allowable soil bearing pressure of 4,500 psf. The floor in the main concert hall will be a double concrete slab that is separated by a 2" isolation mat. Other floors will be a minimum of 8" in thickness with vapor barriers below any floor slabs with an impermeable floor finish/seal.

8.3 Design Progression

Based on the geotechnical results, a conventional spread footing with additional densification of the granular site soils are recommended. In order to achieve the required depth of existing soil densification, vibro-compaction will be used in lieu of surface-only methods of compaction. The recommended maximum spacing for the vibro-probe is 25'0" along continuous footings and at least one probe per column footing. Any areas where the proximity of the vibration will be an issue will be reevaluated.

The integration of the Atune team has resulted in a step down of 18" for the concert hall to accommodate for the under-floor air distribution system without the need for a step down or step up to enter or exit the concert hall. Stepping down the slab/foundation also improves the ADA compliance of the concert hall and recital spaces. In addition to the 18" step down, on the corridor intersections surrounding the concert hall we are including an 8" stepdown of the slab to accommodate the Pavegen system implemented by the electrical team for an innovative educationally energy opportunity.

Atune's structural team identified the opportunity to employ frost protected shallow footings around the perimeter. This design will reduce the amount of concrete needed for the building and will also help with the mechanical load. Integration is at the fore front of Atune's design considerations. By implementing frost-protected shallow footings, the depth of the grade beams is 36" instead of 42". Since this area of Michigan has such a high soil bearing pressure the bearing and uplift moment on the grade beams have been considered and accounted for in the size and reinforcement of the grade beams. For detailed calculation see S2.5, and for foundation plans and details see S3.4.

8.4 Foundation Design Summary

Atune's structural team chose the frost protected shallow footings over the recommend continuous spread footings due to the increased thermal R-value that they provided the mechanical team. The application of frost protected shallow footings for the exterior grade beam on the Jack H. Miller Center for Musical Arts does not require horizontal insulation. This aids the construction timeline compared to standard frost protected footings. The isolated slab and foundation for the main concert hall will prevent any potential vibrations from the nearby train track from affecting the acoustical performances and comfort of the occupants. Other advantages in cost of less concrete and formwork made the frost protected spread footings the preferred foundation design.

9.0 BUILDING ENCLOSURE DESIGN

The structural team designed an integrated glass façade, with the View Glass System, and brick veneer system. The integrated glass façade will be incorporated into the roof-top amenity space as well.

9.1 Building Enclosure Goals

Atune's goals for building enclosure design were heavily driven by the desire to stay cohesive with the Hope College Campus while still incorporating new design. Atune's structural team integrated heavily with all disciplines in order to set criteria that exceeds industry standards and would optimize the building façade for all disciplines.

9.2 Façade Optimization

Atune developed a façade and roof assembly with improved thermal and moisture performance. Though structural performance was in high regards for the enclosure design, Atune focused on thermal performance, acoustical standards, and construction. The structural team primarily focused on selecting connections that would support the implemented façade components addressed below.

9.2.1 View Dynamic Glass

The atrium and roof top amenity space were a major focus when optimizing the façade. Integration with Atune's electrical team was a critical part in the final decision for the atrium glass facade. View Dynamic Glass was selected in order to decrease mechanical loads and optimize daylighting in the space. The MEP benefits of the design matched by the simplicity of View Glass' product connections made View Glass an obvious choice for the building façade. The glass is triple pane for mechanical and acoustical purposes, with a load of 10 psf. The mullions were sized to support this load. See Electrical Section 7.7 for a detailed explanation of the use of View Glass.

9.2.2 Brick Façade

Unity is important to colleges across the world. A college's architecture plays a large role in making a campus look unified. Atune wanted to select a façade that matched the other buildings on Hope College's campus, which all have a brick and/or limestone façade. Atune chose a red face brick façade with limestone accents for the Jack H. Miller Center for Musical Arts. Instead of using the typical modular brick, a 5/8" face brick will be used. This will maintain the unified campus look while decreasing the building dead load. Wood members do not have a very high capacity compared to steel or concrete, so the smaller dead load from 5/8" bricks played a major role in creating a structural design composed of 90% wood construction.

9.2.3 Hydronic Mullions

Atune's structural team initially considered implementing wood mullions on the west glass façade in order to help the structural team reach the highest percentage of wood construction possible. However, through the IPD method, the team collaborated and determined that the mullions could be put to better use. Atune decided to implement hydronic mullions to help overcome the envelope load. Wood did not work well in conjunction with the hydronic piping, so the structural team decided to implement aluminum mullions. The mullions not only house the hydronic piping, but they complement the dynamic look of the atrium. The structural team sized the aluminum mullions to be 2.5" wide in order to conceal the hydronic piping and support the façade view glass. The IPD method allowed Atune to work together and achieve an ideal mullion design. See Mechanical Section 7.4.2 for a detailed explanation of the hydronic mullions.

9.2.4 Envelope Moisture Mitigation

Atune's wood structure surpasses Hope College's desires, but the design does require some additional concerns to be addressed. Moisture and humidity in a building's cavities can have a negative impact on a wood structure. The presence of moisture can cause wood rot, mold growth, expensive structural repairs, and more. Upon considering this, envelope moisture mitigation was of the utmost importance. Atune's structural and mechanical teams worked together to find a solution for moisture control. The DOAS units throughout the building are used for humidity control to eliminate the presence of moisture in the timber structure. The structural team addressed moisture control through the wall cavity design and the use of flashing. Brick, insulation, an air gap, and waterproofing membranes separate the structure from the outside elements. At the bottom of the structure, flashing was implemented to ensure any moisture that does enter the cavity is transferred back to the exterior of the envelope. Between the solutions utilized by both teams, moisture will not be a structural issue for Hope College's Jack H. Miller Center for Musical Arts.

9.3 Building Enclosure Summary

The façade of the Jack H. Miller Center for Musical Arts is made up of a 5/8" brick veneer with limestone accents and a curtain wall with View Glass and hydronic mullions. The result is an innovative building enclosure that unifies the building with the campus and community while also showcasing its cutting-edge design.

10.0 PROJECT BUDGET & CONSTRUCTABILITY

The integrated project delivery method was vital in order to choose a structural design that addressed construction concerns. The design balanced higher costs with optimized constructability.

10.1 Structural Budget Response

The structural design made up 29% of the project budget, which is just above the typical industry average. The innovative use of timber throughout the entire structure is a unique aspect of Atune's design. This innovation, along with the collaboration between the mechanical and electrical teams resulted in the slight increase in the structural system costs. Based on the goals of Hope College to create a sustainable design, the Atune structural team has justified the use of the timber structure. See Construction Narrative Section 11.0 for a detailed report of the project budget.

10.2 Structural Construction Response

The structural design of the Jack H. Miller Center for Musical Arts is highly coordinated with the construction team. The wood structure is a unique design, so unlike many typical and standard steel buildings, this could result in a slightly longer construction schedule. In order to reduce structural impact to the schedule, the structural team designed a structure that includes a lot of prefabricated components. Through the IPD method, the structural and construction teams were able to collaborate in order to control the lead times as much as possible and have the materials ready upon schedule. The design allows for a quick erection of the building and quick schedule, which is very desirable in order to provide minimal disruption to the college campus and community.

10.3 Value Engineering and Life-Cycle Cost

Value engineering was crucial in the final selection of systems. Atune focused on the balance of maximizing the budget while still exceeding the owner's expectations and requirements for the spaces. Though cost is always an important factor, the Jack H. Miller Center for Musical Arts was designed with three primary concerns that take priority.

The three primary concerns are as follows: acoustical awareness, sustainable design using wood, and a versatile rooftop amenity space. An area where value engineering came into play was in regard to the heavy timber columns. Ideally, the team would've liked to use carbon fiber wrapped columns throughout the entire building in order to increase strength without a large increase in column size. Doing so would've caused a cost increase that the team and owner felt was not justifiable. Instead the columns will only be carbon fiber wrapped in the atrium and under the cooling tower, where truly necessary, rather than throughout the whole building. In the end the team decided that delivering owner desires was more important than cost in many portions of the building, but value engineering was utilized wherever possible to make up for it.

The life-cycle cost of the Jack H. Miller Center for Musical Arts is higher than if the building had been designed as a standard steel or concrete building. The increased life cycle cost of the structure is primarily due to the use of wood throughout all structural systems. The primarily wood design causes a longer construction time and larger construction costs. Wood is also an expensive material that lasts an equal amount of time as other building materials. Atune and the owner recognize the increase in life cycle cost but have considered it a trade-off in order to obtain a truly sustainable structure.

11.0 PROJECT CHALLENGES

Hope College put forth a few design considerations in the form of project challenges. These challenges were created in order to drive the design team to create a building that meet all of Hope College's Music Department's needs. The following is a summary of how the Atune structural team addressed and designed for each design challenge.

11.1 Acoustics

Atune's structural team addressed the acoustics of the building in a couple of different ways. The first acoustically aware decisions were made in the selection of the structural systems. The lateral force resisting system and a large portion of the gravity system is made up of CLT panels. The panels not only provide adequate strength to the structure, but the panels play a huge role in acoustically isolating one space from another. The primary performance spaces are constructed entirely of CLT panels in order to provide as much acoustic isolation through the structure as possible. In addition to an acoustically aware system selection, the structure also had to be designed to support loads from many acoustical panels. The structural load from acoustical panels was of the highest concern in the concert hall. Here, there are motorized acoustical panels that can move in and out based on the current use of the space. When the panels are at their maximum extension length there is a moment induced on the structural walls. Large CLT panels were utilized in these areas in order to take the added force. The structural system not only supports the acoustical panels, but it was also utilized to help create acoustical panels. The scrap wood on site was recycled and used to create effective and sustainable acoustical panels. See Integrated Narrative Section 8.2.2 for a detailed explanation of these panels. It is evident that acoustics were a major concern in the Jack H. Miller Center for Musical Arts. Atune's structural team purposefully tried to address the acoustic concerns in all aspects of design.

11.2 Wood, Timber, and Engineered Wood

Atune's Structural team was challenged to create a building consisting of 25% wood construction. The team quickly surpassed this goal and achieved a structural design of 90% wood construction. The design takes advantage of every opportunity to incorporate wood in the structure. The Jack H. Miller Center for Musical Arts is now one of the only buildings in the United States in which every structural system is composed primarily of wood. Atune & Hope College both felt that education of wood design is important. The structural team collaborated with the electrical team to educate the occupants about the sustainability of the structure. This was done through using lighting to highlight the structure and implementing an interactive display that educated the occupants on sustainability. See Electrical Narrative Section 8.3.4 for a detailed explanation of their plan to educate the occupants on structural sustainability, along with other areas of sustainable design.

11.3 Roof Top Amenity Space

Atune decided to replicate the look of the atrium in the design of the rooftop amenity space. The versatile space has been designed to be used year-round. The space will have the ability to be open during the summer months and enclosed during the winter months. The enclosure will be made primarily of glass accordion walls in order to give the space an outdoor feel at all times of the year. The structural team had to strategically place columns in order to avoid obstructing the view or the flow of the space. Additionally, the snow load in Holland is substantial, so Atune decided to utilize a radiant slab system in order to provide snow melt. The Atune team worked to implement a composite deck tile for the portion of the roof-top amenity space that will always be outdoors. These roof/deck tiles easily interlock creating a uniform floor, while also improving all future maintenance of the roof structure and the slab-melt system in the amenity space. The amenity space required a lot of team coordination and the result was a beautiful and versatile amenity space. See I3.5 for the rooftop amenity space floor plans.

12.0 LESSONS LEARNED

Through this design competition, the structural team discovered the true importance of team collaboration and design iteration. Each individual member brought skills and ideas to the table that, when combined with other members, created a diverse team and thought process that resulted in a better overall design. Team collaboration then spurred iterative design processes. A design would be selected by one individual and then reviewed and refined by another until eventually the final product was the best possible iteration. The use of individual's skills paired with design values and iterations produces the best final product.

13.0 CONCLUSION

The structural team focused on designing a structural system that satisfied Hope College's needs and met Atune's design goals. The final design accomplished Atune's goals in the ways discussed below.

13.1 Versatility

Hope College wanted Jack H.Miller Center for Musical Arts to be a building that could accommodate both the college and the community. Versatility was created as a design goal to help create a building that could be used for many functions by many people. This goal also applies to the multi-purpose use of systems and designs. The structural team accomplished this goal in a couple of different ways. In relation to the structural system itself, the team implemented CLT panels that would act as both the gravity and lateral systems, while also providing acoustical isolation. Regarding the variable use of the spaces, the structural team primarily implemented versatility in the rooftop amenity space. The space was designed to be open or closed while still feeling like an outdoor space year-round. To accomplish this the structural team has implemented a design with movable glass accordion walls and a minimal number of columns. The structural team also implemented the slab melt system here so that snow throughout the rear would not affect the use of the space. Through the implementation of the previous items discussed, the structural team was able to obtain an adequate level of versatility.

13.2 Sustainability

The final structural design was composed of 90% timber construction. The structural system utilized wood that is Forest Stewardship Council (FSC) approved. The design primary design implements glulams, CLT panels and wood stud framing. To further the impact of the sustainable design even more, the structural team has worked closely with the electrical team to display the structural design and educate occupants about sustainability. A wood structure was desired by both Atune and Hope College in order to achieve sustainably. Atune is confident this goal was achieved through the structural design. See I3.4 for a report of carbon reductions as a result of 90% wood construction.

13.3 Harmony

Atune chose harmony as a design goal in order to achieve a collective design for the Jack H. Miller Center for Musical Arts. The team used an integrated project delivery method in order to achieve harmony throughout the building design. This delivery method allowed the team to work together and choose a decision matrix that would guide the entire team's design decisions. The creation of the matrix was an act of harmony that then spurred more collaboration. The structural team's design required coordination with other teams at many different points during the design process. The team worked with the acoustical designer in order to select structural systems that not only provided adequate structural capacity but also aided in the acoustical isolation of spaces. Atune's structural and mechanical teams' primary collaboration was related to the foundation and underfloor air distribution system. The mechanical team's implementation of this system required the structural team to drop the foundation slab 18" in certain areas. The electrical team also caused a dropped slab in certain areas due to the Pavegen system they utilized. The electrical team made the decision to place solar panels on the roof, which then required coordination to properly place the panels and account for the additional structural load. Coordination with the construction team was important from start to finish. Working with the construction team helped the structural team figure out what designs were possible and practical. The collaboration was also necessary to work out prefabrication and building erection concerns. The integrated project delivery method and the decision matrix made these harmonized decisions possible across the different discipline design teams. Through all of these collaboration points, Atune was able to achieve a desired level of building harmony.

DECISION MATRIX & SYSTEM SELECTIONS

STRUCTURAL DECISION MATRIX

Atune began the design process by selecting three design drivers: harmony, sustainability, and versatility. The team created a decision matrix to ensure that the design drivers were considered in every design decision made. The decision matrix below was used to select the best structural system for every aspect of the Jack H. Miller Center for Musical Arts.

STRUCTURAL DECISION MATRIX

	VERSATILITY				SUSTAINABLILITY				HARMONY				
	FLEXIBILITY IN USE	ROOM FOR GROWTH	ACOUSTICALLY ADAPTABILITY	AESTHETIC EFFECTIVENESS	LONG LIFESPAN	MAINTNANCE COST	ENVIRONMENTAL IMPACT	EDUCATION TO PUBLIC	MULTIPURPOSE DESIGN	SCHEDULE	BUILDING FACADE	CONSTRUCTABILITY	
ATRIUM													
WEIGHT	4	2	5	3	5	3	4	4	3	4	1	5	
HEAVY TIMBER BEAMS & COLUMNS	4	6	10	9	15	15	20	12	6	12	1	15	125
CLT W/ HEAVY TOPPING & HEAVY TIMBER COLUMNS	16	6	20	9	15	12	16	16	12	8	1	15	141
CLT W/ HEAVY TOPPING & CARBON WRAPPED TIMBER COLUMNS	16	6	20	12	15	12	16	16	12	8	1	15	149
CLT PANELS	12	6	20	6	15	15	16	8	9	8	1	5	121
HEAVY TIMBER BRACED FRAMES	8	6	5	9	15	15	16	8	6	12	1	15	116
HEAY TIMBER MOMENT FRAMES	12	6	5	6	15	15	16	4	9	12	1	15	116
STRUCTURALLY INSULATED PANELS	4	6	20	3	15	12	12	4	3	8	1	5	93
ZIPPER TRUSS	20	6	5	15	15	15	12	16	15	4	1	5	129
PERFORMANCE & REHEARSAL SPACES													
WEIGHT	4	2	5	3	5	3	4	4	3	4	1	5	
HEAVY TIMBER BEAMS & COLUMNS	4	6	10	9	15	15	20	12	6	12	1	15	125
CLT W/ HEAVY TOPPING & HEAVY TIMBER COLUMNS	16	6	20	9	15	12	16	16	12	8	1	15	141
CLT W/ HEAVY TOPPING & CARBON WRAPPED TIMBER COLUMNS	16	6	20	12	15	12	16	16	12	8	1	15	149
CLT PANELS	20	6	20	9	15	15	16	4	15	8	1	5	134
HEAVY TIMBER BRACED FRAMES	8	6	5	9	15	15	16	8	6	12	1	15	116
HEAY TIMBER MOMENT FRAMES	12	6	5	6	15	15	16	4	9	12	1	15	116
STRUCTURALLY INSULATED PANELS	4	6	20	3	15	12	12	4	3	8	1	5	93
ZIPPER TRUSS	16	6	5	6	15	15	12	12	12	4	1	5	109
CLASSROOM & OFFICE SPACES													
WEIGHT	4	2	5	3	5	3	4	4	3	4	1	5	
HEAVY TIMBER BEAMS & COLUMNS	4	6	10	9	15	15	20	12	6	12	1	15	125
CLT W/ HEAVY TOPPING & HEAVY TIMBER COLUMNS	16	6	20	9	15	12	16	16	12	8	1	15	143
CLT W/ HEAVY TOPPING & CARBON WRAPPED TIMBER COLUMNS	16	6	20	12	15	9	12	16	12	8	1	15	142
CLT PANELS	20	6	20	9	15	15	16	4	15	8	1	5	134
HEAVY TIMBER BRACED FRAMES	8	6	5	9	15	15	16	8	6	12	1	15	116
HEAY TIMBER MOMENT FRAMES	12	6	5	6	15	15	16	4	9	12	1	15	116
STRUCTURALLY INSULATED PANELS	12	6	25	3	15	12	12	4	12	8	1	5	115
ZIPPER TRUSS	16	6	5	6	15	15	12	12	12	4	1	5	109
FOUNDATION SYSTEM													
WEIGHT	4	2	5	3	5	3	4	4	3	4	1	5	
CONTINUOUS SPREAD FOOTING	4	4	5	3	15	3	8	4	9	12	1	15	83
FROST PROTECTED SPREAD FOOTING	12	2	5	3	15	3	16	4	15	8	1	10	94
ISOLATED SPREAD FOOTING	4	6	5	3	15	3	8	4	9	12	1	15	85

SYSTEM SELECTIONS

Based on the decision matrix Atune selected the following structural systems for the Jack H. Miller Center for Musical Arts.

FRAMING SYSTEM SELECTION

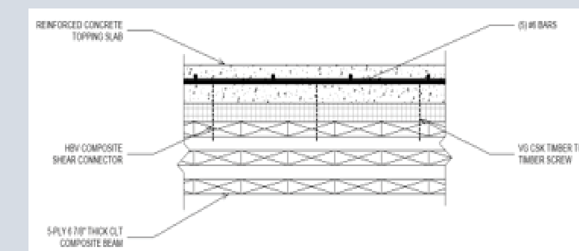
Frost protected shallow footings were selected due to the mechanical and construction advantages discussed.

GLULAM COLUMNS & BEAMS

FLOOR SYSTEM SELECTION

The composite action between the CLT and the concrete allows Atune to achieve the longer spans found in the building.

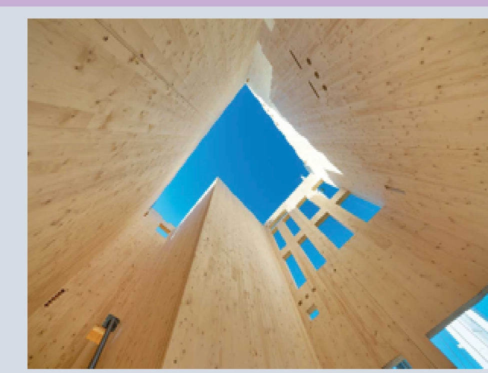
CLT W/ HEAVY TOPPER



SPECIALTY SYSTEM SELECTION

CLT tilt-up walls were selected because of their ability to take gravity and lateral loads in addition to acoustical advantages.

CLT TILT-UP WALL PANELS



FOUNDATION SYSTEM SELECTION

Frost protected shallow footings were selected due to the mechanical and construction advantages discussed.

FROST PROTECTED SHALLOW FOOTINGS

GENERAL DESIGN PARAMETERS

GRAVITY LOADS

DEAD LOADS

ROOF DEAD LOAD	120 psf
FLOOR DEAD LOAD	100 psf
WALL DEAD LOAD (CLT PANELS)	75 psf
WALL DEAD LOAD (WOOD FRAMING)	50 psf

SNOW LOADS

SNOW DESIGN PARAMETERS	
GROUND SNOW LOAD, p_g	50 psf
RISK CATEGORY	III
IMPORTANCE FACTOR, I_s	1.1
THERMAL FACTOR, C_t	1.0
EXPOSURE CONDITION	Fully Exp.
EXPOSURE FACTOR, C_e	0.9
TERRAIN FACTOR	C
SLOPED ROOF FACTOR, C_s	1.0

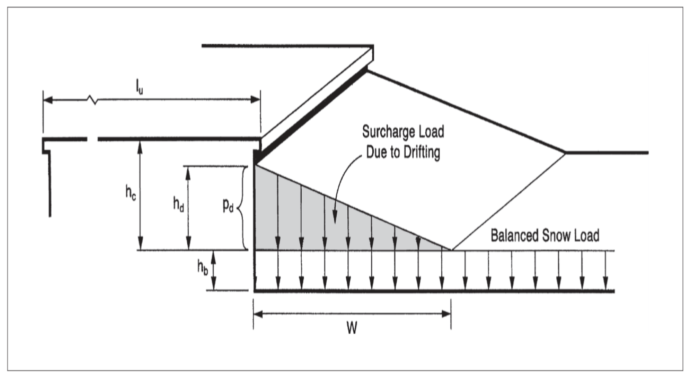
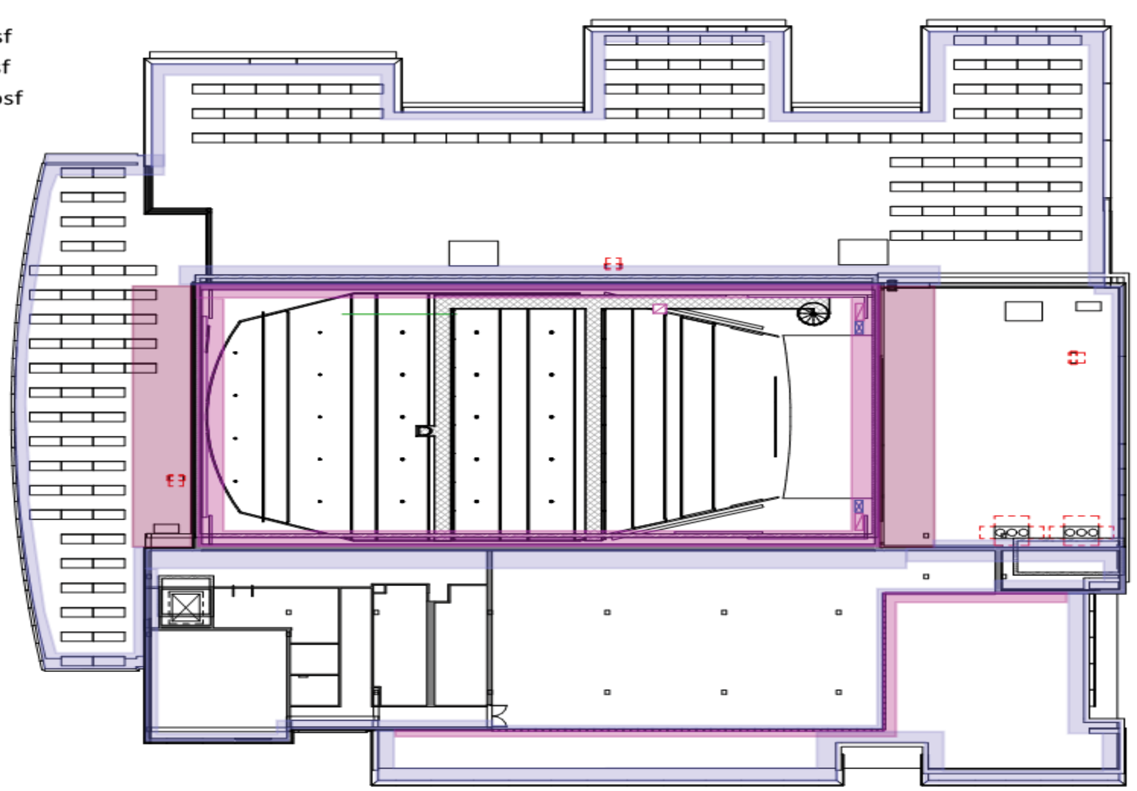


FIGURE 7-8 Configuration of Snow Drifts on Lower Roofs.

SNOW DRIFT LOAD KEY
- 67 psf
- 83 psf
- 101 psf



SNOW DRIFT LOADING MAP

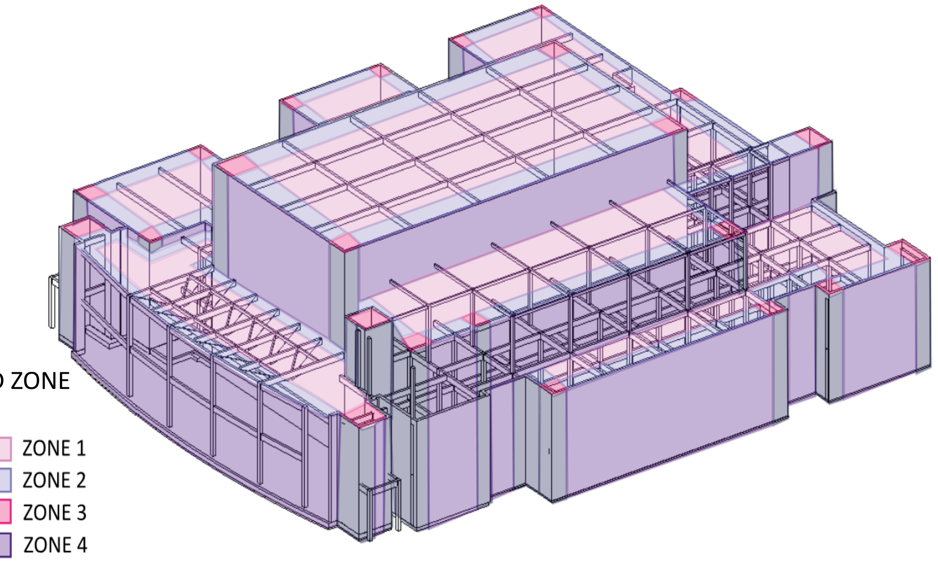
LIVE LOAD MAPPING: SEE S3.2

LATERAL LOADS

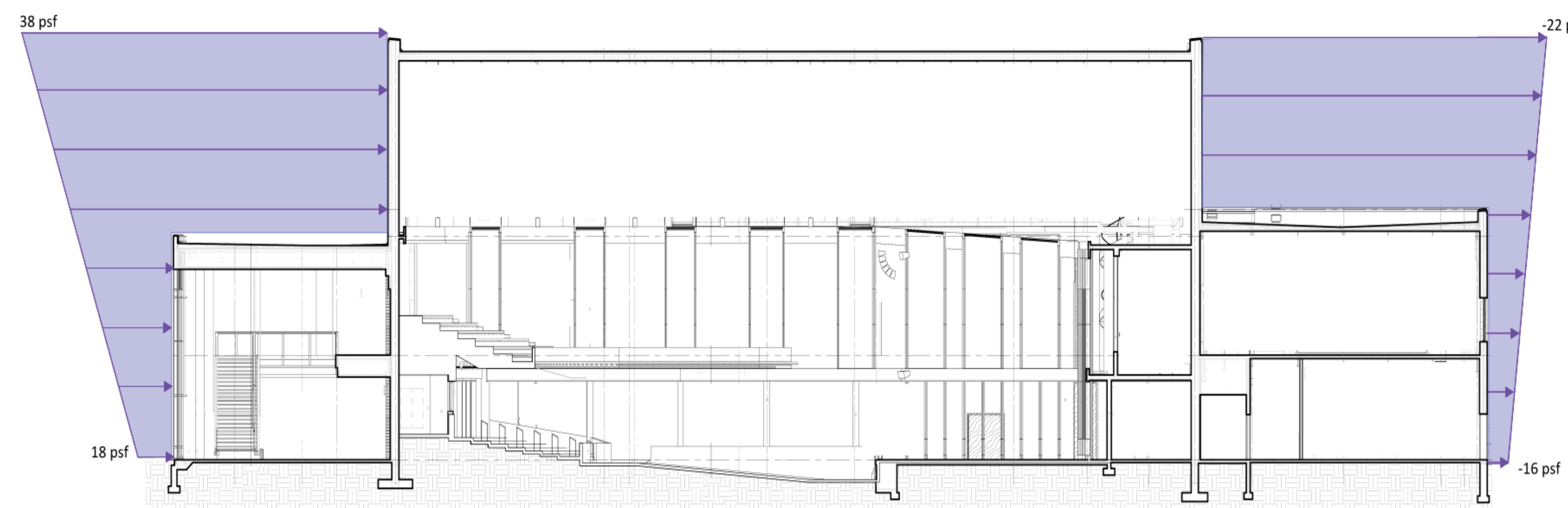
WIND LOADS

WIND DESIGN PARAMETERS	
WIND SPEED, V	120 mph
RISK CATEGORY	III
EXPOSURE CATEGORY	C
ENCLOSURE CLASSIFICATION	Enclosed
INTERNAL PRESSURE	+/- 0.18
DIRECTIONAL FACTOR, K_d	0.85
TOPOGRAPHIC FACTOR, K_{zt}	1.0
ROOF TYPE	Flat
MEAN ROOF HEIGHT, h	49'0"
STRUCTURE TYPE	Rigid
GUST EFFECT FACTOR, G	0.85
WIND BASE SHEAR, V_b	463 k

LOAD ZONE KEY
- ZONE 1
- ZONE 2
- ZONE 3
- ZONE 4
- ZONE 5



COMPONENTS & CLADDING LOADING MAP



WORSE CASE WINDWARD LOADING MAP

SEISMIC LOADS

SEISMIC DESIGN PARAMETERS	
SITE CLASS	D
SPECTRAL RESPONSE ACCEL. PARAMETER - SHORT PERIOD, S_S	0.092
SPECTRAL RESPONSE ACCEL. PARAMETER - 1 SECOND, S_1	0.044
SHORT PERIOD SITE COEFFICIENT, F_a	1.6
LONG PERIOD SITE COEFFICIENT, F_v	2.4
SPECTRAL RESPONSE ACCEL. PARAMETER - SHORT PERIOD, S_{MS}	0.147
SPECTRAL RESPONSE ACCEL. PARAMETER - 1 SECOND, S_{M1}	0.106
DESIGN SPECTRAL RESPONSE ACCEL. PARAMETER - SHORT PERIOD, S_{DS}	0.098
DESIGN SPECTRAL RESPONSE ACCEL. PARAMETER - SHORT PERIOD, S_{D1}	0.070
RISK CATEGORY	III
DESIGN CATEGORY	B
SEISMIC BASE SHEAR, V_b	319 k

GOVERNING LATERAL LOAD: WIND

The Atune structural team checked the wind and seismic loading conditions for Holland, MI. The Jack H. Miller Center for Musical Arts is a risk category III building.

The maximum average wind speed is 120 mph, with an exposure category of C. The structure was assumed to be rigid with the mean roof height at 49'0", between the upper roof of the auditorium and the lower roof of the rest of the building. The wind base shear was calculated to be 463 kips.

The seismic site class of the building was assumed to be D and the desigh category was B. The seismic base shear was calculated to be 319 kips.

All loads were calculated per ASCE 7-05 and ASCE 7-10.

FRAMING DESIGN CALCULATIONS

GLULAM COLUMNS

The glulam columns were sized based on the worst case loading seen in the floor bays. Applicable Code: NDS-2015

First Level Framing:
Colum Dimensions = 16" x 21"

Second Level Framing:
Column Dimensions = 16" x 21"

Roof Top Amenity Framing:
Column Dimensions = 12" x 16.5"

TYPICAL COLUMN SIZE

Column Load Parameters

Height =	16	ft	Dead Load =	200	psf
Trib Width =	11	ft	Live Load =	270	psf
Trib Length =	20	ft	Snow Load =	36	psf
Trib Area =	220	ft^2	Roof Live Load =	20	psf
			Wind Load =	30	psf

Governing Load Combo for Axial: D+L → C_D = 1.0
P_r = 103.4 kips
Governing Load Combo for Bending: D+0.6W → C_D = 1.6
W_u = 8.86 klf
P_r = 94.49 k
M_r = 212.64 k-in

Stress Grade and Species: Western Species, 26F-V2 (26F-1.9E), DF/DF

E_x =	2000	ksi	E_y =	1800	ksi
E_{xmin} =	1060	ksi	E_{ymin} =	950	ksi
$F_{c\perp x}$ =	650	psi	$F_{c\perp y}$ =	560	psi
F_{bx} =	2600	psi	F_{by} =	1850	psi
F_{vx} =	265	psi	F_{vy} =	230	psi
F_c =	1850	psi	F_t =	1350	psi

Axial Design Checks

$f_c' \le F_c' = F_c C_D C_M C_t C_p$

Compression Parrallel to Grain	F_c =	1850	psi
Load Duration Factor	C_D =	1	
Wet Service Factor	C_m =	0.73	
Temperature Factor	C_t =	1.0	
Column Stability Factor	C_p =	0.7	(Assumption)

F'_c = 945.35 psi E'_{min} = 773800 psi

$f_c = \frac{P_r}{A}$ → $A = \frac{P_r}{F_c'}$ = 109.377 in^2

Net Finished Width = 14.25 in
Net Finished Depth = 21 in → A = 299.25 in^2

$$C_p = \frac{1+\left(F_{cE}/F_c^*\right)}{2c} - \sqrt{\left[\frac{1+\left(F_{cE}/F_c^*\right)}{2c}\right]^2 - \frac{F_{cE}/F_c^*}{c}} = 0.56634$$

$$F_{cE} = \frac{0.822E'_{min}}{(l_e/d)^2} = 3503.71 \text{ psi} \qquad \frac{l_e}{d} = 13.4737 < 50$$

c = 0.9 for structural glued laminated members
F^*_c = 1350.5 psi
F'_c = 764.842 psi With Adjusted C_p

$A_{req'd} = \frac{P}{F_c'}$ = 76.5642 in^2

$f_{c\,actual} = \frac{P}{A}$ = 345.53 psi ≤ $F_c' = F_c C_D C_M C_t C_p$ = 764.842 psi

$\frac{f_c'}{F_c'} \le 1.0$ → $\frac{f_c'}{F_c'}$ = 0.45177 < 1.0 OKAY

Axial & Bending Design Checks

$f_c' \le F_c' = F_c C_D C_M C_t C_p$

Compression Parrallel to Grain	F_c =	1850	psi
Load Duration Factor	C_D =	1.6	
Wet Service Factor	C_m =	0.73	
Temperature Factor	C_t =	1.0	
Column Stability Factor	C_p =	0.7	(Assumption)

F'_c = 1512.56 psi E'_{min} = 773800 psi

$f_c = \frac{P_r}{A}$ → $A = \frac{P_r}{F_c'}$ = 62.4702 in^2

Net Finished Width = 14.25 in
Net Finished Depth = 24 in → A = 342 in^2

$$C_p = \frac{1+\left(F_{cE}/F_c^*\right)}{2c} - \sqrt{\left[\frac{1+\left(F_{cE}/F_c^*\right)}{2c}\right]^2 - \frac{F_{cE}/F_c^*}{c}} = 0.53112$$

Bending about X-X Axis	F_b =	2600	psi
Load Duration Factor	C_D =	1.6	
Wet Service Factor	C_m =	0.8	
Temperature Factor	C_t =	1.0	
Beam Stability Factor*	C_L =	0.99	Calculated Below
Volume Factor*	C_v =	0.87	Calculated Below GOVERNS
Flat Use Factor	C_{fu} =	1.0	
Curvature Factor	C_c =	1.0	No curvature
Stress Interaction Factor	C_I =	1.0	Rectangular

Area of Section	A =	299.25	in^2
Section Modulus	S_x =	1368	in^3
Moment of Inertia	I_x =	16416	in^4

$$C_L = \frac{1+\left(\frac{F_{be}}{F_b}\right)}{1.9} - \sqrt{\left[\frac{1+\left(\frac{F_{be}}{F_b}\right)}{1.9}\right]^2 - \frac{\left(\frac{F_{be}}{F_b}\right)}{0.95}} = 0.98915$$

$\ell_e = 1.63\ell_u + 3d$ = 384.96 in

$$F_{be} = \frac{1.20E'_{y\,min}}{{R_B}^2} = 18290.7 \text{ psi} \qquad R_B = \sqrt[2]{\frac{\ell_e d}{b^2}} = 6.74526$$

$$C_v = \left(\frac{21}{L}\right)^{1/x}\left(\frac{12}{d}\right)^{1/x}\left(\frac{5.125}{b}\right)^{1/x} = 0.86556 \le 1.0 \therefore \text{OK}$$

$f_{bx} = \frac{M_r}{S_x}$ = 1865.26 psi < F_{bx}' = 2880.57 psi

$\frac{f_b'}{F_b'} \le 1.0$ → $\frac{f_b'}{F_b'}$ = 0.64753 < 1.0 OKAY

COMBINED AXIAL & BENDING

f_b =	1865.26 psi	f_c =	276.287 psi		
F_b' =	2880.57 psi	F_c' =	1147.65 psi	$F_{cEx} = \frac{0.822E'_{min}}{[(l_e/d)_x]^2}$	
		F_{cEx} =	2472.25 psi		

$\left(\frac{f_c}{F_c'}\right)^2 + \left(\frac{1}{1-f_c/F_{cEx}}\right)\frac{f_b}{F_b'} \le 1.0$ → 0.78696 < 1.0 OKAY

CARBON FIBER WRAPPED GLULAM COLUMNS

The composite columns were sized based on the worst case loading expected to be seen in the atrium. Applicable Code: NDS-2015

TYPICAL COLUMN SIZE

Column Load Parameters

Height =	32	ft	Dead Load =	75	psf
Trib Width =	25	ft	Live Load =	0	psf
Trib Length =	17.5	ft	Snow Load =	35	psf
Trib Area =	437.5	ft^2	Roof Live Load =	20	psf
			Wind Load =	30	psf

Governing Load Combo for Axial: D+L → C_D = 1.0
P_r = 50.2031 kips
Governing Load Combo for Bending: D+0.6W → C_D = 1.6
W_u = 2.00813 klf
P_r = 44.2969 k
M_r = 96.39 k-in

Stress Grade and Species: Western Species, 26F-V2 (26F-1.9E), DF/DF

E_x =	2000	ksi	E_y =	1800	ksi
E_{xmin} =	1060	ksi	E_{ymin} =	950	ksi
$F_{c\perp x}$ =	650	psi	$F_{c\perp y}$ =	560	psi
F_{bx} =	2600	psi	F_{by} =	1850	psi
F_{vx} =	265	psi	F_{vy} =	230	psi
F_c =	1850	psi	F_t =	1350	psi

Axial Design Checks

$f_c' \le F_c' = F_c C_D C_M C_t C_p$

Compression Parrallel to Grain	F_c =	1850	psi
Load Duration Factor	C_D =	1	
Wet Service Factor	C_m =	0.73	
Temperature Factor	C_t =	1.0	
Column Stability Factor	C_p =	0.7	(Assumption)

F'_c = 945.35 psi E'_{min} = 773800 psi

$f_c = \frac{P_r}{A}$ → $A = \frac{P_r}{F_c'}$ = 53.1053 in^2

Net Finished Width = 10.5 in
Net Finished Depth = 11 in → A = 115.5 in^2

$$C_p = \frac{1+\left(F_{cE}/F_c^*\right)}{2c} - \sqrt{\left[\frac{1+\left(F_{cE}/F_c^*\right)}{2c}\right]^2 - \frac{F_{cE}/F_c^*}{c}} = 0.19251$$

$$F_{cE} = \frac{0.822E'_{min}}{(l_e/d)^2} = 475.572 \text{ psi} \qquad \frac{l_e}{d} = 36.5714 < 50$$

c = 0.9 for structural glued laminated members
F^*_c = 1350.5 psi
F'_c = 259.989 psi With Adjusted C_p

$A_{req'd} = \frac{P}{F_c'}$ = 37.1737 in^2

$f_{c\,actual} = \frac{P}{A}$ = 434.659 psi ≤ $F_c' = F_c C_D C_M C_t C_p$ = 259.989 psi

$\frac{f_c'}{F_c'} \le 1.0$ → $\frac{f_c'}{F_c'}$ = 1.67184 > 1.0 NOT OK

Axial & Bending Design Checks

$f_c' \le F_c' = F_c C_D C_M C_t C_p$

Compression Parrallel to Grain	F_c =	1850	psi
Load Duration Factor	C_D =	1.6	
Wet Service Factor	C_m =	0.73	
Temperature Factor	C_t =	1.0	
Column Stability Factor	C_p =	0.2	(Assumption)

F'_c = 432.16 psi E'_{min} = 773800 psi

$f_c = \frac{P_r}{A}$ → $A = \frac{P_r}{F_c'}$ = 102.501 in^2

Net Finished Width = 10.5 in
Net Finished Depth = 11 in → A = 115.5 in^2

$$C_p = \frac{1+\left(F_{cE}/F_c^*\right)}{2c} - \sqrt{\left[\frac{1+\left(F_{cE}/F_c^*\right)}{2c}\right]^2 - \frac{F_{cE}/F_c^*}{c}} = 0.08546$$

$$F_{cE} = \frac{0.822E'_{min}}{(l_e/d)^2} = 475.572 \text{ psi} \qquad \frac{l_e}{d} = 36.5714 < 50$$

c = 0.9 for structural glued laminated members
F^*_c = 2160.8 psi
F'_c = 184.666 psi With Adjusted C_p

$A_{req'd} = \frac{P}{F_c'}$ = 20.5002 in^2

$f_{c\,actual} = \frac{P}{A}$ = 383.523 psi ≤ $F_c' = F_c C_D C_M C_t C_p$ = 184.666 psi

$\frac{f_c'}{F_c'} \le 1.0$ → $\frac{f_c'}{F_c'}$ = 2.07685 > 1.0 NOT OK

$f_b \le F_b' = F_b C_D C_M C_t C_L C_v C_{fu} C_c C_I$

$\left(\frac{f_c}{F_c'}\right)^2 + \left(\frac{1}{1-f_c/F_{cEx}}\right)\frac{f_b}{F_b'} \le 1.0$ → 3.93609 > 1.0 NOT OK

Carbon Fiber Wrap

Elastic modulus	E	=	26250	ksi
Ult. Tensile Strength	σ	=	217.6	ksi
Strain	ε	=	0.00829	
Thickness of wrap	t	=	0.125	in
Column perimeter	P	=	43.00	in
Total area of wrap	A	=	5.4	in^2

Glulam Strain

Stress	σ	=	5000	psi
Elastic modulus	E	=	2000	ksi
Strain	ε	=	0.00250	

Composite Modulus of Elasticity

Glulam Area	A_g	=	116	in^2
Glulam Elastic Modulus	E_g	=	2000	ksi
Carbon Wrap Area	A_c	=	5.38	in^2
Carbon Elastic Modulus	E_c	=	26250	ksi
Composite Area	A_c	=	121	in^2

$E_{comp} = \frac{(A_g E_g + A_c E_c)}{(A_g + A_c)}$ = 2551 ksi

Stain Compatability

$\sigma_{max} = \sigma_{comp} = E * \varepsilon$ = 66 ksi

$\left(\frac{f_c A_g}{F_c' A_g + \sigma_{comp}\frac{A_{comp}}{2}}\right)^2 + \left(\frac{1}{1-f_c/F_{cEx}}\right)\frac{f_b}{F_b'}$ = 0.84481 < 1 OK

CLT PANEL DESIGN CALCULATIONS

CLT TILT-UP WALLS

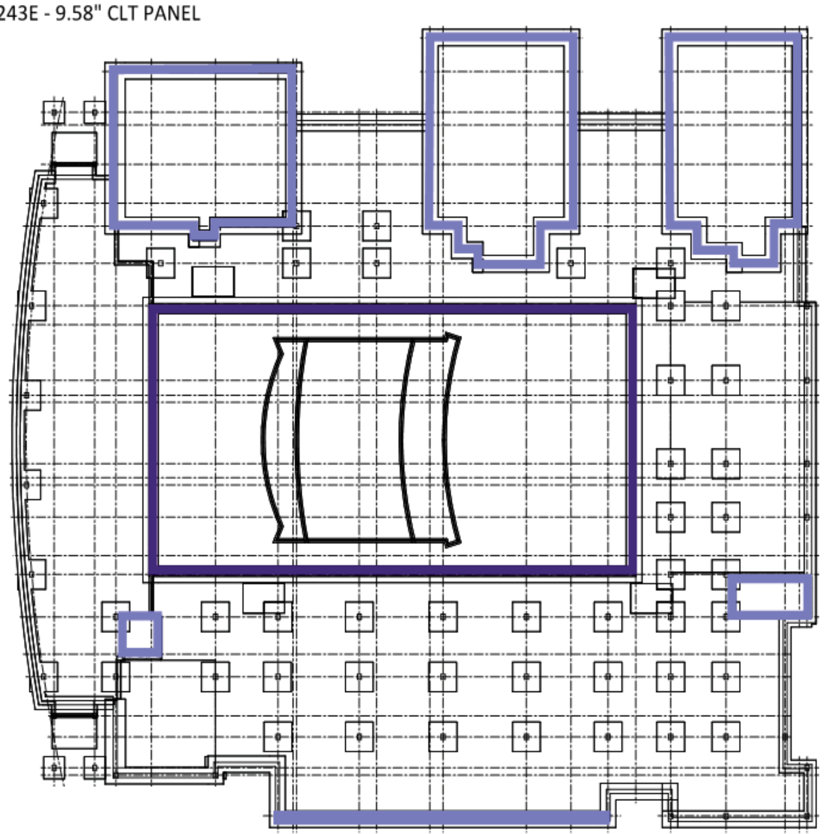
The CLT wall panels were sized based on the worst case loading seen by auditorium and performance halls.

The main auditorium design is a 315E Crosslam Panel:
- Panel Thickness = 12.42”
- CLT Layer Thickness = 1.38” (9 Layers)

The performance space design is 243E Crosslam Panel:
- Panel Thickness = 9.58”
- CLT Major Layer Thickness = 1.38” (5 Layers)
- CLT Minor Layer Thickness = 0.67” (4 Layers)

Required Brackets:
4DA *(4 Brackets Both Sides - Double All)*

CLT PANEL SIZE KEY
- 315E - 12.5" CLT PANEL
- 243E - 9.58" CLT PANEL



MAP OF CLT PANEL PLACEMENT

AUDITORIUM CLT WALL PANELS

Applied Loads

LL = 20 psf
PV Cells = 4 psf
Concrete = (115 pcf)*(3"/12')
= 28.8 psf
Snow = 83 psf *NOTE: Worse Case Drift
TOTAL = 136 psf
= **9638 plf EW**
= **19277 plf NS**

Material Properties

Panel Width = 10 ft E = 1800000 psi
Douglas Fir
Max width of crosslam layers = 1.38 in
CD = 1.15

315E CrossLam CLT Panel

Design Checks

Diaphragm Aspect Ratio

N/S Walls	E/W Walls
L/W = 2.22 < 4	L/W = 1.11 < 4

Governing Lateral Loads - Wind

N/S Walls	E/W Walls
q = 35.9 psf	q = 35.91 psf
VW = (35.91)(62)(142/2)	VW = (35.91)(62)(71/2)
= 158076 lbs	= 79037.9 lbs
vw = 4649 plf	vw = 2324.6 plf

Panel Allowable In-Plane Shear Capacity

N/S Walls	E/W Walls
Vr = 23428 plf	Vr = 23428 plf
Vr > vw OKAY	Vr > vw OKAY

Panel Allowable Shear at Routed Section

V = [(1.38)(10 - width)(160 - Fv)(1.15 - CD)]/1.5

N/S Walls	E/W Walls
V = 1693 plf	V = 1693 plf

Diaphragm Chords

Chord Width = 31.5 in *(Assumed)*

N/S Walls	E/W Walls
Check @ X1 = 52.5 ft	Check @ X1 = 23.5 ft
@ X2 = 87.5 ft	@ X2 = 59.5 ft

d = [(64)(12)-(2)(12.6)-(2)(13.75)]/12
= 59.6 ft

N/S Walls	E/W Walls
Diaphragm Moment	*Diaphragm Moment*
@X1 = (35.91)(62)(142-52.5)(52.5)/2	@X1 = (35.91)(62)(71-23.5)(23.5)/2
= -29222 lb*ft	= 1242621 lb*ft
@ X2= (35.91)(62)(142^2)/8	@ X2= (35.91)(62)(71^2)/8
= 5611692 lb*ft	= 1402923 lb*ft
Chord Force = M/d	*Chord Force* = M/d
@X1 = 298627.6/59.6	@X1 = 298627.6/59.6
= -490.23 lbs	= 20846.43 lbs
@ X2= 388402.6/59.6	@ X2= 388402.6/59.6
= 94142.7 lbs	= 23535.7 lbs

Tension Capacity

CD = 1.15
FT0 = 1575 psi
F'T0 = (1.15)(1575)
= 1811 psi

APARALLEL = (5)(1.38)(31.5)
= 217 in^2
TPARALLEL = (F'T0)(APARALLEL)
= 393675 lbs

Bending Capacity

WDL = (28.8psf - Self Weight)+(20psf - DL)+(40 - Catwalk) + (3.7 - Aco. Panels)
= 92.5 psf

MALLOW = 30838 (lbs*ft)/ft
MDL = 893.72 (lbs*ft)/ft

Bending & Axial Tension

N/S Walls	E/W Walls
= 0.00651 < 1	= 0.00163 < 1

Compression

Unbraced Length = 408 in
EIeff0 = 2,314,000,000 (lb*in^2)/ft
GAeff0 = 2,100,000 lb/ft
Fc0 = 1875 psi
Ks = 11.5

$$EI_{app} = \frac{EI_{eff}}{1+\frac{K_s EI_{eff}}{GA_{eff}L^2}} = \frac{2314000000}{1+\frac{(11.5)(2314000000)}{(2100000)(120)^2}}$$

EIapp = 2150309825 (lb*in^2)/ft
EIapp-min = 0.5184*EIapp
= 1114720613 (lb*in^2)/ft

$$P_{cE} = \frac{\pi^2 EI_{app-min}}{l_e^2}$$

PcE = 66024.4819 lb/ft

$$P_c^* = F_{c0}C_D A = (1875)*(1.15)*(1.38*5*12)$$

Pc* = 178537.5 lb/ft

$$C_p = \frac{1+\left(\frac{P_{cE}}{P_c^*}\right)}{2c} - \sqrt{\left[\frac{1+\left(\frac{P_{cE}}{P_c^*}\right)}{2c}\right]^2 - \frac{\frac{P_{cE}}{P_c^*}}{c}}$$

Cp = 0.2913

$$P_{ALLOW} = C_P F_{C0} C_D A = (0.9542)*(1875)*(1.15)*(1.38*5*12)$$

PALLOW = 52005.5155 lb/ft

Factored Total
PALLOW = 136514.478 lb/ft
PcE = 173314.265 lb/ft

Combined Bending & Compression

$$\left[\frac{P}{P_{ALLOW}}\right]^2 + \frac{M}{M_{ALLOW}\left(1-\frac{P}{P_{cE}}\right)}$$

N/S Walls	E/W Walls
= 0.61567417	= 0.06420141

Strength Level Diaphragm Wind Deflection

-Deflection Due to Bending

$$\delta = \frac{5vL^3}{8EAW}$$

N/S Walls	E/W Walls
δ = 0.00166 in	δ = 0.00083 in

-Deflection Due to Shear

E0 = 1800000 psi

K = 14735 lb/in^3
b = 8.52 in
m = 15
nCA = 2

$$G_{eff,CA} = \frac{Kb^2 n_{CA} m^2}{5t_{gross}(m^2+1)}$$

Geff,CA = 33805.927 psi
Glam = E0/16 = 112500 psi

$$G_{eff,CLT} = \left(\frac{1}{G_{lam}} + \frac{1}{G_{eff,CA}}\right)^{-1}$$

Geff,CLT = 25994.619 psi

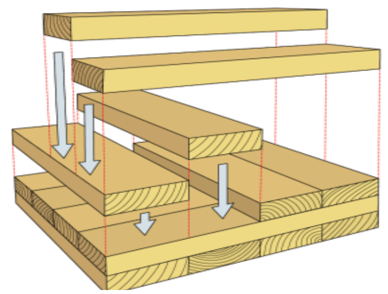
$$\delta = \frac{vL}{4G_v t_v} \qquad v = \frac{wL}{2B} \qquad t_v = \frac{A}{B}$$

N/S Walls	E/W Walls
v = 556.61	v = 1113.21
tv = 64	tv = 64
δ = 0.04175 in	δ = 0.08351 in

TOTAL δ

N/S Walls	E/W Walls
δ = 0.04341 in	δ = 0.08434 in

PANEL IS GOOD



GRAPHIC OF CLT ASSEMBLY

Applicable Code: CLT Handbook, SDPWS-2015, CrossLam Design Guide 2018

FOUNDATION DESIGN CALCULATIONS

ISOLATED SPREAD FOOTING

The isolated spread footings were designed for the worse case loading scenario in the typical bay size. The allowable soil pressure is 4500 psf.

Isolated Spread Footings: 8' x 8' x 30"
8 #8 T&B Both Directions
Applicable Code: ACI 318-2008

SPREAD FOOTING FOUNDATION

Footing Dimensions

$$Area\ of\ Footing = \frac{Total\ Service\ Load}{Allowable\ Soil\ Pressure}$$

DL ONLY
→ Area of Footing = 35.09 ft^2
Square Footing
→ L = B = 5.92 ft = **8.00 ft**
→ h = 30 in

Footing Stability

$$q_u = \frac{\sum P_u}{Area}$$

Load Case 1 = 1.4D = 1.4*(200*336)
qu = 2681.19 psf
qu = 2.68 ksf
Load Case 2 = 1.2D + 1.6L = [1.2*(200*336)]+[1.6*(270*336)]
qu = 6434.86 psf
qu = 6.43 ksf
Load Case 1 = 1.2D+L+E = [1.2*(200*336)]+206000+[270*336]
qu = 10754.40 psf
→ qu = 10.75 ksf **GOVERNS**
Load Case 1 = 0.9D + E = [0.9*(200*336)]+20600
qu = 7594.43 psf
qu = 7.59 ksf

Two-Way Shear Check

bo = 4(c+d)
= 4(12+25.5)
= 150 in

1) $v_c = 4\lambda\sqrt{f'_c}$ **GOVERNS** → vc = 252.98 k

2) $v_c = \left(2 + \frac{4}{\beta}\right)\lambda\sqrt{f'_c}$ vc = 379.47 k

3) $v_c = \left(\frac{\alpha_s d}{b_o} + 2\right)\lambda\sqrt{f'_c}$ vc = 556.56 k

$$\emptyset v_c = \emptyset 4\lambda\sqrt{f'_c}\, b_o d$$

Φvc = 725743 k
Φvc > vu ADEQUATE

$$v_u = q_u[a^2 - (c+d)^2]$$

vu = 583 k

Flexure Check

Φflexure = 0.9

$$M_u = q_u\left(\frac{l-c}{s}\right)^2 * b * 0.5$$

Mu = 526.966 k-ft

$$a = \frac{A_s f_y}{0.85 f'_c b}$$

a = 1.76
= 2.4As

ΦMn = ΦAsfy(d-a/2)
As = 76.34 in^2
Asmin = 54.00 in^2 As > Asmin ADEQUATE
c = [(0.1*13*0.79)/0.85]
= 1.21 in
εt = 0.0603
εt > 0.005

Transfer of Column Forces to Base

$\sqrt{\frac{A_2}{A_1}} \leq 2.0$ = 8.00 > 2.0 ADEQUATE

Φbear = 0.65

$$\emptyset B_n = 2\emptyset(0.85 f'_c A_1^2)$$

ΦBn = 636480 k ΦBn > 191960 ADEQUATE
Asdowel = 0.005*12*12
= 0.72 in^2 → Use #8 Bar
ldc = { fyψr / 50λ√f'c db = 14.99 in **GOVERNS**
0.0003fyψrdb = 14.22 in }
hreqd = 14.99 + (6*0.79) + 0.79 + (2*0.79) + 3
= 25.1 in hreqd < h ADEQUATE

$$l_d = d_b\left(\frac{3}{40}\right)\left(\frac{f_y}{\lambda\sqrt{f'_c}}\right)\left(\frac{\psi_t\psi_e\psi_s}{\frac{c+k_{tr}}{d_b}}\right)$$

ld = 113.842
= 114db
ldprov. = (((6*12)-12)/2)-3
= 27 in **Use # 8 bars both directions**

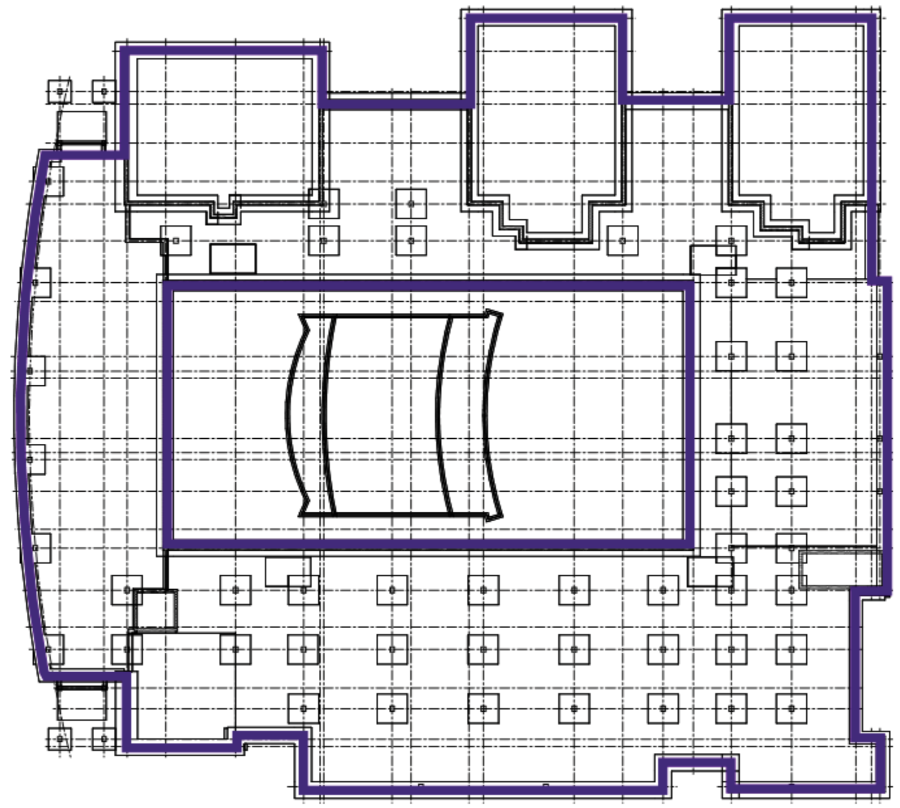
FROST PROTECTED SPREAD FOOTING/GRADE BEAM

The frost protected footings were sized based on the worst case loading scenario on each of the exterior walls. The net allowable soil bearing pressure is 4500 psf.

Applicable Code: ACI 318-2008

FPSF SIZE KEY

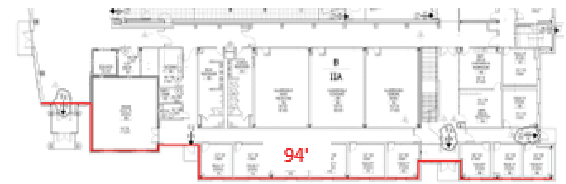
☐ FROST PROTECTED GRADE BEAM



Map of Frost Protected Footings in Building

FROST-PROTECTED GRADE BEAM SCHEDULE			
Location	Size	Reinforcing Steel	Stirrups
West Walls/Atrium	42" x 36"	6#8 T&B Continuous	#4 @ 24" O.C.
Performance Halls	48" x 36"	8#8 T&B Continous	#4 @ 24" O.C.
East Walls	42" x 36"	6#8 T&B Continuous	#4 @ 24" O.C.
South Walls	48" x 36"	8#10 T&B Continous	#4 @ 24" O.C.
Auditorium Walls	54" x 36"	8#10 T&B Continous	#4 @ 24" O.C.

TYPICAL "D" - South Wall



CHECK: 36" x 48"

General Parameters
bw = 48 in
d = 36 in

Dead Loads
1) Wall + Floor
= (75 plf * 2)+(55psf *(23'/2))
= 783 plf
= 0.78 klf → 0.8 klf
2) Roof (1/2 of Roof Load in Atrium)
= (20psf)*(23')*(1/2)
= 230 plf
= 0.23 klf
3) Self Weight
= (150 pcf)*(d/12')*(bw/12')
= 1800 plf
= 1.8 klf
4) Snow
= (100psf)*(23')*(1/2)
= 2000 plf
= 2 klf

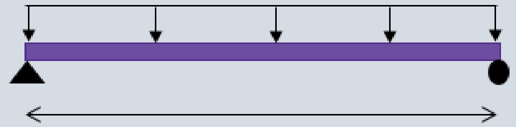
Live Loads
1) Floors
= (250 psf)*(25'/2)
= 3125 plf
= 3.13 klf
2) Roof
= (20psf)*(40')*(1/2)
= 400 plf
= 0.4 klf

Uplift
1) Minimum *Trib Width @ Roof
= 16 psf
= 320 plf
= 0.32 klf

ASD Load Combinations
1) D
2) D+L
3) D+(Lr or S or R)
4) D+0.75L+0.75(Lr or S or R)
5) D+0.6W
6) D+0.75L+0.75(0.6W)+0.75(Lr or S or R)
7) 0.6D+0.6W

1) = (1.7 klf)+(0.4klf)+(1.05klf)
= 2.83 klf
2) = [(1.3 klf)+(0.4klf)+(0.45klf)] + [0.4klf]
= 6.36 klf
3) = [(1.3 klf)+(0.4klf)+(0.45klf)] + 0.75(2klf)
= 4.33 klf
4) = [2.83klf] + 0.75[(0klf)+(0.4klf)] + 0.75(2klf)
= 6.97 klf
5) = [(1.3 klf)+(0.4klf)+(0.45klf)] + 0.6(0.32klf)
= 3.02 klf
6) = [2.83klf] + 0.75[0.4klf] + 0.75(0.6*0.32klf) + 0.75(2klf)
= 7.12 klf **GOVERNS**
7) = [0.6((1.3 klf)+(0.4klf)+(0.45klf))]+0.6(0.32klf)
= 1.89 klf

Loading Diagram



L = 94 ft
→ Initial Checks(0.25L) = 23.0 ft

Shear Strength
Maximum Uniform Bearing Pressure
wu = (Psbp)*bw
= 18.00 klf
Maximum Factored Shear
Vu = (0.25L/2)*(wu)
= 207 k

Flexural Strength
Maximum Factored Moment
Mu = ((wu)*((0.25L)^2))/8
= 1190.3 k-ft
Moment Strength
ΦMn = Φ[(As*fy*d)-((As*fy)/(0.85*f'c*bw*2))]
= 0.9*[(As*60ksi*14.7in)-((As*60ksi)/(0.85*4ksi*bw*2))]
= 17756732 lb-in
= 1479.72766 k-ft ADEQUATE

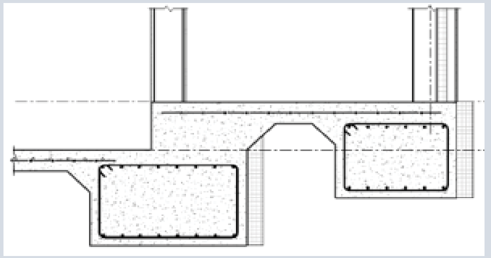
Steel Requirements
AsT&S = 0.0018*(d*bw)
= 3.1104 in^2

→ 8 # 10 (1.27 in^2 & 1.27 in)
AsT&S = 10.16 in^2 T&B Continuous
→ Stirrups: #4 @ 24" O.C.

ρ = As / (bw*d) d = bw-3"-(diameter of rebar/2)
= (1.2in^2)/(bw*(14.75")) = 32.37 in
= 0.002

FROST PROTECTED SHALLOW FOOTINGS

Minimum Vertical Insulation
F100 = 1285 **DEPTH = 18"**
Rv = 5.38
Rh = 0 *NOTE: No Horizontal Insulation Needed



ATUNE STRUCTURAL SYSTEM GOALS

Atune's structural team set the following internal goals for the structural systems of the Jack H. Miller Center for Musical Arts.

ATUNE'S GRAVITY GOALS		
Team Goals	**Structural Team Goals**	**Structural Criteria**
VERSATILITY	Acoustical Adaptability	Make material and system selections that increase the acoustical performance of the structure.
	Flexibility in Use	Design the gravity systems to minimize the members that intrude into the space while still allowing for future growth.
SUSTAINABILITY	Long Lifespan	Material and system selection that allows for longevity of the structural systems and ease of maintenance in future.
	Environmental Impact	Focus on material selection local to the region and environmentally sustainable.
HARMONY	Multipurpose Design	Eliminate design clashes with MEP. Focus on systems that provide opportunities to integrate with MEP.
	Schedule/Constructability	Decrease the schedule for structural system by increasing design of prefab members.

ATUNE'S LATERAL GOALS		
Team Goals	**Structural Team Goals**	**Structural Criteria**
VERSATILITY	Flexibility in Use	Design the gravity systems to minimize the members that intrude into the space while still allowing for future growth.
	Aesthetic Effectiveness	Provide a timber and engineered wood alternative that does not clash with the existing architecture of Hope College.
SUSTAINABILITY	Long Lifespan	Material and system selection that allows for longevity of the structural systems and ease of maintenance in future.
	Education to Public	Increase the timber used in design from the initial challenge to promote sustainable design and providing a environmentally concious building.
HARMONY	Multipurpose Design	Eliminate design clashes with MEP. Focus on systems that provide opportunities to integrate with MEP.
	Constructability	Decrease the schedule for structural system by increasing design of prefab members.

ALTERNATE SYSTEM COMPARISON CHART

The structural team considered several systems at the start of the design process to identify the most sustainable and economical system for the Jack H. Miller Center for Musical Arts. Using the below comparison chart, Atune selected the best systems to move forward with in design.

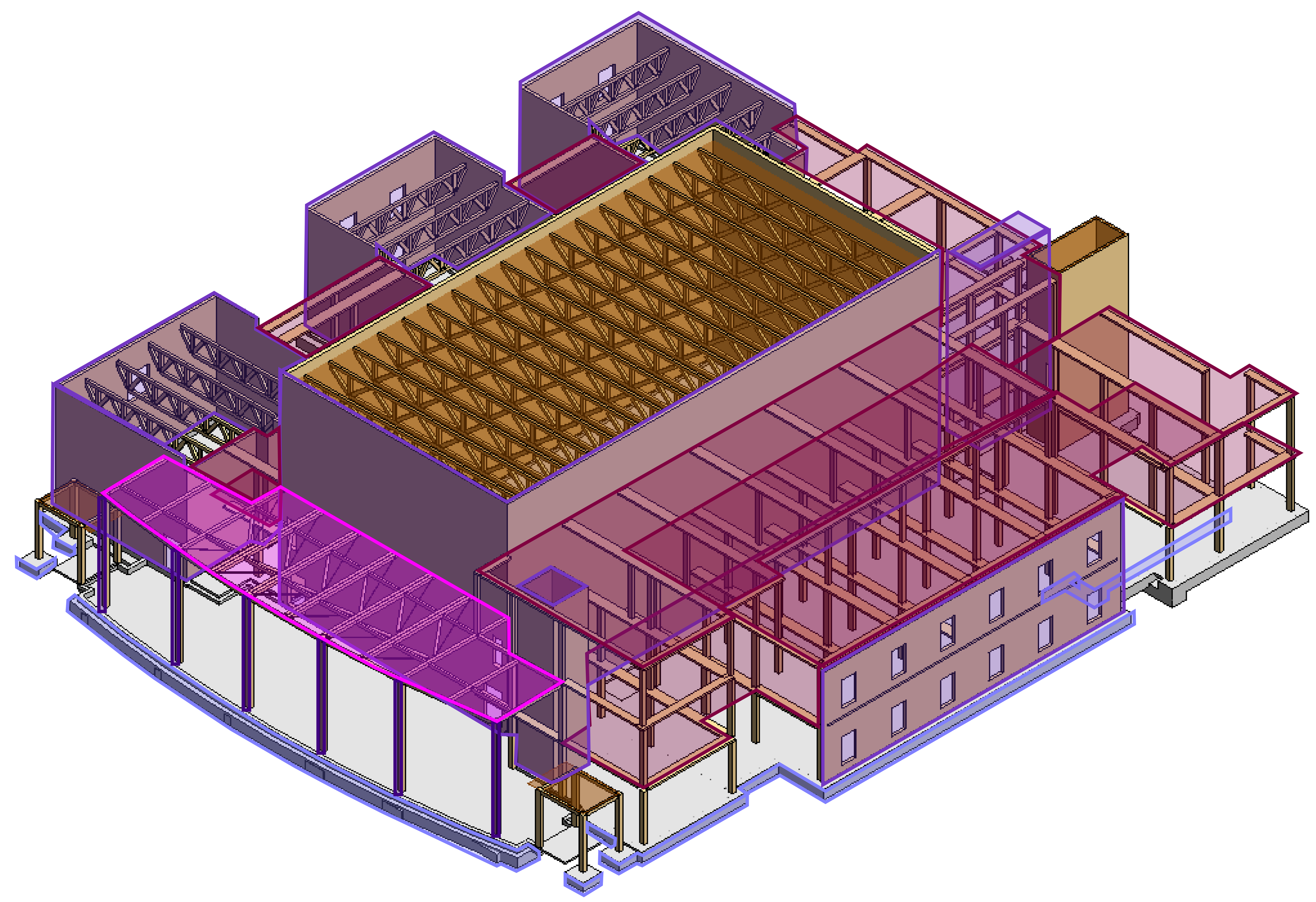
	GRAVITY SYSTEMS				
SYSTEMS	Sawn Lumber Framing	Engineered Wood Framing	Composite Timber & Reinforced Concrete	CLT Tilt-Up Wall Panels	Zipper Truss
ADVANTAGES	Very economical.	Great for constructability, especially for large-scale timber structures.	Composite action, highly innovative design.	Economical and constructable. Acoustical advantages. Takes gravity and lateral loads.	Unique design, with composite action.
DISADVANTAGES	Quality control concerns, limited in design before members become very large.	More commonly used, leaves less room for innovation.	No code to follow for design. Initial cost is unknown.	Connections required extra time to be properly installed.	New design, not as constructable.
VERSATILITY	X	✓	✓	✓	X
SUSTAINABILITY	✓	✓	✓	✓	✓
HARMONY	X	✓	✓	✓	✓

	LATERAL SYSTEMS				
SYSTEMS	Heavy Timber Braced Frames	Timber Moment Frames	Wood Shear Walls	SIP Walls	CLT Tilt-Up Wall Panels
ADVANTAGES	High strength-to-weight ratio, and innovative selection.	Innovative timber system.	Economical and constructable. Takes gravity and lateral loads.	Economical and constructable, has acoustical advantages from extra insulation. Takes gravity and lateral loads.	Economical and constructable. Acoustical advantages. Takes gravity and lateral loads.
DISADVANTAGES	Larger members are required to have a robust system.	Rare due to material properties. No code to follow for design.	More commonly used, leaves less room for innovation.	Restrictions on spanning and MEP chases.	Connections required extra time to be properly installed.
VERSATILITY	X	X	X	X	✓
SUSTAINABILITY	✓	✓	✓	✓	✓
HARMONY	✓	✓	X	X	✓

	ROOF SYSTEMS		
SYSTEMS	Typical Framing	Timber Trusses	Composite Timber & Reinforced Concrete
ADVANTAGES	Economical and constructable.	Relatively constructable.	Innovative design, allows for extra loading on the roof.
DISADVANTAGES	Not very innovative and is not timber construction.	Built up sections would need to be prefabricated to prevent extra time on site.	No code to follow for design. Initial cost is unknown.
VERSATILITY	✓	✓	✓
SUSTAINABILITY	✓	✓	✓
HARMONY	✓	✓	✓

STRUCTURAL SYSTEM GOALS

The main focus of the selected structural systems were to exceed the goals of versatility, sustainability and harmony that the Atune team had set while staying focused on the needs of Hope College and it's students. The following graphic calls out the main structural systems used in the Jack H. Miller Center for Musical Arts.



CLT Wall Panels

The CLT walls provide the LFRS for the entire structure. Additional acoustical advantages are gained by using the panels around the concert hall and recital spaces.

CLT & Reinforced Concrete

The composite Floor system optimizes the use of timber design for the spans and loads seen in the Jack H. Miller Center for Musical Arts.

Frost Protected Spread Footings

Frost protected spread footings reduce the concrete needed in the foundations. This also helps improve the constructibility of the stepped slabs for the underfloor air distribution.

Carbon Fiber Wrapped Columns

To continue the goal for sustainability set by Hope College, Atune's structural team utilized timber composite action for the columns in the atrium to keep the space open and inviting.

Zipper Trusses

Innovative approach to increasing the capacity of the roof in the atrium space.

ATUNE

Jack H. Miller Center for Musical Arts

Composite Floor Calculations

AEI Team No.	7-2019
Date	02/18/2019
Scale	

S3.1

TYPICAL COMPOSITE CLT & REINFORCED CONCRETE FLOOR DESIGN

Composite CLT Parameters

5 Layer - E2 Panel

Thickness of ind. Layer h_i = 1.375 in — Design Width b = 12 in

Major Strength Axis				**Minor Strength Axis**			
Bending Strength	$F_{b,0}$ =	1650	psi	Bending Strength	$F_{b,90}$ =	525	psi
Modulus of Elasticity	E_0 =	1500	ksi	Modulus of Elasticity	E_{90} =	1400	ksi
Tensile Strength	$F_{t,0}$ =	1020	psi	Shear Strength	$F_{v,90}$ =	180	psi
Compression Strength	$F_{c,0}$ =	1700	psi	Rolling Shear Strength	$F_{s,90}$ =	60	psi
Shear Strength	$F_{v,0}$ =	180	psi				
Rolling Shear Strength	$F_{s,0}$ =	60	psi				

Layer	E (ksi)	h (in)	z (in)	GA_{eff} Calc: G (ksi)	GA_{eff} Calc: h/G/b (in^2/kip)	EA Calc (kip)	EI_{eff} Calc: EI_{thk} (kip-in^2)	EI_{eff} Calc: EI_{na} (kip-in^2)	EI_{eff} Calc: Sum (kip-in^2)
1	1500	1.375	2.750	93.8	0.00122	24750	3899.41	187172	191071
2	46.7	1.375	1.375	8.75	0.01310	770	121.315	1455.78	1577.1
3	1500	1.375	0.000	93.8	0.00122	24750	3899.41	0	3899.41
4	46.7	1.375	1.375	8.75	0.01310	770	121.315	1455.78	1577.1
5	1500	1.375	2.750	93.8	0.00122	24750	3899.41	187172	191071
					TOTAL =	75790		TOTAL =	389196

$$EI_{eff} = \sum_{i=1}^{n} E_i b_i \frac{h_i^3}{12} + \sum_{i=1}^{n} E_i A_i z_i^2 \qquad GA_{eff} = \frac{a^2}{\left[\left(\frac{h_1}{2G_1 b}\right) + \left(\sum_{i=2}^{n-1} \frac{h_i}{G_i b_i}\right) + \left(\frac{h_n}{2G_n b}\right)\right]}$$

Cross Sectional Properties (Per foot of width)

EA_{eff} = 75790 kip
EI_{eff} = 389196 kip-in^2
h_2 = 6.875 in
a = 5.44412 in
GA_{eff} = 1035.05 kip

Connector Parameters

HBV Connector Typ 90/500

Connector slip Modulus K_{ser} = 165 kN/mm
Ult Connector Slip Modulus K_u = 110 kN/mm
Shear Strength F_{rk} = 32000 N

$$K_u = \frac{2}{3} K_{ser}$$

Design Equations per Annex B or 1995-1-1

B.2: Effective Bending Stiffness

$$(EI)_{eff} = \sum_{i=n}^{n} \left(E_i I_i + \gamma_i E_i A_i a_i^2\right) \quad (B.1) \qquad a_2 = \frac{\gamma_1 E_1 A_1 (h_1 + h_2)}{(2\gamma_1 E_1 A_1 + 2\gamma_2 E_2 A_2)} \quad (B.6)$$

$$\gamma_1 = \frac{1}{1 + \frac{\pi^2 E_1 A_1 s}{K l^2}} \quad (B.5) \qquad \gamma_2 = 1.0 \quad (B.4)$$

B.3: Normal Stresses

$$\sigma_i = \frac{\gamma_i E_i a_i M}{(EI)_{eff}} \quad (B.7) \qquad \sigma_{m,i} = \frac{0.5 E_i h_i M}{(EI)_{eff}} \quad (B.8)$$

B.4: Maximum Shear Stress — B.5: Fastener Load

$$\tau_{2,max} = \frac{0.5 E_2 h_2^2 V}{(EI)_{eff}} \quad (B.9) \qquad F_1 = \frac{\gamma_1 E_1 A_1 a_1 V}{(EI)_{eff}} \quad (B.10)$$

EFFECTIVE STIFFNESS

Composite CLT & Reinforced Concrete, Strong Axis, Positive Bending
Cross Sectional Properties, Per Foot of Width

General Values

Length	L =	24	ft
Gamma Span Length	L_0 =	24	ft
Connector slip Modulus	K_{ser} =	165	kN/mm
Connector Slip Modulus	K_{ser} =	942.139	kips/in
Connector Spacing	s =	8	in

Concrete Values

Slab Depth	h_c =	3.125	in
Compressive Strength	f'_c =	5000	psi
Weight of Concrete	w_c =	145	pcf
Modulus of Elasticity	E_c =	4074.28	ksi
Area of Concrete	A_c =	37.5	in^2
Inhertia of Concrete	I_c =	30.5176	in^4
	$E_c A_c$ =	152786	kip
	$E_c I_c$ =	124337	kip-in^2
	γ_c =	0.86639	

Composite Properties

Timber to Comp Centroid	a_2 =	3.17954	in
Conc to Comp Centroid	a_1 =	1.82046	in
Eff Composite Sitffness	$(EI)_{ef,comp}$ =	1718420	kip-in^2
Ratio of Comp and CLT	=	4.4153	

Composite CLT & Reinforced Concrete, Strong Axis, Negative Bending

Cross Sectional Properties, Per Foot of Width

General Values

Length	L =	24	ft
Gamma Span Length	L_0 =	24	ft
Connector slip Modulus	K_{ser} =	165	kN/mm
Connector Slip Modulus	K_{ser} =	942.139	kips/in
Connector Spacing	s =	8	in

Concrete Values

Slab Depth	h_c =	3.125	in
Modulus of Elasticity	E_s =	29000	ksi
Area of Steel	A_s =	0.2	in^2
Inhertia of Steel	I_s =	0	in^4
	$E_s A_s$ =	5800	kip
	$E_s I_s$ =	0	kip-in^2
	γ_s =	0.99418	

Composite Properties

Timber to Comp Centroid	a_2 =	0.35351	in
Conc to Comp Centroid	a_1 =	4.64649	in
Eff Composite Sitffness	$(EI)_{ef,comp}$ =	523160	kip-in^2
Ratio of Comp and CLT	=	1.34421	

APPARENT STIFFNESS

Composite CLT & Reinforced Concrete, Strong Axis, Negative Bending
Cross Sectional Properties, Per Foot of Width

Bare CLT Stiffness

Length	L =	24	ft
K Value	K_s =	11.5	
	$EI_{eff,clt}$ =	389196	kip-in^2
	$GA_{eff,clt}$ =	1035.05	kips
	$EI_{app,clt}$ =	369911	kip-in^2
	Eff % =	0.95045	

Composite Section Stiffness

	$EI_{eff,comp}$ =	1718420	kip-in^2
	$GA_{eff,clt}$ =	1035.05	kips
	$EI_{app,comp}$ =	1396876	kip-in^2
	Eff % =	0.81288	
	CLT Ratio =	3.77625	

Apparent Floor Stiffness

$K_{app,clt} = 48EI_{app}/L^3$ = 0.7433 kip/in
$K_{app,comp} = 48EI_{app}/L^3$ = 2.80687 kip/in

Composite CLT & Reinforced Concrete, Strong Axis, Negative Bending

Cross Sectional Properties, Per Foot of Width

Bare CLT Stiffness

Length	L =	24	ft
K Value	K_s =	11.5	
	$EI_{eff,clt}$ =	389196	kip-in^2
	$GA_{eff,clt}$ =	1035.05	kips
	$EI_{app,clt}$ =	369911	kip-in^2
	Eff % =	0.95045	

Composite Section Stiffness

	$EI_{eff,comp}$ =	523160	kip-in^2
	$GA_{eff,clt}$ =	1035.05	kips
	$EI_{app,comp}$ =	488899	kip-in^2
	Eff % =	0.93451	
	CLT Ratio =	1.32166	

Apparent Floor Stiffness

$K_{app,clt} = 48EI_{app}/L^3$ = 0.7433 kip/in
$K_{app,comp} = 48EI_{app}/L^3$ = 0.98239 kip/in

BENDING STRESSES & STRAINS

Composite CLT & Reinforced Concrete, Strong Axis, Positive Bending
Floor Demands, Per Foot of Width

Ultimate Load Demands

L =	24	ft
P_u =	6	kip
V_u =	3	kip
M_u =	180	kip-in

Bending Stess Calulations

Avg Conc Stress	σ_1 =	-0.6731	ksi
Extreme Fiber Stress Delta	$\sigma_{m,1}$ =	0.66683	ksi
Stress at top of concrete	$\sigma_{t/conc}$ =	-1.3399	ksi
Stress at bottom of conc	$\sigma_{b,conc}$ =	-0.0063	ksi
Avg CLT Stress	σ_2 =	0.49957	ksi
Extreme fiber stress delta	$\sigma_{m,2}$ =	0.5401	ksi
Stress at top of CLT	$\sigma_{t/clt}$ =	-0.0405	ksi
Stress at bottom of CLT	$\sigma_{b/clt}$ =	1.03968	ksi

Shear Stress, Fastener Load Calculations

Max rolling shear stress	$\tau_{2,max}$ =	0.06189	ksi
Fastener Load	F_1 =	3.36557	kip

Composite CLT & Reinforced Concrete, Strong Axis, Negative Bending

Floor Demands, Per Foot of Width

Ultimate Load Demands

L =	24	ft
P_u =	4.5	kip
V_u =	5	kip
M_u =	136	kip-in

Bending Stess Calulations

Avg Conc Stress	σ_1 =	34.8251	ksi
Extreme Fiber Stress Delta	$\sigma_{m,1}$ =	N/A	ksi
Stress at top of concrete	$\sigma_{t/conc}$ =	N/A	ksi
Stress at bottom of conc	$\sigma_{b,conc}$ =	N/A	ksi
Avg CLT Stress	σ_2 =	-0.1378	ksi
Extreme fiber stress delta	$\sigma_{m,2}$ =	1.34041	ksi
Stress at top of CLT	$\sigma_{t/clt}$ =	1.20256	ksi
Stress at bottom of CLT	$\sigma_{b/clt}$ =	-1.4783	ksi

Shear Stress, Fastener Load Calculations

Max rolling shear stress	$\tau_{2,max}$ =	0.3388	ksi
Fastener Load	F_1 =	2.04853	kip

CLT with Adjustment Factors

Load Duration Factor	C_D =	1.0	
Wet Service Factor	C_m =	1.0	
Temperature Factor	C_t =	1.0	
Beam Stability Factor	C_L =	1.0	calculated below

$F_t(A_{parallel})' = F_t(A_{parallel}) C_D C_M C_t$ = 3060 lb-f

$F_b(S_{eff})' = F_b(S_{eff}) C_D C_M C_t C_L$ = 4950 lb-f

$F_s(Ib/Q)'_{eff} = F_s(Ib/Q)_{eff} C_D C_M C_t$ = 9759.63

Frk = 2.39796 kip

$$C_L = \frac{1 + \left(F_{bE}/F_b^*\right)}{1.9} - \sqrt{\left[\frac{1 + \left(F_{bE}/F_b^*\right)}{1.9}\right]^2 - \frac{F_{bE}/F_b^*}{0.95}} = 1.0$$

$$F_{be} = \frac{1.20 E'_{min}}{R_B^2} = 2.7E+12 \text{ psi} \qquad R_B = \sqrt[2]{\frac{\ell_e d}{b^2}} = 2E-05$$

Strength Analysis

Wood Tensile Failure

$$\frac{\sigma_2}{F_t(A_{parallel})'} + \frac{\sigma_{2,m}}{F_b(S_{eff})'} \le 1.0 \rightarrow$$ 0.27237 < 1.0 OKAY

Wood Shear Failure

$$\frac{\tau_{2,max}}{F_b(S_{eff})'} \le 1.0 \rightarrow$$ 0.03471 < 1.0 OKAY

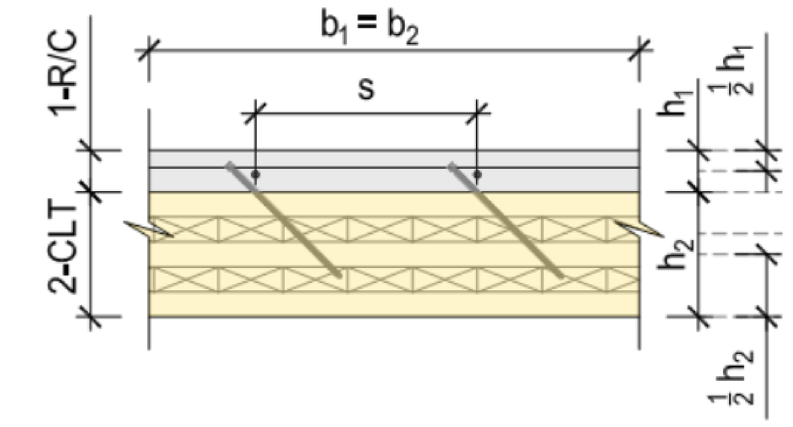
Concrete Compressive Failure

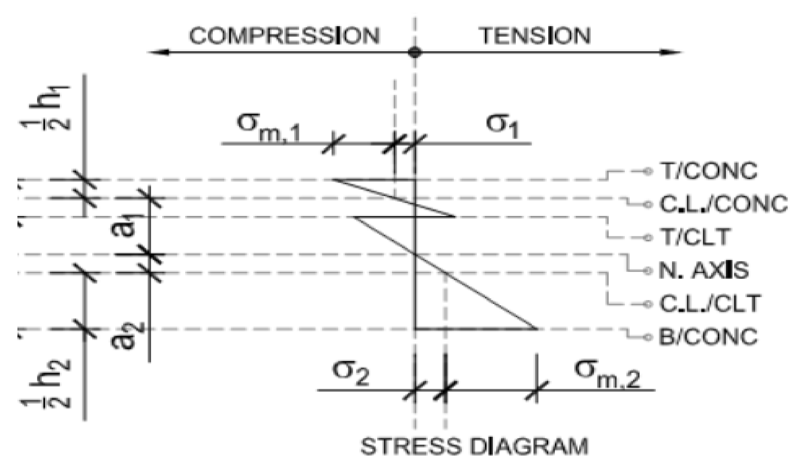
$$\frac{\sigma_{1,m}}{F_c} \le 1.0 \rightarrow$$ 0.26673 < 1.0 OKAY

Connector Shear Failure

$$\frac{F_1}{F_{rk}} \le 1.0 \rightarrow$$ 0.46781 < 1.0 OKAY

The final size or the concrete CLT composite floor ended up being of 5-PLY CLT (6.875") with #4 bars each way and 3.125 concrete slab on top.





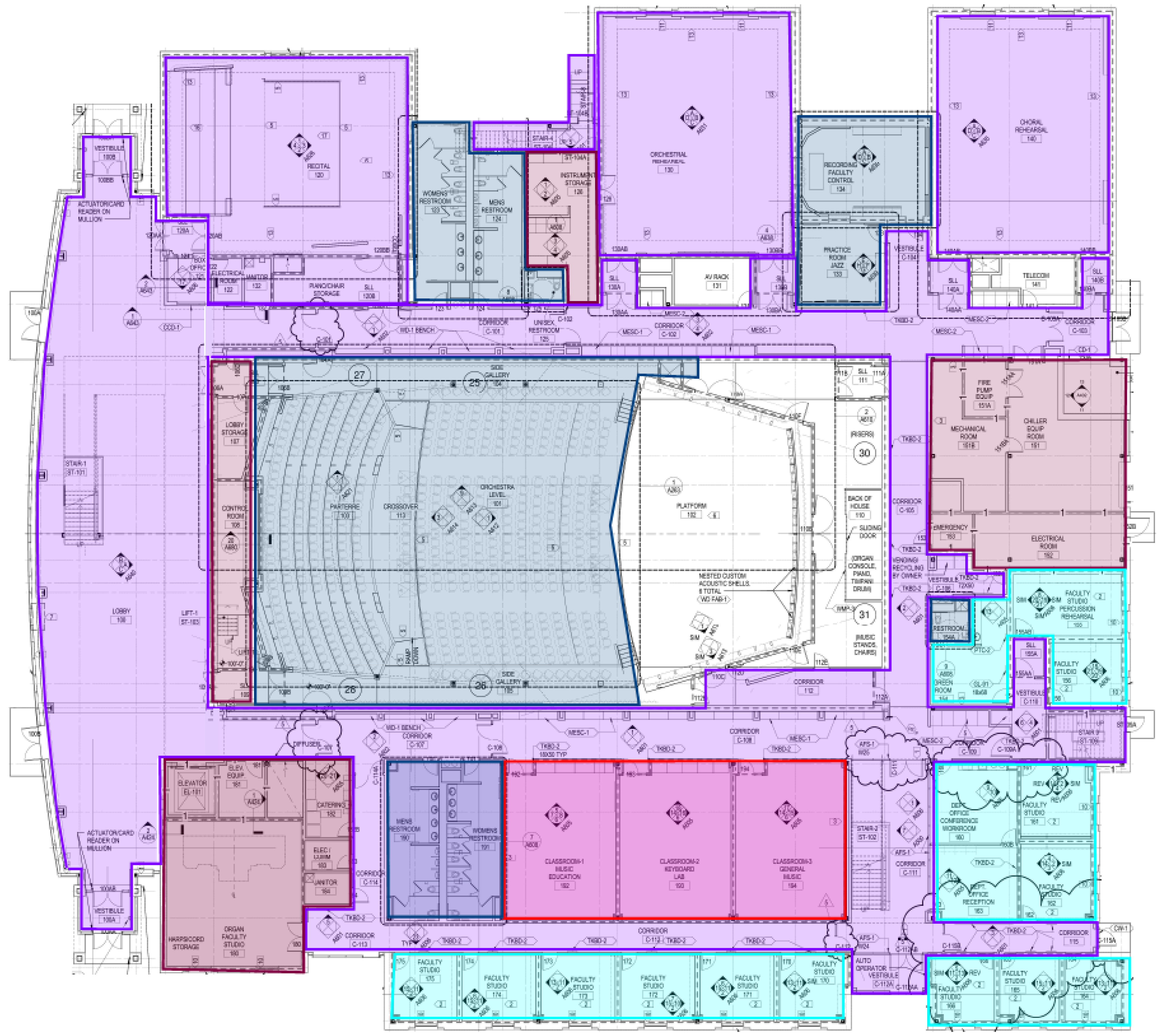
ATUNE

Jack H. Miller Center for Musical Arts

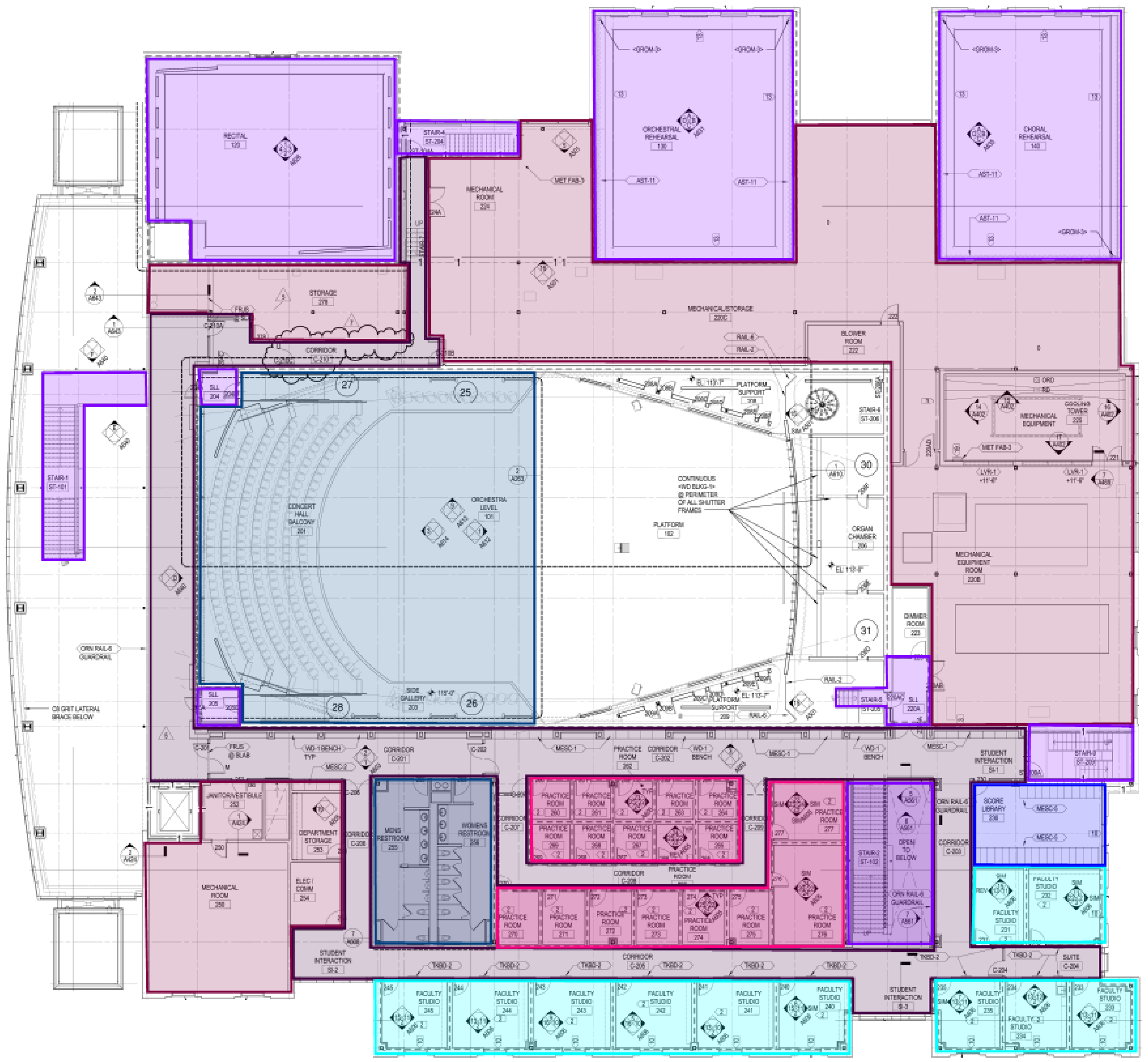
Comparison Charts & System Goals

AEI Team No. 7-2019
Date 02/18/2019
Scale

S3.2

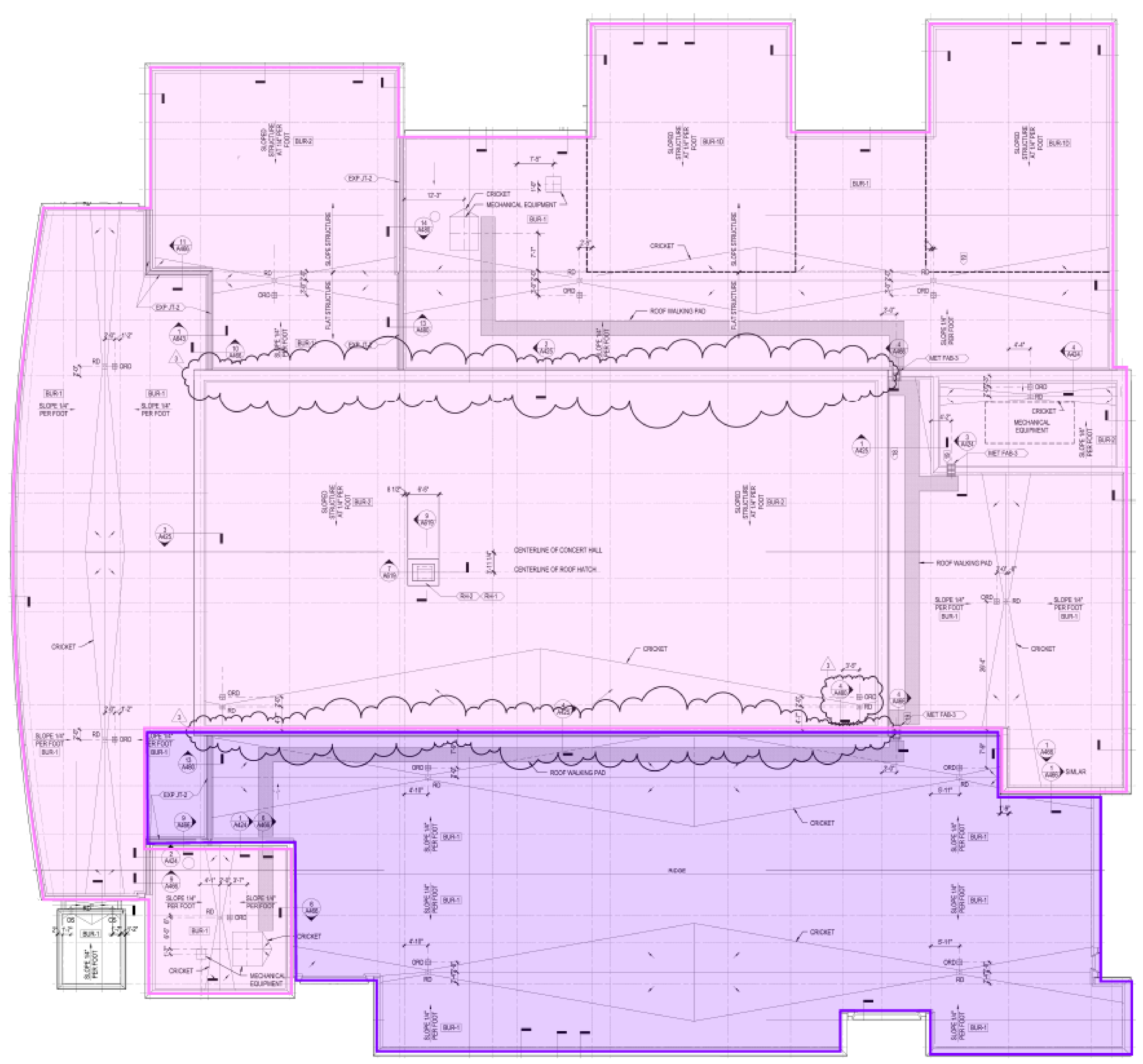


1 FIRST FLOOR LIVE LOAD MAP
1 1/2" = 1'-0"

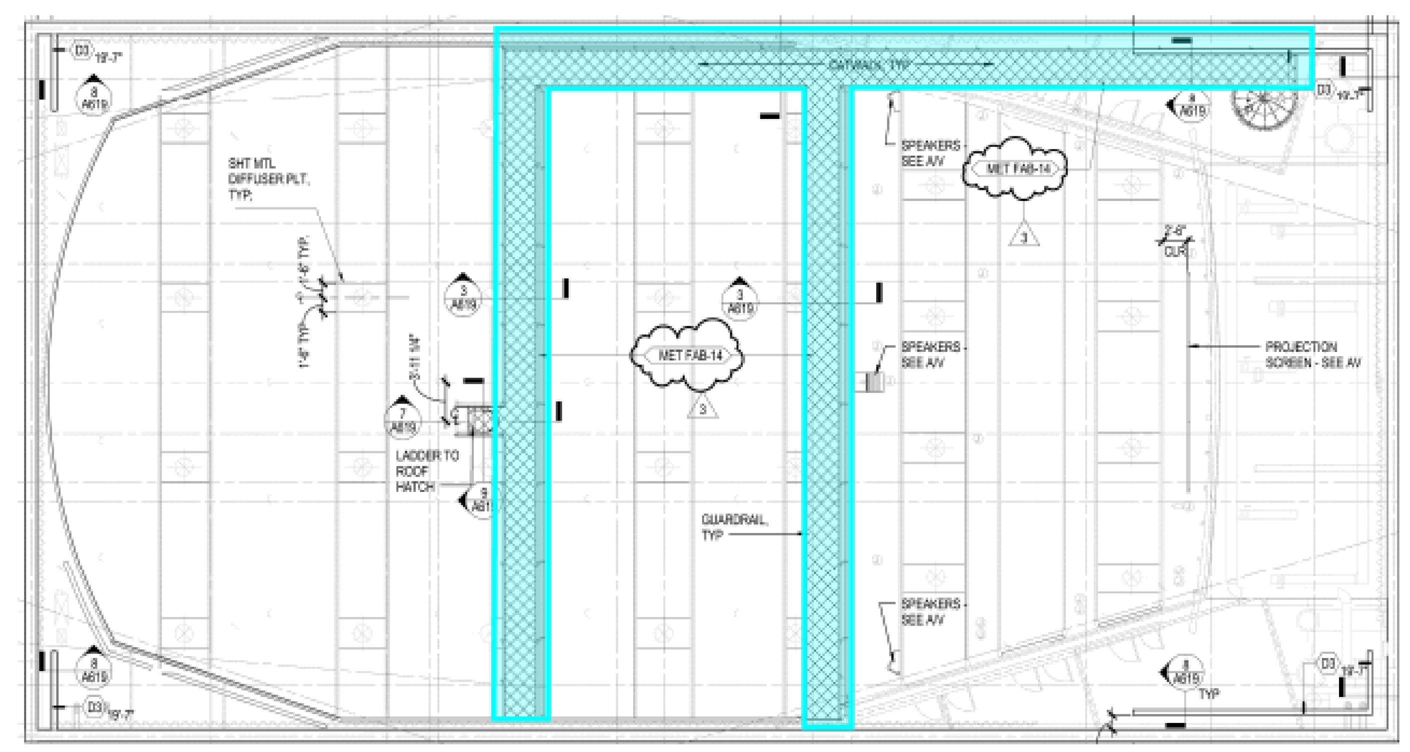


2 SECOND FLOOR LIVE LOAD MAP
1 1/2" = 1'-0"

- 20 psf
- 40 psf
- 50 psf
- 60 psf
- 80 psf
- 100 psf
- 125 psf
- 150 psf



3 ROOF LIVE LOAD MAP
1 1/2" = 1'-0"



4 CATWALK LIVE LOAD MAP
1 1/2" = 1'-0"

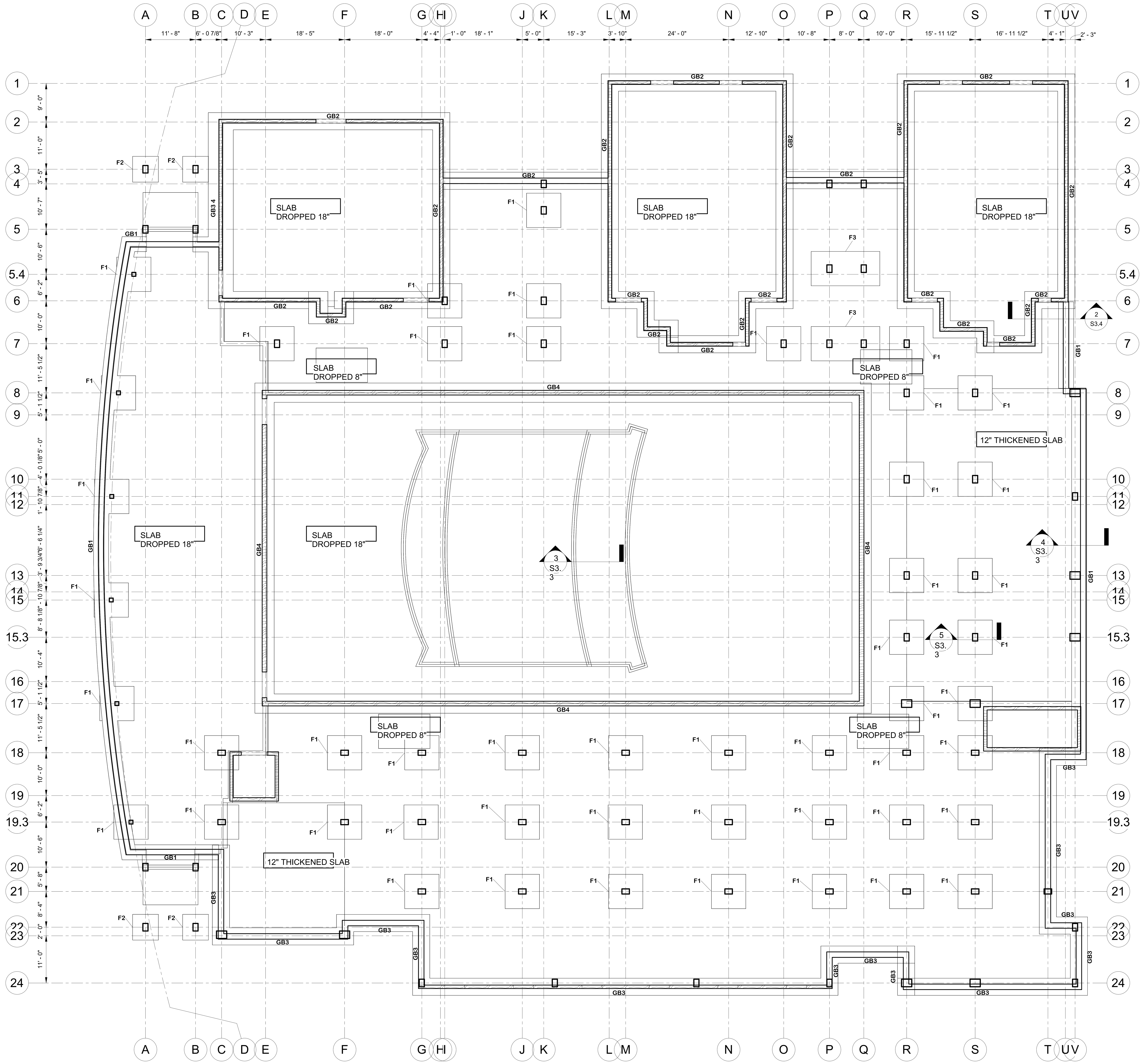
ATUNE

Jack H. Miller Center for Musical Arts

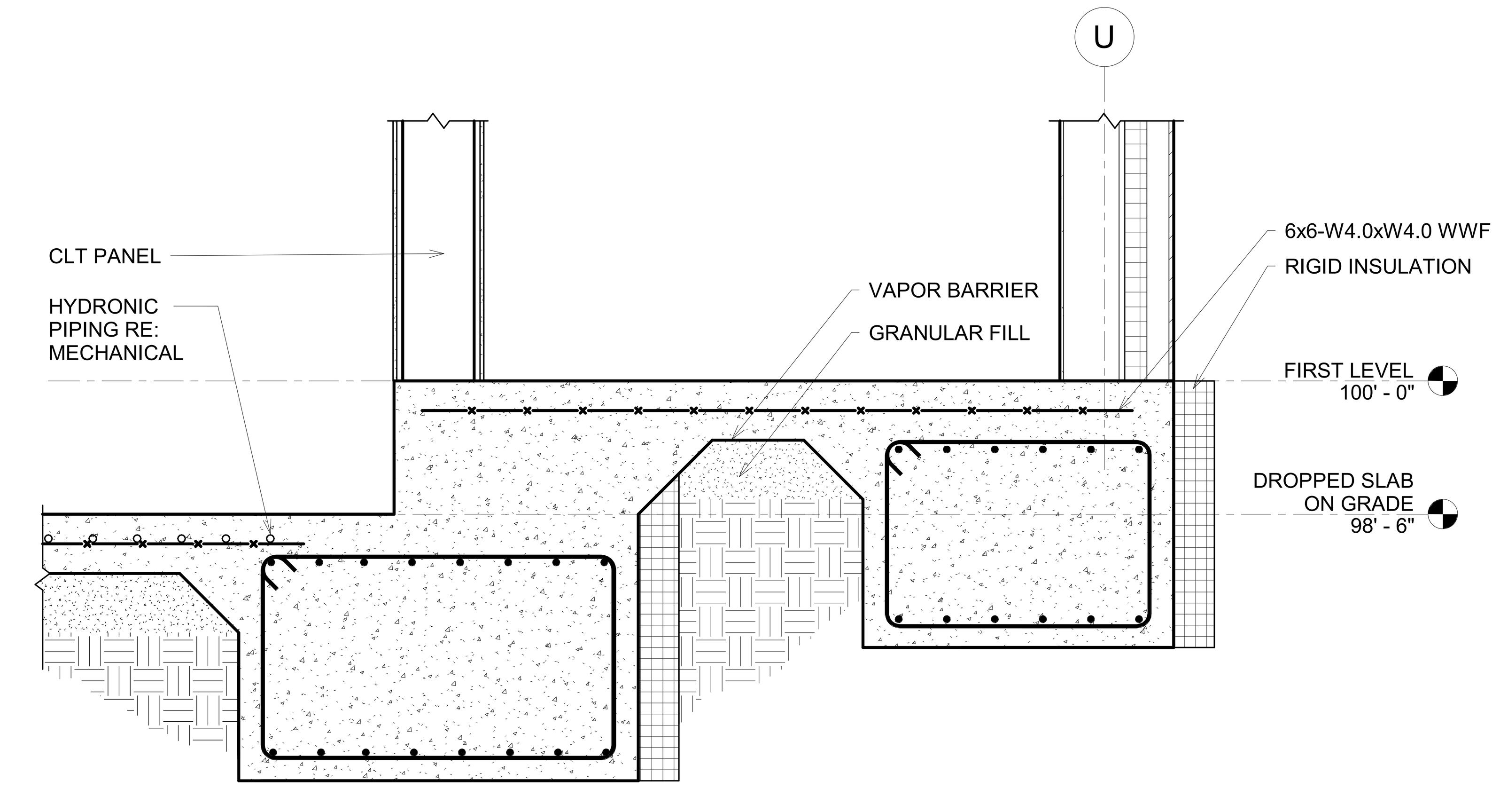
Live Load Maps

AEI Team No.	7-2019
Date	02/18/2019
Scale	1 1/2" = 1'-0"

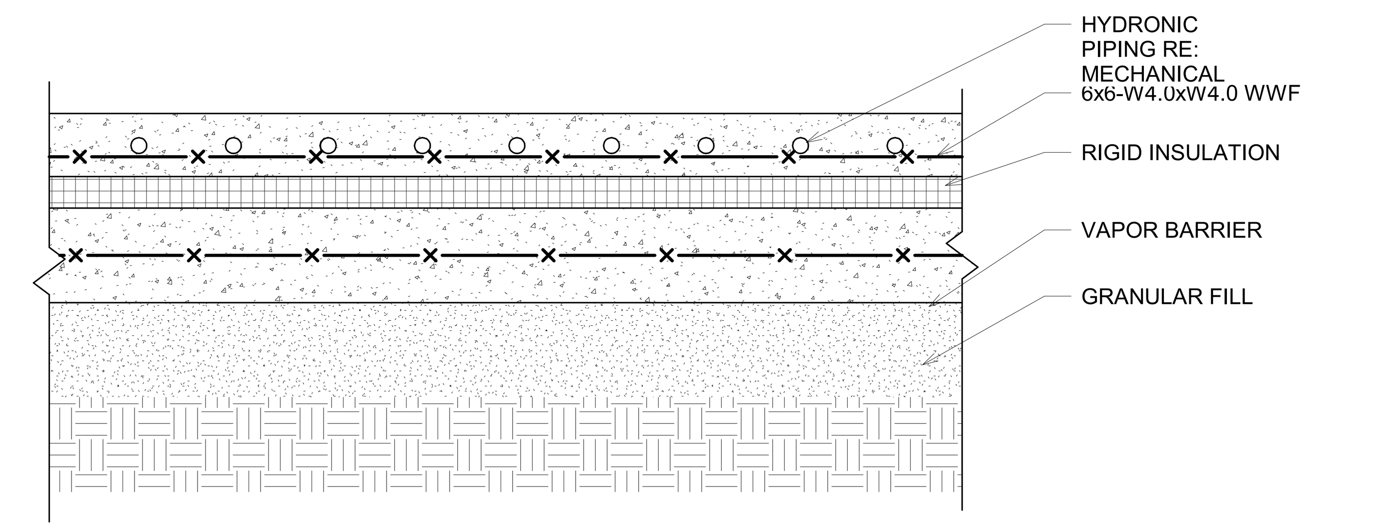
S3.3



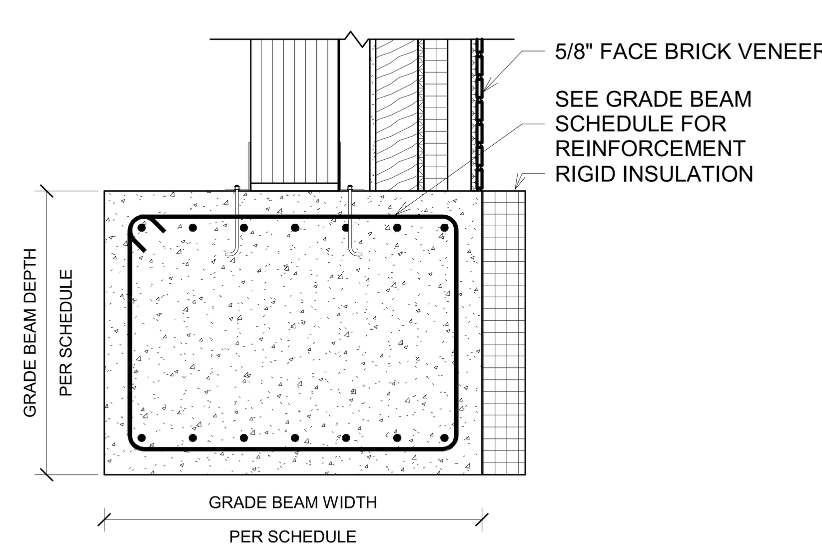
1 Foundation Plan
3/32" = 1'-0"



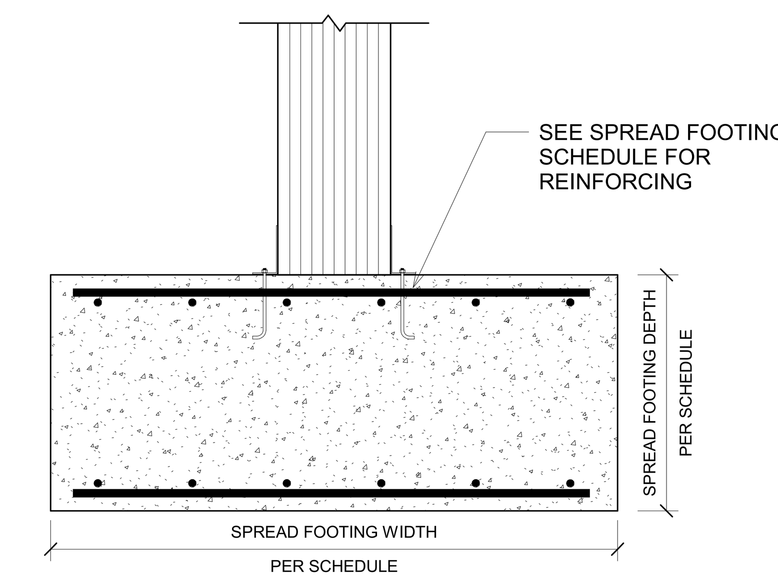
2 Dropped Slab Section
3/4" = 1'-0"



3 Auditorium Slab on Grade
1 1/2" = 1'-0"



4 Frost Protected Grade Beam
3/4" = 1'-0"



5 Spread Footing Detail
3/4" = 1'-0"

GRADE BEAM SCHEDULE

MARK	WIDTH	DEPTH	REINFORCEMENT	STIRRUPS
GB1	42"	36"	(6) #8 T&B Continuous	#4 @ 24" O.C.
GB2	48"	36"	(8) #8 T&B Continuous	#4 @ 24" O.C.
GB3	48"	36"	(8) #10 T&B Continuous	#4 @ 24" O.C.
GB4	54"	36"	(8) #10 T&B Continuous	#4 @ 24" O.C.

6 Grade Beam Schedule
1" = 1'-0"

SPREAD FOOTING SCHEDULE

MARK	SIZE	DEPTH	REINFORCEMENT
F1	8' x 8'	36"	(6) #8 T&B Continuous
F2	6' x 6'	36"	(8) #8 T&B Continuous
F3	16' x 8'	36"	(16) #8 T&B Continuous

7 Spread Footing Schedule
1" = 1'-0"

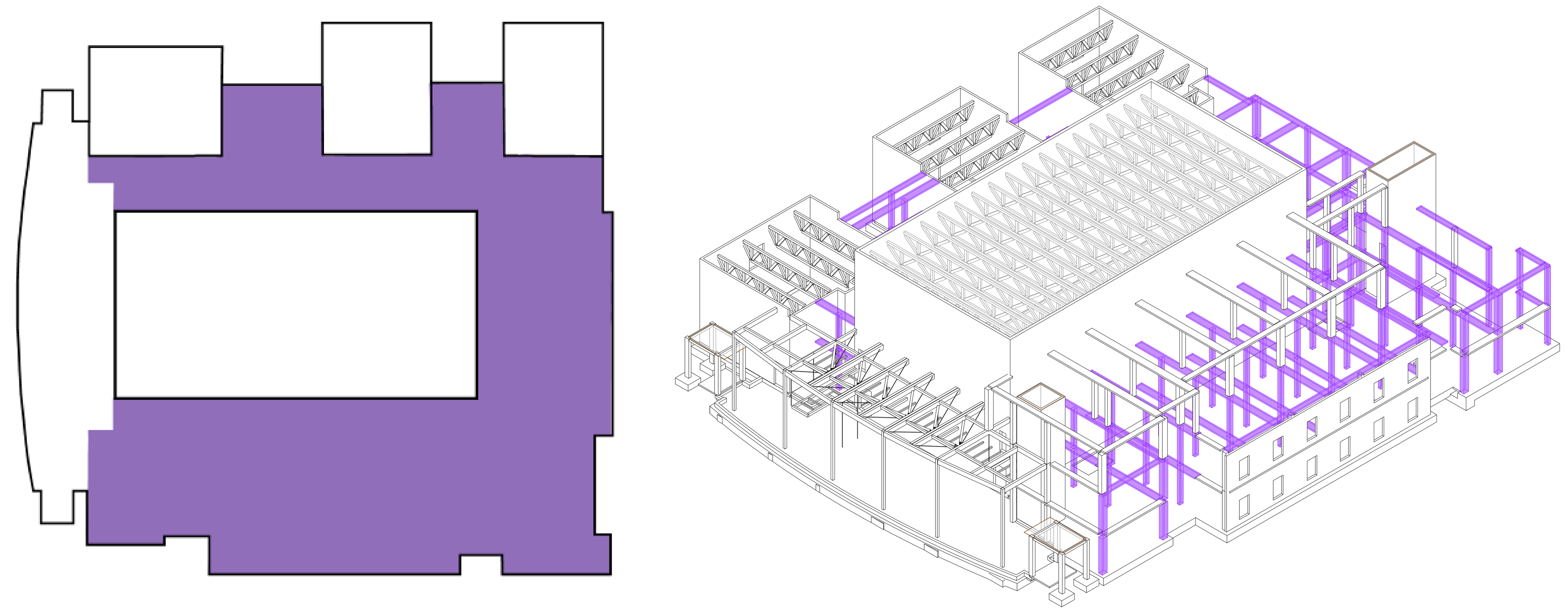
ATUNE

Jack H. Miller Center for Musical Arts

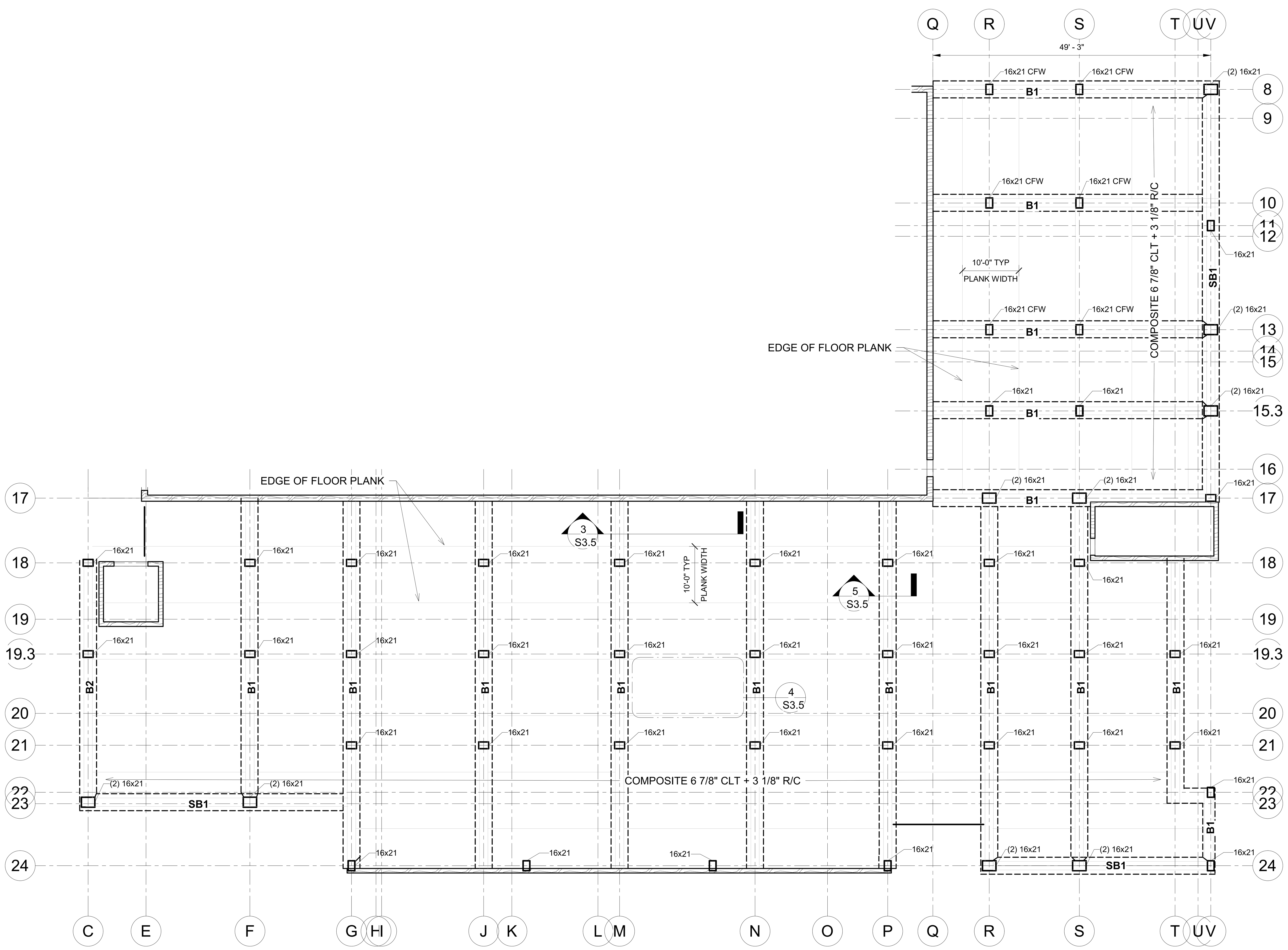
Foundation Plan

AEI Team No. 7-2019
Date 02/18/2019
Scale As indicated

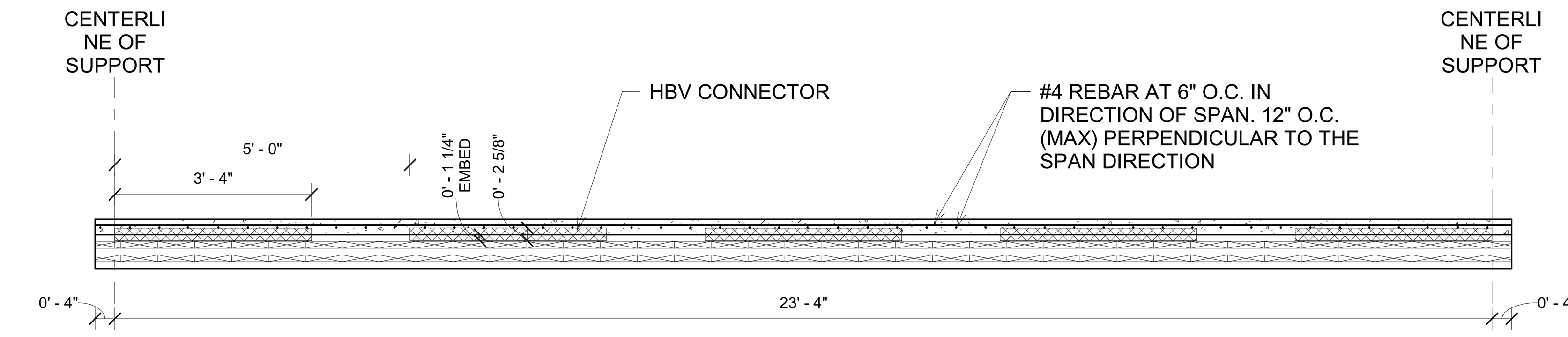
S3.4



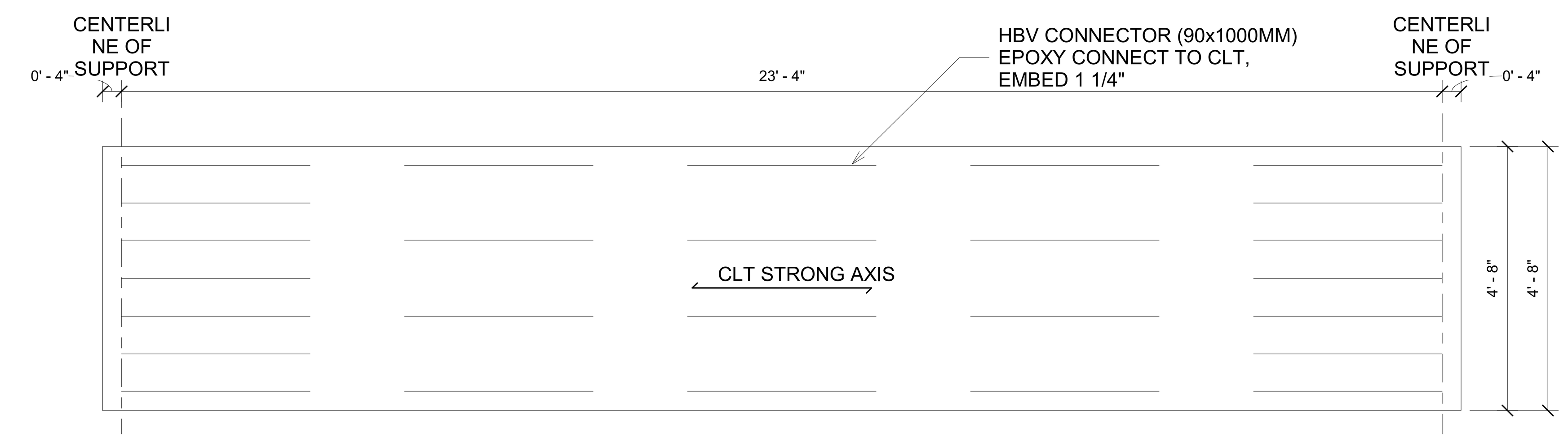
1 Typical Framing Highlight



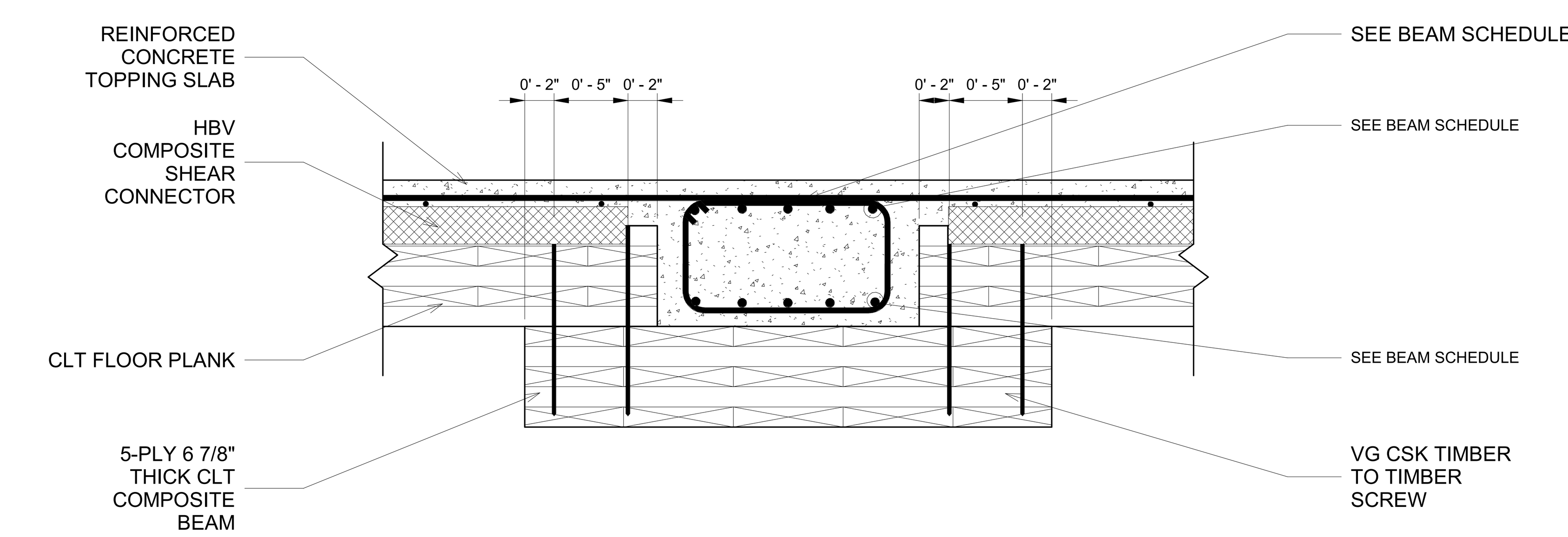
2 Second Floor Framing Plan
3/32" = 1'-0"



3 Elevation View of Composite Floor
1/2" = 1'-0"



4 Plan View of Floor Slab
1/2" = 1'-0"



5 Composite Floor Beam
1 1/2" = 1'-0"

BEAM SCHEDULE

MARK	WIDTH	DEPTH	REINFORCEMENT		STIRRUPS
			TOP	BOTTOM	
B1	16"	10"	(5) #6 BARS	(4) #6 BARS	#4 @ 4" O.C.
B2	16"	10"	(6) #6 BARS	(5) #6 BARS	#4 @ 4" O.C.
B3	16"	10"	(6) #6 BARS	(6) #6 BARS	#4 @ 4" O.C.
SB1	16"	10"	(5) #6 BARS	(5) #6 BARS	#4 @ 4" O.C.

6 Beam Schedule
1" = 1'-0"

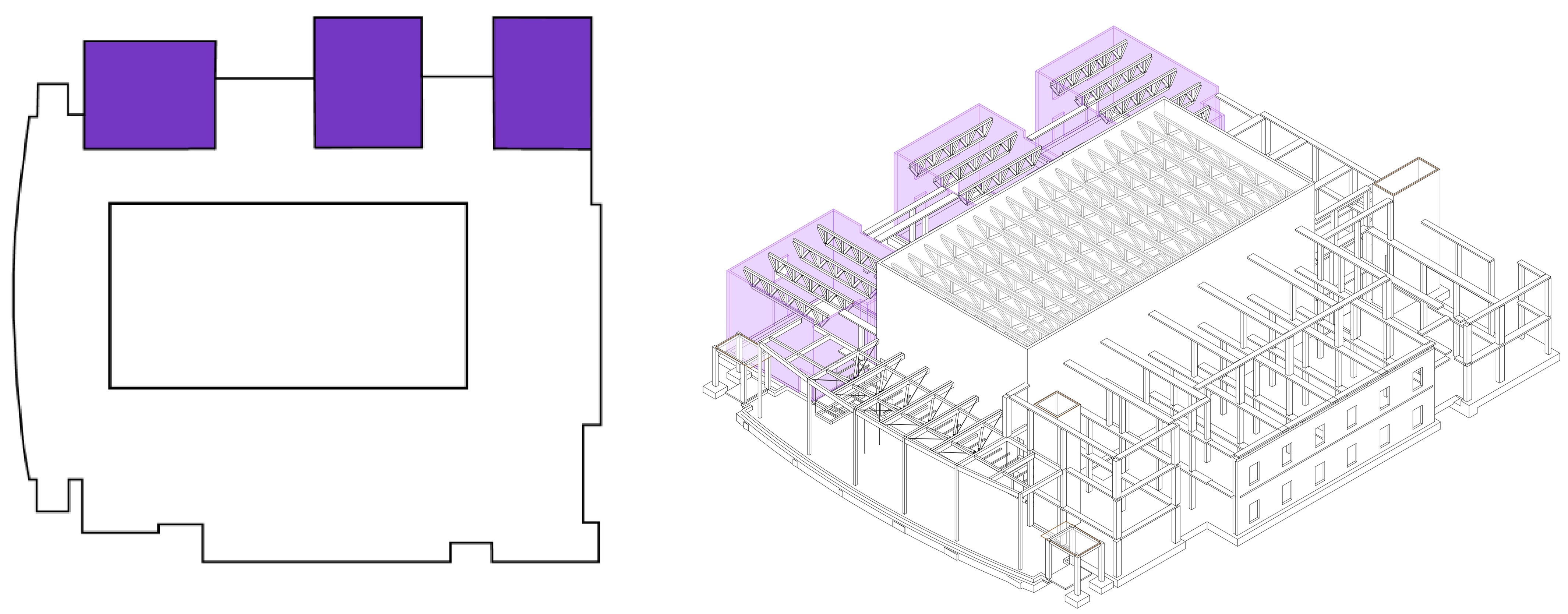
ATUNE

Jack H. Miller Center for Musical Arts

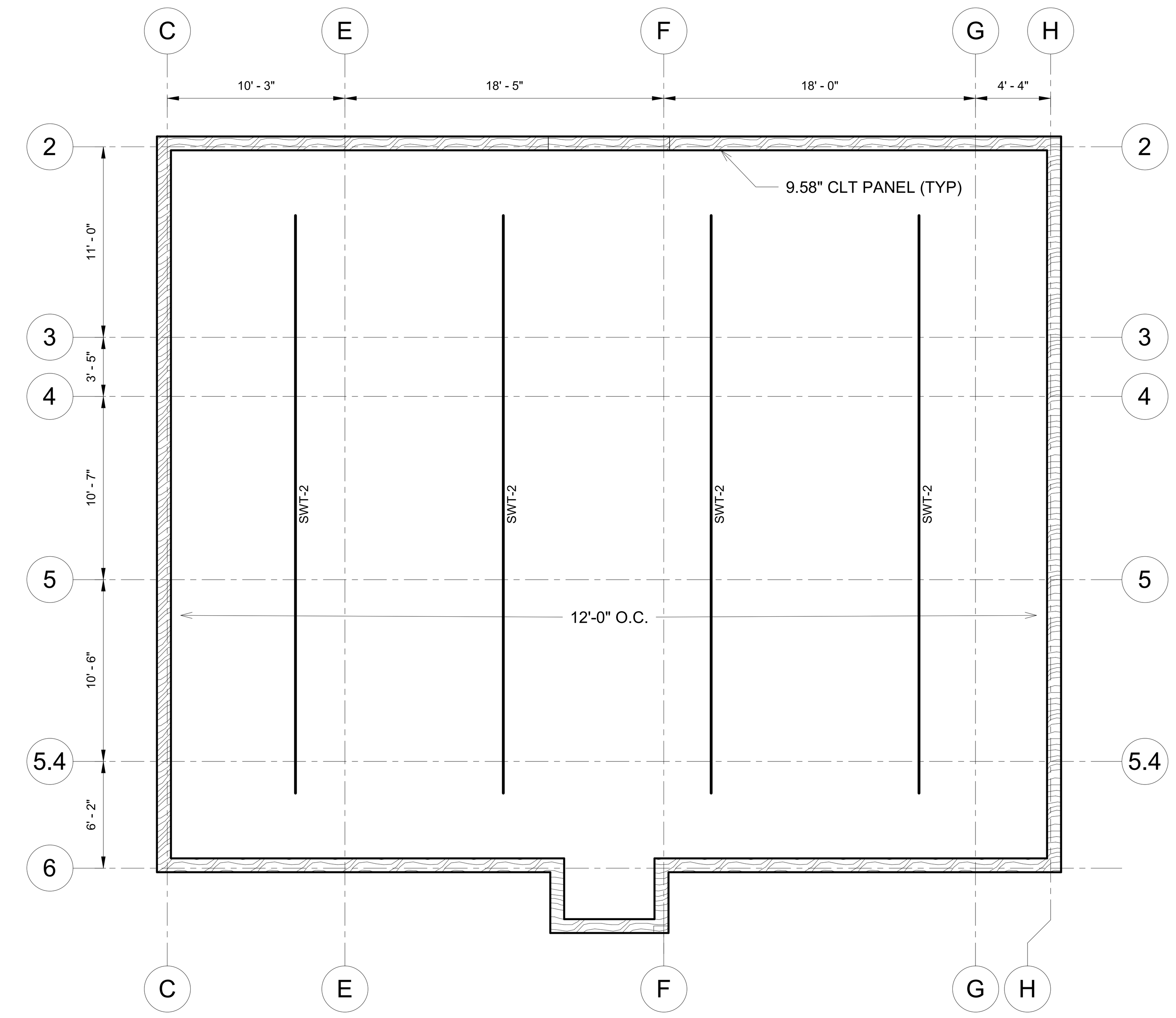
Typical Floor Framing Plan

AEI Team No. 7-2019
Date 02/18/2019
Scale As indicated

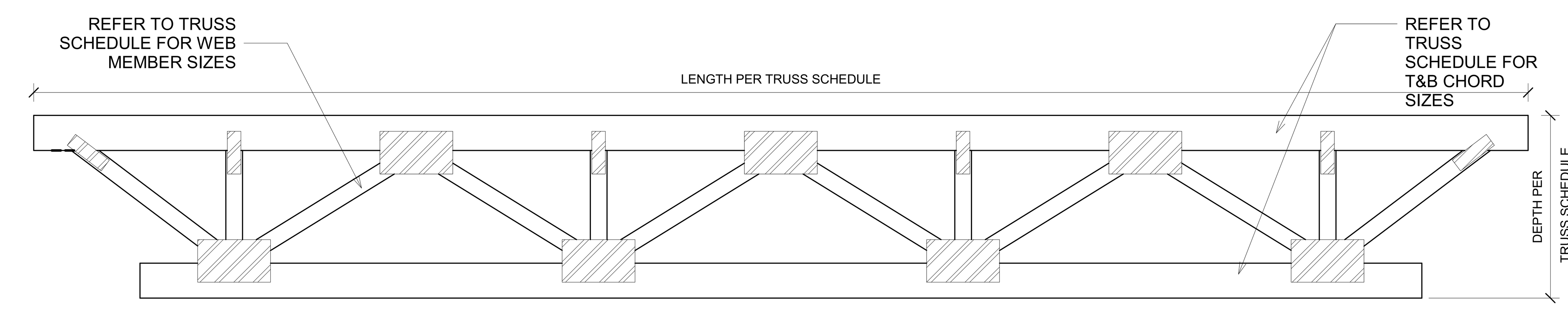
S3.5



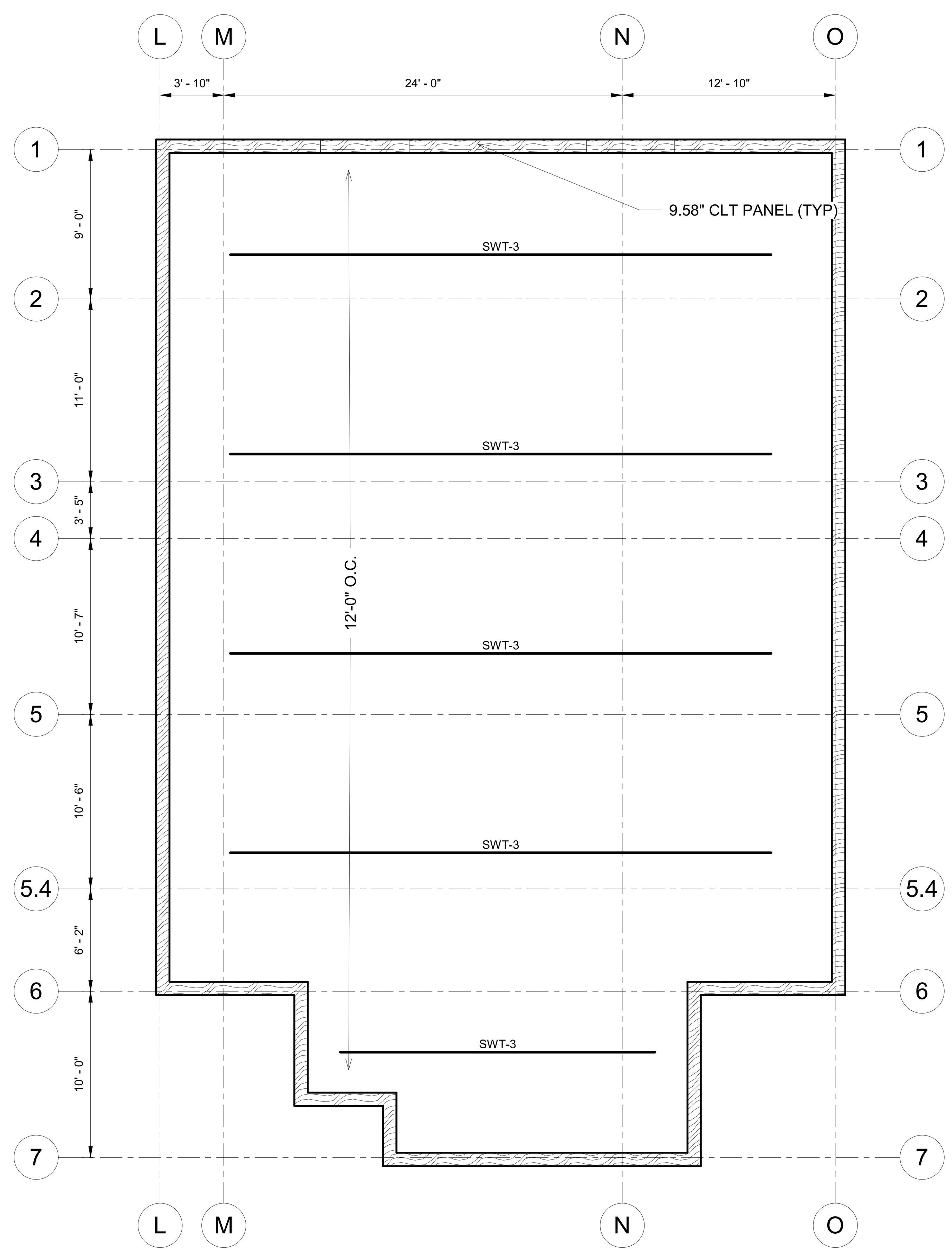
1 Recital/Rehearsal Highlight



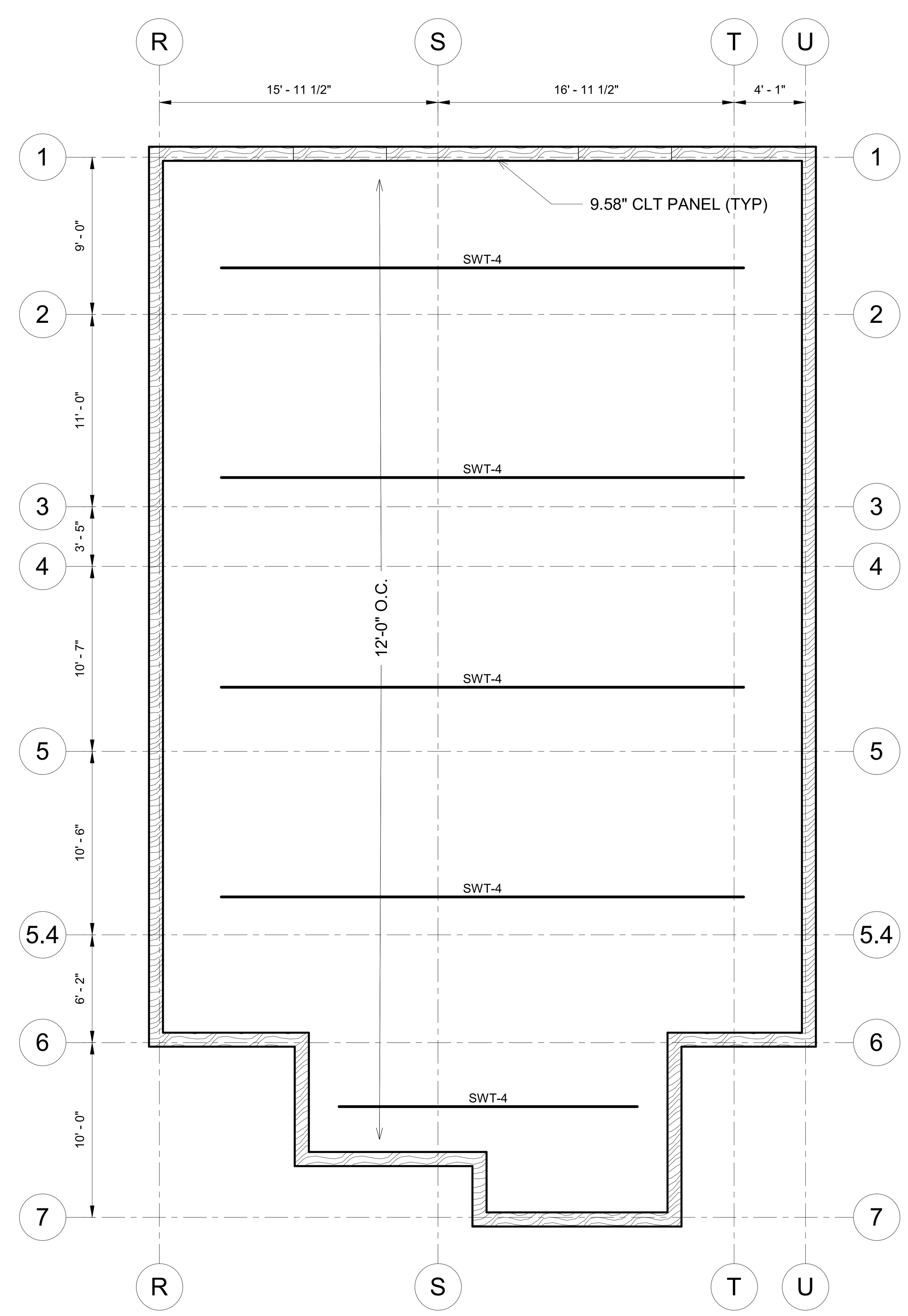
44 Recital Framing
3/16" = 1'-0"



9 Wood Roof Truss
3/8" = 1'-0"



2 Orchestral Rehearsal Plan
3/16" = 1'-0"



3 Choral Rehearsal Plan
3/16" = 1'-0"

WOOD TRUSS SCHEDULE

MARK	LENGTH	DEPTH	T&B CHORD	WEB MEMBERS
SWT-1	72' 5 1/2"	6' 0"	(2) 14" x 36"	12" x 28"
SWT-2	41' 8 3/8"	5' 0"	12" x 12"	6" x 12"
SWT-3	40' 8 3/8"	5' 0"	12" x 12"	6" x 12"
SWT-4	37' 4 3/4"	5' 0"	12" x 12"	6" x 12"

6 Wood Truss Schedule
1" = 1'-0"

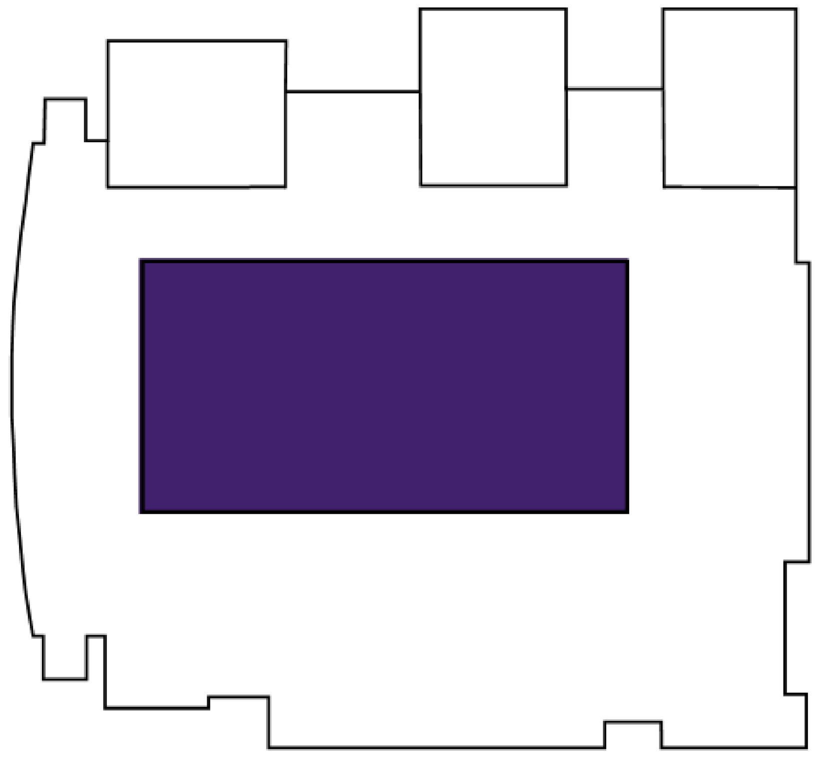
ATUNE

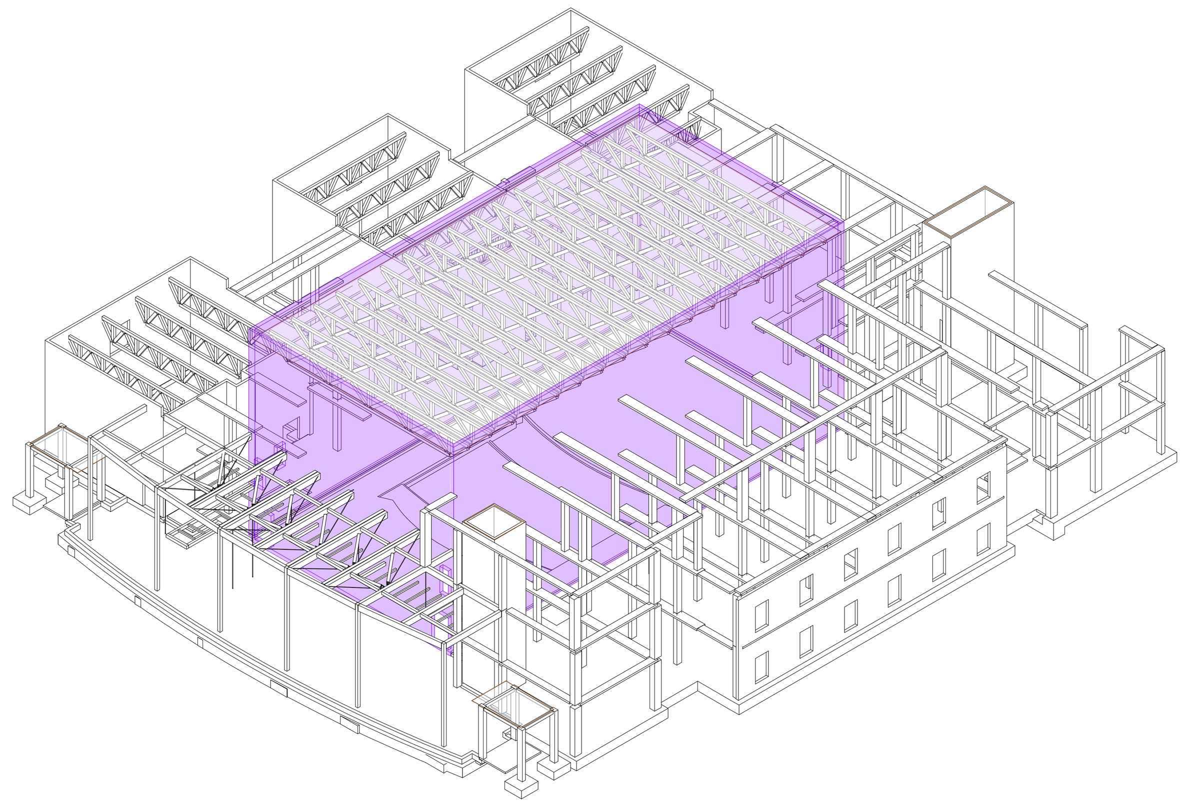
Jack H. Miller Center for Musical Arts

Rehearsal/Recital Framing Plans

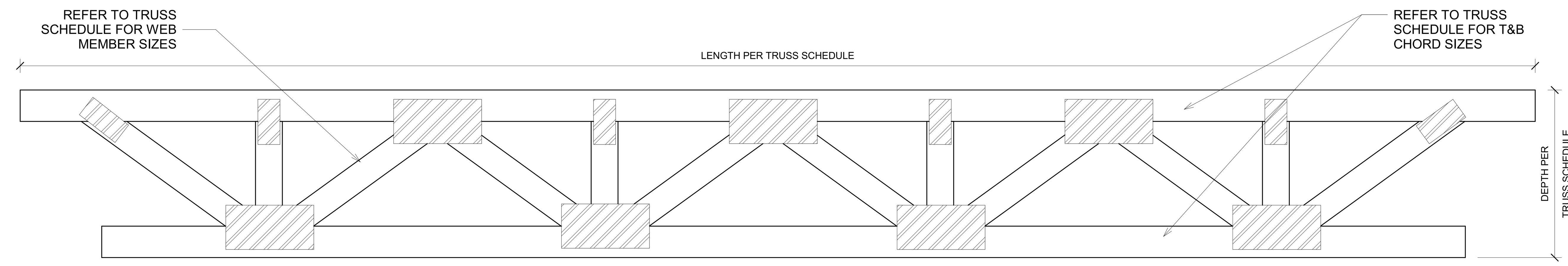
AEI Team No.	7-2019
Date	02/18/2019
Scale	As indicated

S3.6

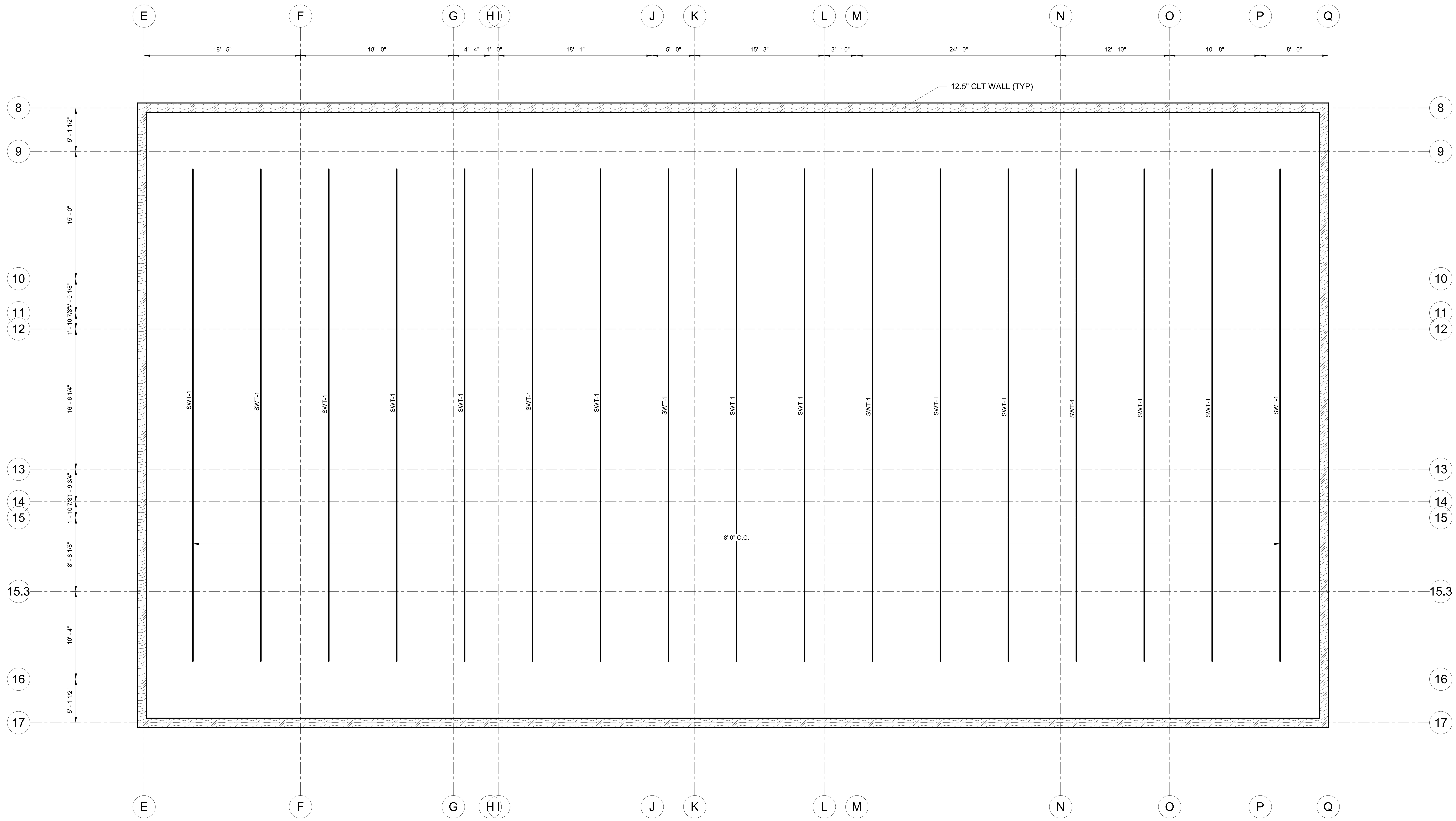




1 Performance Hall Highlight



2 Roof Wood Truss
3/8" = 1'-0"



3 Upper Roof Framing Plan
3/16" = 1'-0"

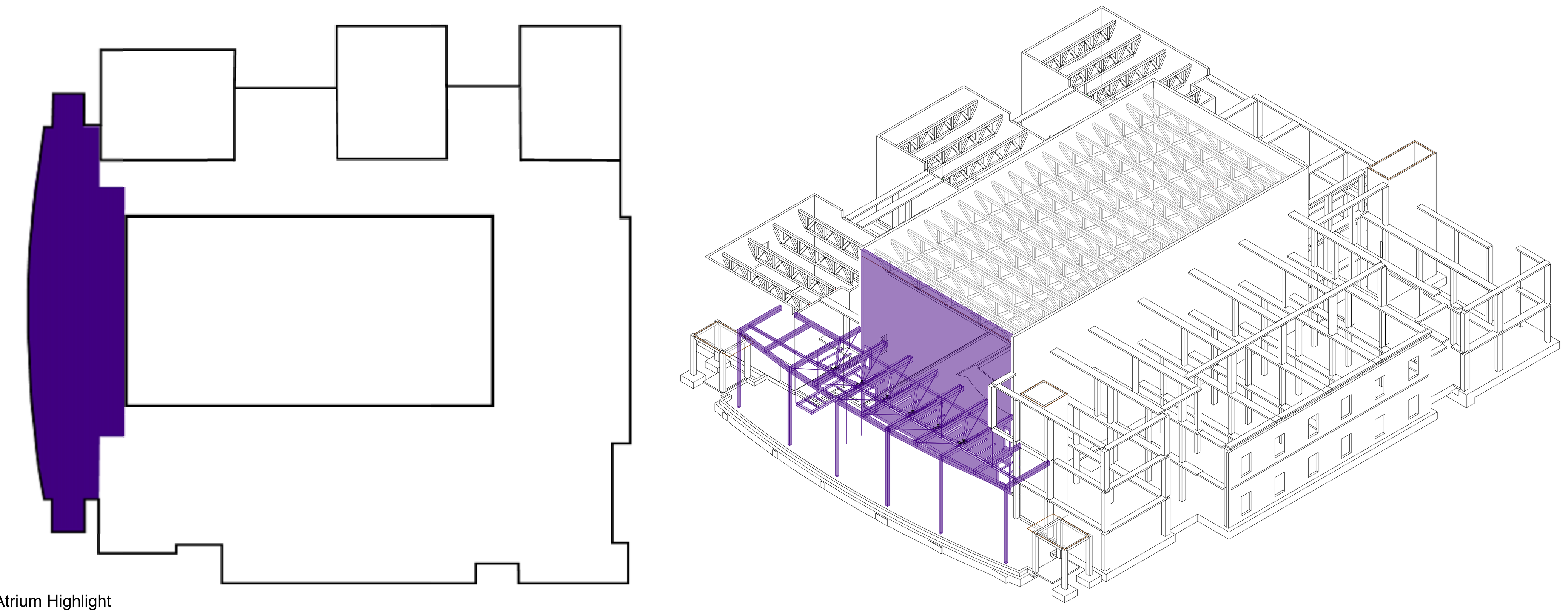
ATUNE

Jack H. Miller Center for Musical Arts

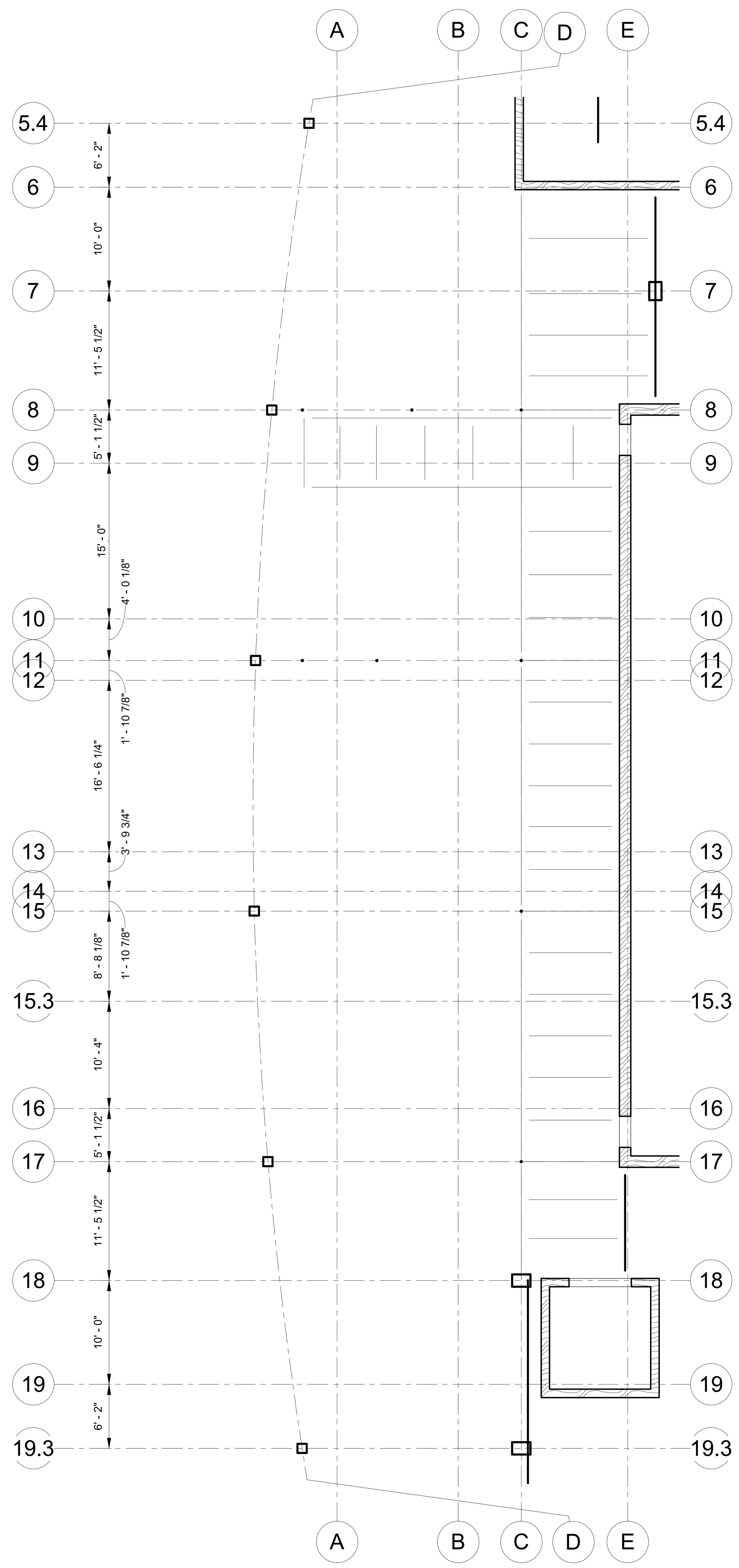
Concert Hall Framing Plan

AEI Team No.	7-2019
Date	02/18/2019
Scale	As indicated

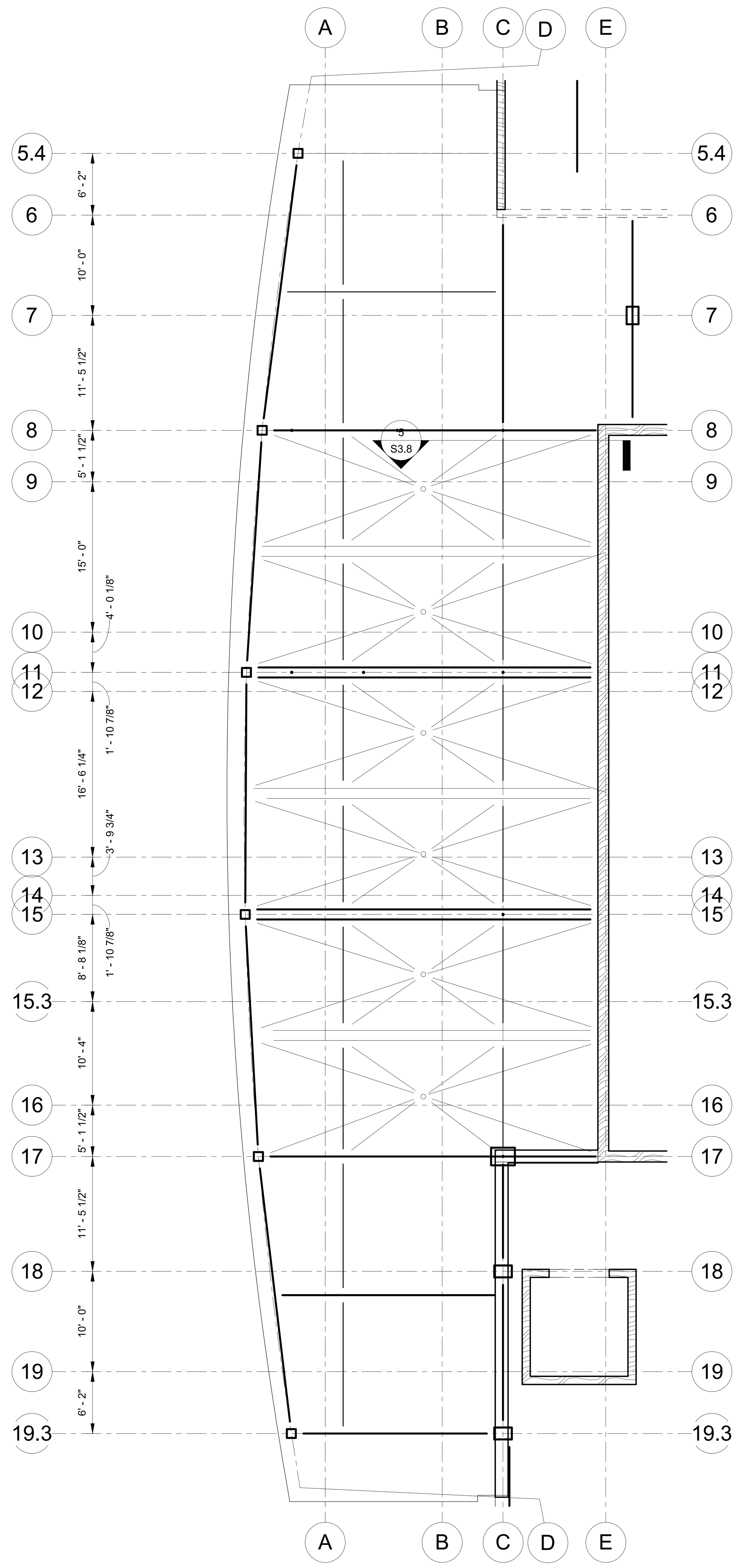
S3.7



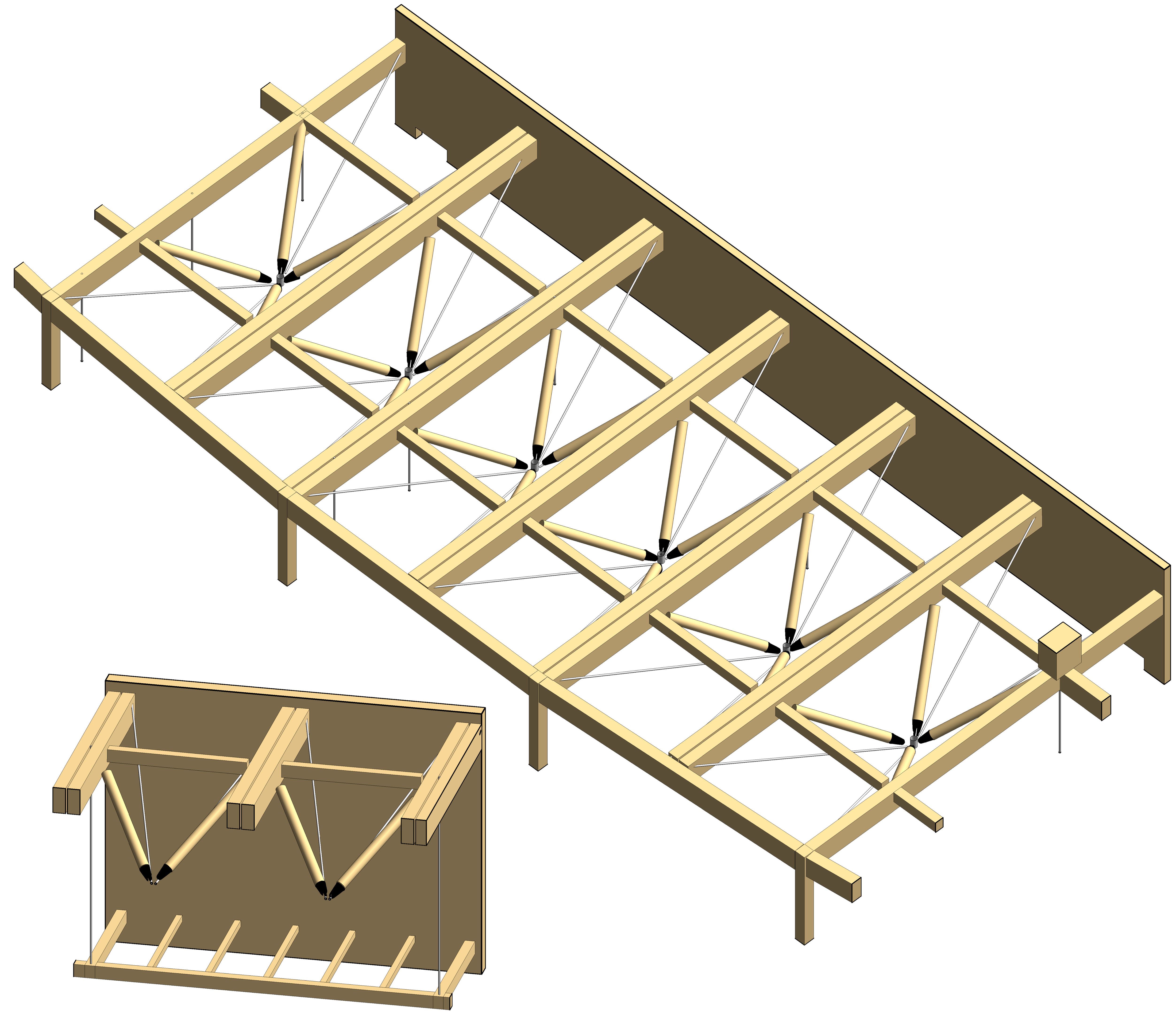
1 Atrium Highlight



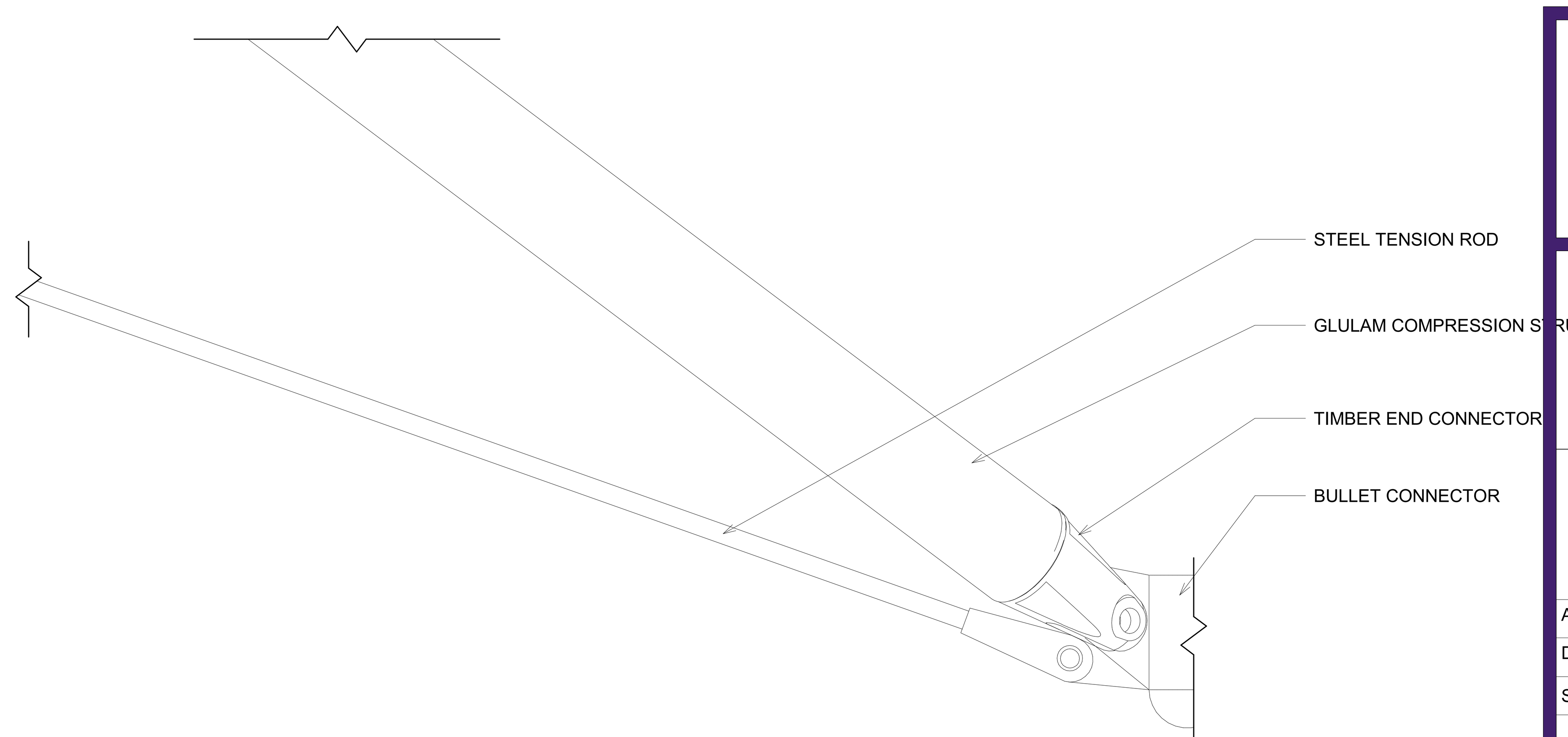
2 Atrium Walkway Framing Plan
1/8" = 1'-0"



3 Atrium Roof Framing Plan
1/8" = 1'-0"



4 Zipper Truss



5 Zipper Truss connection
1 1/2" = 1'-0"

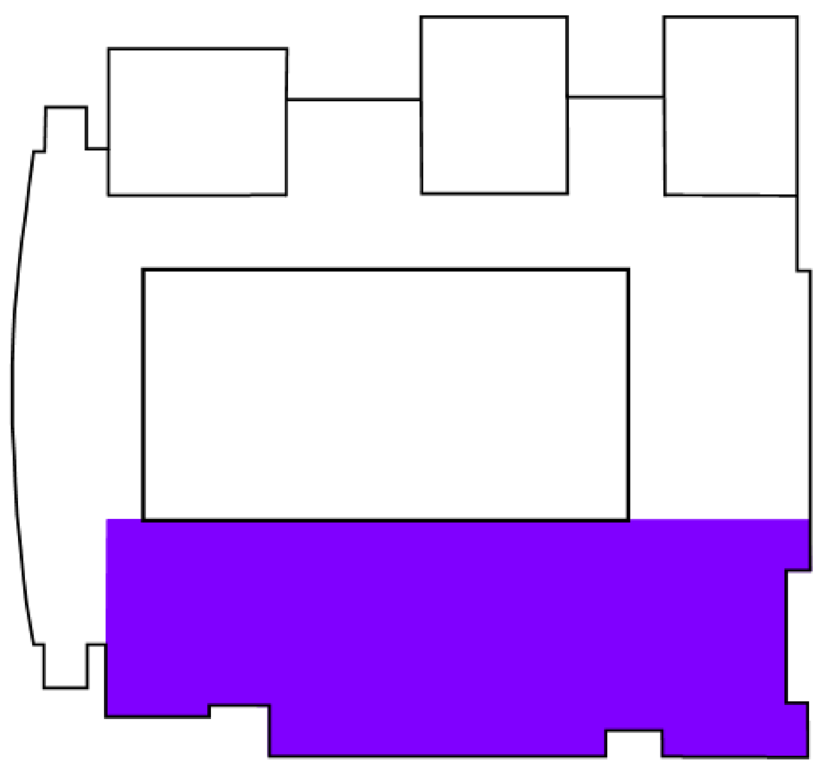
ATUNE

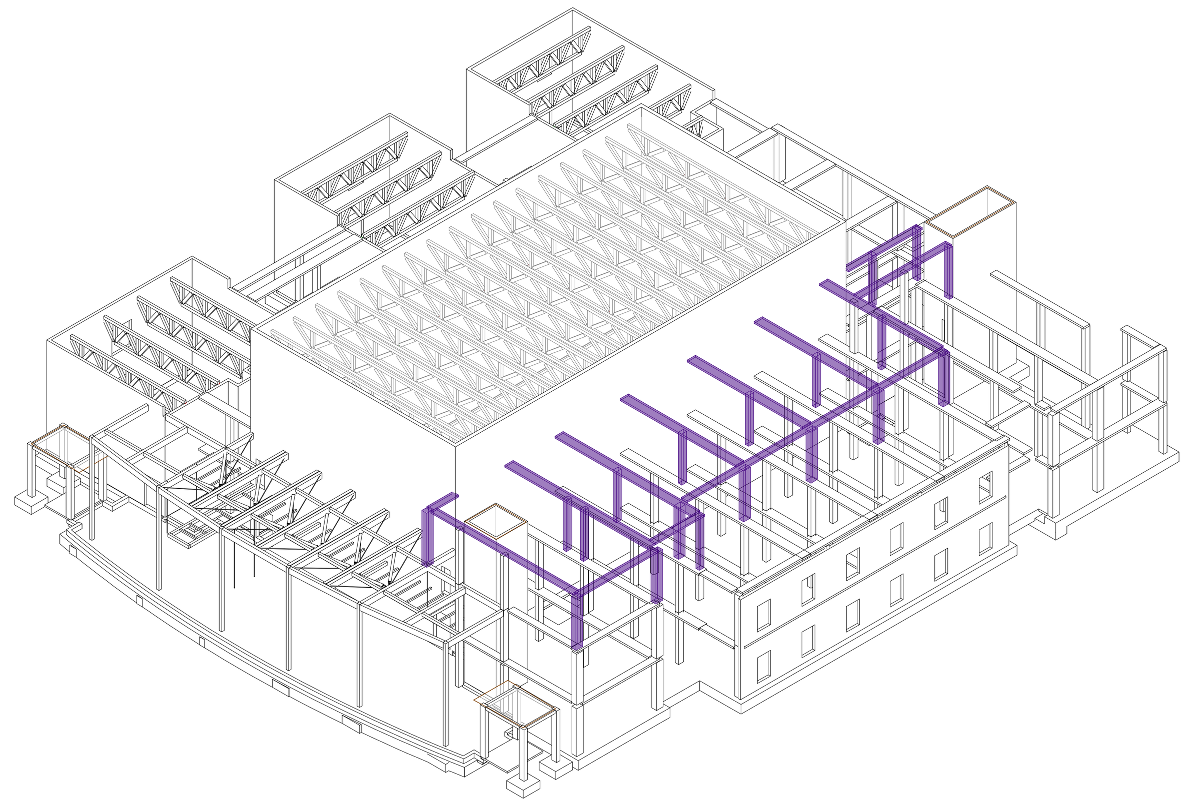
Jack H. Miller Center for Musical Arts

Atrium Framing Plan

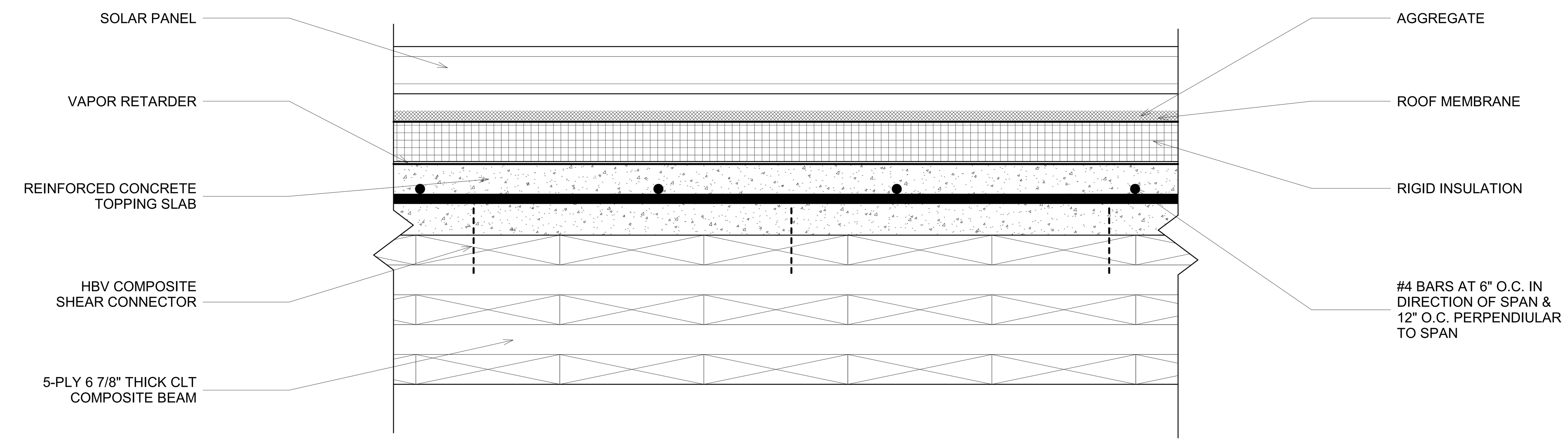
AEI Team No.	7-2019
Date	02/18/2019
Scale	As indicated

S3.8

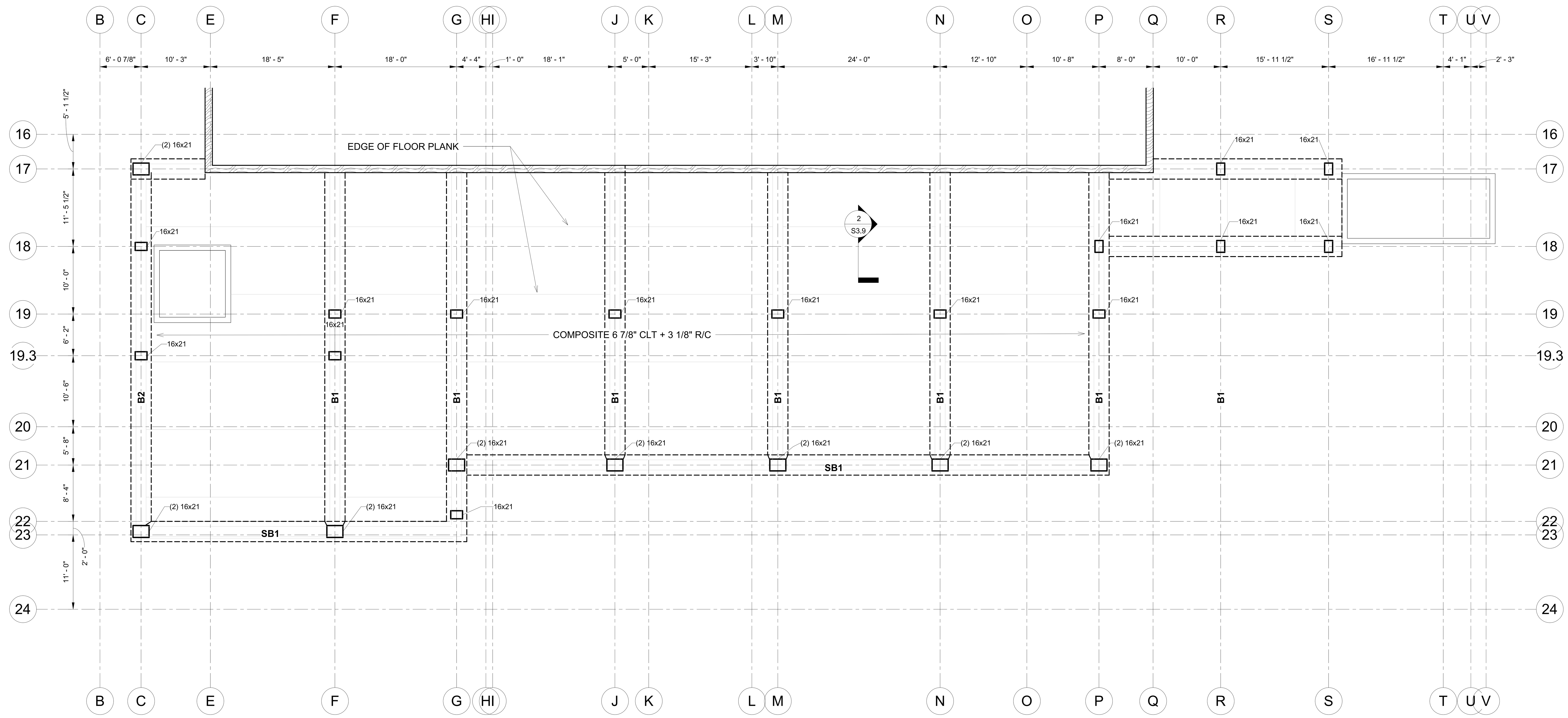




1 Amenity Highlight



2 Roof Section
3" = 1'-0"



REFERENCE 6/S3.5 FOR BEAM SCHEDULES

3 Amenity Roof Framing Plan
1/8" = 1'-0"

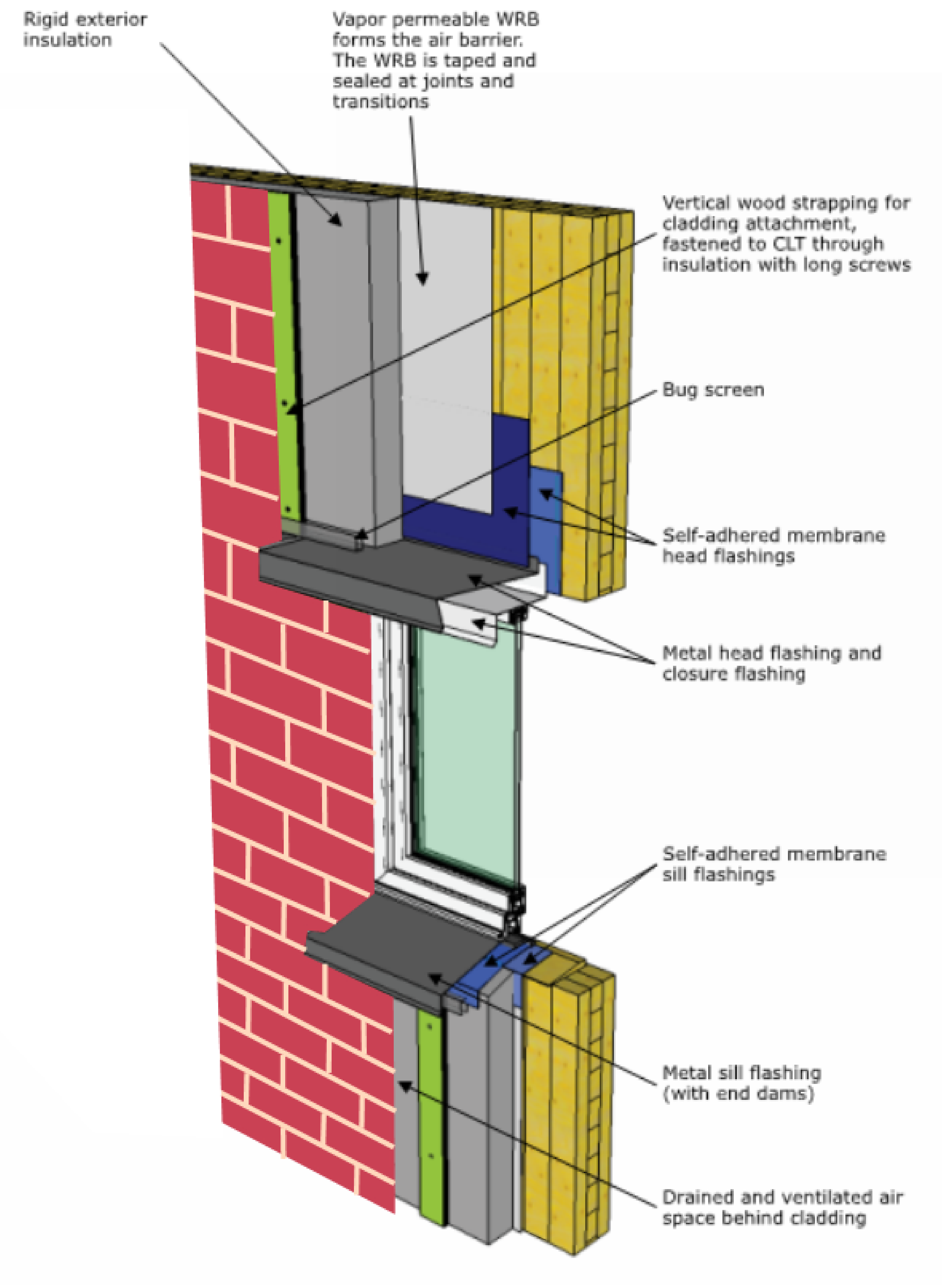
ATUNE

Jack H. Miller Center for Musical Arts

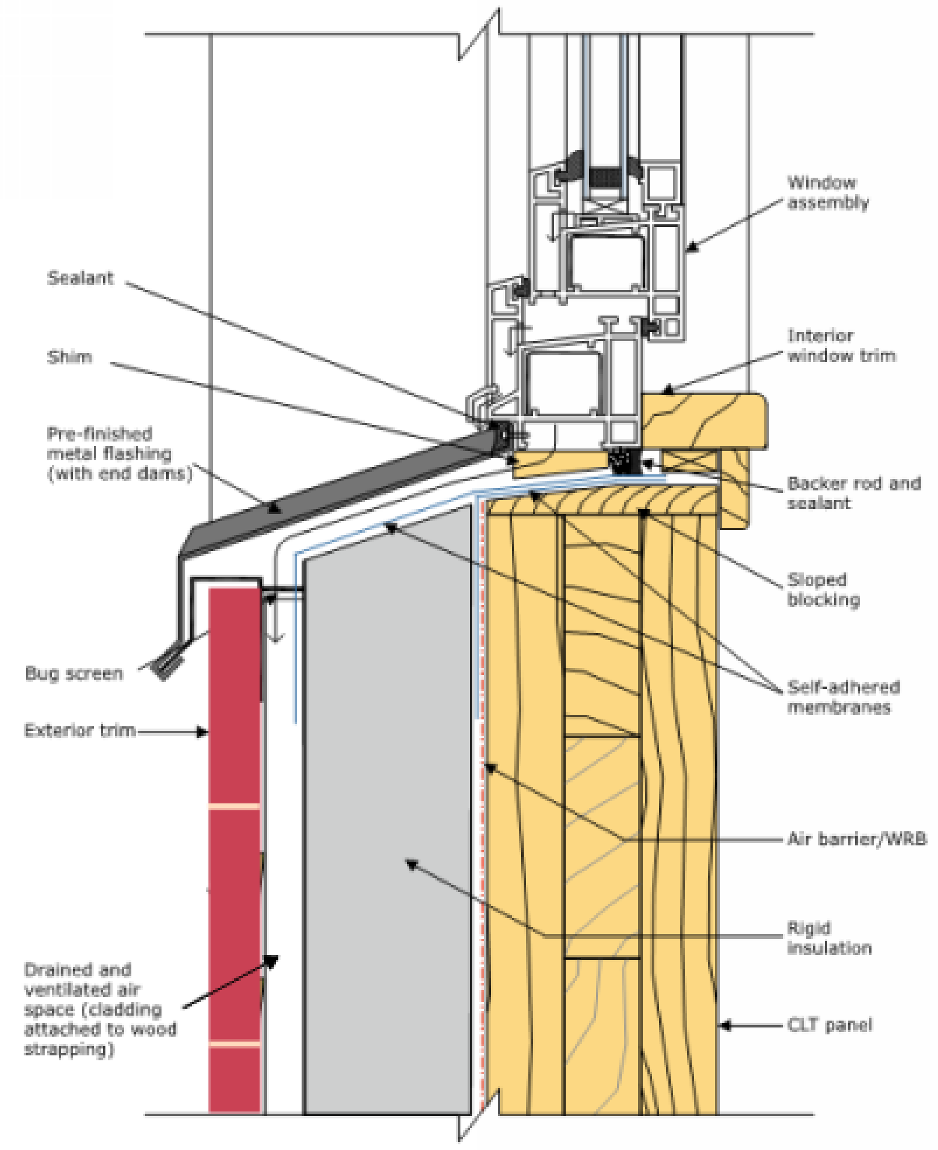
Amenity Roof Framing Plan

AEI Team No.	7-2019
Date	02/18/2019
Scale	As indicated

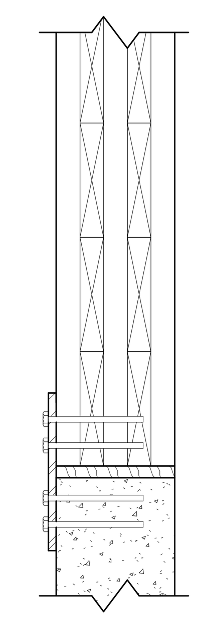
S3.9



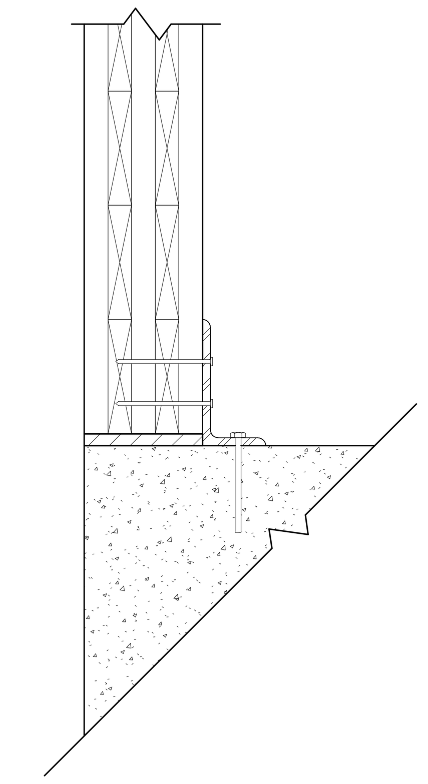
3 CLT Exterior Wall with Exterior Insulation and Ventilation Cladding
1 1/2" = 1'-0"



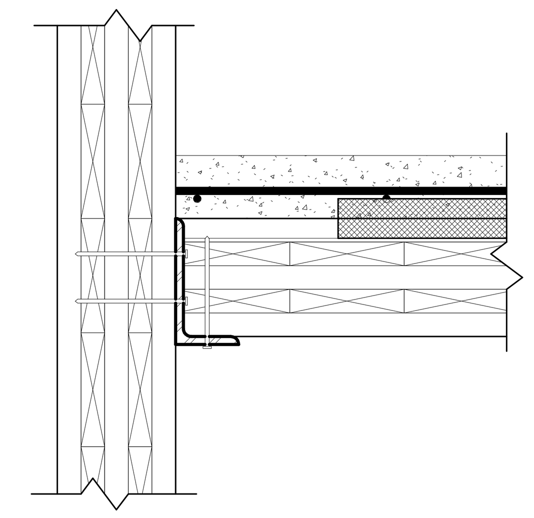
4 Window Installation with Wood Sill
1 1/2" = 1'-0"



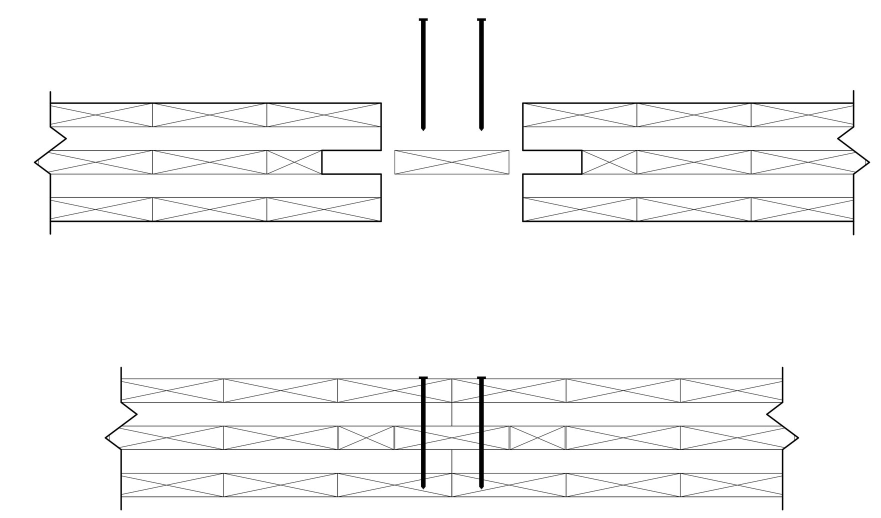
1 Panel to Retaining Wall
1 1/2" = 1'-0"



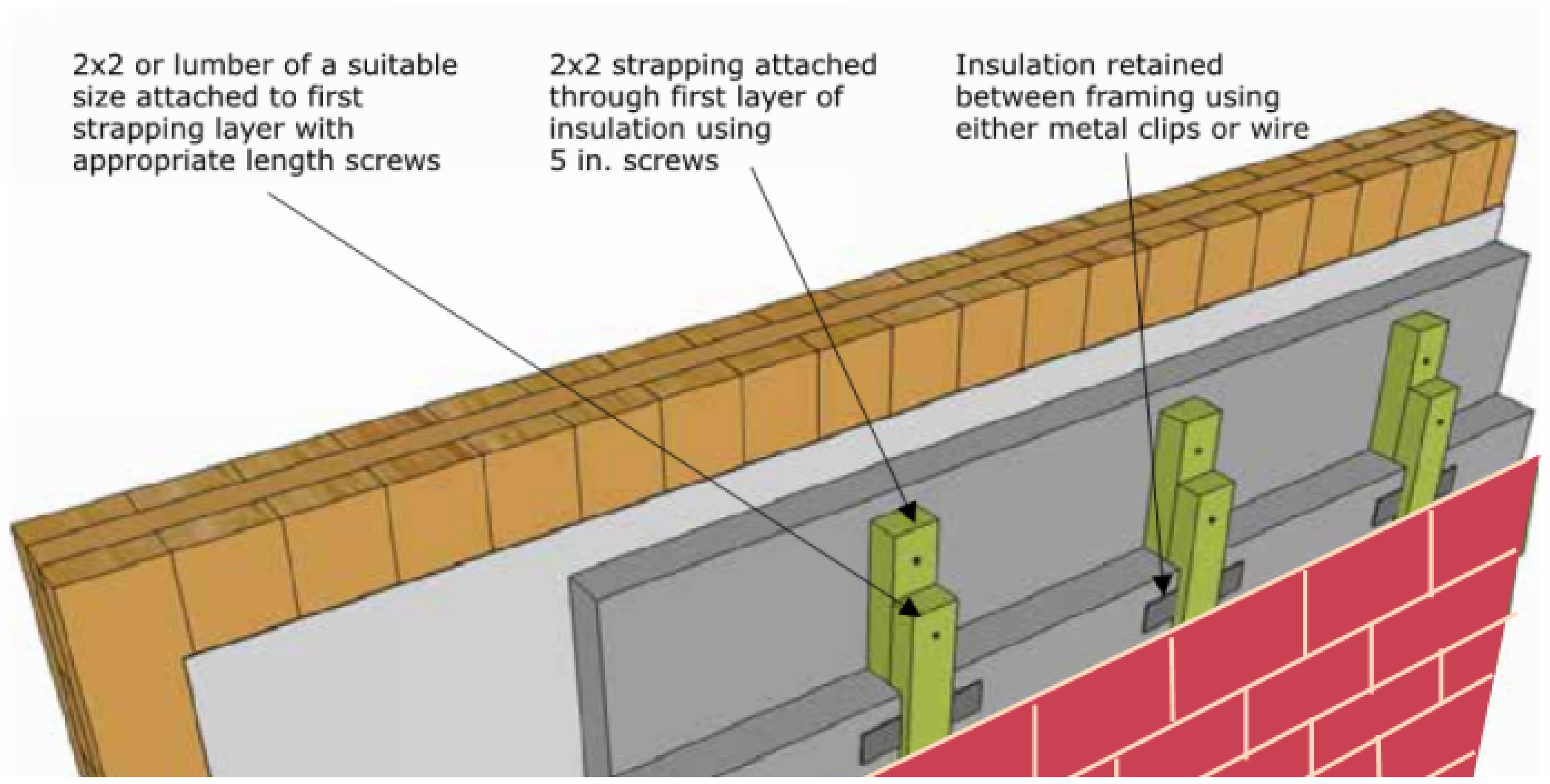
2 Panel to Foundation
1 1/2" = 1'-0"



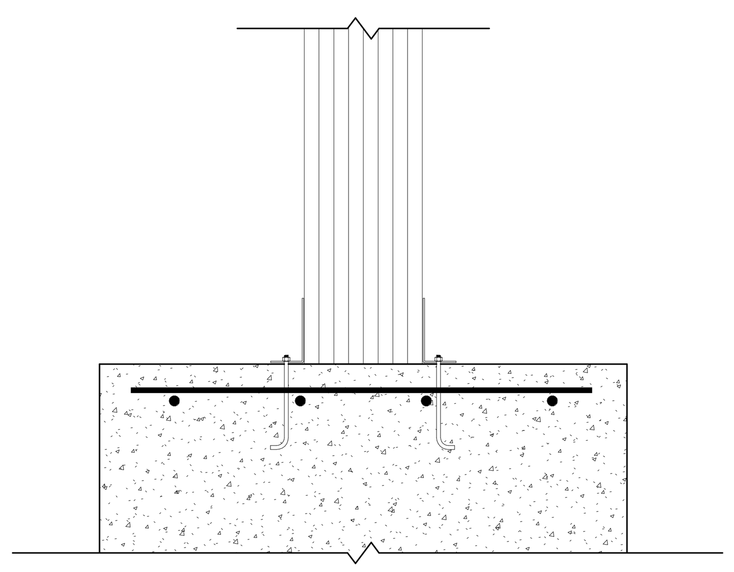
5 Framing to Panel
1 1/2" = 1'-0"



6 Panel to Panel
1 1/2" = 1'-0"



7 Cladding Support
1 1/2" = 1'-0"



8 Spread Footing Detail Copy 1
1" = 1'-0"

ATUNE

Jack H. Miller Center for Musical Arts

Building Enclosure & Connections

AEI Team No.	7-2019
Date	02/18/2019
Scale	As indicated

S3.10

MECHANCIAL EXECUTIVE SUMMARY

Atune utilized the Integrated Project Delivery method to design the Jack H. Miller Center for Musical Arts. It was the duty of the mechanical team to deliver a proficient design for HVAC, plumbing, and fire suppression systems that reflect each of the team goals. Atune chose to utilize an iterative design process and maximized the benefits of an integrated project delivery to complete this design. The team considered many innovative and integrated solutions to meet the building's needs. These solutions address the building's capability to perform efficiently, adapt under varying conditions and serve as a safe environment.

HYDRONIC MULLIONS

This design feature addresses the impact of solar heat gain on the west facade at the envelope.

DOAS

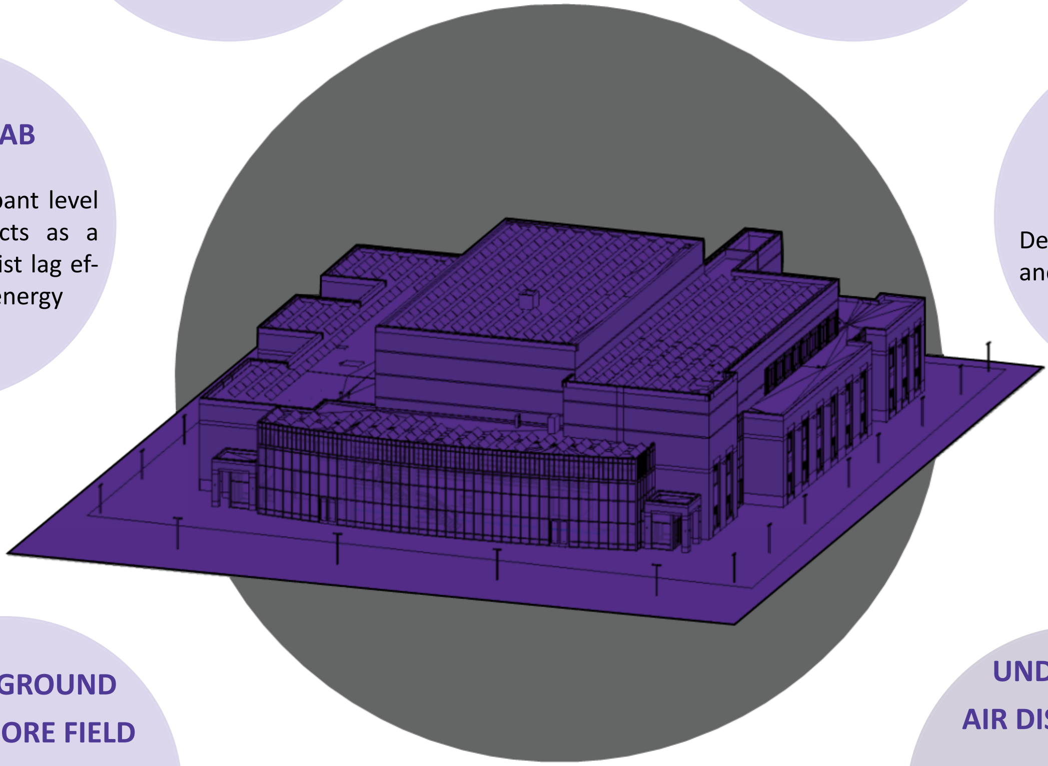
Enthalpy wheel and hot gas reheat dehumidify ventilation air and reduce building loads.

RADIANT SLAB

Provides both occupant level conditioning and acts as a thermal mass to resist lag effects in building energy transfer.

SNOW MELT/ RAINWATER COLLECTION

Decreases structural loading and provides potable greywater.



HYBRID GROUND SOURCE BORE FIELD

Allows for efficient heat reject and absorption throughout the year.

UNDERFLOOR AIR DISTRIBUTION

Conditioned outside air is delivered directly to occupants in voluminous spaces with minimal acoustical impact.

WATER-WATER HEAT PUMPS

Transfer of heat between spaces durring simultaneous heating and cooling periods.

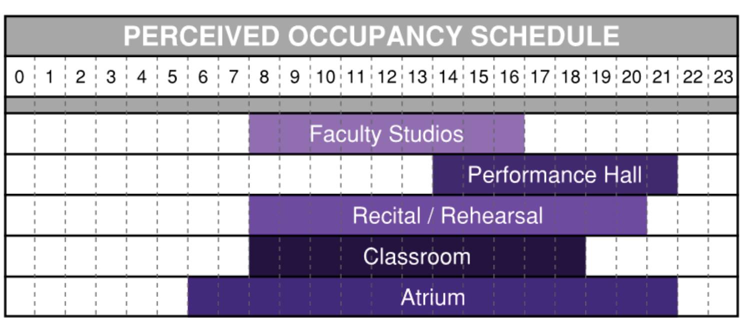
MECHANICAL TABLE OF CONTENTS

1.0 PROJECT INTRODUCTION

The Jack H. Miller Center for Musical Arts is located in Holland, Michigan and is part of the Hope College campus. This 64,000-square-foot building is to serve as the home for Hope College's Department of Music. It houses an 800-seat concert hall, a recital venue, instructional spaces, practice areas, faculty studios, recording rooms, and computer and piano labs. A total budget of $25 million was targeted for the entire project. An additional amenity space was designed to be present as an option for owner review (refer to section 11.3).

1.1 Mechanical Building Challenges

After studying the current architectural plans for the project, the following challenges have been identified due to the building layout and use. First, there are many musical spaces that have been designed with large volumes for acoustical purposes. This large volume of area needs to be conditioned. Another challenge related to the architecture is the large glass façade in the atrium due to its western exposure. This presents a significant challenge related to solar and envelope heat gain during the cooling months. The third challenge related to the building use and geometry is the combination of heating and cooling conditioning that will be necessary due to exterior exposures and internal loads. The fourth and final challenge related to building use is the predicted schedule differences for the different spaces. The large concert hall and the recital space will only be used on specific schedules for events, whereas the other spaces will see a typical Monday-Friday college classroom type occupancy.



Another building challenge that was presented was the lack of central plant. There is no evidence of central steam or chilled water loops for the Hope College campus. This led the team to believe that heating and chilled water must be generated within the site if desired.

Finally, the proximity of mechanical equipment to designated music spaces provoked additional care in equipment location and isolation. Because the majority of rooms are being used for music production, having adjacent mechanical rooms was inherent. Fans and motors in mechanical equipment induce vibrations that penetrate the barriers of the space if not properly attenuated. The mechanical systems also have a direct presence in each space via ducts and diffusers which also spurs careful design consideration.

1.2 Mechanical Climate Challenges

Due to the location of the project site and proximity to Lake Michigan, the following climatic issues have been identified concerning the constraints for the mechanical systems. The first is consistently high humidity year-round; Holland consistently averages a relative humidity range of 60-75% year-round from data collected by the National Weather Service (see page M2.2). This presents a challenge in conditioning outside air for ventilation and removing the moisture from these air streams to a more suitable and consistent relative humidity. Changes in humidity are known to alter tuning of stringed instruments, and too high or too low humidity leads to deterioration of instruments.

Fall			Winter		
Low Temp	High Temp	Humidity	Low Temp	High Temp	Humidity
20.2	89.5	72.4	-5.3	61.5	74.2
Spring			**Summer**		
Low Temp	High Temp	Humidity	Low Temp	High Temp	Humidity
7	88.2	66.6	44.2	93	71.4

Another climatic consideration to the mechanical team was the duration and severity of the winter season. As to be expected in Michigan, a large heating load will have to be conditioned for this project given that this area has a more extreme winter when compared to a temperate climate.

2.0 ATUNE'S MISSION

Atune set out to generate a facility design that is not only optimal for music instruction and performance but is a versatile and sustainable addition to the campus. The Hope College Department of Music's mission pursues promoting a passion for music; Atune pursued aiding in that mission through inventive building schemes. By taking an integrated project delivery approach, the team was able to address building challenges with holistic solutions.

3.0 PROJECT MECHANICAL GOALS

All aspects of the mechanical design were influenced and driven by the Atune's three main goals for the project: versatility, sustainability, and harmony.

3.1 Versatility

Flexibility in Use

This refers to the ability for a system to meet a space's needs regardless of the use. For instance, the atrium will need to be used as an entrance to the building and as an entertainment space. These changes in space use will require the corresponding system to adapt to a variety of occupancies and schedules.

Room for Growth
The ability to expand a mechanical system for future renovations is taken into consideration in the systems that serve the classrooms and faculty studios. This is less of a concern for the concert hall, atrium, or amenities systems since the structure will most likely not be altered for these spaces if expansion is considered.

Acoustical Adaptability
Given the nature of this project, it was a major focus of the mechanical team to prescribe a soundless system that would not take attention away from the musical performance and instruction.

Aesthetic Effectiveness
Along with acoustics, Atune puts value into this building as serving the arts. The design of the building sought to accompany the auditory performance with visual gratification for the occupants. For each space, the mechanical team was tasked with selecting distribution systems that did not distract from appealing structural elements.

3.2 Sustainability
Long Lifespan
Each system will have to be addressed in the future regarding replacement. The ease, cost and longevity of this operation have been evaluated while making system selections.

Maintenance Cost
Day to day operations for Hope College facility and grounds staff focus on maintaining a campus that is considerate to the use of natural resources and environmental impacts. If such maintenance work needs to be done, it should be able to be completed in a timely manner in an accessible location and with as little cost impact to the school as possible.

Environmental Impact
Hope College is best served by systems that abate the use of energy throughout the life of the building. This aims to minimize financial expenditure on behalf of the college while promoting sustainable operation.

Education to Public
Atune seeks to provide a space fabricated for effective musical instruction. This includes utilization of HVAC and plumbing systems that cater to a classroom environment that is conducive to pupil learning and uninhibited instruction from faculty. Occupant comfort and responsiveness to occupancy changes were of priority in design.

3.3 Harmony
Multipurpose Design
It is desirable that the mechanical systems serving the center for musical arts co-exist well with other building systems and aid in meeting their demands. Early and consistent communication throughout the schematic design and design development process is a key element to how Atune came to design decisions.

Building Façade
A visually appealing the façade for the center for musical arts is a priority, so mechanical systems must provide solutions that do not distract from the building's architecture. Minimizing envelope penetrations was also a goal of the mechanical team to reduce the possibility for moisture infiltration over the life of the building.

Schedule
The mechanical system solutions introduced must be conformed to the construction schedule for the project. Longer construction periods equate to loss of revenue for a post-secondary facility, so minimized times benefit the College.

Constructability
On and off-site fabrication can be utilized in the construction process. Working with the construction team allowed for an easier selection process and jump-started conversation about the operations needed for the construction timeline.

The Mechanical Decision Matrix that weighs out the system options categorized by space use and architectural geometry is found on sheet M2.1.

MECHANICAL DECISION MATRIX — ATRIUM

	VERSATILITY				SUSTAINABLILITY				HARMONY				
	FLEXIBILITY IN USE	ROOM FOR GROWTH	ACOUSTICALLY ADAPTABILITY	AESTHETIC EFFECTIVENESS	LONG LIFESPAN	MAINTNANCE COST	ENVIRONMENTAL IMPACT	EDUCATION TO PUBLIC	MULTIPURPOSE DESIGN	SCHEDULE	BUILDING FACADE	CONSTRUCTABILITY	
WEIGHT	4	2	5	3	5	3	4	4	3	4	1	5	
AHU W/ VAV	12	6	10	9	20	12	12	4	3	16	3	20	127
VRF W/ DOAS	8	6	25	9	15	6	8	4	3	12	2	15	113
RTU	8	4	5	3	15	12	8	4	3	20	1	25	108
HYDRONIC MULLIONS W/ DOAS	12	4	20	15	20	9	16	4	12	8	5	15	140
ACTIVE CHILLED BEAMS W/ DOAS	8	6	25	9	20	6	8	4	3	12	3	20	124
RADIANT SLAB W/ DOAS	16	2	25	15	20	15	16	4	6	4	3	10	136
UFAD RAISED FLOOR	20	10	20	9	20	15	12	4	9	12	3	10	144

4.0 MECHANICAL SYSTEMS & INNOVATIONS OVERVIEW
The HVAC systems and elements presented for the Jack H. Miller Center for Musical Arts each utilize hydronic waterlines sourced from a bank of water to water heat pumps. These water to water heat pumps make use of a ground source borefield in peak conditions. Radiant slab and underfloor air distribution schemes assist in delivering occupant-level space conditioning to avoid excess energy consumption. Active chilled beams provide silent conditioning for faculty studios, classrooms, and practice rooms. A dedicated outside air system allows for proficient enthalpy exchange between ventilation and relief airstreams, dehumidification, and reheat.

The plumbing systems make use of rainwater collection and greywater treatment to turn what would be disposed water into potable grey water for water closets and irrigation for surrounding greenspace.

5.0 DESIGN METHODOLOGY

The mechanical systems design was approached sequentially and iteratively with the use of analysis and design software, and building codes and standards.

5.1 Design Codes and Standards

The design of all mechanical systems proposed for the Jack H. Miller Center for Musical Arts followed all codes currently adopted by Ottawa County, as well as the Holland Municipal Code, including all amendments. Refer to the Codes and Standards page for a list of all relevant codes used for design and construction of the Jack H. Miller Center for Musical Arts.

5.2 Analysis and Design Software

Atune's mechanical team utilized hand calculations and industry standard practice to roughly calculate initial heating and cooling loads. This assisted in opening a collaborative dialog regarding system selection, equipment placement, and building massing that began upon initial project disclosure. To accurately calculate HVAC loads a model was carefully constructed using TRACE700. AAON ECat aided in selection of DOAS and AHU equipment.

6.0 SITE ANALYSIS

The geotechnical report for the site detailed a gray clay below depths of 23 feet with a top layer of sand. A water table of 8.8 to 12.3 feet indicates that the subsoil is saturated, which leads to excellent ground source heat absorption and dissipation. Saturated sand and clay have a high thermal conductivity when compared to many other common soil types. There is a portion of the site just east of the building that would provide ample room for a partial-capacity borefield.

7.0 HVAC SYSTEM DESIGN

Atune has aligned it's Heating, Ventilation, and Air Conditioning systems scheme to align with the client needs of the project as well as the team's design goals.

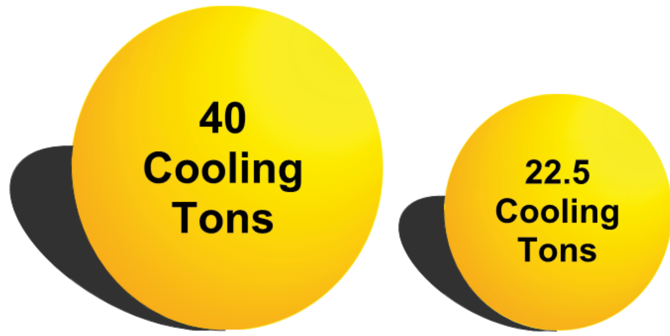
7.1 HVAC System Goals

A primary focus for the HVAC systems in the Jack H. Miller Center for the Musical Arts, as for all HVAC systems, is to provide adequate heating and cooling for occupant comfort. The systems must address the humidity concerns discussed in section 1.2 and diminish energy usage without sacrificing efficacy when it comes to producing the desired environment. The acoustic impact a system imposes must be minimal so as not to distract from the musical arts. Given the space is used for creation of an art form, Atune has also made it a goal to preserve and enhance the aesthetics of the building. The mechanical team has chosen systems that attempt to hide from the scope of vision for the occupants.

7.2 HVAC Loads

An HVAC load model was constructed using TRACE 700. Through analysis of each space, the following loads stood out: the atrium's solar heat gain and internal sensible and latent heat gain from occupants in the concert hall.

The atrium as initially modeled would have encountered over 40 tons of solar heat gain. By specifying the electrochromic design solution outlined in section 7.4.4, the atrium will only be subject to nearly 270,000 BTUh of solar heat gain in peak conditions. That is just over 22.5 tons of cooling demand. The mechanical and electrical design teams worked to find a solution that not only reduced this load, but also provided acoustic attenuation.



Occupant sensible and latent load in the concert hall was also determined to be a large load that the mechanical team could address through directed conditioning. A fully occupied performance hall would introduce 350,000 BTUh of latent load into the space. That is equivalent to 30 cooling tons needed to address just that aspect of the load. The mechanical team also saw this as an area to focus efforts. To address this load, the team collaborated with the structural team to deliver the design solution outlined in section 7.4.2.

7.3 Alternate Systems Evaluation

The first system considered was utilizing air handling units with reheat at the VAV terminal boxes. One air handling unit would have served each of the four occupancy schedules distinguished in section 7.2. Manufacturers could build and customize air handling units tailored to the demand each unit would face. Thus, this option would be adept at addressing the humidity concerns for the climate. Delivering air in the quantities required throughout the building to satisfy the internal loads would magnify avoidable sound manifestation. This sound is sourced from sizable fans that would force air through long lengths of ductwork, requiring additional attention to sound attenuation both enclosing the mechanical room and encasing the ductwork.

Rooftop units are commonly used throughout the HVAC industry. They are highly cost-effective for their capacity; however, they are unitary in nature, and are best used for single zone applications. These units are exposed to the elements and would need to be maintained regularly to ensure they perform correctly. They would also impose a large design feat in placing them out of occupant view atop the facility.

Another design option considered was to place water source heat pumps in each zone. This option would have been great for sharing heat between zones via a common water loop. In a large part of the year, parts of the building will need cooled while others need heated. Utilizing a system like this would allow tremendous efficiency by sharing loads with each other. However, water source heat pumps are not known for responding to the extreme cold temperatures of this project's climate well.

Variable refrigerant flow (VRF) would have been useful since cooling and heating demand in different zones happen simultaneously in this building. The flow of refrigerant throughout the building is silent to the occupant, and minimal sound would be made by ventilation air entering each space. Variable refrigerant flow requires piping of refrigerant throughout the building that is potentially harmful in the case of a leak. In addition, each manufacturer currently makes use of proprietary equipment controls, making replacement of individual pieces of equipment over the life of the system a costly endeavor if employed on a large scale. VRF was used to serve Data, Telecom, Electrical and Mechanical Rooms to temper sensible loads that locally manifest and separate them from a DOAS serving a heavily occupied space.

Combined heat and power could have had the benefit of producing heating hot water in the building. This system would provide electric power for the building and use the heat produced by the generator to offset demand from the heating hot water producing equipment. This option was deemed less than ideal due to the low electricity costs in Holland, Michigan. According to the Energy Information Administration, Michigan is just slightly higher than the national average at $0.1121 per kilowatt hour. There are times in the year when heating hot water is not utilized at all, so this energy would go to waste. The generator would require diesel storage with regular deliveries or costly modification for natural gas combustion.

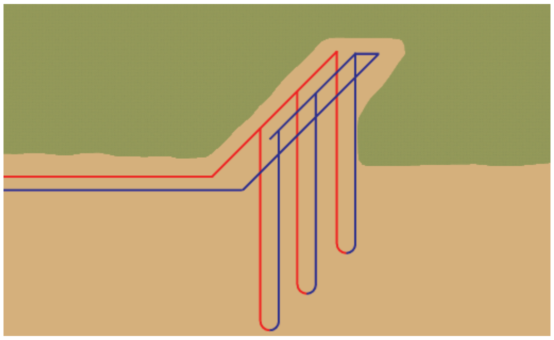
The Seebeck Effect for thermoelectric generation is a scientific principle that allows electric power to be generated from temperature differentials, otherwise known as a thermocouple. Synergine is a thermocouple generator manufactured locally in Holland, Michigan. A temperature differential of at least 70°F is ideal for this system to maximize power production. The water to water heat pumps were identified as a possible place to implement a thermocouple generator, using the leaving source water temperature and leaving load water temperature from multiple pumps. The Electrical team was able to devise a temperature monitoring scheme to maximize the differential the thermocouple would encounter. The mechanical and electrical teams deemed this design use would be ineffective due to complexity of the system and additional load it would place on the water to water heat pump.

7.4 HVAC Design Progression

Due to the variety in the schedules of use present in the building, the mechanical team made the decision to separate HVAC systems by occupancy schedules and space use. This allowed the opportunity for mechanical equipment pieces serving unoccupied or unutilized zones to be completely shut down rather than modulating a larger piece of equipment down which inherently breeds inefficiency. Climatic data pointed to simultaneous cooling and heating modes occurring for a large portion of the year. Exterior zones would need heating while interior zones would be predominately cooling internal heat gains. The ability for a system to transfer heat from one zone to another was identified as a tremendous benefit to efficiency. Occupant level conditioning became a priority for the mechanical team in the performance hall and atrium where tall ceilings create voluminous spaces. Tailoring conditions above the occupant level was deemed wasteful and avoidable if the right system was specified. The following systems are prescribed from Atune's Mechanical Design Team.

7.4.1 Hybrid Ground Source System Design

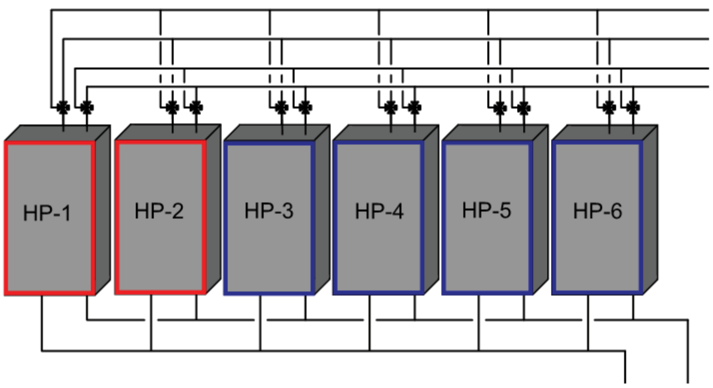
Atune has chosen to implement a hybrid ground source system for heat rejection and absorption. Holland has a relatively high-water table due to its proximity to Lake Michigan, and therefore is very conducive to thermal energy transfer between a ground source loop and subsoil conditions (refer to section 6.0). Utilization of a ground source water loop will allow additional capacity of the building systems by simply operating pumps to harness the subsurface conditions of the Earth. Limited area for a borefield, initial cost, and schedule constraints have caused Atune to move toward a hybrid ground source system. The peak cooling load for the building is larger than the heating load, so the mechanical team has elected tosize the ground source system for the heating load. A cooling tower has been selected to cycle on when ground source cooling demand rises above borefield's capacity.



The borefield has been lain out directly east of the building coordinating with the electrical team to avoid the placement of the generator and transformer serving the building. Fifty bores at 20'-0" O.C. have been placed over a 240 ft. by 60 ft. area. Each bore is specified at 350 feet of depth and four inches in diameter. Through the IPD construction process, a test bore will be drilled at the site at the specified depth. Adjustments to the borefield design can be made to meet design requirements and the remainder of the borefield can be completed before the building design is complete. Three-quarter inch HDPE pipe travels the depth of each bore and will tap off of a four-inch header. Pumps in parallel produce a flow of 300 GPM through the borefield. When cooling loads exceed the borefield's cooling capacity a 30-ton cooling tower starts and modulates to maintain the water to water heat pump rejection loop temperature. The cooling tower is located on the east side of the roof.

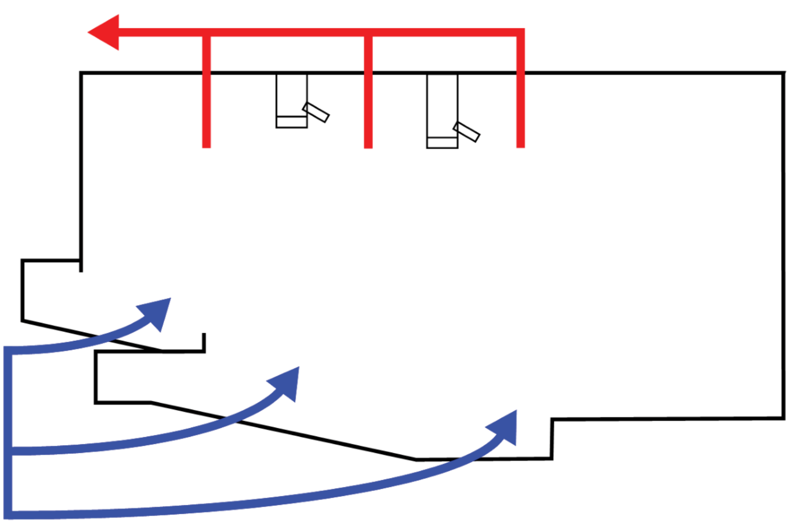
7.4.2 Water to Water Heat Pumps Design

The mechanical team has selected to deploy a group of six water to water heat pumps to supply heating hot water and chilled water to the array of hydronic elements. Each of these heat pumps are sized at 300 MBH and provide an n+1 redundancy strategy. These heat pumps are able to function as either a chiller or a boiler depending on the building's needs, rejecting or absorbing heat from a common water loop. This functionality allows one heat pump to absorb heat from the shared loop and another to reject heat to the shared loop when simultaneous heating and cooling demand is present in the building. The building will only require chilled water in warm weather, so all heat pumps will be rejecting heat to the shared loop. The shared loop will be piped in parallel with the hybrid ground source borefield and cooling tower. The heat pumps will serve chilled water and heating hot water loops that travel out to the radiant slab, chilled beams, and hydronic mullions serving various areas of the building. These heat pumps are not able to deliver temperatures at as high or low of temperatures as a conventional boiler or chiller, however they serve well to provide ample cooling and heating for the hydronic systems selected.



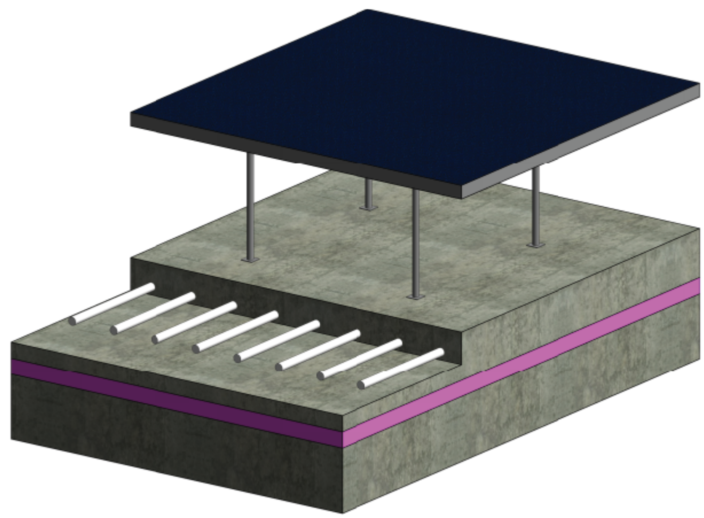
7.4.3 Concert Hall HVAC Design

To address latent internal loads and ventilation, a dedicated outdoor air system (DOAS) will be used. This system is highly efficient in humid climates. It makes use of relief air to aid in ventilation air conditioning and accomplishes this by first passing outdoor air through an enthalpy wheel. This makes the ventilation air conditions closer to that of the relief air. The ventilation air is then passed through a direct expansion (DX) cooling coil to dehumidify the outdoor air further. This is completed through cooling the air to sub-delivery temperatures. The ventilation air passes through a modulating hot gas reheat coil, which uses waste heat from the DX coil to increase the ventilation air temperature to delivery requirements. Utilizing this system will allow effective dehumidification and energy savings. Implementing this, however, will require space allocation for a condensing unit for each DX coil and requires routine maintenance.



The DOAS-1 unit for the concert hall will be located in Mechanical Room 151. It will contain a 62-inch enthalpy recovery wheel, a 32-ton DX cooling coil, a 180 MBH modulating hot gas reheat coil, two 3.5 BHP supply fans and a pair of 2.5 HP exhaust fans. A small condensing unit will need to be placed on the roof of the building to reject heat from the unit's internal DX coil. It will be supplying 6695 CFM of ventilation air to the space in peak conditions and will be controlled by a CO2 sensor.

Cooling is the main concern for this space, as occupant density and internal equipment loads can cause a great deal of demand, especially for a large volume space. Floor diffusers from a ducted underfloor plenum will be placed under every other seat to directly cool occupants with small amounts of ventilation air. Air will be delivered in a similar manner to the stage. As cool air is distributed at the floor, it will cling to the occupants and travel upward as it warms to efficiently cool occupants and reduce ventilation requirements. Stratification of the space must be managed, as higher degrees of the phenomenon will increase energy savings, but sacrifice occupant comfort. It also has the benefit of allowing for a low velocity delivery of conditioned air, which minimizes the acoustical impact in the space. Underfloor coordination and duct aspect ratios can become a challenge with this distribution method. The benefit to other systems that underfloor air distribution offers is the ability to run conduit and piping underfloor as well within the raised floor. Provisions in the mechanical code (IMC 2009 section 403.3.1.2) allow for a ventilation effectiveness value of 1.2 in cooling mode. This reduces the required amount of ventilation air by 16.7%.



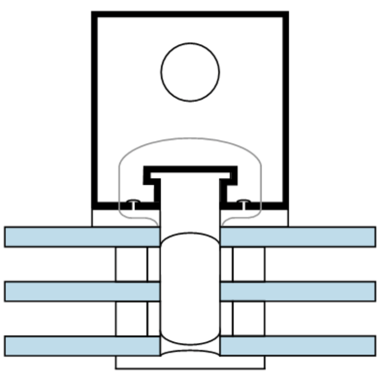
A radiant slab system will provide cooling and heating to meet sensible load demands in the concert hall. Silence in operation and a hidden design are strong benefits that mark a radiant slab system. This feature points directly to Atune's goal of providing a space that is harmonious with musical performance by being acoustically adept and visually appealing. The large thermal mass that is inherent to the system also acts as a source that can radiate throughout the day, helping the building resist lag effects. This system requires a great amount of slab coordination and has a high upfront cost of installation that will be addressed in Section 10.2 regarding the constructability. The system, however, remains low maintenance for a long life cycle.

With appropriate scheduling, the building automation system can begin to precool the space via the radiant slab system. Through the artificial intelligence building controls system, the slab can be precooled before a scheduled event. This creates a large thermal mass that works as a heat sink as the concert hall is filled to its full occupancy. The radiant slab is then able to continue cooling the space throughout the duration of a performance. Radiant slab technology and underfloor air distribution will be utilized on the balcony level as well. The hydronic piping will be zoned into areas separating the orchestra level, stage, parterre, balcony and side galleries using a system of automated valves.

Back of house spaces and the control room do not have a tall, voluminous geometry, so those areas will make use of active chilled beams that source their ventilation air from the DOAS. The stage lighting will be cooled by two direct expansion air handling units that conditions above the architectural ceiling. They will be 16-ton units capable of supplying 7,500 CFM and will be ducted to directly spot cool each light.

7.4.4 Atrium HVAC Design

The atrium will utilize ventilation air from its own DOAS unit. This unit will keep the same configuration as the concert hall unit but is sized appropriately to meet the atrium load requirements. Ventilation air will be distributed via a ducted underfloor air distribution system within the raised-floor on both the ground floor and the atrium lobby walkway. Floor diffusers will be located to provide low velocity air to the atrium which will combat the latent internal load produced by occupants. Low velocity air assists ventilation in cooling, as cool air is denser and therefore less buoyant. It remains in the breathing zone until it is warmed by the occupant and moves upward through the atrium.



The remaining sensible loads in the space will be addressed from a continuation of the concert hall's radiant slab and the introduction of hydronic mullions. The radiant slab will make use of the same configuration as outlined above but will be zoned separately from the concert hall. The term hydronic mullion refers to the piping of chilled water and heating hot water through the mullions of the western glass façade. The benefit to using this system addition is that envelope loads will begin to be tackled before they can penetrate through to the occupied space. In heating mode, these mullions help to prevent the windows from frosting over and snow from building up; in cooling mode, they will work in conjunction with the electrochromic glass (reference Electrical Section 7.2) to reduce envelope conductive and solar heat gain.

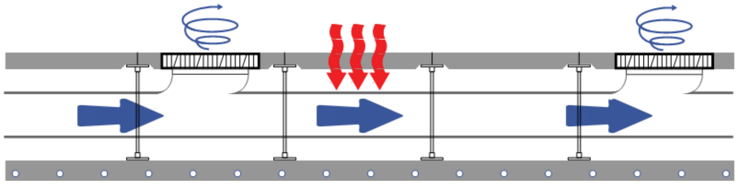
Mechanical Room 250 will house the atrium's DOAS-5 unit. It will also contain a 19-inch enthalpy recovery wheel, a 4.5-ton DX cooling coil, a 27 MBH modulating hot gas reheat, a 1.6 HP supply fan, and a 0.75 HP exhaust fan. It will be supplying 965 CFM of ventilation air to the space in peak conditions and will be controlled by a CO2 sensor.

Condensation on the hydronic mullions is a design concern that must be addressed by the mechanical team and monitored through the construction process. A temperature sensor on the interior surface of the exterior side of the mullion will work in coordination with the building automation system and water to water heat pumps to avoid condensation on the inside and outside of the building's windows. To prevent this, the system control sequence modulates the chilled water valve to the piping inside of the mullions will be constructed with 3/4" inch copper piping.

The radiant slab will be constructed and controlled in a similar manner to the concert hall radiant slab (refer to section 7.4.3). It will be broken into an exterior and interior zone.

7.4.5 Recital and Rehearsal HVAC Design

Like the concert hall design, radiant slab and underfloor air distribution for ventilating will effectively condition these tall spaces. The audiovisual and telecommunications rooms will share the same DOAS unit and underfloor system as the recital and rehearsal rooms. A direct expansion split air conditioning system in each space will maintain space conditions and combat the sensible loads that manifest in the audiovisual and telecommunications rooms. The underfloor plenum proved to be useful to our electrical counterparts, as it keeps low voltage cables and current conductors routed between racks easily organized and protected below the floor.



The recital and rehearsal rooms will be served by the DOAS-2 unit located in Mechanical Room 220C. It will contain a 62-inch enthalpy recovery wheel, a 28-ton DX cooling coil, a 132 MBH modulating hot gas reheat coil, a pair of 3 BHP supply fans, and two 2 BHP exhaust fans. It will be supplying 6245 CFM of ventilation air to the space in peak conditions and will be controlled by a CO2 sensor.

The radiant slabs for each zone will be constructed as three separate entities and controlled in a similar manner to the concert hall radiant slab (refer to Section 7.4.3). The three rooms are their own zones and will have separate thermostats to temper the space accordingly.

7.4.6 Classroom and Faculty Studio HVAC Design

All faculty studios obtain ventilation air from a common DOAS unit, and all other spaces (including classrooms, restrooms, and other general house spaces) will use another DOAS unit. These systems will be identical in their conditioning scheme but will have a large difference in capacity. Each DOAS unit will deliver conditioned ventilation air to active chilled beams located in each space.

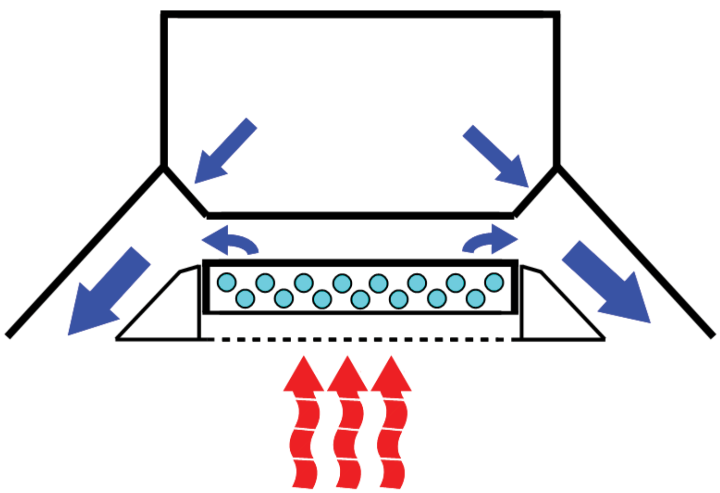
The DOAS-4 unit serving the faculty studio occupancy will be placed in Mechanical Room 220B. It will contain a 34-inch enthalpy recovery wheel, a 20-ton DX cooling coil, a 31 MBH modulating hot gas reheat coil, a 1.25 BHP supply fan, and a 0.85 BHP exhaust fan. It will be supplying 1300 CFM of ventilation air to the space in peak conditions and will be controlled by occupancy sensors with the ability to modulate with the variance of persons in the space.

Classrooms and other spaces will receive ventilation from a DOAS-3 unit in Mechanical Room 220. It will contain a 46-inch enthalpy recovery wheel, a 20-ton DX cooling coil, a 117 MBH modulating hot gas reheat coil, a 5 BHP supply fan, and a 4 BHP exhaust fan. It will be supplying 4860 CFM of ventilation air to the space in peak conditions and will be controlled by occupancy sensors.

Heating hot water and chilled water will be sourced from the bank of water to water heat pumps. Utilizing chilled beams in both exterior and interior zones provided the opportunity for heat to be transferred from zones in cooling mode to zones in heating mode via the shared water loop. Silence in operation was the largest draw for implementing active chilled beams. These are ideal for minimizing the production of background noise so music can become the main focus of the faculty and students.

All electrical, mechanical, audio-visual, and telecommunications rooms on the project will use a small VRF system for managing equipment heat production.

All spaces under these designations will use active chilled beams to deliver ventilation air and condition the space's sensible and latent loads. Care must be taken to ensure that condensation does not occur on the chilled beams. Chilled water running through the chilled beam must not be used at a temperature below 58°F, as that is a point safely above the design temperature dew point. As the water delivered to the chilled beam reaches 58°F, the chilled water valve will modulate to maintain the entry temperature.



All electrical, mechanical, audio-visual, and telecommunications rooms on the project will use a DX split system for managing equipment heat production.

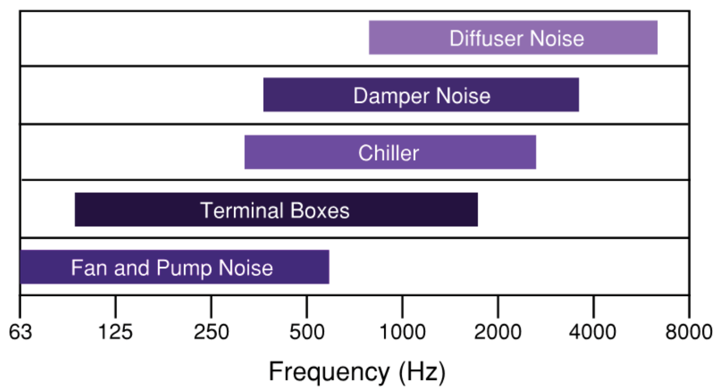
7.4.7 Snow Melt System Design

The snow melt system will be implemented in a similar manner to the radiant slab system, however this portion would not require the ability to deliver chilled water. A heating hot water-glycol mix will pass through PEX tubing embedded in the concrete that is found throughout the roof structure. Melted snow is then treated and collected by the rainwater treatment and collection system. Though this feature does not allow for downsizing of structural members, by providing this service snow loads will be removed from structural members, prolonging their life. The structural team mentions how this benefits their system in Structural Section 6.5.4.

Snow melt hydronic water heat will be sourced from the water to water heat pumps but will be located in its own closed loop which contains a 40% glycol mixture. Multiple zones are specified for different areas of the roof. This feature will be directed from automatic valves controlled by the artificial intelligence building management system, which analyses outdoor conditions and precipitation probability. Further discussion of this control can be found in section 7.6.

7.5 Acoustics

Early decision making was based heavily on the distribution of air to the spaces and the effects that the equipment would have on the acoustic performance of the building. With HVAC noise, we are concerned with the octave band of the equipment and the sound pressure sensed by the occupants. The mechanical team focused on the distance equipment was from rooms in relation to the area of the space and the acoustic properties of the furniture in those rooms.



7.5.1 Mechanical Room Equipment

Sound can transfer through ducts, dampers, walls and floors. The mechanical equipment placed in the building will need to be accounted for with sound isolation since the four main mechanical rooms will house the largest contributors for noise: dual wheel dedicated outdoor air systems. Steel spring vibration isolators with neoprene pads will be installed under equipment with at least 2 inches of clearance to the floor. All connections to the unit should be non-rigid with offsets no more than 15 degrees.

The walls of the mechanical room will be airtight with concrete block walls from floor to ceiling that are caulked at the joints at the top of the wall. We will also make the airtight seals around each opening that are made for ducts and doors. The use of timber improved the sound transmission class of the interior and exterior walls to reduce the amount of noise resonating from the mechanical rooms as well.

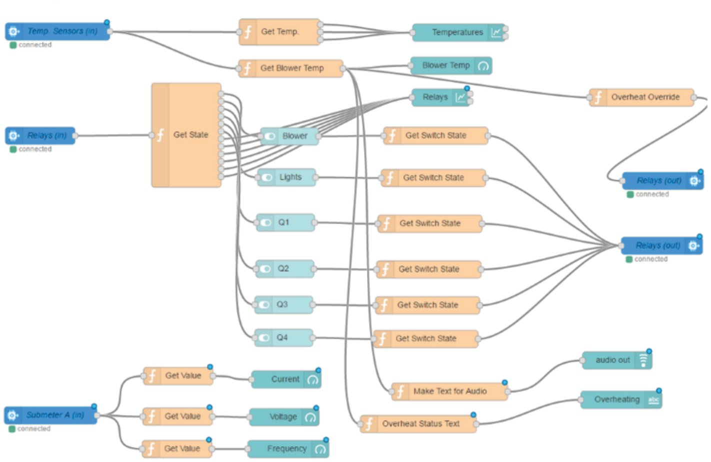
7.5.2 Distribution Equipment

When choosing the distribution equipment in the building the conversation circulated around the attenuation of sound. Underfloor air distribution in the atrium and concert hall delivers air at low velocities that reduce the vibration in the ducts and the sound of the air passing through the floor diffusers. Active chilled beams introduce little to no noise in a space without additional attention or equipment provided. The systems that focus on serving the internal sensible loads like radiant slab that run within the floor of the atrium and concert hall along with hydronic mullions that run vertically along the curtain wall in the atrium add no noise to the space because of the low velocity of the fluids and having additional exterior coverage to mask the little amount of sound that is made. The noise transmitted from the ducts and airflow noise under the floor of the atrium and performance hall will be addressed with minimal bends and silencers where there are higher velocities in the airstreams, especially coming out of the mechanical rooms. Another way to improve the sound impact is to enlarge the size of the ductwork and implement radius elbows where the space allows. Where radius elbows do not fit, mitered elbows with turning vanes will be used.

7.6 Artificial Intelligence Building Automation System

Mechanical efficiencies can be greatly improved through control schemes that are directed from an artificial intelligence building automation system (AIBAS). The first benefit of AIBAS is that room schedulers can be adjusted to precool rooms with large occupancies. This works well in the concert hall, as the radiant slab system would not be able to adapt swiftly to an occupancy swing of 800 people. The AIBAS will work to cool the floor slab before occupants arrive for a performance, allowing the slab to act as a heat sink. This concept is applicable to every room, as each occupied room has a room scheduler that communicates with the AIBAS. Users are able to input anticipated occupancies and times for room use, and occupancy sensors can verify occupancy during the scheduled time. IBM's Watson has a gateway to BACnet and can collect Mechanical system data. Performance trends can be presented to the facilities team, pointing out where efficiency opportunities can be gained. Furthermore, building savings and efficiency will be displayed on the interactive educational display as discussed in Electrical Section 8.3.4. For more information on AIBAS in general, see Electrical Section 8.3.2.

IBM Watson



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7.7 HVAC System Summary

The HVAC systems proposed for the Jack H. Miller Center for Musical Arts maximizes the use of water to water heat pumps to efficiently transfer heat between a variety of hydronic features. This system is complemented by use of efficient DOAS units that provide high quality air to the occupant promoting a healthy environment to learn. By separating the DOAS units by occupied schedules, building monitoring is able to shut entire portions of the building HVAC equipment off at different times of the day. Collaborative efforts between disciplines allowed for implementation of a snow melt system to reduce snow loads on the structural system and electrochromic glass on the atrium façade.

8.0 PLUMBING SYSTEM DESIGN

The plumbing design aims to fulfill the desires and needs of Hope College through ease of access to occupants, and through efficient design that will decrease the building's operating costs.

8.1 Plumbing Design Goals

Atune has pursued a design with low environmental impact, multipurpose design, and constructability to fulfill the team's design goals of sustainability and harmony for the proposed plumbing system.

8.2 Plumbing Scope

The plumbing scope for the Center for the Musical Arts includes domestic water, sanitary drainage and venting, and storm drainage. No gas service will be provided as electric water heaters are being specified, and there are no other gas needs in the building. There are four sets of multi-occupant restrooms (men's and women's) in the building, including the impending set of restrooms located in the rooftop amenity space. The amenity space restrooms meet the necessary fixture quantities to serve the occupancy as dictated by the IPC. There are a limited number of other miscellaneous plumbing fixtures throughout such as mop sinks, kitchen sinks, and water coolers.

8.3 Alternate Systems Evaluation

The following systems were also evaluated for potentially being incorporated in to the plumbing scheme. Supporting Document M2.1 shows how the design decisions were finalized between these system features and the selected system features.

Greywater Reuse: This system would aim to conserve water by treating lavatory drainage for reuse as greywater. This conservation method was not included in the design because of the low quantity of lavatories, and the cost associated with routing and incorporating this system with the rainwater collection scheme to produce combined greywater distribution.

Flue Gas Heat Recovery: If utilizing a gas-fired water heater for the building, this system could be used to make use of the heat given off in the gas flue. This proposition was not included in the design because of limited water heater size due to the quantity of lavatories, and because the utility for the water heater will be electric due to the lack of any other need for natural gas on the project.

8.4 Design Optimization

The plumbing features included in the design were chosen based on relevance in aligning with project conditions and design goals as set by Atune. These features are described in the following sections and include Rainwater Collection, Fixture Selection, and System Monitoring Capabilities.

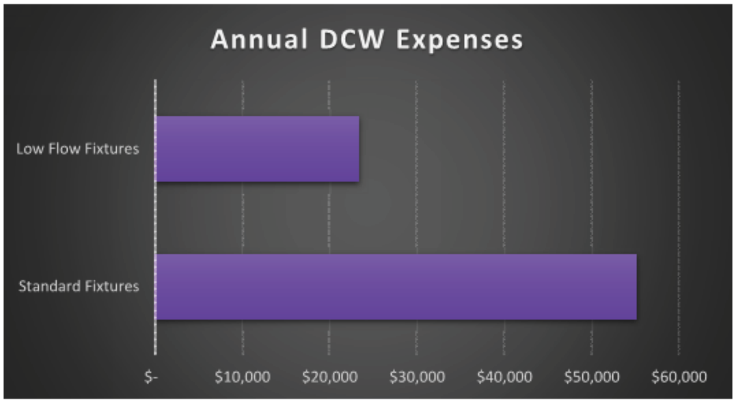
8.5 Rainwater Collection

The roof drainage system will implement rainwater collection that will be used as potable greywater. This system will reduce environmental impact and utility costs through water conservation.

Roof drainage, consisting of either rainwater or melted snow from the hydronic snow melt system discussed in Section 7.4.7, will be collected via the roof drains and routed to the cistern buried on the south exterior of the building. A pump will route rainwater from the tank to the rainwater control station that serves the water closets and irrigation on site (see system schematic on Sheet M3.8). The control station will be located near the storage tank location, on the interior of the building in Mechanical Room 250 (see Sheet M3.4). This design will save 11,380,000 gallons of water per year resulting in a payback period of 16 years (see Supporting Document M2.3).

8.6 Fixture Selection and Routing

Water Conservation: Low flow water closets and waterless urinals will be implemented for water conservation and as a good practice for sustainable design. These fixtures use 42% less water, which results in about $32,000 saved in utility costs as demonstrated in the figure.



Power Supply: The motion sensors for the lavatories will be self-powered through turbine technology. This multipurpose system will reduce the electrical energy drawn from the grid, which will in turn decrease electrical utility costs and environmental impact.

Routing: The pipe runs for the room spaces will be prefabricated off-site so that appropriate elbows and routing are already in place when the piping arrives on site. This will reduce installation time in the field as the prefabrication can occur off-site while a different phase of construction is going on at the same time. The domestic water, fire sprinkler, and sanitary sewer connections will come in through the east back of house area of the building, allowing accessibility to the nearby chase for routing to be continued to the upper floor (see Sheet M3.3). The water heaters are both sized to serve the demand capacity of 125 gallons and include a recirculation loop. They reside in Mechanical Room 151, allowing proximity to the domestic water main and the piping chase (see Sheet M3.4). The venting will be stacked through the chases for the north and south sets of restrooms through both floors and the amenity space restrooms.

Acoustics: Pipe insulation will assist in reducing noise potentially produced by the movement of fluid in the plumbing pipes. Besides this there is not much acoustical concern associated with the plumbing system as it has little interaction with the occupied acoustical spaces.

8.7 System Monitoring Capabilities

When considering the long lifespan of this building application on a college campus, the mechanical team decided that it would implement a monitoring system for water leaks for piping systems within the building. This will be integral within the Artificial Intelligence Building Automation System (see Electrical Section 8.3.2) and will use sensors placed around the pipe routing.

8.8 System Monitoring Capabilities

In short, the plumbing system was designed to meet the needs of the IPC while providing innovative solutions that are environmentally friendly through water conservation, contributed to the building integration, and have the potential to positively impact the building lifespan.

9.0 FIRE SUPPRESSION SYSTEM DESIGN

The fire suppression system design was carefully tailored to fulfill the project and client needs based on the parameters, constraints, and characteristics of the building.

9.1 Fire Suppression Design Goals

Atune has pursued a design with aesthetic effectiveness, long lifespan, and constructability to fulfill the team's design goals of versatility, sustainability, and harmony for the proposed fire suppression system. Fire Suppression was given special attention in order to protect the building and its occupants, especially given the mostly timber structure being implemented.

9.2 Fire Suppression Scope

The fire suppression scope for the Center for the Musical Arts includes fire sprinkling and smoke control. This is of special concern in the areas that have been identified as high occupancy/life safety concern: Atrium, Concert Hall, Recital Hall, Orchestral and Choral Rehearsal, and the Rooftop Amenity Space.

9.3 Alternate Systems Evaluation

The following systems were also considered to be incorporated in to the fire suppression system. Supporting Document M2.1 shows how the design decisions were finalized between these system choices and the selected systems.

Wet Sprinkler System: This form of fire sprinkling was decided against due to the presence of wood and musical instruments in the occupied space. Though this system delivers sprinkling immediately to the space in the event of a fire, the danger of architectural and equipment damage in the event of a pipe leak made this system less favorable.

Smoke Control Methods: Exhaust and passive smoke control are both being implemented in various regions of the building. The factors considered to determine the appropriate selection for each region is discussed below. Pressurization smoke control was considered for the stairwell, but not implement due to the short (three story maximum) height of the stairwells. The pressurization method is typically only implemented in high-rise buildings (those taller than 75 feet).

9.4 Design Optimization
The fire suppression design was chosen based on relevance in aligning with project conditions and design goals as set by Atune. These features are described below and include a dry sprinkler system, smoke detection, and exhaust or passive smoke control depending upon region of the building.

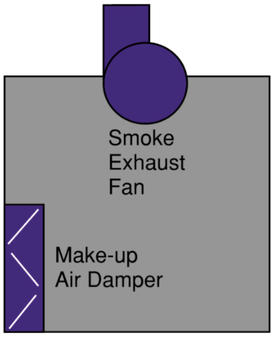
9.5 Fire Sprinkler System
As stated above, the building will be sprinkled with a dry pipe system due to the non-critical occupancy that justifies the delayed delivery time associated with this system. The advantages include providing an adequate fire protection system that contributes to a long lifespan and lower maintenance cost in the event that there was damage to the building in the event of a fire. This sustainable consideration combined with the reduced risk of damage for the instruments and timber architecture in the event of a pipe leak makes a dry pipe system the best choice for this application. The system will be automatic per NFPA 101, and concealed sprinkler heads will be used to provide aesthetic effectiveness for performance spaces. The table below shows the spacing criteria used for this NFPA occupancy type: Light Hazard. The fire pump is placed in its allocated room, and sample sprinkler layouts can be found on M3.4. The fire sprinkler piping will be prefabricated off site with elbows and routing accounted for. This added constructability will reduce time needed in the field for installation and positively impact the project timeline.

Light Hazard Sprinkler Spacing Requirements	
SF per Head	200
Max Spacing (FT)	15

9.6 Smoke Control
The goals of the smoke control system are to contribute to the sustainability of the building by increasing the lifespan and reducing the maintenance cost through adequate smoke control in the event of a fire.

9.6.1 Smoke Detection
The smoke detection system will be automatic and will be tied to the fire alarm system. There will be smoke detectors in the occupied space as well as in the ducts associated with DOAS units that are carrying over 2,000 cfm supply or 15,000 cfm return per NFPA 90A.

9.6.2 Exhaust Smoke Control
Exhaust smoke control will be implemented in the large volume spaces with high occupancy/life safety concern: Atrium, Concert Hall, Recital Hall, and Orchestral and Choral Rehearsal. These spaces will have smoke exhaust fans with side wall or ceiling access to the space. This will comply with the architectural design in the existing space, providing versatility through aesthetic effectiveness. Appropriate pressure will be maintained in these spaces with a damper supplying makeup air if the smoke exhaust fan is on. Maintaining neutral/positive pressure in the space will be critical in keeping door opening forces low so occupant egress can safely occur. The goal of this system is to keep smoke 6 feet above the highest walking surface for that space for occupant safety and egress during a fire.



9.6.3 Passive Smoke Control
In all areas, passive smoke control will be utilized to prevent the spread of smoke. Fire/smoke dampers are needed at shaft penetrations between floors and at fire walls to prevent the spread of smoke. At a signal from the fire alarm system, the DOAS fan will turn off and the fire/smoke dampers will close to achieve this smoke isolation. The mechanical design is advantageous from this perspective in that the only forced (not radiant) airflow is that which is being supplied from the DOAS units. Because of this, fewer smoke detectors are needed for this configuration with a DOAS only versus a system that has additional ducting not associated with the DOAS. Finally, zoning was also conducted with smoke control considered, as zones were divided at fire doors so there are no duct penetrations through these components.

9.7 Fire Suppression Design Summary

In summary, the fire suppression system was designed to meet the needs of life safety and building protection while also integrating with the architecture and construction processes. The focus of the fire sprinkler and smoke control design was to provide sustainability by creating the potential to improve the building's lifespan and reduce potential maintenance costs in the event of a fire.

10.0 PROJECT BUDGET AND CONSTRUCTABILITY
Atune considered feasibility of the project related to cost and construction during the course of the design iterations. Throughout this process, a design was achieved that met the constraints of the target budget and helped decrease the construction schedule.

10.1 Mechanical Budget Response

This project has a budget constraint of $25 million, with the mechanical systems budget occupying just over $4.6 million of the total. At this stage of design development, the projected HVAC systems account for $3.5 million, plumbing for under $450,000, and fire protection for under $300,000 of the mechanical estimate.

10.2 Mechanical Construction Response

Due to the large amount of hydronic piping throughout the building, the mechanical and construction teams have developed a prefabrication-aimed approach to reduce labor costs in installation. The mechanical design team will work to model all piping for the building early in the construction documents phase of the project. The mechanical contractor will be heavily involved in pipe routing to verify and manufacture prefabricated piping on struts that can be easily shipped to the project site and installed. This will cut down on spatial conflicts that might arise as a vast network of pipes deliver water to every corner of the building. The same process will be used for ductwork runs that will not be site-fabricated.

A radiant slab system can be very difficult to complete while remaining on schedule and budget. To proactively approach this feat, the construction and mechanical teams have elected to pursue a prefabrication method that allows the mechanical contractor to prepare spools of PEX piping cut to the required length for installation. This will aid in cutting down on installation time and reduce scrap that may manifest on site.

10.3 Value Engineering and Life-Cycle Cost Analysis

Hope College's financial interests were held with high regard as Atune made design decisions. Systems and components that yielded marginal benefits for substantial premiums were forgone. An example of this would be in the mechanical team's selection of chilled beams over a variable refrigerant flow system. As discussed in section 7.3, controls systems for VRF systems can become expensive to replace due to their proprietary nature at this point in time. Combined heat and power production was ruled out early in the design phase due to the unreasonable payback time given the local utility rates. The mechanical team saw this as ultimately irresponsible to the financial interests of the college as they encounter maintenance and troubleshooting over the building's lifespan. Initial costs were analyzed and compared to life-cycle costs. Each system was required by the design team to payback within a time frame that aligned with Hope's interests.

For current utility rates, the HVAC system is expected to payback in 10 years at a yearly utility savings rate of an estimated $75,500 per year. Based on Holland's current water utility rates, rainwater collection and greywater treatment offer $3,200 of yearly savings with a 16 year payback period, and low flow fixtures have little additional cost for $32,000 of annual savings.

11.0 PROJECT CHALLENGES

The mechanical team carefully considered the design challenges during the HVAC, plumbing, and fire suppression design processes. Considerations and descriptions of attention given to each challenge are outlined below.

11.1 Acoustics

Atune has the goal to be acoustically adapt throughout the building. The mechanical team made decisions during the design process with this goal in mind. The mechanical rooms have been laid out to serve the different building areas in a manner that worked well with the design team's priority for accessibility for maintenance. Mechanical rooms often share walls with occupied spaces. Therefore, vibration isolation coordination with the structural team led to creating barriers between the equipment and the building to inhibit the transfer of vibration. A focus for the mechanical team was to choose distribution systems that will not contribute to noise propagation. This will be accomplished by delivering low air velocities into the occupied spaces, routing ductwork to create minimal air turbulence, and by employing radiant conditioning mechanisms. Radiant slab systems, hydronic mullions, and chilled beams that are quieter than traditional forced air systems will assist in reducing the noise propagation in the building. Adequate duct and pipe insulation will also be implemented to aid in sound attenuation.

11.2 Wood, Timber, and Engineered Wood

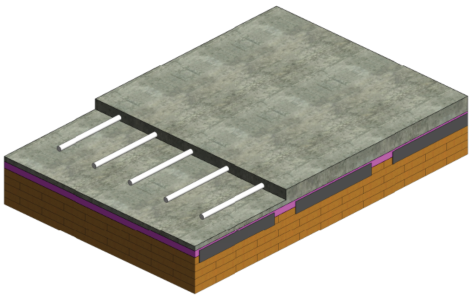
Although timber construction cannot be directly utilized for mechanical system components, the mechanical team coordinated with the structural team for the successful implementation of the structural and architectural timber components to achieve aesthetic and architectural integration. One way this is being provided in the building is through careful attention to humidity control. Humidity is already a site challenge due to the geographical location, but relative humidity levels around 50 percent must be maintained constantly and accurately to protect the wood and other materials from moisture damage. In addition, a design precaution employed specifically with concern to the wood is the choice of a dry-type sprinkler system. This system is less likely to cause architectural damage in the event of a sprinkler pipe leak, which has the potential to contribute to the long lifespan and reduced maintenance cost of the Center for Musical Arts.

11.3 Roof Top Amenity Space

Atune has designed the rooftop amenity space with the desire to create an environment that is advantageous for events, weather-responsive, and conscience of security and safety. The following mechanical system was designed with these same considerations in mind.

11.3.1 Covered Rooftop Space

HVAC: The portion of the rooftop amenity space that is covered has the opportunity to be open air or closed in with the retractable glass panels. Because of this, the HVAC system has modulating options related to the level of conditioning that will be provided based on the use and climate conditions in particular scenarios. If the space is enclosed, an upsized Atrium DOAS unit will provide conditioned ventilation air to the space via underfloor air distribution. This will be achieved through diffuser penetrations in the roof slab. Space conditioning will be achieved through radiant slab piping that will be chilled or heating hot water fed from the water to water heat pumps. The area will also feature ceiling fans to aid in cooling during events when the space is open air. These systems were chosen for their ability to be used in combination with one another depending on the needs of the situation, which provides versatility and flexibility in use for Hope College.



Plumbing/Fire Suppression: The covered rooftop area will need to be sprinkled given the occupancy anticipated in this space. Domestic water needs will be supplied to the rooftop bar to enhance the flexibility of the space to serve various events. The covered space will have storm drainage in similar scheme to the rest of the roof, however this is presumed to be less of a need since the space will likely be enclosed if adverse weather conditions are present.

11.3.2 Open Rooftop Space

Roof Drainage: In the open area of the rooftop amenity space, the hydronic piping be employed through the snow melt slab technology discussed in section 7.4.7 matching the rest of the roof slab design. This area will also contain roof drains that will feed into the rainwater collection system discussed in section 8.5. This will ensure that the amenity space remains suitable for occupancy.

11.3.3 Support Spaces

HVAC: The stairwells, restrooms, and storage/catering space will be served by DOAS with active chilled beams supplied by water to water heat pumps and will be an extension of the HVAC system for the Faculty Studio/Classroom spaces on the levels below.

Plumbing/Fire Suppression: Plumbing and fire sprinkler will be an extension of the floors below as the restrooms and spaces are stacked similarly between floors. Pressurization smoke control will be implemented in the stairwells as described in section 9.6.2, and passive smoke control will be provided elsewhere as described in section 9.6.4.

12.0 LESSONS LEARNED

The mechanical team unanimously agrees that participation in this design competition has caused an appreciation for collaborative teamwork. Individually, each member was able to conceptualize a portion of the design solution but working together, in both intradisciplinary and interdisciplinary teams, allowed developed and well-integrated solutions to surface. The team has also come to appreciate the significance of an iterative design process. Design solutions were able to be thought through and analyzed for gaps in design. Prioritizing core design values aided in decision making throughout the process of design in a way that was unforeseen at times.

13.0 CONCLUSION

Versatility was achieved through use of silent systems and careful attention to acoustical impacts at each stage of design development. Architecturally appealing systems and devices were implemented throughout the building. Multipurpose systems such as the thermocouple generator and snow melt roof system promote system integration.

Sustainability is achieved through rainwater collection, greywater treatment systems and the ground source borefield. Reducing source water treatment and substituting site provisions produce an environmentally responsible way to meet building necessities. The combination of water to water heat pumps and a hybrid ground source system minimize power consumption, which benefits the financial status of Hope College, and minimizes environmental impacts.

Harmony manifested in Atune's designs through use of underfloor air distribution and prefabrication schemes. Underfloor air distribution in a raised floor plenum allowed Atune to accommodate mechanical and electrical needs. The snow melt roof system assists the structural system by removing loads and promoting member longevity. Prefabrication of hydronic piping, plumbing piping, and duct runs provided and accelerated schedule and required constructability conversations between the construction and mechanical teams to be held early in the process.

MECHANICAL DECISION MATRIX

ATRIUM

	VERSATILITY: FLEXIBILITY IN USE	VERSATILITY: ROOM FOR GROWTH	VERSATILITY: ACOUSTICALLY ADAPTABILITY	VERSATILITY: AESTHETIC EFFECTIVENESS	SUSTAINABLILITY: LONG LIFESPAN	SUSTAINABLILITY: MAINTNANCE COST	SUSTAINABLILITY: ENVIRONMENTAL IMPACT	SUSTAINABLILITY: EDUCATION TO PUBLIC	HARMONY: MULTIPURPOSE DESIGN	HARMONY: SCHEDULE	HARMONY: BUILDING FACADE	HARMONY: CONSTRUCTABILITY	
WEIGHT	4	2	5	3	5	3	4	4	3	4	1	5	
AHU W/ VAV	12	6	10	9	20	12	12	4	3	16	3	20	127
VRF W/ DOAS	8	6	25	9	15	6	8	4	3	12	2	15	113
RTU	8	4	5	3	15	12	8	4	3	20	1	25	108
HYDRONIC MULLIONS W/ DOAS	12	4	20	15	20	9	16	4	12	8	5	15	140
ACTIVE CHILLED BEAMS W/ DOAS	8	6	25	9	20	6	8	4	3	12	3	20	124
RADIANT SLAB W/ DOAS	16	2	25	15	20	15	16	4	6	4	3	10	136
UFAD RAISED FLOOR	20	10	20	9	20	15	12	4	9	12	3	10	144

AUDITORIUM

	FLEXIBILITY IN USE	ROOM FOR GROWTH	ACOUSTICALLY ADAPTABILITY	AESTHETIC EFFECTIVENESS	LONG LIFESPAN	MAINTNANCE COST	ENVIRONMENTAL IMPACT	EDUCATION TO PUBLIC	MULTIPURPOSE DESIGN	SCHEDULE	BUILDING FACADE	CONSTRUCTABILITY	
WEIGHT	4	2	5	3	5	3	4	4	3	4	1	5	
AHU W/ VAV	12	6	10	9	20	12	8	4	3	16	3	20	123
VRF W/ DOAS	8	8	25	9	15	6	12	4	3	12	2	15	119
RTU	8	4	5	6	15	12	8	4	3	20	1	25	111
ACTIVE CHILLED BEAMS W/ DOAS	8	8	25	9	15	9	12	4	3	12	3	20	128
RADIANT SLAB W/ DOAS	16	2	25	15	20	12	12	4	6	4	3	10	129
UFAD RAISED FLOOR	20	10	20	9	20	15	12	4	9	12	3	10	144

CLASSROOMS / FACULTY STUDIOS

	FLEXIBILITY IN USE	ROOM FOR GROWTH	ACOUSTICALLY ADAPTABILITY	AESTHETIC EFFECTIVENESS	LONG LIFESPAN	MAINTNANCE COST	ENVIRONMENTAL IMPACT	EDUCATION TO PUBLIC	MULTIPURPOSE DESIGN	SCHEDULE	BUILDING FACADE	CONSTRUCTABILITY	
WEIGHT	4	2	5	3	5	3	4	4	3	4	1	5	
AHU W/ VAV	8	8	10	9	20	12	12	4	3	16	3	20	125
VRF W/ DOAS	12	8	25	9	15	6	16	4	3	12	2	15	127
RTU	8	6	10	3	15	12	8	4	3	20	1	25	115
ACTIVE CHILLED BEAMS W/ DOAS	12	8	25	9	20	6	16	4	3	12	3	20	138
RADIANT SLAB W/ DOAS	4	2	25	15	20	15	16	4	3	4	3	10	121
UFAD RAISED FLOOR	12	6	20	6	20	15	12	4	3	12	3	10	129

MECHANICAL DECISION MATRIX

AMENITIES

	VERSATILITY: FLEXIBILITY IN USE	VERSATILITY: ROOM FOR GROWTH	VERSATILITY: ACOUSTICALLY ADAPTABILITY	VERSATILITY: AESTHETIC EFFECTIVENESS	SUSTAINABLILITY: LONG LIFESPAN	SUSTAINABLILITY: MAINTNANCE COST	SUSTAINABLILITY: ENVIRONMENTAL IMPACT	SUSTAINABLILITY: EDUCATION TO PUBLIC	HARMONY: MULTIPURPOSE DESIGN	HARMONY: SCHEDULE	HARMONY: BUILDING FACADE	HARMONY: CONSTRUCTABILITY	
WEIGHT	4	2	5	3	5	3	4	4	3	4	1	5	
AHU W/ VAV	12	6	10	12	20	12	12	4	3	16	3	20	130
ACTIVE CHILLED BEAMS W/ DOAS	12	6	25	9	20	6	16	4	3	12	3	20	136
RADIANT SLAB W/ DOAS	12	0	25	15	20	15	16	4	15	4	4	10	140
UFAD RAISED FLOOR	12	0	20	9	20	15	12	4	12	12	3	10	129

PLUMBING

	FLEXIBILITY IN USE	ROOM FOR GROWTH	ACOUSTICALLY ADAPTABILITY	AESTHETIC EFFECTIVENESS	LONG LIFESPAN	MAINTNANCE COST	ENVIRONMENTAL IMPACT	EDUCATION TO PUBLIC	MULTIPURPOSE DESIGN	SCHEDULE	BUILDING FACADE	CONSTRUCTABILITY	
WEIGHT	4	2	5	3	5	3	4	4	3	4	1	5	
RAINWATER COLLECTION	8	8	15	9	15	6	20	8	6	8	3	15	121
FIXTURE SELECTION & ROUTING	12	8	15	9	20	6	20	8	12	16	3	20	149
SYSTEM MONITORING CAPABILITIES	12	6	10	6	25	12	12	8	6	8	3	10	118
GREYWATER REUSE	8	4	15	9	20	3	12	8	6	8	3	15	111
FLUE GAS HEAT RECOVERY	8	4	10	9	10	6	16	8	9	8	3	10	101

FIRE SUPPRESSION

	FLEXIBILITY IN USE	ROOM FOR GROWTH	ACOUSTICALLY ADAPTABILITY	AESTHETIC EFFECTIVENESS	LONG LIFESPAN	MAINTNANCE COST	ENVIRONMENTAL IMPACT	EDUCATION TO PUBLIC	MULTIPURPOSE DESIGN	SCHEDULE	BUILDING FACADE	CONSTRUCTABILITY	
WEIGHT	4	2	5	3	5	3	4	4	3	4	1	5	
DRY PIPE SPRINKLING	12	6	15	12	20	12	12	12	9	16	3	15	144
WET PIPE SPRINKLING	8	6	15	6	10	6	12	12	9	16	3	20	123
EXHAUST SMOKE CONTROL	16	6	5	6	25	15	12	8	6	8	3	10	120
PASSIVE SMOKE CONTROL	12	4	5	9	20	12	12	4	9	8	4	15	114

DECISION MATRIX

Early in the schematic design process Atune sought to establish a procedure for selecting between potential systems. It was important that each decision be linked back to the core values of Versatility, Sustainability, Harmony, and each of their subcategories.

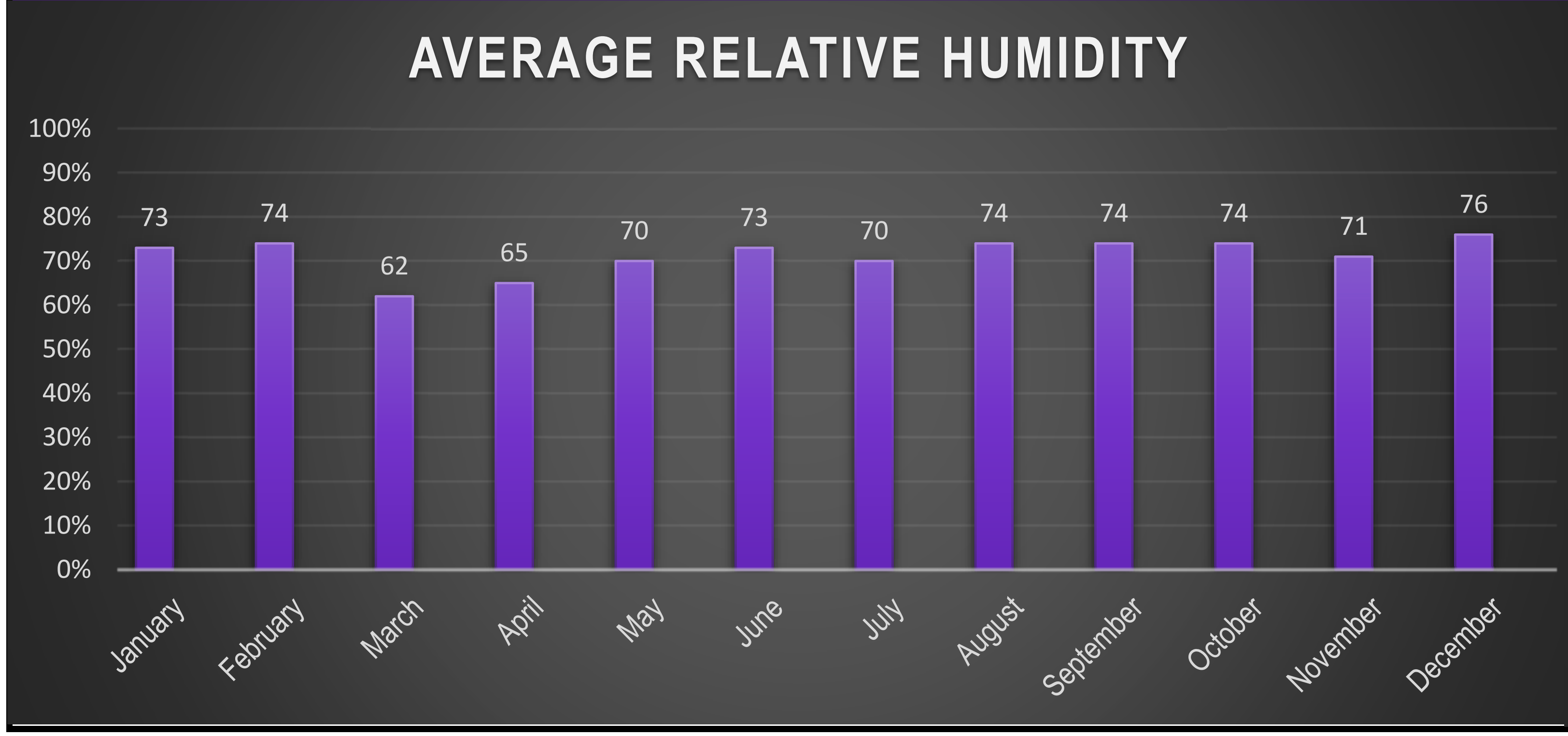
These subcategories were given weights between one and five to reflect the elements that would be a priority to Hope College.

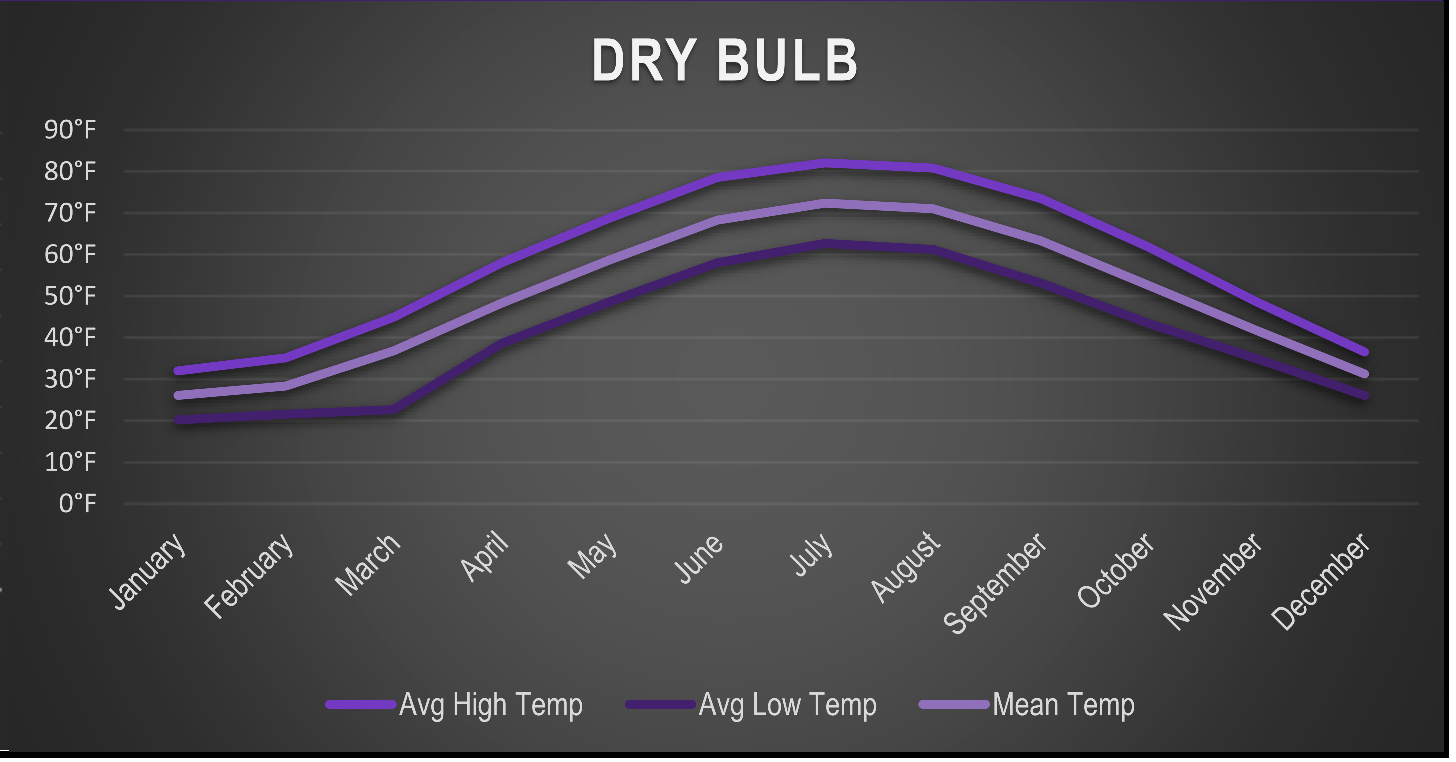
For each system type and application, each perceived design solution was listed on the left. It was then ranked on a scale from one to five for how well it suited the core values.

The object score was multiplied by the weight to achieve a weighted score and summed to determine the optimal systems. The chosen systems are found boxed in purple.

Fall				Winter				Spring				Summer			
Year	Low Temp	High Temp	Humidity	Year	Low Temp	High Temp	Humidity	Year	Low Temp	High Temp	Humidity	Year	Low Temp	High Temp	Humidity
2018	23	88	73	2018	-11	65	74	2018	19	95	66	2018	48	93	72
2017	20	93	70	2017	7	65	75	2017	17	85	68	2017	46	94	70
2016	22	89	76	2016	3	62	75	2016	5	87	68	2016	43	92	72
2015	21	90	71	2015	-14	52	71	2015	-2	85	66	2015	40	91	72
2014	18	84	72	2014	-11	58	76	2014	-8	87	65	2014	45	91	71
2013	17	93		2013	-6	67		2013	11	90		2013	43	97	
averages	20.2	89.5	72.4	averages	-5.3	61.5	74.2	averages	7	88.2	66.6	averages	44.2	93	71.4

National Weather Service Normal Data												
Criteria	January	February	March	April	May	June	July	August	September	October	November	December
Avg RH	73	74	62	65	70	73	70	74	74	74	71	76
Avg High	32	35.1	44.9	58	68.8	78.6	82.1	80.8	73.5	61.8	48.6	36.5
Mean	26.1	28.3	36.8	48.3	58.7	68.3	72.4	71	63.3	52.6	41.7	31.3
Avg Low	20.2	21.6	22.7	38.6	48.6	58	62.7	61.2	53.1	43.4	34.9	26.1





CLIMATE ANALYSIS

Holland proved to have a humid climate to design for. Atune took a fairly conservative approach to estimating humidity, as humidity control is a primary concern both for instrument and timber structure protection.

SAMPLE CALCULATIONS

SAMPLE VENTILATION CALCULATIONS

ROOM INFORMATION					IMC REQUIREMENTS						ADJUSTMENTS			SUPPLIED FROM	
ROOM NAME	ROOM #	OCCUPANCY CATEGORY	AREA (SF)	# PPL (FURNITURE)	PPL/1000SF	CFM/ PERSON	CFM/SF	# PPL (CODE)	FINAL OCCUPANCY	VENTILATION (CFM)	Ez	Vz	OA REQUIRED BY CODE	DOAS	ZONE
LOBBY INTERIOR	100D	RECEPTION	3184	-	30	5	0.06	96	96	671	1.2	559.2	560	5	2
RECITAL	120	MULTIUSE ASSEMBLY	1975	125	100	7.5	0.06	198	198	1603.5	0.7	2290.7	2295	3	10
FACULTY STUDIO	156	OFFICE	207	2	5	5	0.06	2	2	22.4	0.8	28	30	1	23
CLASSROOM-2 KEYBOARD LAB	193	CLASSROOM (9+)	748	18	35	10	0.12	27	27	359.8	0.8	449.7	450	4	34
PRACTICE ROOM	260	PRIVATE OFFICE	62	1	5	5	0.06	1	1	8.7	0.8	10.9	15	4	51
CORRIDOR	112	CORRIDOR	248	-	0	0	0.06	0	0	14.9	1.2	12.4	15	2	9

SAMPLE EXHAUST CALCULATIONS

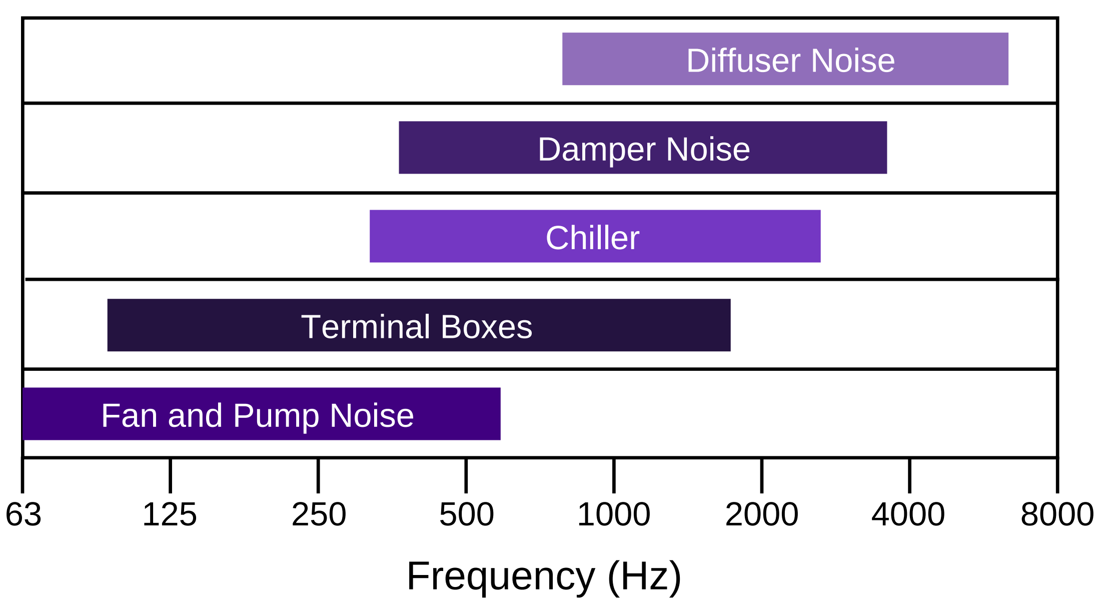
ROOM INFORMATION			OPTION 1: IMC				OPTION 2: CFM/SF		OPTION 3: AIR CHANGES				FINAL EXHAUST CFM	DOAS
ROOM NAME	ROOM #	AREA (SF)	WC/URINALS	RATE	CALC	CFM	CALC	CFM	HEIGHT (FT)	ACH	CALC	CFM		
WOMENS RESTROOM	123	390	6	50	300	300	780	780	8	10	520	520	780	1
MENS RESTROOM	124	322	5	50	250	250	644	645	8	10	429.33	430	645	1
UNISEX RESTROOM	125	54	1	50	50	50	108	110	8	10	72	75	110	1
JANITOR	132	56	-	0.5	28	30	112	115	10	10	93.33	95	115	1
GREEN ROOM	154	268	-	0.25	67	70	536	540	10	10	446.67	450	540	4
CATERING	182	156	-	0.7	109.2	110	312	315	10	10	260	260	315	3
JANITOR	184	65	-	0.5	32.5	35	130	130	10	10	108.33	110	130	3

SAMPLE FIRE SPRINKLER LAYOUT CALCULATIONS

ROOM NAME	ROOM NUMBER	AREA	SPRINKLER RATE (1/X SF)	SPRINKLER CALC	FINAL SPRINKLER COUNT
CLASSROOM 3 - GENERAL MUSIC	194	730	200	3.65	6
FACULTY STUDIO	165	165	200	0.825	2
PRACTICE ROOM	273	91	200	0.455	1
ORCHESTRAL REHEARSAL	130	1937	200	9.685	16

DESIGN GUIDELINES FOR HVAC RELATED BACKGROUND SOUND ROOMS

ROOM TYP.	CLASSIFICATION	OCTAVE BAND ANALYSIS	APPROXIMATE OVERALL SOUND PRESSURE LEVEL	
		NC/ RCb	dBA	dBC
CLASSROOMS	MUSIC TEACHING STUDIO	25	30	55
REHEARSAL	RECITAL HALL	20	25	50
CONCERT	CONCERT HALL	20	25	50
FACULTY STUDIO	MUSIC PRACTICE ROOM	30	35	60
ATRIUM	LOBBY	40	45	65



SANITARY SEWER MAIN

FIXTURE	SINGLE DFU	QUANTITY	DFU	NOTES
LAVATORY	1	30	30	
ELEC WATER COOLER	0.5	12	6	
JANITOR SINK	2	4	8	
KITCHEN SINK	2	5	10	
SHOWER	2	1	2	5.7 GPM OR LESS
DISHWASHER	2	2	4	
WASHING MACHINE	3	1	3	
WATER CLOSET	4	34	136	1.6 GPF OR LESS (LOW FLOW 1.1 GPF)
URINAL	0.5	12	6	NONWATER SUPPLIED
FLOOR DRAIN	2	13	26	
TOTAL DFU			**231**	
SEWER MAIN SIZE			**6"**	

DOMESTIC WATER MAIN

FIXTURE	SINGLE WSFU	QUANTITY	WSFU
LAVATORY	2	30	60
ELEC WATER COOLER	0.25	12	3
JANITOR SINK	3	4	12
KITCHEN SINK	4	5	20
SHOWER	1.4	1	1.4
DISHWASHER	1.4	2	2.8
WASHING MACHINE	3	1	3
WATER CLOSET	10	34	340
URINAL	0	12	0
TOTAL WSFU			**442.2**
TOTAL GPM			**143**
DCW MAIN SIZE			**3"**

HOT WATER DEMAND

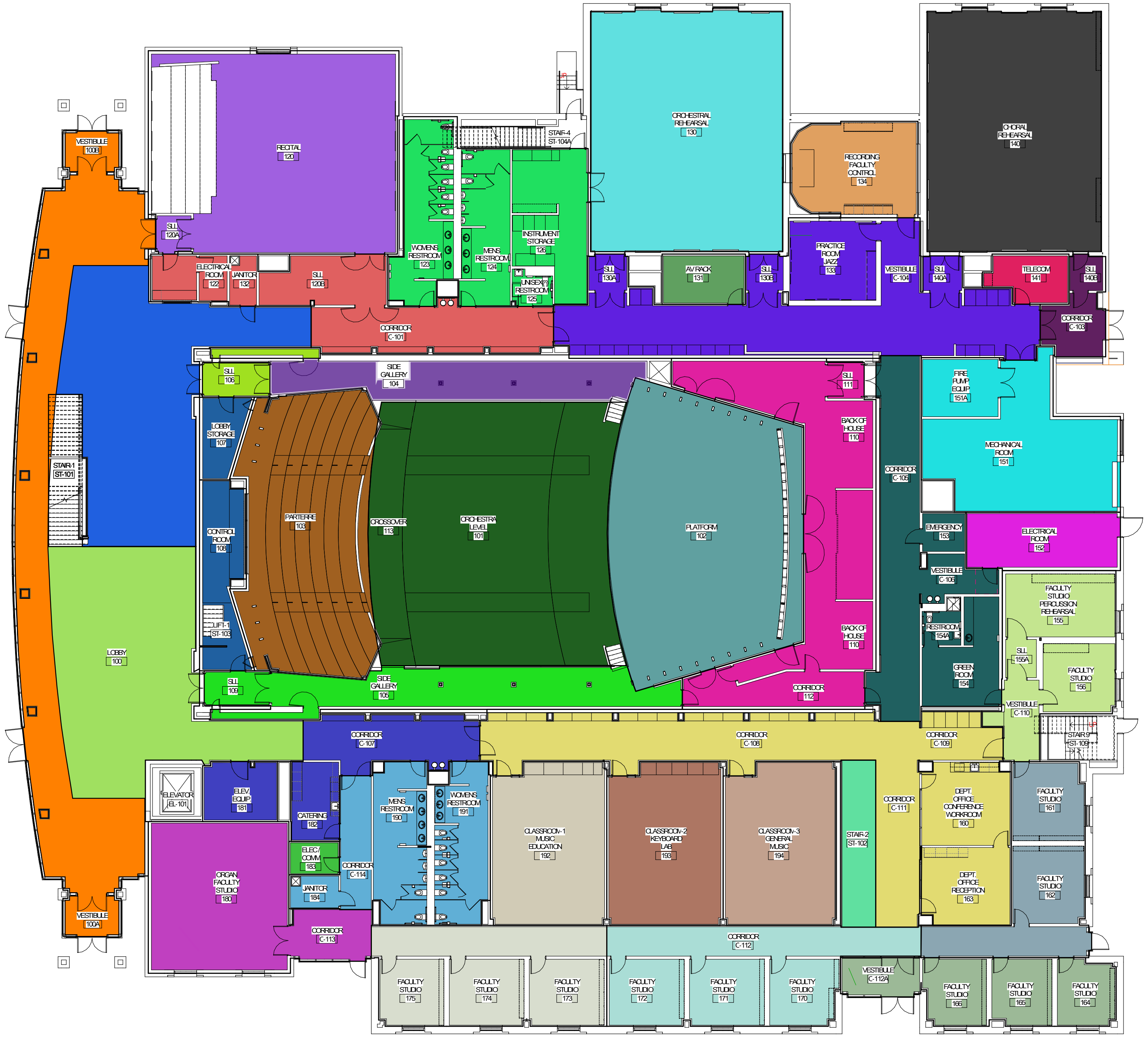
FIXTURE	SINGLE HFU	QUANTITY	HFU
LAVATORY	1.5	30	45
JANITOR SINK	2.25	4	9
KITCHEN SINK	3	5	15
SHOWER	1	1	1
DISHWASHER	1.4	2	2.8
WASHING MACHINE	2.25	1	2.25
TOTAL HFU			**75**
TOTAL GPM			**38**
HW SERVICE			**1 1/2"**

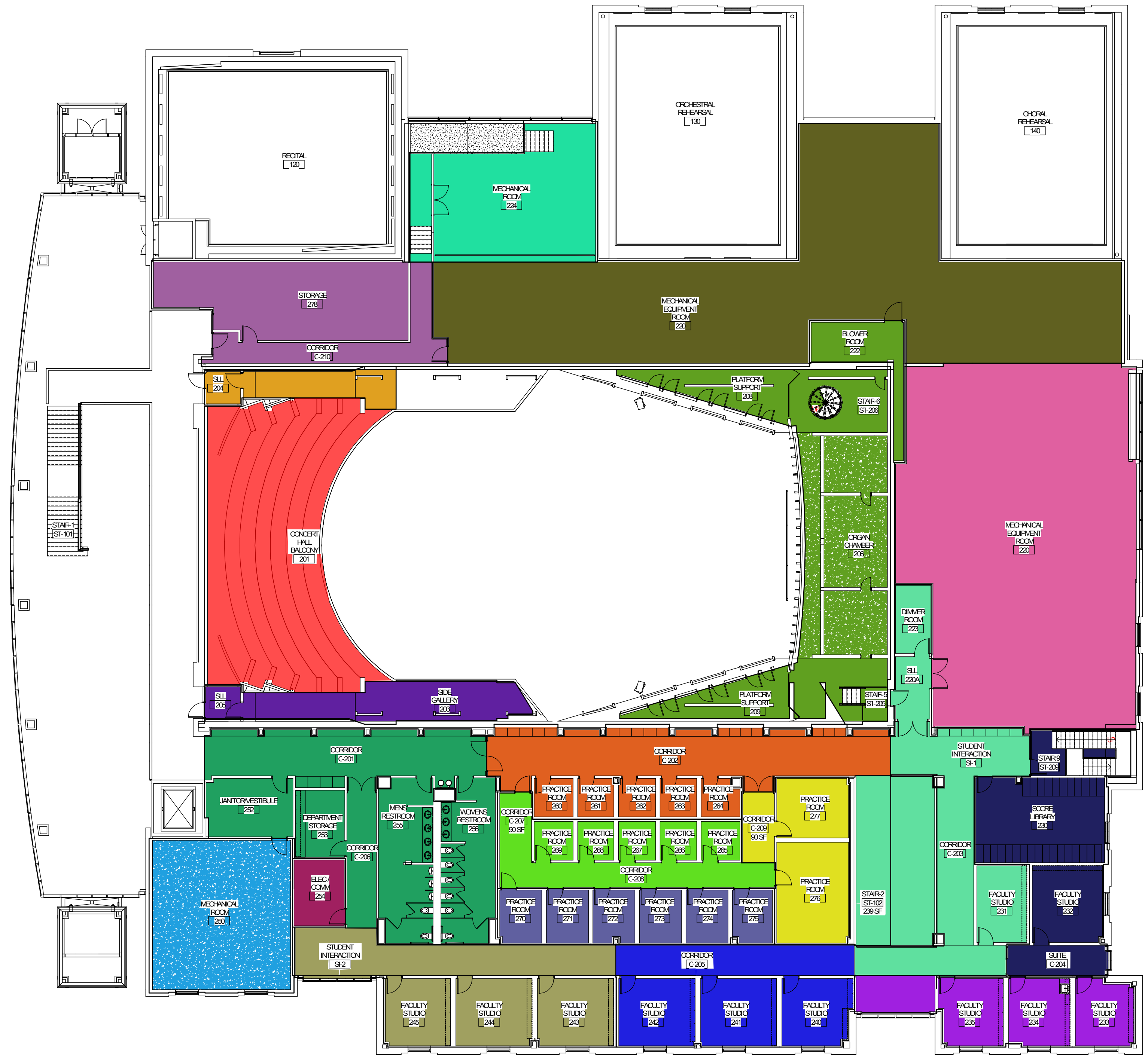
NORTH VENT PIPING SIZE

FIXTURE	SINGLE DFU	QUANTITY	DFU	NOTES
LAVATORY	1	9	9	
ELEC WATER COOLER	0.5	4	2	
JANITOR SINK	2	1	2	
KITCHEN SINK	2	1	2	5.7 GPM OR LESS
WATER CLOSET	4	10	40	1.6 GPF OR LESS (LOW FLOW 1.1 GPF)
URINAL	0.5	3	1.5	NONWATER SUPPLIED
FLOOR DRAIN	2	4	8	
TOTAL DFU			**64.5**	
VTR SIZE			**3"**	
DEVELOPMENT LENGTH			**210'**	

SOUTH VENT PIPING SIZE

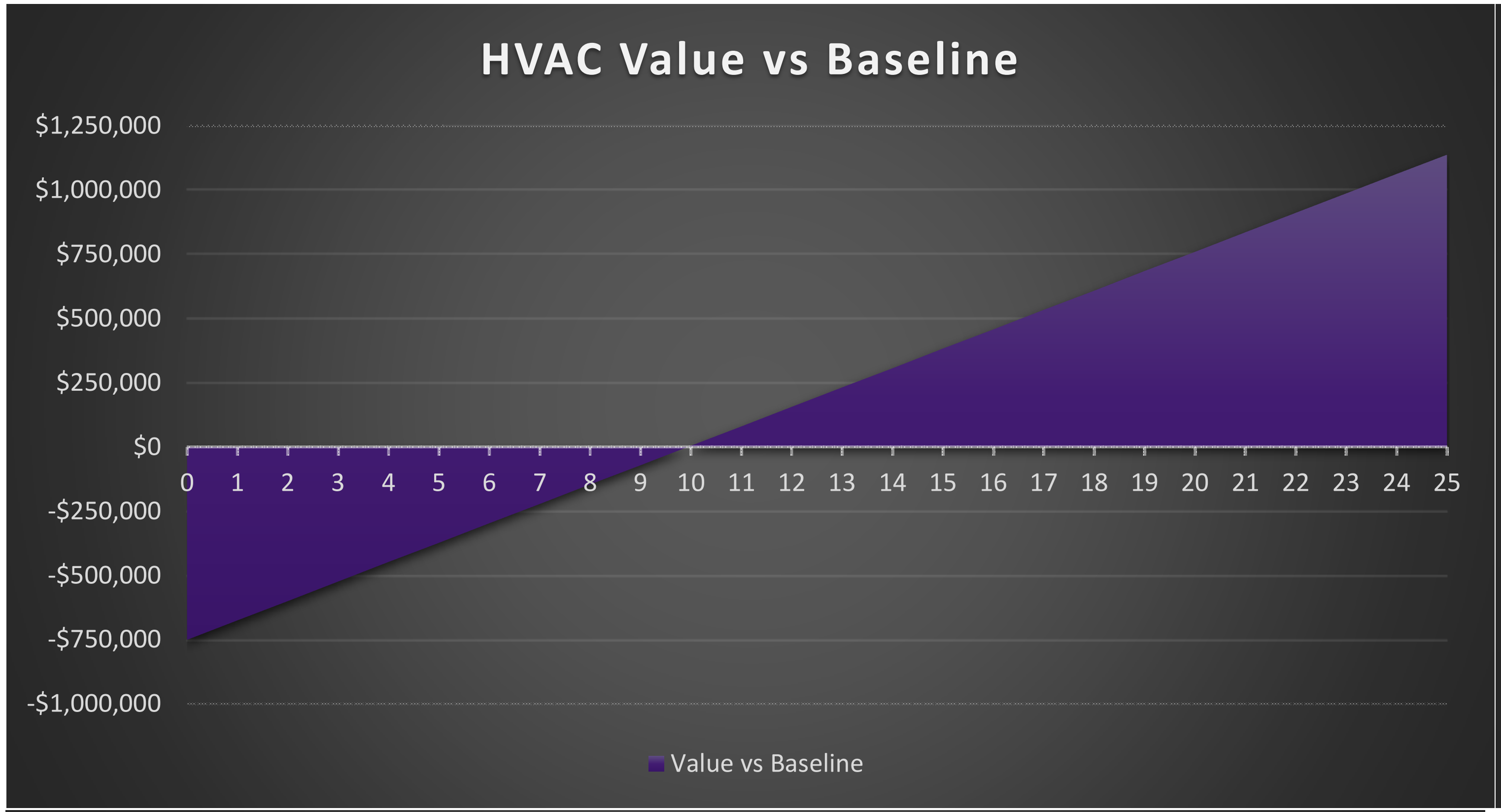
FIXTURE	SINGLE DFU	QUANTITY	DFU	NOTES
LAVATORY	1	21	21	
ELEC WATER COOLER	0.5	8	4	
JANITOR SINK	2	3	6	
KITCHEN SINK	2	5	10	
DISHWASHER	2	2	4	
WASHING MACHINE	3	1	3	
WATER CLOSET	4	24	96	1.6 GPF OR LESS (LOW FLOW 1.1 GPF)
URINAL	0.5	9	4.5	NONWATER SUPPLIED
FLOOR DRAIN	2	9	18	
TOTAL DFU			**166.5**	
VTR SIZE			**3"**	
DEVELOPMENT LENGTH			**78'**	

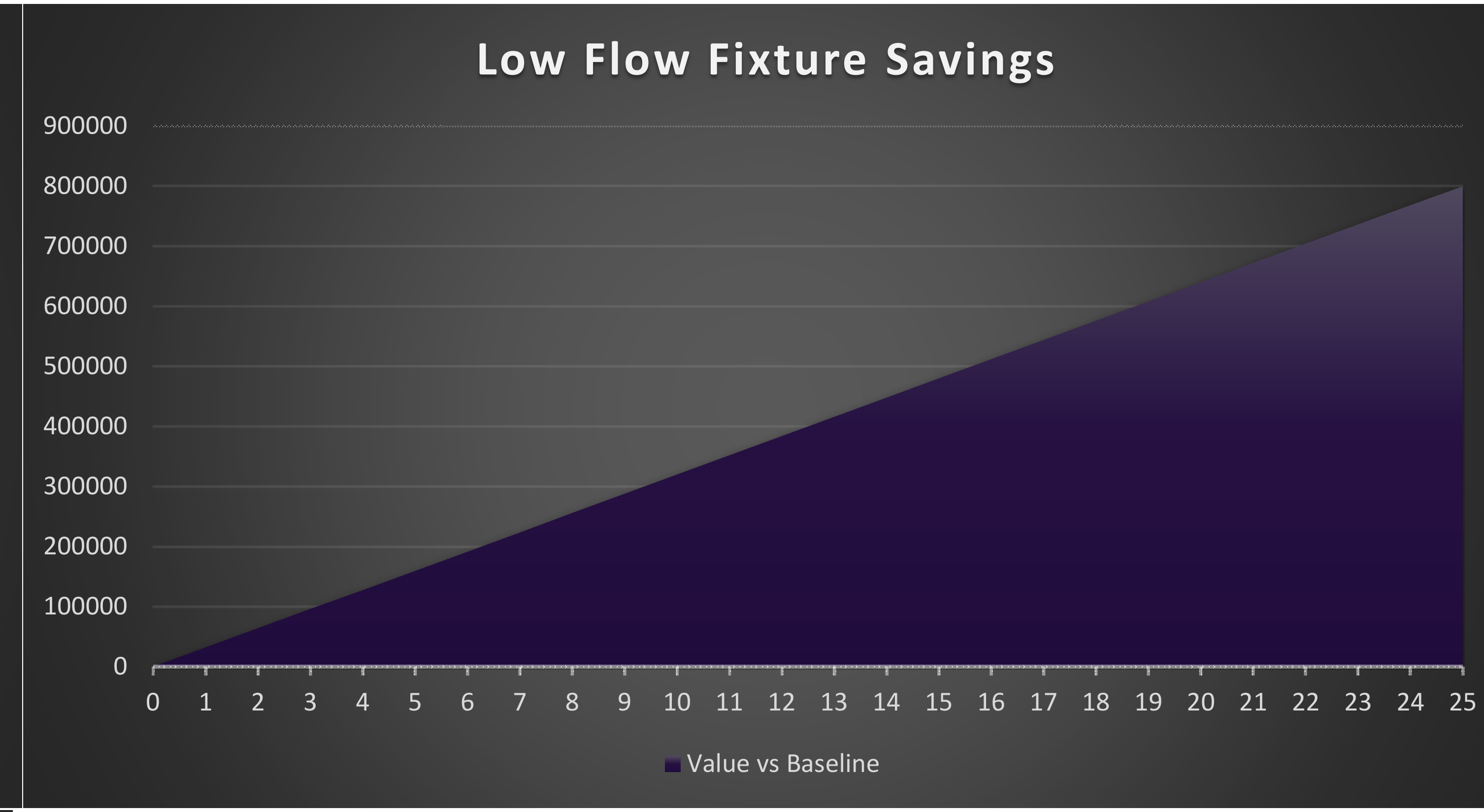


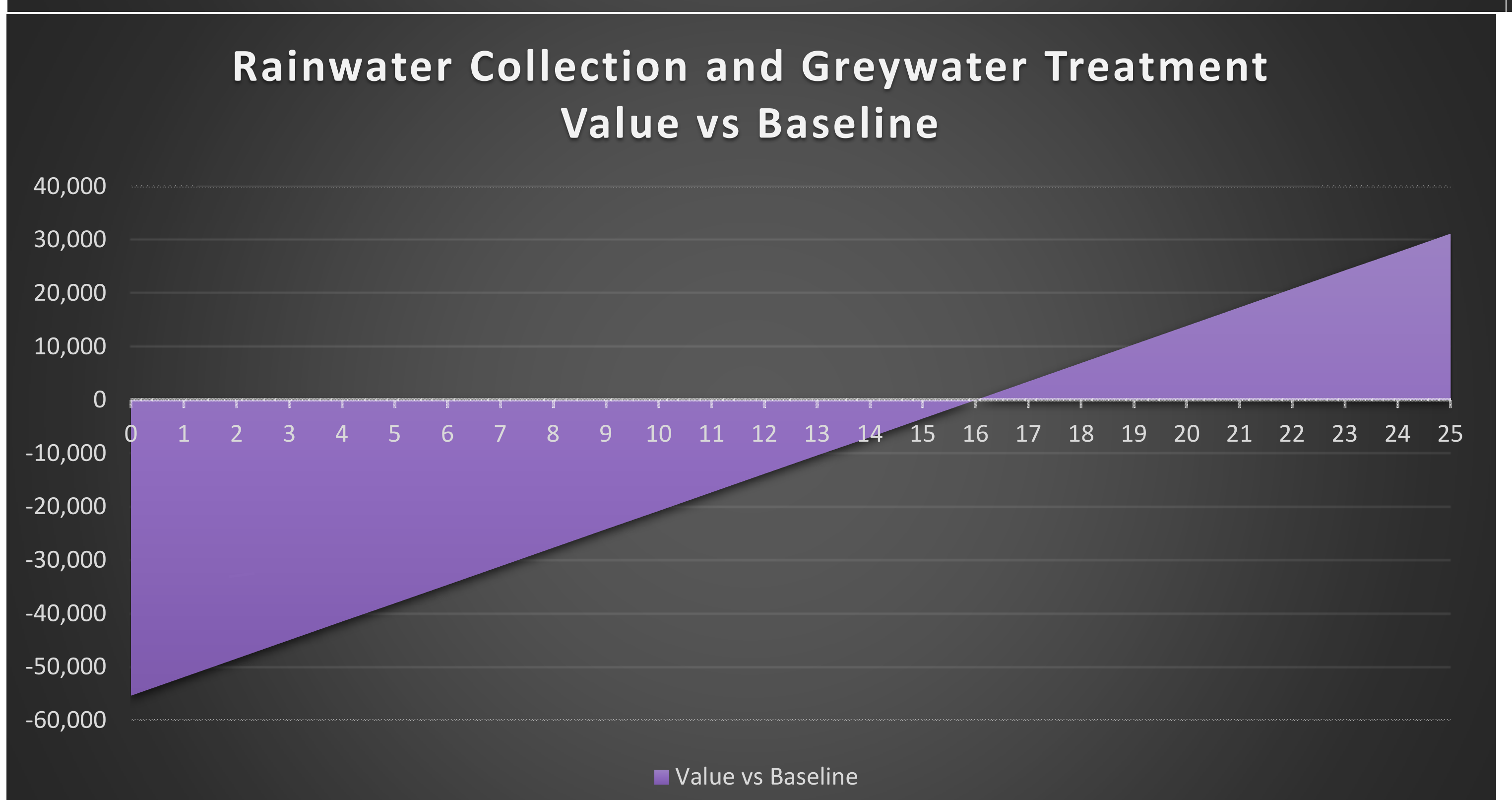


HVAC ZONING

Atune's Mechanical Team broke the building up into manageable zones. These zones are based on similar load profiles and occupancies. This was ultimately used to select system types and separate them using the aforementioned criteria.







UTILITY SAVINGS FROM RAINWATER COLLECTION TANK

ANNUAL DEMAND (1,000 GALLONS)	ANNUAL SUPPLY FROM TANK (1,000 GALLONS)	PERCENT OF DEMAND SUPPLIED	AVERAGE ANNUAL UTILITY RATE ($/1,000 GAL)	AVERAGE ANNUAL COST SAVED	PAYBACK PERIOD (YRS)
12,893.28	11,381.82	88%	$ 2.87	$ 3,215.37	16

ECONOMIC ANALYSIS

Atune prescribed systems that had rapid paybacks for the college campus setting. The HVAC System had a payback period of 10 years, Rainwater collection had a payback period of 16 years, and low-flow fixtures provided annual savings of $32,000 for negligible additional cost to the college.

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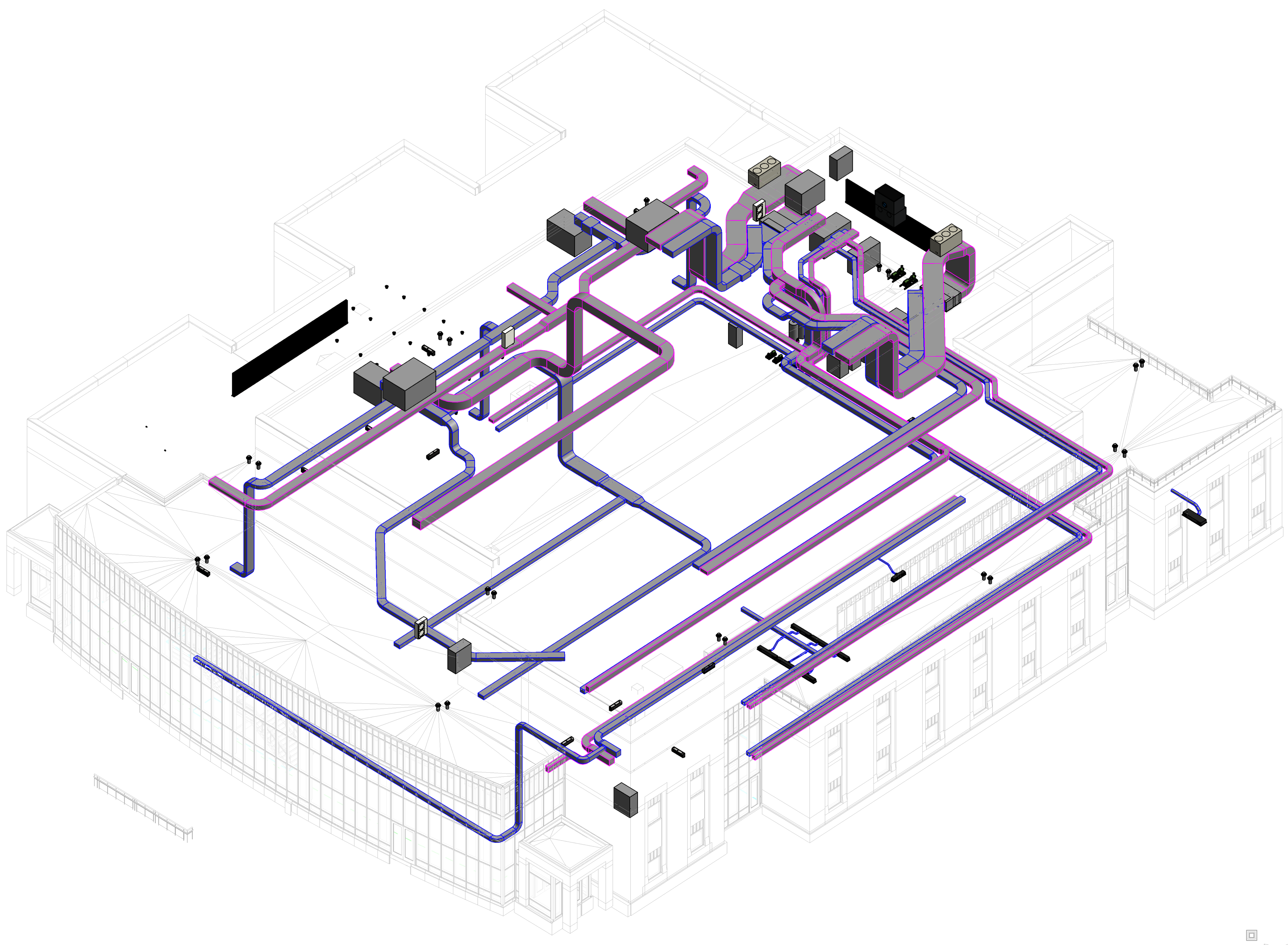
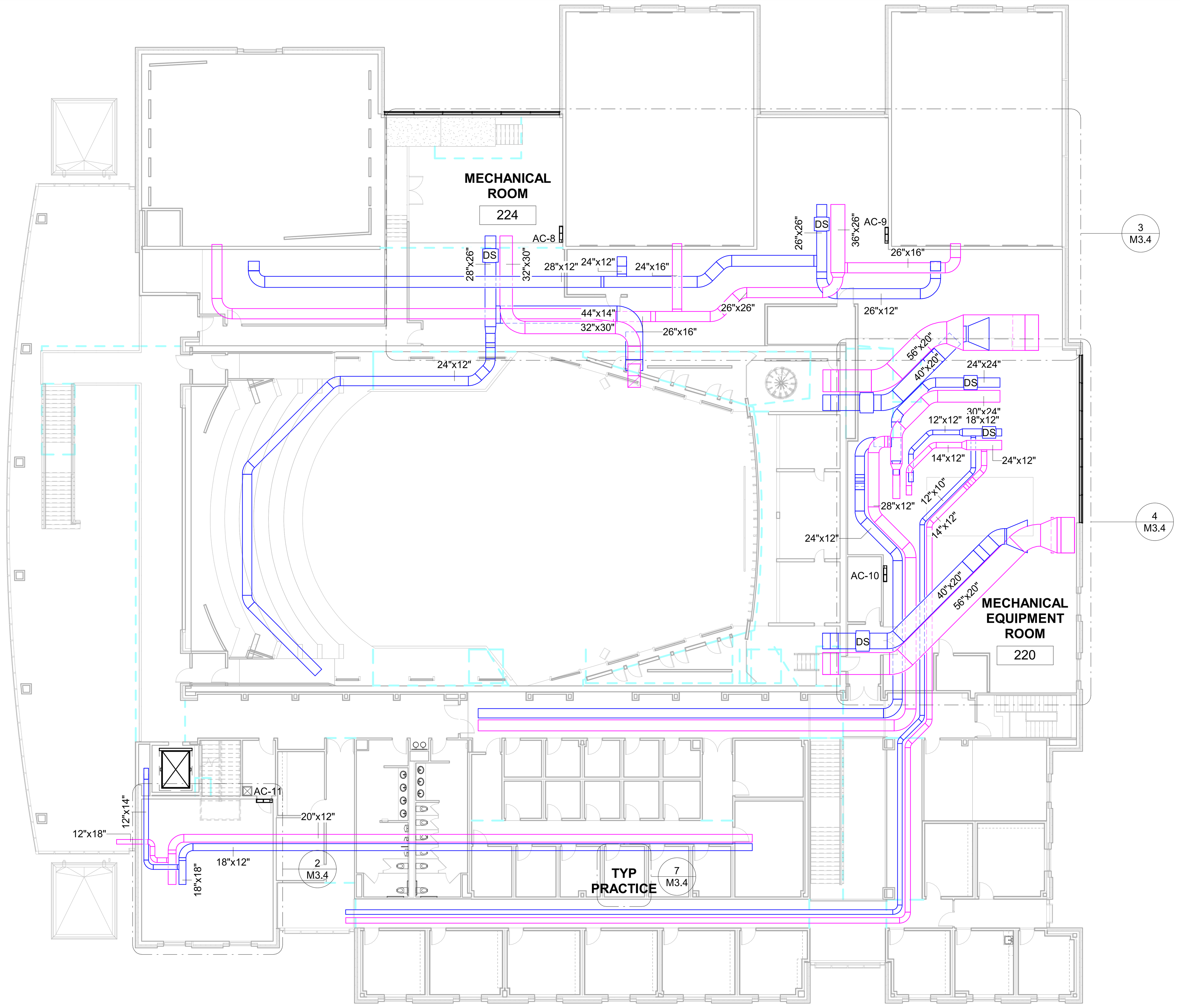
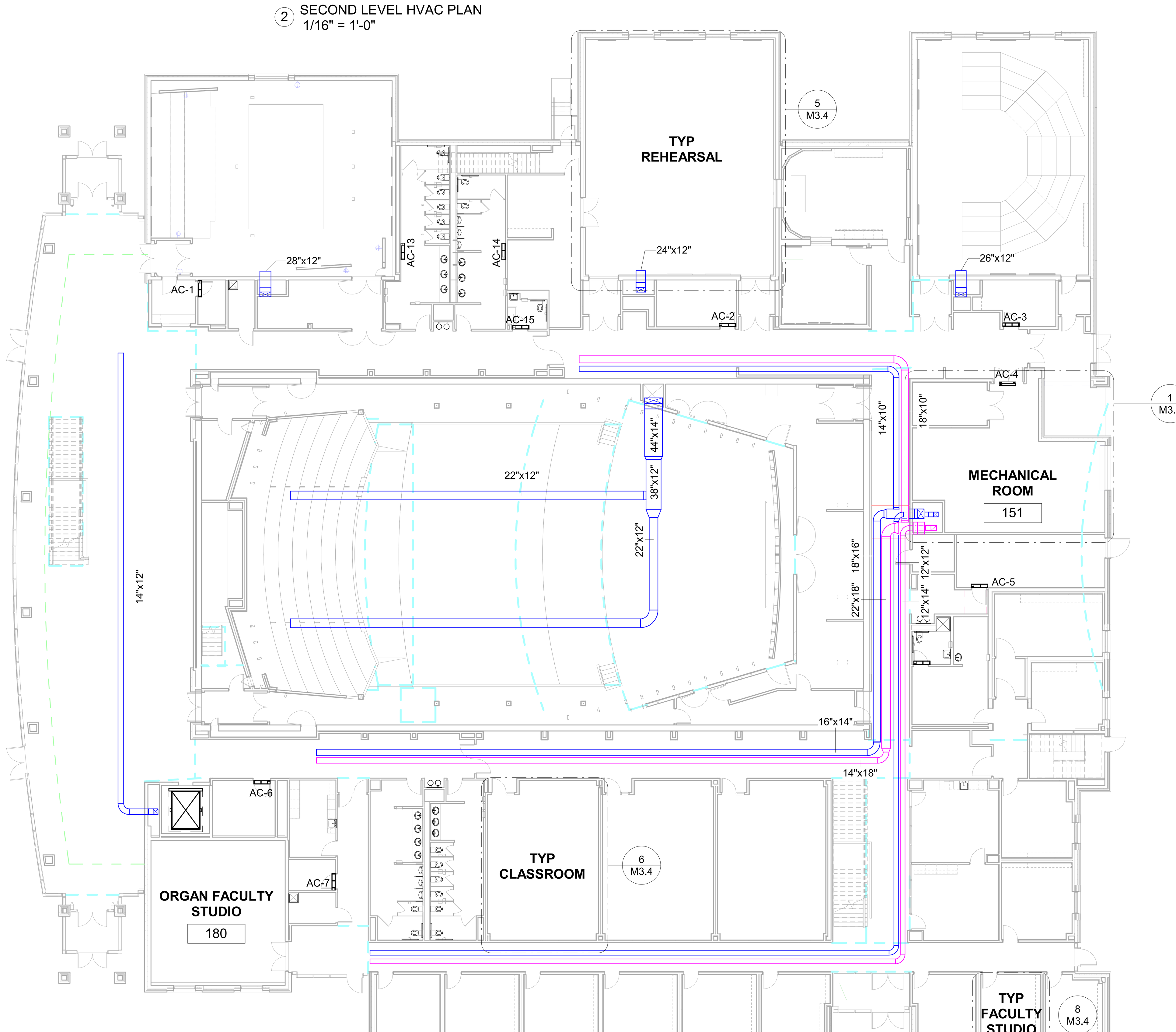


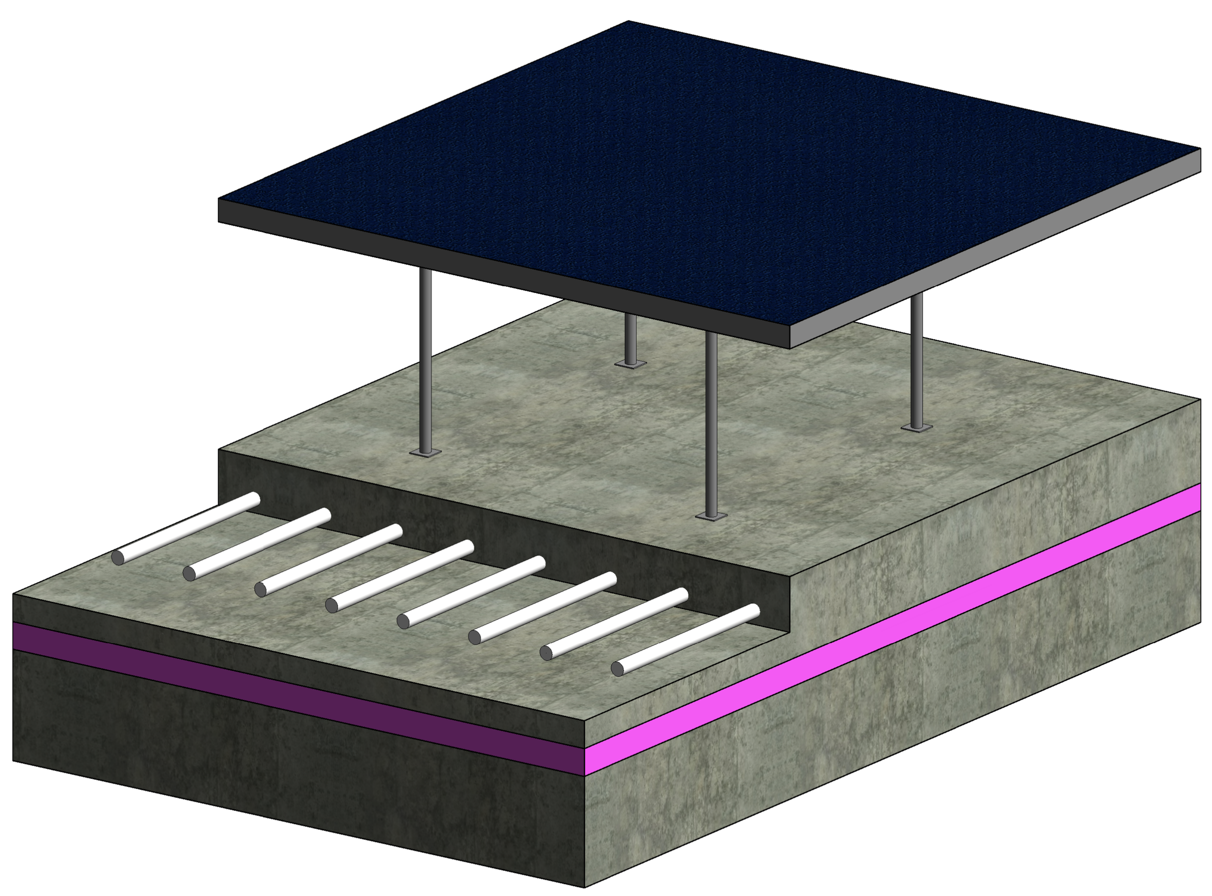
3 HVAC 3D RENDERING



2 SECOND LEVEL HVAC PLAN
1/16" = 1'-0"



1 FIRST LEVEL HVAC PLAN
1/16" = 1'-0"



RADIANT SLAB SYSTEM

The radiant floor system is constructed of 3/4" PEX piping spaced at 6" O.C. placed in the slab at a depth of 1" below the top of slab elevation. Radiant flooring provides occupant level conditioning in spaces with high ceilings. This system is silent to the occupant and maximizes acoustic effectiveness.

ATUNE

Jack H. Miller Center for Musical Arts

HVAC Plans

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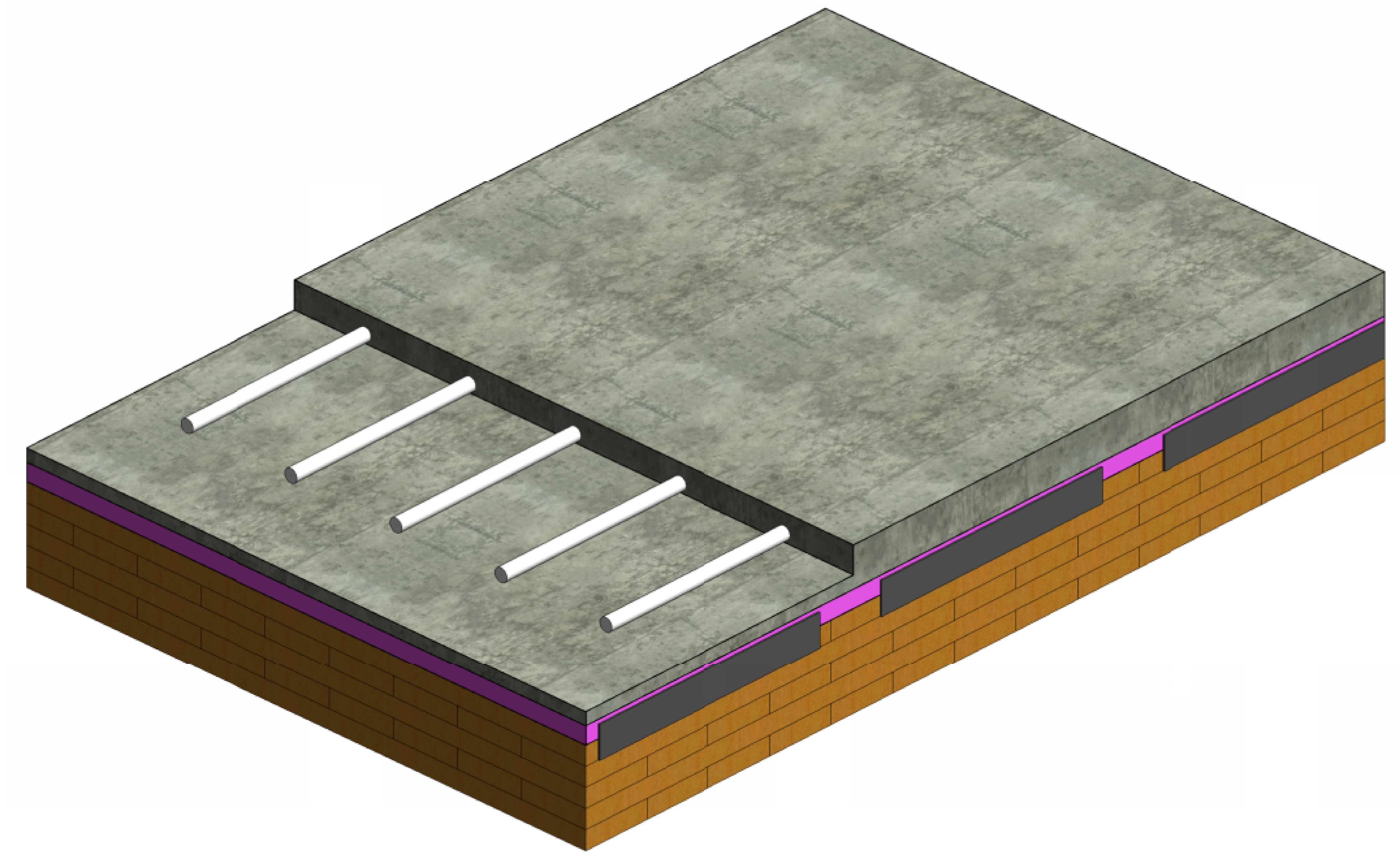
Date	2/18/2019
Scale	1/16" = 1'-0"

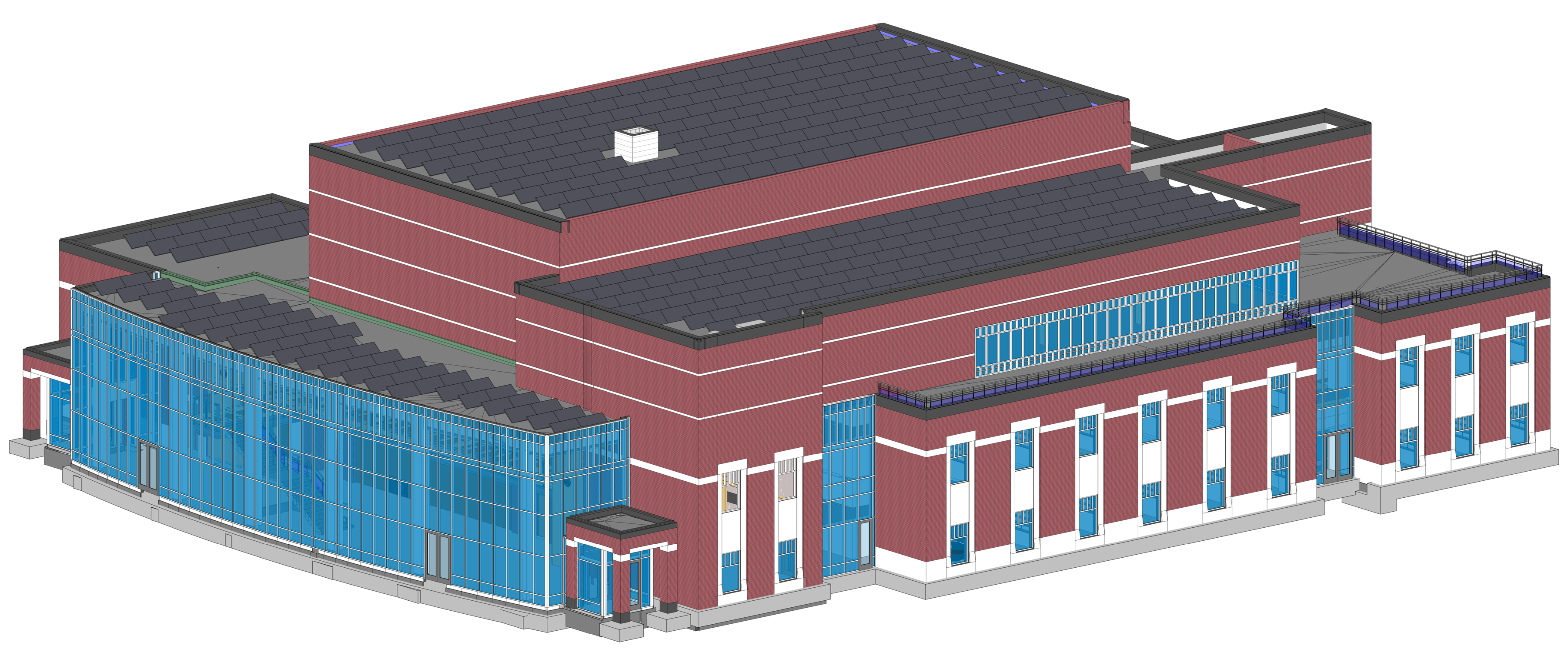
M3.1

RADIANT SNOW MELT ROOF SYSTEM

The snow melt system is constructed of 3/4" PEX piping spaced at 9" O.C. and placed in the roof slab. Snow melt provides benefits for both the Structural and Mechanical systems. Structural members benefit from reduced loading while the system functions, prolonging member life. Runoff from snow melt is sent to the rainwater collection and subsequent greywater treatment system for use throughout the plumbing system.

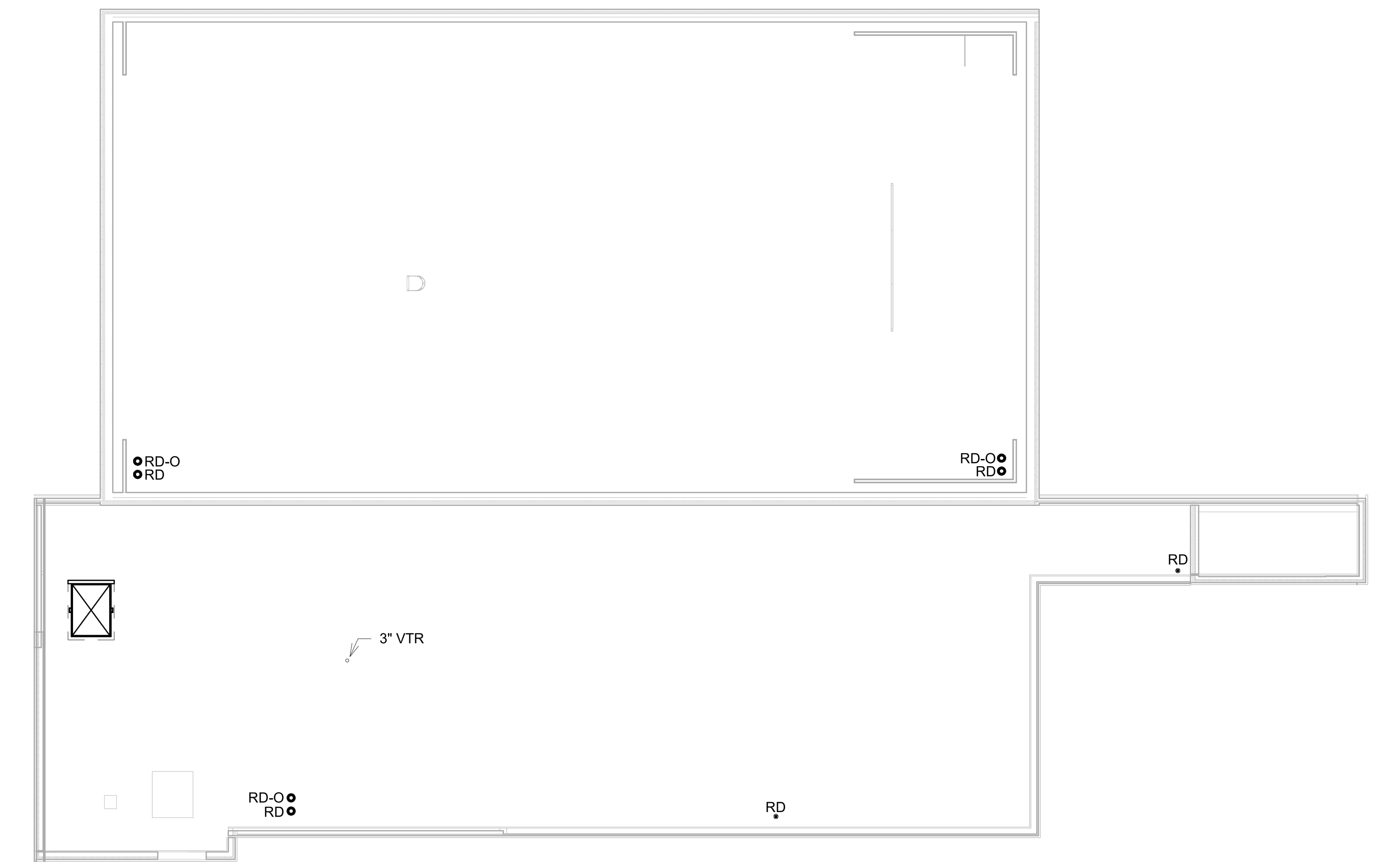


3 RADIANT SNOW MELT SYSTEM 3D RENDERING
NO SCALE

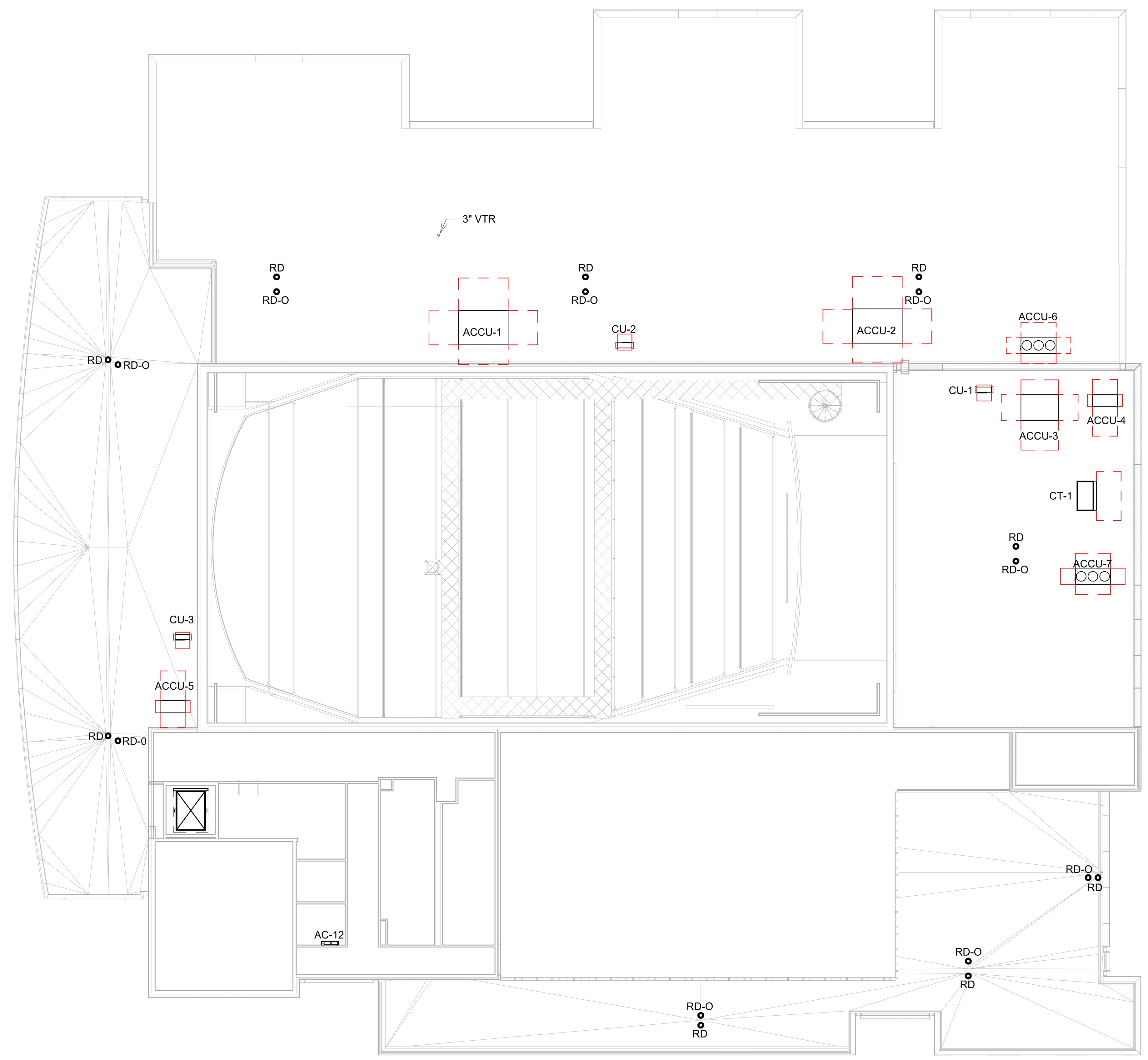


ROOFTOP COORDINATION

Rooftop equipment was placed to minimize acoustic effects on performance spaces while reserving prime solar harvesting locations for PV panels. Shaded areas, while impractical for photovoltaics, are ideal locations for heat rejecting equipment, like condensers and the cooling tower.



1 AMMENITIES ROOF LEVEL MECHANICAL PLAN
1/16" = 1'-0"



2 ROOF LEVEL MECHANICAL PLAN
1/16" = 1'-0"

ATUNE

Jack H. Miller Center for Musical Arts

Mechanical Roof Plans

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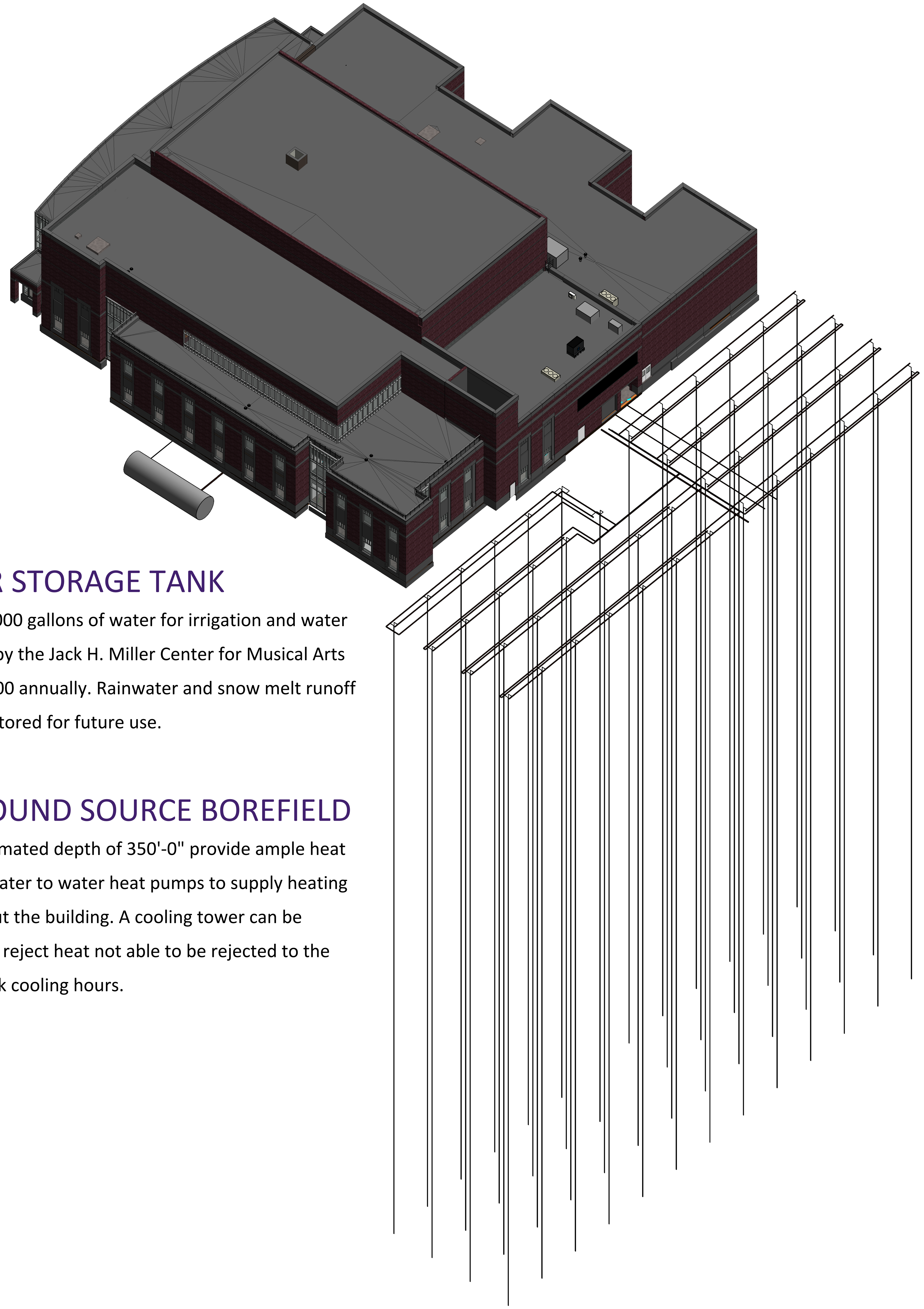
Scale	1/16" = 1'-0"

M3.2



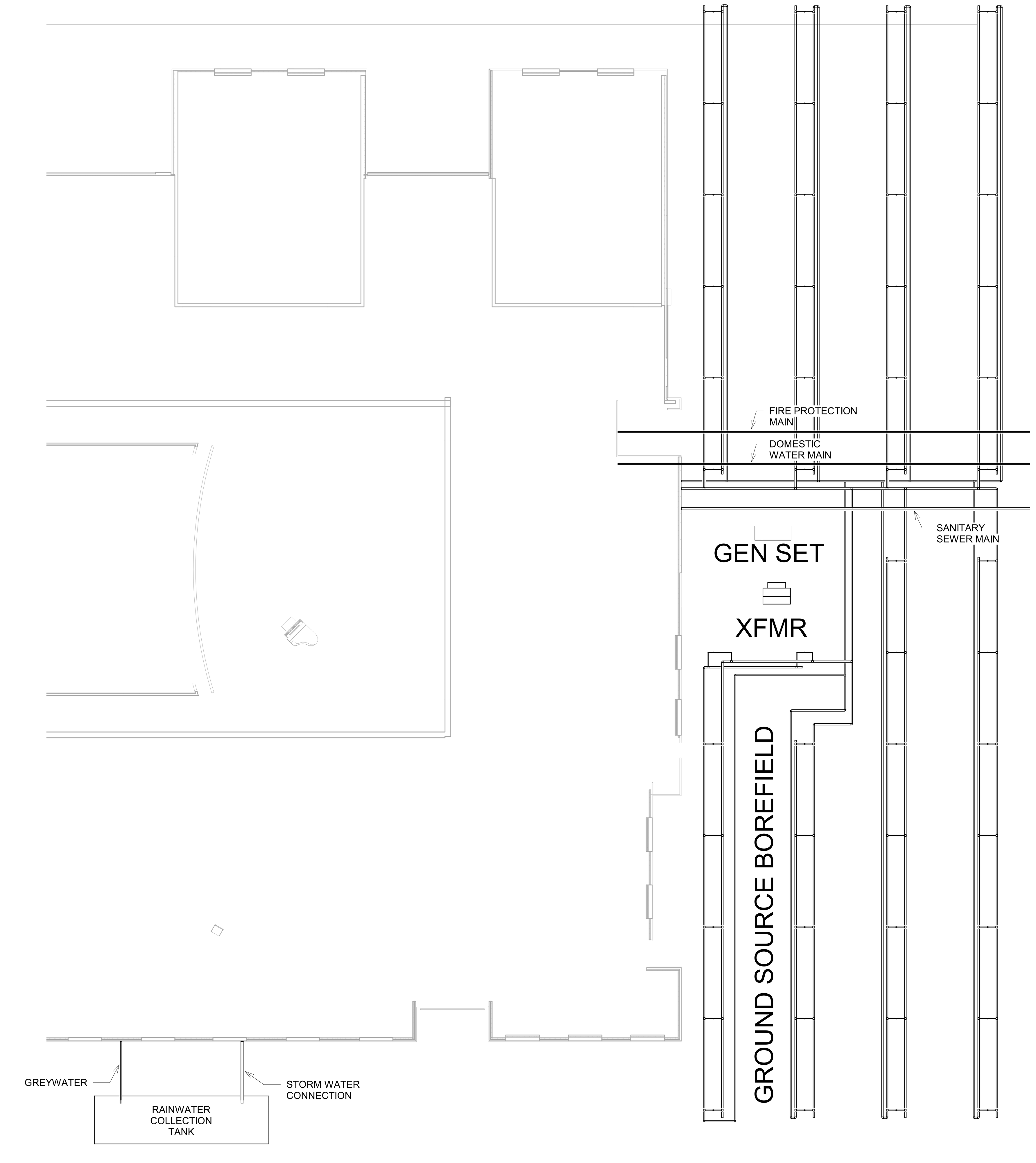
RAINWATER STORAGE TANK

Storage of up to 20,000 gallons of water for irrigation and water closets can be used by the Jack H. Miller Center for Musical Arts for a savings of $3,200 annually. Rainwater and snow melt runoff can be treated and stored for future use.

HYBRID GROUND SOURCE BOREFIELD

Fifty bores at an estimated depth of 350'-0" provide ample heat absorption for the water to water heat pumps to supply heating hot water throughout the building. A cooling tower can be efficiently utilized to reject heat not able to be rejected to the borefield during peak cooling hours.

2 SITE 3D RENDERING



1 MECHANICAL SITE PLAN
1/16" = 1'-0"

SITE COORDINATION

Care must be taken during the site work phase of construction to provided the generator set and utility transformer ample clearance. The borefield must be placed well below the electrical distribution system.

ATUNE

Jack H. Miller Center for Musical Arts

Mechanical Plans

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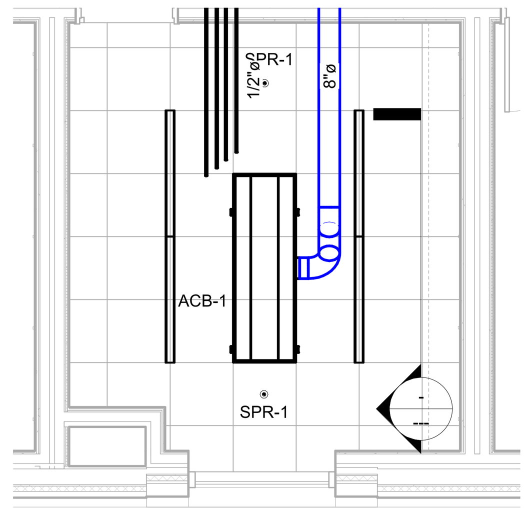
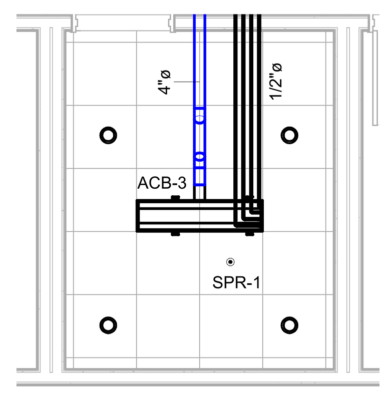
Scale	1/16" = 1'-0"

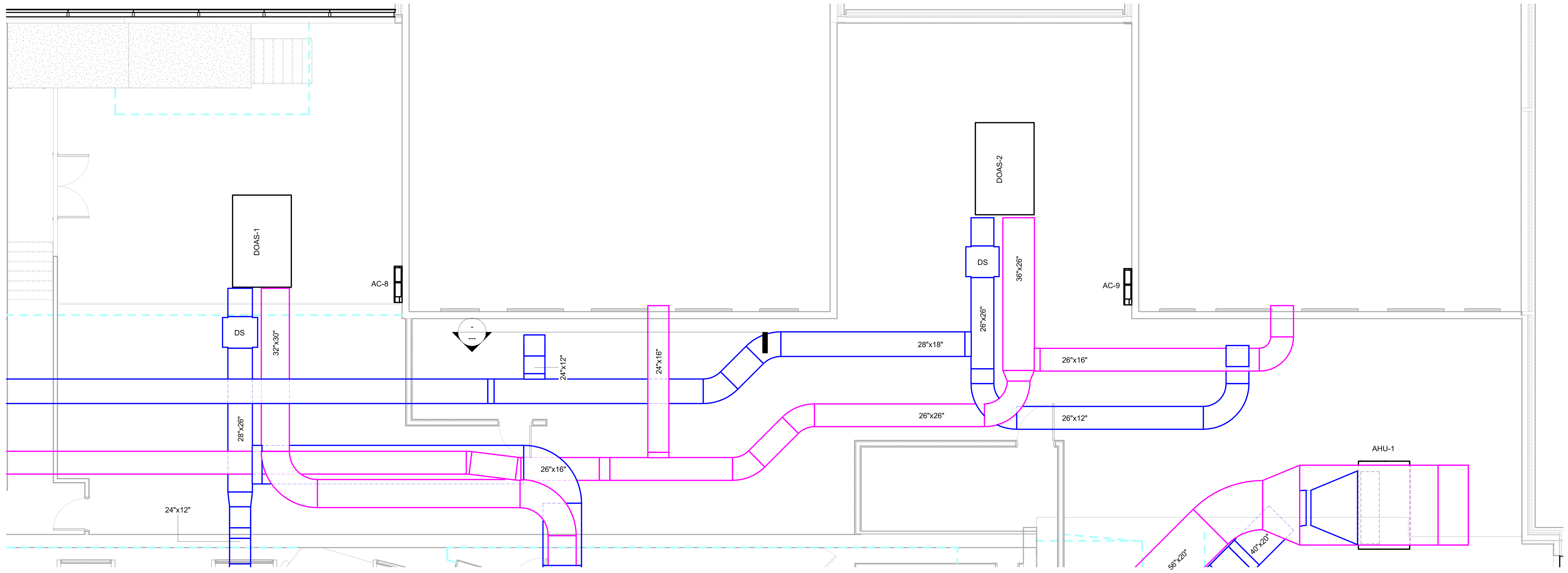
M3.3



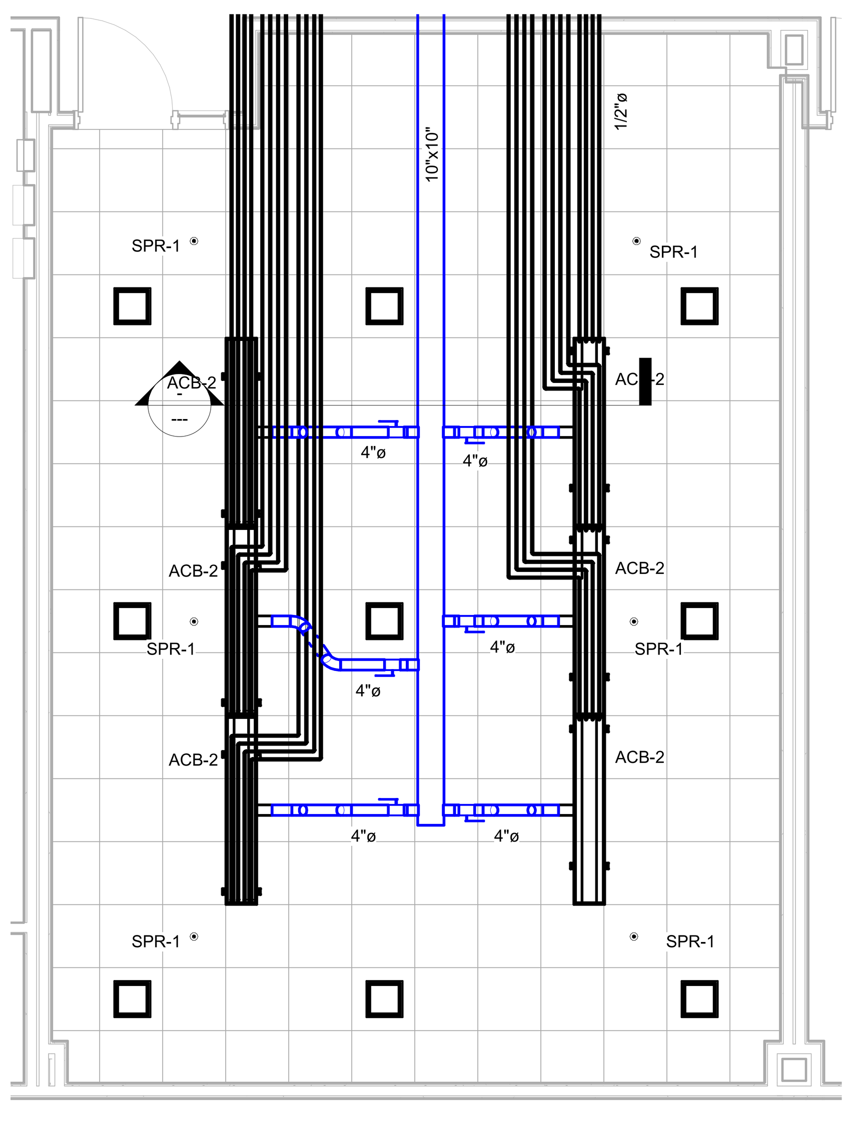
8 FACULTY STUDIO TYPICAL LAYOUT
1/4" = 1'-0"



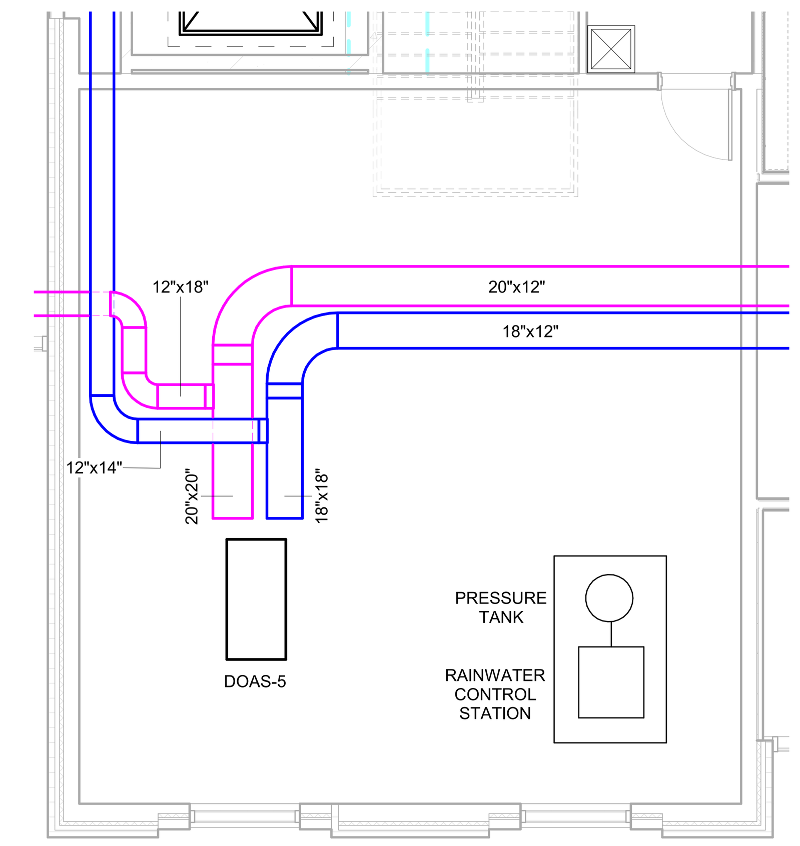
7 PRACTICE ROOM TYPICAL LAYOUT
1/4" = 1'-0"



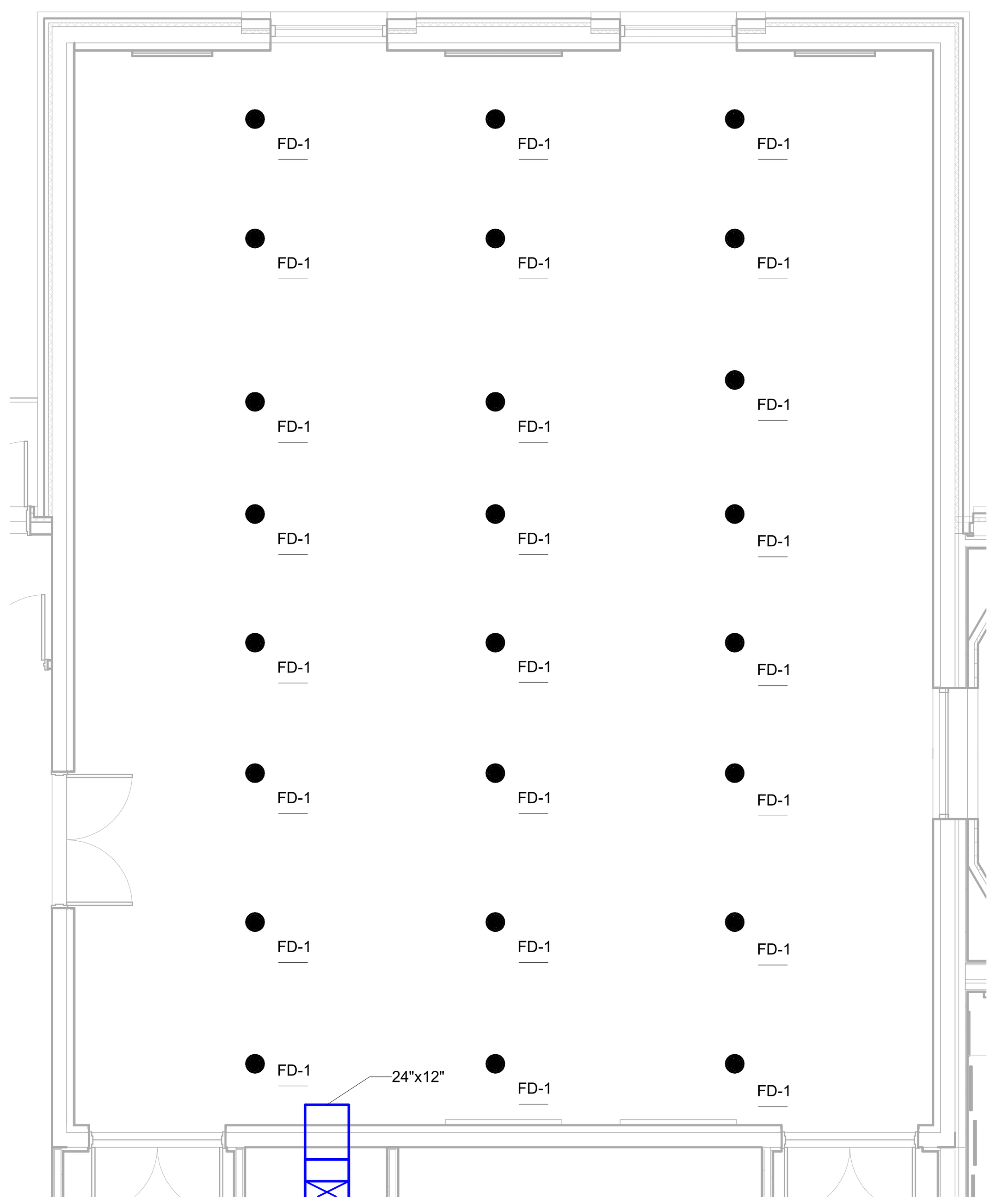
3 MECHANICAL ROOM 224
3/16" = 1'-0"



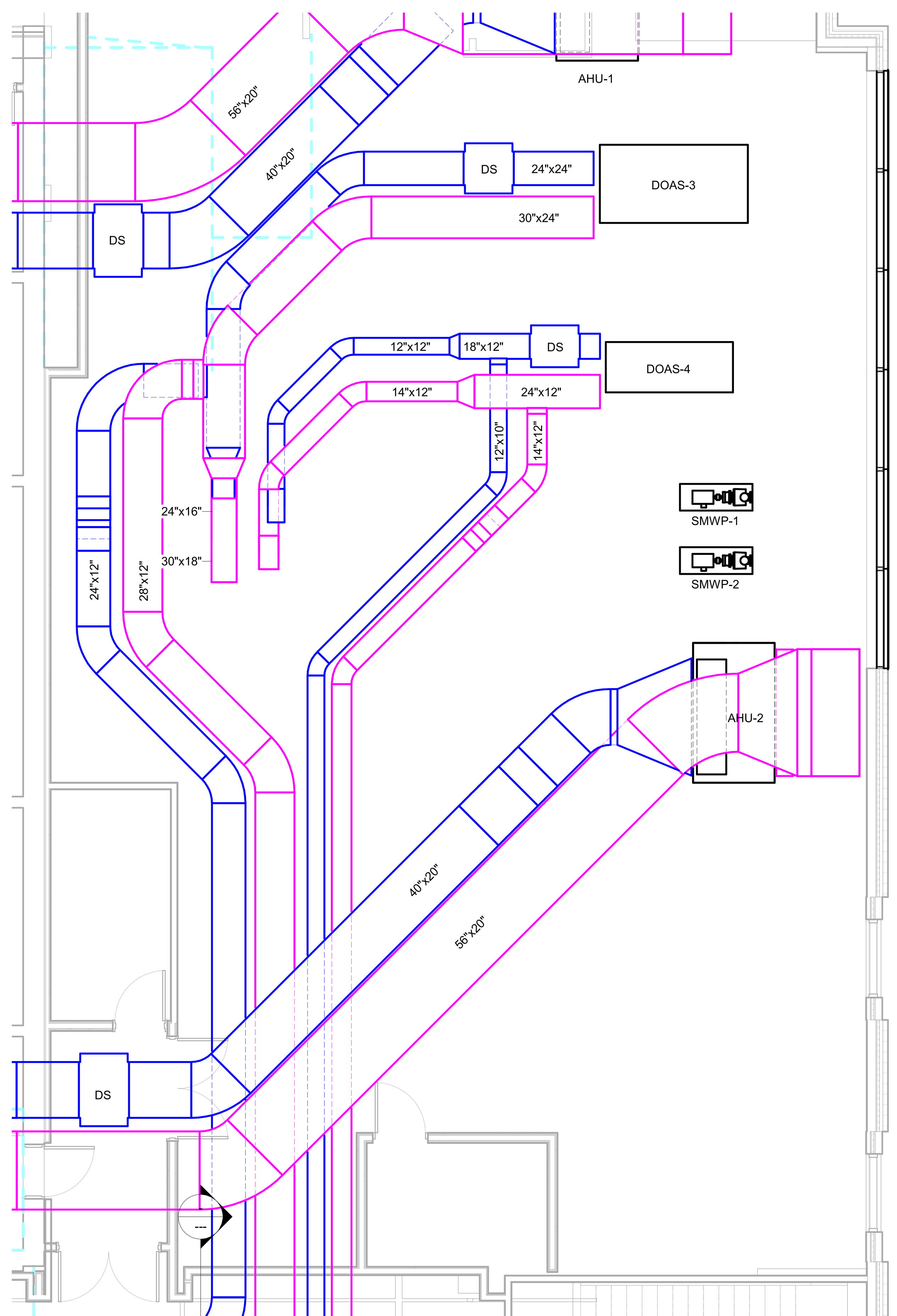
6 CLASSROOM TYPICAL LAYOUT
1/4" = 1'-0"



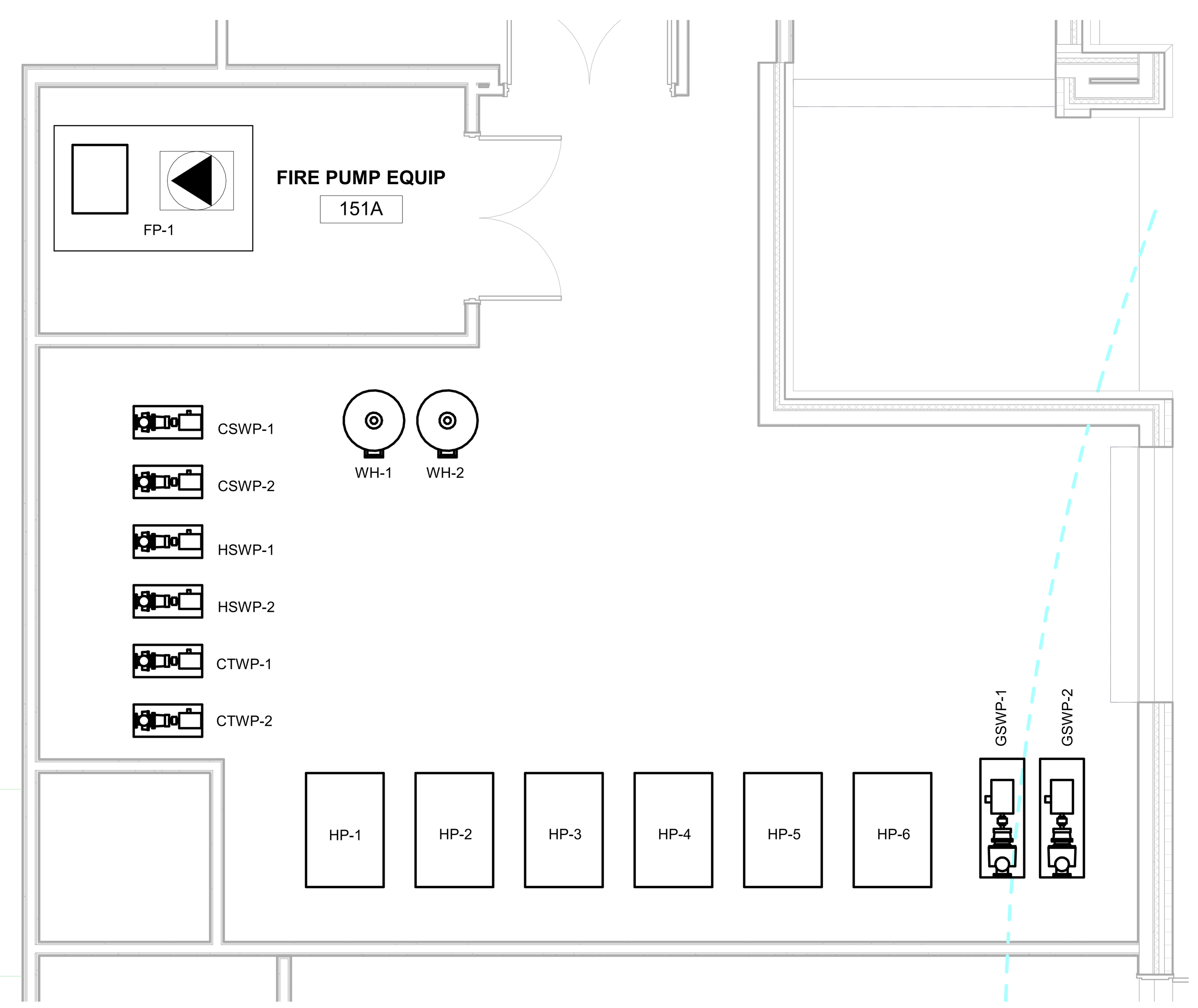
2 MECHANICAL ROOM 250
3/16" = 1'-0"



5 REHEARSAL TYPICAL LAYOUT
3/16" = 1'-0"



4 MECHANICAL ROOM 220
3/16" = 1'-0"



1 MECHANICAL ROOM 151
1/4" = 1'-0"

ATUNE

Jack H. Miller Center for Musical Arts

Mechanical Enlarged Plans

AEI Team No.	7-2019
Date	2/18/2019
Scale	As indicated

M3.4

Control Sequence

Space

Occupancy Classification

CLASSROOM / FACULTY STUDIO

HEATING

UNOCCUPIED

Occupancy sensor and room schedule identify room as unoccupied

- DOAS fan modulates to satisfy a duct static pressure sensor reading
- Zone VAV modulates closed to allow remaining CFM into occupied rooms of zone
- Active Chilled Beam hot water valve is closed

When zone temperature falls below 60 deg, the hot water valve is commanded open and modulates down until 65 deg is reached (Adj.)

When the humidistat reads below 45% or above 55% the DOAS will turn on

When the humidistat reads 50% the DOAS will turn off

PREOCCUPIED

30 minutes (Adj.) before scheduled occupancy thermostat identifies temperature below 75 (Adj.)

Active chilled beam chilled water valve is confirmed closed » Active chilled beam hot water valve modulates open until temperature reaches 75 (Adj.)

- Zone VAV modulates open to allow design CFM into occupied rooms of zone
- DOAS fan modulates to satisfy a duct static pressure sensor reading

System transitions into occupied mode

OCCUPIED

Schedule and/or occupancy sensors identify space as occupied

active chilled beam chilled water valve is confirmed closed

If the space temperature continues to decrease the Active chilled beams hot water valve is commanded 100% open until temperature reaches 75 (Adj)

Once the space set point is reached, the valve continues to be modulated from 100% to the closed position

COOLING

UNOCCUPIED

Occupancy sensor and room schedule identify room as unoccupied

- DOAS fan modulates to satisfy a duct static pressure sensor reading
- Zone VAV modulates closed to allow remaining CFM into occupied rooms of zone
- Active Chilled Beam chilled water valve is closed

When zone temperature rises above 85 deg, the chilled water valve is commanded open and modulates down until 80 deg is reached (Adj.)

When the humidistat reads below 45% or above 55% the DOAS will turn on

When the humidistat reads 50% the DOAS will turn off

PREOCCUPIED

30 minutes (Adj.) before scheduled occupancy thermostat identifies temperature above 75 (Adj.)

Active chilled beam chilled water valve is confirmed closed

- Active chilled beams chilled water valve modulates open until temperature reaches 75 (Adj)

  When Active chilled beam sensor reads 58 deg (Adj.) the chilled water valve will modulate to maintain reading
- » Zone VAV modulates open to allow design CFM into occupied rooms of zone

  DOAS fan modulates to satisfy a duct static pressure sensor reading

System transitions into occupied mode

OCCUPIED

Schedule and/or occupancy sensors identify space as occupied

active chilled beam hot water valve is confirmed closed

If the space temperature continues to increase the Active chilled beams chilled water valve is commanded 100% open until temperature reaches 75 (Adj)

Once the space set point is reached, the valve continues to be modulated from 100% to the closed position

ATRIUM & AMENITY SPACE

HEATING

UNOCCUPIED

Occupancy sensor and room schedule identify room as unoccupied

- DOAS fan modulates to satisfy a duct static pressure sensor reading
- Zone VAV modulates closed to allow remaining CFM into occupied rooms of zone
- Mullion and Radiant Slab 3-way water valve hot water pathway is closed

When zone temperature falls below 60 (Adj.), the hot water pathway is commanded open and modulates down until 65 (Adj.) is reached

When the humidistat reads below 45% or above 55% the DOAS will turn on

When the humidistat reads 50% the DOAS will turn off

PREOCCUPIED

1 hour (Adj.) before scheduled occupancy thermostat identifies temperature below 75 (Adj.)

3-way water valve confirms the chilled water pathway is closed » 3-way water valve modulates hot water pathway open until temperature reaches 75 (Adj.)

- Zone VAV modulates open to allow design CFM into occupied rooms of zone
- DOAS fan modulates to satisfy a duct static pressure sensor reading

System transitions into occupied mode

OCCUPIED

Schedule and/or occupancy sensors identify space as occupied

3-way water valve confirms the chilled water pathway is closed for the Radiant Slab and Hydronic Mullion

If the space temperature continues to decrease the three way valve hot water pathway is commanded 100% open for the Radiant Slab and Hydronic Mullions until thermostat temperature reaches 75 (Adj)

Once the space set point is reached, the valve continues to be modulated from 100% to the closed position

COOLING

UNOCCUPIED

Occupancy sensor and room schedule identify room as unoccupied

- DOAS fan modulates to satisfy a duct static pressure sensor reading
- Zone VAV modulates closed to allow remaining CFM into occupied rooms of zone
- Mullion and Radiant Slab 3-way water valve chilled water pathway is closed

When Mullion temperature sensor reads 58 (Adj.), the mullion 3-way valve will modulate to maintain reading

When zone temperature rises above 85 (Adj.), the chilled water pathway is commanded open for the radiant slab and Hydronic Mullions modulates down until 80 (Adj.) is reached

When the humidistat reads below 45% or above 55% the DOAS will turn on

When the humidistat reads 50% the DOAS will turn off

PREOCCUPIED

1 hour (Adj.) before scheduled occupancy thermostat identifies temperature above 75 (Adj.)

3-way water valve confirms the hot water pathway is closed for the Radiant Slab and Hydronic Mullions

- 3-way water valve modulates chilled water pathway open for the Radiant Slab and Mullions until temperature reaches 75 (Adj.)

  When Mullion temperature sensor reads 58 (Adj.) the 3-way valve will modulate to maintain reading
- » Zone VAV modulates open to allow design CFM into occupied rooms of zone

  DOAS fan modulates to satisfy a duct static pressure sensor reading

System transitions into occupied mode

OCCUPIED

Schedule and/or occupancy sensors identify space as occupied

3-way water valve confirms the hot water pathway is closed for the Radiant Slab and Hydronic Mullion

- If the space temperature continues to increase the three way valve chilled water pathway is commanded 100% open for the Radiant Slab and Hydronic Mullions until thermostat temperature reaches 75 (Adj)
- When Mullion temperature sensor reads 58 (Adj.) the mullion three way valve will modulate to maintain reading

Once the space set point is reached, the valve continues to be modulated from 100% to the closed position

PERFORMANCE HALL / RECITAL

HEATING

UNOCCUPIED

Occupancy sensor and room schedule identify room as unoccupied

- DOAS fan modulates to satisfy a duct static pressure sensor reading
- Zone VAV modulates closed to allow remaining CFM into occupied rooms of zone
- Radiant slab 3-way water valve hot water pathway is closed

When zone temperature falls below 60 , the hot water valve is commanded open and modulates down until 65 is reached (Adj.)

When the humidistat reads below 45% or above 55% the DOAS will turn on

When the humidistat reads 50% the DOAS will turn off

PREOCCUPIED

1 hour (Adj.) before scheduled occupancy thermostat identifies temperature below 75 (Adj.)

3-way water valve confirms the chilled water pathway is closed » 3-way water valve modulates hot water pathway open until temperature reaches 75 (Adj.)

- Zone VAV modulates open to allow design CFM into occupied rooms of zone
- DOAS fan modulates to satisfy a duct static pressure sensor reading

System transitions into occupied mode

OCCUPIED

Schedule and/or occupancy sensors identify space as occupied

3-way water valve confirms the chilled water pathway is closed for the Radiant Slab

If the space temperature continues to decrease the Active chilled beams hot water valve is commanded 100% open until temperature reaches 75 (Adj)

Once the space set point is reached, the valve continues to be modulated from 100% to the closed position

COOLING

UNOCCUPIED

Occupancy sensor and room schedule identify room as unoccupied

- DOAS fan modulates to satisfy a duct static pressure sensor reading
- Zone VAV modulates closed to allow remaining CFM into occupied rooms of zone
- Radiant slab 3-way water valve chilled water pathway is closed

When zone temperature rises above 85°, the chilled water valve is commanded open and modulates down until 80 °reached (Adj.)

When the humidistat reads below 45% or above 55% the DOAS will turn on

When the humidistat reads 50% the DOAS will turn off

PREOCCUPIED

1 hour (Adj.) before scheduled occupancy thermostat identifies temperature below 75 (Adj.)

3-way water valve confirms the chilled water pathway is closed » 3-way water valve modulates hot water pathway open until temperature reaches 75 (Adj.)

- Zone VAV modulates open to allow design CFM into occupied rooms of zone
- DOAS fan modulates to satisfy a duct static pressure sensor reading

System transitions into occupied mode

OCCUPIED

Schedule and/or occupancy sensors identify space as occupied

3-way water valve confirms the hot water pathway is closed for the Radiant Slab

If the space temperature continues to increase the Active chilled beams chilled water valve is commanded 100% open until temperature reaches 75 (Adj)

Once the space set point is reached, the valve continues to be modulated from 100% to the closed position

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ATUNE

Jack H. Miller Center for Musical Arts

HVAC Control Sequence

AEI Team No.	7-2019
Date	2/18/2019
Scale	

M3.5

DOAS UNIT SCHEDULE

TAG NO	SERVES	LOCATION	SUPPLY FAN AIRFLOW CFM	SUPPLY FAN STATIC PRESSURE TOTAL	SUPPLY FAN STATIC PRESSURE EXTERNAL	SUPPLY FAN MOTOR RPM	SUPPLY FAN MOTOR BHP	SUPPLY FAN MOTOR VOLTS	SUPPLY FAN MOTOR PHASE	SUPPLY FAN MOTOR HZ	SUPPLY FAN QTY	SUPPLY FAN SIZE IN.	EXHAUST / RELIEF FAN AIRFLOW CFM	EXHAUST / RELIEF FAN STATIC PRESSURE TOTAL	EXHAUST / RELIEF FAN STATIC PRESSURE EXTERNAL	EXHAUST / RELIEF FAN MOTOR RPM	EXHAUST / RELIEF FAN MOTOR BHP	EXHAUST / RELIEF FAN MOTOR VOLTS	EXHAUST / RELIEF FAN MOTOR PHASE	EXHAUST / RELIEF FAN MOTOR HZ	EXHAUST / RELIEF FAN QTY	WEIGHT LBS	ENTHALPY WHEEL INCHES	DX COOLING COIL REFRIGERANT	DX COOLING COIL AREA SQ FT	DX COOLING COIL ROWS	DX COOLING COIL FPI	DX COOLING COIL VELOCITY FPM	HOT GAS REHEAT COIL CAPACITY MBH	NOTES
DOAS-1	CONCERT HALL	MECH 224	6695	3.75	1.5	2050	3.5	460	3	60	2	18	6050	2.4	1.5	2050	2.5	460	3	60	2	1600	62"x3"	R-410A	17	6	12	400	180	INTEGRAL VFD
DOAS-2	RECITAL / REHEARSAL	MECH 224	6245	3.5	1.5	2050	3	460	3	60	2	18	5600	2.3	1.5	1700	2	460	3	60	2	1600	62"x3"	R-410A	17	6	12	375	132	INTEGRAL VFD
DOAS-3	CLASSROOM	MECH 220	4860	4	1.5	2750	5	460	3	60	1	18	3905	2.5	1.5	2750	4	460	3	60	1	2300	46"x3"	R-410A	10	4	14	475	117	INTEGRAL VFD
DOAS-4	FACULTY STUDIO	MECH 220	1300	3.25	1.5	2550	1.25	460	3	60	1	12.5	540	2.3	1.5	2200	0.85	460	3	60	1	1525	34"x3"	R-410A	3.5	4	14	375	31	INTEGRAL VFD
DOAS-5	ATRIUM	MECH 250	965	4	1.5	2600	1.6	460	3	60	1	16	565	2.5	1.5	3000	0.75	460	3	60	1	1200	19"x3"	R-410A	2	6	12	475	27	INTEGRAL VFD

ACTIVE CHILLED BEAM SCHEDULE

TAG NO	SIZE LENGTH FT	SIZE WIDTH FT	SIZE AIR INLET DIA. IN	ROOM CONDITIONS COOLING DEG F	ROOM CONDITIONS COOLING RH	ROOM CONDITIONS HEATING DEG F	ROOM CONDITIONS HEATING RH	PRIMARY AIR EAT COOLING DEG F	PRIMARY AIR EAT HEATING DEG F	PRIMARY AIR FLOW CFM	PRIMARY AIR MAX APD IN WG	MAX NC	CHILLED WATER EWT DEG F	CHILLED WATER LWT DEG F	CHILLED WATER FLOW GPM	CHILLED WATER COIL PD FT WG	SENSIBLE COOLING PERFORMANCE AIR CAPACITY BTUH	SENSIBLE COOLING PERFORMANCE WATER CAPACITY BTUH	SENSIBLE COOLING PERFORMANCE TOTAL CAPACITY BTUH	HOT WATER EWT DEG F	HOT WATER LWT DEG F	HOT WATER FLOW GPM	HOT WATER COIL PD FT WG	HEATING PERFORMANCE AIR CAPACITY BTUH	HEATING PERFORMANCE WATER CAPACITY BTUH	HEATING PERFORMANCE TOTAL CAPACITY BTUH
ACB-1	6	2	4	75	50	72	50	58	90	35	0.65	22	58	64	1.5	9	640	3860	4500	120	114	1.5	2.5	560	2940	3500
ACB-2	6	1	8	75	50	72	50	58	90	75	0.25	20	58	64	1	2.15	225	2415	2640	120	114	0.5	0.1	205	5785	5990
ACB-3	4	1	5	75	50	72	50	58	90	15	1.5	20	58	64	1	0.1	275	605	880	120	114	1	1	295	1015	1310

AIR HANDLING UNIT

TAG NO	LOCATION	AREA SERVED	SUPPLY FAN AIRFLOW CFM	SUPPLY FAN STATIC PRESSURE TOTAL	SUPPLY FAN STATIC PRESSURE EXTERNAL	SUPPLY FAN MOTOR RPM	SUPPLY FAN MOTOR BHP	SUPPLY FAN MOTOR VOLTS	SUPPLY FAN MOTOR PHASE	SUPPLY FAN MOTOR HZ	SUPPLY FAN QTY	SUPPLY FAN SIZE IN.	DX COOLING COIL REFRIGERANT	DX COOLING COIL AREA SQ FT	DX COOLING COIL ROWS	DX COOLING COIL FPI	DX COOLING COIL VELOCITY FPM
AHU-1	MECH 220	PERFORMANCE HALL LIGHTS	7500	1.8	1	2750	7.5	460	3	60	2	8	R-410A	17.5	4	14	450
AHU-2	MECH 221	PERFORMANCE HALL LIGHTS	7500	1.8	1	2750	7.5	460	3	60	2	8	R-410A	17.5	4	14	450

WATER TO WATER HEAT PUMP SCHEDULE

TAG NO	WATER FLOW LOAD FLOW GPM	WATER FLOW SOURCE FLOW GPM	WPD FT WC	COOLING ELWT DEG F	COOLING LLWT DEG F	COOLING ESWT DEG F	COOLING LSWT DEG F	COOLING HEAT OF REJECTION MBH	ESWT DEG F	LSWT DEG F	HEATING EWT DEG F	HEATING LWT DEG F	HEATING HEAT OF ABSORPTION MBH	ELECTRICAL DATA MCA AMPS	ELECTRICAL DATA V-PH-HZ	EER
HP-1	37.4	30	4	70	58	95	110	140	32	24	114	120	70	36	480-3-60	12
HP-2	37.4	30	4	70	58	95	110	140	32	24	114	120	70	36	480-3-60	12
HP-3	37.4	30	4	70	58	95	110	140	32	24	114	120	70	36	480-3-60	12
HP-4	37.4	30	4	70	58	95	110	140	32	24	114	120	70	36	480-3-60	12
HP-5	37.4	30	4	70	58	95	110	140	32	24	114	120	70	36	480-3-60	12
HP-6	37.4	30	4	70	58	95	110	140	32	24	114	120	70	36	480-3-60	12

PUMP SCHEDULE

TAG NO	TYPE	CONNECTION	GPM	FT. HD.	IMPELLER SIZE	RPM	VOLTAGE	BHP	HP	NOTES
CSWP-1	END SUCTION	FLEXIBLE-COUPLED	190	75	9	1760	480	4.93	4.83	INTEGRAL VFD
CSWP-2	END SUCTION	FLEXIBLE-COUPLED	190	75	9	1760	480	4.93	5	INTEGRAL VFD
HSWP-1	END SUCTION	FLEXIBLE-COUPLED	190	75	9	1760	480	4.93	5	INTEGRAL VFD
HSWP-2	END SUCTION	FLEXIBLE-COUPLED	190	75	9	1760	480	4.93	5	INTEGRAL VFD
GSWP-1	END SUCTION	FLEXIBLE-COUPLED	300	60	6	1760	480	5.93	7.5	INTEGRAL VFD
GSWP-2	END SUCTION	FLEXIBLE-COUPLED	300	60	6	1760	480	5.93	7.5	INTEGRAL VFD
CTWP-1	VERTICAL INLINE	FLEXIBLE-COUPLED	100	80	9	1760	480	4.93	5	INTEGRAL VFD
CTWP-2	VERTICAL INLINE	FLEXIBLE-COUPLED	100	80	9	1760	480	4.93	5	INTEGRAL VFD
SMWP-1	END SUCTION	FLEXIBLE-COUPLED	260	100	12	1760	480	9.86	10	INTEGRAL VFD
SMWP-2	END SUCTION	FLEXIBLE-COUPLED	260	100	12	1760	480	9.86	10	INTEGRAL VFD

COOLING TOWER SCHEDULE

TAG NO	LOCATION	FAN CHARACTERISTICS CFM	FAN CHARACTERISTICS MOTOR HP	COOLING CAPACITY TONS	WATER CHARACTERISTICS FLOW GPM	WATER CHARACTERISTICS EWT DEG F	WATER CHARACTERISTICS LWT DEG F	OPERATING WEIGHT LBS	NOTES
CT-1	Roof	11,500	5	30	90	103	93	1590	INTEGRAL VFD

AIR COOLED CONDENSING UNIT SCHEDULE

TAG	SERVES	CAPACITY TONS	REFRIGERANT	FAN	COMPRESSOR QTY	CIRCUITS	WEIGHT LBS
ACCU-1	DOAS-1	40	R-410A	ECM	1	1	2500
ACCU-2	DOAS-2	31	R-410A	ECM	4	2	2200
ACCU-3	DOAS-3	25	R-410A	ECM	2	2	1550
ACCU-4	DOAS-4	7	R-410A	ECM	1	1	475
ACCU-5	DOAS-5	5	R-410A	ECM	1	1	475
ACCU-6	AHU-1	16	R-410A	DIRECT DRIVE	3	1	950
ACCU-7	AHU-2	16	R-410A	DIRECT DRIVE	3	1	950

RAINWATER COLLECTION TANK SCHEDULE

NOMINAL GALLONS	TANK DIAMETER	TANK LENGTH	NOMINAL WEIGHT
20,000	10'-6"	38'-0"	5,700 LB

FIRE PUMP SCHEDULE

GPM	PSI	HP	SUCTION SIZE	DISCHARGE SIZE
300	80	25	4"	4"

WATER HEATER SCHEDULE

MARK	QTY	GALLONS	ELECTRIC KW	CW SIZE	HW SIZE
WH-1	2	150	160	1 1/2"	1 1/2"

ATUNE

Jack H. Miller Center for Musical Arts

Equipment Schedules

AEI Team No. 7-2019

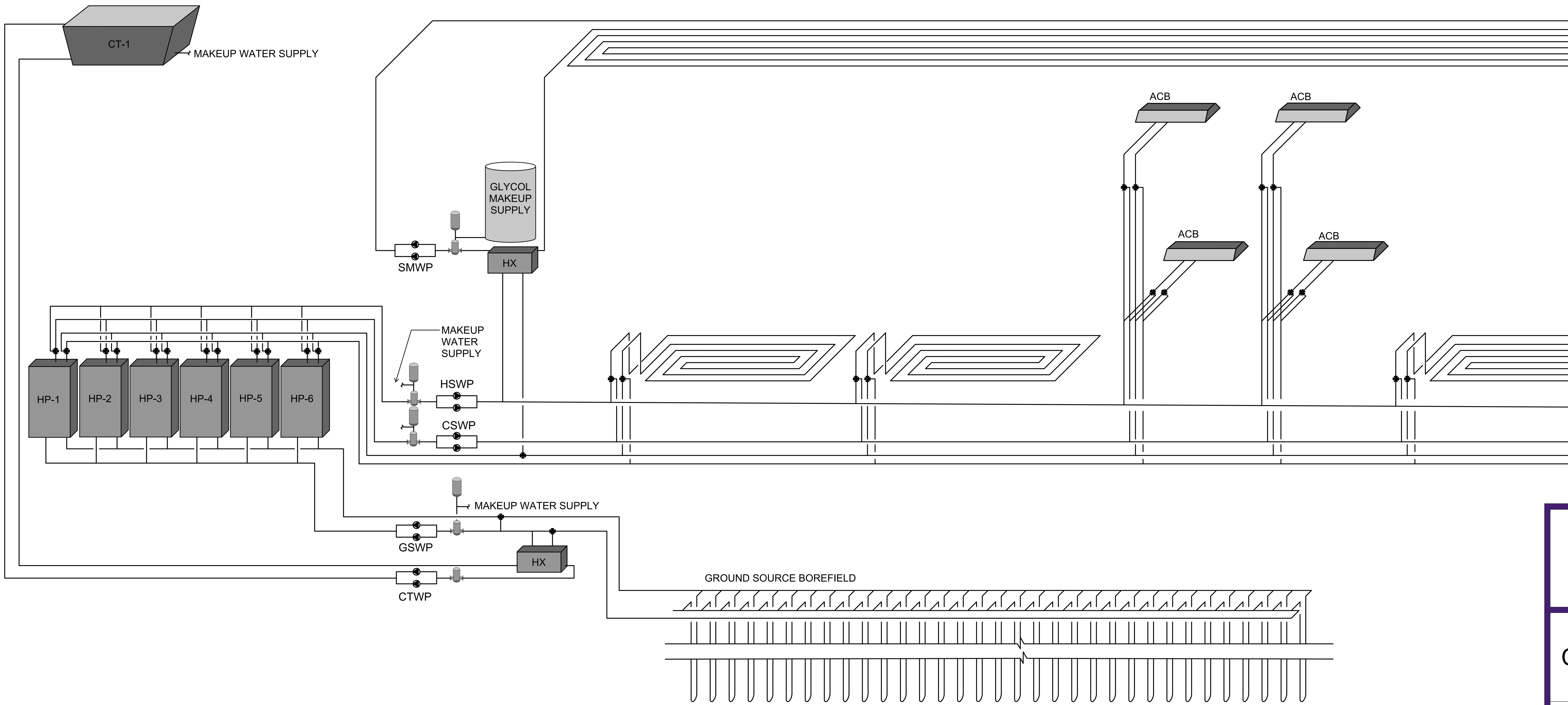
Date 2/18/2019

Scale

M3.6

HYDRONIC DISTRIBUTION SCHEME

Simultaneous heating and cooling conditions pointed to water to water heat pumps being a wise selection. Heat pumps can be staged to be in either heating or cooling mode, which enables load sharing when exterior zones need heating while interior loads demand cooling.



1 WATERSIDE RISER DIAGRAM
NO SCALE

ATUNE

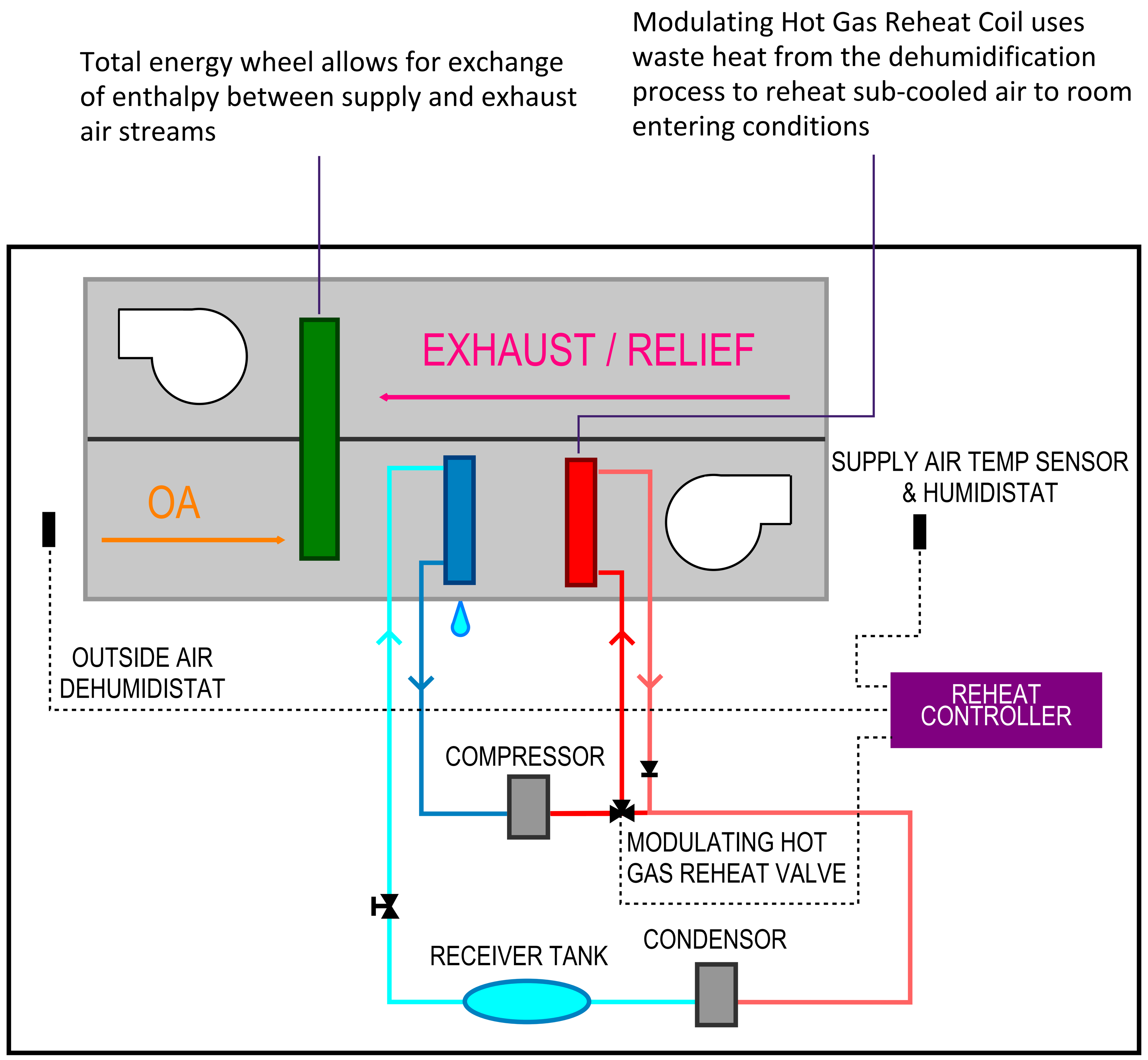
Jack H. Miller Center for Musical Arts

Waterside Riser Diagram

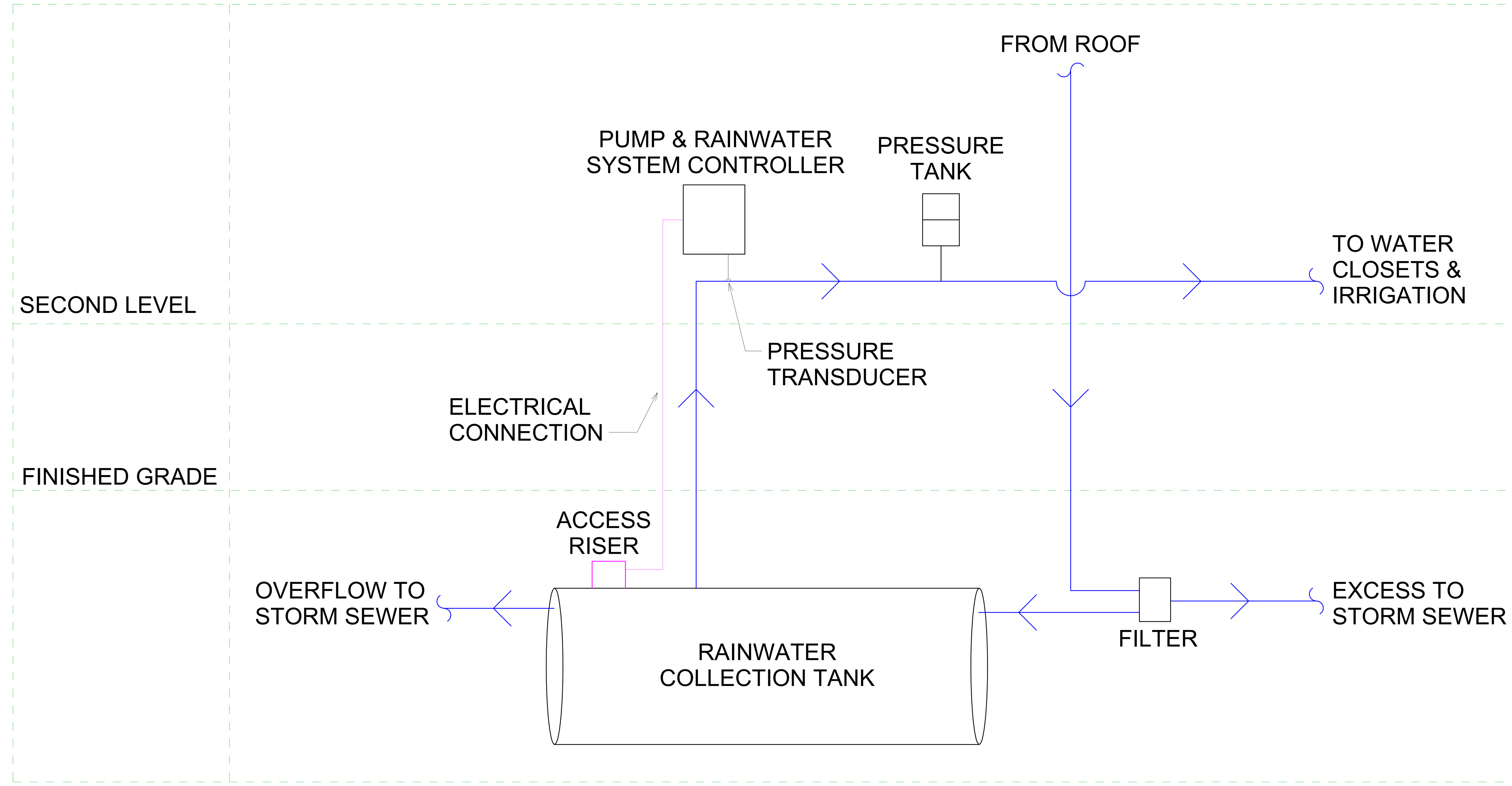
AEI Team No.	7-2019
Date	2/18/2019
Scale	

M3.7

DOAS UNITS



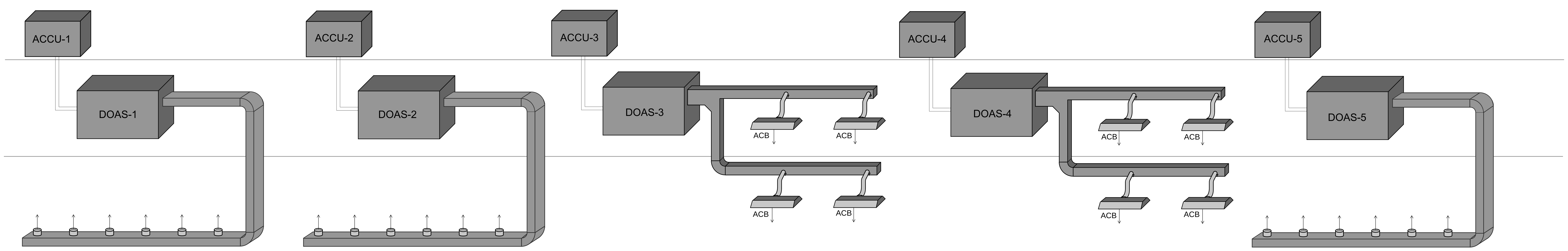
(3) DOAS WITH TOTAL ENERGY WHEEL AND MODULATING HOT GAS REHEAT
NO SCALE



(1) RAINWATER RISER DIAGRAM
NO SCALE

AIR DISTRIBUTION SCHEME

Atune's Mechanical team selected systems that only require ventilation air to be conditioned and introduced to the building which minimized ductwork. Using multiple separate systems provided inherent redundancy and an added level of efficiency over a conventional system. When any given system's zones become unoccupied, the entire unit can be shut down. Had a more conventional system (AHU with VAV terminal reheat for example) been used, units would still have to operate to temper space conditions in unoccupied mode. The hydronic system is able to address building sensible loads more efficiently through radiant conditioning.



(2) AIRSIDE RISER DIAGRAM
NO SCALE

ATUNE

Jack H. Miller Center for Musical Arts

Riser Diagrams

AEI Team No.	7-2019
Date	2/18/2019
Scale	

M3.8

ELECTRICAL EXECUTIVE SUMMARY

Atune utilized the Integrated Project Delivery method to design the Jack H. Miller Center for Musical Arts. This process enabled the design team to create a versatile and sustainable building with all its systems working in harmony. The electrical/lighting team aimed to create a high performance building while not exceeding the project budget. In doing so, the team considered many innovative and integrated solutions to meet the building's needs. These solutions address the building's capability to perform efficiently, adapt under varying conditions and serve as a safe environment.

SOLAR ENERGY

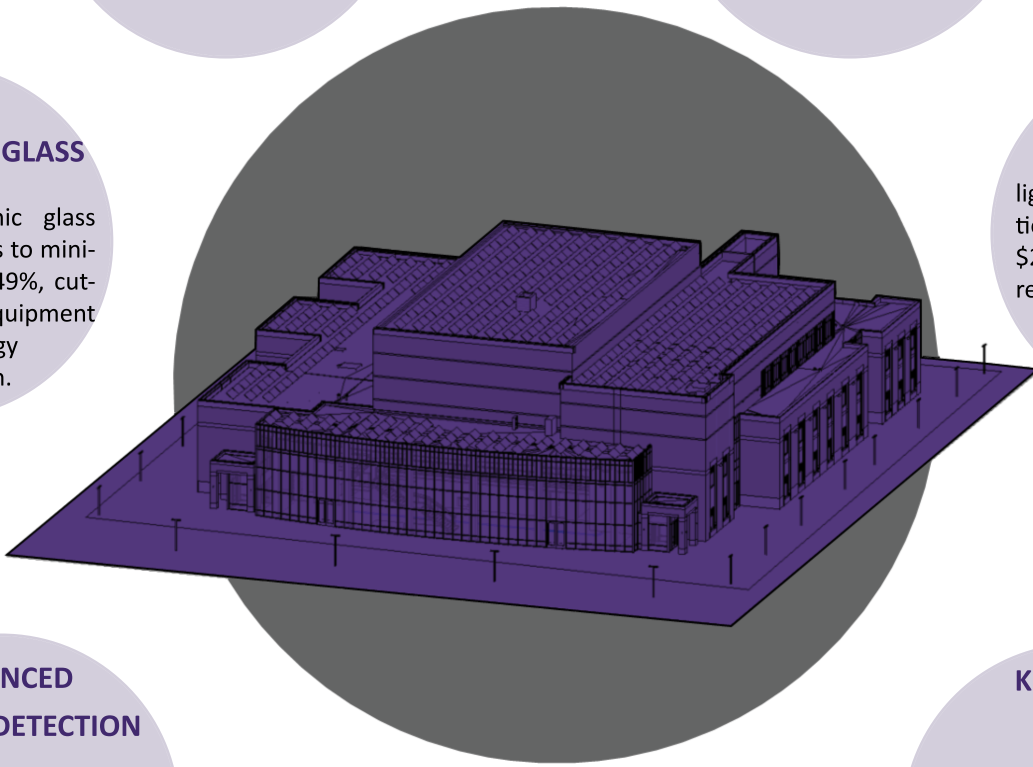
506 solar panels provide 20% of the annual building costs and reduce building utility costs through Watson BAS.

WATSON BAS

Artificial Intelligent Building Automation System increases building efficiency, comfort and systems integration.

DYNAMIC VIEW GLASS

Triple pane dynamic glass utilizes 4 tint settings to minimize heat gain by 49%, cutting mechanical equipment size and energy consumption.



PoE LIGHTING

Power over Ethernet lighting reduces construction/material costs by over $200,000. Additionally, a 65% reduction in lighting energy use was achieved.

ADVANCED SHOOTER DETECTION

Dual criteria sensors located in strategic locations of the building detect gunshots, track active shooters and alert local authorities.

KINEMATIC ENERGY

Pavegen was placed in the heaviest foot traffic areas enable users to power interactive education displays and power over 500,000 phones annually.

ADVANCED ROOM SCHEDULING

With Watson BAS, rooms can be scheduled through IoT and monitored to adjust meeting times based on real time space occupancy.

STRUCTURAL TABLE OF CONTENTS	
1.0	PROJECT INTRODUCTION
2.0	ATUNE'S MISSION
3.0	PROJECT ELECTRICAL GOALS
4.0	STRUCTURE & INNOVATIONS OVERVIEW
5.0	DESIGN METHODOLOGY
6.0	POWER DISTRIBUTION
7.0	LIGHTING SYSTEMS AND DESIGN
8.0	SPECIALITY SYSTEMS
9.0	PROJECT BUDGET & CONSTRUCTABILITY
10.0	PROJECT CHALLENGES
11.0	LESSONS LEARNED
12.0	CONCLUSION

1.0 PROJECT INTRODUCTION

The Jack H. Miller Center for Musical Arts is located at Hope College in Holland, Michigan. The 64,00 square-foot building includes multiple performance venues, classrooms, practice rooms, faculty studios and office spaces for Hope College's Music Department. The building is situated along Columbia Avenue between 9th and 10th street and is adjacent to railroad tracks running by the campus. Atune will exceed expectations through innovative systems, ingenious technologies and Integrated Project Delivery construction methods.

2.0 ATUNE'S MISSION

The design intentions that the Atune team has set forth for the Jack H. Miller Center for Musical Arts are versatility, sustainability, and harmony. Atune's design chose to tackle the Jack H. Miller Center for Musical Arts through Integrated Project Delivery (IPD) and Building Information Modeling (BIM). Although IPD is a more demanding and strenuous process, the work that was achieved through this process would not be possible without this method.

Along with Atune's three goals an electrical design matrix was created. See electrical design matrix in the supporting documents.
The design matrix helped to quantify decisions and make them become more objective, tangible and presentable.

3.0 PROJECT ELECTRICAL GOALS

The following electrical goals reflect the electrical contributions to Atune's overall team goals for Hope College's Jack H. Miller Center for Musical Arts.

3.1 Versatility

Atune set forth the goal to create a versatile and resilient building for Hope College to utilize for centuries to come. The Jack H. Miller Center for Musical Arts impact past the borders of the college and into the community. The building will serve variable purposes and events and thus must be able to adapt to said demands. Therefore, electrical engineers created flexibility of use through implementing multi-purpose systems to deliver an adaptable building for variable future use.

3.2 Sustainability

One of Hope's sustainable goals is to reduce the college's carbon footprint, the electrical team reached said goal using renewable systems and materials. Atune was cognizant a carbon footprint can also be created by using materials not readily available. Therefore, the price required to acquire renewable systems and materials was considered when choosing the systems and materials.

3.3 Harmony

Atune's goal is to create a building that displays harmony at every level, with every discipline and every component working together to create one collective building. Electrical engineers were able to assimilate whole project systems and values through efficient Integrated Project Delivery methods to provide a competitive state-of-the-art facility to steward Hope's Mission. Electrical engineers worked closely with all disciplines to reduce building schedule and cost. IPD also allowed construction conflicts to be acknowledged early and solved quickly and efficiently.

4.0 BUILDING STRUCTURE & INNOVATION OVERVIEW

The electrical, lighting and special systems selected for the Jack H. Miller Center for Musical Arts reflect versatility, harmony and sustainability. The electrical team contributes to the building's sustainability by the reduction of power and lighting distribution construction cost using Power over Ethernet (PoE) distribution. Equipment rooms are also allocated at the epicenter of powered loads to further reduce runs. Renewable power sources such as Photovoltaic Panels (PV) and Door Power Harvesting (DPH) were used in conjunction with lithium-ion battery banks to address the imbalance of power production and power demand through the day. Additionally, electrical engineers integrated the building's view glass façade with hydronic mullions to decrease the solar gain and lighting power consumption. Next, electrical engineers interconnected with the mechanical team using Internet of Things (IoT) through Artificial Intelligent Building Automation System (AIBAS) for optimal coordination to reduce operational costs. Lighting power consumption was also minimized by using daylighting, occupancy, vacancy, schedule, time of day, and user preference as criteria for lighting controls.

Additionally, lighting and power systems were designed for versatility by delivering PoE in conjunction with traditional power distribution methods. Accordingly, task, ambient and accent lighting was layered to maximize space versatility, comfort of use and aesthetic appeal. Finally, Atune educates the public of the sustainable engineering systems incorporated in the building through interactive displays located in student interaction spaces, corridors and atrium to attract potential students and private investors of the college.

5.0 DESIGN METHODOLOGY

The design process used by the electrical team first focused on the life, safety and well-being of the occupants. Secondly, electrical engineers adequately addressed the needs and wants of Hope College by examining all options and their life-cycle cost. These finding were compared, analyzed and discussed in IPD meetings. This improved construction schedule and decreased construction clashes among systems. In turn, Atune was able to provide a safe, efficient and pleasing musical arts building for Hope College and the community in Holland Michigan.

5.1 Design Codes and Standards

The design of all electrical systems proposed for the Jack H. Miller Center for Musical Arts followed all codes currently adopted by Ottawa County, as well as the Holland Municipal Code, including all amendments. Refer to the Codes and Standards page for a list of all relevant codes used for design and construction of the Jack H. Miller Center for Musical Arts.

5.2 Design and Analysis Software

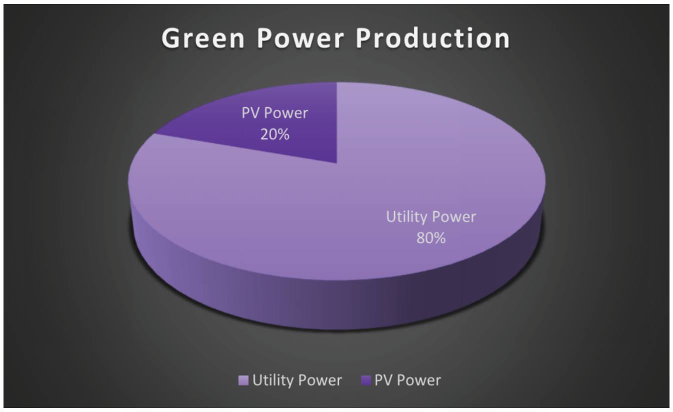
Atune used a variety of tools to aid in the design of the building's electrical systems. The use of these design and analysis software packages gave Atune's electrical team the enhanced ability to further develop and improve efficiency in the building design process. One key element in choosing the software was the ability to collaborate with all other disciplines and communicate effectively the concerns of the systems being designed. Refer to supporting document I2.1 for the programs utilized.

6.0 POWER DISTRIBUTION

A focus for the power distribution within the Jack H. Miller Center for Musical Arts was to create a resilient and low maintenance system to provide efficient and reliable power. The electrical engineers designed a distribution system that can adapt to the multiple uses of the building, while providing the infrastructure for seamless performance.

6.1 Renewable Power Generation

To meet Atune's electrical goal for sustainability, alternative methods of power generation were explored first. This was done to be able to approach the power distribution system with an idea of the different sources that were to be implemented. In turn, this led to a more cohesive and seamless performing system.

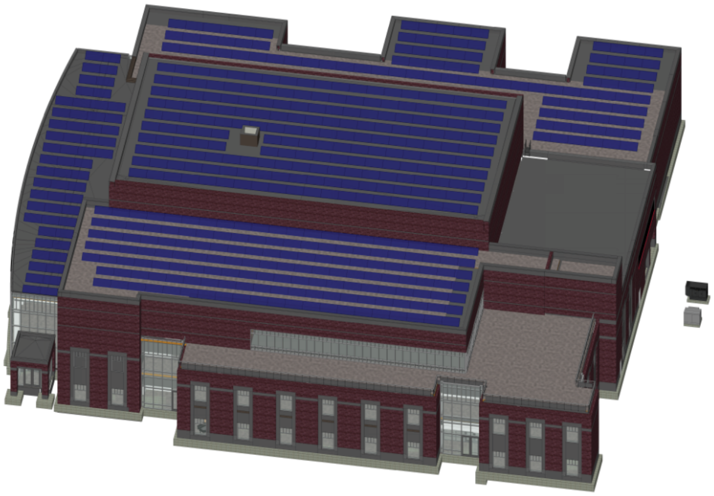


The following sections contain systems that were implemented or considered to be a source of renewable power generation.

6.1.1 Photovoltaic (PV) System

The electrical team conducted analysis to determine the feasibility of installing a PV system on multiple sections of the roof. The building is located at 42.8°N which produces an average daily incident shortwave solar energy of 4.53 kWh/m^2 (0.4201 kWh/ft^2). The roof consists of 42,000 square feet and after deducting space that equipment is occupying and areas that will be shaded for a large portion of the day, the remaining square footage that can be utilized for solar panels is 26,850. Four individual sections of the roof will be utilized to create a 185-kW system. The four sections being used are as follows: above the Concert Hall, the west lobby roof, the rooftop amenity space and part of the north section of the roof. These allow for a total of (506) 72-cell mono-crystalline modules that have the capability of generating up to 365W at a maximum efficiency of 18.46%. After analyzing the annual power production from the system, Atune's electrical team determined that the solar panels will produce 242,360 kWh a year, saving an average of $26,126 a year, or nearly 20% of the total energy cost for the building.

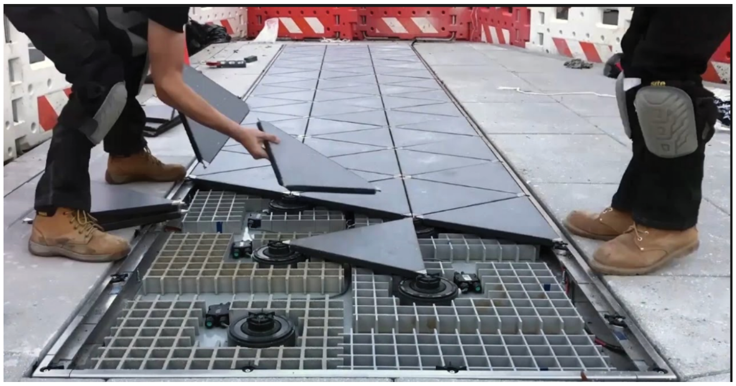
The electrical team was able to design the array with a payback period of 10.8 years, which was an initial concern, but after discussing the team's goal of sustainability and energy savings over the long life of the building, it was determined that the system would be an effective method for power generation. With the selected solar panels, Atune's electrical team will be able to guarantee a minimal 0.67% decrease in panel efficiency over the first 25 years. This means that the Solar panels will still produce energy at more than 80% of their initial output rating. Refer to sheet E3.4 for more information regarding the calculations, design of the installation and the payback period.



6.1.2 Kinematic Power Generation

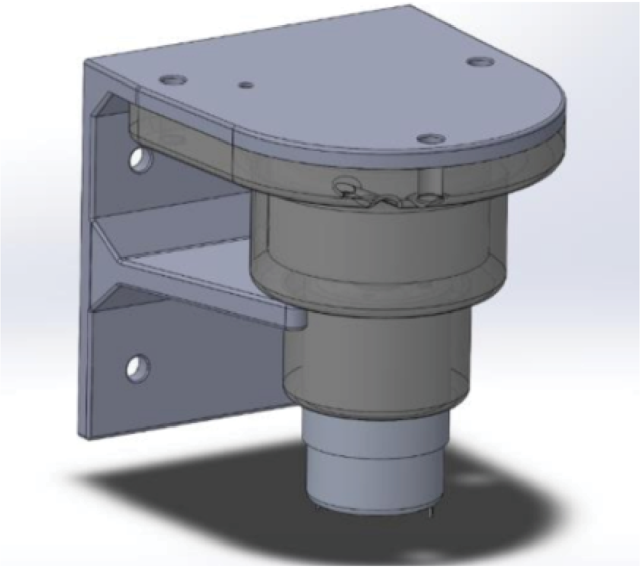
The Jack H. Miller center for musical arts is located on a college campus with daily traffic Monday through Friday. With an estimated 127 shows annually, the building experiences heavier traffic for roughly 40% of the year. For this reason, Atune sought out and researched the implementation of kinematic power generation. Building occupant loads reach nearly 800 people a day traveling through the building during performance seasons. Kinematic energy produced by Pavegen tiles ranges from 6 to 8 joules of energy produced per step.

The price of production for said tiles was estimated by the electrical team at $100/SF based on an article published in 2017 . Therefore, evaluation of the heaviest and most used areas by the public was conducted. Consequently, a limited area of kinematic floor tiles placed in those areas result in a balance of cost of production and power generation. The total cost of installation was calculated to be $38,400 and with the ability to be removed, maintenance cost is minimal. The system produces 18.11 kWh per day and 3,139 kWh annually. This is enough power to charge over 575,000 phones annually. As a result of working closely with the Structural team, the infrastructure in place allows for upgrades or replacements of the tiles as more efficient ones become available. Refer to the supporting document E2.4 for a more in depth analysis of the system. The figure below shows an example of the infrastructure and assembly required.



6.1.3 Door Power Harvesting (DPH)

While exploring innovative power generation, the team proposed to harvest the energy used to open a door. After further research was conducted, Atune Engineers found that energy could be harvested both in the opening and closing of a door. This is achievable using a clutch mechanism activated during the transition between opening and closing. The power generation of 0.00595 mW per pull would not be enough to store in a battery for future use by the activation switch of ADA accessible doors. However, the power generation mechanism can be adjusted to provide the maximum allowed force of 5 pounds to open the door without sacrificing power generation. Atune decided to go take a different approach and wire it to the occupancy sensor in the room. The circuiting of this device would be simillar to any low voltage sensor and contrlloer combination; the DPH would simply just require an additional sensor input. The goal is to provide the occupancy sensor with a multi-criteria detection system for faster response of turning on lights when an occupant comes into the room, specifically a handicapped occupant. The team evaluated this as an innovative solution to lag time of lights turning on in high ceiling areas. Thus, increasing health and safety of the building occupants. Picture below is an example of one of these devices and how it would be mounted.



6.1.4 Alternative Power Generation Explorations

During the first IPD meetings, multiple alternate ideas for power generation were proposed. Among these include acoustical energy harvesting, thermocouple power generation, wind energy and duct turbines. The ideas were investigated in initial design. Below are the findings and explanation as to why these sources were rejected.

6.1.4.1 Acoustical Energy Harvesting

The Jack H. Miller Center for Musical Arts presents a unique form of energy source not found in other buildings – acoustical energy. Electrical engineers at Atune researched the possibility of harvesting acoustical energy in the building. The most apt rooms for this implementation would include the practice rooms, performance rooms, and two performance halls. The acoustical harvesters that Atune researched used electromagnetic materials to generate electrical energy from induced magnetic flux provided by Sound Pressure Levels (SPL). The instrument table located on supporting document E2.4 shows a list of dB SPL created by different instruments to be used in the building. AEH are on average the size of a C battery thus, making the placement of this technology more aesthetically pleasing. The allocation of the devices was studied in such a way to minimize reverberation losses of the acoustical energy. The energy harvested from the devices would then have been stored in a small battery bank near restrooms to power low voltage plumbing fixtures such as automated flushing water closets and automated lavatories.

Atune found that a single AEH power production ranges from 1.5 – 1.96 mW at 143 – 470 Hz.Thus making them a plausible implementation in this building as resonant frequencies are produced by tuned instruments in harmony. Electrical engineers then conducted further research and found that the production cost of a single AEH would be about $500 (based on Vicoustic Vari Bass Tunable Helmholtz Resonator) and produce 16.2 Wh a day. Therefore, the payback for the estimated installation of devices would be over 2300 years. Atune decided that although the source is renewable and easily accessible, the technology is not developed enough to be justified as a sustainable solution.

6.1.4.2 Thermocouple Power Generation

Inspired by local residential thermocouple power generation – Synergine, Atune sought to implement similar concepts at a commercial building level. In coordination with mechanical engineers at Atune, electrical engineers evaluated the HVAC system being used to temper the space to find a location adequate for thermocouple implementation. The water-to-water heat pumps used by mechanical engineers proved to be the most apt for this use. The water-to-water heat pumps contain two inlet and outlet streams of varying temperature water. Ideally a 70-degree temperature differential is required to produce 100 kWh of power monthly.

Mechanical engineers evaluated that none of the water-to-water heat pumps would have a constant 70° temperature difference. However, the proposed design by electrical engineering would be to interconnect all input and output sources to every water source heat pump in a single room and use the artificial intelligence building automation system to detect the two lines with the greatest temperature difference and use those as the source lines for the thermocouple power generation equipment. Consulting with Atune's construction team, lead us to discover that the system has never been built before and would have a high construction and maintenance cost. Additionally, Atune engineers found the implementation of the system in such with a complex system of inlets and outlets would create more situations for operation error. It was concluded that although the system would be generating nearly 100kWh per month, it was not a long-term investment that would pay off.

6.1.4.3 Wind Energy

Atune analyzed the building's potential for a wind power generation system. The building is one of the taller buildings in the area, so there would not be many obstructions. The average wind speed in this area varies substantially throughout the year. In the fall and winter months, the average wind speed is 11.8 mph, with a highest average of 14.8 mph in the beginning of January. In the spring and summer months, the average wind speed is less intense, with the lowest hourly wind speed of 8.7 mph. All of these wind speeds were taken at 10m above the ground.

During an IPD meeting, structural engineers pointed out design requirements wind turbines would cause to the building's structure. In addition, the design team had concerns about the possible shading impacts it would cause to the PV panels. With that in mind, electrical engineers concluded it would be a waste of energy to pursue the idea further.

6.1.4.4 Duct Turbines

Atune's electrical and mechanical engineers explored the idea of utilizing turbines in ducts as an alternative method to generate energy. This idea was developed by a team at The University of Arizona as a part of a Senior Design Project. It was determined that a minimum velocity of 1,000 FPM was required to generate approximately 5 watts from a test conducted by the students. After consulting with the design team, Atune decided that they did not have enough evidence that this design would work in the project, plus it could have possibly added acoustic problems to spaces where they were to be placed. This was due to both the required air velocity and the fact that this design's success was based on the design of the turbine blade itself.

6.2 Schematic Riser Diagram

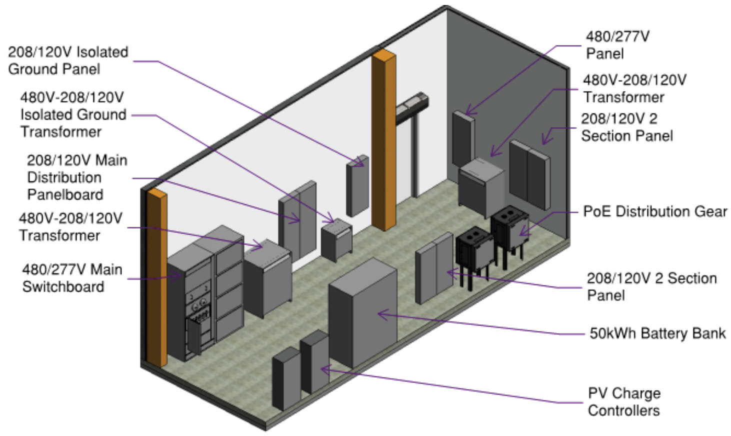
Electrical engineers developed a system design with heavy coordination in IPD meetings to best locate the service entrance, main electrical room and satellite electrical rooms. Following are a detailed description of said items. Refer to sheets E3.1 and E3.2 for the one-line diagram and riser diagram.

6.2.1 Service Entrance

Upon calculating the power needs for the facility, Atune has determined that there will be a 2,000A 480V/3PH service required. This will be supplied by one 750 kVA utility transformer located on a concrete slab outside the main electrical room on the east side of the building. The proximity of the transformer to the main switchgear inside the electrical room allows for minimal feeder length, ensuring a minimal cost for the utility feeder. The electrical team worked closely with the mechanical team to ensure that the borefield piping system doesn't interfere with the underground conduit.

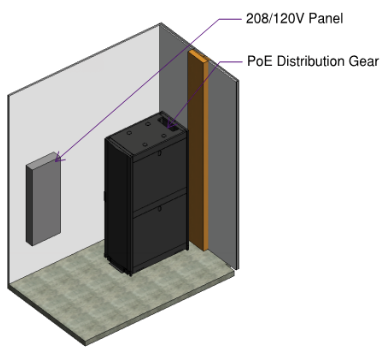
6.2.2 Main Electrical Room

The Main Electrical Room – 152, is located on the first floor at the intersection of gridlines S and 13 and will contain the 2,000A switchboard with an exterior exit on the east side and a south exit opening into Vestibule C-106. Refer to the following figure for a detailed layout of the room and its contained equipment.



6.2.3 Main Distribution

Atune's electrical team has designed the power distribution system to not only sufficiently provide for the building's power demand, but to do so in an efficient matter. The 480V feeders will originate from MSB and deliver power to distribution panelboards and the emergency automatic transforer switches (ATS), as shown on the one-line. In addition, the 480V feeders will serve (2) two transformers which are located in the main electrical room, the largest being 225 kVA serving DPLA. DPLA will serve as the main distribution board for the (7) seven 208/120V panels located in satellite electrical rooms throughout the building. These panels will have nearly all the building's normal 208/120V loads; including receptacles, PoE lighting (refer to section 6.2.5) and other miscellaneous loads. These zones were created using the maximum voltage drop length of 100' radius. Each one of the 208/120V panels will have low voltage power sourcing equipment fed from it for the PoE system. See figure below for typical equipment arrangement in satellite room.



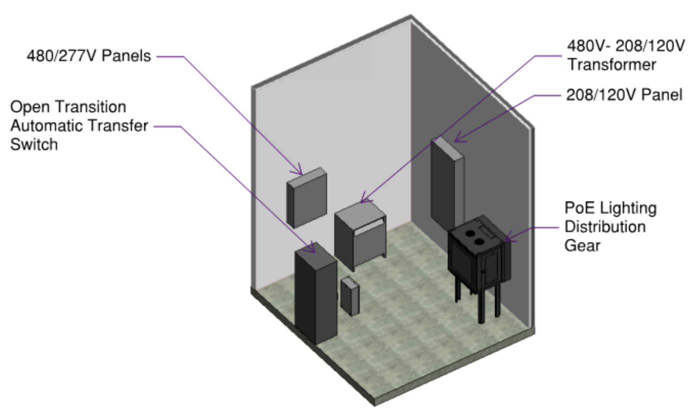
Solar and kinematic energy sources are connected to the power distribution system in the main electrical room. The systems tie together into a central battery bank. The battery bank will be monitored through the Artificial Intelligence automation system and will release stored energy at peak demand to offset the duck curve created by the imbalance of power generation and power demand. Atune worked under the assumption that Hope College is charged commercial utility rates that fluctuate with respect to time and demand.

Through the implementation of this strategy, Atune estimated to save the building $26,000 a year in energy costs. The battery bank is connected to a 98% efficient inverter. The inverter is then connected to a PLC charged controller. The charge controller is connected to a 208V distribution panel to further serve low voltage panels at the seven identified zones in the supporting documents. These local low voltage panels then serve low voltage devices via PoE distribution. Such items include occupancy sensors, plumbing fixtures, luminaires, VoIP phones and the educational AV display. The secondary input to the ATS comes from the switchboard. This configuration was designed for redundancy and versatility of use of renewable power sources.

6.2.4 Emergency Power Distribution

While assessing the needs for emergency power, Atune's electrical team referenced NFPA 101 and the NEC (articles 695 and 700-702). The Jack H. Miller Center for Musical Arts will require emergency power for life safety systems as well as other specified systems that the team decided were crucial during a loss in power for the building. The primary loads to be served during a utility failure will be egress lighting, the fire alarm system, the fire pump and smoke exhaust fans. Although smoke exhaust fans are not typically required for life safety power distribution, Atune's electrical team concluded that these fans, located in large volume spaces, fit the requirement for ventilation needed to maintain life.

These systems have a relatively low demand, which not only led the designers to grouping the systems together (meeting the standards for NEC 700), but also eliminating the need for selective load pickup. This decision will not only save costs for equipment and required infrastructure but will allow for better use of the space within the electrical room. The equipment will be located inside the Emergency Electrical Room 153 and will include an open transfer automatic transfer switch, and both 480/277V and 208/120V panels. As shown in the preliminary calculations table on sheet E3.3, both panels have enough capacity to serve future emergency loads if that is ever desired by the building owner.

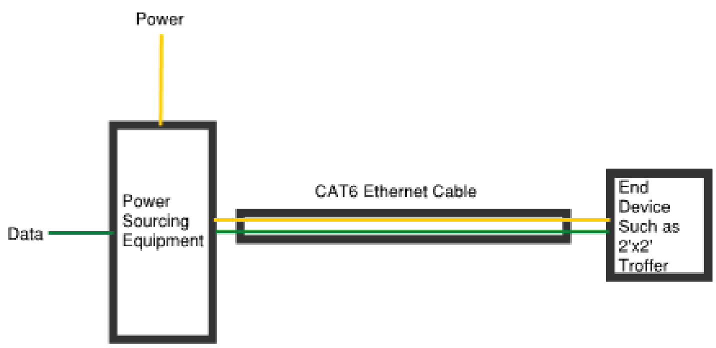


These loads will be served by a 60kW diesel generator. The generator will be located outside the main electrical room on a slab near the utility transformer, with an integral belly tank. The tank will have enough capacity to run the emergency systems for 8 hours. The parking lot that is directly adjacent will serve as the location for the refueling truck. The generator enclosure shall be rated at a dB level allowed by the city of Holland.

Atune's electrical team recommended two feeders from the generator; a dedicated circuit for the fire pump and the other for the other emergency loads. The fire pump's normal feeder will originate from a secondary tap on the utility transformer and the emergency feeder will originate from a dedicated circuit breaker on the generator set. This design will provide minimal failure points for the fire pump in the case that a fire has damaged the equipment within the main electrical or emergency electrical rooms. This is also illustrated on the one-line located on sheet E3.1.

6.2.5 PoE Distribution

The goals behind the Power over Ethernet (PoE) lighting distribution system is to increase efficiency, ease maintenance and accessibility while being versatile for future use of the building. IEEE 802.3at Standards were used to adequately design the system. The system is comprised of multiple PoE power sourcing equipment located at the epicenter of the eight designated power distribution zones. They combine network data and power via an injector and network switches. The PoE switches are interconnected via routers to allow communication among building networks. Additionally, the PoE network switches are specified to come with integral overload protection in case of downstream devices trip. Cat6 cable is then routed to deliver specified voltages to power the end devices such as sensors, controllers and high efficiency LED fixtures. PoE allows the use of non-PoE-connectable lighting fixtures using splitters, thus reducing the cost of excess cabling to connect to the device. A simplified diagram of how PoE is achieved is illustrated below.



The benefits of using PoE for lighting distribution include the ability to add or subtract devices easily from the system with minimal construction impact. PoE requires less wiring and the operating cost are smaller, creating a more efficient system. Overall the system-improves productivity, programmability and interconnectivity due to both network and data being provided together.

7.0 LIGHTING SYSTEMS AND DESIGN

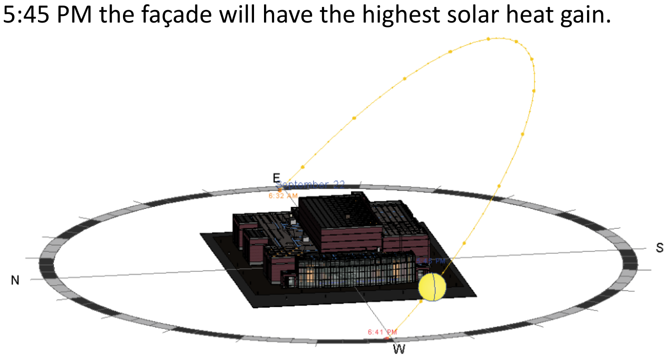
The primary objective of the lighting system design was to harmonize aesthetic appeal, user functionality, energy efficiency and versatility for future use. Atune's lighting scheme was to use all the wooden finishes as a reflective finish to create a warm and inviting feeling in the building. Directional LED recessed cans were primarily used to create dynamic variant illumination levels. Recessed cans were also chosen because they are the most efficient luminaire to use with the PoE distribution system. Following is an example of what a recessed can might look like in the building.

The IES Handbook recommendations were used as guiding principles to design lighting schemes. In addition, mesopic vision factors were used to adjust light output and avoid glare and unnecessary light intensity. This was done because the eye is comprised of both cones (photopic vision) and rods (scotopic vision) working in unison (mesopic vision). Therefore, design solely based on photopic vision results in overtly intense light that creates monotonous uninform lighting. Integration with other systems in the building was another essential focus to the lighting design. Mechanically, the daylighting was designed according to the global location and orientation of the building to reduce solar heat gain. Structurally, luminaires specified coordinate with coves, beams and columns to create dynamic lighted surfaces, ease of maintenance and accessibility. Architecturally, surface finishes were analyzed to specify the adequate light temperature and color to provide the most optimal color rendition. Finally, the PoE distribution system implemented reduces material use, skilled labor costs and construction time. Special focus was directed to the 800-seat-concert hall, 125-seat-performance hall, building atrium and roof amenity space.

7.1 Solar Analysis

Prior to tackling the daylighting and controls for the building, Atune engineers conducted a solar analysis to maximize building façade, minimize solar gain and perfect daylighting controls.

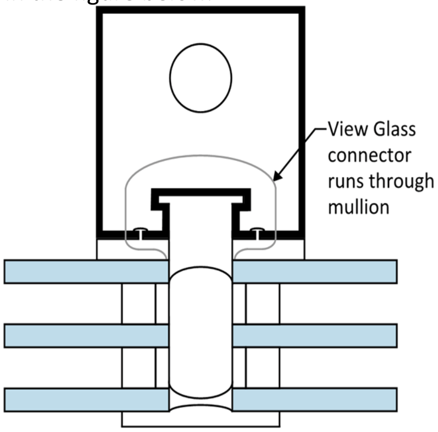
The Jack H. Miller Center for Musical Arts is located at 42.78° North and 86.1° West. Using Revit and Elumtools software, electrical engineers were able to break down precisely the effects of the solar path at this location throughout the year. The sun path at peak solar load is on the South side. However, during sunrise and sunset, the sun is located slightly northern, thus impacting the Western façade. This data was used to develop the optimal daylighting scheme and lighting controls. Below is a figure of the sun path during the fall equinox; at 5:45 PM the façade will have the highest solar heat gain.



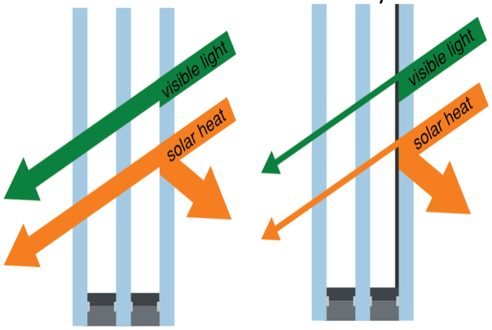
7.2 Daylighting

The primary focus of daylighting design was the Western façade. It accounts for 526,463 BTUh of cooling in the atrium. To address this issue, electrical engineers decided to implement triple pane View

Dynamic Glass on the building façade. This innovative technology uses an electrochromic coating to adapt to the solar rays it receives during the day. It is activated when a small voltage of electricity runs through the coating. Ions move between metal oxides to create the glass tint. Thus, solar loads and glare are rejected, keeping the space at a comfortable temperature. Calculations after implementation resulted in a reduced load of 269,052 BTUh, 51% of the initial calculation. The triple pane glass units also enhance building façade attenuation. As shown in the figure below, the dynamic glass has the ability adjust the amount of light transmission value from 1% to 58% through 4 available tint settings throughout the day. The tint state directly correlates to the visible light and solar heat gain entering the space as seen in the figure below.



The system is powered from a low-voltage (<5 volts) connector that charges electrochromic coating on the interior surface of the outermost pane of glass. In the case of power loss to the system, the failure model consists of returning the glass to its clear state. As a result, the triple pane Insulating Glass Unit (IGU) controls the glare and maximizes the amount of daylight, while minimizing the amount of heat gain. Refer to section 7.4.4 in the Mechanical Narrative for details and calculations pertaining to the annual savings in energy and how this system will work in unison with the hydronic mullions.



In consequence to having a glass curtain wall for the Wester façade of the building, the daylighting zone extends 34 feet into the building. This area covers all the atrium space. All general lighting in the atrium will have daylight responsive controls per 2015 IECC. Atune decided to go a step further and adjust decorative lighting fixtures relative to the daylighting setting of the general lighting. IES recommends lighting levels of 10 foot-candles during the day and 5 foot-candles at night. These illumination levels will be achieved through daylighting during the day and decorative lighting at night.

7.3 Site Lighting

Site lighting is a crucial part of the lighting design for this building as it is on a college campus. Double headed light poles were chosen along this location and to produce .2 foot-candles of light minimum in the sidewalk area. The height of the poles will be 15 feet. Four total poles are located along the atrium to minimize the distraction of the site lighting and emphasize the lighting within the atrium that will be visible through the curtain wall façade. The poles will be arranged to allow for first responder vehicles to have access to the entrance of the building. The building mounted luminaires will be selected to provide illumination horizontally and vertically. They will also highlight the architectural features of the building. Atune will limit the night sky pollution by ensuring that no more than 5 five percent of initial lumens of the fixtures will be produced at an angle of 90 degrees or higher.

The parking lot adjacent to the East side of the building will be lit to the recommended level of 1 foot-candle. The light will be provided via poles located at 45 feet on center with a height of 20 feet. The light source for these will be LED and the fixture will allow for no uplighting above 90°.

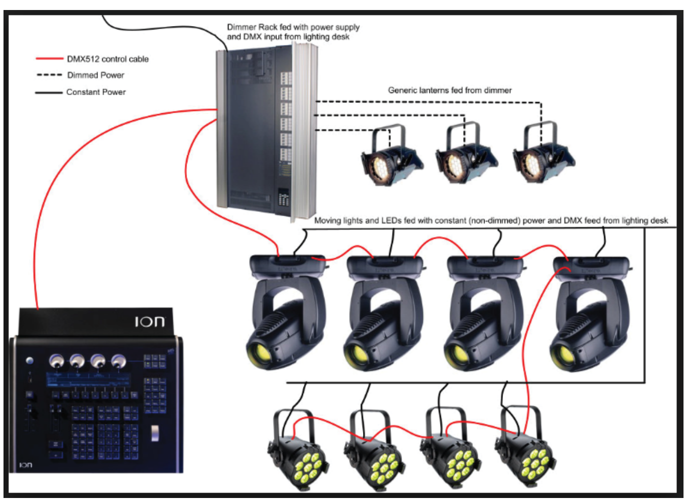
Finally, on the north side of the building, a maximum level of .01 foot-candles will be provided no greater than 15 feet away from the project boundaries. All these illumination levels will be adjusted using a mesopic multiplier of .9 because all the exterior lighting will be specified at 4000 CCT. Atune chose to specify a cooler, more neutral color for the exterior to amplify the warm welcoming lighting on the interior of the Jack H. Miller Center for musical Arts.

7.4 Lighting Controls

Lighting controls were established based on the requirements in the IECC. Occupant sensor controls are used in classroom, lounges, offices, janitor closets and storage rooms. The sensors in these spaces vary between occupancy sensors and vacancy sensors depending on the use of the room. Lights are to turn off automatically after 30 minutes of inactivity, dim to 50 percent of max output upon occupancy and all spaces will have manual override switches to said controls. Rehearsal spaces are to be included in the lighting control scheme. Corridors and other spaces not included in the occupant sensor control category will be time-switched controlled. These spaces will be programmed to Hope College's schedule to determine shutoff days. Following is an example of the the occupant lighting control panel to be used in most rooms.

7.5 Concert Hall

Atune's primary concerns for the concert hall was to make it possible to read notes and not overwhelm the musicians with intensive over stage lighting. In order to achieve this, a versatile design is important. It must be able to satisfy the players, conductor and audience. The first concerns lighting designers addressed were shadows and glare. It was found that more fixtures make it harder to control shadows, thus Atune used minimal fixtures at opposing angles to provide optimal lighting for music. To address glare, lighting designers employed steep lighting angles to avoid spill light into other areas of the concert hall where light is not wanted. Next, front lights are used at lower intensities to create fill lighting. This was done to avoid shadows on faces. In terms of luminaires and lamps, Atune specified focusable fixtures with barndoors such as 1000W Source Four PARs/PARnells. Based on preliminary design, it is estimated 48 lamps will be needed to provide enough versatility for different performances. All the luminaires in the concert hall will be DMX controlled. Refer to the attached sheet E3.9 for a layout of the maps located in the concert hall and other related details. Following is a simplified graphic of the desired lighting control layout for the concert hall.



Ambient lighting is to be provided by 6" recessed can fixtures and recessed wall washing luminaires, dimmable to 0.01 percent of full output. This is to provide 5 foot-candles pre/post show and 0.2 foot-candles during shows. Direct delivery was chosen to create a dark ceiling. Atune made this design choice because the focus would be on the architecture below the ceiling not the components in the ceiling such as the catwalk and lamp riggings. Accent lighting is to be indirect linear led strips and used along the wooden trim of the architectural structure in the auditorium. Using the wood finish as a reflectance with 85 CRI and 3000 CCT will give the space a warm and welcoming look.

Emergency egress lighting will consist of red LED strips along the path of egress to guide occupants to safety.

7.6 Recital, Rehearsal and Practice Rooms

Recital and rehearsal spaces still require the same criteria as the concert hall, just in a smaller scale. Lighting designers at Atune chose to also use fresnels in these spaces in combination with 6" downlight cans and wall wash fixtures. The fresnel luminaires in this space will be adjustable to accommodate different room layouts. These lamps will be hidden by the acoustical ceilings in the spaces. Overall the spaces will reflect the same lighting design as seen on stage to properly rehearse for performances. This lighting scheme also creates a dark ceiling and places the attention on the architectural components of the room.

7.7 Building Atrium

The building's atrium will be the first impression for many who visit the Jack H. Miller Center for Musical Arts. For this reason, the lighting design must invoke a warm and inviting feeling in order to ensure a positive first impression. This will also be the first time the occupants will be exposed to our lighting scheme. Atunes primary focus is to highlight the 2 clocks in the Atrium by using LED cove lights and directional fixtures behind the clocks. Each has a 85 CRI and 3000 CCT. The secondary focus will be the structurally suspended stairs. Atune will highlight the stairs by incorporating Linear LED lights under the steps to create a feeling of ascension as the occupant walks up them. These fixtures will be specified at low wattages and running at 10% output capacity to avoid overtly intense light. Semi-direct pendant fixtures will be placed symmetrically in the high bay of the atrium to tie all the lighting together. The fixtures will highlight the wooden zipper truss structure in the space while providing the necessary ambient light in the space. Finally, recessed cans in the low bay areas of the atrium will be used to add dynamic wall washes on the wooden walls.

7.8 Typical Classrooms and Office Spaces

IES recommends 30 foot-candles of illumination for classrooms and spaces that would require reading such as that found on a sheet a music. Lighting designers decided after research that the best type of lighting in these spaces was uniform lighting. Classrooms, studios and offices are environments of learning; thus, the lighting must keep the occupant alert. For these spaces recessed 2'x2' troffers are used, dimmable to 10% of full output and can be controlled from two switches. One is to be located at the entrance of the room and the other near the anticipated work-space in the room.

8.0 SPECIALTY SYSTEM DESIGN

Atune's electrical team took advantage of the extra low voltage systems (ELV) infrastructure being used for all communication and data systems within the building to connect the specialty systems in the building. These proposed systems will help ensure that the occupants remain safe in emergency situations and that the building is constantly operating at the designed levels of efficiencies.

8.1 Fire Alarm System (FAS)

In accordance with NFPA 72, NFPA 101 and the 2015 IBC; Atune has developed a plan for all the requirements and specifications needed in a fire alarm system for the Jack H. Miller Center for Musical Arts. The design team worked under the assumption that the finalized fire alarm design will be evaluated and approved by a fire alarm consultant. Following are the team's recommendation for said system. Atune deemed it necessary to propose design intentions for establishing a budget and construction schedule.

The FAS is to be UL listed and in accordance with NFPA 72. The system will contain an ELV infrastructure to connect the Fire Alarm Control Unit (FACU). The FACU is to be located on the first floor right outside the Fire Pump Room – 151A. There will also be an Emergency Operations Center to communicate with the AV displays located on the outside of every room to report any security, health or life risks in case of an emergency. Four areas of refuge will be identified that will include a firefighter's emergency telephone. Other incorporated equipment to be included are audible notification devices, manual pull stations, visible notification devices and detection devices. Detection devices include smoke/ heat detectors an multi criteria detectors where deemed necessary.

8.1.1 Directional Sounders

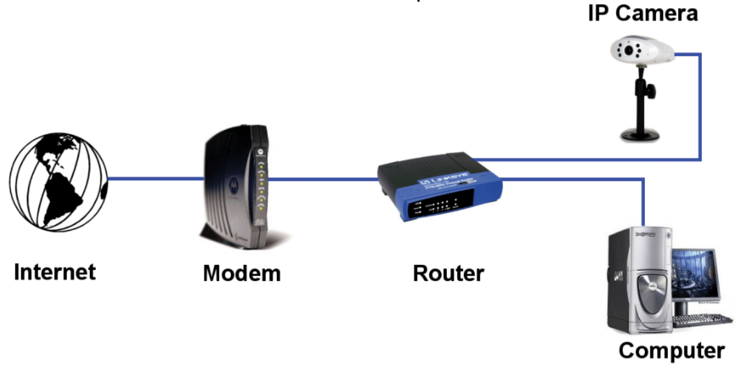
Utilizing 24V power supplies, the electrical team will include the use of the PF24V directional sounders with optional voice messaging as audible notification devices. In the event of a fire, this system will aid in a rapid evacuation of the building's occupants. The directional sounders are used in addition to other standard fire alarm notification items. This system will include four levels of distinguished pulse patterns of broadband noise, that can be placed in a layout in the form of an egress path. The pattern of sound created by the four separate types of directional sounders increases as occupants approach the exits. This system will prove most useful in the scenario where there is a high level of smoke in the building and visibility is extremely low. This technology was incorporated after an IPD meeting where it was decided that the entire structure of the building was to be wood.

8.2 Emergency Notification Systems (ENS) and Security

The Jack H. Miller Center for musical arts is located on a college campus and thus Atune sought out to provide the optimal communications technology to protect the building occupants from natural disasters, active shooters and other unexpected security threats. To address these issues, an integrated approach will be implemented to ensure maximum preparedness for an emergency utilizing the specified equipment explained below.

8.2.1 PoE Cameras

The building will utilize a system of PoE cameras that will be able to track any person entering the building or moving through any of the building's corridors. Atune's electrical team carefully designed the camera system to ensure that both the quality of camera and the layout allow for a seamless recording of the building's most crucial areas. Additionally, because the cameras are IP based there is no need to local recording device required. These cameras will also be used in conjunction with the active shooter detection system to resolve threats quickly and precisely. Upon activation of the active shooter detection system the Watson will analyze video feed and look for a gun. Once the system locates the room, the Watson will notify local law enforcement. The cameras will continue to track the gun through frame-by-frame analysis until it leaves the building. Below is a schematic of the connections to make this possible.



8.2.2 Automatic Locking Doors

Automatic locking doors will be utilized to control movement within the building during an emergency. The doors will all be equipped with automated locking mechanisms that will be activated if there is an imminent threat inside the building. However, these doors will have the ability for manual override on the interior of classrooms and offices.

8.2.3 Active Shooter Detection

To address active shooters in the building Atune decided to implement an active shooter detection system that incorporates two criteria detection. Guardian detection systems use advanced acoustic gunshot detection and infrared gunfire flash detection and send mass notification alerts. Watson BAS will work cohesively with this software and engage the building into an emergency state mode. The system will then work will all other systems to resolve the threat. Including locking doors, providing occupants with real-time progress of the situation and notify law enforcement.

8.2.4 Emergency Blue Light Systems

In order to ensure the safety of people walking about campus in the evenings, the electrical team decided to implement Code Blue Centry help points due to their reliability and ability to be seen from far distances. The help points have an integrated camera with a 125° wide angle lens that work with the emergency signaling to ensure that the camera will be able to capture and record video in the event of an emergency. Picture below is what the help points will look like throughout the site.

These help points require an ethernet connection, that will be fed from within the building. The two proposed locations for these are on the Northeast corner of 10th and Columbia Avenue and just north of 10th street, at the eastern most edge of the property.

8.3 Telecommunications

Atune designed the telecommunications system that closely aligns with the team's goal of creating a flexible network infrastructure that is sustainable for the future and is cohesive with all the disciplines in the building.

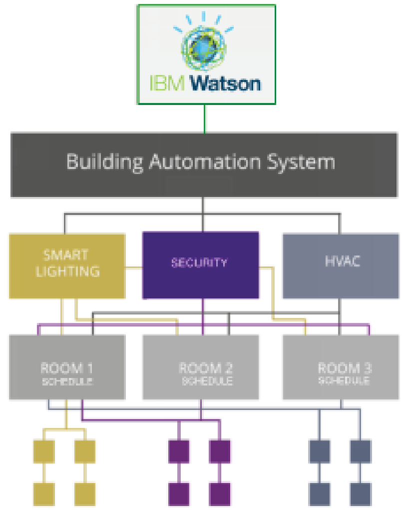
8.3.1 Demarcation Room

The telecommunications system will start at the demarcation point located in Room – 141. Telecomm closets will be located in rooms – 122 and 183. These closets will be fed via a Cat 7 backbone cable. All horizontal cabling will be Cat 6 cable to connect with end devices. All Ethernet cable will be plenum rated and ran through cable trays in plenum spaces along corridors and to end devices. End devices include IP security cameras, VoIP phones and AV educational displays.

8.3.2 Artificial Intelligent Building Automation

In combination with PoE and IoT, the building automation system sets a new outlook on building integration between systems. It incorporates building servers, field controllers, output devices, sensors and direct digital control communications protocols to cohesively find optimal solutions to ever changing climates and use of space. Watson BAS accomplishes its goals through the combination of a large collection of data provided by building sensors and fast iterative processing using intelligent algorithms. The algorithms enable the system to analyze live data and make decisions based on a collection of past data and user set preferences. The public will be educated of the benefits of the implementation for a more sustainable future through the interactive displays to be implemented.

Atune explored the possibility to build an AI system on Hope College.



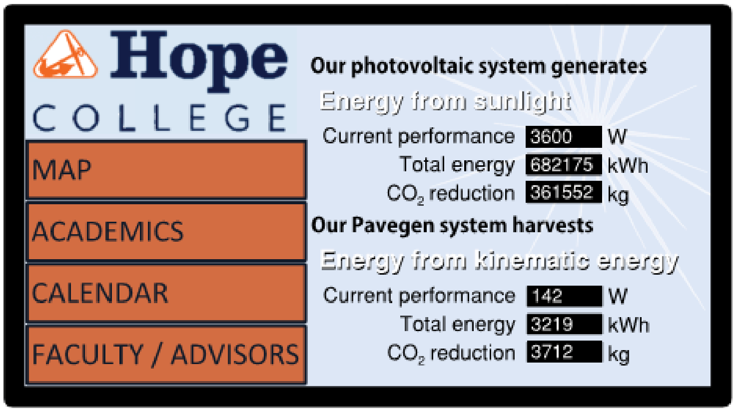
Atune discovered that the system would cost approximately three million dollars. Therefore, the electrical team decided to work in conjunction with IBM. IBM developed Watson, an AI system that already has the infrastructure to accomplish what Atune seeks to build. Atune would continue to work through the design and construction process to customize further the AI that Hope College requires. This system reduces the initial cost of building a system and would only require a monthly payment to IBM for Watson. The monthly rate could range from \$80-\$160 dollars a month. Compared to the benefits that Hope College would reap from this technology is the monthly payment would easily pay for itself through the increased efficiency of its systems.

8.3.3 Voice over Internet Protocol (VoIP) Phones

To continue with Atune's versatility goals, electrical engineers found it possible with all the ELV distribution in the building to use VoIP phones. This increases flexibility and convenience of the staff because with the use of VoIP, phones can be moved from one side of the building to the other while maintaining the same caller ID. This also enables the phone to sync directly to the staff's computer to be accessed remotely if necessary.

8.3.4 Interactive Educational Display

Atune has found within their sustainability research that education to the public will be crucial to the success of the design team's innovative designs. Research suggests that education or the lack thereof is one of the major barriers to solving sustainable problems for the future. Educating the occupants on the building's sustainable efforts will not only inform them of the environmental impact of the building's systems, but it will invoke the interest and support of students. It would also serve as an attraction to private donors of Hope College. This goal will be achieved by placing the interactive educational display in the atrium; an area of the building that has heavy foot travel.



The most foot traffic within the building will occur in the atrium area, corridors and student interaction spaces. For this reason, Atune's electrical team has proposed the use of a 75" interactive display that will include real time data and statistics related to the buildings performance and efficiencies. The design team wanted to ensure that the implementation of the display did not take away from the aesthetic experience in the implemented space, therefore the interactive station will be located in the wall and outlined in a wood enclosure that matches all surrounding finishes.

8.3.5 Room Schedulers

Atune understood the hectic and ever-changing schedules that result from a college campus atmosphere even more so for a college building with 127 anticipated shows and rehearsals to prepare for said shows. Therefore, Atune proposes a design solution to aid in the organization and scheduling of room functions. All rooms will have a 7" digital room scheduler located outside that will display the information relevant to the room's use and serve as an emergency notification device.

The schedulers located outside classrooms and performance areas will include a schedule of classes and performances for that day, and the schedulers located outside faculty studios will present their availability throughout the day. Rooms will be scheduled through the buildings IoT system, thus making them available to be scheduled on phones, tablets and computers connected to the administrative network connection. Additionally, the Watson Building Automation System will use the room occupancy sensors to continuously update the online room schedule. The Watson BAS will compare room schedule to inactivity in the room. If inactivity is detected during the first five minutes of the scheduled time, Watson will cancel the reservation allowing others to reserve the room instantly. Watson will also continuously look at scheduled time and alert any occupant who is trying to reserve a room that conflicts with already existing room schedules. Following is an example of what the room schedulers will look like.

The Watson room scheduling system will also work with the mechanical system to economically temper the space. During a reservation the scheduler will be asked for the number of anticipated occupants. This number will be compared to the time of day of the reservation, location of the room in the building and anticipated building load to decide if it would be economical to pre-temper the room.

9.0 PROJECT BUDGET AND CONSTRUCTABILITY

The Jack H. Miller Center for Musical Arts has a $25 million budget and is located on Hope College. Thus, the constructability of building is essential to minimizing campus automotive and foot traffic. Additionally, the faster the building is erect and occupied the quicker Hope College can begin to profit.

9.1 Electrical Budget Response

Atune reflected on budget after every major innovative element was added to the design. Holding life cycle cost and acquiring cost as an important part of a sustainable design, all of the systems selected were chosen because they proved to be sustainable for the future and profitable for Hope College. In total, the electrical and lighting systems located within the building make up for $5,154,638 of the $25,000,000 budget.

9.2 Electrical Construction Response

The electrical team worked directly with the construction team to help reduce the schedule and labor requirements for lighting. With the reduced time required for power distribution, the decrease in material cost and the reduction of labor rates, construction becomes faster and less labor intensive. Additionally, PoE allows for plug-n-play adaptability, which enables the construction of the ceiling and plenum to go much more smoothly, decreasing the quantity and time required for conduits and conductors.

9.3 Value Engineering and Life-Cycle Cost

The primary concern for the electrical team was the initial design and implementation of a custom Artificial Intelligence Building Automation System. As mentioned previously, the hardware required would exceed three million dollars. After conducting further research, it was apparent that the implementation of this would not only require substantially increased commissioning, but would inevitable require larger amounts of maintenence. As a result, the electrical team concluded that IBM Watson would be able to provide a much more reliable day-to-day operation for a minimal fraction of the cost.

10.0 PROJECT CHALLENGES

The Jack H. Miller Center also desires to have superior acoustical properties, a resilient rooftop amenity space and wood, timber & engineered wood in at least 25 percent of its structure.

10.1 Acoustics

Working closely with the mechanical and structural team, Atune decided to implement adjustable acoustical panels in the concert hall. These panels would replace the curtain systems currently designed by the architect. These panels were chosen to be implemented to enhance quality of sound for the different performances that may take place in the concert hall. They would be controlled from through a password protected 9" AV display that only staff would have access to. The panels adjust to either absorb or reflect sound at different locations in the concert hall. Reverberation is required with adequate spacing for orchestra and instrumental performances. Whereas during graduation ceremonies the sound should be absorbed early to avoid echoing. In order to ensure a seamless installation, Atune would work with sound consultants to set up all of the different scenarios that the concert hall would be utilized for.

10.2 Wood, Timber, and Engineered Wood

Atune's electrical team also approached the wood and timber challenge by using recycled wood in luminaires for reflecting and diffusing point source LED fixtures. Pendant and wall sconces will be located in the concert hall and atrium. The fixtures seamlessly integrated with the buildings wooden structure and gave spaces with said fixtures a warm and glowing feel.

10.3 Roof Top Amenity Space

The roof amenity space was the discussion of many IPD meetings. Atune found it best suitable to be placed on the south side of the building to stack restrooms, elevator wells and stair access easily. Atune also decided to make the exterior walls glass to allow the exterior to transition into the interior. Additionally, the walls are retractable to open the space to the outside for summer events. However, due to the south facing exposure a tinted glass was chosen to reduce solar heat loads and glare from direct sunlight. This heavily impacted the lighting design in the space as our window head height is 8 feet, thus creating a daylighting zone along all the exterior walls. The remainder of the space was designed in a layered fashion with multiple settings for different events. This was accomplished through recessed-can-downlights circuited alternately to three different circuits. All lights specified have the capability to dim to .1% output. The different lighting settings can be achieved via a 9" AV display located near the entrance of the room. The intent was to be able mimic a starry night in the space and create a seamless transition from the exterior to the interior of the building.

11.0 LESSONS LEARNED

Atune learned a great deal through Integrated Project Delivery method. The electrical team's take away from the process dealt with learning many things about the other disciplines. It also made design and construction challenges more approachable and feasible.

12.0 CONCLUSION

Atune's electrical team strived to create a design that exceeded the team's overall goals of Versatility, Sustainability and Harmony.

12.1 Versatility

The electrical team strived to provide the necessary infrastructure that will allow the building to evolve and adapt as the building's functionality does so. In doing so, the electrical team has introduced the PoE distribution system and Watson AI service that will serve as the backbone for the building's versatility.

12.2 Sustainability

The Jack H. Miller Center for Musical Arts provided the electrical team with a blank canvas of opportunities to incorporate sustainable elements into the design. The team introduced multiple methods for generating green energy, including the PV system and the Pavegen installations. Through the use of these green energy sources, and the reduced lighting power, Atune's electrical team strives to save nearly 500,000 kWh a year, equating to approximately $50,000 a year in utility costs.

12.2 Harmony

Atune collaborated throughout the ongoing IPD process to create a well-rounded building design. In order for all of the systems to work cohesively, the infrastructure must be designed to handle the varying tasks. The electrical team worked hard to ensure that this is not only true, but that the building will be constantly improving its efficiency.

In addition, Atune strived to educate the public about the innovative and efficient systems within the building. These main sources, combined with the other discipline's goal sustainable design will be displayed on the 75" educational display located within the Atrium. The statistics will be summarized utilizing different metrics, ensuring that Atune's design leaves a lasting impact on Hope College for years to come.

DECISION MATRIX & SYSTEM SELECTIONS

ELECTRICAL DECISION MATRIX

Atune began the design process by selecting three design drivers: harmony, sustainability, and versatility. The team created a decision matrix to ensure that the design drivers were considered in every design decision made. The decision matrix below was used to select the best electrical system for every aspect of the Jack H. Miller Center for Musical Arts.

ELECTRICAL DECISION MATRIX

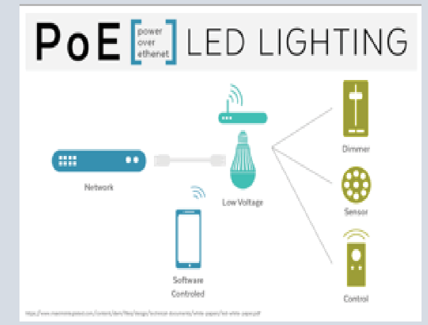
	VERSATILITY				SUSTAINABLILITY				HARMONY				
	FLEXIBILITY IN USE	ROOM FOR GROWTH	ACOUSTICALLY ADAPTABILITY	AESTHETIC EFFECTIVENESS	LONG LIFESPAN	MAINTNANCE COST	ENVIRONMENTAL IMPACT	EDUCATION TO PUBLIC	MULTIPURPOSE DESIGN	SCHEDULE	BUILDING FACADE	CONSTRUCTABILITY	
POWER DELIVERY													
WEIGHT	4	2	5	3	5	3	4	4	3	4	1	5	
GRID - STANDARD	8	6	5	3	20	15	4	4	3	12	3	20	103
GRID + PHOTOVOLTAIC	12	8	5	3	15	6	20	16	6	8	2	15	116
GRID + WIND POWER	8	2	5	3	20	9	8	12	3	12	1	15	98
EMERGENCY POWER													
WEIGHT	4	2	5	3	5	3	4	4	3	4	1	5	
GENERATOR SET	12	6	5	3	20	12	4	4	3	16	1	25	111
GENERATOR SET WITH BATTERY STORAGE	16	8	10	6	20	6	12	12	15	8	1	15	129
BATTERY BANK	12	6	25	9	10	9	8	8	3	8	2	10	110
LIGHTING													
WEIGHT	4	2	5	3	5	3	4	4	3	4	1	5	
120V	12	4	0	9	15	9	8	4	3	12	0	15	91
277V	16	4	0	9	20	9	8	4	6	12	0	15	103
LOW VOLTAGE	20	8	0	12	20	9	16	16	15	20	0	20	156
BUILDING MANAGEMENT													
WEIGHT	4	2	5	3	5	3	4	4	3	4	1	5	
MANUAL	12	4	0	12	20	9	4	4	3	16	0	20	104
BAS	16	6	0	9	20	9	12	12	9	12	0	15	120
AIBAS	20	10	0	6	20	12	20	20	12	8	0	10	138

SYSTEM SELECTION

POWER DISTRIBUTION SYSTEM

480/277V system reduces equipment sizes and costs. PoE distribution reduces labor and material costs.

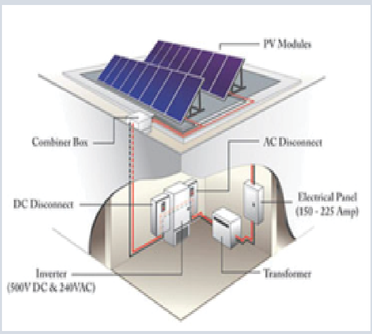
PoE LIGHTING DISTRIBUTION



RENEWABLE ENERGY SYSTEM

Solar energy produces renewable energy and provides Hope college with a sustainable energy source.

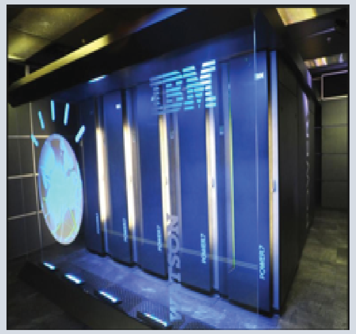
PHOTOVOLTAIC PANELS



SPECIALTY SYSTEM SELECTION

IBM Watson integrates all the systems together to create an efficient and flexable building.

ARTIFICIAL INTELLIGENT BUILDING AUTOMATION

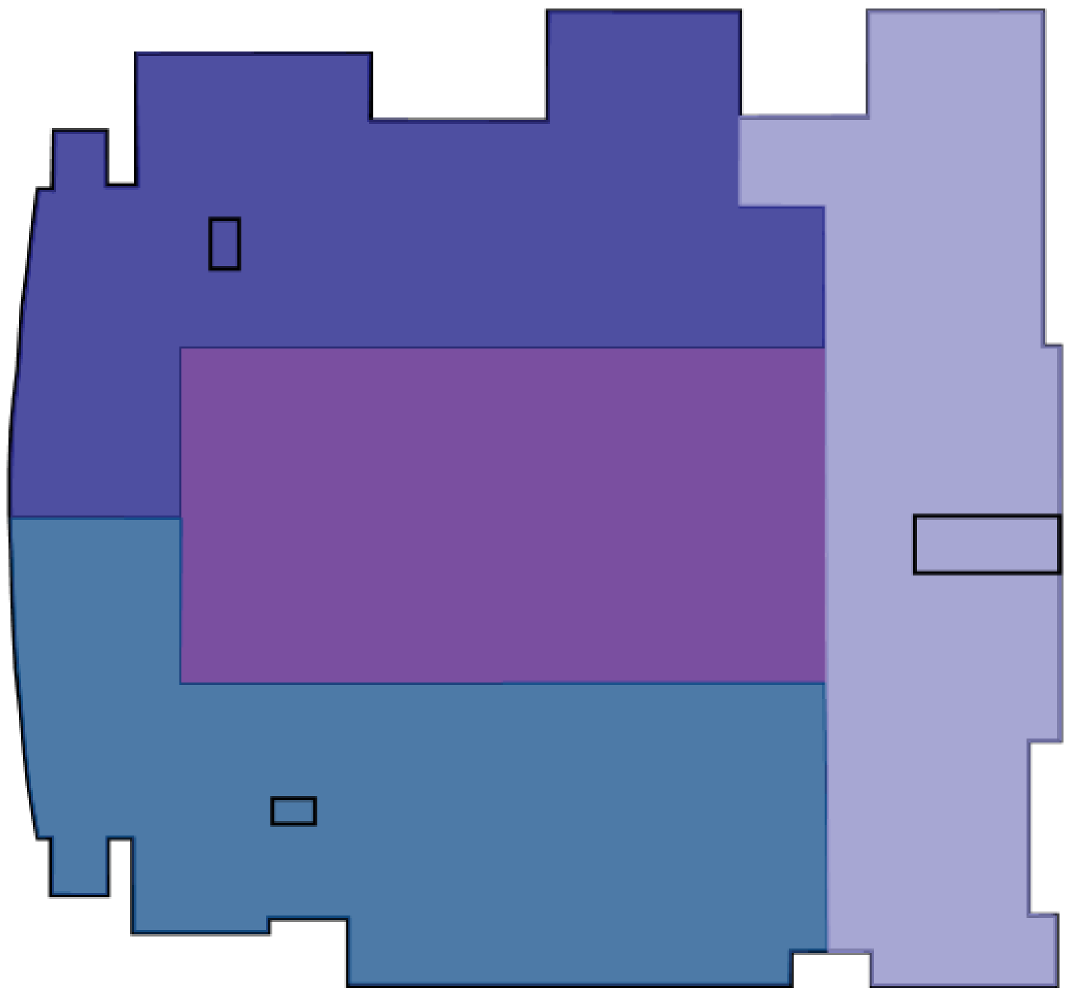


SECURITY SYSTEM

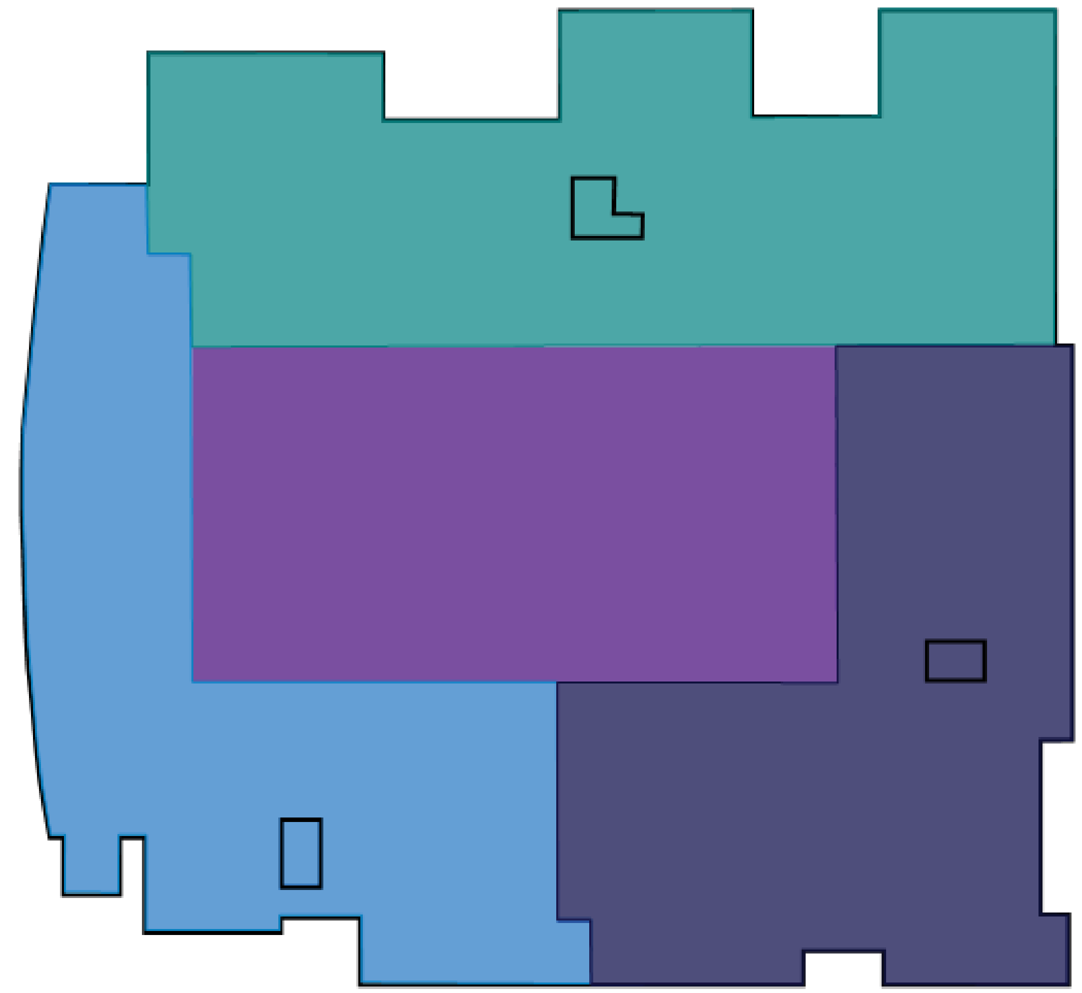
Guardian provides dual criteria detection to pin point active shooters and alert the local authorities.

GUARDIAN SHOOTER DETECTION

POWER DISTRIBUTION ZONING



FIRST FLOOR POWER DISTRIBUTION



SECOND FLOOR POWER DISTRIBUTION

THIRD FLOOR POWER DISTRIBUTION

ZONING KEY

- 1L1
- 1L2
- 1L3
- 1L4
- 2L1
- 2L2
- 2L3
- 3L1

DESIGN OF ELECTRICAL ZONES

Atune looked closely at the physical attributes of the building while taking into consideration the power distribution. One key factor in design was the location of the Satellite electrical rooms.

These satellite electrical rooms not only contain the normal power distribution equipment, but also all of the servers required to operate the PoE lighting systems. Having these servers close to the load will reduce the amount of CAT6e cabling for the project.

Electrical rooms 220B and 220C were added on the second floor to increase the proximity of the loads from the distribution equipment. These additional rooms increase the flexibility for potential increases in power in the future.

LIGHTING DESIGN

ILLUMINATION LEVEL TARGETS

Space Type	Space Classification	Recomeded Illumination Level	Planned CCT of Luminaires	Mesopic Multiplier	Design Illumination Level	Lighting Dynamic
		Footcandles	No.	No.	Footcandles	
Atrium	Common Applications, Transition Spaces, Building Entries, Day, Night	10, 5	3000	0.95	9.5, 4.75	Nonuniform
Concert Hall House - Pre/ Post	Education, Performance, House	7.5	3000	0.95	7.125	Nonuniform
Concert Hall House - During	Education, Performance, House	0.02	3000	0.95	0.019	Nonuniform
Concert Hall Stage	Education, Performance, Stage, Music	30	3000	0.95	28.5	Nonuniform
Rehearsal	Education, Performance, Stage, Music	30	3000	0.95	28.5	Nonuniform
Practice	Education, Classroom, Music Room	30	3000	0.95	28.5	Nonuniform
Faculty Studios	Education, Classroom, Music Room	30	3000	0.95	28.5	Uniform
Classrooms	Education, Classroom, Music Rooms	30	4000	0.9	27	Uniform
Corridors/ Study Spaces	Education, Transition Spaces, Break-out Study Passageways	20	3000	0.95	19	Uniform
Corridors	Education, Transition Spaces, Independent Passageways	5	3000	0.95	4.75	Nonuniform
Restrooms	Common Applications, Toilets/ Locker Rooms, General	5	4000	0.9	4.5	Uniform
Equipment Rooms	Common Aplications, Support Spaces, Equipment Rooms	20	4000	0.9	18	Uniform
Janitor and Maintenance Rooms	Education, Support Spaces, Janitor's Closet	10	4000	0.9	9	Uniform
Stairs	Education, transition Spaces, Stairs, High Activity	10	3000	0.95	9.5	Nonuniform
Site	Exterior, Facades, Medium Activity, LZ2	2.5	4000	0.9	2.25	Nonuniform

LIGHTING CONTROL SCHEDULE

Space Type	Occupancy Sensor	Vacancy Sensor	Manual Control	Time-of-Day Control	Daylight Controls	Plug Load Control
Atrium		X			X	
Concert Hall House		X	X			
Rehearsal		X	X			
Practice		X	X		X	X
Faculty Studios	X		X		X	X
Classrooms	X		X			X
Corridors/ Study Spaces	X		X			X
Corridors	X		X	X		X
Restrooms	X		X			X
Equipment Rooms	X		X			
Janitor and Maintenance Rooms	X		X			
Stairs		X	X	X	X	
Site				X		

NOTES:

1) Occupant Sensors shall automatically turn off lights within 30 minutes of all occupants leaving the space.
2) Upon lighting turn-on lights shall power to no more than 50% power.
3) Time-of-Day shall have 7-day clock with 7 different settings for each day of the week, automatic holiday shutoff and a 10 hour program backup.
4) All exterior lighting to have photosensor and reduce lighting to 50 % from 12 a.m. to 6 a.m.

LUMINAIRE SCHEDULE

Key	Lumens	CCT	CRI	Description	Mounting	Distribution	Voltage	Dimming	Notes
A	796	3000	85	2' 6" LED Step Strip	Surface	Direct	LV	0-10V	
B	610	2700	85	4" Trimless Downlight	Recessed	Direct	LV	0-10V	
C	610	2700	85	4" Trimless Wall Wash 60 degrees	Recessed	Direct	LV	0-10V	
D	610	2700	85	4" Trimless Wall Wash 30 degrees	Recessed	Direct	LV	0-10V	
E	610	3000	85	4" Trimless Wall Wash 30 degrees	Recessed	Direct	LV	0-10V	
F	1107	3000	85	24" Pendant	Pendant	Direct	LV	0-10V	
G	993	3000	85	4' 0" Linear LED	Recessed	Direct	LV	0-10V	
H	2900	3000	85	18" Recessed Downlight	Recessed	Direct	LV	0-10V	
X1	-	-	85	Exit Sign - No Arrows	Surface	-	LV	-	
X2	-	-	85	Exit Sign - 1 Sided w/LR Arrows	Surface	-	LV	-	
X3	-	-	85	Exit Sign - 1 Sided w/R Arrow	Surface	-	LV	-	
X4	-	-	85	Exit Sign - 2 Sided w/LR Arrows	Surface	-	LV	-	
X5	-	-	85	Exit Sign - 2 Sided w/R Arrows	Surface	-	LV	-	
N	1898	3000	85	6" Downlight	Pendant		LV	0-10V	
O	1407	3000	85	Linear LED	Cove	Indirect	LV	0-10V	
P	2382	4000	85	Wall Pack	Surface	Indirect	277	0-10V	
Q	127	4000	85	30" Bollard	Floor	Indirect	277	0-10V	
R	378	3000	85	Exterior Wall Step Light	Recessed	Indirect	277	0-10V	
S	993	3000	85	4' Linear LED	Pendant	Indirect	LV	0-10V	
T	3700	4000	85	4' Linear LED	Recessed	Indirect	LV	0-10V	
U	TBD	3000	85	Theater Spot	Pendant	Indirect	120	0-10V	
V	TBD	3000	85	Theater Spot	Pendant	Indirect	120	0-10V	
W	1600	4000	85	Sconce	Surface	Semi-direct	277	0-10V	
Y	1600	4000	85	Sconce	Surface	Semi-direct	277	0-10V	
Z	610	3000	85	Accent 6" Can	Pendant	Direct	LV	0-10V	

LIGHTING DESIGN PROCESS

Atune lighting designers began the process of quality design by analyzing the spaces in the Jack H. Miller Center for Musical Arts. The use of the spaces were taken into account and divided into categories described in the Illumminating Engineering Society Handbook.

The **ILLUMINATION LEVEL TARGET** table lists the all the different space types along with the IES recommended illumination level. The illumination was then compared to the correlated color temperature to be used in the space. The LUMINAIRE SCHEDULE illumination level was then adjusted using mesopic multipliers to avoid overtly intense light.

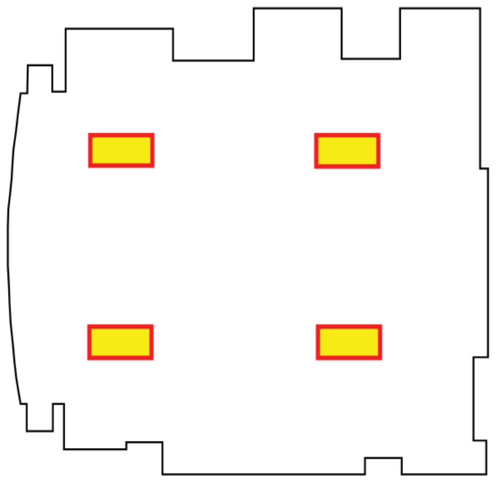
The **LUMINAIRE SCHEDULE** lists the current selection of types of luminares to be used in the project. Lighting designers focused on the descriptive nature of the luminaires to help the owner and architect best see the lighting design proposed. Samples of the chosen luminaires can be found in Reflected Ceiling Plans and renderings that are located on the lighting sheets below.

The **LIGHTING CONTROL SCHEDULE** provides the outlook of lighting controls to be used in conjunction with the building's IoT and Watson BAS. Atune engineers decided to reduce energy consumption by also controling plug loads in designated areas.

RENEWABLE ENERGY EXPLORATIONS

PAVEGEN

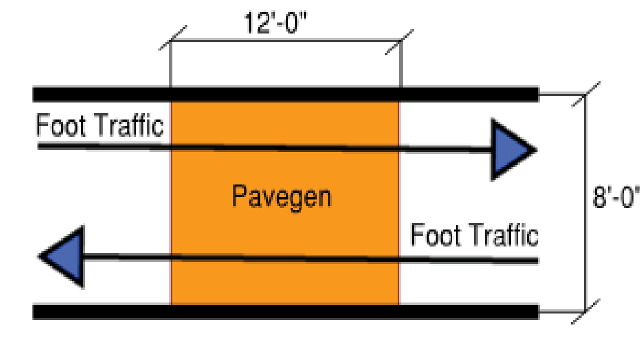
Atune chose to implement kinematic energy harvesting to educate the public of all the sustainable energy sources that can be used on a college campus. Below are Atune's findings and allocation of Pavegen sections.



	Steps (No.)	Items Powered (No.)	Power of Item (W)	Run Time (sec)	Energy Generated (Wh/step)
Study 1*	1	1	30	30	0.25
Study 2**	250000	10000	5.45	3600	0.218
				Average	**0.234**

*Based on 1-step powering a LED Street Lamp for 30 seconds. Electrical estimated the wattage of the lamp at 30W.
**Based on 250,000 steps charging 10,000 phones. Electrical estimated average energy needed at 5.45Wh based on the iPhone.

Elham Maghsoudi Nia *et al* 2017 *IOP Conf. Ser.: Mater. Sci. Eng.* **291** 012026



Corridor Installation

	Max Building Occupant Load 1st Floor (No. People)	Occupant Diversity Factor	No. Occupant Changes	Length of Pavegen Sections (ft)	No. Sections	Section Diversity Factor	Steps Taken in Section (No.)	Energy Generated (Wh/step)	Total Power Generated (kWh/day)	Power Generated Annually (kWh)	Utility Rate ($/kWh)	Annual Savings ($)	Total Area (SF)	Price ($/SF)	Initial Cost ($)	Payback Period (Years)
Average Day	1612	0.5	8	12	4	0.5	6	0.234	18.105984	3138.3706	0.1116	350.24	384.00	100.00	38,400.00	109.6384

Assumptions:
1 The school is in session for 8 of 12 months.
2 School is 5 days a week.
3 The people walking through will step on at least 2 sections.
4 Every person wilL take 6 steps to cross the section, based on US average height of 5'-9".

No
575847.81 Cellphones
9.69 Laptops
29.06 30W Lights for 1 Hour

ACOUSTICAL ENERGY HARVESTERS

Atune researched the posibility of using the acoustical energy harvesters to harvest the ascoustical energy being produced in the Jack H. Miller Center for Musical Arts. Listed below is the dB pressure created by the different list of instruments to be played in the building and the analysis of Atune's findings.

Instrument	dB Rating at Loudest
Trombone	99.5
Flute	98
Cello	97
Clarinet	97.5
Piano (normal)	65
Piano (fortissimo)	93.5
Oboe	92
Organ	95
Average	**92.1875**

AEH Power Production (mW/ device)	No. Devices	Total Power Generated (Wh/day)	Power Generated Annually (kWh)	Utility Rate ($/kWh)	Annual Savings ($)	Price ($/device)	Initial Cost ($)	Payback Period (Years)
1.5	28	16.2	2.808	0.1116	0.313373	500	$14,000.00	44675.22

Assumptions:
1 The school is in session for 8 of 12 months.
2 School is 5 days a week.
3 Rooms with AEHs will be exposed to 3 hours a day of ideal conditions for power generation.

Farid Ullah Khan and Izhar 2015 *J. Micromech. Microeng.* **25** 023001

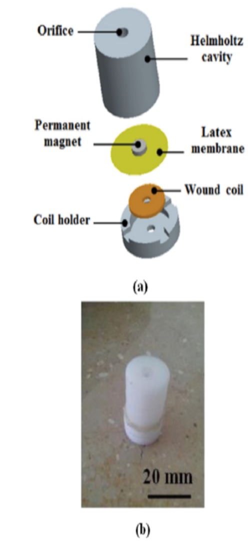
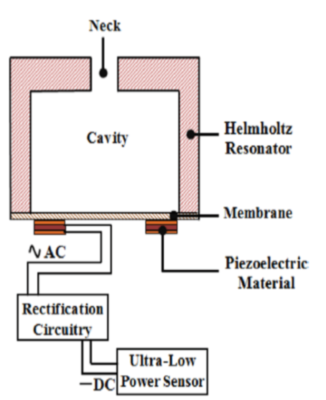


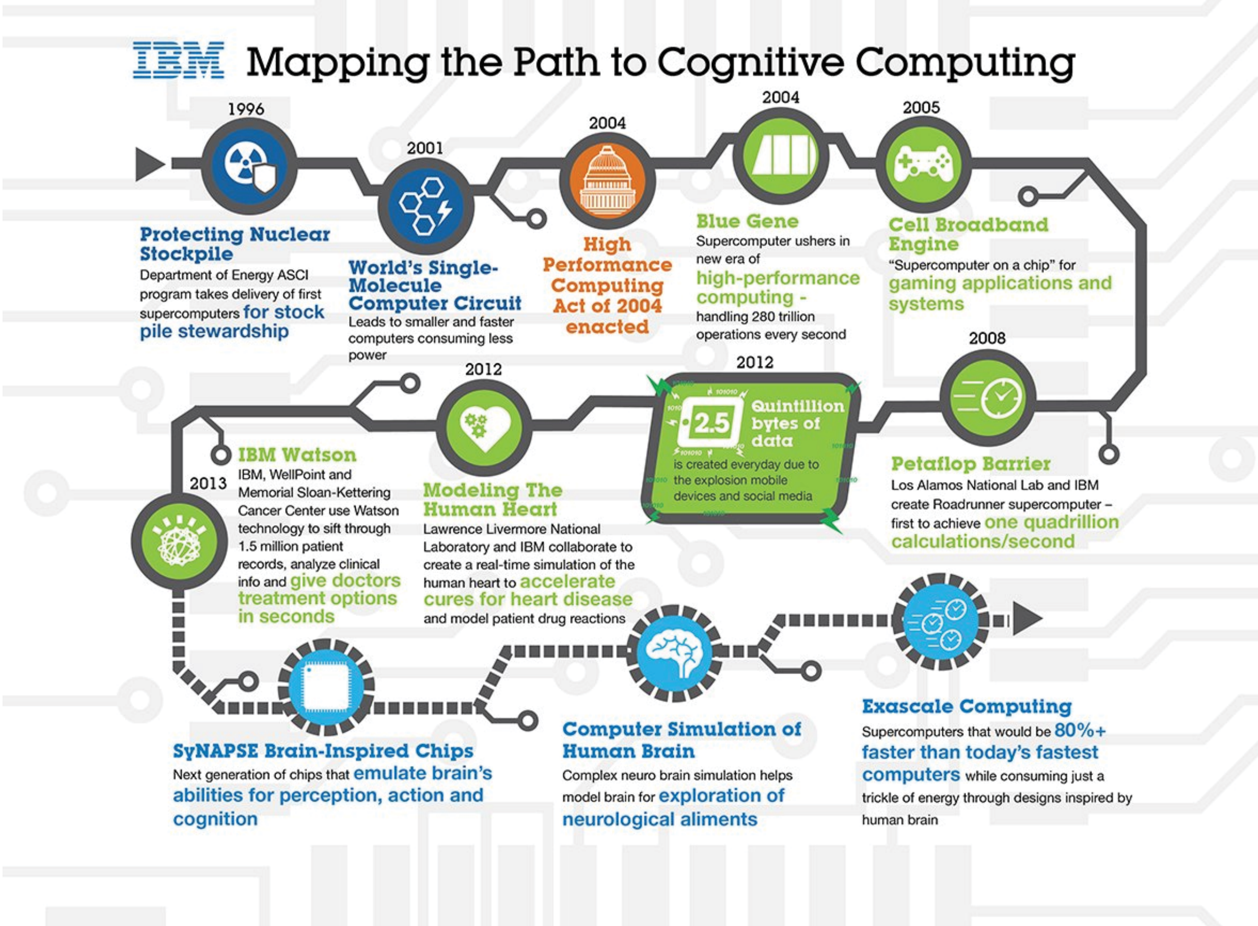
Figure 12. Electromagnetic AEH: (*a*) exploded view; (*b*) assembled harvester. Reproduced with permission from [51].

Figure 2. Cross-sectional view of the quarter-wavelength resonator. Reproduced from [31]. Copyright © 2012 Elsevier Masson SAS. All rights reserved.



WATSON & BUILDING AUTOMATION

WATSON



PREDICTIVE ENERGY OPTIMIZATION

Buildings optimize energy through analyzing energy consumption data after the energy has been used. After a change in the system is implemented, the data is re-analyzed to figure out if energy use was actually reduced. With AI and Watson, these solutions are constantly analyzed and optimized. The system can also analyze other data such as weather, where it can act proactively to help boost efficiency.

PREVENTIVE MAINTENANCE & FAULT DETECTION

Artificial intelligence (AI) and machine learning (ML) excel at learning the relationships between inputs and outputs using only data. Thus, the system can identify anomalies and inconsistencies. Finally, it can develop a diagnosis. However, this reaches the limits of AI and ML, human intuition and expertise is needed to fix the problem.

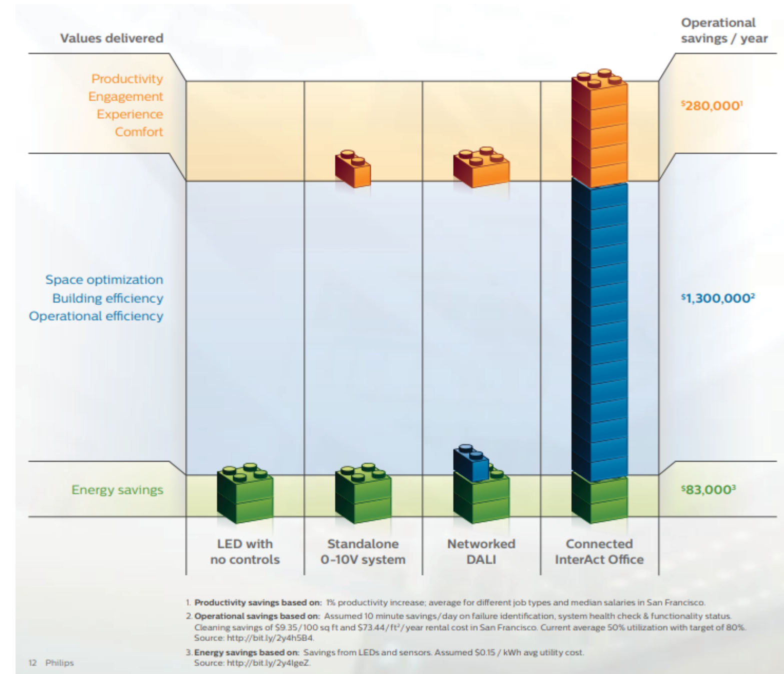
IMPROVE TENANT COMFORT

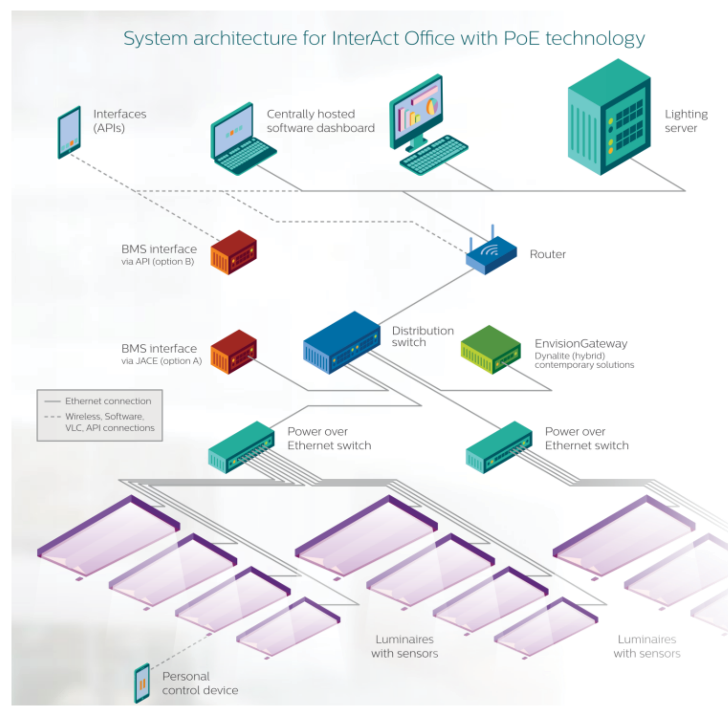
Improved efficiency and preventive maintenance inherently improve occupant comfort. Additionally, due to the functionality and ability to sort through a large volumes of data, improvements in occupant comfort can be achieved. This occurs through the collection of occupant feedback and correlating equipment set points.

POE LIGHTING INFRASTRUCTURE

Phillips PoE Lighting System

While designing the PoE lighting distribution, Atune decided the Phillips PoE Lighting System would best serve as the most reliable system infrastucture for the Jack H. Miller Center for Musical Arts. Although InterAct is primarily geared toward offices, the Faculty Studios and Practice Studios would serve as a great application to improve building efficiency.





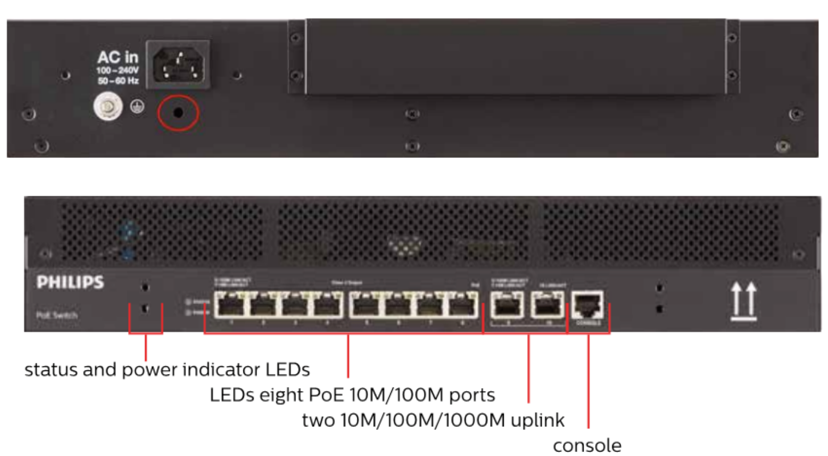
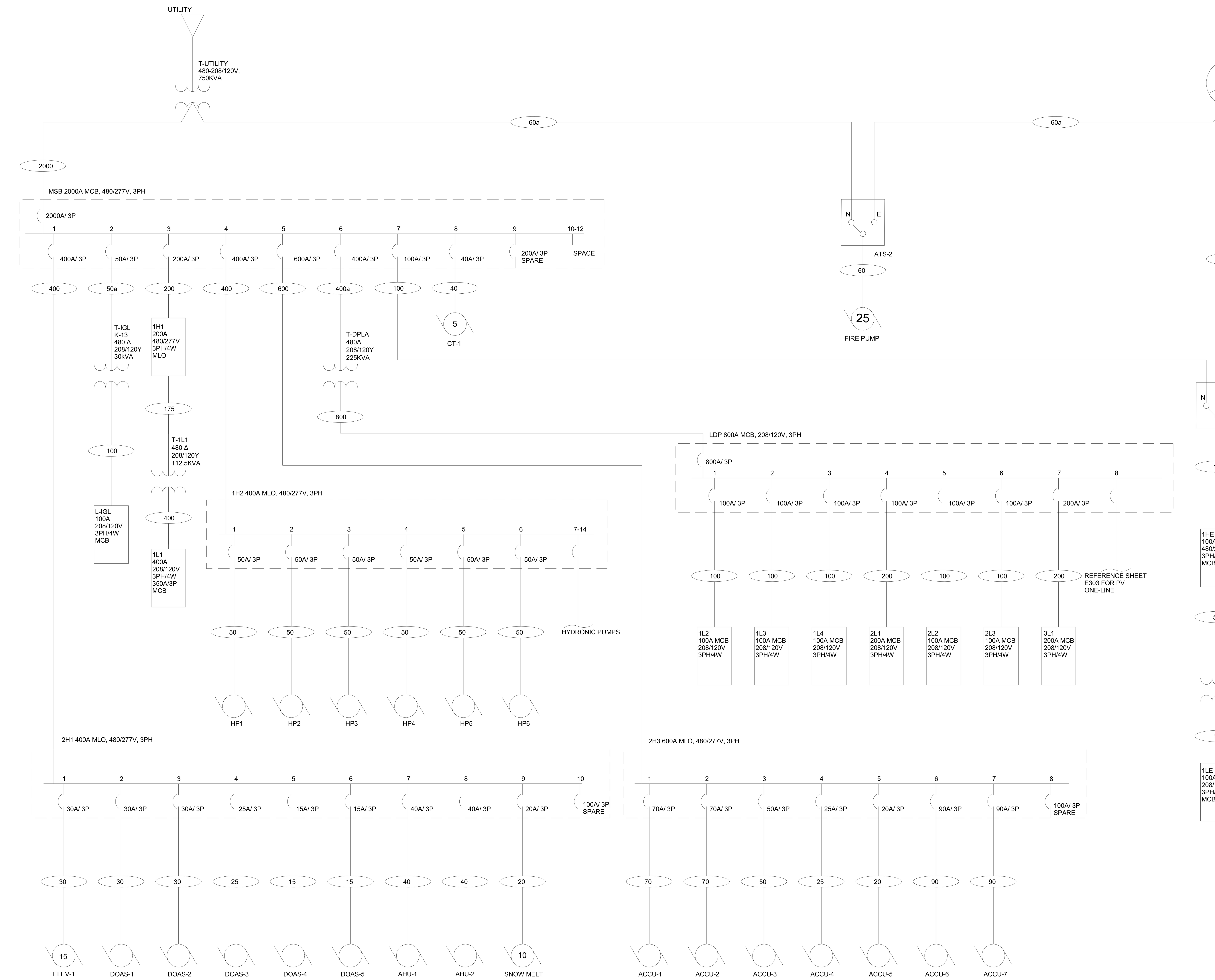
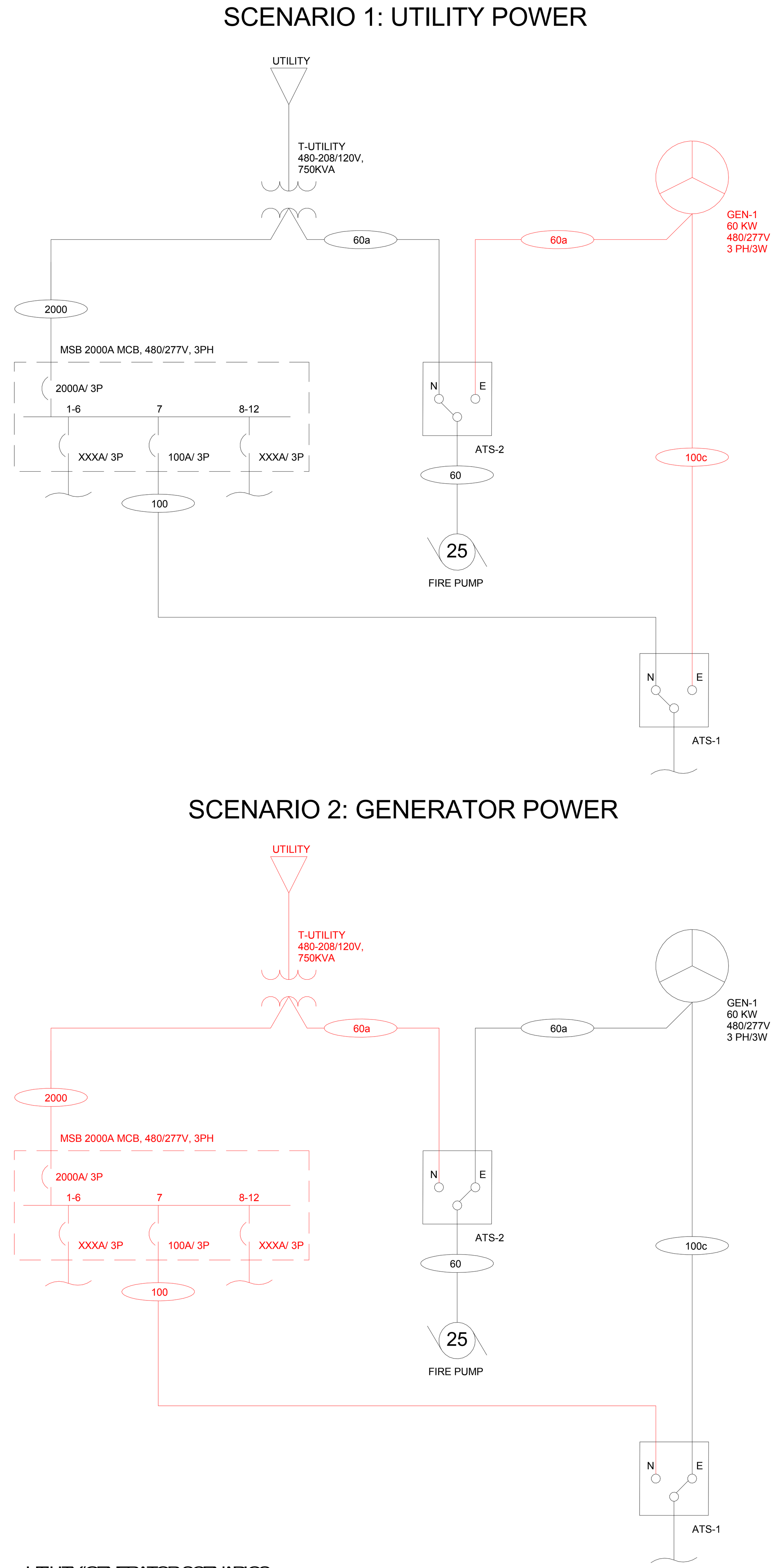


Figure 1 Front panel PoE switch



1 ONE-LINE
NTS



2 UTILITY/GENERATOR SCENARIOS
NTS

FEEDER SCHEDULE		
KEY	DESCRIPTION	NOTES
15	4 #12, #12G, 3/4"EMT	
20	5 #12, #12G, 3/4"EMT	
25	4 #10, 10#, 3/4" EMT	
40	4 #8, #10, 3/4" EMT	
50a	3#6, #10G, 3/4" EMT	
50	4 #6, #10G, 3/4" EMT	
60a	3 #3, #8G, 1 1/4" PVC	
60	3 #3, #8G, 1 1/4" EMT	
70	4 #4, #8G, 1 1/4" EMT	
90	4 #2, #8G, 1 1/4" EMT	
100a	5 #1, #6G, 2" EMT	
100b	4 #1, #8, 1 1/2" EMT	
100c	4 #1, 1 1/2" PVC	
100	4#1, #8, 1 1/2" EMT	
175	3 #2/0, #6G, 2" EMT	
200	3 #3/0, #6G, 2" EMT	
400a	4 #600, #1/0G, 3 1/2" EMT	
400	4 #600, #3G, 3 1/2" EMT	
600	(2 SETS) OF 4 #250, #1G, 3" EMT	
800	(2 SETS OF) 4 #600, #3/0G, 3 1/2" EMT	
2000	(5 SETS OF) 3#600, 3" PVC	

3 FEEDER SCHEDULE
NTS

GENERATOR SIZING CALCULATIONS					
LOAD	kVA		BELLY TANK MINIMUM CAPACITY		
EGRESS LIGHTING	2.1		DESIRED RUN TIME AT FULL LOAD:	8	HOURS
FIRE ALARM	2.2		CONSUMPTION AT FULL LOAD:	4.9	GAL/HR
FIRE PUMP	25.0		REQUIRED CAPACITY:	39.2	GAL
SMOKE EVAC FANS	21.2		SELECTED CAPACITY:	79	GAL
SPARE (25%)	12.6				
TOTAL:	63.1				
CONVERSION TO kW:	50.5	1	SIZED FOR POTENTIAL FUTURE LOAD INCREASE OF 25%		
SIZE SELECTED (kW):	**60**	2	0.8 POWER FACTOR FOR GENERATOR SIZING		

5 GENERATOR SIZING
NTS

UTILITY TRANSFORMER SIZING CALCULATIONS	
MAIN SWITCHGEAR SIZE	2000A
kVA	1,663
DIVERSITY	50%
SUBTOTAL	831.4 kVA
SELECTED SIZE	750kVA

NOTES:

1 SIZING BASED OFF OF NATIONAL STATISTICS AND UTILITY STANDARDS

2 SELECTED AS NEXT NOMINAL SIZE BELOW SUBTOTAL

4 TRANSFORMER SIZING
NTS

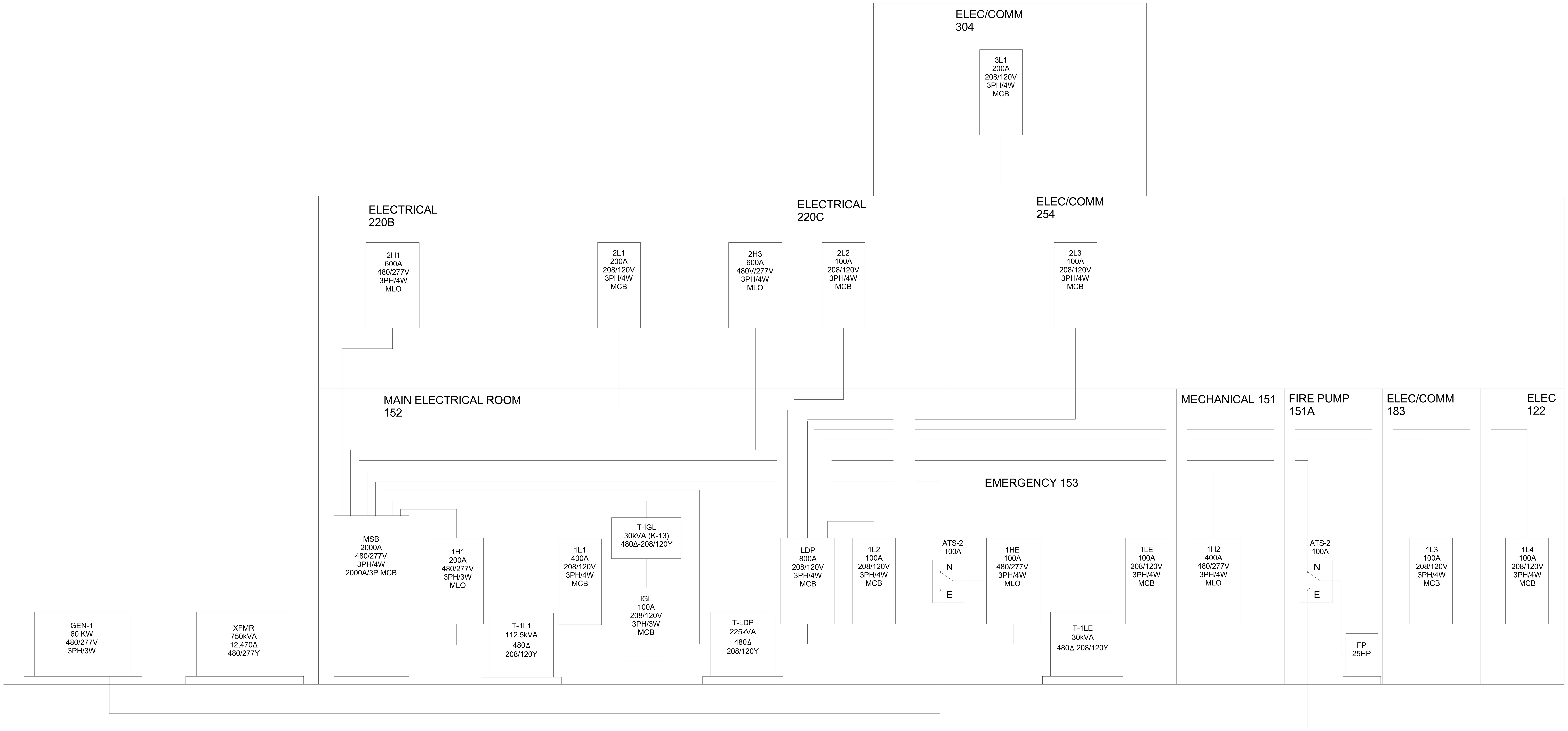
ATUNE

Jack H. Miller Center for Musical Arts

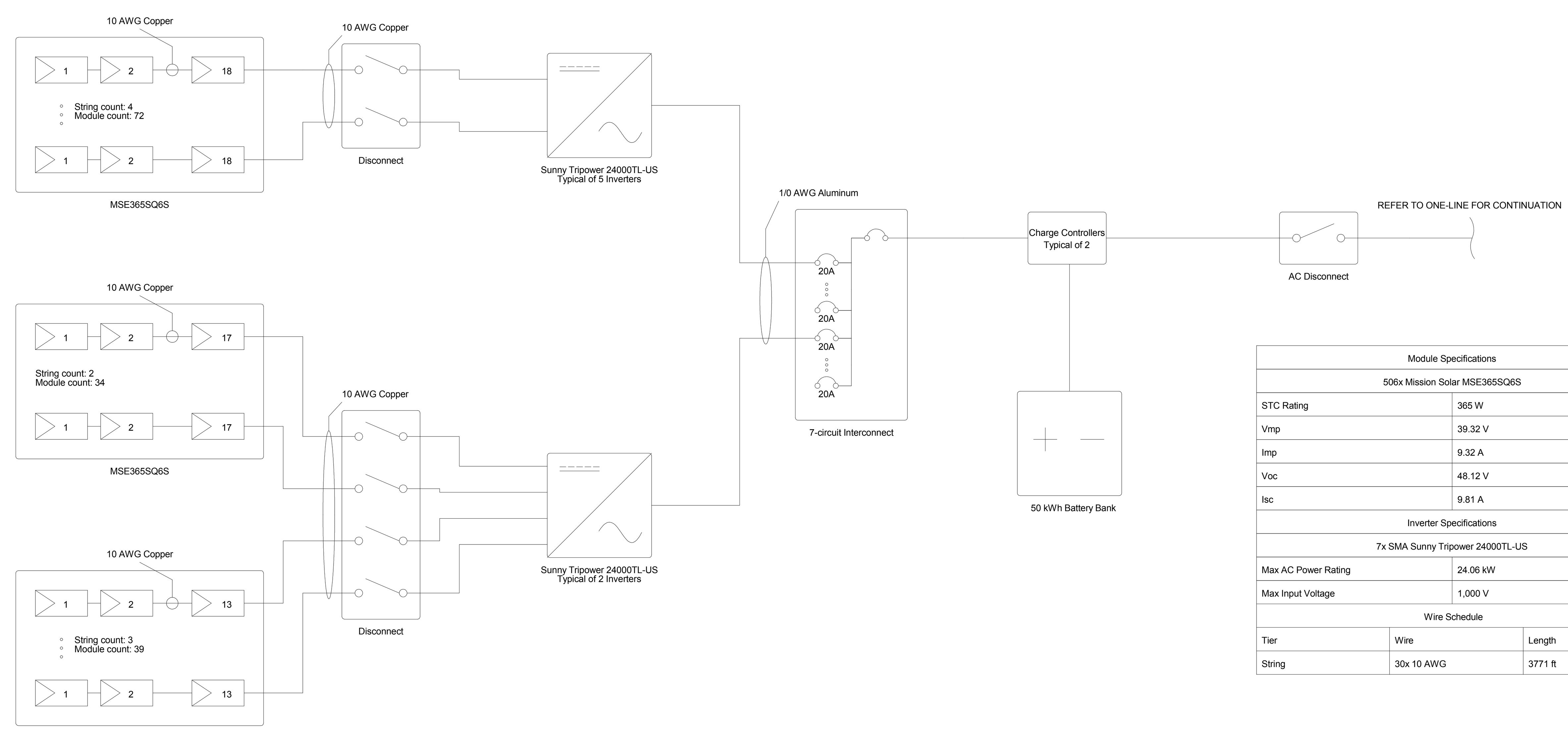
ONE-LINE AND SIZING

AEI Team No.	7-2019
Date	02/18/2019
Scale	As indicated

E3.1



1 RISER
NTS



Module Specifications		
506x Mission Solar MSE365SQ6S		
STC Rating	365 W	
Vmp	39.32 V	
Imp	9.32 A	
Voc	48.12 V	
Isc	9.81 A	
Inverter Specifications		
7x SMA Sunny Tripower 24000TL-US		
Max AC Power Rating	24.06 kW	
Max Input Voltage	1,000 V	
Wire Schedule		
Tier	Wire	Length
String	30x 10 AWG	3771 ft

2 Solar One-line
NTS

ATUNE

Jack H. Miller Center for Musical Arts

RISER AND PV ONE-LINE

AEI Team No.	7-2019
Date	02/18/2019
Scale	As indicated

E3.2

PRELIMINARY EQUIPMENT LOAD ANALYSIS

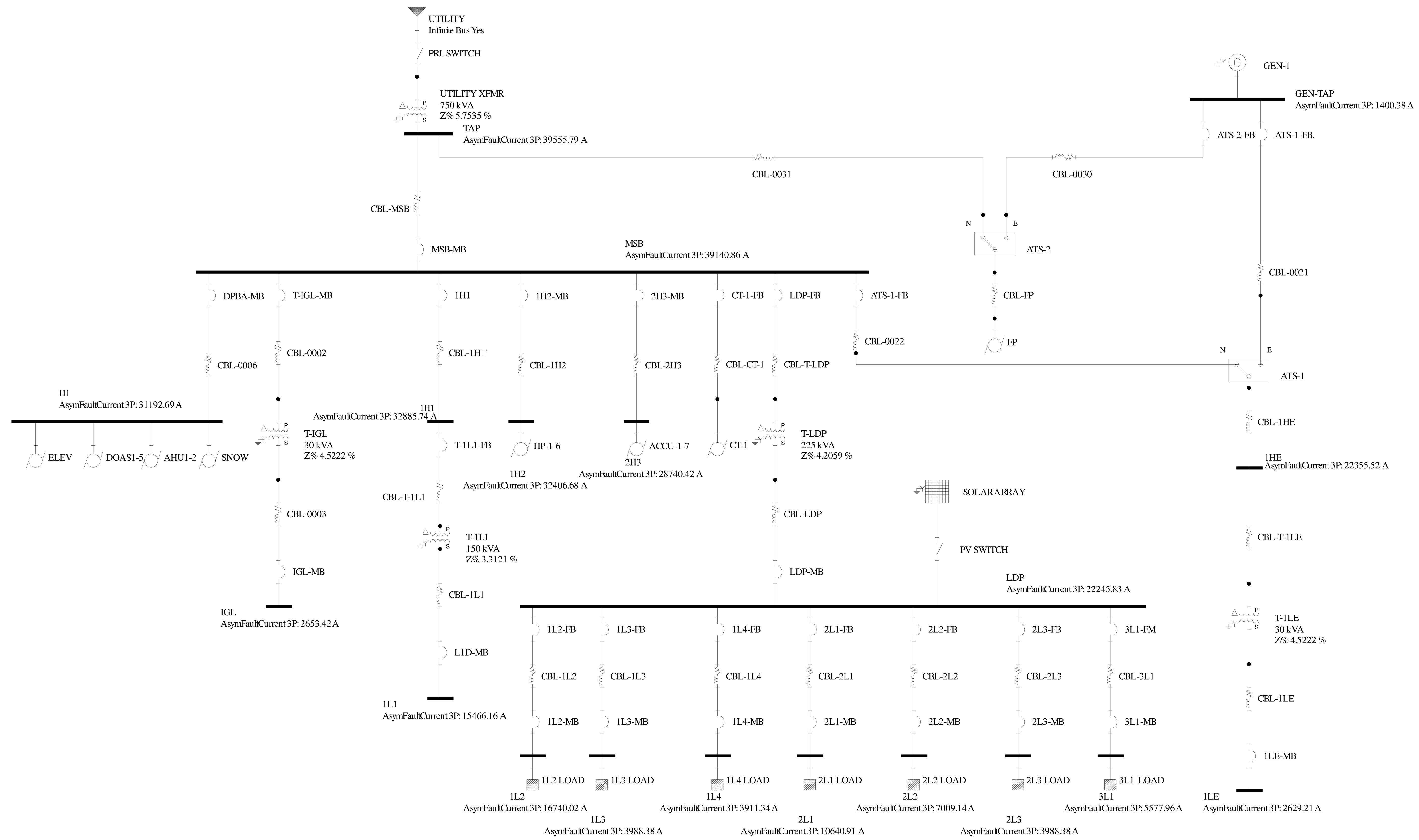
Tag	Equipment Description	Load [kVA]	Voltage [V]	Phase	Load [Amps]	No. Breakers	Poles Per Breaker
MSB	2000A, 2000A/ 3P MCB, 480/277V 3PH SWITCHBOARD, 1 SECTION, FLOOR MOUNTED						
	H1D	125.4	480.0	3.0	150.8	1.0	3.0
	DPBC	267.4	480.0	3.0	321.7	1.0	3.0
	DPBA	143.8	480.0	3.0	173.0	1.0	3.0
	DPLA	175.5	480.0	3.0	211.1	1.0	3.0
	DPBD	313.0	480.0	3.0	376.5	1.0	3.0
	EPH	50.5	480.0	3.0	60.7	1.0	3.0
	IGL	30.0	480.0	3.0	36.1	1.0	3.0
	CT-1	16.5	480.0	3.0	19.8	1.0	3.0
	Subtotals	**1122.1**	**--**	**--**	**1349.7**	**8.0**	**24.0**
1H1	200A, MLO, 480/277V 3PH PANELBOARD, 1 [42 POLE] SECTION, WALL MOUNTED						
	L1D	95.4	480.0	3.0	114.7	1.0	3.0
	Acoustical Panel Motors	30.0	480.0	3.0	36.1	6.0	3.0
	Subtotals	**125.4**	**--**	**--**	**150.8**	**7.0**	**21.0**
1HE	100A, MLO, 480/277V 3PH PANELBOARD, 1 [30 POLE] SECTION, FLOOR MOUNTED						
	EPL	4.3	480.0	3.0	5.2	1.0	3.0
	Smoke Evac Fans	21.2	480.0	3.0	25.5	1.0	3.0
	Fire Pump	25.0	480.0	3.0	30.1	1.0	3.0
	Subtotals	**50.5**	**--**	**--**	**60.7**	**3.0**	**9.0**
2H3	400A, MLO, 480/277V 3PH PANELBOARD, 1 [42 POLE] SECTION, FLOOR MOUNTED						
	DOAS1 - PERF. HALL		480.0	3.0	23.0	1.0	3.0
	DOAS2 - RECITAL		480.0	3.0	21.0	1.0	3.0
	DOAS3 - CLASSROOM		480.0	3.0	17.0	1.0	3.0
	DOAS4 - FAC. STUD.		480.0	3.0	6.0	1.0	3.0
	DOAS5 - ATRIUM		480.0	3.0	4.0	1.0	3.0
	AHU-1		480.0	3.0	28.0	1.0	3.0
	AHU-2		480.0	3.0	28.0	1.0	3.0
	ELEV1		480.0	3.0	25.0	1.0	3.0
	SNOW MELT		480.0	3.0	14.0	2.0	3.0
	Subtotals	**0.0**	**--**	**--**	**173.0**	**10.0**	**30.0**
LDP	800A, 800A/3P MCB, 208/120V 3PH PANELBOARD, 1 [42 POLE] SECTION, WALL MOUNTED						
	L1A	20.3	208.0	3.0	56.4	1.0	3.0
	L1B	23.1	208.0	3.0	64.3	1.0	3.0
	L1C	21.4	208.0	3.0	59.4	1.0	3.0
	L2A	29.3	208.0	3.0	81.2	1.0	3.0
	L2B	13.6	208.0	3.0	37.7	1.0	3.0
	L2C	17.6	208.0	3.0	48.9	1.0	3.0
	L3A	50.1	208.0	4.0	120.5	1.0	3.0
	Subtotals	**175.5**	**--**	**--**	**487.0**	**7.0**	**21.0**
1H2	400A, MLO, 480/277V 3PH PANELBOARD, 2 [42 POLE] SECTIONS, WALL MOUNTED						
	HP1	51.6	480.0	3.0	35.8	1.0	3.0
	HP2	51.6	480.0	3.0	35.8	1.0	3.0
	HP3	51.6	480.0	3.0	35.8	1.0	3.0
	HP4	51.6	480.0	3.0	35.8	1.0	3.0
	HP5	51.6	480.0	3.0	35.8	1.0	3.0
	HP6	51.6	480.0	3.0	35.8	1.0	3.0
	PUMPS (8)	141.0	480.0	3.0	97.9	8.0	3.0
	Subtotals	**450.3**	**--**	**--**	**321.7**	**14.0**	**42.0**
2H1	600A, MLO, 480/277V 3PH PANELBOARD, 1 [42 POLE] SECTION, WALL MOUNTED						
	ACCU-1		480.0	3.0	62.5	1.0	3.0
	ACCU-2		480.0	3.0	63.0	1.0	3.0
	ACCU-3		480.0	3.0	50.0	1.0	3.0
	ACCU-4		480.0	3.0	16.3	1.0	3.0
	ACCU-5		480.0	3.0	11.0	1.0	3.0
	ACCU-6		480.0	3.0	77.2	1.0	3.0
	ACCU-7		480.0	3.0	77.2	1.0	3.0
	Subtotals		**--**	**--**	**376.5**	**7.0**	**21.0**

PRELIMINARY EQUIPMENT LOAD ANALYSIS

Tag	Equipment Description	Load [kVA]	Voltage [V]	Phase	Load [Amps]	No. Breakers	Poles Per Breaker
1LE	100A, MCB, 208/120V, 3PH PANELBOARD, 1 [18 POLE] SECTION, WALL MOUNTED						
	Lighting	2.1	120.0	1.0	17.5	1.0	3.0
	Fire Alarm	2.2	120.0	1.0	18.3	1.0	3.0
	Subtotals	**4.3**	**--**	**--**	**11.9**	**2.0**	**6.0**
1L2	100A, MCB, 208/120V, 3PH PANELBOARD, 1 [42 POLE] SECTION, WALL MOUNTED						
	Receptacles	9.0	120.0	1.0	75.2	5.0	1.0
	Lights	11.3	120.0	1.0	94.0	6.0	1.0
	Misc.	7.9	120.0	1.0	65.8	5.0	1.0
	Subtotals	**20.3**	**--**	**--**	**56.4**	**16.0**	**16.0**
1L3	100A, MCB, 208/120V, 3PH PANELBOARD, 1 [42 POLE] SECTION, WALL MOUNTED						
	Receptacles	8.3	120.0	1.0	68.8	5.0	1.0
	Lights	8.8	120.0	1.0	73.0	5.0	1.0
	Misc.	6.1	120.0	1.0	51.1	4.0	1.0
	Subtotals	**23.1**	**--**	**--**	**64.3**	**14.0**	**14.0**
1L4	100A, MCB, 208/120V, 3PH PANELBOARD, 1 [42 POLE] SECTION, WALL MOUNTED						
	Receptacles	7.7	120.0	1.0	64.2	5.0	1.0
	Lights	8.1	120.0	1.0	67.2	5.0	1.0
	Misc.	5.6	120.0	1.0	47.0	3.0	1.0
	Subtotals	**21.4**	**--**	**--**	**59.4**	**13.0**	**13.0**
1L1	400A, MCB, 208/120V, 3PH PANELBOARD, 2 [42 POLE] SECTIONS, WALL MOUNTED						
	Receptacles	10.8	120.0	1.0	89.7	6.0	1.0
	Lights	20.2	120.0	1.0	168.3	11.0	1.0
	Theatre lighting	55.0	120.0	1.0	458.3	29.0	1.0
	Misc.	9.4	120.0	1.0	78.5	5.0	1.0
	Subtotals	**95.4**	**--**	**--**	**264.8**	**51.0**	**51.0**
2L1	200A, 200 MCB, 208/120V, 3PH PANELBOARD, 1 [42 POLE] SECTION, WALL MOUNTED						
	Receptacles	7.6	120.0	1.0	63.1	4.0	1.0
	Lights	9.5	120.0	1.0	78.9	5.0	1.0
	Misc.	6.6	120.0	1.0	55.2	4.0	1.0
	CU-1	5.6	208.0	1.0	27.0	1.0	1.0
	Subtotals	**29.3**	**--**	**--**	**81.2**	**13.0**	**13.0**
2L2	100A, MCB, 208/120V, 3PH PANELBOARD, 1 [42 POLE] SECTION, WALL MOUNTED						
	Receptacles	4.7	120.0	1.0	39.3	6.0	1.0
	Lights	4.7	120.0	1.0	39.3	3.0	1.0
	Misc.	4.1	120.0	1.0	34.4	3.0	1.0
	Subtotals	**13.6**	**--**	**--**	**37.7**	**12.0**	**12.0**
2L3	100A, MCB, 208/120V, 3PH PANELBOARD, 1 [42 POLE] SECTION, WALL MOUNTED						
	Receptacles	3.0	120.0	1.0	25.0	3.0	1.0
	Lights	4.8	120.0	1.0	40.0	3.0	1.0
	Misc.	4.2	120.0	1.0	35.0	3.0	1.0
	CU-2	5.6	208.0	1.0	27.0	1.0	1.0
	Subtotals	**17.6**	**--**	**--**	**48.9**	**10.0**	**10.0**
3L1	200A, 200A/ 3P MCB, 208/120V, 3PH PANELBOARD, 1 [42 POLE] SECTION, WALL MOUNTED						
	Receptacles	6.4	120.0	1.0	53.4	4.0	1.0
	Lights	8.0	120.0	1.0	66.8	5.0	1.0
	Motors	19.5	120.0	1.0	162.5	5.0	3.0
	Catering Equipment	5.0	208.0	3.0	13.9	3.0	1.0
	Misc.	5.6	120.0	1.0	46.7	3.0	1.0
	CU-3	5.6	208.0	1.0	27.0	1.0	2.0
	Subtotals	**50.1**	**--**	**--**	**139.2**	**21.0**	**32.0**
IGL	100A, MCB, 208/120V, 3PH PANELBOARD, 1 [18 POLE] SECTION, WALL MOUNTED						
	Teledata Equip. (2 @15kVA)	30.0	208.0	3.0	83.3	2.0	3.0
	Subtotals	**30.0**	**--**	**--**	**83.3**	**2.0**	**6.0**

NOTES:

1. TOTAL AMPS CALCULATED USING NEC DEMAND FACTORS
2. LOW VOLTAGE PANELS SIZE BASED ON TYPICAL LOADS PER SQUARE FOOT



1 AVAILABLE FAULT CURRENT
NTS

FEEDER VOLTAGE DROP CALCULATIONS

BUS 1	BUS 2	NOMINAL	DISTANCE (FT)	LOAD (AMPS)	ACTUAL	DROP	%
T-UTILITY	MSB	480	30	1350	479.9997	0.0003	0.000062%
T-UTILITY	FIRE PUMP	480	70	30.1	479.3	0.7	0.15%
GEN-1	FIRE PUMP	480	85	30.1	479.1	0.9	0.19%
GEN-1	ATS-1	480	50	60.7	479.2	0.8	0.17%
MSB	2H3	480	60	173	479.3	0.73	0.15%
MSB	1H2	480	55	321.7	479.3	0.7	0.15%
MSB	2H1	480	110	376.5	476.4	3.59	0.75%
LDP	1L2	208	15	56.4	207.8	0.2	0.10%
LDP	1L3	208	210	64.3	204.4	3.6	1.73%
LDP	1L4	208	215	59.4	204.6	3.4	1.63%
LDP	2L1	208	50	81.2	206.9	1.1	0.53%
LDP	2L2	208	100	37.7	207	1	0.48%
LDP	2L3	208	210	48.9	205.3	2.7	1.30%
LDP	3L1	208	240	139.2	202.6	5.44	2.62%

AVAILABLE FAULT CURRENT

NO.	BUS	VOLTAGE	FAULT CURRENT (AMPS)
1	UTILITY	12470	999999
3	TAP	480	39556
2	GEN	480	1400
4	MSB	480	39141
5	2H1	480	31193
6	1H1	480	32886
7	1H2	480	32407
8	2H3	480	28740
9	1HE	480	22356
10	IGL	208	2653
11	1L1	208	15466
12	LDP	208	22246
13	1L2	208	16740
14	1L3	208	3988
15	1L4	208	3911
16	2L1	208	10641
17	2L2	208	7009
18	2L3	208	3988
19	3L1	208	5578
20	1LE	208	2629

NOTES:

1. An Infinite bus calulcation was performed on the system due to the lack in utility information provided.
2. The selected Utility Transformer used for the calculations has a impedence value of 5.7535%.
3. In order to continue the study, the utility information must be confirmed and then an arc flash study may be conducted on the system.

ATUNE

Jack H. Miller Center for Musical Arts

SYSTEM SIZING AND STUDIES

AEI Team No.	7-2019
Date	02/18/2019
Scale	As indicated

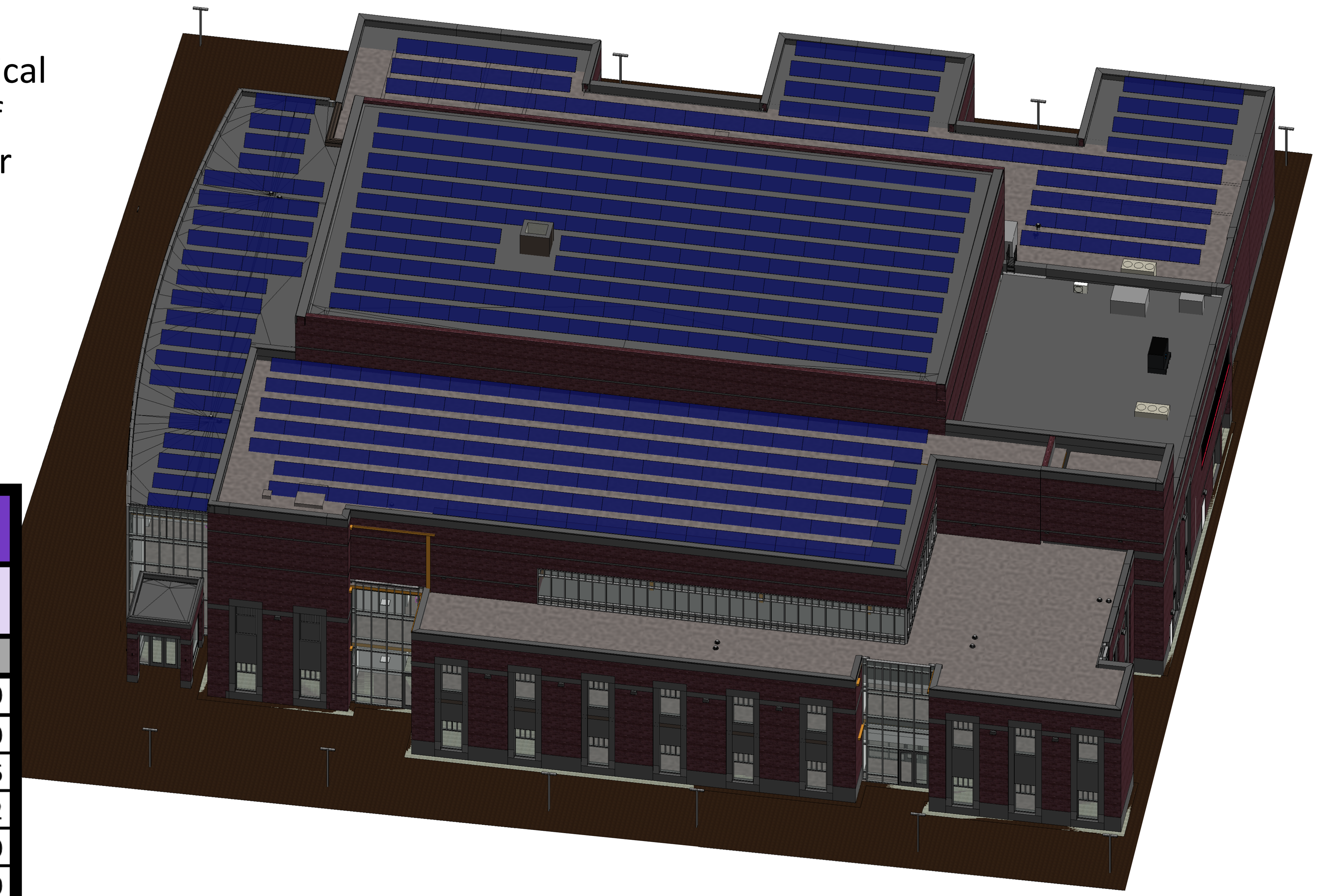
E3.3

Average Daily Incident Shortwave Solar Energy				
Month	Beginning	Middle	End	Average
	kWh/m^2			
Jan	1.4	1.6	1.9	1.63
Feb	2	2.6	3.1	2.57
Mar	3.2	3.9	4.5	3.87
Apr	4.5	5.2	5.8	5.17
May	5.8	6.3	6.7	6.27
Jun	6.7	7	7.1	6.93
July	7.2	6.9	6.6	6.9
Aug	6.5	6.1	5.6	6.07
Sept	5.5	4.9	4.1	4.83
Oct	4.1	3.3	2.6	3.33
Nov	2.5	1.9	1.6	2
Dec	1.5	1.4	1.3	1.4
	Yearly Average:		kWh/m^2	**4.53**
			kWh/ft^2	**0.4201**

Atune's first step was to analyze Holland, Michigan's potential for harvesting energy from the sun. The average daily incident shortwave solar energy is **4.53** kWh/m^2, or **0.4201** kWh/ft^2. Atune used these average values to calculate the potential for a roof mounted Photovoltaic system.

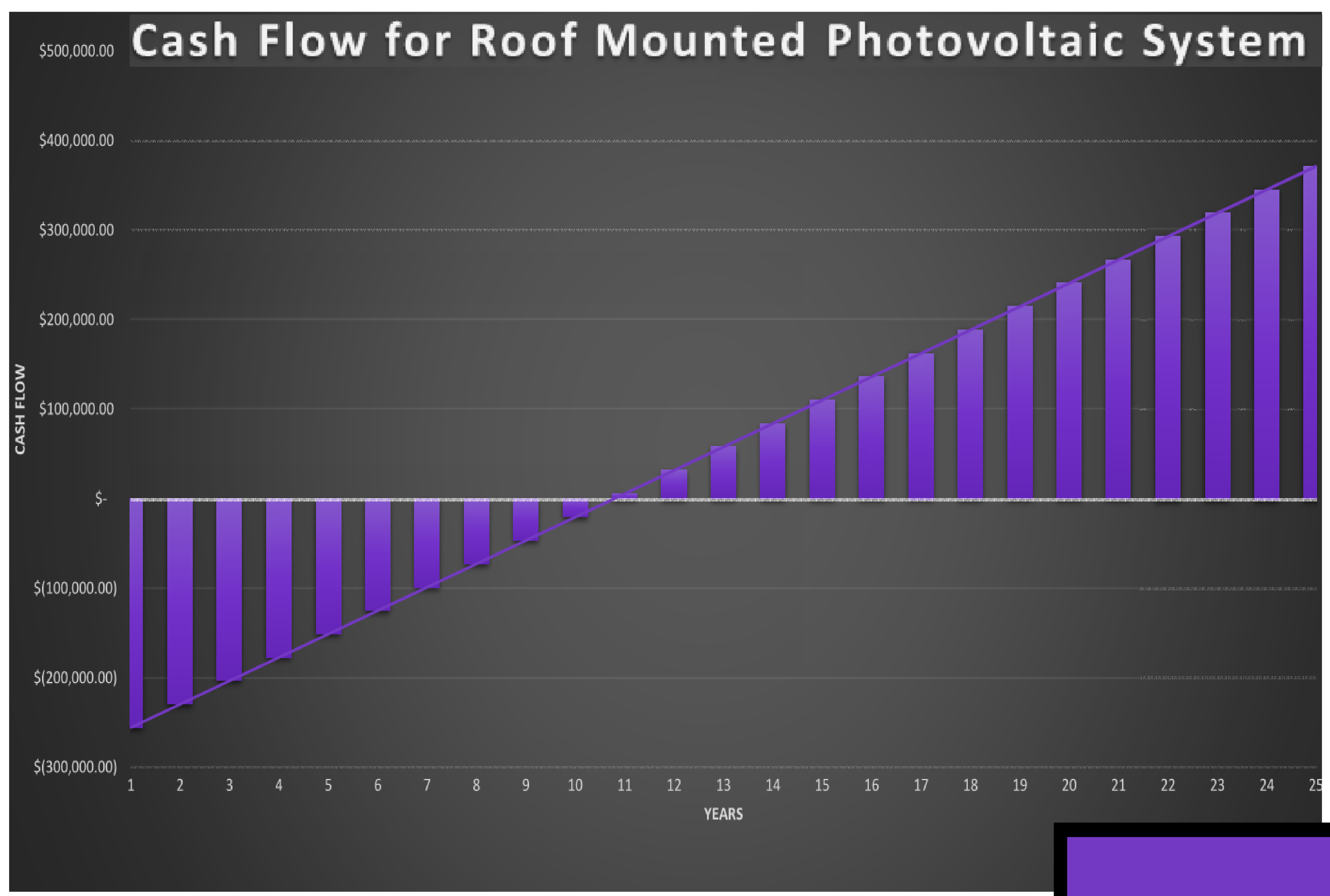
The First Cost Analysis Table was created using market information available to the team at the time of design. The estimated first cost came to a grand total of **$281,368.28**. This total breaks down to just over **$556** per panel, and **$1.52** per watt installed. This number was achieved due to the scale of the arrays and the improved efficiency of solar panels.

Holland is located at **42.78°N,** which requires an average mounting angle of **45°** from the roof/surface. For this reason, Atune's Electrical Team concluded that a minimum distance of **4'-0"** would be required in order for the solar panels to avoid casting shadows onto each other. This distance will make the panels as efficient as possible while also providing sufficient room in between rows in the case that maintenance needs to be performed on a panel.

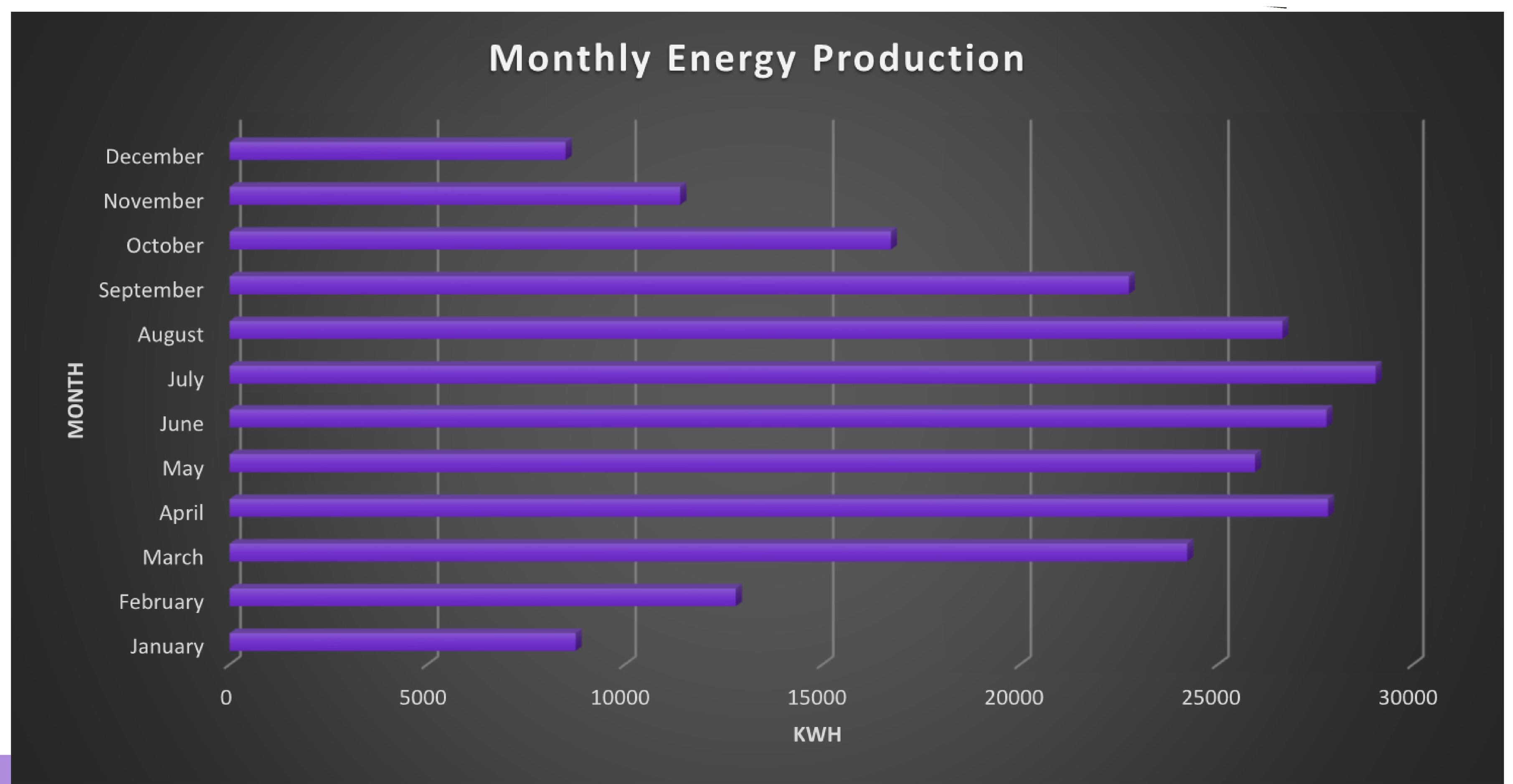


Photovoltaic First Cost Analysis			
Items	Quantity	Cost/ Quantity	Total Cost
	No.	$/No.	$
Panels	506	$ 300.00	$ 151,800.00
Inverters	7	$ 4,425.00	$ 30,975.00
10 AWG CU Conductors (1000 ft)	4	$ 346.94	$ 1,387.76
1/0 AWG AL Conductors (1000ft)	2	$ 697.76	$ 1,395.52
Labor (2 man hours/panel)	1012	$ 65.00	$ 65,780.00
Racking (1 per Panel)	506	$ 50.00	$ 25,300.00
MPPT Charge Controllers	2	$ 2,500.00	$ 5,000.00
		Final Cost	$ 281,638.28
		$/Panel	$ 556.60
		$/Watt	$ 1.52

Photovoltaic Payback Cost Analysis								
Panels	Power Produced/ Panel	Daily Power Produced	Yearly Power Produced	Inverter Efficiency	Utility cost	Yearly Savings	Estimated First Cost	Payback Period
No.	kWh/day	kWh	kWh	No.	$/kWh	$	$	Years
506	1.31	664	242360	0.98	0.11	$ 26,126.41	$ 281,638.28	10.8



Atune performed a 25 year Cash Flow Analysis in order to determine the viability of the Photovoltaic System. The results showed a annual savings of **$26,126.41** with a payback period of **10.8** years. With utility rates staying constant, the 25 year studied showed that the panels will save the owner **$371,521.92.**



Utilizing non-shaded and unused roof space, Atune's Electrical Team calculated the monthly energy production using an industry leading **18.46%** efficient solar panel.

Monthly Production	
Month	kWh
January	8750.6
February	12804
March	24224.1
April	27809.7
May	25942.4
June	27772.3
July	29041.9
August	26635.1
September	22751
October	16733.8
November	11399.3
December	8501.3

BATTERY BANK SIZING CALCULATIONS						
SQUARE FOOTAGE	kWh/YR PER SQUARE FOOT (1)	DAILY kWh CONSUMPTION	% OF kWh USED FOR LV LOADS(2)	DAILY kWh FOR LV LOADS(2)	MIN. BATTERY SIZE kWh(3)	APPROX. SIZE (L x W x D) IN.
64000	18.9	3,314	30.5%	1011	42.46	29 x 96 x 27

1 BASED ON U.S. ENERGY STUDY FOCUSED ON ELECTRICITY END USES ON COLLEGE CAMPUS'

2 LOW VOLTAGE (208/120V) LOADS INCLUDE RECEPTACLES, OFFICE AND MISC.

3 BASED ON MAINTAINING LOADS FOR 24 HOUR PERIOD

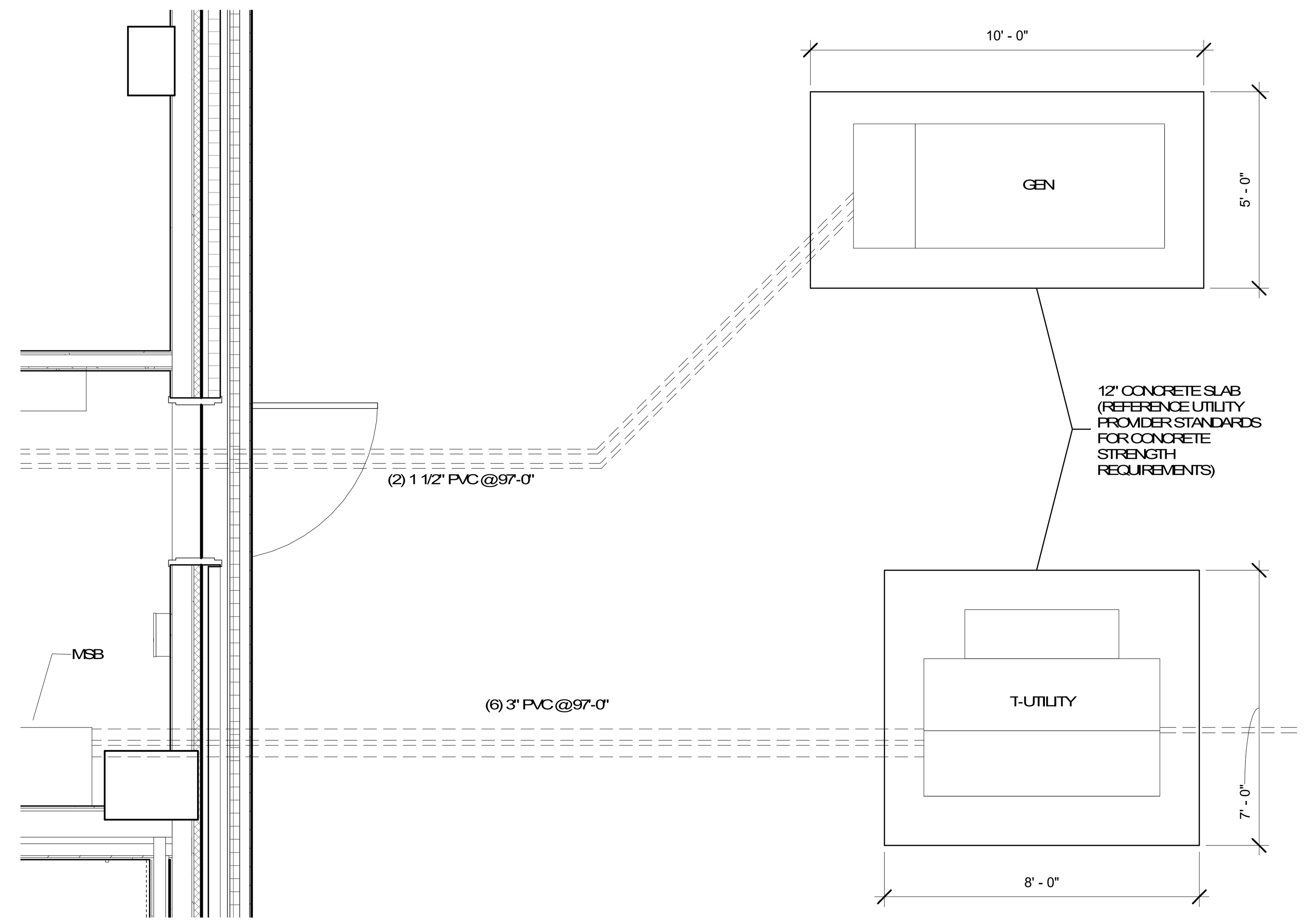
ATUNE

Jack H. Miller Center for Musical Arts

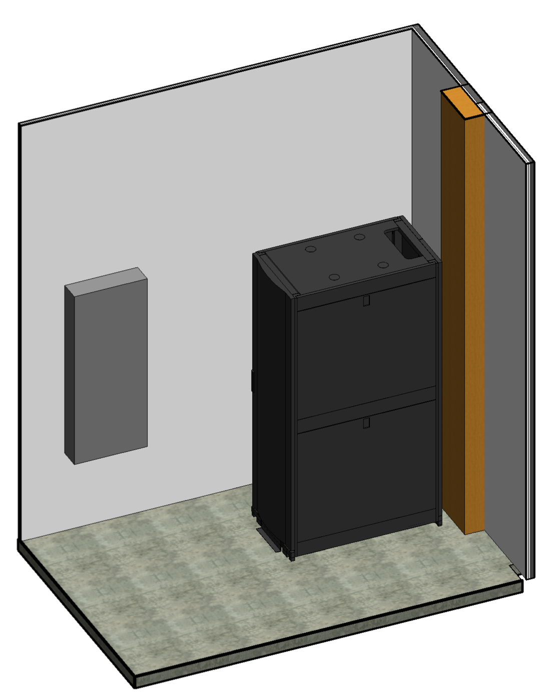
PV LIFE-CYCLE ANALYSIS

AEI Team No.	7-2019
Date	02/18/2019
Scale	As indicated

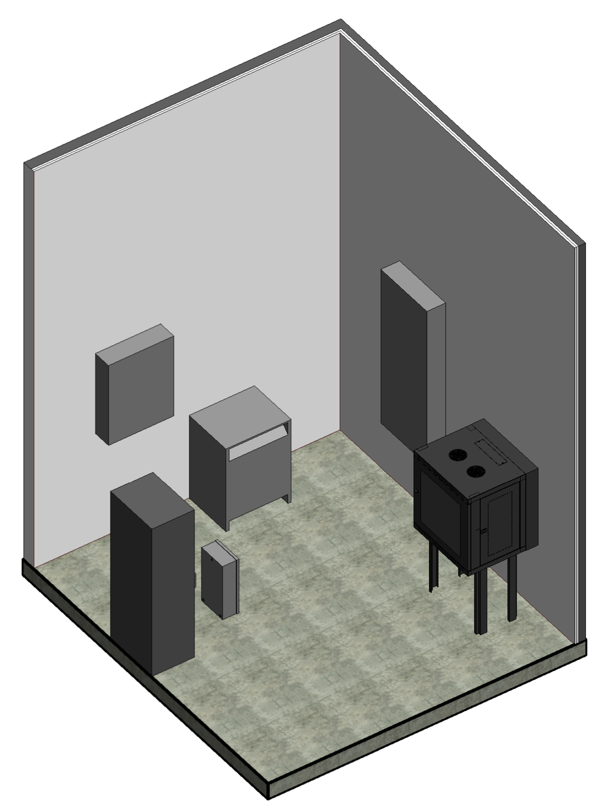
E3.4



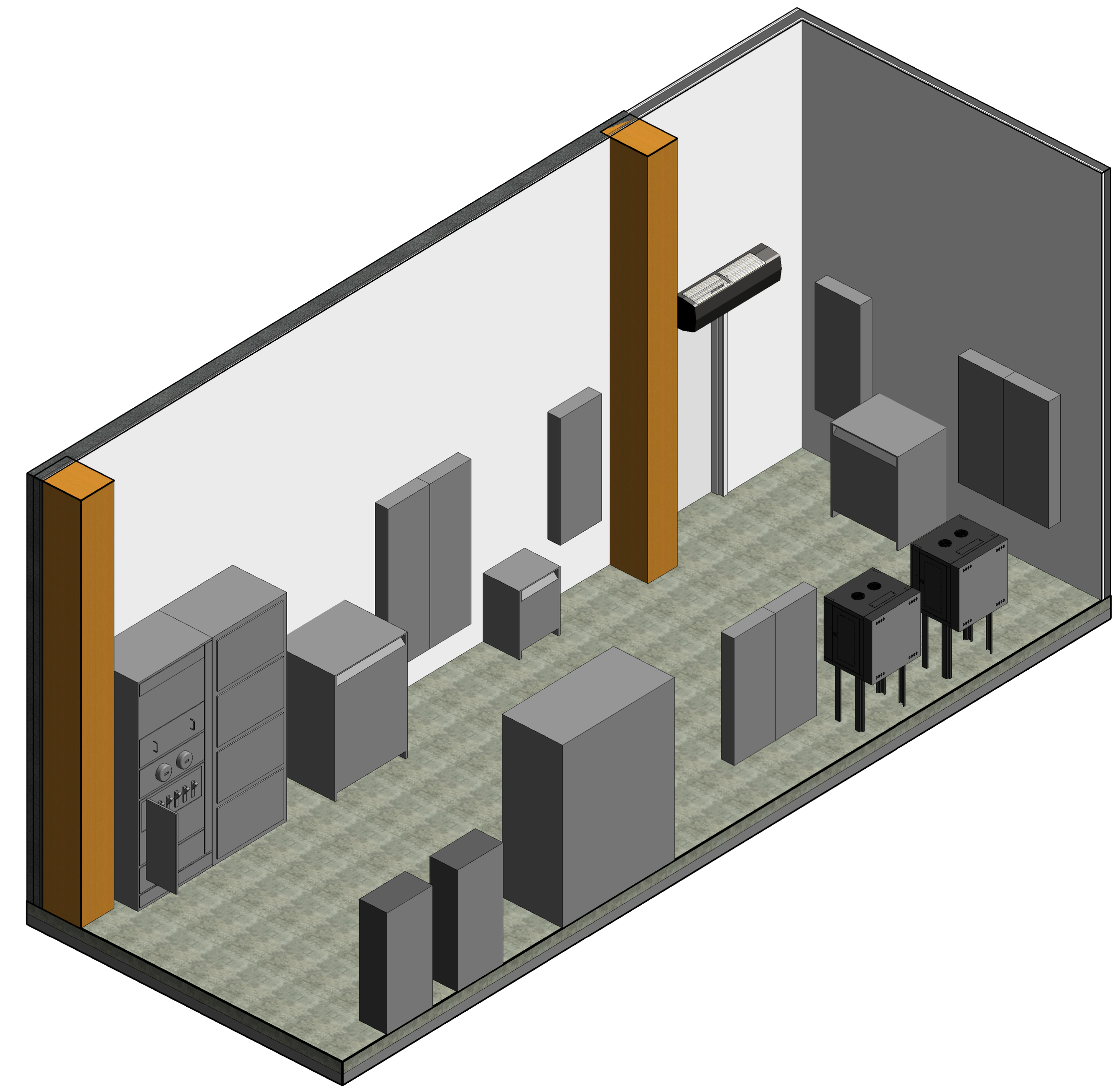
6 UTILITY AND GENERATOR CONNECTION
3/8" = 1'-0"



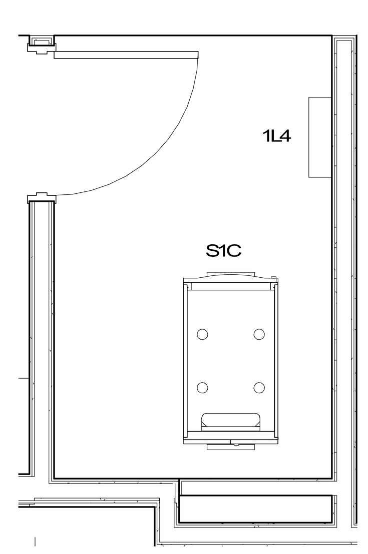
5 SATELLITE



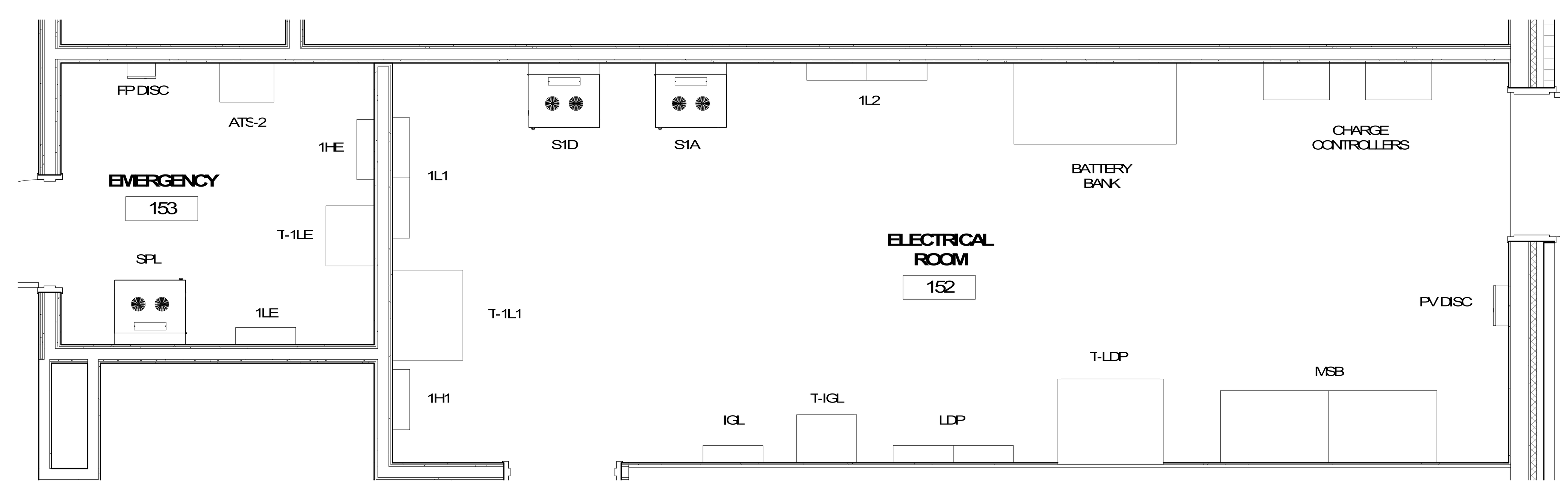
3 EMERGENCY ELECTRICAL ROOM - 153



4 MAIN ELECTRICAL ROOM - 152



2 TYPICAL SATELLITE
3/8" = 1'-0"



1 ELECTRICAL - 152/153
3/8" = 1'-0"

ATUNE

Jack H. Miller Center for Musical Arts

ELECTRICAL ROOM DETAILS

AEI Team No.	7-2019
Date	02/18/2019
Scale	3/8"=1'-0"

E3.5

PUMP SCHEDULE

TAG NO	RPM	BHP	HP	FLA	VOLTAGE	PHASE	HZ	MOCP	NOTES
CSWP-1	1760	4.93	5	7.6	480	3	60	15	1,2
CSWP-2	1760	4.93	5	7.6	480	3	60	15	1,2
HSWP-1	1760	4.93	5	7.6	480	3	60	15	1,2
HSWP-2	1760	4.93	5	7.6	480	3	60	15	1,2
GSWP-1	1760	2.96	7.5	11	480	3	60	15	1,2
GSWP-2	1760	2.96	7.5	11	480	3	60	15	1,2
CTWP-1	1760	4.93	5	7.6	480	3	60	15	1,2
CTWP-2	1760	4.93	5	7.6	480	3	60	15	1,2
SMWP-1	1760	9.86	10	14	480	3	60	20	1,2
SMWP-2	1760	9.86	10	14	480	3	60	20	1,2

NOTES

1 MANUFACTURER TO PROVIDE INTEGRAL VFD
2 MANUFACTURER TO PROVIDE EQUIPMENT DISCONNECTING MEANS

DOAS UNIT SCHEDULE

TAG	SERVES	LOCATION	FAN CHARACTERISTICS		ELECTRICAL DATA						WEIGHT (LBS)	NOTES
			AIRFLOW (CFM)	ESP (IN W.G.)	VOLTAGE / PHASE	HZ	MOTOR HP	QTY.	FLA	MOCP		
DOAS-1	PERF HALL	MECH 224	6695	1.5	460 / 3	60	3.5	2	23	30	1600	1,2
DOAS-2	RECITAL / REHEARSAL	MECH 224	6245	1.5	460 / 3	60	3	2	21	30	1600	1,2
DOAS-3	CLASSROOM	MECH 220	4860	1.5	460 / 3	60	5	1	17	25	2300	1,2
DOAS-4	FACULTY STUDIO	MECH 220	1300	1.5	460 / 3	60	1.25	1	6	15	1525	1,2
DOAS-5	ATRIUM	MECH 250	965	1.5	460 / 3	60	1.6	1	4	15	1200	1,2

NOTES:

1 MANUFACTURER TO PROVIDE INTEGRAL VFD
2 MANUFACTURER TO PROVIDE EQUIPMENT DISCONNECTING MEANS

HEAT PUMP SCHEDULE

TAG	MANUFACTURER	MODEL	ELECTRICAL DATA						NOTES
			VOLTAGE	PHASE	FREQUENCY	FLA	MCA	HACR CB	
HP1	DAIKIN	WRA 300	480	3 PH	60 HZ	36	40.5	50	1,2
HP2	DAIKIN	WRA 300	480	3 PH	60 HZ	36	40.5	50	1,2
HP3	DAIKIN	WRA 300	480	3 PH	60 HZ	36	40.5	50	1,2
HP4	DAIKIN	WRA 300	480	3 PH	60 HZ	36	40.5	50	1,2
HP5	DAIKIN	WRA 300	480	3 PH	60 HZ	36	40.5	50	1,2
HP6	DAIKIN	WRA 300	480	3 PH	60 HZ	36	40.5	50	1,2

NOTES

1 MANUFACTURER TO PROVIDE INTEGRAL VFD
2 MANUFACTURER TO PROVIDE EQUIPMENT DISCONNECTING MEANS

AIR COOLED CONDENSING UNIT SCHEDULE

TAG	SERVES	CAPACITY (TONS)	FAN TYPE	FLA	MOCP	VOLTAGE	PHASE	HZ	WEIGHT (LBS)	NOTES
ACCU-1	DOAS-1	40	ECM	62.5	70	480	3	60	2500	1,2
ACCU-2	DOAS-2	31	ECM	63	70	480	3	60	2200	1,2
ACCU-3	DOAS-3	25	ECM	50	50	480	3	60	1550	1,2
ACCU-4	DOAS-4	7	ECM	16.3	25	480	3	60	475	1,2
ACCU-5	DOAS-5	5	ECM	11	20	480	3	60	475	1,2
ACCU-6	AHU-1	16	DIRECT	77.2	90	480	3	60	950	1,2
ACCU-7	AHU-2	16	DIRECT	77.2	90	480	3	60	950	1,2

NOTES

1 MANUFACTURER TO PROVIDE INTEGRAL VFD
2 MANUFACTURER TO PROVIDE EQUIPMENT DISCONNECTING MEANS

AIR HANDLING UNIT SCHEDULE

TAG NO	LOCATION	AREA SERVED	SUPPLY CFM	FLA	MOCP	VOLTAGE	PHASE	HZ	WEIGHT (LBS)	NOTES
AHU-1	MECH 220	PERFORMANCE HALL LIGHTS	7500	29	40	480	3	60	900	1,2
AHU-2	MECH 221	PERFORMANCE HALL LIGHTS	7500	29	40	480	3	60	900	1,2

NOTES

1 MANUFACTURER TO PROVIDE INTEGRAL VFD
2 MANUFACTURER TO PROVIDE EQUIPMENT DISCONNECTING MEANS

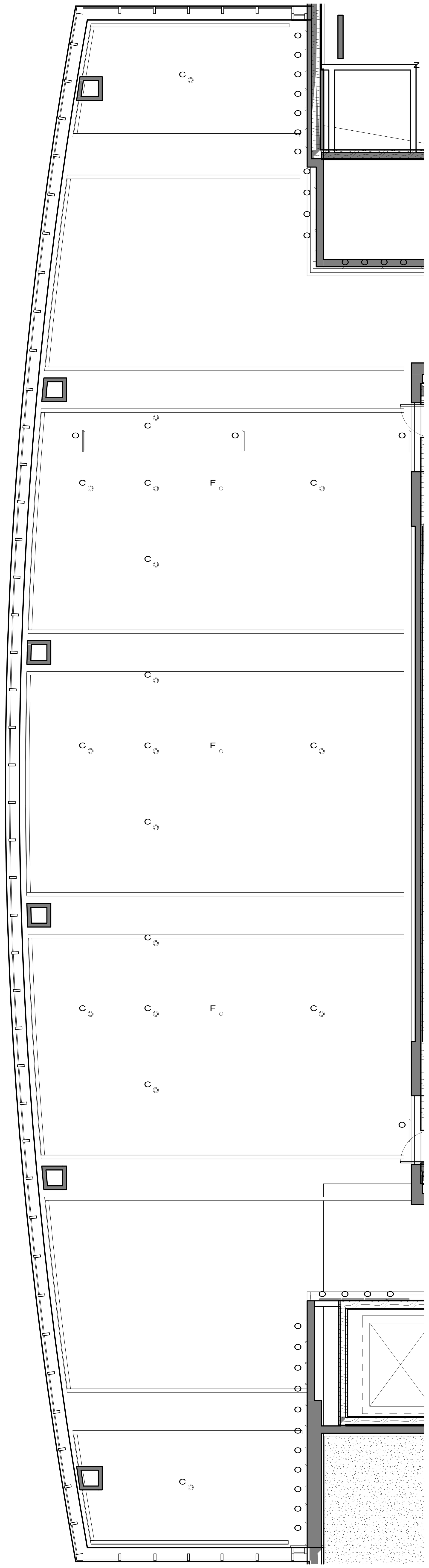
ATUNE

Jack H. Miller Center for Musical Arts

ELECTRICAL SCHEDULES

AEI Team No.	7-2019
Date	02/18/2019
Scale	As indicated

E3.6

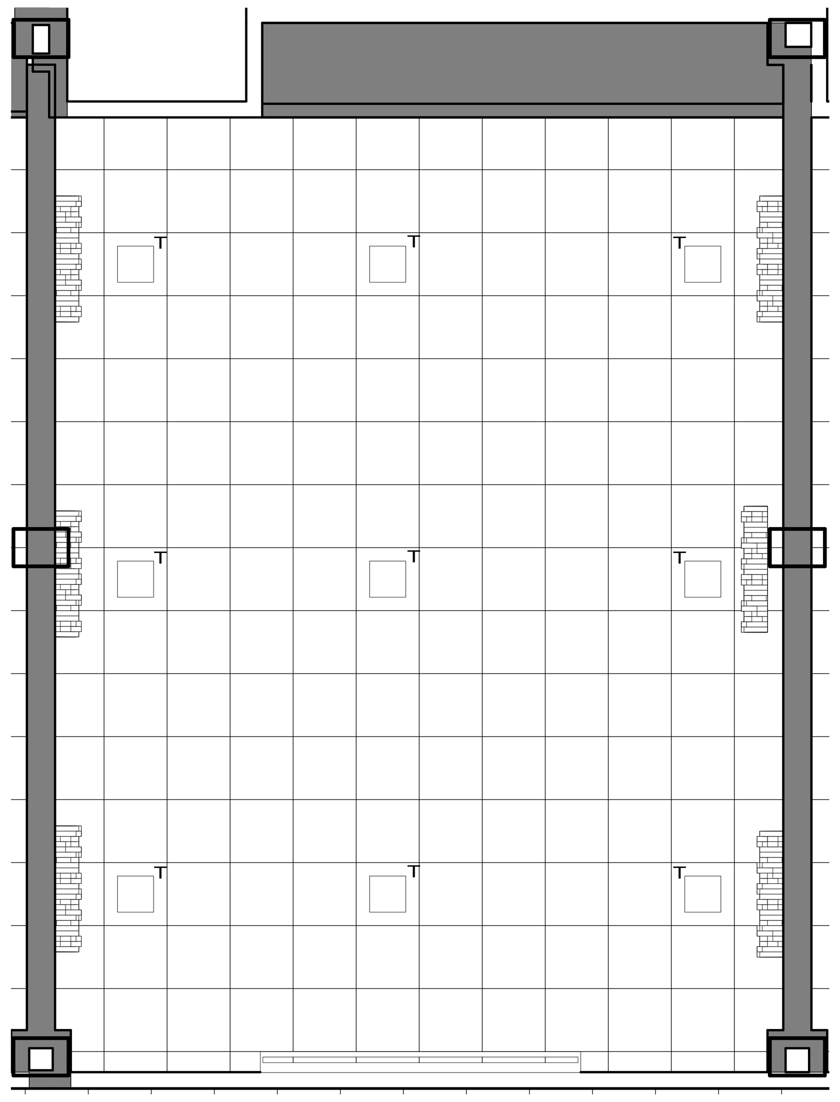


7 ATRIUM REFLECTED CEILING PLAN
3/16" = 1'-0"

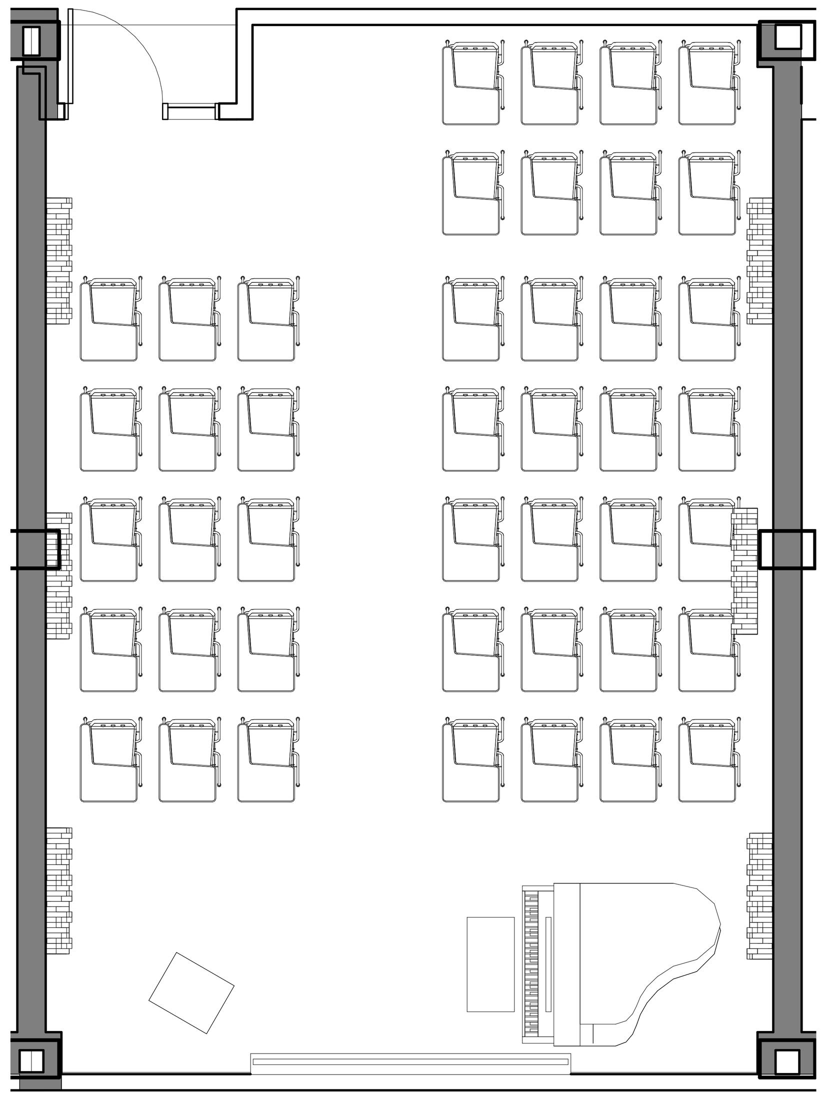
8 ATRIUM DAYLIGHT RENDERING
NTS

6 TYPICAL CLASSROOM
NTS

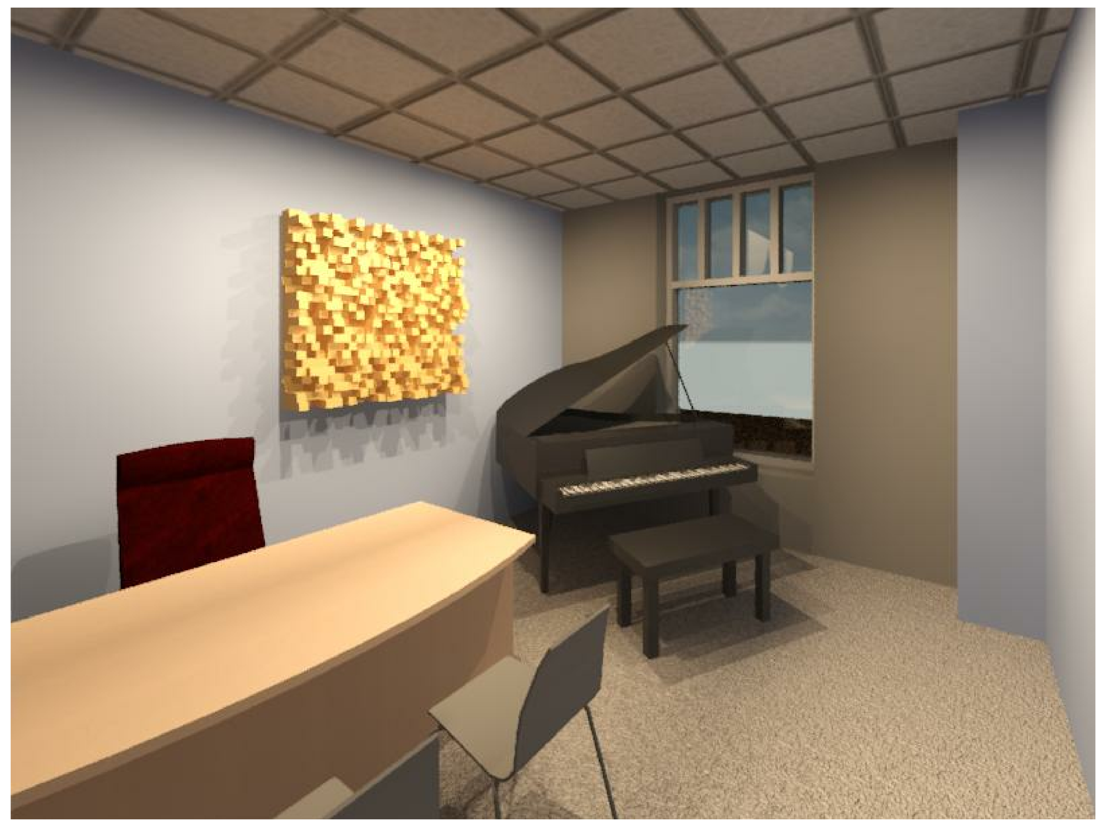
9 ATRIUM EVENING RENDERING
NTS



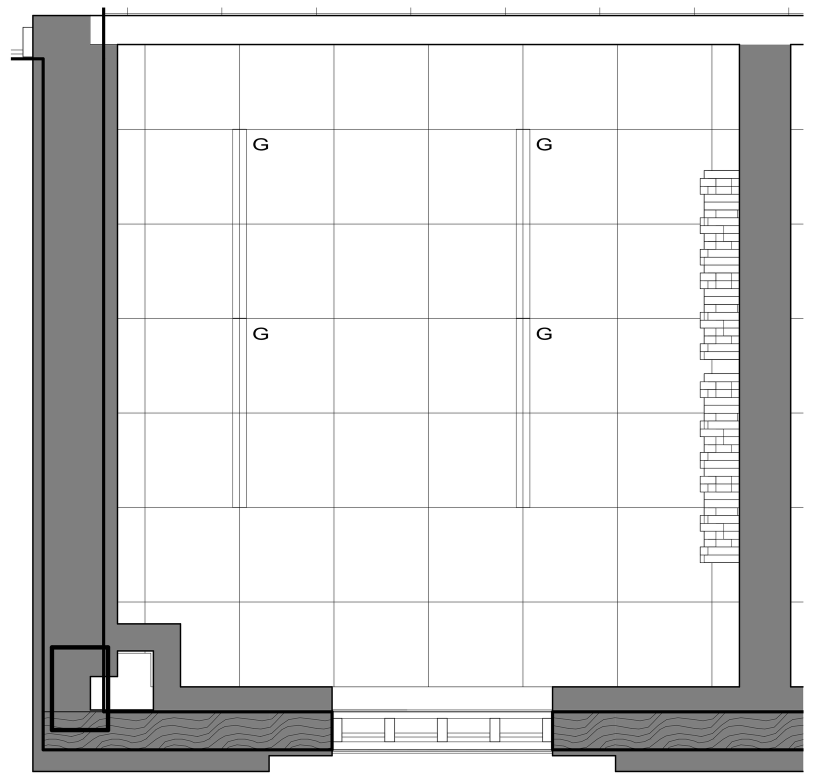
5 TYPICAL CLASSROOM
1/4" = 1'-0"



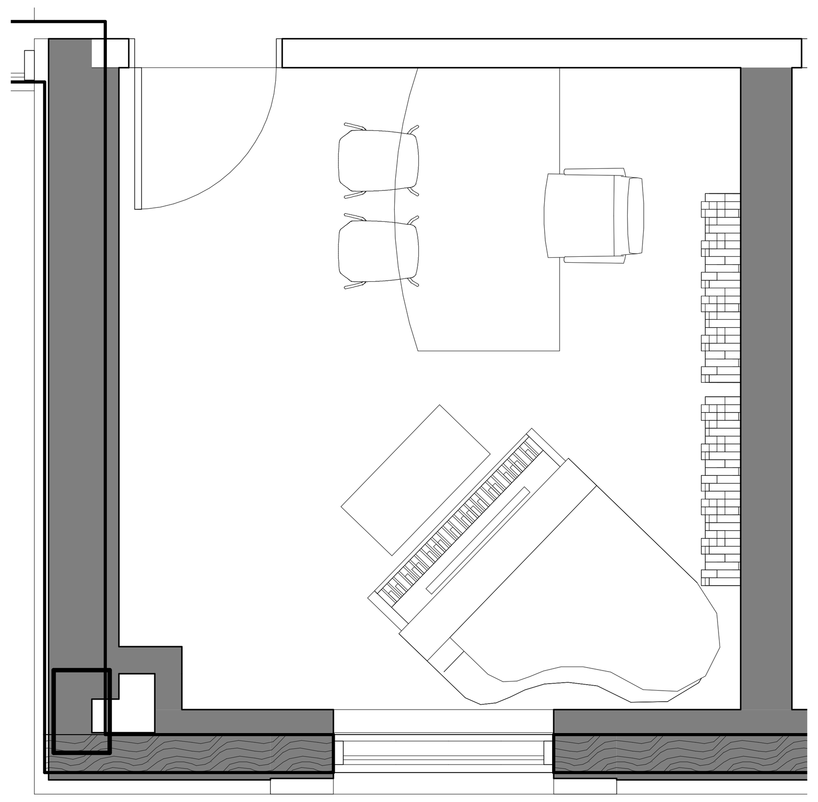
4 TYPICAL CLASSROOM
1/4" = 1'-0"



3 TYPICAL FACULTY STUDIO
NTS



2 Typical Faculty Studio
3/8" = 1'-0"



1 Typical Faculty Studio
3/8" = 1'-0"

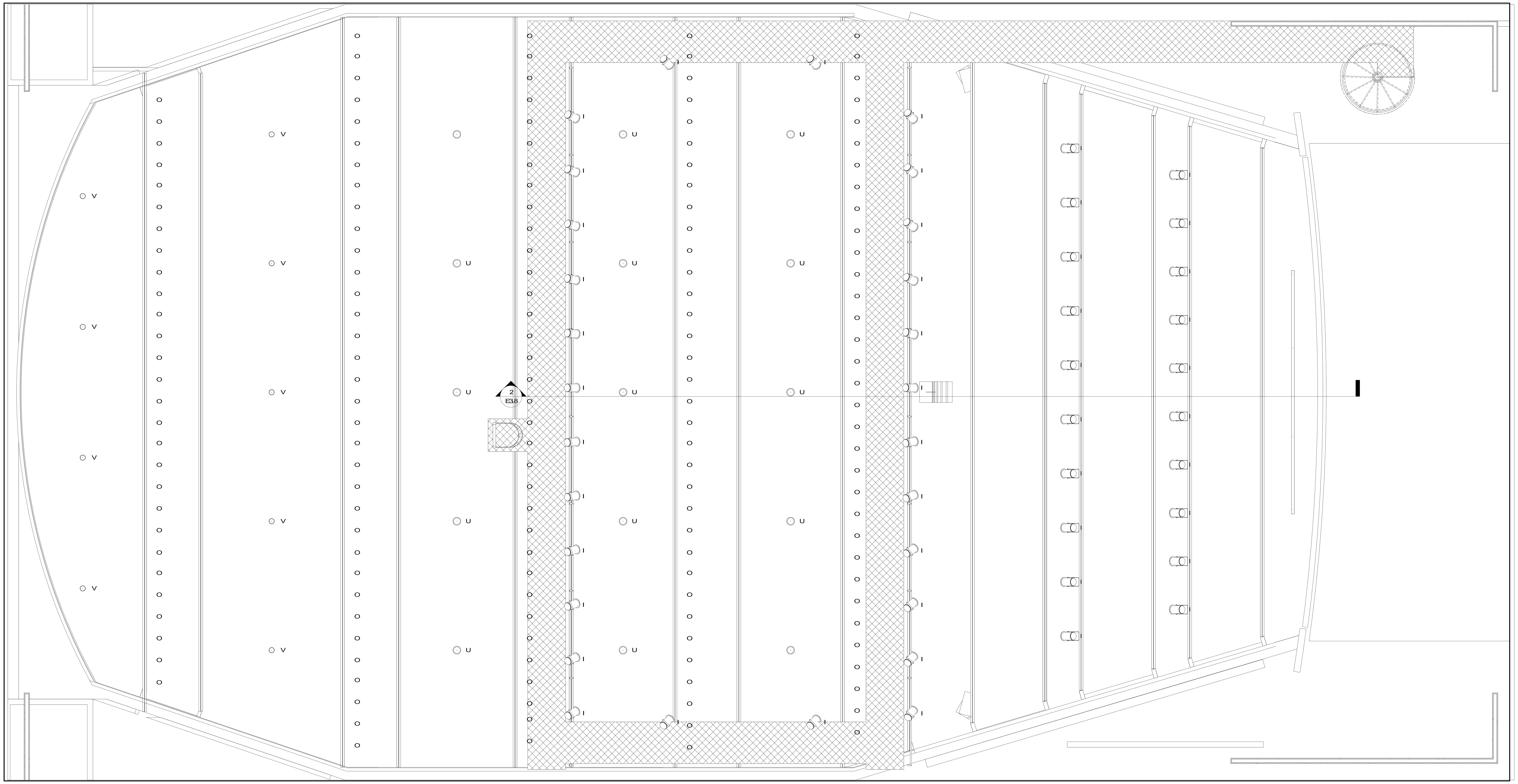
ATUNE

Jack H. Miller Center for Musical Arts

TYPICAL LTG AND RENDERINGS

AEI Team No.	7-2019
Date	02/18/2019
Scale	As indicated

E3.7



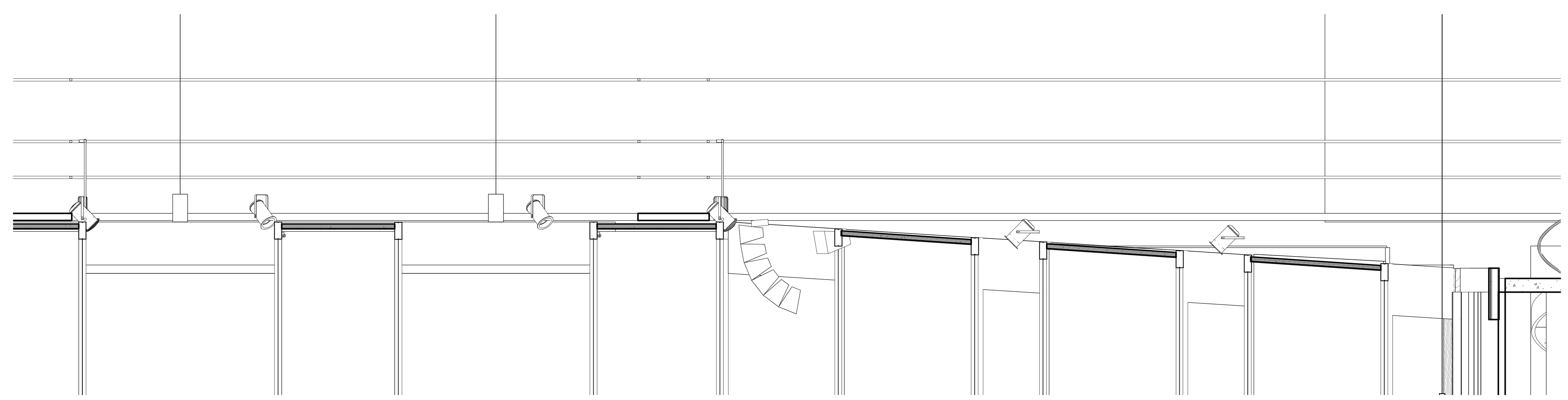
1 Concert Hall Lighting
1/4" = 1'-0"

6 FIXTURE V - MEDIUM OUTPUT PENDANT
NTS

5 FIXTURE U - HIGH OUTPUT PENDANT
NTS

4 FIXTURE O - EXAMPLE 2' LINEAR COVE
NTS

3 FIXTURE I - EXAMPLE 1000W PARNELL
NTS



2 Concert Hall Lighting - Section
1/4" = 1'-0"

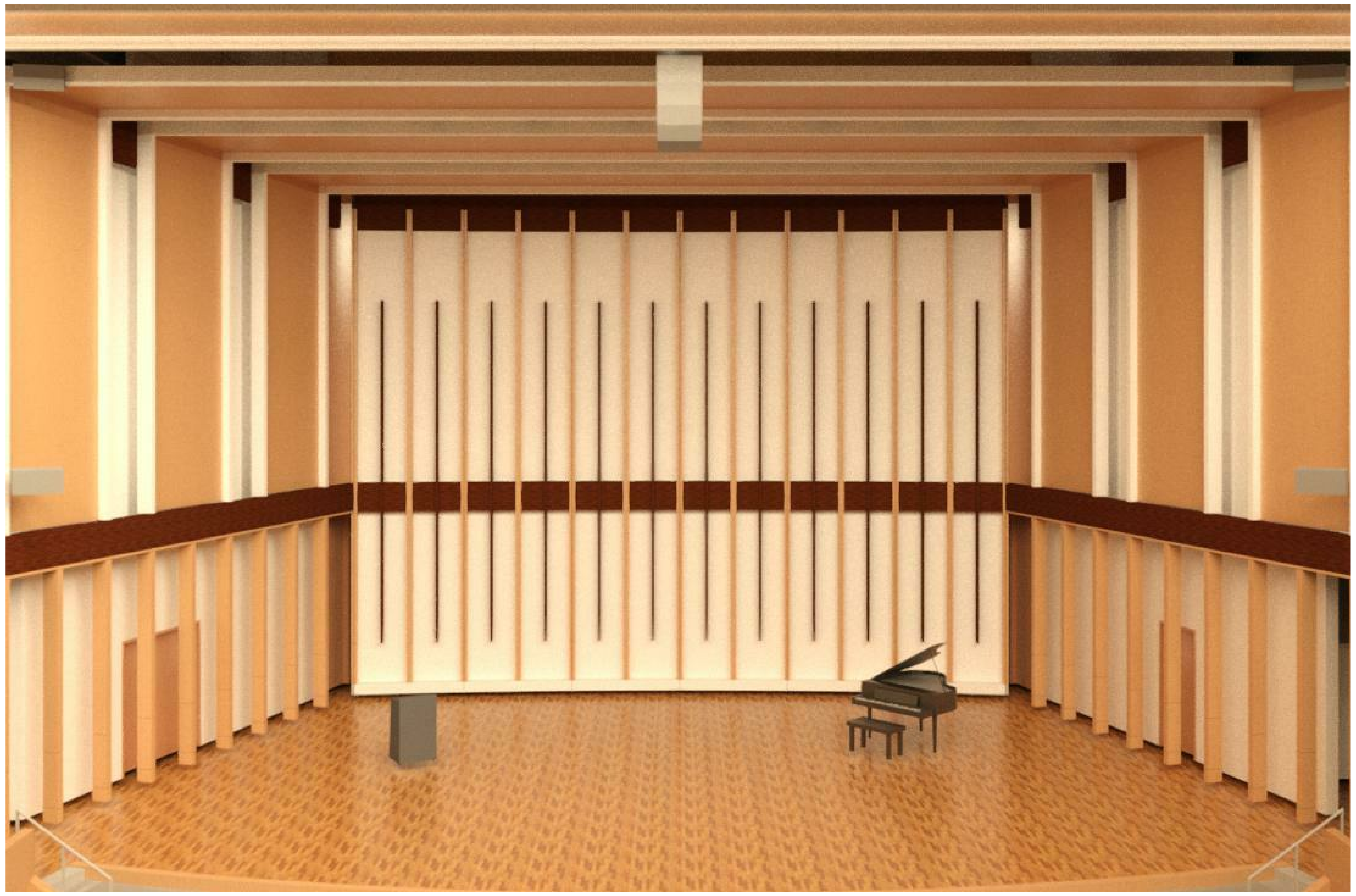
ATUNE

Jack H. Miller Center for Musical Arts

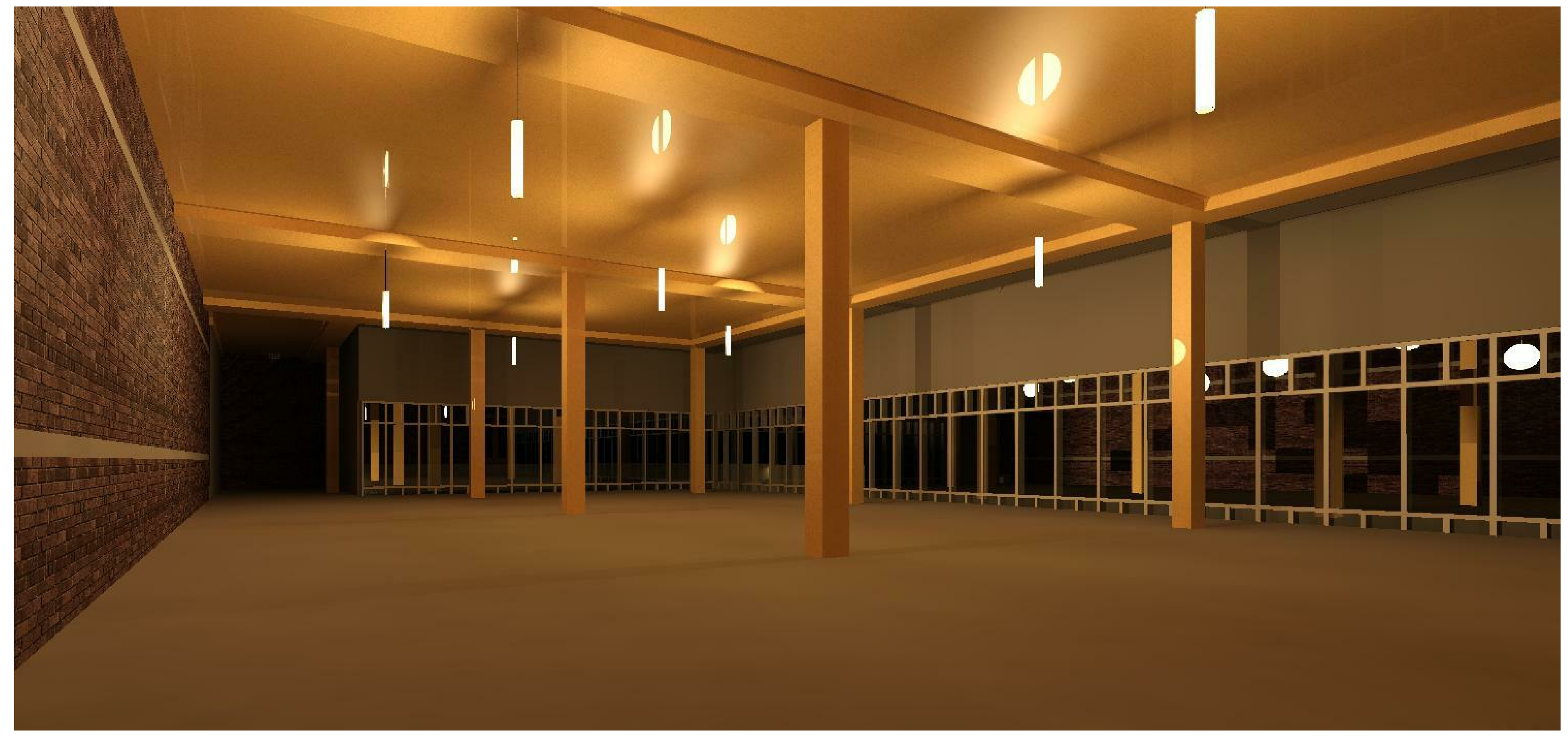
CONCERT HALL LIGHTING

AEI Team No.	7-2019
Date	02/18/2019
Scale	As indicated

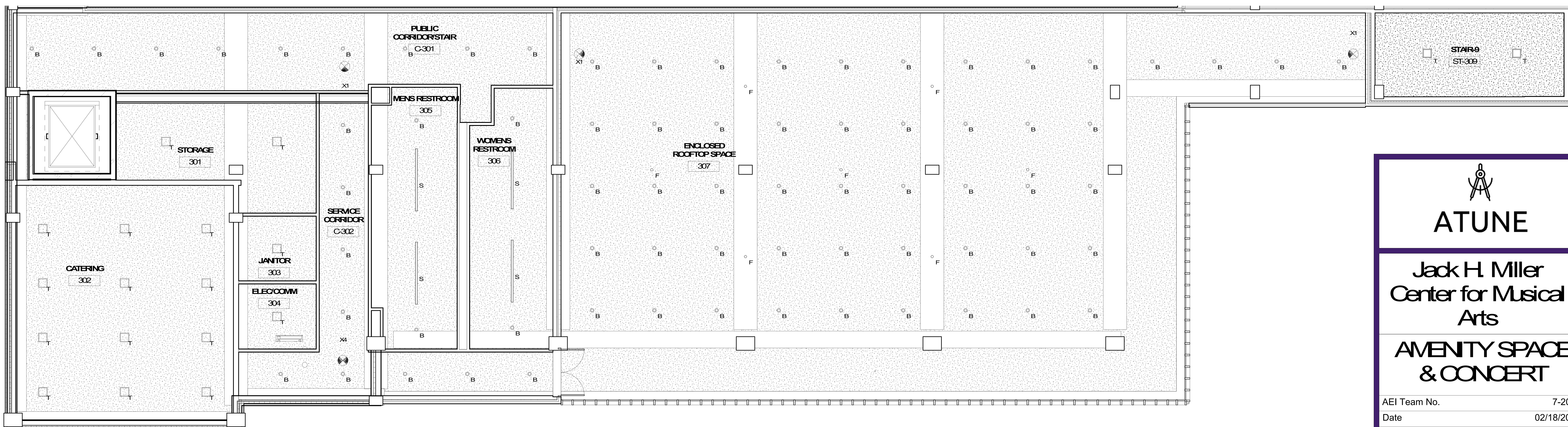
E3.8



3 CONCERT HALL
NTS



2 AMENITY SPACE
NTS



1 Amenity Space RCP
3/16" = 1'-0"

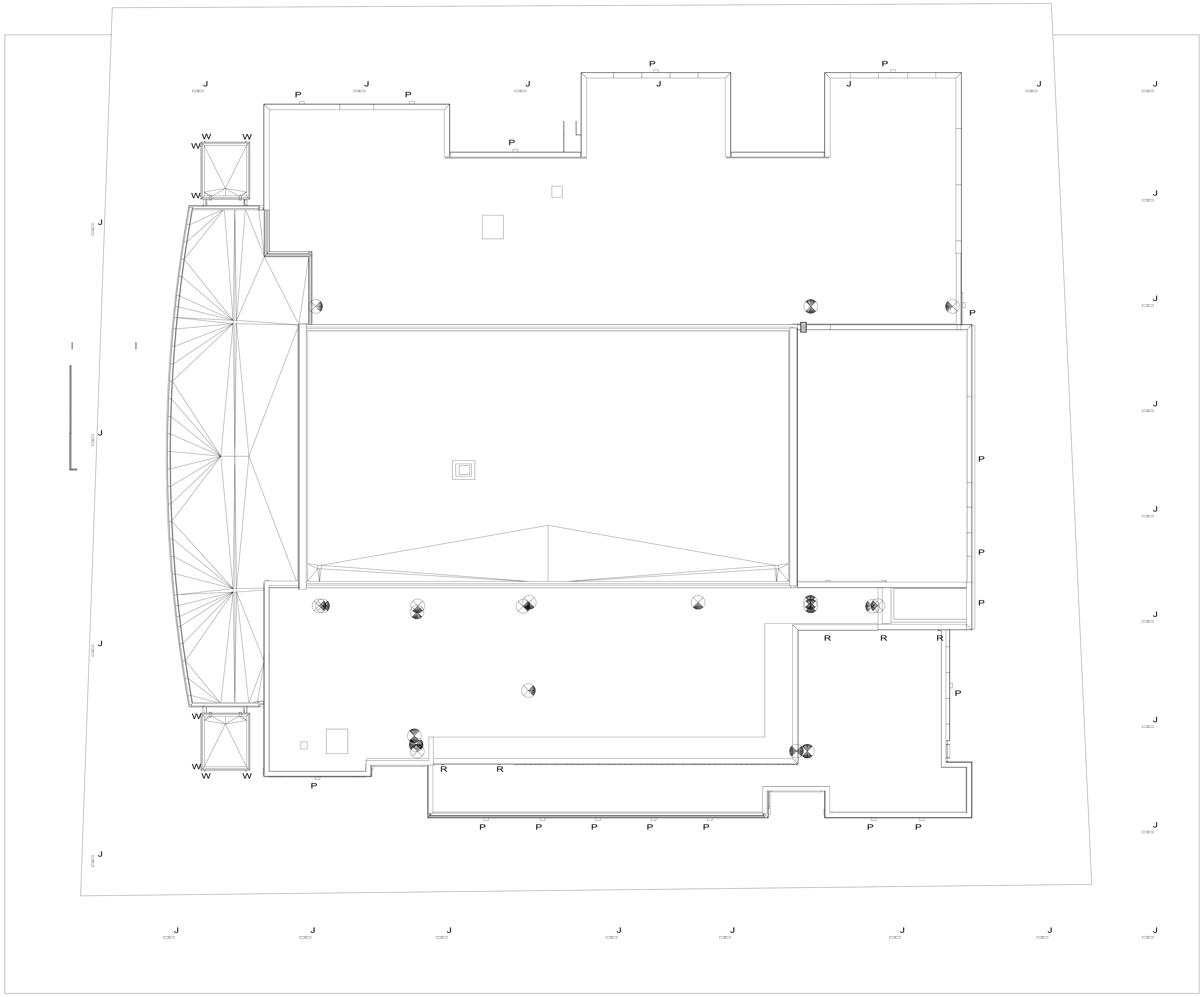
ATUNE

Jack H. Miller Center for Musical Arts

AMENITY SPACE & CONCERT

AEI Team No.	7-2019
Date	02/18/2019
Scale	As indicated

E3.9



1 Site
1/16" = 1'-0"

COMcheck Software Version COMcheck-Web

Interior Lighting Compliance Certificate

Project Information

Energy Code: 2015 IECC
Project Title: Jack H. Miller Center for Musical Arts
Project Type: New Construction

Construction Site:
221 Columbia Avenue
Holland, Michigan 49423

Owner/Agent:

Designer/Contractor:

Additional Efficiency Package(s)

On-site Renewable Energy

Allowed Interior Lighting Power

A Area Category	B Floor Area (ft2)	C Allowed Watts / ft2	D Allowed Watts
1-School/University	71500	0.87	62205
		Total Allowed Watts =	62205

Proposed Interior Lighting Power

A Fixture ID : Description / Lamp / Wattage Per Lamp / Ballast	B Lamps/ Fixture	C # of Fixture	D Fixture Watt.	E (C X D)
1-School/University				
A: 2'6" Long - White: Other:	1	8	50	400
B: 4" Trimless Downlight: Other:	1	221	22	4862
C: 4" Trimmed Wall Wash: Other:	1	88	22	1936
D: 4" Trimmed Wall Wash 30: Other:	1	2	22	44
E: 4" Trimmed Wall Wash 3000k: Other:	1	12	22	264
F: 24" Pendant - 4" Cylinder: Other:	1	13	15	195
G: 4' Linear Strip: Other:	1	106	12	1272
H: 24" x 24" Troffer: Other:	1	95	20	1900
N: 4' Linear Strip: Other:	2	202	35	7070
S: 4' Linear Strip: Other:	1	18	12	216
T: 24" x 24" Troffer: Other:	1	118	35	4130
U: Pendant - Round: Other:	1	13	35	455
V: Pendant - Round: Other:	1	9	35	315
Z: Pendant: Other:	1	70	35	2450
			Total Proposed Watts =	25509

Interior Lighting PASSES: Design 59% better than code

Interior Lighting Compliance Statement

Compliance Statement: The proposed interior lighting design represented in this document is consistent with the building plans, specifications, and other calculations submitted with this permit application. The proposed interior lighting systems have been designed to meet the 2015 IECC requirements in COM*check* Version COMcheck-Web and to comply with any applicable mandatory requirements listed in the Inspection Checklist.

COMcheck Software Version COMcheck-Web

Exterior Lighting Compliance Certificate

Project Information

Energy Code: 2015 IECC
Project Title: Jack H. Miller Center for Musical Arts
Project Type: New Construction
Exterior Lighting Zone 3 (Other)

Construction Site:
221 Columbia Avenue
Holland, Michigan 49423

Owner/Agent:

Designer/Contractor:

Allowed Exterior Lighting Power

A Area/Surface Category	B Quantity	C Allowed Watts /	D Tradable Wattage	E Allowed Watts (B X C)
Walkway >= 10 feet wide	35968 ft2	0.16	Yes	5755
			Total Tradable Watts (a) =	5755
			Total Allowed Watts =	5755
			Total Allowed Supplemental Watts (b) =	750

(a) Wattage tradeoffs are only allowed between tradable areas/surfaces.
(b) A supplemental allowance equal to 750 watts may be applied toward compliance of both non-tradable and tradable areas/surfaces.

Proposed Exterior Lighting Power

A Fixture ID : Description / Lamp / Wattage Per Lamp / Ballast	B Lamps/ Fixture	C # of Fixture	D Fixture Watt.	E (C X D)
Walkway >= 10 feet wide (35968 ft2): Tradable Wattage				
P: Wall Pack: Other:	1	19	65	1235
J: Poles: Other:	1	26	92	2392
R: Step Light: Other:	1	5	14	69
W: Exterior Scone - Black: Other:	1	8	30	240
Y: Exterior Sconce - Brown: Other:	1	4	30	120
			Total Tradable Proposed Watts =	4056

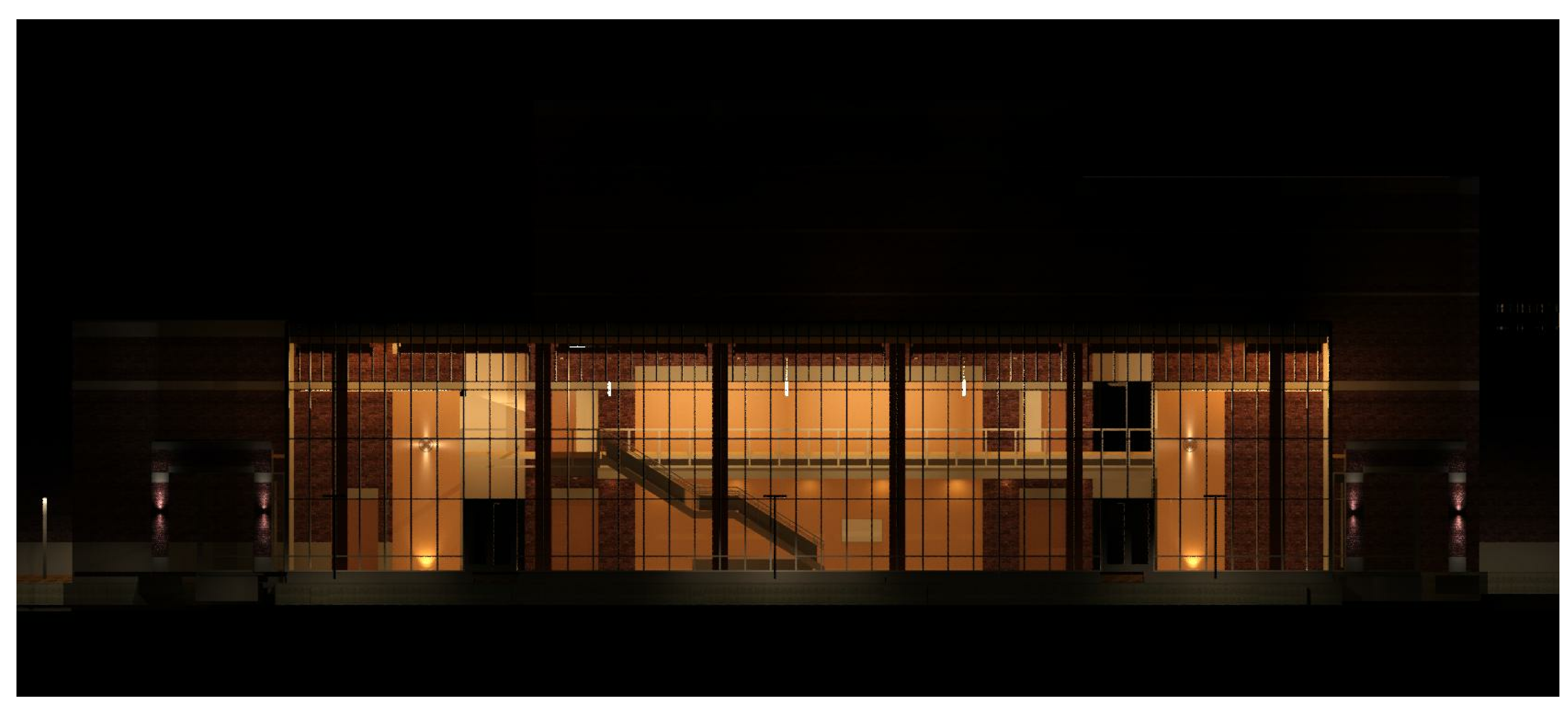
Exterior Lighting PASSES: Design 38% better than code

Exterior Lighting Compliance Statement

Compliance Statement: The proposed exterior lighting design represented in this document is consistent with the building plans, specifications, and other calculations submitted with this permit application. The proposed exterior lighting systems have been designed to meet the 2015 IECC requirements in COM*check* Version COMcheck-Web and to comply with any applicable mandatory requirements listed in the Inspection Checklist.

Name - Title ________ Signature ________ Date ________

3 EXTERIOR LIGHTING - SW
NTS



2 EXTERIOR LIGHTING - ATRIUM
NTS

ATUNE

Jack H. Miller Center for Musical Arts

EXTERIOR LTG AND COMPLIANCE

AEI Team No.	7-2019
Date	02/18/2019
Scale	As indicated

E3.10

CONSTRUCTION EXECUTIVE SUMMARY

Atune worked in an Integrated Project Delivery method to design and build the Jack H. Miller Center for Musical Arts. This process enabled the entire design team to create a versitile, sustainable building working in harmony. The construction team worked with the rest of Atune's design team throughout the pre-construction process to ensure that the proposed design exceeds the expectation of the owner. The team focused on innovative and integrated solutions to the buildings's needs and challenges in acoustical design, performance versatility and community servicability.

TIMBER STRUCTURE

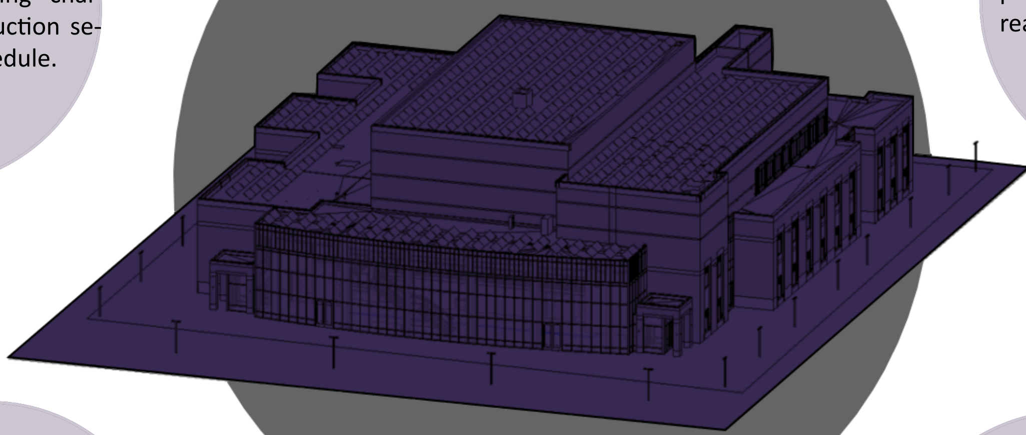
The use of timber for the structural systems was optimized for construction through the use of prefabricated members.

ROOFTOP AMENITY SPACE

Integrated with the construction phasing, the rooftop amenity sapce should easily be constructed, aiding the overall construction schedule.

BOREFIELD

The mechanical borefield proved an interesting challenge to the construction sequence and schedule.



REDPOINT

Live time tracking for on site-personnel productivity and real time response to any potential emergency.

FOUNDATIONS

The step slab foundations and the frost-protected spread footings provided a unique integration opportunity with construction and all disciplines.

LEAN PROCESSES

Delivery's are set to match the phases of construction. Prefabrication is also going to greatly improve the goal for the construction timeline.

SCHEDULE

Schedule was set to have minimal impacts on the college campus during the school semesters.

1.0 PROJECT INTRODUCTION

The Atune construction team is excited to build the Jack H. Miller Center for Musical Arts. Our goal is to provide the best result through schedule coordination, an accurate ongoing estimate and careful delivery of the project. The Atune team holds the interests of the owner at the center of all decisions. We have taken many steps to ensure the schedule, estimate and final product will be of the highest quality. This document will identify our goals and the procedures necessary to achieve them as we move from schematic design through a full set of construction documents, and on through construction.

2.0 ATUNE'S MISSION

Atune's design and construction teams have centered all innovations and processes for the Jack H. Miller Center for Musical Arts around versatility, sustainability, and harmony. The construction methods were developed and centered around these three goals in order to provide Hope College with an efficient timeline, a high-quality structure, and a worthwhile investment. Atune's team approached the Center for Musical Arts project with the Integrated Project Delivery (IPD) method to ensure our teams are in sync with one another and remain focused on the needs and desires of the owner.

3.0 PROJECT CONSTRUCTION GOALS

The Atune team has three main goals to implement for this project. We have chosen to keep a focus on versatility, sustainability and harmony. These three driving factors play into each discipline in a different yet significant way.

3.1 Versatility

It is important for the Jack H. Miller Center for Musical Arts to be completed on or before the project deadline. Our Integrated Project Delivery method allows the Atune construction team to achieve the overarching goal of versatility. Having the entire team in open communication will allow for the adaptability that will be crucial to this project.

3.2 Sustainability

Our goal of sustainability has affected our decisions so that we may have a low environmental impact. Our design incorporates recycled materials and our large amount of prefabricated materials will improve the quality of the building while producing less trash, affecting sustainability both during construction and after building completion.

3.3 Harmony

A low impact on the surrounding campus will keep the jobsite in harmony with the campus. We intend to take up the smallest footprint possible and reduce it over the course of the project. Additionally, the student's schedules will play into a variety of the site logistics decisions.

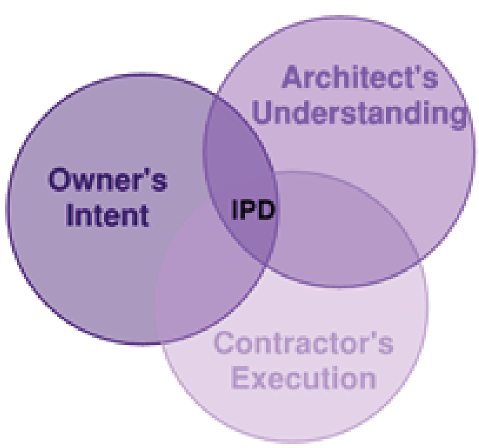
4.0 LEAN CONSTRUCTION

Lean construction is a way to do more with less – less effort, less equipment, less time and less space while providing the client with the desired final product. The two most common ways to implement lean processes is to eliminate waste in a strategic manner and by creating continuous flow through a project. Waste can take on many forms during the construction process; examples include building ahead of time, early deliveries, and building defective parts or sections.

The Atune construction team is implementing a lean organization through a few different methods. To reduce building ahead of time, the Center for Musical Arts will be constructed in phases. Each floor will be delayed slightly behind the floor below so each trade can work their way up through the structure. Deliveries are scheduled to arrive just a few days before they are needed on site. Some of the larger items will be delivered on the day of installation so that they can be rolled off the truck and into position. Prefabrication efforts will reduce the chance of building defective parts or sections. Work completed in a prefabrication setting improves the quality of the work while improving the safety of those doing the work.

5.0 PROJECT DELIVERY METHOD

Atune is utilizing an Integrated Project Delivery method to execute this project. While Integrated Project Delivery (IPD) is still relatively new to the construction industry, we felt it would be the best choice for the Jack H. Miller Center for Musical Arts project for multiple reasons. IPD is a project delivery approach that brings the owner, designer, and contractor together for extensive collaboration through the project.



The biggest identifying factor of a team using an IPD approach is the diverse project team and shared liability. The contract structure takes the project costs, liabilities, and profits of the project and divides them among the members of the team. Team member liability is increased with IPD because the time it takes to design elements of the building can directly impact how soon other members of the team can move forward. The design of the bore field is an example of this increased liability and improved versatility. If the mechanical team starts designing their bores quickly, the construction team can get test bores completed with results back to the mechanical team much faster than if we were to use a different project delivery method. Typically, the mechanical design team would finalize the plans for the bore field and if a problem was found with the test results, they would have to redo the entire design.

It is important when working with universities to have representatives from the school involved in decision making throughout the project. With IPD, the owner is made an integral part of the project team from the very beginning. This allows us to consult with them on design decisions early in the process and then continues to keep the representatives well informed up to the date of substantial completion. Involving the staff and faculty of Hope College is very important to the Atune team. We will be consulting with staff members who will frequent the Jack H. Miller Center for Performing Arts so their thoughts on the design can be considered. This will ensure that the final product will be a building they find both functional and enjoyable.

Keeping the owner involved during the entirety of the project, in addition to having a project team that consists of multiple specialized members, has a list of benefits as well. Diversified teams result in faster construction, meaning shorter project durations, leading to a greater cost savings. Well integrated teams open the lines of communication for open collaboration during the design and construction of a project. When all the disciplines work together during the design process, there is a reduction of errors and less need for redesign of the building. This is especially important for the Jack H. Miller Center for Musical Arts due to its high level of specialized features.

6.0 INTEGRATED DESIGN WITH CONSTRUCTION

Atune's construction team has worked closely with the structural, mechanical, and electrical teams to integrate innovative designs throughout the entire project. The construction team had a differing approach than the other teams, in that we had to bring a sense of reasonable constructability to all designs and processes on site. Our primary focus was on the foundations, timber structure, bore field, Roo!op Amenity Space, Redpoint Positioning Technology, project schedule, and Lean construction processes.

Site coordination was a major concern for all large systems. Our approach was to phase the installation of the spread footings, grade beams, slabs-on-grade, and timber CLT panel structural portions of the building and the geothermal bore field on the east side of the building. With the addition of the mechanical bore field, our already small site was even more restricted due to not being able to impose significant loads on the bore field a!er installation. Using an integrated approach allowed the Atune team to develop a plan to streamline the design of the bore field. The mechanical team has begun a preliminary design for the bores. The construction team has scheduled a date of May 15, 2019 for the mechanical team to bring out a consultant to test the soil conditions in the area where the bore field will be located. The results from the test bore will be delivered to the mechanical team in order to verify the validity of their design. This ability to finalize designs a!er site work has begun is a large reason the Atune team has found Integrated Project Delivery so successful for this project.

The Roo!op Amenity space was another area of logistical concern. A!er the structural portion of this space is complete, all systems will be placed with extreme caution due to the reduced free area around the exterior of the building. These systems and their installation required coordination between the construction, structural, and mechanical teams, but also with the overall project schedule.

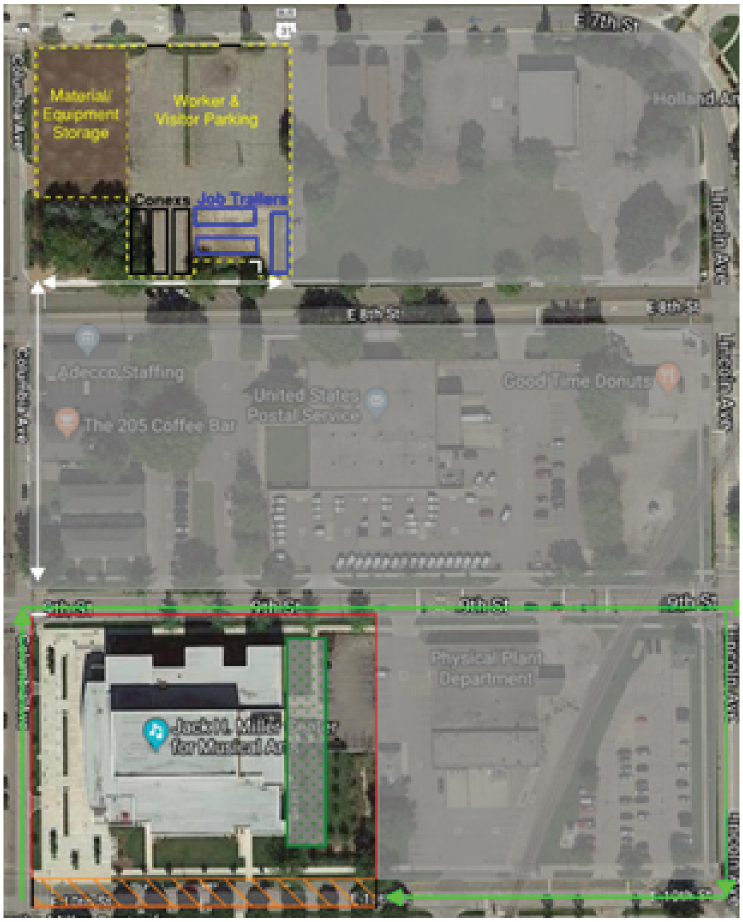
The management processes we pursued will be key factors in this project's success. The decision to utilize Redpoint Positioning Technology for all crew members was selected to provide the most efficient and safe construction project for everyone involved. This efficiency is key for completing the project on time. Our schedule is a living document that will be coordinated with the subcontractors awarded to this project. This not only ensures all are aware of their upcoming deadlines, but also puts responsibility on all teams involved. Our schedule is one of the key features of our lean processes. The prefabrication portion of our lean processes required immense integration with all of the Atune design teams. Each team is able to prefabricate a portion of their work to reduce the overall project schedule. These processes do not solely benefit the construction team but will ensure a higher quality final project for Hope College and its students, faculty, and visitors. Lean processes are further defined in 4.0 Lean Construction.

7.0 PLANNING

7.1 Site Logistics and Management

Due to the additional danger of having college students walking near the site for the majority of construction, site security, delivery coordination, and student safety are of utmost importance. Our team intends to demolish all sidewalks, redirect pedestrians to open walkways, and install security fencing along all streets and to the east of the site, between the Physical Plant Department, as shown (in red, below). In order to reduce the impact deliveries w ill have on the campus, the portion of 10th street directly next to the site will remain closed for deliveries. This closure will still allow workers to access the Plant to the east of the site and additional traffic will not have to see any major detours. Trucks will maintain a clockwise route around the site (shown in green).

Even before the installation of the bore field and the rainwater collection tank, there is limited space available on site to accommodate equipment, materials, and personnel. Our team will utilize just-in-time deliveries, off-site prefabrication, and daily communication to ensure crews are working safely and efficiently. All office and storage trailers will be parked in a vacant lot one block north of the site, along with worker and visitor parking and any stored materials and equipment. This lot would be rented from the city of Holland, Michigan for a negotiated price in the range of $900 per month. Workers would follow the designated path from the jobsite to the trailers (in white). Enlarged images of both the north lot and the jobsite are located on page C2.2.



7.2 Crane Selection

For the crawler crane, a Manitowoc 14000 Series 2 No. 76 was selected based on the load and reach requirements for this project. This is a 220-ton crane with a maximum reach radius of 240 feet. The crane will be primarily placed on the south side of the site where it can unload trailers as needed and place materials relatively easily on the east and west sides of the site. According to the crane specifications, the body is 9'-10" by 10'-6" and is set on two crawlers that measure 27'-3" long by 5'-1" wide, setting the body 3'-9" off the ground. This crane will easily fit between the east, south, and west sides of the site, allowing for the option to move around the site to place the foundations and CLT panels. Once the structure is complete, the crane can be downsized to accommodate the smaller loads of the solar panels and HVAC equipment. During operation, proper swinging and maneuvering techniques will be critical to ensure no contact is made with completed work, site fencing, and any surrounding material and personnel. This crane was selected for its ability to reach the center of the building from any side and its capability of lifting the heaviest structural component (CLT panels). Documentation of the selection criteria can be found on C2.3.

7.3 Prefabrication and BIM

Models of all mechanical, electrical, and structural systems will be used to pre-fabricate materials prior to installation. This model will be updated at least bi-weekly with changes made on site to ensure an accurate representation of systems are being placed. A representative from each subcontractor on site will be required to attend these coordination meetings to ensure all crews are aware of any potentials conflicts and can address them before they become costly fixes. This helps with site logistics due to the minimal storage space available on site. Pre-fabrication also allows for a higher quality product to be installed with an increased safety factor. These two benefits are direct results of the controlled, consistent pre-fabricated environment.

The Atune construction team is working with our design counterparts to pre-fabricate their systems in order to speed up the construction process as much as possible. Electrical prefabrication consists of the solar panel racks and the conduit runs and racks in the building. Mechanical is able to prefabricate the hydronic runs, snow melt system piping, piping for the plumbing system, fire suppression sprinkler piping, and the majority of the ductwork. The complexity of the structural design will require pre-fabricated cross laminated timber panels for the various auditoriums and concert halls, the wood zipper trusses highlighted in the atrium, and the wood portion of the composite floor system.

Each trade will be responsible for storing their prefabricated materials before they are shipped to the site. To reduce the amount of deliveries sitting on site, we intend to receive necessary materials within 2-3 days of installation. This means that prefabricated materials will not be laying out, thus affecting the productivity of other tasks happening onsite.

With the increased amount of wood sourced materials on site, additional precautionary measures will be implemented to protect these elements. All members arriving on site will be properly protected for shipping, but this will not be sufficient enough for the time period between being installed and before the building envelope is enclosed. Our team is aware of the potential risks of exposure to moisture and sunlight and we are prepared to protect the structural members until 100% dry-in is achieved.

8.0 SAFETY

8.1 Personal Protective Equipment

Safety is of high priority on all Atune project sites and will be a site mentality of all trades on this project. Our team will work closely with all contractors and visitors to be sure everyone is aware of hazards and our safety objectives.

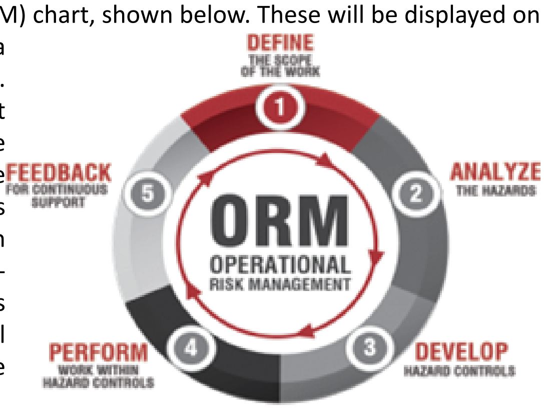
Our means of safety begin with individual worker safety and their equipment. This will include a site wide requirement of the proper personal protective equipment as required by the Occupational Safety and Health Administration (OSHA). This personal protective equipment includes hardhats, protective eyewear, high visibility vests, safety gloves, and work boots that are adequate for construction work.

All safety vests used on site will be equipped with Redpoint Positioning technology, being utilized in the image to the right. This innovative device utilizes real-time location and navigation to quickly and accurately monitor employee's safety on the jobsite. Managers and superintendents will be able to use a tablet to view locations of all personnel and see if they are being both productive and safe, demonstrated in the image above. After a safety barrier has been physically placed around a restricted area, the supervisors are able to draw the same perimeter on the tablet, thus allowing the Redpoint device in the safety vest to both visually and audibly notify the user if they enter the area. This technology has and will continue to ensure our company maintains a desirable ENR rating, but most importantly allows all of our crew members to return home safely.

Our building is primarily made of wood, meaning there is significantly less concrete than on traditional construction projects. However, there will still be times when we must drill into the concrete that does exist in our structure. This presents a safety concern of exposing employees to silica dust. To combat this hazard, each employee working is areas where silica dust is a concern will be provided with a dust mask. In addition, any employee actively drilling into concrete will have the option to use a variety of methods to wet down the concrete while drilling to prevent an excess product of dust.

8.2 Safety Meetings and Walks

The Atune construction team expects each trade to conduct daily safety meetings. For their convenience, subcontractors can choose which method they would like to implement. Each employee may conduct a daily safety analysis worksheet that they must keep on or around them for the entirety of the work day. This worksheet would have spaces to determine what tasks a person will be completing during the day, safety risks associated with those tasks, and proper measures to prevent any incidents. The other option is for tradesmen to gather in groups in the morning to complete an Operational Risk Management (ORM) chart, shown below. These will be displayed on marker board in a central location. The ORM chart serves the same purpose as the safety analysis worksheet but can be more convenient when groups of people are all working on the same tasks.



Our safety measures will not be limited to each worker's individual awareness. Our construction team will have weekly safety meetings with all onsite crews in attendance. These meetings will create a unanimous understanding regarding deliveries, schedule changes, and any activity affecting other trades. Additionally, our site dedicated "Safety Manager and Site Coordinator" will walk the site once per week with at least one manager or supervisor from each subcontractor on site to identify and intercept any safety violations. All violations will be documented and the subcontractors responsible will be notified. After one warning, a second offense will result in the worker(s) receiving a one (1) day suspension and a third offense will be cause for project reassignment. These daily walks and weekly meetings will help ensure a safe and orderly construction site, thus minimizing unnecessary delays or accidents.

8.3 Natural Disaster and Emergency Response

Upon arriving on site, all subcontractors will be equipped with a Natural Disaster Response Plan. The preliminary Response Plan will inform all crews, if time allows, to secure any equipment and materials and seek shelter in one of the college's site adjacent designated shelter areas of Dykstra Hall, Gilmore Hall, Phelps Hall, or the Martha Miller Center. The evacuation and take-cover plans will also be lined out in the Atune office trailer. These plans will be updated throughout all phases of construction to ensure the safety of all personnel on site remains a top priority.

In the event of an onsite emergency, Emergency Response Plans will also be distributed to subcontractors upon their arrival to the site. Locations of fire extinguishers will be clearly marked on site and in the Response Plan. Procedures for directing emergency vehicles and personnel on site and responsibilities of each trade will also be included.

Our Redpoint Positioning technology will come into play in the event of an emergency. Managers and superintendents will be able to quickly see if all crew members made it to safety. They will also be able to inform any emergency response teams of workers in precarious locations.

8.4 Public Safety

Due to the site being located on an active college campus, the safety of student, employees of the college, and the general public is a top priority for the Atune construction team. We have accomplished this by securely fencing in our jobsite and designated storage and parking lot, installing security cameras at fencing, and scheduling trucks during low populated times.

College students and the general public are notorious for being curious of construction project. In order to protect the public's safety and protect our equipment and materials, a temporary chain link panel fencing system will be built around the jobsite and parking area (red line and yellow line, respectively, on site plan). We will also install a privacy screen on the fencing to both reduce the amount of wind for our crews and deter any potential curious vandals. To ensure student's safety and ensure our own protection, four (4) security cameras will be installed at the jobsite and at the north lot.

As stated in 7.1 Site Logistics and Management, with the many trucks and large pieces of equipment scheduled to enter and leave our site, we will be closing the portion of 10th street directly next to the site. It will be the responsibilities of the subs to notify our on-site management team of any incoming deliveries so our "Safety Manager and Site Coordinator" can open and immediately secure the site gates for the trucks. By keeping this responsibility with our team, we are able to maintain a level of integrity and consistency that ensure the security of our site. Signs will be posted at frequent intervals both along the site fencing and on the nearby streets to ensure all in the area are aware of the large trucks in the area.

9.0 SITEWORK

9.1 Hauling of Materials

The greatest soil disturbances will be for the fifty (50) geothermal bores on the east side of the building and the rainwater collection tank on the south side. Trucks will be loaded with the cut material either on site or in the blocked off section of road. They will then follow the path designated in green on the site logistics map. The soil excavation for the foundations and auditorium seating will be a relatively minor component of the construction process, but it is imperative that it is still addressed. Any soil that is not used for fill will be removed from the site while following city protocol. There are no nearby buildings that will be structurally influenced by our excavations and any active excavations will be properly banked and marked via OSHA standards.

All incoming and outgoing trucks will be scheduled either at the beginning of the work day (7am-9am) or end of the work day (1pm-3pm). This will be in an attempt to occupy campus and city roads when the fewest number of students are present. Our team will also coordinate with Hope College to ensure our site is not producing heavy traffic at the same time as any collegiate events.

9.2 Dewatering and Erosion Control

According to the Atune structural team, perimeter foundations are to be 42 inches deep. With the water table predicted to be anywhere between 8.8 feet and 12.3 feet, our excavations should not need dewatering caused by the water table. However, precautions will be in place in the form of pumps in the case of excessive precipitation.

The construction team will implement erosion control measures on site to reduce sediment run-off to other parts of campus. Erosion control methods include, but are not limited to, erosion control blankets and straw bales near the perimeter of the site.

9.3 Work Sequences

To ensure we stay productive and on schedule during the foundation and structural durations, we will be phasing the spread footing, grade beam, and slab-on-grade pours as well as phasing the lifting of the cross laminated timber (CLT) panels into place. In general, our pours will work from the north to the south, starting in the north-east corner. The driving factor in this decision making was the laydown area needed for the tilt-up CLT panels. Due to the restricted space to the north of the site, we are starting with the northern rooms and laying the panels to the south of where they will be placed. When dealing with the pours, activities will progress seamlessly from one area to the next. This will ensure any skilled labor will remain on site until their task is done and will be able to remain productive the entire time. Our phasing will also enable other activities to continue while the concrete is curing. Our phasing sequence schedules and drawings are represented on pages C3.7 through C3.10.

10.0 SCHEDULE

10.1 Process

The success of a construction project is determined by many things, including completion within a certain time constraint. A construction schedule is the main driver of the construction process. The schedule determines the time logistics for the project as a whole and is critical for a successful project. When determining the schedule for a project, many factors must be considered. This includes not only the actual duration of the work to be performed, but also the lead times for certain materials, equipment, and pre-construction services.

Consideration of the major components of the project will be effective in creating the initial schedule for the Jack H. Miller Center for Musical Arts. After these areas are considered, the sub-contracted and specialty scopes of work will be accounted for by utilizing pull planning, just-in-time deliveries, and a last planner system. These methods of scheduling will be helpful in minimizing the duration of the project, as well as reducing costs by way of timely deliveries.

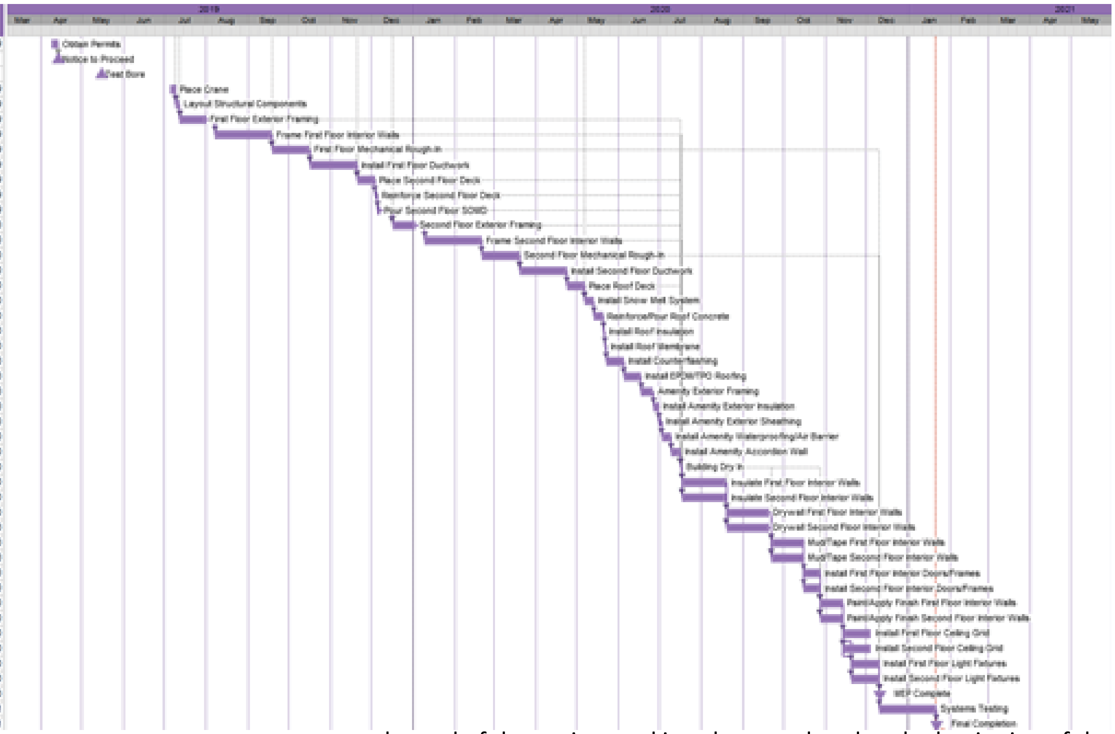
A way for the construction team to understand if they are staying on schedule is to utilize milestones. Milestones are not events within the schedule but are representations of the completion of certain aspects of the project. Some milestones that are significant in the completion of the project include the start of prefabrication, building dry-in, and substantial completion. It will be helpful for managers of the project to make these milestones part of their daily, weekly, and monthly goals. This will keep everyone within the same time-frame from the beginning of construction until the completion date.

An important thing to note about our current schedule is that it is a preliminary estimate to be used while soliciting bids from and selecting subcontractors. It is based off prior knowledge and historical data. Once contracts have been awarded to the subcontractors, a pull planning meeting can be held to determine the final project schedule that each discipline gets to approve. Pull planning is a scheduling method that works backwards from completion to create a faster and more accurate project schedule. To keep the project running on track, the same major milestones will need to be reached either at or before the dates currently set. Since each trade will have more knowledge about the actual durations of tasks, some of the smaller items can be shifted to reflect a more accurate schedule.

10.2 Summary

The critical path of the Center for Musical Arts consists of the events necessary to complete the project within the designated time constraint. This path relies on the major milestones of the project. The critical path is included in the figure on the next page. The complete project schedule can be found on pages C3.2 through C3.6.

ID	Description	Original Duration	Start	Finish
110	Obtain Permits	5	04/08/19	04/12/19
115	Notice to Proceed	0	04/13/19	
145	Test Bore	0	05/15/19	
170	Place Crane	2	07/05/19	07/08/19
225	Layout Structural Components	3	07/09/19	07/11/19
230	First Floor Exterior Framing	13	07/12/19	07/30/19
250	Frame First Floor Interior Walls	30	08/07/19	09/17/19
285	First Floor Mechanical Rough-in	20	09/18/19	10/15/19
305	Install First Floor Ductwork	25	10/16/19	11/19/19
310	Place Second Floor Deck	9	11/20/19	12/02/19
315	Reinforce Second Floor Deck	2	12/03/19	12/04/19
320	Pour Second Floor SOMD	2	12/05/19	12/06/19
325	Second Floor Exterior Framing	13	12/16/19	01/01/20
350	Frame Second Floor Interior Walls	30	01/09/20	02/19/20
410	Second Floor Mechanical Rough-in	20	02/20/20	03/18/20
420	Install Second Floor Ductwork	25	03/19/20	04/22/20
430	Place Roof Deck	9	04/23/20	05/05/20
445	Install Snow Melt System	5	05/06/20	05/12/20
450	Reinforce/Pour Roof Concrete	5	05/13/20	05/19/20
455	Install Roof Insulation	1	05/20/20	05/20/20
460	Install Roof Membrane	1	05/21/20	05/21/20
465	Install Counterflashing	9	05/22/20	06/03/20
475	Install EPDM/TPO Roofing	9	06/04/20	06/16/20
480	Amenity Exterior Framing	7	06/17/20	06/25/20
485	Install Amenity Exterior Insulation	2	06/26/20	06/29/20
495	Install Amenity Exterior Sheathing	2	06/30/20	07/01/20
500	Install Amenity Waterproofing/Air Barrier	5	07/02/20	07/08/20
605	Install Amenity Accordion Wall	5	07/09/20	07/15/20
505	Building Dry In	1	07/16/20	07/16/20
510	Insulate First Floor Interior Walls	23	07/17/20	08/18/20
515	Insulate Second Floor Interior Walls	23	07/17/20	08/18/20
620	Drywall First Floor Interior Walls	23	08/19/20	09/18/20
625	Drywall Second Floor Interior Walls	23	08/19/20	09/18/20
705	Mud/Tape First Floor Interior Walls	18	09/21/20	10/14/20
710	Mud/Tape Second Floor Interior Walls	18	09/21/20	10/14/20
730	Install First Floor Interior Doors/Frames	8	10/15/20	10/26/20
735	Install Second Floor Interior Doors/Frame	8	10/15/20	10/26/20
750	Paint/Apply Finish First Floor Interior Wal	13	10/27/20	11/12/20
755	Paint/Apply Finish Second Floor Interior \	13	10/27/20	11/12/20
775	Install First Floor Ceiling Grid	15	11/13/20	12/03/20
780	Install Second Floor Ceiling Grid	15	11/13/20	12/03/20
790	Install First Floor Light Fixtures	15	11/19/20	12/09/20
795	Install Second Floor Light Fixtures	15	11/19/20	12/09/20
810	MEP Complete	0		12/09/20
815	Systems Testing	30	12/10/20	01/20/21
855	Final Completion	0		01/20/21



10.3 Milestones and Durations

Some important things to note in the schedule are the start date, end date and a variety of milestones. We will gain access to the site on April 13, 2019. Construction begins on April 17, 2019. This date will follow several items including the completion of pre-construction services, acquiring the notice to proceed and proper permits, gaining access to the site, and receipt of a signed contract.

One large benefit to using an Integrated Project Delivery method is that the construction documents do not have to be at 100% before work can begin on site. There is a list of tasks that can be completed before construction begins on the structure, meaning the design team can continue finalizing their plans while preliminary work is being completed on site.

Project completion is dependent on a series of milestones. Some of these milestones include the notice to proceed, building dry in, and substantial completion. Each milestone plays a key role in the on-time completion of the project. A good understanding of the critical path allows the Atune construction team to prioritize the tasks that require more attention than others in the schedule. The tasks that fall on the critical path directly impact our ability to complete this project on time. Many of our milestones will also be items on the critical path.

There is a handful of major milestones between the beginning of construction and substantial completion. These include the completion of the structure, and the completion of the building envelope. There is also a date marking when the mechanical, electrical, and plumbing systems will be complete, and when all the finishes will be installed.

Substantial completion of the project will happen on December 24, 2020. This is followed with a punch list that will be determined near the end of the project and is to be completed at the beginning of the building's operation. The construction team will not impede with use of the arts center by coordinating with the Hope College staff during this time.

It can be noted that the project is set for final completion on January 20, 2021. The Atune construction team set a goal to impact the students and faculty of Hope College for the least amount of time possible. The team will be on campus for one month during the spring semester of 2019, the entire 2019-2020 school year, the fall semester of 2020 and the project will reach substantial completion before school starts again in the spring of 2021. The Jack H. Miller Center for Musical Arts will be fully operational at substantial completion. The punch list and minor activities leading to final completion will not have an impact on the use of the building at the start of the semester.

11.0 PROJECT BUDGET AND CONSTRUCTABILITY

11.1 Process

The estimate take-off for the newly proposed Jack H. Miller Center for Musical Arts on the Hope College Campus in Holland, Michigan is comprised of historic averages of similar auditoriums and 2-3 story college classrooms, as well as detailed research for unique items. Bluebeam Revu, Microsoft Excel Spreadsheets, and RS Means Construction Cost Data books were utilized in creating this estimate.

The Atune construction team conducted Level 1 and 2 estimates before reaching the final Level 3 estimate presented. Our Level 1 estimate used unit costs from Square Foot Costs RSMeans Data for both the classroom and auditorium spaces. These unit costs of $164.2/sf and $190.45/sf, respectively, result in an estimate of **$11,974,116**. This was identified as a low budget for this project but gave our team a starting point for a more refined estimate. We then took this cost and added 50% to account for the larger overall size and complexity of our project. This gave us a Level 2 Estimate of **$17,961,174**.

Our Level 3 estimate will include general conditions and preconstruction fees. General conditions will include the indirect costs our team will sustain from this project. These fees will include mobilization, project and administrative staff wages, dumpsters, storm water pollution prevention plans, company vehicles, and utilities needed for job trailers. The 5 percent preconstruction (precon) fees indicated on our estimate is the cost associated with the six months of preconstruction work our four Atune teams spent preparing for the construction of the Center for Musical Arts.

11.2 Grand Total

Our estimate includes costs for first and second floor collegiate classroom space, auditorium space, as well as labor, overhead, and preconstruction costs. The Grand Total of the Center for Musical Arts in Holland, Michigan is:
NINETEEN MILLION, THREE HUNDRED SIXTY-SEVEN THOUSAND, THIRTY DOLLARS. **($19,367,030)**

11.3 Alternates

Alternates have been determined based on the integrated design completed by the Atune Design Team. These specific systems can be incorporated with the owner's discretion on a "pick and choose" basis. These alternates have been priced as follows:

Alternate #1: Acoustics	**($40,000.00)**
Alternate #2: Wood, Timber, Engineered Wood	**($4,771,016.50)**
Alternate #3: Roof Top Amenity Space	**($930,516.00)**

The Grand Total with the Add Alternates for the Center for Musical Arts in Holland, Michigan is:
TWENTY-FIVE MILLION, EIGHTY THOUSAND, SIXTY-THREE DOLLARS. **($25,080,063)**

11.4 Summary

Classroom Level 2	Total =	$	5,509,968
Classroom Level 1	Total =	$	6,298,965
Auditorium	Total =	$	3,997,388
New Designs Applicable to Entire Building	Total =	$	3,560,709
Alternate #1	Total =	$	40,000
Alternate #2	Total =	$	4,747,517
Alternate #3	Total =	$	925,516
Jack H. Miller Center for the Musical Arts =		$	19,367,030
Grand Total Including Add Alternates =		$	25,080,063

12.0 PROJECT CHALLENGES

12.1 Acoustics

To improve the acoustics in both the auditorium and in the faculty studios, Atune is implementing moving panels and scrap wood walls. The largest schedule consideration for the moving panels include preordering the hardware and motors required to hang them on the walls and ceiling.

The scrap wood walls will take wood left over from other aspects of the site to create walls that are both visually appealing and improve acoustics in the space they are in. The Atune team is placing a large emphasis on the recyclability of this feature. The wood walls will not only reduce construction waste but will also help to incorporate more wood into the overall project.

12.2 Wood, Timber, and Engineered Wood

The Atune team set a goal to achieve a building design made of at least 25% wood. The current design totals approximately 90% wood in both structural and acoustical applications. There will be timber incorporated in the walls and floors through the use of cross laminated timber panels, pictured above. The CLT walls will go up the same way traditional concrete tilt up walls are placed and the connectors between panels are easy to install. The only major construction consideration for these panels is the additional weight of the wood compared to concrete.

Composite flooring made from wood panels and concrete will be implemented in many areas of the building. Longer spans can be achieved by using these wood panels. The addition of concrete with the wood panels allows for thinner wood components, thus giving us a reduced total amount of wood. This allows us to provide this alternate at a lower fee as opposed to offering an entirely wood floor system. A scheduling element to consider is that the shear connectors are produced by a company in Germany, so there will be a significant lead time on those items. However, once they arrive, they can be used in the prefabrication process of the floor panels.

Special precautionary measures will need to be taken with the wood elements. They will be shipped to the site with protective shipping materials, but these will not be sufficient for protecting the wood from the elements before they have been installed and before the building envelope has been completed. The Atune team is aware of the risks posed by exposure to moisture and ultraviolet radiation and we are prepared to protect our structural elements until the building has reached 100% dry in.

Making the columns out of wood will increase the column size compared to standard steel columns but adding the carbon fiber around the members in the atrium will reduce the size required of typical wood columns. Additionally, the construction team is aware of the unique installation challenges associated with wrapping the columns in carbon fiber such as the special epoxy to secure the wrap, and properties of the carbon fiber itself.

12.3 Roof Top Amenity Space

The Atune construction team intends to treat the roof top amenity space as a third floor where the schedule is concerned. Construction will occur simultaneously on the first and second floors, with the second floor having a delay behind the first floor. To maintain a substantial completion date of December 24, 2020, the amenity space will be delayed behind the second floor, but due to its smaller size this space can be completed in a much shorter time.

13.0 LESSONS LEARNED

Through the design of the Jack H. Miller Center for Musical Arts, the construction team has taken away a few lessons that can be applied to future design projects. The biggest lesson we are taking away is that design is not a linear process - it requires a series of iterations. During the design changes, it is important to have constructability reviews. The construction team was able to open paths of communication between the disciplines so questions could be both asked and answered in a way that kept the entire Atune team on the same page. With the significant number of innovative systems in our design, many systems needed to be to assessed for feasibility and potential constructability challenges. Operating under an Integrated Project Delivery method assisted tremendously with the amount of communication this project required.

14.0 CONCLUSION

The Jack H. Miller Center for Musical Arts project presented the construction team with a variety of opportunities to test our knowledge of pre-construction and building processes. Communication between the construction team and the design team was vital to project success. It was critical for each team member to understand the possibilities and limitations of design and construction. The structural elements are a good example of a system with both wide possibilities and strict limitations. Open communication with the design team allowed all parties to come to an understanding of the true time and resource commitment of the wood system.

Through team collaboration, the Atune team will deliver an attractive, functional, and sustainable final product. The construction team partnered with the design teams for the Jack H. Miller Center for Musical Arts and are determined to provide Hope College with the most complete and satisfying project possible. We will exceed the expectations of the owner through proper project planning, task coordination, and open communication between owner, designer, and contractor.

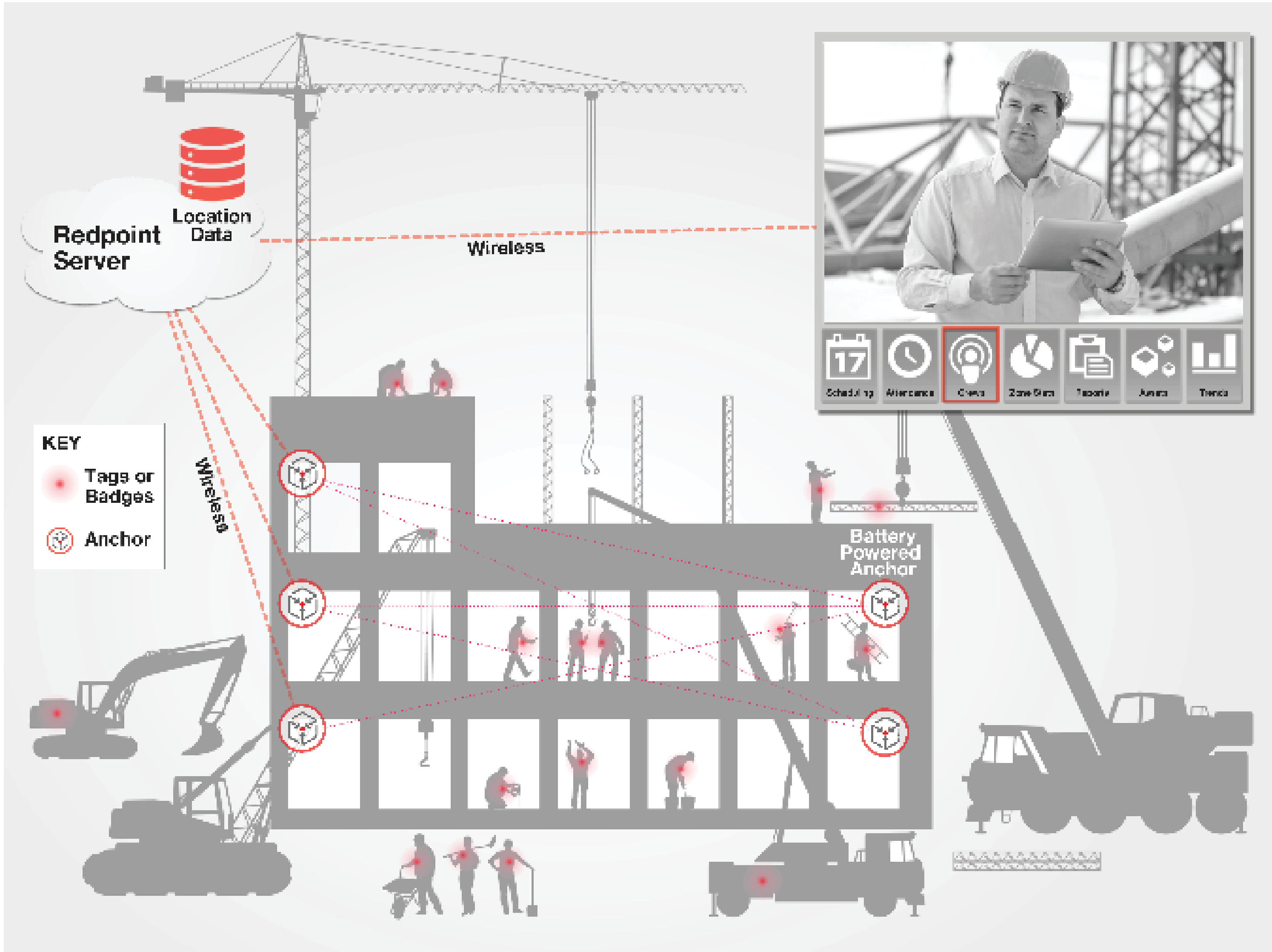
DECISION MATRIX & SYSTEM SELECTIONS

CONSTRUCTION DECISION MATRIX

CONSTRUCTION DECISION MATRIX	VERSATILITY				SUSTAINABLILITY				HARMONY				
PROJECT DELIVERY METHOD	FLEXIBILITY IN USE	ROOM FOR GROWTH	ACOUSTICALLY ADAPTABILITY	AESTHETIC EFFECTIVENESS	LONG LIFESPAN	MAINTNANCE COST	ENVIRONMENTAL IMPACT	EDUCATION TO PUBLIC	MULTIPURPOSE DESIGN	SCHEDULE	BUILDING FACADE	CONSTRUCTABILITY	
WEIGHT	5	4	5	3	5	4	3	4	5	4	4	3	
CONSTRUCTION MANAGEMENT AT RISK	10	8	20	15	15	12	3	4	10	12	8	9	126
CONSTRUCTION MANAGEMENT AGENCY	15	8	25	3	15	12	3	4	25	4	4	15	133
DESIGN BUILD	15	16	25	15	15	16	15	20	10	8	20	15	190
INTEGRATED PROJECT DELIVERY	25	20	25	15	25	20	15	20	25	20	20	15	245

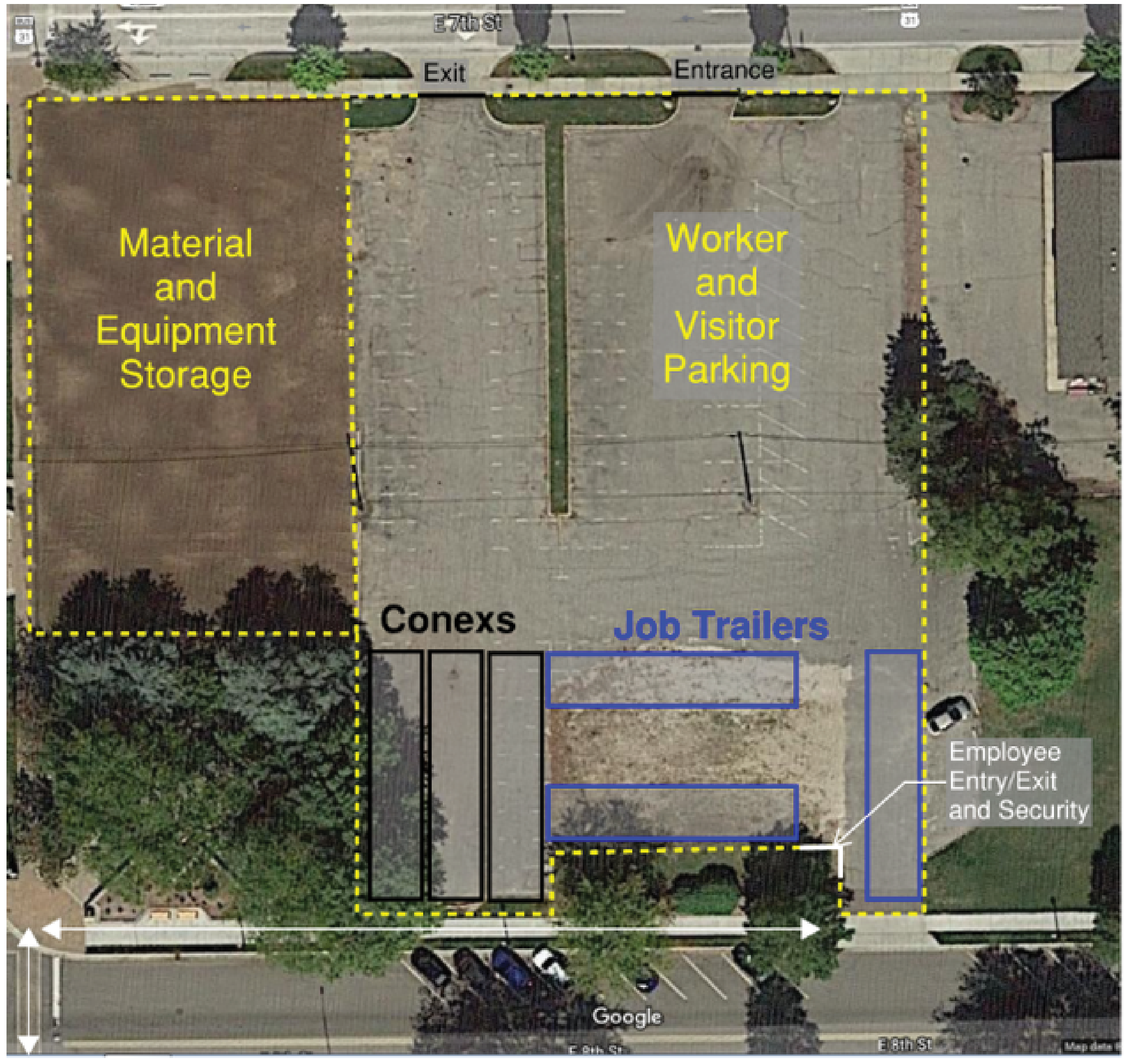
REDPOINT TECHNOLOGY

REDPOINT TECHNOLOGY IS UTILIZED TO ENSURE SAFETY AND PRODUCTIVITY OF OUR CREWS ONSITE. THIS TECHNOLOGY UTILIZES A WIRELESS SERVER TO CONNECT THE TRACKERS IN THE SAFETY VESTS TO THE REDPOINT SERVERS LOCATED THROUGHOUT THE BUILDING AND TO THE MANAGER'S TABLET.

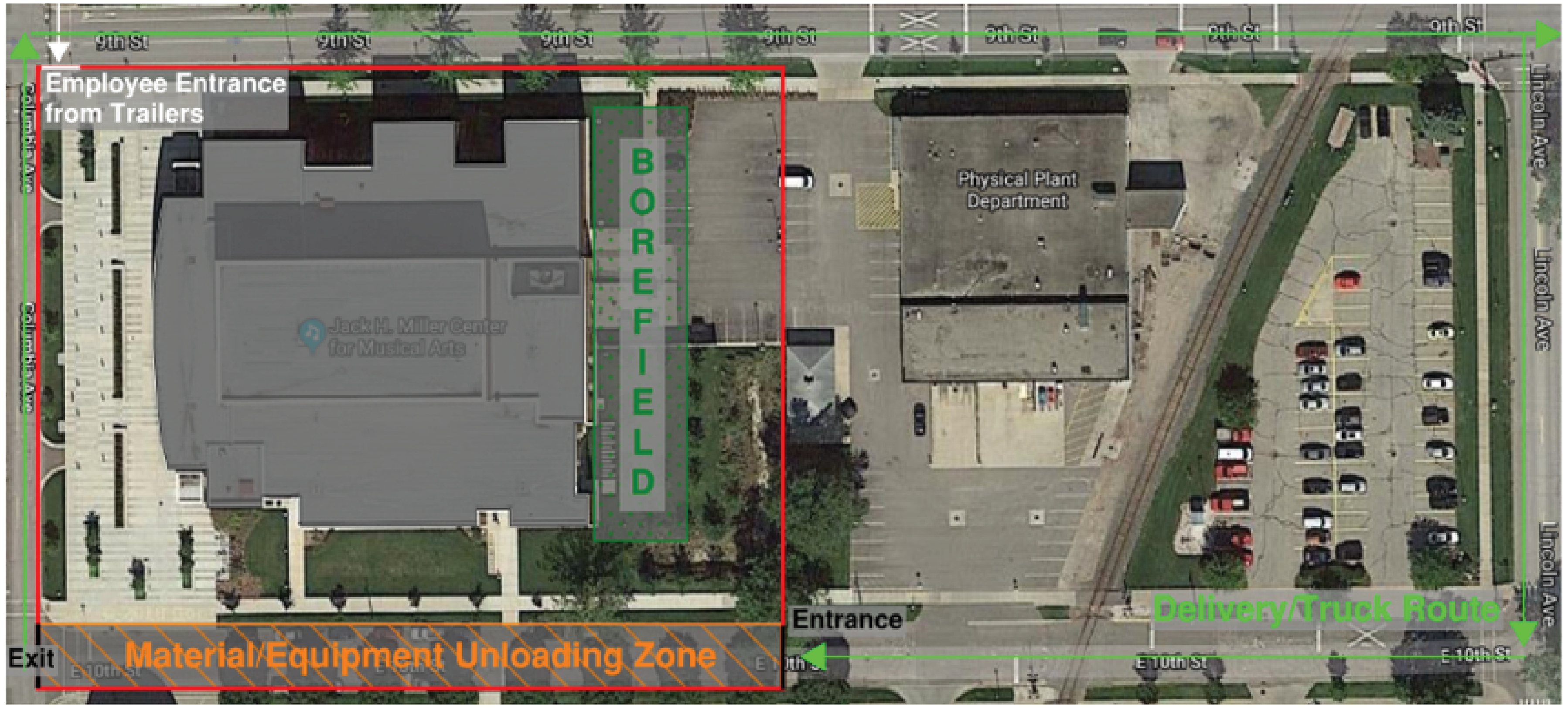


SITE LOGISTICS - ENLARGEMENTS

NORTH PARKING LOT



PROJECT SITE

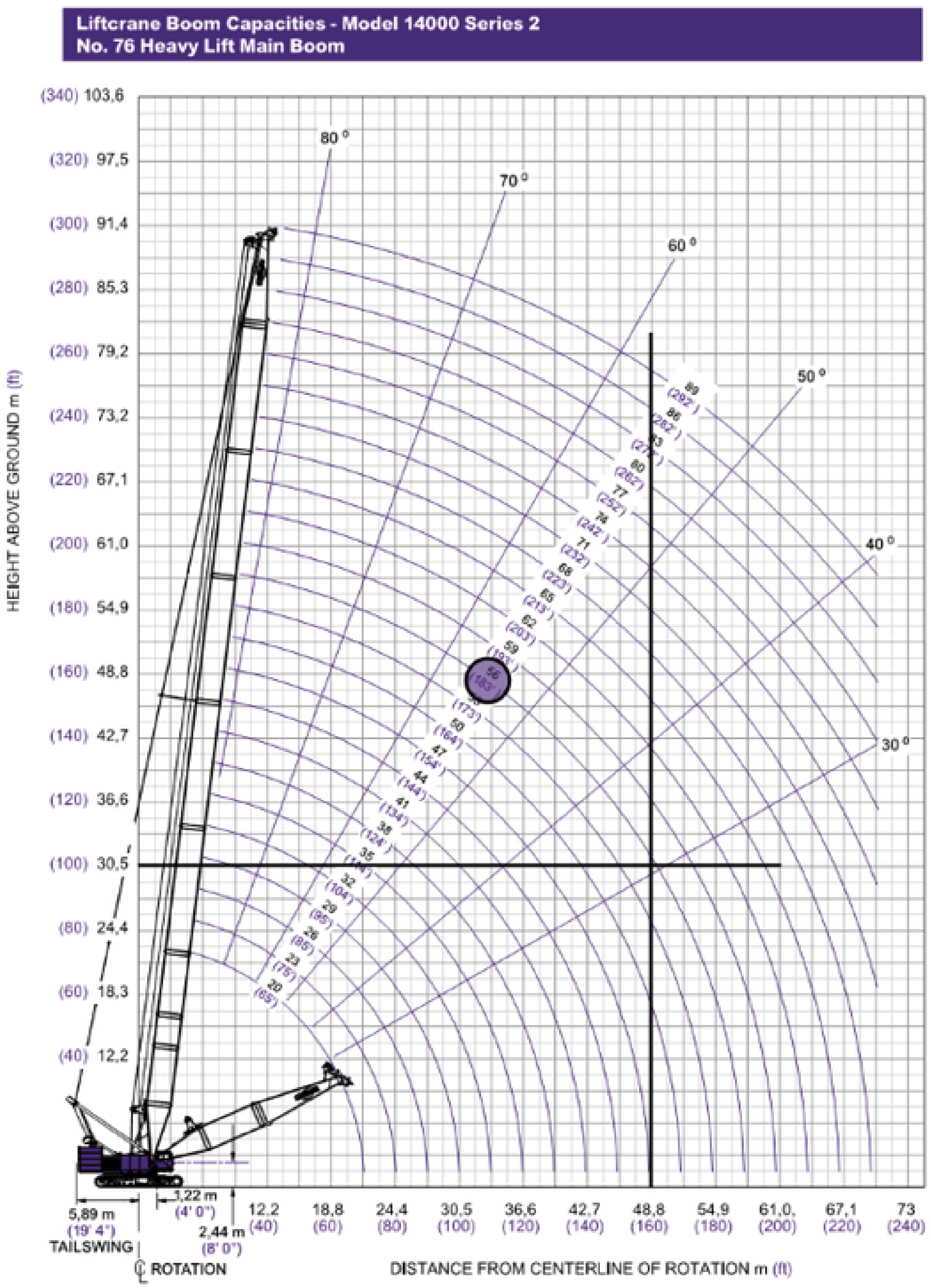


KEY:

RED - PROJECT SITE PERIMETER FENCING
ORANGE - PORTION OF 10TH STREET CLOSED FOR DELIVERIES
YELLOW - PARKING LOT AND STORAGE AREA PERIMETER FENCING
DARK GREEN - BORE FIELD LOCATION
BRIGHT GREEN - DELIVERY TRUCK ROUTE
BLUE - JOB TRAILER LOCATIONS
BLACK - CONEX STORAGE TRAILERS AND VEHICLE EGRESS
WHITE - SAFE PERSONNEL ROUTE BETWEEN SITES

CRANE SELECTION

HEAVY-LIFT BOOM RANGE DIAGRAM



X-AXIS: WE WILL ONLY NEED A RADIUS OF HALF THE WIDTH OF THE BUILDING (APPROXIMATELY 150 FEET). WE WILL BE ABLE TO REACH EVERY CORNER OF THE BUILDING FROM EITHER THE EAST, SOUTH, OR WEST SIDES OF THE SITE.
Y-AXIS: WE DESTERIMINED OUR MAXIMUM VERTICAL NEEDED FOR OUR CRANE TO REACH WOULD BE 100 FEET. THIS IS DETERMINED FROM THE 64 FOOT HEIGHT OF THE MAIN AUDITOI-RUM SPACE PLUS ADDITIONAL HEIGHT FOR THE CRANE EQUIPMENT.

RESULT: WE WILL REQUIRE A 183 FOOT BOOM ON OUR CRANE FOR THIS PROJECT

HEAVY-LIFT BOOM LOAD CHART

Liftcrane Boom Capacities - Model 14000 Series 2
No. 76 Heavy Lift Main Boom

76 200 kg (168,000 lb) Counterweight 24 040 kg (53,000 lb) Carbody Counterweight

360° Rating kg (lb) x 1 000

Boom m (ft)	20,0 (66)	26,0 (85)	32,0 (105)	38,0 (125)	44,0 (144)	50,0 (164)	56,0 (184)	62,0 (203)	68,0 (223)	74,0 (243)	80,0 (263)	86,0 (282)	89,0 (292)
Radius													
4,3 (14)	200,0 (441.0)												
8,0 (26)	109,3 (243.4)	109,0 (242.4)	108,7 (242.1)	108,5 (241.6)									
10,0 (32)	87,1 (198.0)	87,0 (197.5)	86,8 (196.9)	86,7 (196.5)	104,7 (195.7)	86,5 (195.0)	77,9 (173.4)	67,9 (150.4)					
12,0 (40)	67,0 (144.6)	67,1 (144.8)	67,1 (144.8)	67,1 (144.8)	86,4 (144.5)	66,9 (144.2)	66,8 (143.8)	65,4 (143.4)	58,8 (129.4)	50,2 (110.6)			
14,0 (46)	53,9 (118.8)	54,0 (119.0)	54,0 (118.9)	53,9 (118.8)	67,0 (118.4)	53,6 (118.0)	53,4 (117.6)	53,2 (117.2)	52,9 (116.5)	49,4 (109.0)	40,6 (9.5)	35,2 (77.6)	32,4 (71.5)
18,0 (60)	38,0 (82.2)	38,1 (82.4)	38,1 (82.3)	38,0 (82.2)	53,8 (81.7)	37,6 (81.3)	37,4 (80.7)	37,1 (80.2)	36,8 (79.4)	36,8 (79.5)	36,7 (78.9)	34,1 (75.0)	31,3 (69.0)
22,0 (70)		28,9 (66.6)	28,8 (66.5)	28,8 (66.4)	37,8 (65.8)	28,3 (65.4)	28,1 (64.8)	27,8 (64.3)	27,4 (63.4)	27,5 (63.5)	27,1 (62.8)	26,8 (62.1)	26,7 (61.8)
26,0 (85)			22,8 (50.6)	22,7 (50.4)	28,5 (49.9)	22,3 (49.5)	22,0 (48.8)	21,7 (48.2)	21,3 (47.4)	21,3 (47.4)	21,0 (46.7)	20,7 (46.0)	20,5 (45.6)
30,0 (100)			18,4 (39.8)	18,4 (39.7)	22,5 (39.2)	18,0 (38.8)	17,7 (38.1)	17,4 (37.5)	17,0 (36.6)	17,0 (36.6)	16,7 (35.9)	16,4 (35.2)	16,2 (34.8)
34,0 (110)				15,2 (34.3)	18,2 (33.8)	14,8 (33.4)	14,4 (32.7)	14,2 (32.2)	13,8 (31.3)	13,8 (31.2)	13,4 (30.5)	13,1 (29.8)	12,9 (29.4)
38,0 (120)					14,9 (29.4)	12,3 (29.0)	12,0 (28.3)	11,7 (27.7)	11,3 (26.8)	11,3 (26.8)	10,9 (26.0)	10,6 (25.3)	10,4 (24.9)
40,0 (130)					12,5 (25.7)	11,2 (25.3)	10,9 (24.6)	10,7 (24.1)	10,3 (23.2)	10,2 (23.1)	9,9 (22.3)	9,6 (21.6)	9,4 (21.2)
44,0 (140)					11,4 (22.5)	9,5 (22.2)	9,1 (21.5)	8,9 (20.9)	8,5 (20.0)	8,5 (20.0)	8,1 (19.2)	7,8 (18.5)	7,6 (18.1)
48,0 (155)						7,9 (18.2)	7,7 (17.6)	7,4 (17.0)	7,0 (16.1)	7,0 (16.1)	6,6 (15.3)	6,3 (14.6)	6,1 (14.2)
52,0 (170)							6,4 (14.4)	6,2 (13.8)	5,7 (12.9)	5,7 (12.9)	5,4 (12.1)	5,1 (11.4)	4,9 (11.0)
56,0 (180)								5,1 (12.0)	4,7 (11.1)	4,7 (11.1)	4,3 (10.3)	4,0 (9.6)	3,8 (9.2)
60,0 (195)								4,2 (9.6)	3,8 (8.7)	3,8 (8.7)	3,4 (7.9)	3,1 (7.2)	2,9 (6.8)
64,0 (210)									3,0 (6.7)	3,0 (6.7)	2,6 (5.9)	2,3 (5.2)	2,1 (4.8)
68,0 (220)										2,3 (5.5)	1,9 (4.7)		
70,0 (230)										2,0 (4.4)			

X-AXIS: THIS VALUE WAS DETERMINED FROM THE FIRST TONNAGE THAT WAS WAS CLOSEST TO, BUT NOT LESS THAN, OUR GREATEST LOAD (12,000 POUNDS) WHILE ALLOWING FOR SOME ROOM FOR ERROR.
Y-AXIS: WE WILL ONLY NEED A RADIUS OF HALF THE WIDTH OF THE BUILDING. WHEN SELECTING THE WEIGHT CAPACITY OF OUR CRANE, WE INCREASED THIS TO 170 FEET.

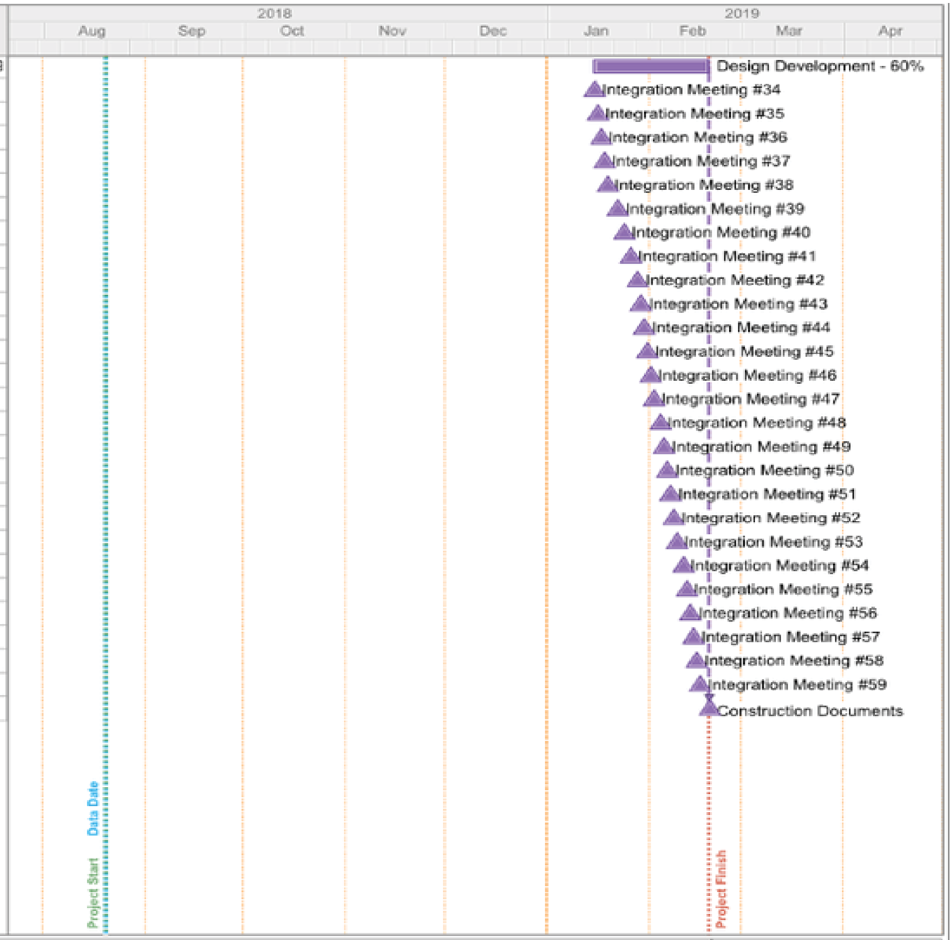
RESULT: THE MANITOWOC 14000 SERIES 2 NO. 76 CRANE IS SUFFICIENT FOR THE LOAD OF THE CLT PANELS.

DESIGN SCHEDULE

ID	Description	Original Duration	Start	Finish
10	Planning and Programming	20	08/20/18	09/14/18
20	Integration Meeting #1	0	08/20/18A	
30	Integration Meeting #2	0	08/22/18A	
40	Integration Meeting #3	0	08/27/18A	
50	Integration Meeting #4	0	08/29/18A	
60	Integration Meeting #5	0	09/05/18A	
70	Integration Meeting #6	0	09/10/18A	
80	Integration Meeting #7	0	09/12/18A	
90	Integration Meeting #8	0	09/17/18A	
100	Schematic Design	60	09/17/18	12/07/18
110	Integration Meeting #9	0	09/19/18A	
120	Integration Meeting #10	0	09/24/18A	
130	Integration Meeting #11	0	09/26/18A	
140	Integration Meeting #12	0	10/01/18A	
150	Integration Meeting #13	0	10/03/18A	
160	Integration Meeting #14	0	10/08/18A	
170	Integration Meeting #15	0	10/10/18A	
180	Integration Meeting #16	0	10/15/18A	
190	Integration Meeting #17	0	10/17/18A	
200	Integration Meeting #18	0	10/22/18A	
210	Integration Meeting #19	0	10/24/18A	
220	Integration Meeting #20	0	10/29/18A	
230	Integration Meeting #21	0	10/31/18A	
240	Integration Meeting #22	0	11/05/18A	
250	Integration Meeting #23	0	11/07/18A	
260	Integration Meeting #24	0	11/12/18A	
270	Integration Meeting #25	0	11/14/18A	
280	Integration Meeting #26	0	11/26/18A	
290	Integration Meeting #27	0	11/28/18A	
300	Integration Meeting #28	0	12/03/18A	
310	Integration Meeting #29	0	12/05/18A	
320	Design Development - 30%	26	12/10/18	01/14/19
330	Integration Meeting #30	0	12/13/18A	
340	Integration Meeting #31	0	12/14/18A	
350	Integration Meeting #32	0	12/15/18A	
370	Integration Meeting #33	0	01/14/19A	

THE DESIGN SCHEDULE WAS USED BY THE INTEGRATED ATUNE DESIGN AND CONSTRUCTION TEAM TO REMAIN ON TRACK TO COMPLETE THE SCHEMATIC DESIGN, DESIGN DEVELOPMENT - 30%, DESIGN DEVELOPMENT - 60% AND EVENTUALLY CONSTRUCTION DOCUMENTS. OUR INTEGRATION MEETINGS WERE TYPICALLY TWICE A WEEK, BUT WHEN ADDITIONAL WORK WAS NEEDED TO BE COMPLETED, THE ENTIRE TEAM MET OUTSIDE THE STANDARD TIME IN ORDER TO STAY ON SCHEDULE. THIS SCHEDULE IS ALSO REPRESENTED IN THE OVERALL PROJECT SCHEDULE AS "PRECONSTRUCTION".

ID	Description	Original Duration	Start	Finish
375	Design Development - 60%	25	01/15/19	02/18/19
380	Integration Meeting #34	0	01/15/19A	
390	Integration Meeting #35	0	01/16/19A	
400	Integration Meeting #36	0	01/17/19A	
410	Integration Meeting #37	0	01/18/19A	
415	Integration Meeting #38	0	01/19/19A	
420	Integration Meeting #39	0	01/22/19A	
425	Integration Meeting #40	0	01/24/19A	
427	Integration Meeting #41	0	01/26/19A	
428	Integration Meeting #42	0	01/28/19A	
429	Integration Meeting #43	0	01/29/19A	
430	Integration Meeting #44	0	01/30/19A	
435	Integration Meeting #45	0	01/31/19A	
437	Integration Meeting #46	0	02/01/19A	
438	Integration Meeting #47	0	02/02/19A	
440	Integration Meeting #48	0	02/04/19A	
445	Integration Meeting #49	0	02/05/19A	
447	Integration Meeting #50	0	02/06/19A	
448	Integration Meeting #51	0	02/07/19A	
449	Integration Meeting #52	0	02/08/19A	
459	Integration Meeting #53	0	02/09/19A	
460	Integration Meeting #54	0	02/11/19A	
470	Integration Meeting #55	0	02/12/19A	
480	Integration Meeting #56	0	02/13/19A	
490	Integration Meeting #57	0	02/14/19A	
495	Integration Meeting #58	0	02/15/19A	
497	Integration Meeting #59	0	02/16/19A	
500	Construction Documents	0	02/19/19	



Start Date: 08/20/18
Finish Date: 02/18/19
Data Date: 08/20/18
Run Date: 02/15/19

Atune Design Schedule.ppx Page 2A

Description	Material	Equipment: Days	Equipment: Cost/Day	Equipment: Extension	Total
Alternate #1: Acoustics					
Automated Acoustical Panels	$ 20,000.00				$ 20,000.00
Scrap Wood Panels	$ 20,000.00				$ 20,000.00
					$ 40,000.00

Alternate #2: Wood, Timber, Engineered Wood	Material	Days	Cost/Day	Extension	Total
CLT Panels - Structurlam	$ 2,837,349.00	17	$500.00	$ 8,500.00	$ 2,845,849.00
CLT Floor and Gluelam	$ 1,365,109.00	20	$500.00	$10,000.00	$ 1,375,109.00
Shear Connector Flooring	$ 89,520.00				$ 89,520.00
Zipper Truss	$ 231,686.00	10	$500.00	$ 5,000.00	$ 236,686.00
Carbon Fiber Wrapped Wood Columns	$ 223,852.50				$ 223,852.50
					$ 4,771,016.50

Alternate #3: Roof Top Amenity Space	Material	Days	Cost/Day	Extension	Total
Underfloor and Radiant Slab	$ 394,512.00				$ 394,512.00
Build-up Main Stairs	$ 22,650.00	5	$500.00	$ 2,500.00	$ 25,150.00
Build-up Side Stairs	$ 22,650.00	5	$500.00	$ 2,500.00	$ 25,150.00
Accordion Wall	$ 142,404.00				$ 142,404.00
Glass Parapet	$ 172,200.00				$ 172,200.00
View Glass	$ 166,138.00				$ 166,138.00
Additional Catering Space and Restrooms	$ 4,962.00				$ 4,962.00
					$ 930,516.00

Classroom Level 2	Total = $ 5,509,968	
Classroom Level 1	Total = $ 6,298,965	
Auditorium	Total = $ 3,997,388	
New Designs Applicable to Entire Building	Total = $ 3,560,709	
Alternate #1	Total = $ 40,000	
Alternate #2	Total = $ 4,747,517	
Alternate #3	Total = $ 925,516	Square Footage Costs
Jack H. Miller Center for the Musical Arts =	$ 19,367,030	$302.61
Grand Total Including Add Alternates =	$ 25,080,063	$391.88

NEW DESIGNS FOR ENTIRE PROJECT

Description	Quantity	Unit	Cost Per Unit: Material	Cost Per Unit: Extension	Additional Costs: Days	Labor	Extension	Equipment	Extension	Total
Site Security	8	Cameras	$ 150	$ 1,200	4	$ 375	$ 1,500	--	$ -	$ 2,700
North Lot - Rent	16	Months	$ 900	$ 14,400	--	--	$ -	--	$ -	$ 14,400
North Lot - Trailers	16	Months	$ 106	$ 1,690	--	--	$ -	--	$ -	$ 1,690
Generator - 40kW	1	EA	$ 15,000	$ 15,000	2	$ 613	$ 1,227	$ 500	$ 1,000	$ 17,227
w/ Diesel Tank - 168 gal	--	--	--	--	--	--	$ -	--	$ -	$ -
Transformer - 750kVA	1	EA	$ 28,100	$ 28,100	2	$ 613	$ 1,227	$ 500	$ 1,000	$ 30,327
Power over Ethernet	200	EA	$ 150	$ 40,880	40	$ 617	$ 24,694	--	$ -	$ 65,574
AIBAS	64000	SF	$ 5	$ 346,880	40	$ 617	$ 24,694	--	$ -	$ 371,574
Pavegen	384	SF	$ 100	$ 38,400	10	$ 617	$ 6,173	--	$ -	$ 44,573
Solar Panels	506	EA	$ 383	$ 193,545	95	$ 500	$ 47,500	$ 500	$ 47,500	$ 288,545
Door Power Harvesting	215	DOORS	$ 75	$ 16,125	10	$ 617	$ 6,173	--	$ -	$ 22,298
Automated Room Schedulers	30	EA	$ 62,900	$1,887,000	20	$ 617	$ 12,347	--	$ -	$1,899,347
Borefield	50	EA	$ 1,130	$ 56,500	25	$ 613	$ 15,334	$ 398	$ 9,960	$ 81,794
Rainwater Collection Tank - 20,000gal	1	EA	$ 52,000	$ 52,000	3	$ 613	$ 1,840	$ 500	$ 1,500	$ 55,340
Slab Melt	38714	SF	$ 15	$ 580,710	5	$ 577	$ 2,883	--	$ -	$ 583,593
Hydronic Mullions	4446	SF	$ 16	$ 71,136	20	$ 530	$ 10,592	--	$ -	$ 81,728
									Grand Total of New Designs for Entire Building =	$3,560,709

CONCERT HALL AUDITORIUM

Description	Quantity	Unit	Cost Per Unit: Material	Cost Per Unit: Extension	Total
Basement Excavation	16,334	SF	$ 0.13	$ 2,675.51	$ 2,675.51
Standard Foundation					
Dropped Slab	16,334	SF	$ 6.31	$133,330.30	$ 133,330.30
SOG	16,334	SF	$ 4.85	$102,480.50	$ 102,480.50
Superstructure					
Floor Construction	4,796	SF	$ 4.71	$ 99,507.41	$ 99,507.41
Roof Construction	16,334	SF	$ 4.76	$100,578.80	$ 100,578.80
Exterior Enclosure					
Exterior Walls	6,707.20	SF	$ 15.31	$323,488.26	$ 323,488.26
Roofing					
Roof Coverings	16,334	SF	$ 4.54	$ 95,872.41	$ 95,872.41
Roof Openings	16,334	SF	$ 0.15	$ 3,270.07	$ 3,270.07
Interior					
Doors	52	EA	$ 2.69	$ 56,878.64	$ 56,878.64
Wall Finishes	6,707.20	SF	$ 1.61	$ 34,118.86	$ 34,118.86
Floor Finishes	21,130	SF	$ 6.76	$142,866.27	$ 142,866.27
Ceiling Finishes	16,334	SF	$ 4.14	$ 87,548.61	$ 87,548.61
Plumbing					
Domestic Water Distribution	21,130	SF	$ 4.11	$ 86,911.92	$ 86,911.92
Rain Water Drainage	16,334	SF	$ 0.91	$ 19,323.12	$ 19,323.12
HVAC					
Terminal & Package Units	21,130	SF	$ 12.97	$274,003.28	$ 274,003.28
Underfloor and Radiant Slab	21,130	SF	$ 14.56	$307,652.80	$ 307,652.80
Condensing Units	21,130	SF	$ 11.75	$248,277.50	$ 248,277.50
Cooling Tower	0.33	SF	$ 0.11	$ 2,324.30	$ 2,324.30
Smoke Exhaust	8.00	EA	$ 0.08	$ 1,690.40	$ 1,690.40
Fire Protection					
Sprinklers	21,130	SF	$ 3.93	$ 83,040.90	$ 83,040.90
Standpipes	21,130	SF	$ 0.36	$ 7,691.32	$ 7,691.32
Electrical					
Electrical Service/Distribution	21,130	SF	$ 1.74	$ 36,726.05	$ 36,726.05
Lighting and Branch Wiring	21,130	SF	$ 11.87	$250,737.03	$ 250,737.03
Communications and Security	21,130	SF	$ 3.89	$ 82,297.12	$ 82,297.12
Other Electrical Systems	21,130	SF	$ 1.45	$ 30,573.00	$ 30,573.00
Stage Equipment					
Equipment, curtains, etc.	5,510	SF	$ 2.67	$ 56,417.10	$ 56,417.10
Seating					
Auditorium: Vaneer Back, Padded Se	800	EA	$ 11.71	$247,520.00	$ 247,520.00
				Estimate Total =	$ 2,917,801.46 (138.09 $/sf)
				Preconstruction Fees, 5% =	$ 145,890.07
				General Conditions, 25% =	$ 729,450.37
				Architect Fees, 7% =	$ 204,246.10
				Auditorium Estimate Total =	$ 3,997,388.00

LEVEL 1 TYPICAL CLASSROOM ESTIMATE

Description	Quantity	Unit	Cost Per Unit: Material	Extension	Total
Standard Foundation					
Grade Beams	2,233.49	LF	$ 10.66	$225,245.80	$ 225,245.80
Spread Footings	59.00	EA	$ 2.30	$ 48,599.00	$ 48,599.00
Frost Protection	2,233.49	LF	$ 0.84	$ 17,749.20	$ 17,749.20
SOG	26036	SF	$ 3.22	$155,899.52	$ 155,899.52
Exterior Enclosure					
Exterior Walls	41256.00	SF	$ 7.75	$375,224.00	$ 375,224.00
Exterior Windows	1787	SF	$ 1.75	$ 84,728.00	$ 84,728.00
View Glass; Atrium Space	2223	SF	$ 5.85	$283,233.60	$ 283,233.60
Exterior Doors	17	EA	$ 1.85	$ 89,726.00	$ 89,726.00
Interior					
Partitions	41273.34	SF	$ 5.07	$245,634.13	$ 245,634.13
Interior Doors	73	EA	$ 1.65	$ 79,848.86	$ 79,848.86
Fittings	24208	SF	$ 2.52	$122,017.71	$ 122,017.71
Stair Construction	5	FLIGHT	$ 1.89	$ 91,682.50	$ 91,682.50
Wall Finishes	49528	SF	$ 0.67	$ 32,676.10	$ 32,676.10
Floor Finishes	24208	SF	$ 2.05	$ 99,035.74	$ 99,035.74
Ceiling Finishes	24208	SF	$ 2.88	$139,550.36	$ 139,550.36
Conveying					
Elevators	1	EA	$ 1.63	$ 78,918.08	$ 78,918.08
Plumbing					
Plumbing Fixtures	34.5	EA	$ 1.50	$ 72,616.64	$ 72,616.64
Domestic Water Distributior	24208	SF	$ 1.62	$ 78,659.96	$ 78,659.96
HVAC					
Terminal & Package Units	24208	SF	$ 10.35	$501,101.87	$ 501,101.87
Active Chilled Beams	9585	SF	$ 4.32	$209,157.12	$ 209,157.12
Underfloor and Radiant Slab	5042	SF	$ 1.52	$ 73,592.32	$ 73,592.32
Condensing Units	26036	SF	$ 6.32	$305,989.12	$ 305,989.12
Cooling Tower	0.33	SF	$ 0.06	$ 2,904.96	$ 2,904.96
Fire Protection					
Sprinklers	24208	SF	$ 1.68	$ 81,338.88	$ 81,338.88
Standpipes	24208	SF	$ 0.20	$ 9,477.10	$ 9,477.10
Electrical					
Electrical Service/Distributio	24208	SF	$ 11.87	$574,697.92	$ 574,697.92
Lighting and Branch Wiring	24208	SF	$ 6.78	$328,144.73	$ 328,144.73
Communications and Securit	24208	SF	$ 3.62	$175,326.42	$ 175,326.42
Additives					
Lockers	53.50	EA	$ 0.31	$ 15,008.96	$ 15,008.96
				Estimate Total =	$ 4,597,784.60 ($ 176.59 $/sf)
				Preconstruction Fees, 5% =	$ 229,889.23
				General Conditions, 25% =	$ 1,149,446.15
				Architect Fees, 7% =	$ 321,844.92
				Classroom Level 1 Estimate Total =	$ 6,298,964.90

LEVEL 2 TYPICAL CLASSROOM ESTIMATE

Description	Quantity	Unit	Cost Per Unit: Material	Extension	Total
Superstructure					
Floor Construction	22,380	SF	6.78	$328,296.70	$ 328,296.70
Roof Construction	22,380	SF	4.51	$218,321.38	$ 218,321.38
Exterior Enclosure					
Exterior Walls	41,256.00	SF	7.75	$375,224.00	$ 375,224.00
Exterior Windows	1,787	SF	1.75	$ 84,728.00	$ 84,728.00
View Glass; Atrium Space	2,223	SF	5.85	$283,233.60	$ 283,233.60
Roofing					
Roof Coverings	22,380	SF	2.38	$115,270.43	$ 115,270.43
Roof Openings	1	EA	0.05	$ 2,257.71	$ 2,257.71
Interior					
Partitions	41,273.34	SF	5.07	$245,634.13	$ 245,634.13
Interior Doors	73	EA	1.65	$ 79,848.86	$ 79,848.86
Fittings	24,208	SF	2.17	$104,883.87	$ 104,883.87
Stair Construction	5	FLIGHT	1.89	$ 91,682.50	$ 91,682.50
Wall Finishes	49,528	SF	0.67	$ 32,676.10	$ 32,676.10
Floor Finishes	24,208	SF	1.76	$ 85,129.04	$ 85,129.04
Ceiling Finishes	24,208	SF	2.48	$119,954.56	$ 119,954.56
Conveying					
Elevators	1	EA	1.63	$ 78,918.08	$ 78,918.08
Plumbing					
Plumbing Fixtures	69	EA	1.50	$ 72,616.64	$ 72,616.64
Domestic Water Distributior	48,416	SF	1.40	$ 67,614.46	$ 67,614.46
Rain Water Drainage	22,380	SF	0.44	$ 21,180.43	$ 21,180.43
HVAC					
Terminal & Package Units	48,416	SF	8.90	$430,736.67	$ 430,736.67
Active Chilled Beams	5,080	SF	2.29	$110,872.64	$ 110,872.64
Condensing Units	22,380	SF	5.43	$262,898.88	$ 262,898.88
Cooling Tower	0.33	SF	0.05	$ 2,420.80	$ 2,420.80
Fire Protection					
Sprinklers	48,416	SF	1.45	$ 70,203.20	$ 70,203.20
Standpipes	48,416	SF	0.17	$ 8,146.32	$ 8,146.32
Electrical					
Electrical Service/Distributio	48,416	SF	1.61	$ 77,797.36	$ 77,797.36
Lighting and Branch Wiring	48,416	SF	10.03	$485,612.48	$ 485,612.48
Communications and Securit	48,416	SF	3.11	$150,706.92	$ 150,706.92
Additives					
Lockers	107	EA	$ 0.31	$ 15,008.96	$ 15,008.96
				Estimate Total =	$ 4,021,874.70 ($ 179.71 $/sf)
				Preconstruction Fees, 5% =	$ 201,093.74
				General Conditions, 25% =	$ 1,005,468.68
				Architect Fees, 7% =	$ 281,531.23
				Classroom Level 2 Estimate Total =	$ 5,509,968.34

ATUNE

Jack H. Miller Center for Musical Arts

CONSTRUCTION ESTIMATES

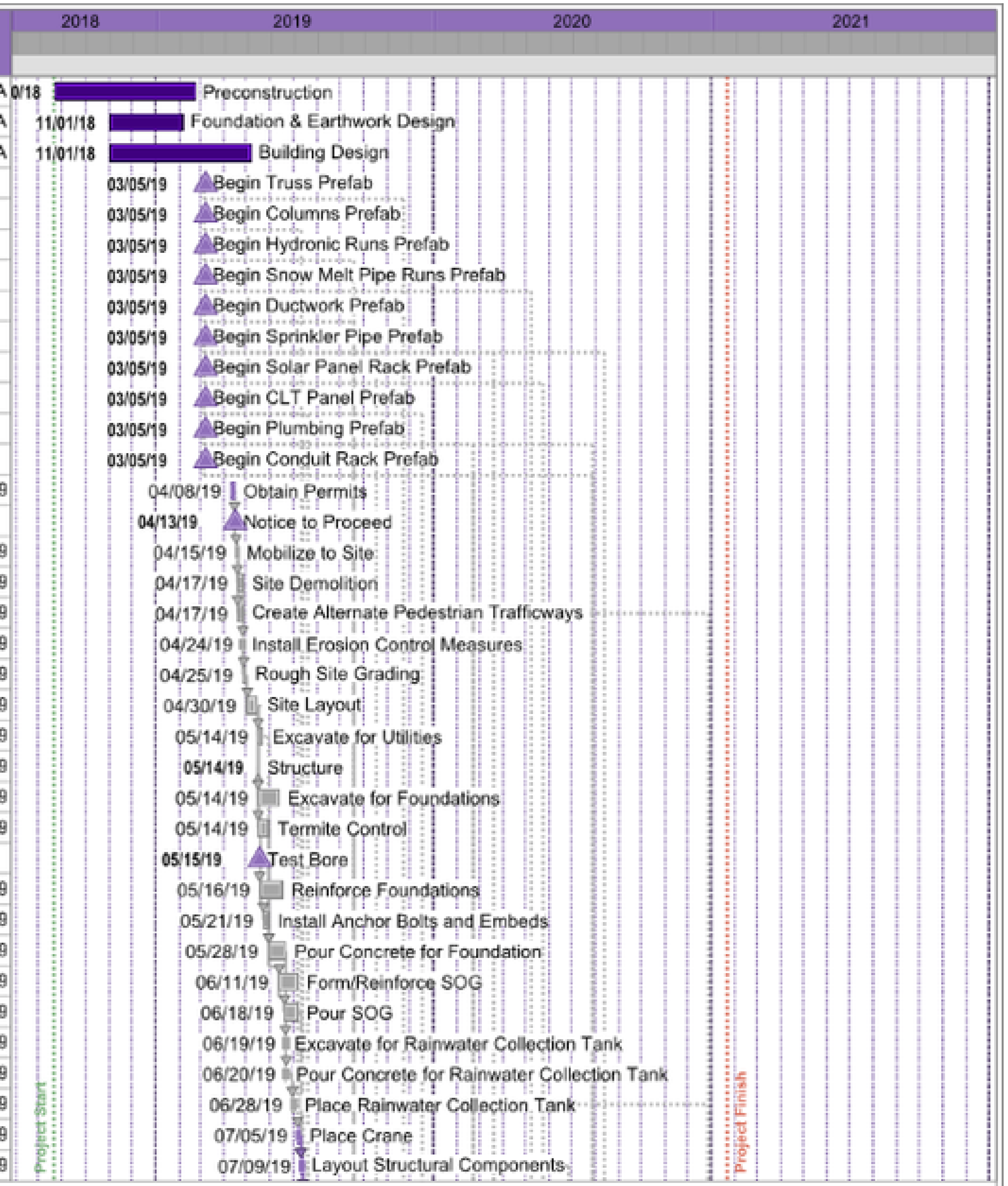
AEI Team No. 7-2019

Date

Scale

C3.1

ID	Description	Original Duration	Start	Finish
10	Preconstruction	131	08/20/18A	02/18/19A
15	Foundation & Earthwork Design	67	11/01/18A	02/01/19A
20	Building Design	131	11/01/18A	05/02/19A
60	Begin Truss Prefab	0	03/05/19	
65	Begin Columns Prefab	0	03/05/19	
70	Begin Hydronic Runs Prefab	0	03/05/19	
75	Begin Snow Melt Pipe Runs Prefab	0	03/05/19	
80	Begin Ductwork Prefab	0	03/05/19	
85	Begin Sprinkler Pipe Prefab	0	03/05/19	
90	Begin Solar Panel Rack Prefab	0	03/05/19	
95	Begin CLT Panel Prefab	0	03/05/19	
100	Begin Plumbing Prefab	0	03/05/19	
105	Begin Conduit Rack Prefab	0	03/05/19	
110	Obtain Permits	5	04/08/19	04/12/19
115	Notice to Proceed	0	04/13/19	
120	Mobilize to Site	2	04/15/19	04/16/19
125	Site Demolition	5	04/17/19	04/23/19
130	Create Alternate Pedestrian Trafficways	5	04/17/19	04/23/19
135	Install Erosion Control Measures	1	04/24/19	04/24/19
140	Rough Site Grading	3	04/25/19	04/29/19
150	Site Layout	10	04/30/19	05/13/19
155	Excavate for Utilities	5	05/14/19	05/20/19
160	Structure	0	05/14/19	05/13/19
165	Excavate for Foundations	20	05/14/19	06/10/19
175	Termite Control	10	05/14/19	05/27/19
145	Test Bore	0	05/15/19	
180	Reinforce Foundations	22	05/16/19	06/14/19
185	Install Anchor Bolts and Embeds	5	05/21/19	05/27/19
190	Pour Concrete for Foundation	16	05/28/19	06/18/19
205	Form/Reinforce SOG	19	06/11/19	07/05/19
215	Pour SOG	14	06/18/19	07/05/19
195	Excavate for Rainwater Collection Tank	1	06/19/19	06/19/19
200	Pour Concrete for Rainwater Collection	1	06/20/19	06/20/19
210	Place Rainwater Collection Tank	2	06/28/19	07/01/19
170	Place Crane	2	07/05/19	07/08/19
225	Layout Structural Components	3	07/09/19	07/11/19



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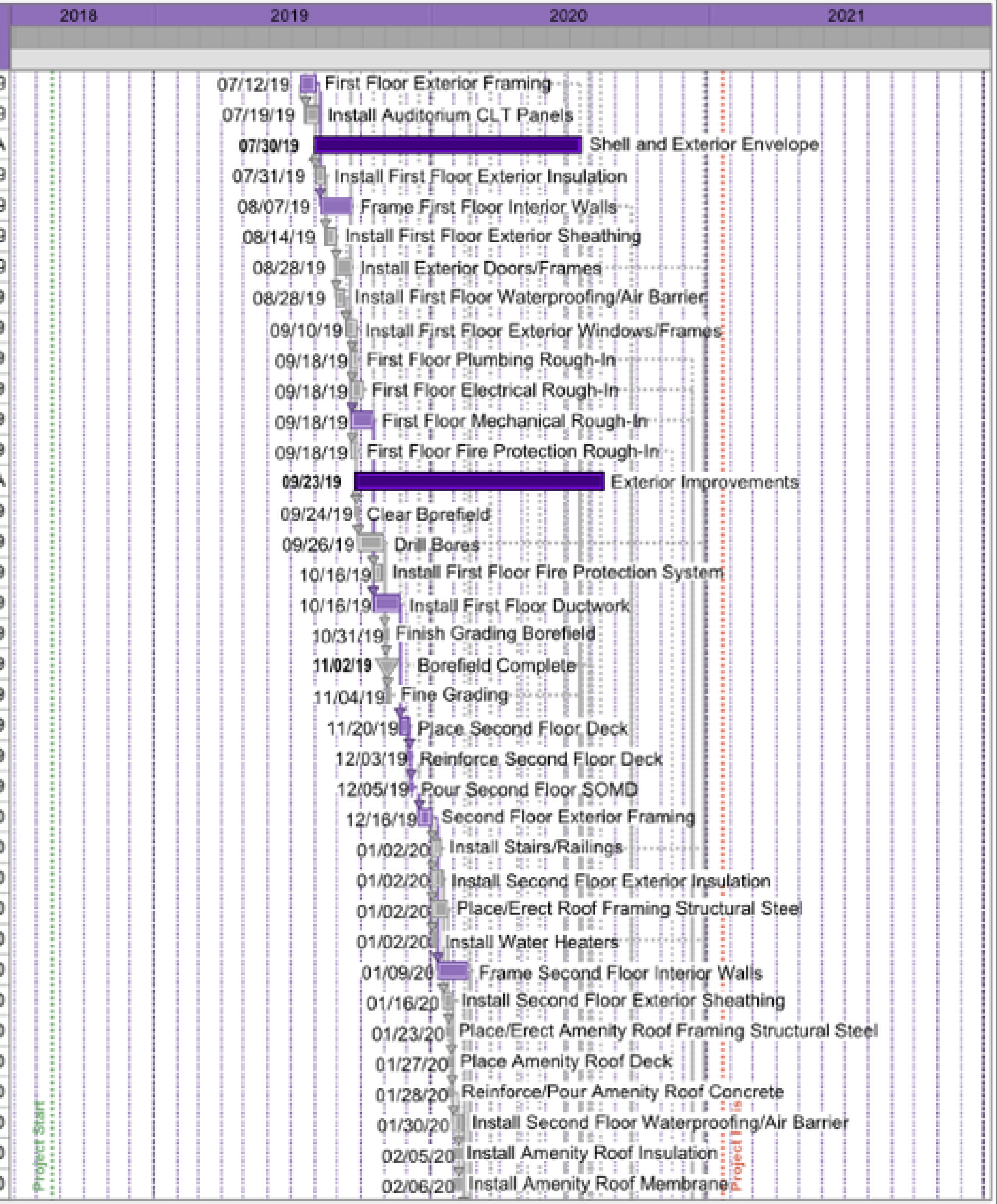
Jack H. Miller Center for Musical Arts

CONSTRUCTION SCHEDULE

AEI Team No. 7-2019
Date
Scale

C3.2

ID	Description	Original Duration	Start	Finish
230	First Floor Exterior Framing	13	07/12/19	07/30/19
235	Install Auditorium CLT Panels	12	07/19/19	08/05/19
220	Shell and Exterior Envelope	251	07/30/19A	07/14/20A
240	Install First Floor Exterior Insulation	10	07/31/19	08/13/19
250	Frame First Floor Interior Walls	30	08/07/19	09/17/19
255	Install First Floor Exterior Sheathing	10	08/14/19	08/27/19
260	Install Exterior Doors/Frames	15	08/28/19	09/17/19
265	Install First Floor Waterproofing/Air Barr	9	08/28/19	09/09/19
270	Install First Floor Exterior Windows/Fran	10	09/10/19	09/23/19
275	First Floor Plumbing Rough-In	5	09/18/19	09/24/19
280	First Floor Electrical Rough-In	10	09/18/19	10/01/19
285	First Floor Mechanical Rough-In	20	09/18/19	10/15/19
290	First Floor Fire Protection Rough-In	6	09/18/19	09/25/19
295	Exterior Improvements	233	09/23/19A	08/12/20A
660	Clear Borefield	2	09/24/19	09/25/19
670	Drill Bores	25	09/26/19	10/30/19
300	Install First Floor Fire Protection Systerr	9	10/16/19	10/28/19
305	Install First Floor Ductwork	25	10/16/19	11/19/19
725	Finish Grading Borefield	2	10/31/19	11/01/19
745	Borefield Complete	0		11/01/19
740	Fine Grading	5	11/04/19	11/08/19
310	Place Second Floor Deck	9	11/20/19	12/02/19
315	Reinforce Second Floor Deck	2	12/03/19	12/04/19
320	Pour Second Floor SOMD	2	12/05/19	12/06/19
325	Second Floor Exterior Framing	13	12/16/19	01/01/20
330	Install Stairs/Railings	8	01/02/20	01/13/20
335	Install Second Floor Exterior Insulation	10	01/02/20	01/15/20
340	Place/Erect Roof Framing Structural Ste	15	01/02/20	01/22/20
345	Install Water Heaters	3	01/02/20	01/06/20
350	Frame Second Floor Interior Walls	30	01/09/20	02/19/20
355	Install Second Floor Exterior Sheathing	10	01/16/20	01/29/20
360	Place/Erect Amenity Roof Framing Struc	2	01/23/20	01/24/20
365	Place Amenity Roof Deck	1	01/27/20	01/27/20
370	Reinforce/Pour Amenity Roof Concrete	1	01/28/20	01/28/20
375	Install Second Floor Waterproofing/Air E	9	01/30/20	02/11/20
380	Install Amenity Roof Insulation	1	02/05/20	02/05/20
385	Install Amenity Roof Membrane	1	02/06/20	02/06/20



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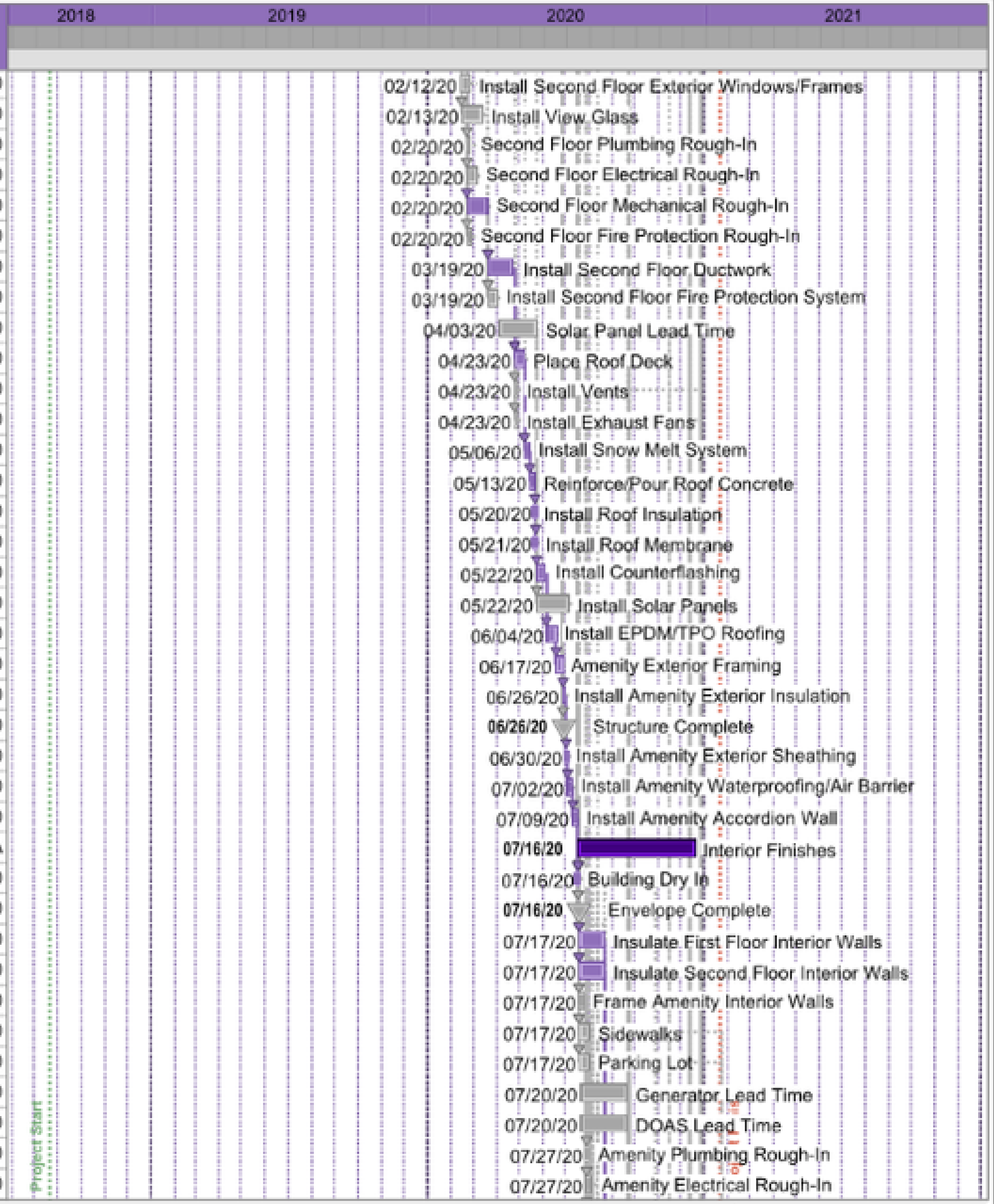
Jack H. Miller Center for Musical Arts

CONSTRUCTION SCHEDULE

AEI Team No. 7-2019
Date
Scale

C3.3

ID	Description	Original Duration	Start	Finish
390	Install Second Floor Exterior Windows/F	10	02/12/20	02/25/20
395	Install View Glass	20	02/13/20	03/11/20
400	Second Floor Plumbing Rough-In	5	02/20/20	02/26/20
405	Second Floor Electrical Rough-In	10	02/20/20	03/04/20
410	Second Floor Mechanical Rough-In	20	02/20/20	03/18/20
415	Second Floor Fire Protection Rough-In	6	02/20/20	02/27/20
420	Install Second Floor Ductwork	25	03/19/20	04/22/20
425	Install Second Floor Fire Protection Sys	9	03/19/20	03/31/20
30	Solar Panel Lead Time	35	04/03/20	05/21/20
430	Place Roof Deck	9	04/23/20	05/05/20
435	Install Vents	3	04/23/20	04/27/20
440	Install Exhaust Fans	3	04/23/20	04/27/20
445	Install Snow Melt System	5	05/06/20	05/12/20
450	Reinforce/Pour Roof Concrete	5	05/13/20	05/19/20
455	Install Roof Insulation	1	05/20/20	05/20/20
460	Install Roof Membrane	1	05/21/20	05/21/20
465	Install Counterflashing	9	05/22/20	06/03/20
470	Install Solar Panels	30	05/22/20	07/02/20
475	Install EPDM/TPO Roofing	9	06/04/20	06/16/20
480	Amenity Exterior Framing	7	06/17/20	06/25/20
485	Install Amenity Exterior Insulation	2	06/26/20	06/29/20
490	Structure Complete	0		06/25/20
495	Install Amenity Exterior Sheathing	2	06/30/20	07/01/20
500	Install Amenity Waterproofing/Air Barrier	5	07/02/20	07/08/20
605	Install Amenity Accordion Wall	5	07/09/20	07/15/20
245	Interior Finishes	109	07/16/20A	12/15/20A
505	Building Dry In	1	07/16/20	07/16/20
665	Envelope Complete	0		07/15/20
510	Insulate First Floor Interior Walls	23	07/17/20	08/18/20
515	Insulate Second Floor Interior Walls	23	07/17/20	08/18/20
520	Frame Amenity Interior Walls	6	07/17/20	07/24/20
875	Sidewalks	10	07/17/20	07/30/20
885	Parking Lot	10	07/17/20	07/30/20
25	Generator Lead Time	45	07/20/20	09/18/20
40	DOAS Lead Time	45	07/20/20	09/18/20
525	Amenity Plumbing Rough-In	3	07/27/20	07/29/20
530	Amenity Electrical Rough-In	6	07/27/20	08/03/20



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Jack H. Miller Center for Musical Arts

CONSTRUCTION SCHEDULE

AEI Team No. 7-2019

Date

Scale

C3.4

ID	Description	Original Duration	Start	Finish
535	Amenity Mechanical Rough-In	12	07/27/20	08/11/20
540	Install Amenity Ductwork	10	07/27/20	08/07/20
545	Insulate Amenity Interior Walls	3	07/27/20	07/29/20
550	Amenity Fire Protection Rough-In	6	07/27/20	08/03/20
555	Drywall Amenity Interior Walls	3	07/30/20	08/03/20
865	Sod & Landscaping	10	07/31/20	08/13/20
560	Finish Amenity Plumbing	3	08/04/20	08/06/20
565	Finish Amenity Electrical	3	08/04/20	08/06/20
570	Mud/Tape Amenity Interior Walls	2	08/04/20	08/05/20
575	Install Amenity Interior Doors/Frames	2	08/06/20	08/07/20
580	Install Amenity Vents	1	08/10/20	08/10/20
585	Install Amenity Exhaust Fans	1	08/10/20	08/10/20
590	Paint/Apply Finish Amenity Interior Wall	5	08/10/20	08/14/20
595	Finish Amenity Mechanical	3	08/12/20	08/14/20
600	Install Amenity Fire Protection System	3	08/12/20	08/14/20
50	Transformer Lead Time	25	08/17/20	09/18/20
610	Install Amenity Tile	3	08/17/20	08/19/20
615	Install Amenity Ceiling Grid	5	08/17/20	08/21/20
620	Drywall First Floor Interior Walls	23	08/19/20	09/18/20
625	Drywall Second Floor Interior Walls	23	08/19/20	09/18/20
630	Install Shelving	4	08/20/20	08/25/20
635	Install Cabinets	4	08/20/20	08/25/20
640	Install Amenity Light Fixtures	1	08/20/20	08/20/20
645	Install Amenity Ceiling Tile	3	08/21/20	08/25/20
650	Install Countertops	4	08/26/20	08/31/20
655	Install Lavatories	4	08/28/20	09/02/20
35	Elevator Lead Time	45	09/10/20	11/11/20
45	Pavegen Lead Time	40	09/18/20	11/12/20
675	Finish First Floor Plumbing	5	09/21/20	09/25/20
680	Finish Second Floor Plumbing	5	09/21/20	09/25/20
685	Finish First Floor Electrical	10	09/21/20	10/02/20
690	Finish Second Floor Electrical	10	09/21/20	10/02/20
695	Finish First Floor Mechanical	8	09/21/20	09/30/20
700	Finish Second Floor Mechanical	8	09/21/20	09/30/20
705	Mud/Tape First Floor Interior Walls	18	09/21/20	10/14/20
710	Mud/Tape Second Floor Interior Walls	18	09/21/20	10/14/20
715	Prep Elevator Shafts	7	10/05/20	10/13/20

Start Date: 08/20/18
Finish Date: 01/20/21
Data Date: 03/01/19
Run Date: 02/15/19

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ATUNE

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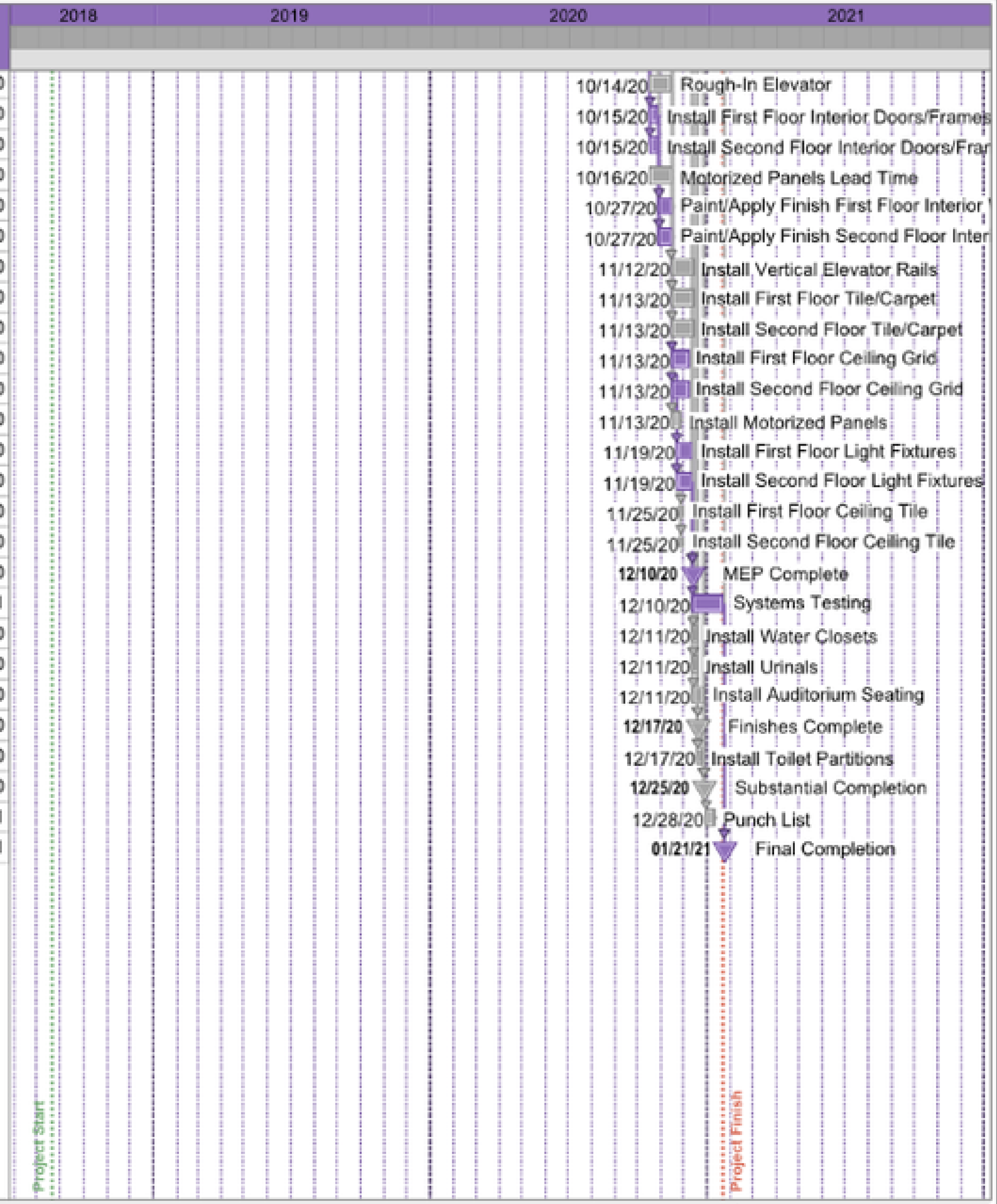
Jack H. Miller Center for Musical Arts

CONSTRUCTION SCHEDULE

AEI Team No. 7-2019
Date
Scale

C3.5

ID	Description	Original Duration	Start	Finish
720	Rough-In Elevator	21	10/14/20	11/11/20
730	Install First Floor Interior Doors/Frames	8	10/15/20	10/26/20
735	Install Second Floor Interior Doors/Fram	8	10/15/20	10/26/20
55	Motorized Panels Lead Time	20	10/16/20	11/12/20
750	Paint/Apply Finish First Floor Interior Wa	13	10/27/20	11/12/20
755	Paint/Apply Finish Second Floor Interior	13	10/27/20	11/12/20
760	Install Vertical Elevator Rails	21	11/12/20	12/10/20
765	Install First Floor Tile/Carpet	20	11/13/20	12/10/20
770	Install Second Floor Tile/Carpet	20	11/13/20	12/10/20
775	Install First Floor Ceiling Grid	15	11/13/20	12/03/20
780	Install Second Floor Ceiling Grid	15	11/13/20	12/03/20
785	Install Motorized Panels	8	11/13/20	11/24/20
790	Install First Floor Light Fixtures	15	11/19/20	12/09/20
795	Install Second Floor Light Fixtures	15	11/19/20	12/09/20
800	Install First Floor Ceiling Tile	3	11/25/20	11/27/20
805	Install Second Floor Ceiling Tile	3	11/25/20	11/27/20
810	MEP Complete	0		12/09/20
815	Systems Testing	30	12/10/20	01/20/21
820	Install Water Closets	4	12/11/20	12/16/20
825	Install Urinals	3	12/11/20	12/15/20
830	Install Auditorium Seating	10	12/11/20	12/24/20
835	Finishes Complete	0		12/16/20
840	Install Toilet Partitions	5	12/17/20	12/23/20
845	Substantial Completion	0		12/24/20
850	Punch List	10	12/28/20	01/08/21
855	Final Completion	0		01/20/21



Start Date: 08/20/18
Finish Date: 01/20/21
Data Date: 03/01/19
Run Date: 02/15/19

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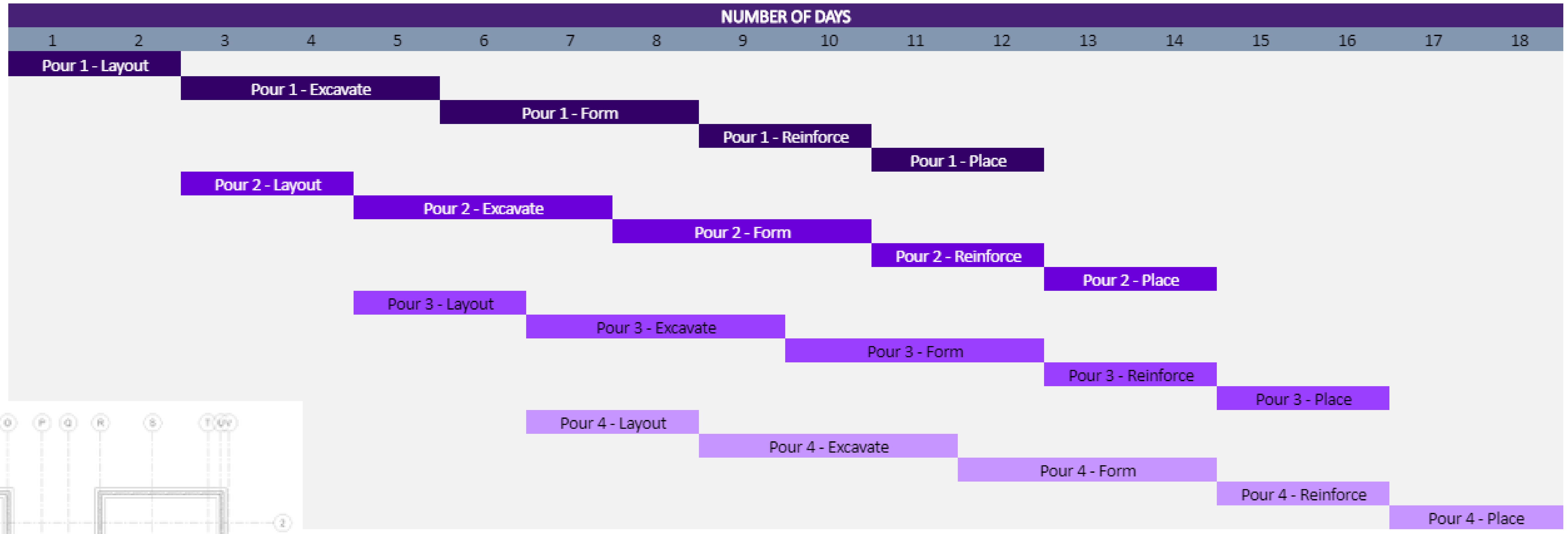
Jack H. Miller Center for Musical Arts

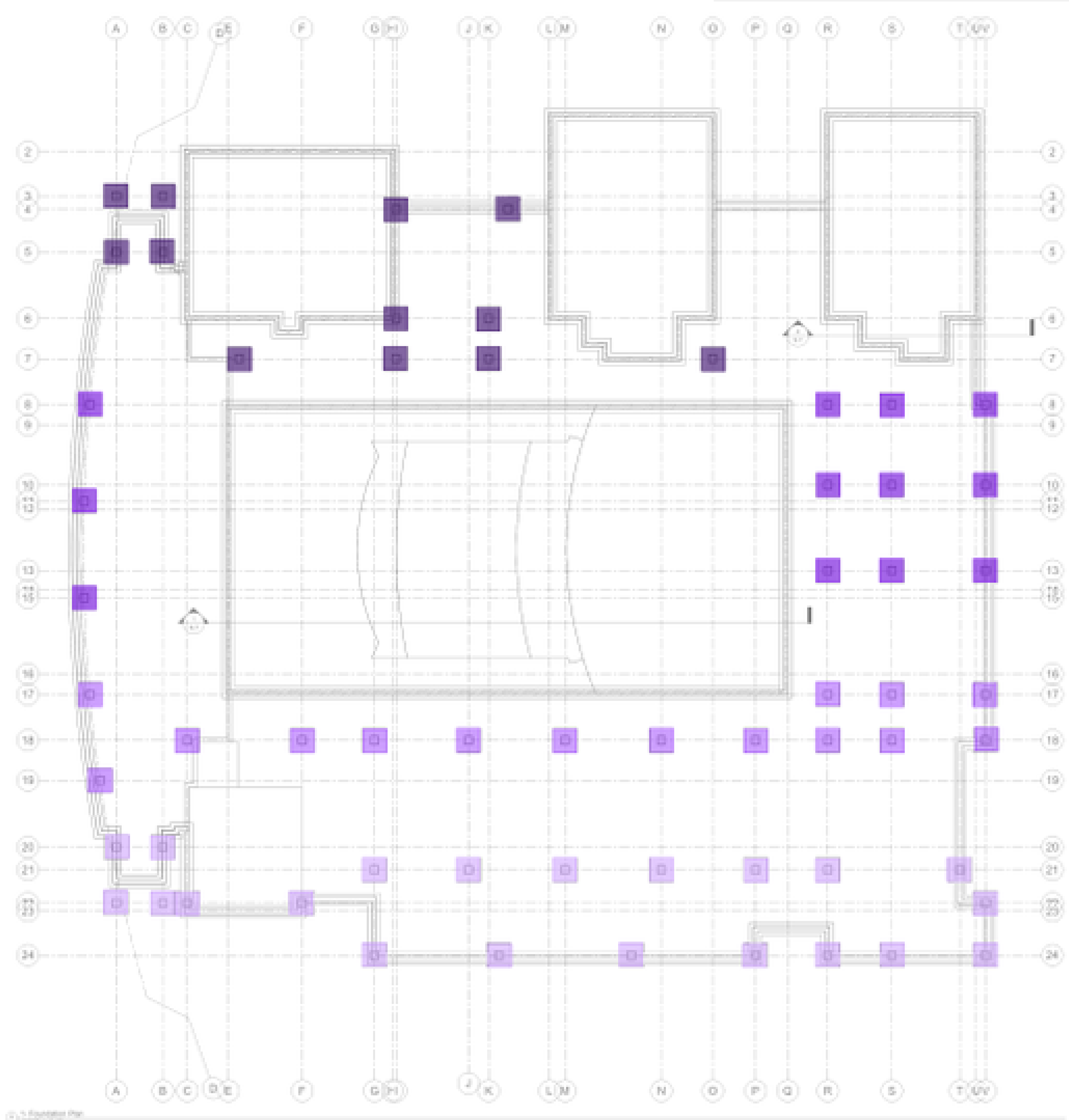
CONSTRUCTION SCHEDULE

AEI Team No. 7-2019
Date
Scale

C3.6

SPREAD FOOTING PLACEMENT PHASING





Pour 1 - GL 3-7

Pour 2 - GL 8-15

Pour 3 - GL 17-19

Pour 4 - GL 20-24

ATUNE

Jack H. Miller Center for Musical Arts

CONSTRUCTION POUR SEQUENCE

AEI Team No.	7-2019
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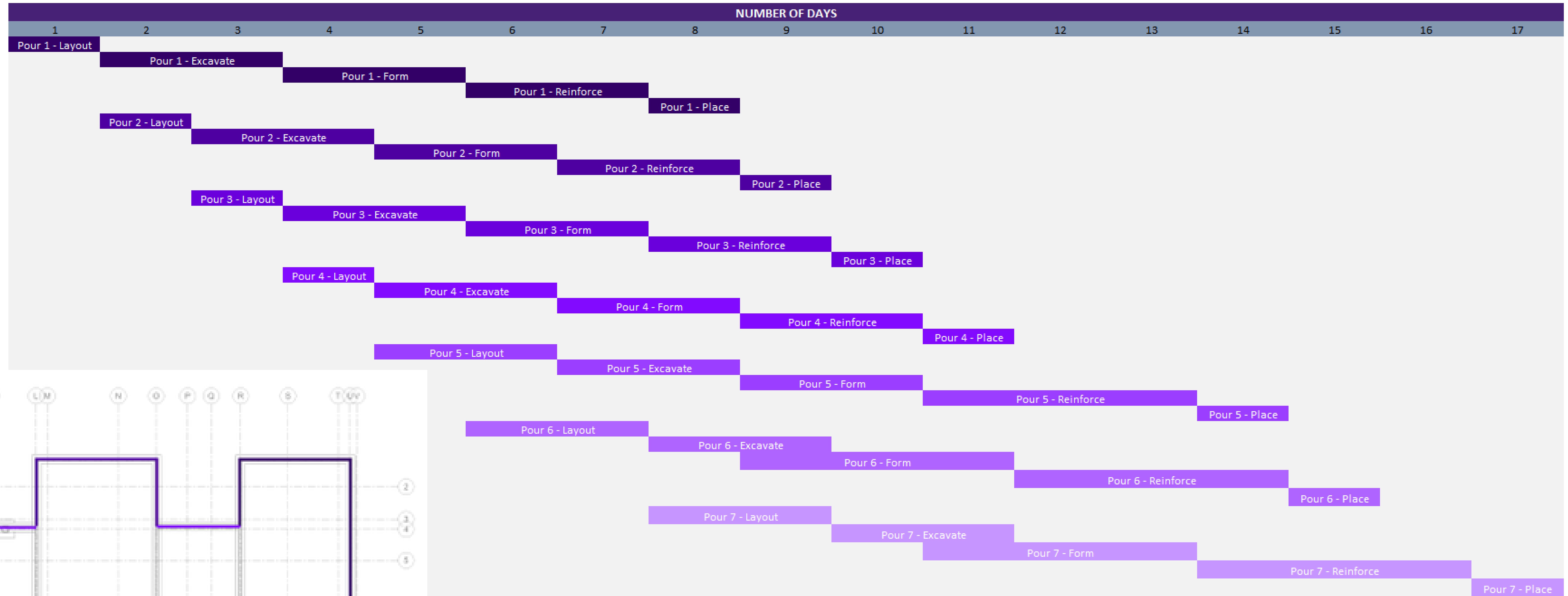
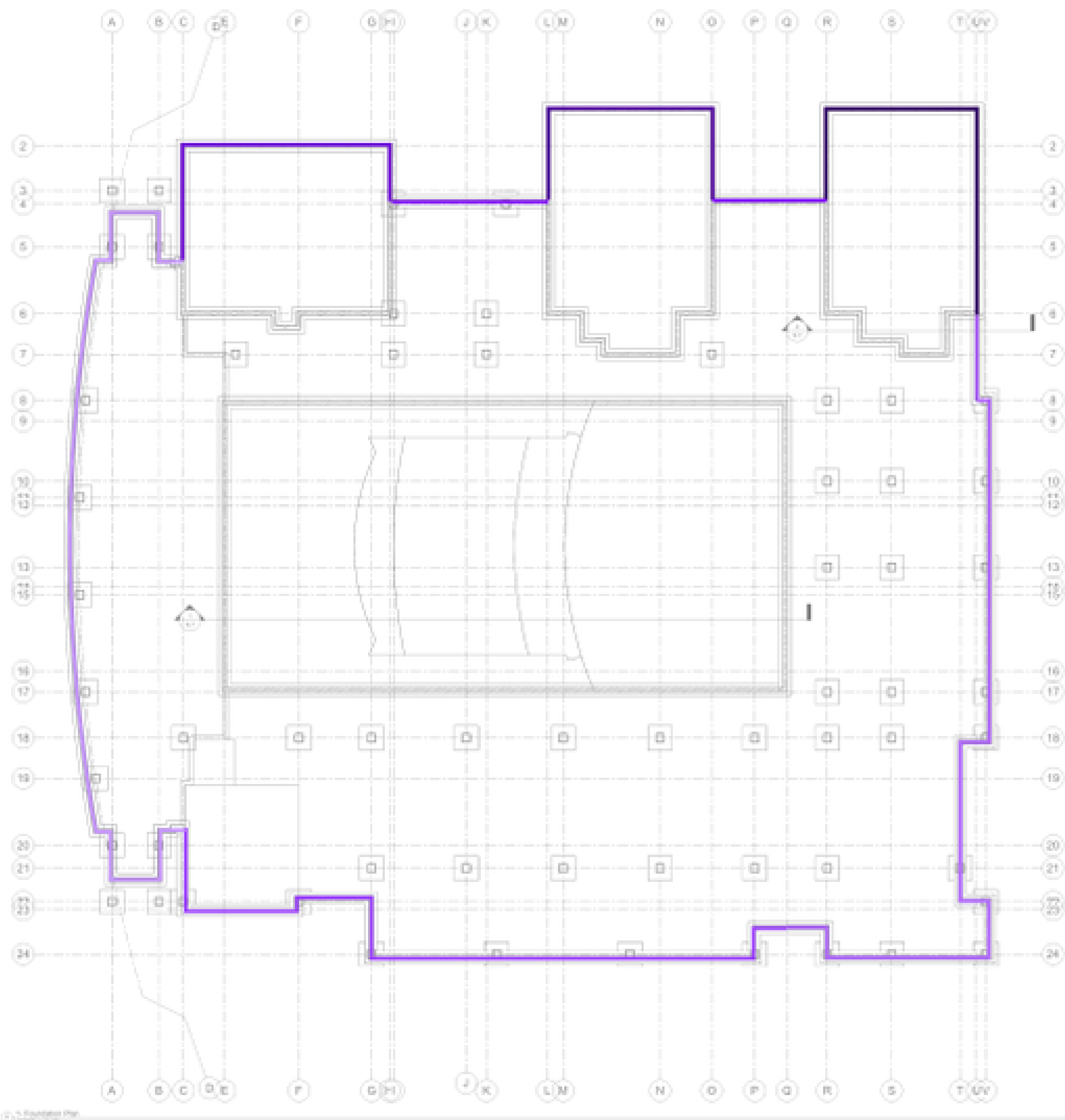
Scale	

C3.7

GRADE BEAM PLACEMENT PHASING





Pour 1 - NE Auditorium

Pour 2 - N Auditorium

Pour 3 - NW Auditorium

Pour 4 - N Slab

Pour 5 - S Slab

Pour 6 - E Slab

Pour 7 - W Slab/Atrium

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Jack H. Miller Center for Musical Arts

CONSTRUCTION POUR SEQUENCE

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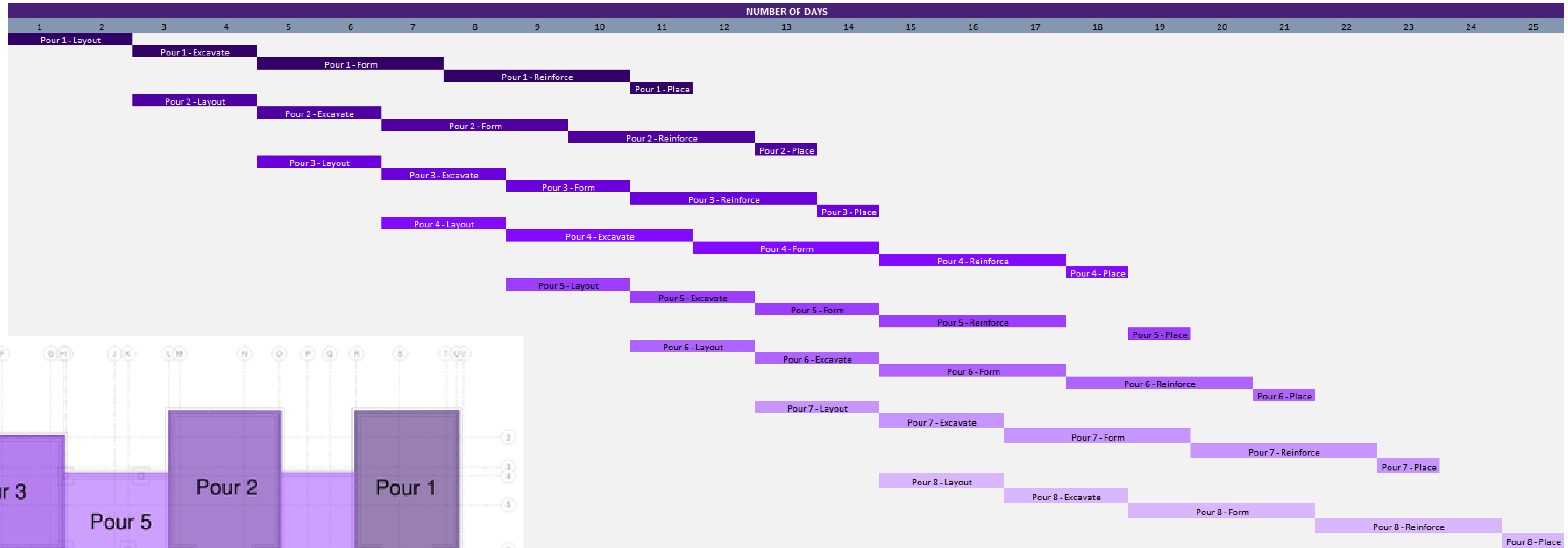
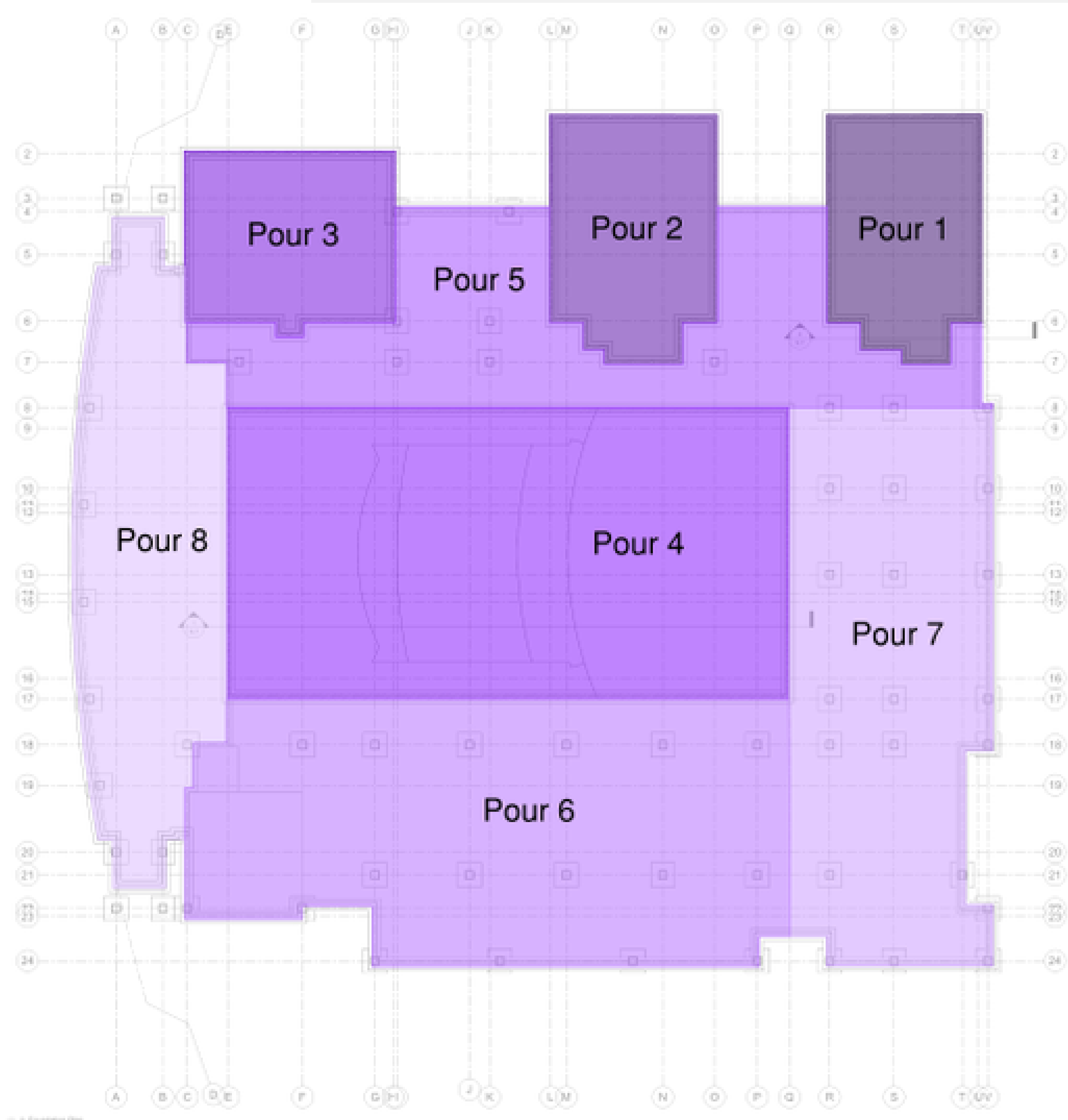
C3.8

SLAB-ON-GRADE PLACEMENT PHASING





Pour 1 - NE Auditorium

Pour 2 - N Auditorium

Pour 3 - NW Auditorium

Pour 4 - Main Auditorium

Pour 5 - N Slab

Pour 6 - S Slab

Pour 7 - E Slab

Pour 8 - W Slab/Atrium

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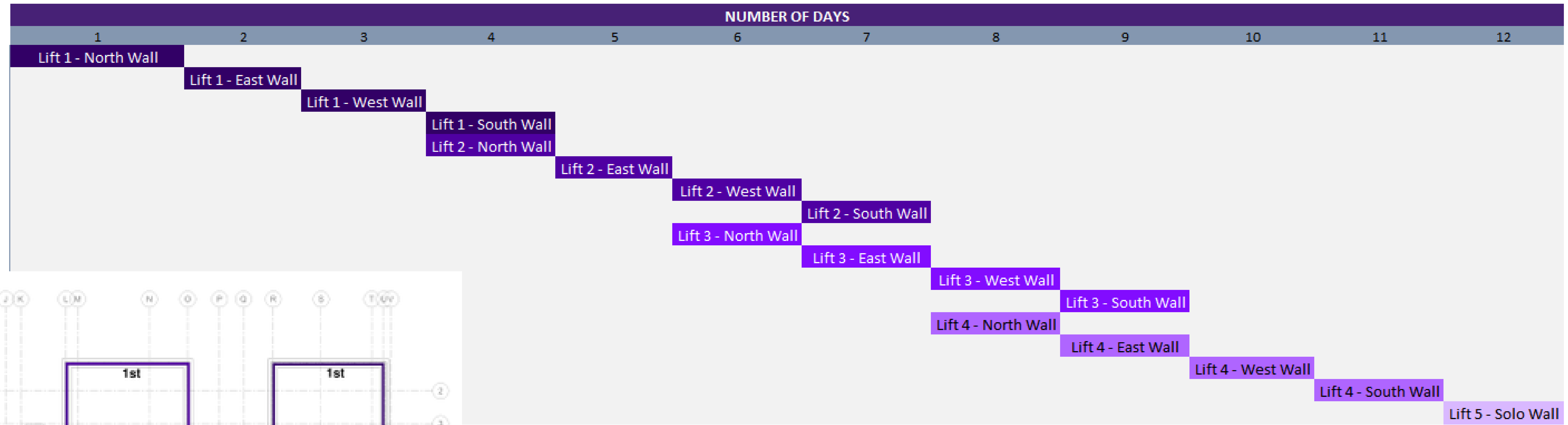
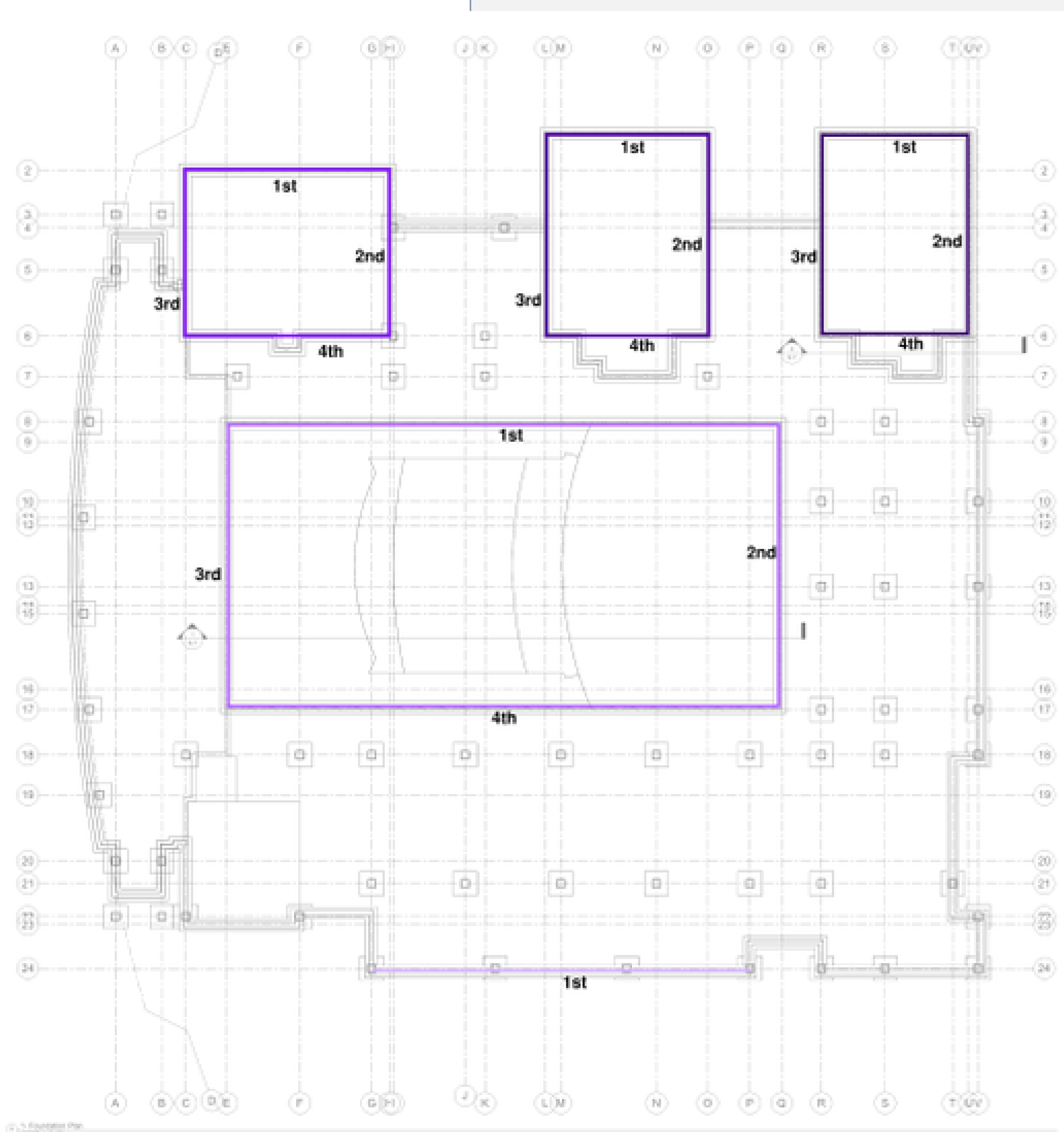
CONSTRUCTION POUR SEQUENCE

AEI Team No.	7-2019
Date	
Scale	

C3.9

CLT PANEL PLACEMENT PHASING





Lift 1 - NE Auditorium

Lift 2 - N Auditorium

Lift 3 - NW Auditorium

Lift 4 - Main Auditorium

Lift 5 - South Wall

*Panels will be laid on the ground and lifted from the side it's sequence designation is on.

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CONSTRUCTION PANEL SEQUENCE

AEI Team No.	7-2019
Date	
Scale	

C3.10