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Revision 1

Penn State University

Ice Hockey Arena

lightsout DESIGN

BIM Thesis Proposal

Team 3

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Executive Summary

The following report contains the proposal of Lights-Out Design's ideas for the design of the new Penn State Ice Hockey Arena. The team consisting of Nate Babyak, Alex Ho, Brian Sampson, and Alex Schreffler will employ a highly integrated approach to create an iconic new arena for the Pennsylvania State University. The purpose of this proposal is to provide an outline of redesigns that will provide an energy efficient "symbol" for Penn State Hockey. Building information modeling will be used extensively to integrate and coordinate all team members and their analyses.

Three specific areas were chosen as areas of focus for specific analysis and redesign. These areas were chosen to encourage integration and input from all design disciplines. These areas include the following:

1. The redesign of the main roof to create an iconic symbol for Penn State Hockey.
2. The analysis and redesign of the arena façade to create a lightweight energy efficient envelope of glass and metal panels.
3. An investigation into redesigning the community rink to provide daylighting and increasing the efficiency of the mechanical system by relocating several air handling units.

Lights-Out Design has chosen to pursue a cable-stayed structural solution to support the roof of the main arena. The towering masts and cables will provide a unique image for Penn State as the roof will seemingly float above the ground. There will be extensive coordination between the structural and construction team members to optimize the cost and construction schedule of the mast and cable system. The ceiling of the main arena will be coordinated among design disciplines to ensure there are no clashes between the structure, ductwork, and luminaires.

Having decided to employ a lightweight structural system, it became imperative that the team redesign the current brick panel and glass façade. The mechanical and lighting/electrical team members will work together with the construction team member to choose a cost efficient and energy efficient system of glass and metal panels for the new façade. Once the materials are chosen, the structural team member will analyze the panels to ensure structural integrity. The façade will be designed to allow for daylighting concourse areas and the need for shading will be examined.

To allow flexibility to the roof design of the community rink, the existing exterior mechanical space will be reduced and several mechanical units will be relocated to the front of the arena above the lobby. This decision allows for a more efficient mechanical system that eliminates long duct runs and reduces fan energy. The added flexibility to the roof design will be analyzed for daylighting potential and new shape will be chosen. The roof structure will be coordinated with daylighting strategies to reduce energy loads in the community rink while maintaining the championship quality of the ice.

Each team member will be responsible for creating a portion of a collaborative building information model to allow for integrated coordination between team members. Cost, schedule, and site logistics will assist in assessing each design decision made by the team. Throughout the design, each decision will impact every team member and compromises will be necessary to produce the best overall solution for the new Penn State Ice Hockey Arena.

Project Background

The Penn State Ice Arena is an approximately 216, 240 square foot arena that will house two ice sheets, a 6,000 seat main arena, a 300 seat community rink, food and retail facilities, offices for the NCAA Division 1 men's and women's hockey teams, and other team facilities. The project is owned by The Pennsylvania State University and is located on the University Park campus just south of the intersection of Curtin Road and University Drive. The arena neighbors the Shields Buildings to its north, the Tennis Facility to the southwest, and Holuba Hall to the south. The main goal of the arena is to provide a championship quality facility for the new hockey teams.

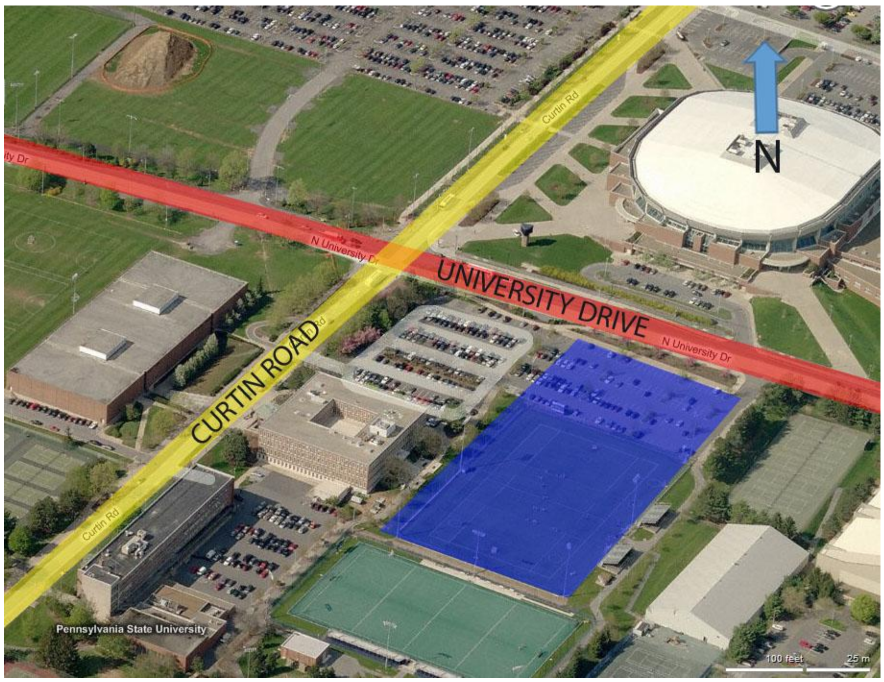


Figure 1. Site Plan of the Penn State Ice Arena (Image from Bing.com)

There are three occupiable floors of the arena. The base level is the Event Level at an elevation of 1156'-1" above sea level. The second level is the Main Concourse Level at 1176'-10" above sea level and the third level is the Club Level, which sits 1206'-1" above sea level. Because the site slopes approximately 21' from the north side of the arena to the south side of the arena, the two main entrances to the main arena occurs at the Main Concourse Level, where entry to community rink on the south of the arena occurs at the Event Level (See Appendix F for selected architectural drawings).

The Event Level houses the community rink which requires locker rooms, skate rentals, and concessions. Both the ice making system and ice supplies are located in the northwest corner of the Event Level providing direct access to both ice sheets. On the north side of the entry level are the division 1 home locker rooms and team lounges, as well as physical therapy rooms. Along the east side of the Event Level, there are rooms for strength training and skill development. The loading dock for the arena is located in the southeast corner of the Event

Level and provides direct access to the main ice sheet. The administrative facilities for the Division 1 hockey teams are located along the south side of the Event Level.

The Main Concourse level serves as the main entry to seating bowl of the main ice sheet. The two entrances are located in the northwest and northeast corners of the arena. In addition to providing direct access to the main seating bowl for patrons, the Main Concourse contains the concession stands, restrooms, and press box. A special banquet facility is located in the southeast corner and provides spectacular views of Mount Nittany.

The Club Level is accessed by a large open stairway in the lobby along the east side of the arena. The Club Level provides 12 suites along the north side of the arena with the potential of adding 12 future suites along the south side of the arena. The suites allow for a more relaxed area to watch games and events with direct access to food and drinks provided by a support staff. Again, there is a special gathering area in the southeast corner of the arena to provide views of Mount Nittany.

Figure 2. A 3D rendering of the Ice Arena's Main Entrance
(Image adapted from Crawford Architects)

The façade of the Ice Arena reflects on the architectural style of Penn State University with a mix of traditional brick and glass. There is a large class curtain wall that spans the entire façade along University Drive providing a welcoming look into the Arena from the exterior. While the front east façade presents a large open feel, the north and south facades of the arena present a more closed anchored feeling of brick mixed with small glass accents. At the entry level of both the north and south façade, there is a 9' glass curtain wall. Above the entry level, there is a large brick façade with long 2' x 27' slot windows that light the outer concourses. The facades of the community rink are simple brick facades.

Construction Management

The Penn State Ice Arena has a hard completion date of August 2013 in order to be ready for the Penn State Hockey team's inaugural season in the Big Ten Conference. Funding for the project was attained by a donation of $88 million from an alumnus. Roughly $77 million has been set aside for the initial cost of the arena. Mortenson Construction has been named the Construction Manager for the project, and the rest of the project is still in the process of accepting bids for work.

The project site itself is located to the immediate west of University Drive and directly to the south of Shields Building, in the northeast corner of campus. The University's athletic facilities are in the surrounding vicinity, with the field hockey fields to the arena's west, the football practice facilities to its south, and the Bryce Jordan Center and Multi Sport Facility to its east. Because of its location on campus, the project will encounter challenges in site logistics as it must not obstruct and must protect pedestrian traffic on the surrounding sidewalks and vehicular traffic on adjacent University Drive. For the size of the arena's footprint, the job site is limited and therefore, logistics will be a concern as there will not be enough room on site for equipment and material storage if not managed carefully. Another constraint of the site is the major utilities duct bank that runs west to east across the north edge of the job site. Work must not damage the duct bank in any way as it is the source of electricity, heat, and plumbing for a huge portion of the University's campus. An additional restriction for the job site is the soil and rock content of the site, which the geological survey reports contains pinnacle rock very close to the surface, which will likely require blasting for deep excavation.

Existing Structural

Foundation

The foundation of the Penn State Ice Arena is a combination of spread footings, strip footings, and micropiles. To combat the slope of the site, foundation walls exist on the North, East, and West sides of the building. Supporting the foundation walls are strip footings ranging from 1'-6" deep to 2' deep. On the South side of the arena, grade beams connect the spread footings underneath the exterior columns. In a designated area, micropiles are used instead of spread footings due to the pinnacled nature of the rock on the site of the arena (See Figure 3). Where pile caps were necessary, steel pipe piles ranging in diameter from 5 ½" to 9 ¾" extend through the soil allowing friction to carry the load of the building. The geotechnical report suggested spread footers for columns that carry a load of less than 150 kips, micropiles w/ 5 ½" steel pipes for columns that carry less than 350 kips, and micropiles w/ 7" or 9 ¾" steel pipes where the load was greater than 350 kips.

The slab on grade has some special considerations due to the ice surface needed for both the community and main ice rink. Underneath the two ice surfaces, there is a 6" slab on grade with a 4" thermal barrier and a 10" sand base. It is imperative that the slab under the ice rinks be thermally isolated to prevent frost heave and thaw weakening. This ensures that the ice surface remains flat and uncompromised. The rest of the building has a 6" slab on grade with less strict thermal isolations. The 28 day compressive strength required for formed concrete slabs and beams is 5,000 psi. All other concrete elements require a 28 day compressive strength of 4,000 psi.

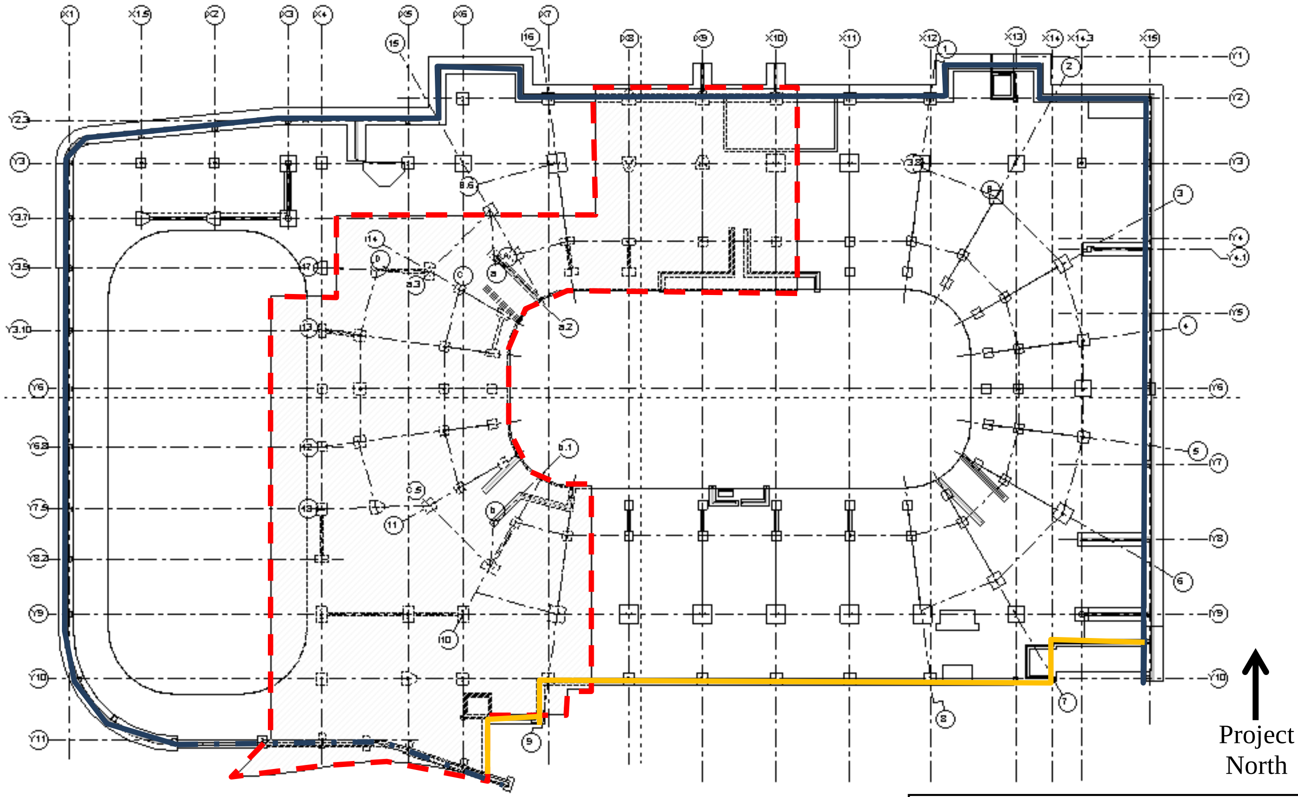


Figure 3. Layout of Foundation System
(Plans Courtesy of Thornton Thomasetti)

Legend:
Foundation Walls
(Dashed= 2' Wall)
Area of Micropiles
Grade Beams

Floor System

The Main Concourse Level and the Club Level are supported by a one way composite steel beam system with varying bay sizes due to the oval seating of the main bowl. The most typical bay size is 32' x 28' along the long sides of the main bowl. The floor deck consists of 3" 18 gauge metal deck with 4 ½" normal weight concrete topping. The floor deck of the typical bay is supported by W24 girders and W18 beams that frame into exterior W14 and interior W24 columns. The main seating bowl consists of precast concrete seating supported by W30 rakers which frame into the W24 columns at the Main Concourse Level.

Roof System

The most difficult part of a long span structure is how to span the long distance required between supports. A 196' steel truss spans the roof over the main seating bowl and main ice rink. The truss consists of W14s for both the top and bottom chord with double angles for web members. There are also vertical W14 members at certain panel points. The top chord of the truss is sloped slightly as the truss is 10' thick at the ends and 12'-6" thick at its center. The truss system supports a center scoreboard, rigging loads, and catwalk, in addition to the roof deck. The roof deck consists of 3" 18 gauge metal deck type N with a built-up membrane roofing material. The bottom chord of the truss sits 50'-0" above the floor of the arena. The overall max height of the high roof is 65'-0" from the top of the roofing material to the Entry Level slab.

The roofs of the surrounding parts of the buildings are supported by steel joists or conventional steel framing. The roof over the Club Level concourse sits approximately 6' below the high roof supported by the roof trusses. The Club Level roof is supported by 24K8 steel joists. The roof over the lobby area along University Drive slopes slightly up and is supported by taper W30x90s and custom 36LH long span joists. The roof over the student section on the west side of the main bowl is supported by W14s and sits approximately 8'-6" below the high roof. Both the lobby roof and the roof above the student section frame into their respective end steel truss. The roof over the community rink consists of 68DLH16 long span steel joists leaving a clear height of approximately 32'-6" between the bottom chord and the ice slab.

Lateral System

To resist the governing lateral loads caused by wind, the arena relies on a combination of concrete shear walls, braced frames, and moment frames. Shear walls are located on the entry level and extend from the slab on grade to the Main Concourse Level (See Figure 4 for location of shear walls). Because it is necessary to have large open concourse areas, moment frames are used along the concourse corridors. Braced frames are used in the walls behind the student section and extend from the Main Concourse Level to the roof (See Figure 5 for location of frames). There are also braced frames located on the edge of the upper roof that is spanned by the large roof trusses. The steel trusses also aide in the lateral resistance.

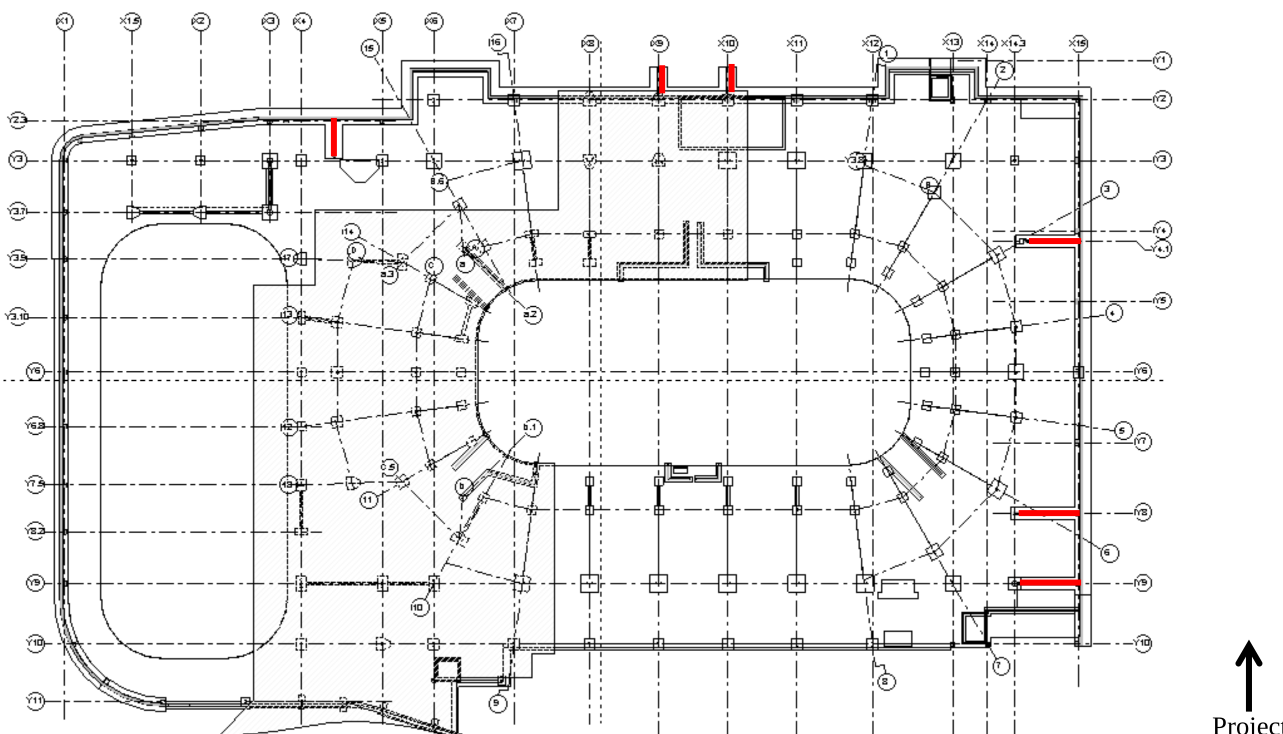


Figure 4. The red lines designate the location of shear walls at the Event Level
(Plans Courtesy of Thornton Thomasetti)

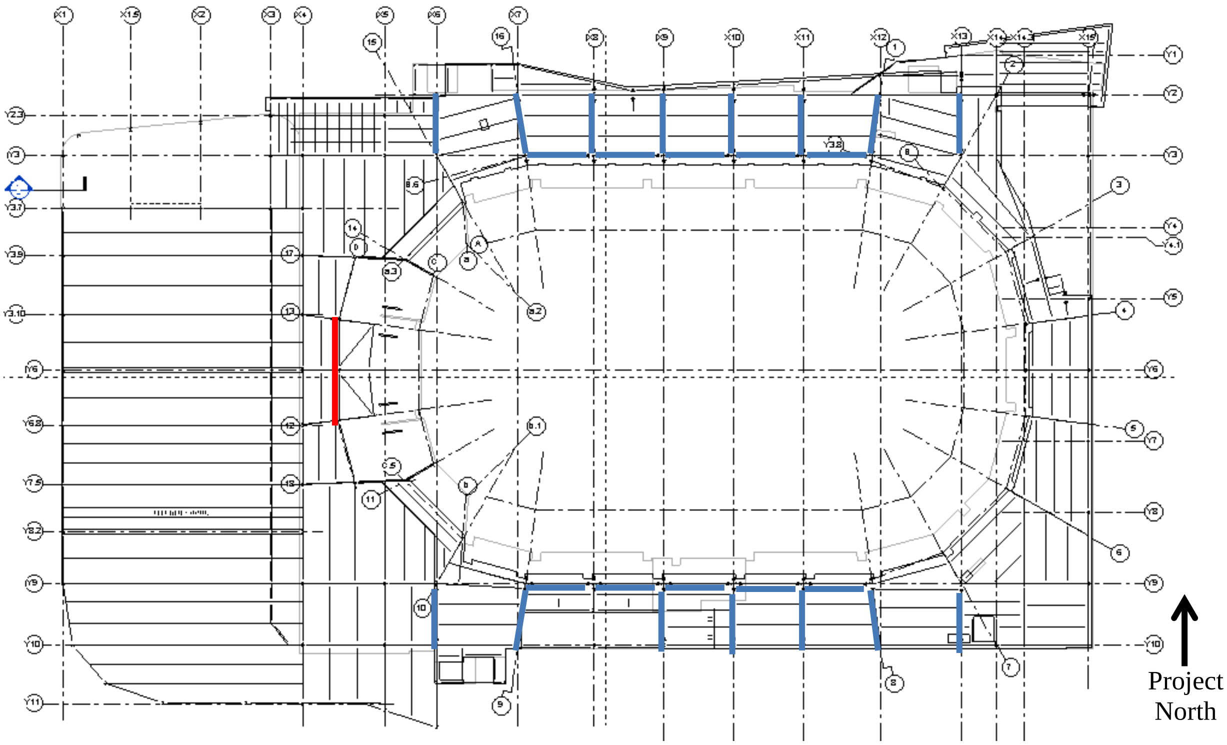


Figure 5. Schematic location of the moment frames and braced frames at the Club Level (Plans Courtesy of Thornton Thomasetti)

Legend:
- Braced Frame
- Moment Frame

Existing Mechanical

The Pegula Ice Arena brings in chilled water and steam from the main campus plant through the mechanical room adjacent to the community rink. Chilled water is distributed by two 770 gpm chilled water pumps. The 150 psi high pressure steam is converted to low pressure steam at a pressure reducing station. Two heat exchangers transfer heat from the low pressure steam to the domestic hot water supply system. Two 230 gpm hot water pumps distribute hot water to the building loads.

The arena heating and cooling loads are met by 14 VAV air handling units. All AHUs are located on the roof between the main arena and community ice rink (See figures 6-9 for AHU/Zones). Suite boxes, mechanical rooms, electrical rooms, concessions, and tel/data rooms are serviced by fan coil units. Electric radiant heaters are located above the stands in the community rink.

On site ammonia chillers are utilized for ice making. There are three screw compressors and one reciprocating compressor. There are also two evaporative condenser towers and three plate and frame evaporators to transfer heat from the glycol to the ammonia refrigerant. Glycol is distributed through concrete slabs under the ice.

The main arena is serviced by two 45,000 CFM VAV AHUs. Outdoor air is sent through an enthalpy wheel and then mixed with return air. The mixed airstream is then sent through a pre-cooling coil to remove humidity and then through a gas fired desiccant wheel for further humidity control. Both units are located on the roof between the main arena and community rink. A single duct from each unit runs the entire length of the arena over the stands on each side.

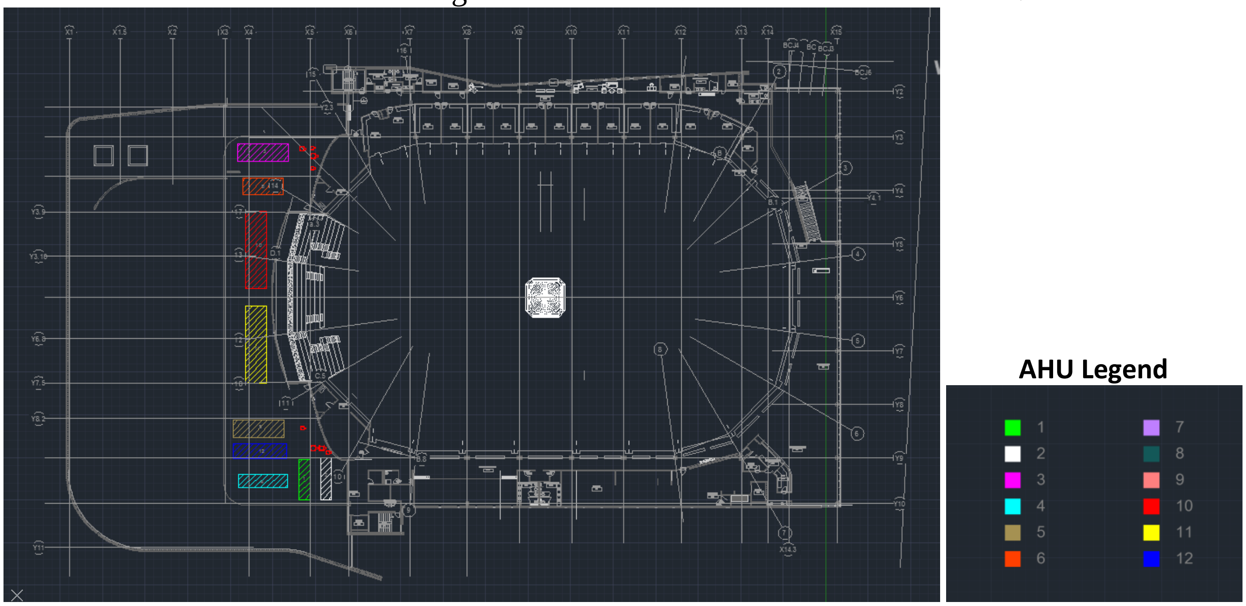


Figure 6. Existing Location of AHUs (Adapted from Drawings Provided by Moore Engineers)

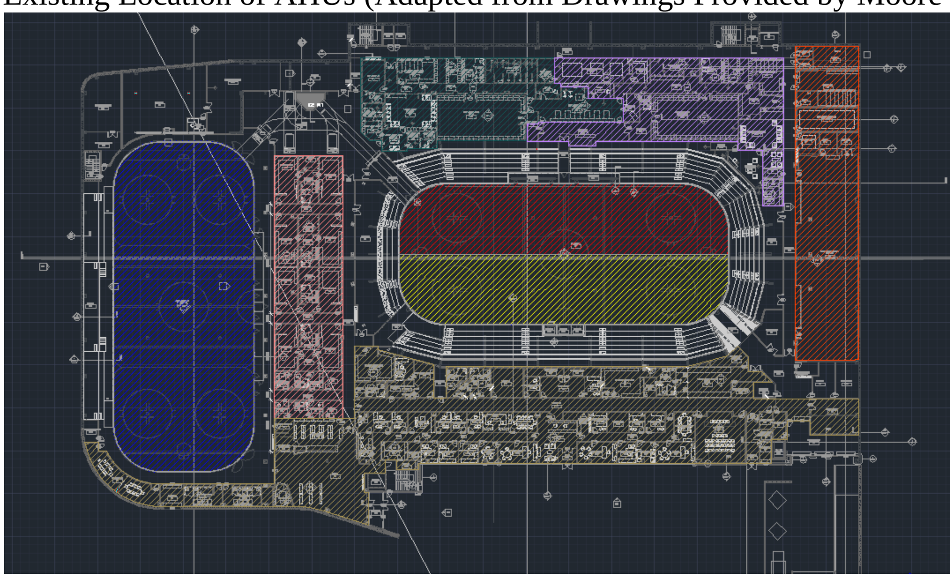


Figure 7. Event Level AHU Zone Diagram (Adapted from Drawings Provided by Moore Engineers)

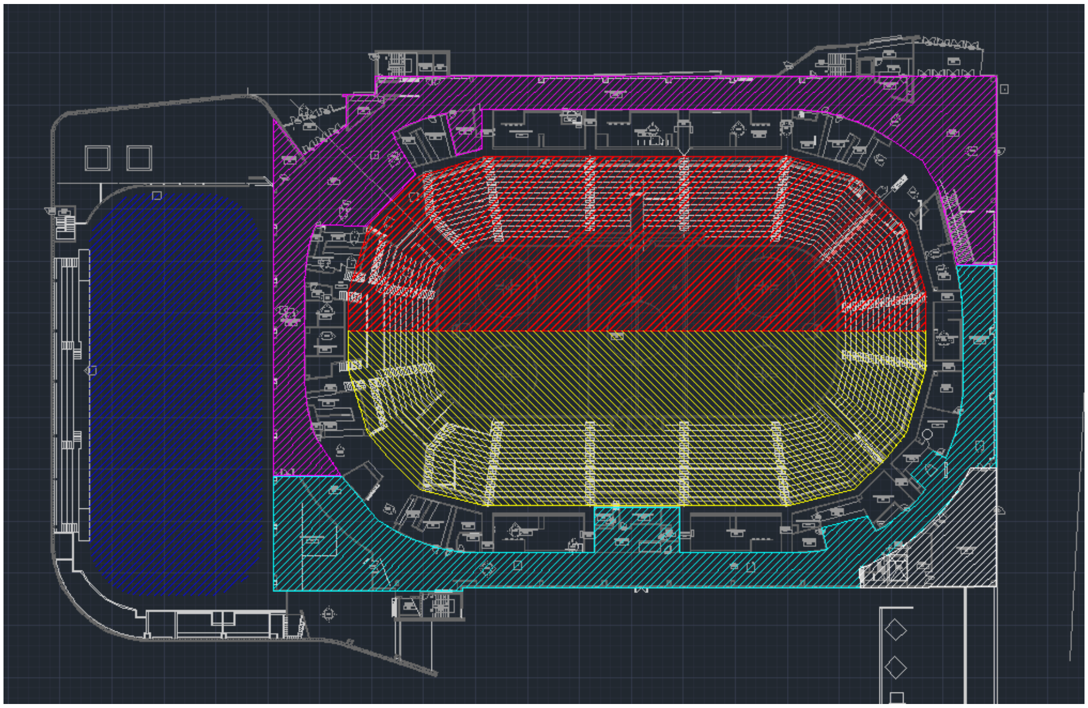


Figure 8. Concourse Level AHU Zone Diagram (Adapted from Drawings Provided by Moore Engineers)

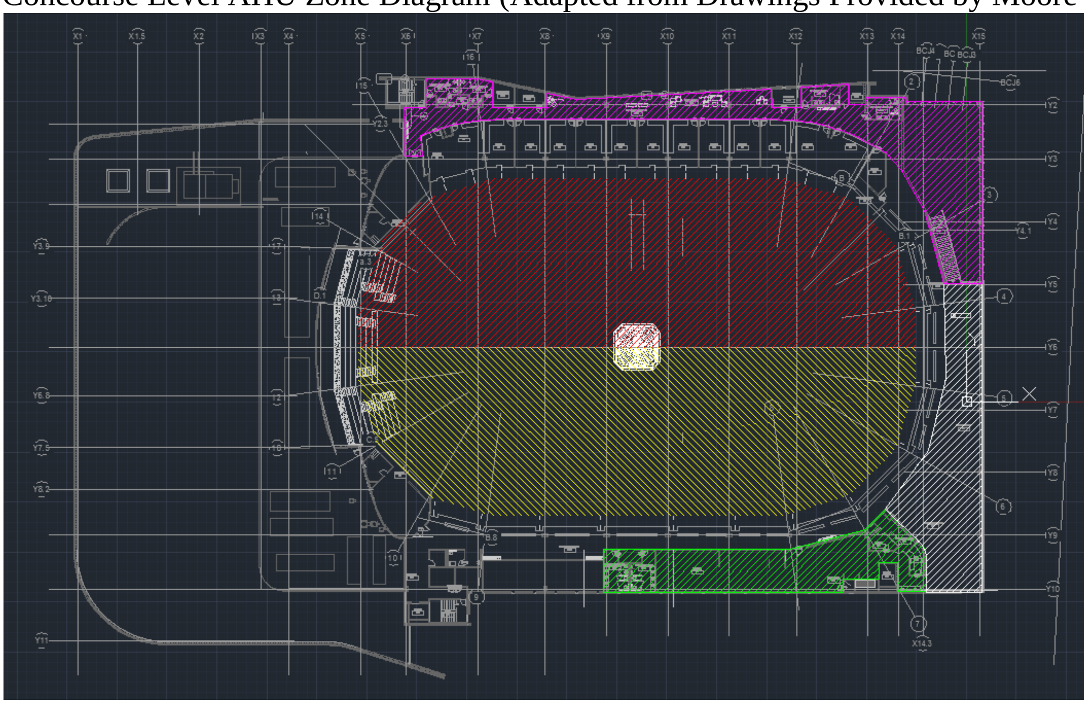


Figure 9. Club Level AHU Zone Diagram (Adapted from Drawings Provided by Moore Engineers)

Existing Lighting

The only spaces where existing lighting was provided (as of July 8, 2011) were the exterior site lighting, main arena and community rink. The exterior lighting utilizes "Penn State standard" 250W high pressure sodium path lighting fixtures. These fixtures are mounted on 12' poles with the exception of the fixtures located in the south western parking lot, which are mounted at 25' above the ground. The lighting for the main arena is provided by eighty-four metal halide fixtures with wattages unspecified. These fixtures provide the necessary illuminance levels for NCAA Division 1 hockey and also the broadcasting requirements. The community rink is lit with 2x4 fluorescent fixtures most likely coupled with T8 or T5 lamps. Using fluorescent fixtures greatly decreases the lighting power consumption within the community rink and the building as a whole while still achieving necessary illuminance requirements.

Existing Electrical

The electrical system currently feeding the Ice Hockey Arena is a 12.47kV service through two oil filled 2500kVA service transformers feeding two 3000A main-tie-main switchgears. Distribution begins with the 12.47kV service being stepped down to 480Y/277V to supply equipment and motor loads, then stepped down further at various locations to 208Y/120V service to supply receptacle, lighting and other loads such as sound systems for the two sheets of ice. Emergency power is supplied by a 4160kV service fed through an oil filled 150kVA service transformer 4160kV service is stepped down to 480Y/277V when then feeds an automatic transfer switch with both normal and emergency power. Standby power is fed from one of the two 3000A switchgears, which then feeds an automatic transfer switch with both normal and emergency power.

Main Roof Redesign

Problem Statement

After reading the feasibility study for the new Penn State Hockey Arena, the main goal of the new design is to create a championship caliber facility that symbolizes Penn State Hockey. To accomplish this goal, the team began focusing on the idea of using a cable structure to create a unique iconic structure for Penn State. Cables would allow the roof to efficiently span the entire 252-foot dimension of the main arena. After choosing to focus on a cable structure, the team selected the type of cable structure that would provide the iconic symbol that was desired for Penn State. Through case studies, research, and iterations the group chose to design a cable-stayed structure to support the roof over the main arena.

The cable-stayed structure was selected for multiple reasons. From the exterior, people will be able to see the tall masts and cables towering above the arena and everyone will know that this is the home of Penn State Hockey. In combination with a new façade design, the roof will appear to be suspended above the ground. On the interior of the arena, the size of the roof trusses can be reduced because they are no longer responsible for carrying the roof loads. The roof load will be transferred to the masts by cables which will be attached to the roof girders. This will create a sleeker interior that will not require as much steel. By reducing the size of roof members, the entire volume of the main arena can be reduced, lessening the energy load on the mechanical system.

The design of the cable-stayed structure will be driven by the structural engineer and construction manager. The mechanical engineer will ensure the roof system is energy efficient and coordinate ductwork with lighting and structural systems. Through the semester, the number of masts and cables will be optimized for structural efficiency, cost efficiency, and aesthetic appearance. Throughout the design process, erection procedures will be developed in order to construct the masts as quickly and safely as possible. The final cable-stayed structure will accomplish the goal of creating an iconic symbol for Penn State Hockey.

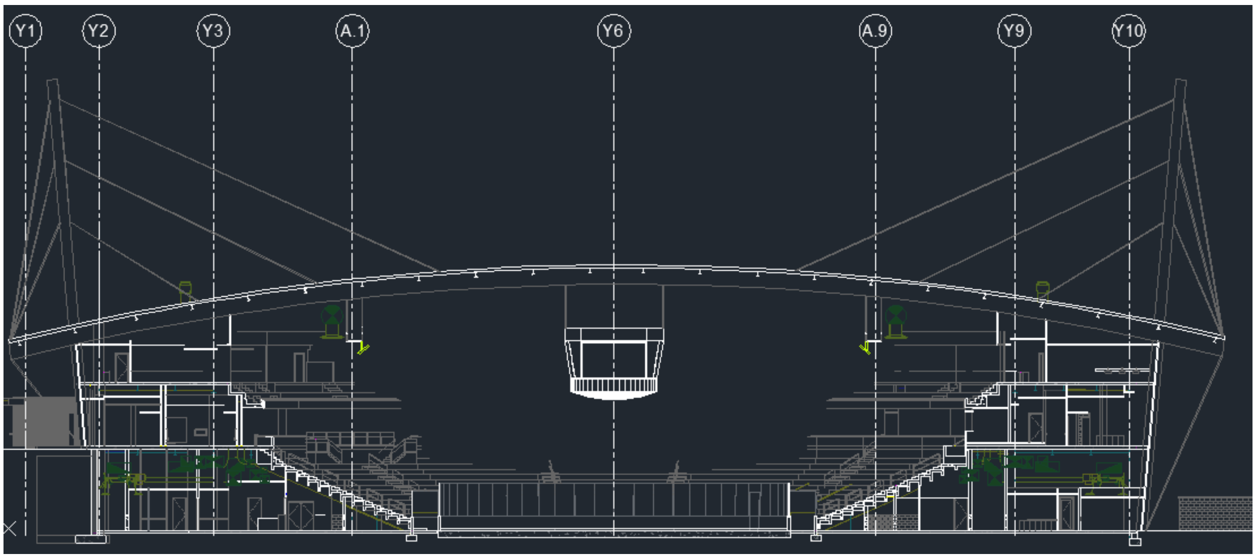


Figure 10. Preliminary Section of Proposed Cable-stayed Design

Construction Solution Methods

The role of the construction manager on the proposed roof redesign consists of two primary roles: cost evaluation and schedule sequencing. The construction manager will also be responsible for coordinating collaboration efforts between disciplines in order to deliver an efficient and cost effective redesign.

The proposed redesign of the main arena's roof system must be compared to the existing roof design in order to determine whether the redesign is beneficial and/or feasible. Therefore, the construction manager must obtain pricing information from the Construction Manager for the project, Mortenson Construction, where possible. Most cost data will have to be obtained by performing quantity take offs from the provided construction documents, 3D Revit model, and 2D drawings, and referencing published resources such as RS Means to estimate realistic cost values for the system. Furthermore, labor and equipment costs for the existing roof design will have to be estimated in order to reflect a comprehensive total cost of the system. Such data will depend on the established construction sequence, therefore the construction manager will cross reference scheduling data provided by Mortenson Construction with labor and equipment pricing provided by RS Means, or other reputable sources. Any gaps in the provided construction sequence logic will be filled in as necessary by using assumptions that are accepted as industry standard. A similar process will be utilized to establish a cost estimate for the redesigned roof system. Once the structural engineer finalizes the proposed structural design and the mechanical, structural, and construction engineers finalize the materials for the new roof system, the construction manager will perform another quantity take off of the proposed system as well as a scheduling estimate. Using RS Means and information obtained from manufacturers and subcontractors, the construction manager will prepare a final cost estimate for the total cost of the proposed system, including the cost of materials, manufacture, labor, and equipment.

Changing the roof system from a steel truss system to a cable-stayed tensile system will require an entirely new construction sequence. To analyze the benefits and disadvantages of such a change, the originally proposed system must first be examined in terms of sequencing, and how the original roof's construction impacts the rest of the project. The original construction sequence will be obtained from Mortenson Construction if at all possible. If not, or if there are lapses in the sequence's logic, then the construction manager will create an assumed construction schedule based on the provided construction documents and accepted industry standards. As previously mentioned, this schedule will also be used to estimate costs for labor and equipment. After completing the analysis of the original construction schedule, the construction manager will produce a schedule for the propose roof system. This will require collaboration with the structural engineer to understand the intricacies of such a complex roof system and understand how the sequencing of the roof construction will impact the roof's performance, as well as how the roof construction will impact manpower on site and necessary equipment, such as cranes. The new schedule will have to take into account how the construction of the roof will also impact other activities on site, especially with crane coordination and location, and the coordination of materials deliveries.

Having completed a construction schedule for the new roof system, the project's site plan will also have to be analyzed and adapted in order to facilitate the new construction. Furthermore, as safety is the main concern on the site, the new site plan will have to take into account safety measures as defined by Penn State's Office of the Physical Plant and by industry standards. Crane location will be analyzed in order to provide the maximum reach for lifts while requiring the least amount of relocating. The presence of cables and tensioning equipment will also require unique circumstances and therefore will have to be coordinated according to industry standards. Due to the physical constraints of the site, material laydown and shake out areas will have to be defined and may need to be located off site if possible.

Mechanical Solution Methods

The roof composition over the main bowl needs to be air tight and resistant to accumulating condensation. The most energy efficient composition will be selected while considering cost and structural requirements. The roof material analysis will be done using H.A.M. Toolbox and Trane Trace 700. The values gained from H.A.M. Toolbox will be inputted into Trane Trace 700 to compare potential energy savings. An emissivity study will be done for optimal humidity and condensation control. Rain and snow control will be coordinated with the structural engineer.

The main arena ductwork will be laid out in Revit MEP. The layout will be coordinated with the roof structure in Revit architecture and coordinated with lighting in Revit MEP. With a cable roof structure there will be no trusses for the ductwork to snake through, so the main arena diffusers can be placed anywhere and the ductwork will hang from the roof. The final model will be run in Navisworks to detect clashes.

Lighting/Electrical Solution Methods

For the lighting/electrical aspect of the roof redesign; lighting fixture structural loads and thermal loads will need to be reanalyzed. The existing lighting scheme provided with the design development drawings will be kept as is while investigating mounting methods for the redesigned cable roof system. The arena will be modeled in Revit with luminaires and catwalks then coordinated with mechanical and structural models to determine clash detection in Navisworks.

Once the lighting criteria are met the main arena scoreboard's mounting will also be investigated to ensure that the scoreboard proposed in the design-development drawings will be able to be supported by the roof structure; if the structural load is too great alternative scoreboards will be looked at.

The final step of the lighting/electrical component of the roof redesign, once the lighting system has been finalized, is to determine power consumption and insure that it is under ASHRAE 90.5.
Loads will be calculated according to equipment specified in design-development drawings.

Structural Solution Methods

It is essential that the new Penn State Ice Arena provide a unique championship quality facility to the new NCAA Division 1 men's and women's hockey team. After extensive research and discussion, a cable-stayed system has been selected to provide such an iconic arena. The cable-stayed system will support an arched roof that will span the entire 252-foot span of the arena. By spanning the entire roof span, there is greater flexibility in the placement of interior columns and loads on the interior columns are reduced. By removing interior columns from the Club Level, Penn State is free to add 12 additional suites to the south concourse without the worry of clashing with interior columns. An arched roof was selected to provide drainage and to provide an architectural acknowledgment of the curved skating lines created by skaters.

The first things that patrons of the hockey arena will see are the mast and cables of the roof system. The mast will be constructed of steel to integrate with the rest of the structural framing and to provide the feeling that the roof is floating above the arena. The selection of steel also allows the masts to be erected quickly rather than waiting for concrete to cure and reach appropriate strength. The masts will be spaced at 30 feet on center to reduce loads on both the roof girders and the masts themselves. Due to this slight alteration (from the original column spacing of 35 feet on center), the interior framing of the main arena will be redesigned by the structural engineer to optimize the amount of structural steel. In addition, an investigation into the number of masts necessary will be done to optimize the structure and economy of the design.

The mast height will be initially set at 90 feet above the Main Concourse Level to meet zoning requirements, but this may be altered based on the structural needs of the cables and zoning discussions (See Figure 11 for section of proposed design). For aesthetic purposes, the masts will be angled at a 5 degree angle from the vertical. The roof girders will cantilever off of the masts 15-20 feet to provide a connection for the cable back stays to return back to the mast foundation. The purpose for angling the backstays back to the mast foundation is to refrain from interfering with the large duct bank that runs the length of the northern portion of the site and to not interfere with parking and drop-off on the south portion of the arena. The foundations will be designed to resist the mast and cable loads in an economically and structurally efficient manner.

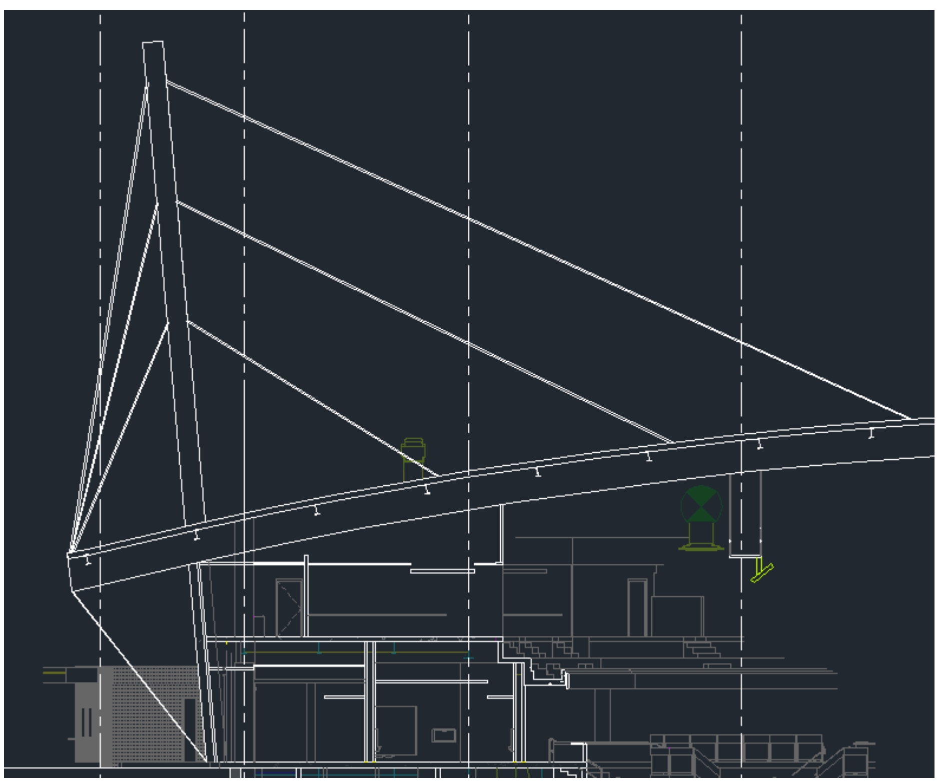


Figure 11. Sketch of Proposed Cable-Stayed Mast System

The main goal of the structural design of the main roof will be to minimize the necessary masts and cables while still providing the necessary support and architectural image that the team desires. In coordination with the Construction Manager, the erection process will be designed and analyzed to ensure that the masts and cables can be erected as quickly and safely as possible. Inside the main arena, the location of ductwork, the catwalk, and rigging loads will be coordinated with the Mechanical and Lighting/Electrical team members.

Construction Tasks and Tools

1. Cost Analysis
    a. Create cost estimate of original roof design by using quantity take offs from provided construction documents and 2D and 3D models, then apply cost data provided by RS Means.
    b. Coordinate with structural and mechanical to finalize materials for proposed roofing system in 3D models.
    c. Create quantity take off from proposed redesign meetings and updated 3D models.
    d. Apply cost data from manufacturers, vendors, and RS Means to quantity take offs and prepare the cost estimate.
    e. Compare and contrast the results of both cost estimates with the team and discuss whether or not to proceed with proposed redesign.
2. Schedule Analysis
    a. Organize schedule data provided by Mortenson for the sequencing of roof construction. Where there are gaps in logic, assumptions will be made based on accepted industry practices and RS Means data.
    b. Coordinate with structural and mechanical to finalize proposed roofing system design and update the 3D model.
    c. Develop construction sequence with the structural, taking into account new processes, site logistics, and crane schedule.
    d. Apply scheduling data from RS Means and detailed sequence analysis to activities on prepared construction sequence.
    e. Analyze impact of new roof construction schedule on overall existing schedule.
    f. Compare and Contrast the results of both schedules and report back to team for discussion of whether nor not to proceed with proposed redesign.
3. Site Plan Analysis
    a. Obtain current site plan from Mortenson or OPP. If current site plan cannot be obtained, create a basic site plan from assumptions about the site and existing construction plan and schedule, as well as from accepted industry practices.
    b. Coordinate with structural in order to determine the size and type of crane to be used on site. Apply the proposed roof redesign schedule to determine the location and pick points of the crane.
    c. Based on crane location, coordinate the layout of the new site, including locations for materials delivery and shake-out, locations for roof erection equipment, location of cables to be installed, and coordination of other tasks being accomplished throughout roof construction. Ensure that all safety standards are met in the new plan.
    d. Create new site plan drawings based on the sequence of construction.

4. MEP Coordination
    a. Meet with mechanical, electrical, and structural to determine the requirements of all parties in regards to moving the mechanical equipment on the roof.
    b. Update Revit model to take into account the changes of the roof's structure and the relocation of the mechanical equipment and corresponding ductwork.
    c. Run clash detection software (Navisworks) to establish preliminary conflicts between MEP and structural elements in the proposed roof system.
    d. Coordinate with all parties to resolve the conflicts.
    e. Finalize relocation plan by running clash detection without producing any conflicts.

Mechanical Tasks and Tools

1. Material Selection
    a. Roof composition thermal analysis using H.A.M. Toolbox
    b. Coordinate cost with construction manager
    c. Coordinate material weight and strength with structural engineer
    d. Main arena load calculations/energy model with Trane Trace 700
2. Design Main Arena Ductwork Layout
    a. Size/layout ductwork using Revit MEP
    b. Coordinate ductwork with Structural with Revit Architecture/Navisworks
    c. Study how best to distribute air in bowl with cable roof
    d. Coordinate ductwork layout with lighting/electrical with Revit MEP/Navisworks

Lighting/Electrical Tasks and Tools

1. Main Arena Lighting Structural Load Analysis
    a. Determine luminaire structural loads from manufacturers data
    b. Determine scoreboard loads from manufacturers data
    c. Relay and coordinate loading information to structural team member

2. Main Arena Lighting Power Consumption Analysis
    a. Determine criteria from ASHRAE 90.1
    b. Determine luminaire power consumption from manufacturers data
    c. Calculate total power consumption and compare with ASHRAE 90.1

3. Luminaire/Catwalk Clash Detection
    a. Model arena in Revit MEP
    b. Determine catwalk position and luminaire mounting locations
    c. Coordinate with structural and mechanical models in Navisworks to analyze clash detection

Structural Tasks and Tools

1. Main Roof
    a. Determine loads from IBC and roof materials
    b. Calculate snow loads and potential drifting/sliding conditions
    c. Design roof deck using Vulcraft deck manuals
    d. Determine potential curve/radius and mast height/angle with group
    e. Model mast, roof beams and cables two dimensionally in SAP
    f. Design roof beams, masts, and cables using forces attained in load analysis so that they satisfy the code requirements of the AISC manual and standards of ASCE 19-10 (Structural Applications of Steel Cables for Buildings)
    g. Confirm roof load assumptions are ok with Mechanical and Lighting/Electrical (i.e. rigging loads, ductwork, etc)
    h. Redesign as necessary based on cost, strength, and service requirements
    i. Model roof system in Revit

2. Erection Procedure
    a. Determine construction process of cable-stayed system with Construction Manager
    b. Analyze mast and cable system in construction process using SAP
    c. Determine if the roof system has adequate strength for construction process
    d. Model erection process in Navisworks

3. Foundation
    a. Take loads determined for columns in floor frame design and mast design
    b. Choose potential foundation system
    c. Design foundation system to meet IBC
    d. Redesign as necessary

4. Floor Framing
    a. Layout column grid to minimize architectural impact
    b. Determine loads using IBC and flooring materials
    c. Design floor deck using Vulcraft deck manuals
    d. Size beams and columns using RAM/ETABS
    e. Coordinate shaft locations with Mechanical team member
    f. Model structural system in Revit and check for clashes

Main Roof BIM/IPD

Our team will use integrated project delivery concepts in our roof redesign. Through integrated team meeting with all members, we will develop a finalized roof design. After completing preliminary analyses, all team members will model their systems in their discipline specific Revit program. The structural Revit model will consist of designed beams, columns, masts, cables, and foundations for the roof system, but will not consist of detailed connection work. The mechanical Revit model will consist of ductwork, diffusers, mechanical equipment, and mechanical piping. The lighting/electrical Revit model will consist of the lighting system provided in the existing design development model. Once these designs are completed, the separate Revit models will be linked into the Architectural Revit model in order to complete clash detections in Navisworks. In addition, the structural engineer and construction manager will model the erection process in SAP using staged construction modeling. From there, we will complete a 4D model of this process in Navisworks.

See Appendix B for a table of the team's BIM goals as they relate to the overall project.

Main Roof Redesign Conclusion

Lights-Out Design saw an opportunity to create an iconic arena through the use of a unique cable-stayed structure to support the roof of the main arena. This creates a unique opportunity to use building information modeling in the design and coordination of the roof as well as the design of the erection process. The structural team member will optimize the number of masts and cables to help minimize the cost of the system and maintain the schedule. The construction team member will aid in keeping cost low by creating an efficient erection process in coordination with the structural team member. Inside the arena, the mechanical, lighting/electrical, and structural team members will coordinate the locations of ductwork, luminaires, and catwalks to prevent clashes.

The structural engineer will be responsible for creating an analytical model of the structure using structural analysis programs and then modeling the final design in Revit Structure. The construction manager will estimate the cost of the new roof structure and create an efficient erection process with the structural engineer. Inside the arena, the mechanical engineer will design the ductwork and size of units needed to supply the main seating bowl. The lighting/electrical team member will ensure the existing lighting system provides proper illuminance levels for hockey and ice productions. Together, the team will coordinate the design using building information modeling to prevent clashes and create an optimal roof design.

There are many goals that the team is trying to accomplish through our main roof redesign. Through the cable-stayed structure, the team will create a strong architectural form that is easily recognizable as the home of Penn State hockey. By moving the main roof supports to the exterior of the arena, the team will create interior flexibility, especially at the club level. This will allow future suite additions to be designed and built without the hindrance of avoiding existing columns. By removing the existing truss design, the interior of the rink will become a much sleeker design reducing the amount of coordination needed in the design of ductwork, catwalks, and lighting of the main arena. Throughout the design, the team will attempt to maintain the originally planned cost and schedule of the main roof.

Façade Redesign

Problem Statement

Continuing with the team's vision of an iconic design the overall building façade is the next system that merits extensive investigation. In keeping with the main concept of a visually light-weight structure and facade, the design-development façade we were given, which utilized a heavy brick façade, will be redesigned to produce a building that, architecturally, is more cohesive with our proposed roof design and contextually appropriate. The goal, through this redesign, is to create a visually appealing roof and façade integration where the roof appears to be floating and hovering above the structure itself.

To achieve this goal, thin lightweight materials such as glass and metal panels will be investigated for use on the exterior. A secondary consideration in the selection of materials is their context and use around campus. Although the end goal is for an iconic building, our team feels that, by effectively utilizing similar building materials found around campus our proposed design can better fit into the context of the university while still maintaining visual prominence. A large part of inspiration for the selection of materials came from the HUB-Robeson Center located on campus and also from the Ratner Center located at the University of Chicago.

The proposed design will have the North, South and East facades predominantly clad in glass and metal panels with the western community rink mostly comprised of brick with glass clerestories. On the other hand, the existing design appears mainly as a monolithic brick façade with slotted glass windows on the North and South facades of the main rink. This dramatic influx of glass could lead to increased solar thermal loads due to sun penetration, thus extensive analysis, especially between the lighting/electrical and mechanical team members will be required in the selection of materials, daylight penetration, and shading coordination to minimize or eliminate excessive gains.

For each façade the team will begin by investigating materials for optimal energy efficiency and condensation control while balancing performance with material and construction costs. Computer aided daylighting analysis will then be conducted to determine daylight autonomy and wall-to-glass ratios will be analyzed to measure the thermal impacts of sun penetration in the space and the thermal efficiency of the wall system. A shading study will then be performed to enhance building performance and life-cycle cost. Lastly, coordination with the Structural team member will be needed to ensure that the façade can withstand structural loads such as material weights and wind.

Construction Solution Methods

The construction manager has two primary responsibilities for the façade redesign process. The construction manager is accountable for analyzing the cost of the building's shell system and comparing the cost of the original façade system to that of the newly proposed system. This estimate is also affected by the construction schedule, and therefore, the differences in the construction schedule need to be analyzed with a scheduling estimate for both conditions: one for the existing/planned façade and one for the proposed façade. The construction manager will be integral to the redesign process for both the lobby and main rink façades. The redesign will require the selection of new materials and new aesthetic look for the ice rink, including glazing, mullion, masonry, and metal panels. Therefore the construction manager will be required to coordinate and work closely with the mechanical, lighting/electrical, and structural options. The new materials will have to be researched and chosen based on their ability to daylight the interior spaces, resist the impact of external temperatures and air quality, their required construction/installation sequence, and their aesthetic properties.

After our group has collectively selected potential materials to be used on the façade based on their performance, the construction manager will compile the cost information for the selected materials from vendors and reliably published sources such as RS Means, as well as a rough estimate of the schedule impact of each material and system. The construction manager will then advise the team on which materials should be selected, based on all performance properties, cost, and impact to schedule. Once the materials have been selected, the group will update the 3D Revit model with the selected materials and new design. The sequencing of installing the new materials and constructing the new design can be ascertained from research of the industry and from RS Means. A quantity take off will then be performed in order to establish the precise quantity of materials to be used in the redesign. The previously attained material cost information can then be applied to the quantity take offs and a new cost estimate can be created. With an understanding of the sequence, the labor and equipment costs required for the façade's construction can be calculated with RS Means, and the cost estimate will be complete. This new cost estimate should then be compared to the cost estimate, created through the same process, of the existing façade system.

Changes in the façade materials are often accompanied by complete changes in the installation process and required systems to support the façade. The installation sequence required of these materials will be explored and analyzed during the initial materials research phase and will be used in order to make a decision on materials selection. Firstly, the new façade construction sequence will be compared to the existing façade's sequence in order to determine pros and cons of the proposed system. Afterwards the sequence will be integrated into the project site plan to compare the logistical needs of the sequence to those of the surrounding work. Specifically, the sequences will be inspected to determine if required equipment such as scaffolding, telescoping lifts, mortar mixers, etc. can be used during the same time period for different tasks throughout the job, thereby eliminating extra costs for equipment rental and costs associated with reorganizing the jobsite. Analysis of the crane schedule will also be required in order to establish if and when the façade construction will require use of the crane, and where the crane will be need to be located during façade construction.

Mechanical Solution Methods

The façade redesign is going to be much lighter and thinner than the façade shown in the existing design development drawings. Thermal analysis is a key criterion in selecting the proposed wall composition. The thermal analysis for the façade design will consist of an energy analysis, materials study, shading, and wall to glass ratios.

Based on the design development drawings, a baseline model of the brick façade will be analyzed. The wall configuration analysis will be done using H.A.M. Toolbox. The results from this analysis will be compared to the proposed façade design.

The new design will consist of metal panels and glazing. H.A.M. Toolbox will be used for R-value analysis, condensation analysis, and air leakage analysis. This data will be input into Trane Trace 700 to calculate energy consumption for different wall configuration models. The most energy efficient wall that coordinates with optimal daylighting will be used. These results will be compared to the design development base model.

A significant addition of glass will require a well designed shading strategy. Energy savings will be gained in the winter by maximizing solar energy but minimize solar gain in the summer. Different shade lengths for different sides of the building will be analyzed to find the most energy efficient strategy. The shading and wall to glass ratio analysis will be done in Trane Trace 700. The final façade selection will be coordinated with the structural engineer for support and the construction manager for cost and schedule analysis.

Lighting/Electrical Solution Methods

For the Façade redesign the lighting/electrical member will primarily be responsible for conducting daylight analysis and ensuring that daylight harvesting can be smoothly integrated within the building without negatively impacting the overall efficiency of the building. The daylighting analysis will be split into three distinct parts of the building; the front East lobby wall, the North façade and the South façade. A large majority of the exterior façade will be altered, thus appropriate and efficient materials will need to be analyzed in coordination with all the team members to ensure that our building envelope is not only tight and leak-proof, but also cost-effective and structurally sound. Lastly, within the Façade redesign, is the lighting redesign of three of the building's spaces and also the branch circuits for those spaces.

Material selection will be done by coordinating with the mechanical and construction management team member in the early phase. As more materials are narrowed down structural implications will be conveyed to the structural team member to design for accordingly. Building materials will be selected based upon their thermal efficiency, ability to be integrated with daylighting, cost and the prevalence of the material found on campus.

Once materials are selected a glass-to-panel ratio analysis will be conducted with the mechanical team member to ensure a balance between heat gain and light penetration and to determine a suitable ratio between glass and paneling that minimizes thermal gain while allowing for target daylight levels of 100-200 footcandles to be achieved. This analysis will be done in Daysim for the lighting/electrical member and Trane Trace for the mechanical team member. This process of materials selection will be done for all three façade orientation and will allow for a building envelope that can effectively harvest daylight while still maintaining energy efficiency.

The final step of the daylighting aspect of the façade redesign will be a shading analysis. Shading for the three façade orientations will be done primarily through roof overhangs. Shading will be taken into account when redesigning the roof and selecting materials to ensure that the material and amount of overhang will coordinate with what is necessary to effectively control daylighting. This will be especially important within the South façade as this orientation will receive the most sun exposure and will also most likely have the most glass area. The first step of the shading analysis will be a profile angle study to determine the angle of light penetrating the space, especially during the summer solstice. Next a preliminary shading analysis will be done using AGi32 to determine shadows and light penetration into the space and also approximate dimensions of the overhang to effectively eliminate solar infiltration. Once shade dimensions have been selected, the Revit model will be modeled and updated to reflect the proposed shades and imported to 3DS Max for further daylight analysis.

Lastly, as stated above, within the façade redesign scope, is the redesign of three of our buildings spaces; these three spaces are the exterior building façade, main entrance/lobby and the club lounge/bar. These redesigns will be done according to the lighting schematic design proposal with changes made accordingly to the feedback received by Dr. Mistrick and the Lutron lighting panel (see Appendix E). The final step of the lighting/electrical component of the roof redesign, once the lighting system has been finalized, is to determine power consumption and insure that it is under ASHRAE 90.5 requirements and design the branch circuits feeding the lighting system. Loads will be calculated according to equipment selection and branch circuits will be designed according to 2011 NEC. The electrical design will also be done in Revit MEP.

Structural Solution Methods

After selection of the cable-stayed roof system, the brick façade of the existing design did not match the new airy architecture. A new façade system consisting of metal and glass panels will be chosen to create the appearance of the roof suspending above the arena only supported by the cable-stayed and mast system. The mechanical and lighting/electrical engineer will drive the selection of the panels to create an energy efficient wall system. The structural engineer will assist in the analysis and design of the panels and panel supports to ensure that they will resist component and cladding wind design pressures. Panel connections will not be a focus of this design.

With the changes to the façade and structural system, the structural engineer will investigate the lateral stability of the arena. To decrease loads on the cable-stayed system, the exterior column/mast spacing has been reduced to 30 feet spacing. The re-spacing of interior columns to 30 feet causes minimal architectural impact. The steel framing will be redesigned to ensure that structural steel is optimized. The current design of the lateral system mainly relies on moment frames at the Club Level to resist the lateral loads placed on the arena. With the rearrangement of columns, the structural engineer will investigate the possibility of coordinating braced frames into the exterior façade similar to the braced frames seen at the Ratner Center at the University of Chicago. The braced frames would be a stiffer, cheaper solution to lateral resistance, but the impact on the architectural appearance of the arena will be a major factor in this decision. In coordination with the rest of the team, the lateral system will be designed to minimally impact the exterior architecture while providing the necessary lateral support.

Construction Tasks and Tools

1. Cost Analysis
   a. Create cost estimate of original façade design by using quantity take offs from provided construction documents and 2D and 3D models, then apply cost data provided by RS Means.
   b. Coordinate with mechanical and lighting/electrical to finalize materials for proposed facade system in 3D models.
   c. Create quantity take off from proposed redesign meetings and updated 3D models.
   d. Apply cost data from manufacturers, vendors, and RS Means to quantity take offs and prepare the cost estimate.
   e. Compare and contrast the results of both cost estimates with the team and discuss whether or not to proceed with proposed redesign.

2. Schedule Analysis
   a. Organize schedule data provided by Mortenson for the sequencing of roof construction. Where there are gaps in logic, assumptions will be made based on accepted industry practices and RS Means data.
   b. Coordinate with structural, mechanical, and lighting/electrical to finalize proposed façade system design and update the 3D model.
   c. Develop construction sequence with the structural, taking into account new structural frame design, site logistics, and special equipment for installation.
   d. Apply scheduling data from RS Means and detailed analysis to activities on prepared construction sequence.
   e. Analyze impact of new façade construction schedule on overall existing schedule.
   f. Compare and Contrast the results of both schedules and report back to team for discussion of whether nor not to proceed with proposed redesign.

3. Site Plan Analysis
   a. Obtain current site plan from Mortenson or OPP. If current site plan cannot be obtained, create a basic site plan from assumptions about the site and existing construction plan and schedule, as well as from accepted industry practices.
   b. Determine proper equipment that will be required to be used during the installation of the proposed façade. Determine the amount of materials that will be required to be delivered to the job site in order to meet the construction schedule, and locate material drop off sites accordingly. Ensure that all safety standards are met in the new plan.
   c. Create a new site plan that would reflect the changes in design and accompanying changes in the construction sequence.

Mechanical Tasks and Tools

1. Material Selection
    a. Wall composition analysis using H.A.M. Toolbox
    b. Compare main bowl energy loads in Trane Trace 700 model
    c. Coordinate materials with structural system
    d. Model in Revit Architecture
2. Panel To Glass Ratio Analysis
    a. Compare ratios in Trane Trace 700 model
    b. Coordinate with optimal daylighting
    c. Panel and glass cost analysis coordinated with CM
3. Shading Analysis
    a. Shade length analysis using Trane Trace 700 model
    b. Update Revit Architecture model

Lighting/Electrical Tasks and Tools

1. Glass to Panel Ratio Analysis
    a. Determine baseline daylighting illuminance level
    b. Determine varying glass-to-panel ratios for analysis
    c. Analyze each glass-to-panel ratio in Daysim
    d. Record results of glass-to-panel ratio/illuminance
    e. Coordinate with mechanical team member to determine optimal glass-to-panel ratio
    f. Model proposed ratio/design in Revit Architecture

2. Shading Analysis
    a. Analyze proposed design without shades in AGi32 to determine baseline illuminance level
    b. Solar profile angle study
    c. Preliminary modeling in AGi32 to determine overhang/shade dimensions, angles, interior illuminance levels and shadows
    d. Model overhang/shades in Revit Architecture
    e. Export Revit model into 3DS Max for daylight analysis
    f. Relay shade information to mechanical team member to analyze reduction of thermal load
    g. Conduct life cycle cost analysis with mechanical and construction management team member

3. Electric Lighting Redesign
    a. Determine illuminance criteria and considerations for spaces accordingly
    b. Incorporate Lutron suggestion into schematic design
    c. Finalize schematic design

   d. Fixture/luminaire selection
   e. Build lighting model
   f. Analyze/render spaces

4. Lighting Power Consumption Analysis
   a. Determine criteria for each space from ASHRAE 90.1
   b. Determine luminaire power consumption from manufacturers data
   c. Calculate total power consumption and compare with ASHRAE 90.1

5. Lighting Branch Circuit Design
   a. Determine total loads
   b. Size branch circuits accordingly
   c. Final design done in Revit MEP

Structural Tasks and Tools

1. Lateral System
   a. Determine lateral loads using ASCE 7-10
   b. Determine potential locations of braced frames/moment frames based on architecture
   c. Model braced frames, moment frames, and diaphragms of arena in ETABS
   d. Analyze lateral system in ETABS
   e. Redesign as necessary
2. Façade
   a. Aide in selection of panel materials focusing on weight and strength of panels
   b. Design panels and mullions to resist components and cladding wind pressures
   c. Schematic design of connections to ensure structural integrity
   d. Redesign as necessary

Facade BIM/IPD

Our team will use integrated project delivery concepts in our facade redesign. Through integrated team meeting with all members, we will develop a finalized facade design. After completing preliminary analyses, all team members will model their systems in their discipline specific Revit program. The façade redesign will primarily focus on the electrical and mechanical team members in coordinating and selecting appropriate building materials while balancing the ratio of glass-to-wall. These analyses will be done through the use of Trane Trace 700, DaySim, Revit MEP and Revit Architecture. The Architectural Revit model will consist of the wall and modeled according to materials selected. The structural Revit model will consist of bracing, columns, and beams but will not consist of detailed connection work. Once these designs are completed the Architectural Revit model will be exported into Navisworks for clash detection.

See Appendix B for a table of the team's BIM goals as they relate to the overall project.

Façade Redesign Conclusion

Having chosen a cable-stayed structure, the team felt it was necessary to redesign the façade to create a lighter energy efficient façade with the goal of producing an illusion of the roof suspended above the ground. The mechanical and lighting/electrical team members will drive the selection of the façade materials based on daylighting and energy efficiency. In coordination, the construction team member will estimate the cost of the materials to allow for the optimum façade possible based on cost and energy efficiency. The panels and mullions will be designed by the structural engineer to resist gravity and lateral loads.

Several deliverables will result from the façade redesign. The final façade model will allow the lighting/electrical team member to analyze energy usage with various daylighting strategies to create well lit concourse areas. The mechanical and lighting/electrical engineers will work together to provide an energy analysis of the new façade. The final façade design will be modeled to show wall composition and shading devices to allow the construction manager to estimate the total cost of the new façade. The construction team member will then create a 4D model to illustrate schedule implications of the new façade.

For the façade redesign, the team's goals revolve around architectural form and the balance of energy efficiency. The façade will be designed to add to the new architectural style and complement the cable-stayed structural system. With the greater infusion of glass, the lighting team member will control the daylighting to 100-200 footcandles based on IES recommendations. The façade will be optimized for energy efficiency. It is important to balance the cost of metal panels and glass with energy efficiency and the overall lifecycle cost. Throughout the façade design, it will be important to maintain a schedule similar to the actual design to create the best overall product.

Community Rink Redesign

Problem Statement

The community rink will be utilized almost 24 hours a day 7 days a week. Due to its extensive use, Lights-Out Design wanted to improve the feel of the space by incorporating daylighting into the rink. In addition, the team wanted to make the community rink more prominent by redesigning the shape of the roof. In order to add flexibility to the roof design, the edge exterior mechanical space needs to move 15 feet to gridline X4 (See Figures 12 and 13). This decision also presented an opportunity to increase the efficiency of the mechanical system by moving several units to the front of the arena above the lobby roof.

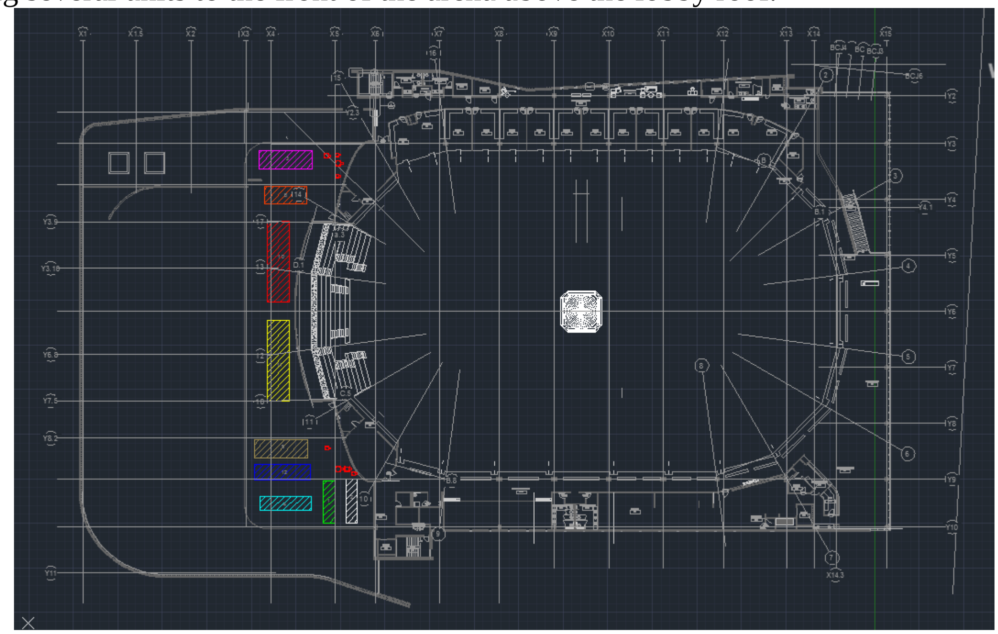


Figure 12. Existing Mechanical Room Layout (Adapted from Drawings Provided by Moore Engineers)

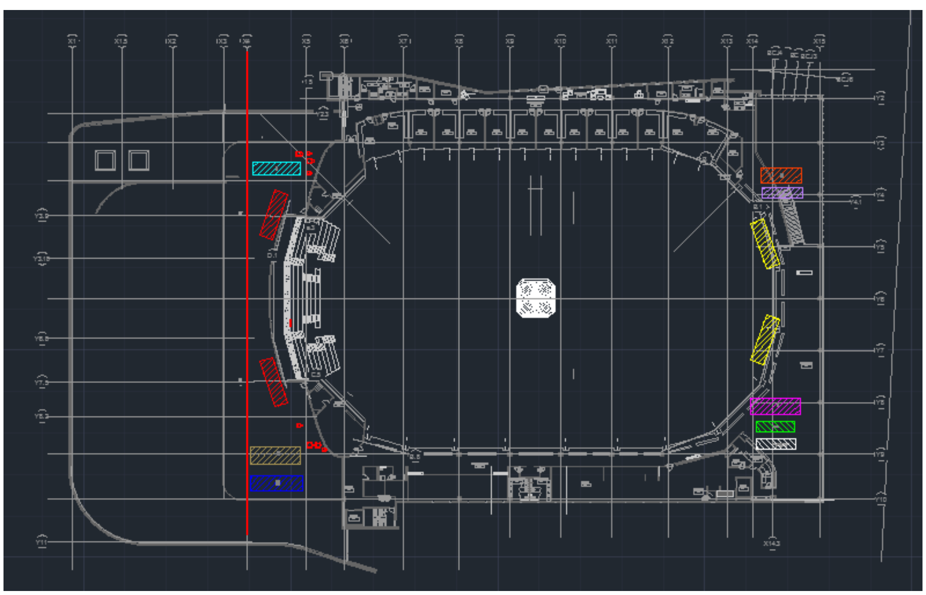


Figure 13. New Layout Highlighting Gridline X4

The current design of the mechanical system requires long duct runs and high pressure drops from the existing mechanical space above the community rink to service spaces in the front of the arena such as the lobby and weight room. The new design will move mechanical units that service those spaces above the main lobby thus eliminating the long duct runs and reducing fan energy (See Figures 14 and 15). In the design development drawings the main arena is serviced by two large air handling units in the existing mechanical space. The new design will move one of the two air handling units to the new mechanical space on the opposite side of the main bowl which will reduce overall energy consumption. Shorter ductwork runs will result in lower fan energy required to overcome the greater pressure drops in the existing layout. Each unit will be split into two separate units in order to make the system more efficient at part loads. By moving the units above the lobby, strong coordination efforts will be required between the structural and mechanical team members to redesign the structural elements to support the added weight and to address vibration concerns.

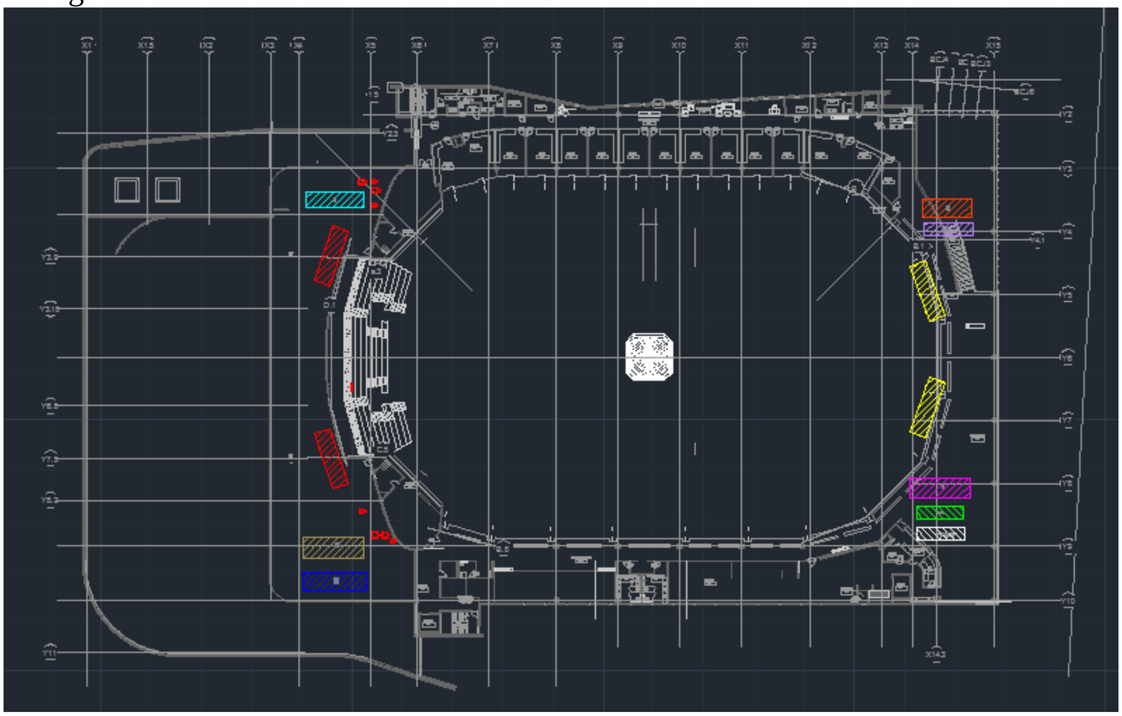


Figure 14. Mechanical Room Redesign Layout

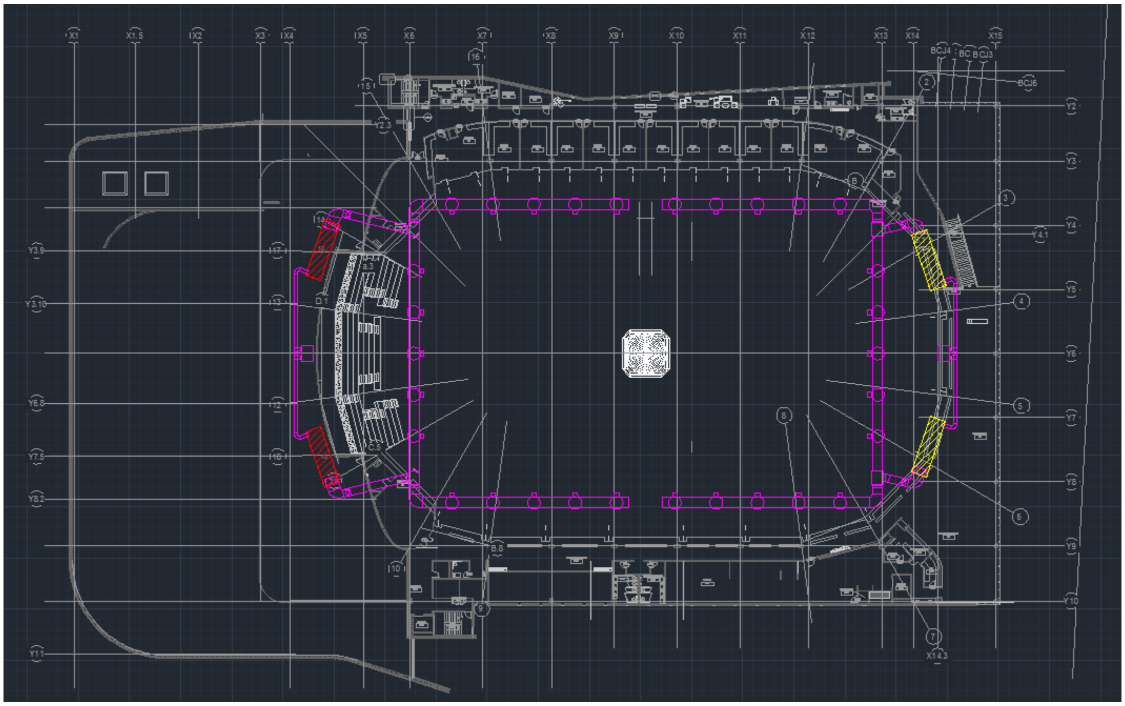


Figure 15. Schematic Design of Main Bowl Air Distribution

By moving the units, the roof structure will become more flexible for different daylighting strategies (See Figures 16 and 17). A bi-directional clerestory integration will be analyzed to harvest sunlight coming from the east during early morning hours with a second orientation to be determined through the potential for daylighting for the remaining three orientations. Duration and intensity of sun penetration will need to be carefully analyzed to ensure that daylight harvesting does not negatively impact the ice quality. The majority of the community rink roof redesign will be driven by the findings and design of the daylighting analysis in coordination with the structural team member to ensure structural integrity.

Figure 16. Community Rink Section (Daylighting)

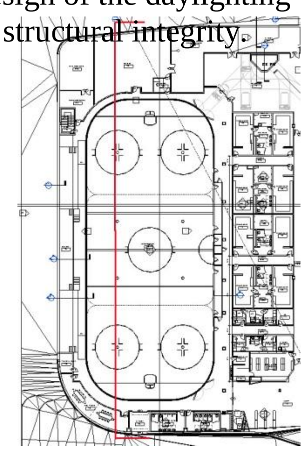


Figure 17. Community Rink Section Line

Construction Solution Methods

As required in the other two portions of this project, the construction manager will be responsible for analyzing the cost and schedule impacts from the redesign of the community rink located west of the main arena. The redesign will include a new roof shape and composition, changes in the brick façade to allow for more daylighting, and the relocation of mechanical units and equipment. Effects of these changes on the site plan will have to be analyzed as well.

With the aid of the mechanical and structural, the construction manager will perform a quantity take off estimate for the existing conditions of the community rink's façade, roof, and the mechanical equipment to be moved. A cost estimate will then be created by referencing cost information from RS Means and applying it to the quantity take off. Furthermore, the existing construction schedule for the community rink work will be analyzed and used to determine the durations for the work, which will determine the cost of labor and equipment and which will complete the cost estimate. After the mechanical equipment is relocated, the roof is redesigned, and windows and clerestories are added to the façade, the construction manager will again perform a quantity take off for the updated design. RS Means and vendors will be consulted for pricing information, which will then be applied to the quantity take off for an updated cost estimate. The resulting construction sequence will also be analyzed in order to determine the change in costs associated with labor and equipment.

The changes made to the community rink will require a reworking of the existing construction schedule, and therefore, said changes must be analyzed in order to determine their impact on the construction sequences of the work surrounding it. The proposed construction schedule will be determined by understanding the processes and methods of construction that are required by the proposed changes to the design. Once the processes are understood, the sequence can be determined, and durations and costs associated with the new sequence can be calculated from RS Means and vendors. The proposed schedule can then be compared to the existing schedule (obtained from Mortenson and industry standards) and the pros and cons of the redesigned work can be assessed. As it is the last focus of the proposal to be examined, the proposed construction schedule for the community rink redesign will be the last element to add to the overall proposed construction schedule, and the differences between the completed proposed construction schedule and the existing schedule can by analyzed. Furthermore, the changes in construction sequence for the community rink will have to be examined in relation to their effect on the jobsite. The crane requirements for roof construction will have to be determined, and those requirements will have to be integrated into the crane schedule and used to establish the most efficient process of using the crane.

The community rink redesign will impact the mechanical and construction manager. Included in the proposed redesign is the relocation of mechanical units, specifically air handling units, currently located between the existing community rink roof and main arena roof, to the east side of the main arena. From preliminary coordination and value engineering efforts, it has been determined that moving aforementioned equipment would create savings in energy, materials, as well as a potential savings in labor and time. The construction manager will again have to analyze how these operations will impact both the original construction schedule and the proposed schedule. Furthermore, the construction manager will be required to coordinate the efforts with the mechanical and structural engineers of actually installing the rerouted equipment and how the equipment will penetrate the shell and reach their corresponding zones.

Mechanical Solution Methods

The addition of another mechanical room will allow for changes in AHU sizing and ductwork sizing. In the design development drawings, zones on the east side of the building are being served by AHUs located on the roof to the west of the main arena. Moving the units to the new location will eliminate duct runs of 250+ feet. Moving the units will result in significant fan energy savings and ductwork installation and cost savings. A Revit MEP 2012 model of the design development drawings with correct ductwork and AHU sizes will be created as a baseline. Calculations for new load and ductwork sizes will be done using Trane Trace 700 and Revit MEP 2012. Revit MEP will be used to calculate duct length and static pressure drop for the baseline model and the redesign. Trane Trace 700 will be used to compare fan energy consumption between the two models.

The new mechanical space coordination will include locations for shafts and air intakes. Shifting the wall on the west side will reduce the size of the mechanical space which will call for smaller air handling units for the main arena. In the design development drawings the main bowl is served by two large AHUs in the west mechanical space. In the redesign one of the units will be moved to the other side of the arena. The ductwork from each unit will only run halfway across the arena. This will save on fan energy and ductwork size.

The redesign will split each of the units for the main arena into two separate AHUs. The desiccant wheel will be taken out of the unit and will be shared between the two new units. The new units will also lose the enthalpy wheel and indirect dehumidification will be done with return air bypass. Enthalpy wheel controls are expensive and susceptible to inaccuracies. Each set of units will be connected by a ductwork loop. At part load, when the there are no spectators in the main bowl, one of the units can be turned off to improve the efficiency of the system. One of the units on the west side of the arena will be connected to the community rink. This will create redundancy and potential energy savings within the system.

Lighting/Electrical Solution Methods

The lighting/electrical focus of the Community Rink will be primarily daylighting. The lighting/electrical member will also be reanalyzing the proposed lighting design that was included with the design-development drawings to ensure that adequate light levels are achieved by the existing fluorescent lighting design and to determine cost savings of integrating daylighting.

Through the relocation of mechanical units above the Community Rink, the structure and shape of the roof became much more flexible due to the reduced structural load of the equipment. This flexibility in roof design allowed for better and more efficient daylighting strategies. The goal of this design is to enhance the way the space of the community rink feels through the integration of clerestories and a redesigned façade.

The proposed design will utilize bi-directional clerestories coupled with increased window area along the façade to harvest daylight for the community rink. Material selection will be integral within the redesign. Special attention will be paid to materials ability to diffuse sunlight entering the community rink to minimize the impact of light striking the ice surface and any shadows that may be casted onto the playing surface. Materials will be chosen in coordination with all the team members to ensure not only just a daylighting appropriate and thermally efficient envelope, but also a cost and structurally efficient one.

A preliminary AGi32 analysis of the East and West clerestory orientations will be analyzed to determine effectiveness of daylight harvesting, shadows, glare and dimensions of clerestories. Shadows from the main arena cast onto the community rink will have to be carefully looked at when determining location and size of Eastern clerestory. Once clerestory dimensions have been determined a thermal load analysis will be done in coordination with the mechanical team member to ensure that solar thermal loads will not impact the quality of ice or the overall efficiency of the building. Once a balance between daylight integration and thermal loads is achieved, a more detailed daylighting analysis will be done in Daysim using an updated Revit Architecture model reflecting any changes.

Structural Solution Methods

In order to gain added flexibility on the roof of the community rink and to gain efficiency of the mechanical system, some of the mechanical units will be moved from the originally planned location to the roof over the lobby. By moving the units over so that they do not cross grid line X4, the roof of the arena can now be sloped. The slope of the roof will be coordinated with the Lighting/Electrical Engineer to allow for daylighting of the arena, while not compromising the championship quality of the community ice rink. There are significant structural advantages to moving the units off of the existing long span joists. First, the movement of mechanical units off the joists reduces a large load placed on the long community roof which spans 110 feet. Second, the joists will now see a more uniform load rather than a significant load on the last 15 feet of the joist. Thirdly, by sloping the roof, the roof snow load will decrease because the snow will slide off more easily (also shedding rain water quicker as well). The goal of the roof design will be to optimize the roof to use less steel and costing less than the original design.

The flexibility gained for the community roof creates new structural issues for the roof over the lobby. By placing mechanical units on top of the lobby roof, the roof must now handle an increased load and vibration issues must be taken into account. Another potential issue is that the mechanical units may be seen from the ground. The current design of the lobby roof sets the top of the roof 24 feet above Club Level floor. In order to accommodate the new mechanical units, the ceiling of the lobby/club lounge above the Club Level will be set at 12 feet and 5 feet will be left for plenum space. This will allow the roof height to be dropped 7 feet and a 6 foot high screen wall to be added to prevent the units from being seen (See Figure 18). The addition of the screen wall creates an enclosed area for snow to be trapped in. Drifting snow off of the main arena roof will be calculated to ensure that the roof can support not only the additional mechanical units, but large snow drifts as well.

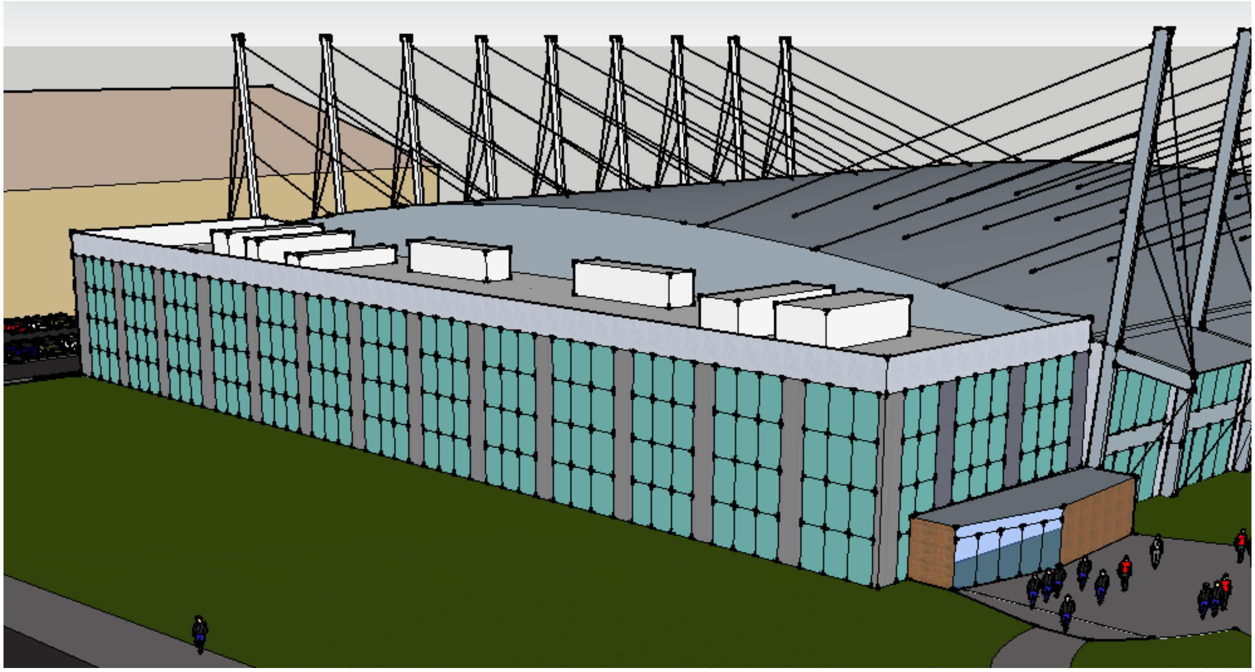


Figure 18. Schematic Design of Open Mechanical Area

In addition to the option of dropping the roof and creating an area for outdoor units, an option to enclose the units by continuing the cable-stayed system over the lobby will be investigated (See Figure 19). This solution would add a mechanical loft above the lobby set 17 feet above the Club Level. The main roof would then extend all the way to the east façade of the main arena. This solution creates a stronger exterior architectural statement, but may affect the interior lobby spaces negatively as additional columns may be needed to support the mechanical loft. The best option will be chosen based on architectural impact, cost, and energy implications.

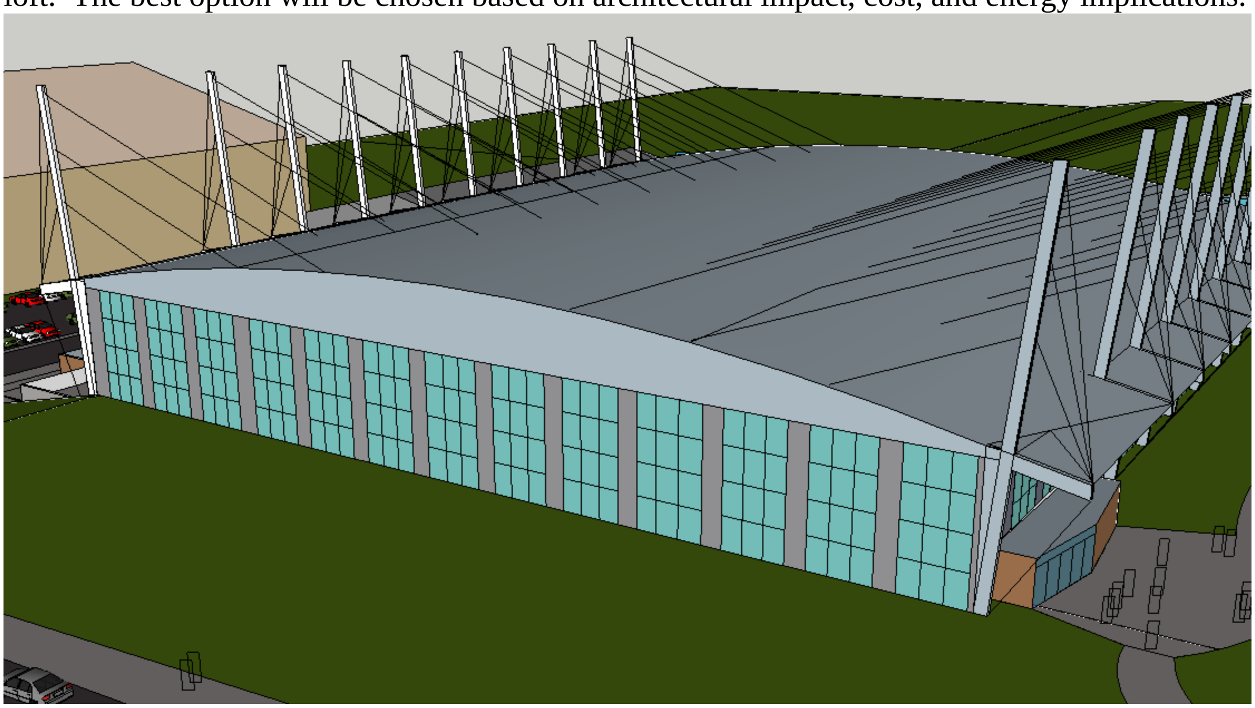


Figure 19. Schematic Design of Extended Roof

Construction Tasks and Tools

1. Cost Analysis
    a. Create cost estimate of original community rink design, including façade, structure, and mechanical systems, by using quantity take offs from provided construction documents and 2D and 3D models, then apply cost data previously established from RS Means.
    b. Coordinate with structural, mechanical, and lighting/electrical to finalize materials for proposed facade system in 3D models.
    c. Create quantity take off from proposed redesign meetings and updated 3D models.
    d. Apply cost data from manufacturers, vendors, and RS Means to quantity take offs and prepare the cost estimate.
    e. Compare and contrast the results of both cost estimates with the team and discuss whether or not to proceed with proposed redesign.

2. Schedule Analysis
    a. Organize schedule data provided by Mortenson for the sequencing of façade, roof, and mechanical systems construction on the community rink. Where there are gaps in logic, assumptions will be made based on accepted industry practices and RS Means data.
    b. Coordinate with structural, mechanical, and lighting/electrical to finalize proposed community rink design and update the 3D model.
    c. Develop construction sequence with the structural, taking into account new structural frame design, site logistics, and special equipment for installation of façade and mechanical equipment.
    d. Apply scheduling data from RS Means to activities on prepared construction sequence.
    e. Analyze impact of new community rink construction schedule on overall existing schedule.
    f. Compare and Contrast the results of both schedules and report back to team for discussion of whether nor not to proceed with proposed redesign.

3. Site Plan Analysis
    a. Obtain current site plan from Mortenson or OPP. If current site plan cannot be obtained, create a basic site plan from assumptions about the site and existing construction plan and schedule, as well as from accepted industry practices.
    b. Determine proper equipment that will be required to be used during the construction of the community rink. Determine the amount of materials that will be required to be delivered to the job site at one time in order to meet the construction schedule, and locate material drop off sites accordingly.
    c. Coordinate crane location and scheduling with the main rink's roof construction sequence in order to efficiently use the crane.
    d. Adapt the site plan throughout the sequence of the community rink construction.

Mechanical Tasks and Tools

1. Mechanical Room Redesign and Addition
    a. Coordinate space requirements
    b. Model spaces in Revit MEP
        i. Energy model in Trane Trace 700
        ii. Size ductwork and equipment in Revit MEP
    c. Coordinate shaft locations and dead loads with structural engineer
2. Air Handling Unit Redesign
    a. Model diagrams in AutoCAD 2012
    b. Model units in Trane Trace 700 and Revit MEP models
3. Community Rink Ductwork Layout
    a. Model in Revit MEP
    b. Coordinate with lighting and structural models
    c. Daylighting/shading analysis energy model in Trane Trace 700

Lighting/Electrical Tasks and Tools

1. Clerestory Analysis
    a. Exterior shadow analysis in Revit Architecture to ensure that the Main Arena roof's shadow does not cast over the Eastern clerestory
    b. Preliminary daylight analysis using AGi32 to determine clerestory orientation, illuminance levels, shadows and glare.
    c. Load analysis done in coordination with mechanical team member to determine increased solar heat gain
    d. Redesign clerestories (if necessary to reduce thermal loads) with respect to load analysis
    e. Reanalyze daylight model in Daysim
    f. Update Revit Architecture model to reflect new Community Rink design

2. Electric Lighting Analysis
    a. Determine illuminance criteria and considerations for spaces accordingly from NCAA or IES recommendations
    b. Analyze space illuminance levels using AGi32

3. Lighting Power Consumption Analysis
    a. Determine criteria for space from ASHRAE 90.1
    b. Determine luminaire power consumption from manufacturers data
    c. Calculate total power consumption and compare with ASHRAE 90.1

Structural Tasks and Tools

1. Lobby Roof
    a. Determine extra mechanical loads on lobby roof
    b. Coordinate locations of mechanical units with cable-stayed system
    c. Model mast, roof beams and cables two dimensionally in SAP
    d. Design roof beams, masts, and cables using forces attained in load analysis so that they satisfy the code requirements of the AISC manual and standards of ASCE 19-10 (Structural Applications of Steel Cables for Buildings)
    e. Redesign as necessary based on cost, strength, and service requirements
    f. Model lobby roof in Revit

2. Community Rink
    a. Determine roof shape with group emphasizing daylighting
    b. Determine loads from IBC and roofing materials
    c. Calculate snow loads and drifting/sliding conditions
    d. Design roof using long span joists if possible
    e. Coordinate with Mechanical and Lighting designs
    f. Model roof system in Revit

Community Rink BIM/IPD

Our team will use integrated project delivery concepts in our community rink redesign. Through integrated team meeting with all members, we will develop a finalized community rink design. After completing preliminary analyses, all team members will model their systems in their discipline specific Revit program. The lighting/electrical team member will drive the redesign of the community rink through the daylighting design and the orientation of the clerestories. During the daylighting design the electrical/lighting team member will need to heavily coordinate with the structural member to ensure roof integrity. The other aspect of the community rink redesign will be the relocation of the mechanical equipment currently on top of the community rink. The mechanical, structural and construction team members will coordinate roof heights, plenum spaces and openings to ensure maintenance is not an issue.

These tasks and analyses will once again be carried out using computer software. The lighting/electrical team member will be using DaySim to determine solar penetrations and clerestory orientation and Revit Architecture for the final model. The structural Revit model will consist of bracing, columns, and beams but will not consist of detailed connection work. The mechanical Revit model will include mechanical equipment and ductwork; mechanical shafts will be modeled in Revit Architecture. Once these designs are completed the Architectural Revit model will be exported into Navisworks for clash detection.

See Appendix B for a table of the team's BIM goals as they relate to the overall project.

Community Rink Redesign Conclusion

The decision to redesign the community rink was driven by two main ideas. The first was to allow for a more flexible roof design over the rink to allow for daylighting. The second was to increase the efficiency of the mechanical system by relocating units that serve the front of the arena to an area above the lobby. The movement of mechanical units will be coordinated between the mechanical, structural, and construction team members to ensure that the structure can resist the additional loads above the lobby and to maintain the schedule. The community rink roof design will be driven by the lighting/electrical team member in coordination with the structural team member to infuse daylighting into the community rink without impacting the ice quality.

The community rink redesign will require extensive coordination amongst all team members. The mechanical engineer must size the units that are to be placed above the lobby and analyze the new mechanical system. The structural engineer will work with the mechanical engineer to design the structure to support the units. In order to redesign the roof of the community rink, the lighting/electrical engineer will analyze proposed daylighting strategies to ensure championship level ice quality and coordinate the daylighting design with the structure of the roof. As these designs and analyses progress, the construction manager will develop the schedule and estimate the costs of construction and design to allow for an optimal design.

The goals of the community rink design are based on the two main ideas. By rearranging and moving several air handling units, the team will reduce long duct runs thus reducing the amount of fan energy needed to heat and cool the arena spaces. The new mechanical area will be successfully integrated with the structure of the arena by maintaining the architectural form of the main roof. The community rink roof will be designed to improve daylighting of the community rink without impacting the ice rink. Ideally, the added daylighting strategies would reduce the costs of electrical lighting and electrical heat gain. The roof structure will be designed for economic efficiency. The overall design of the community rink will balance the lighter "floating" structure of the main arena. Overall, the team will attempt to maintain a similar cost and schedule to that of the actual design.

Conclusion

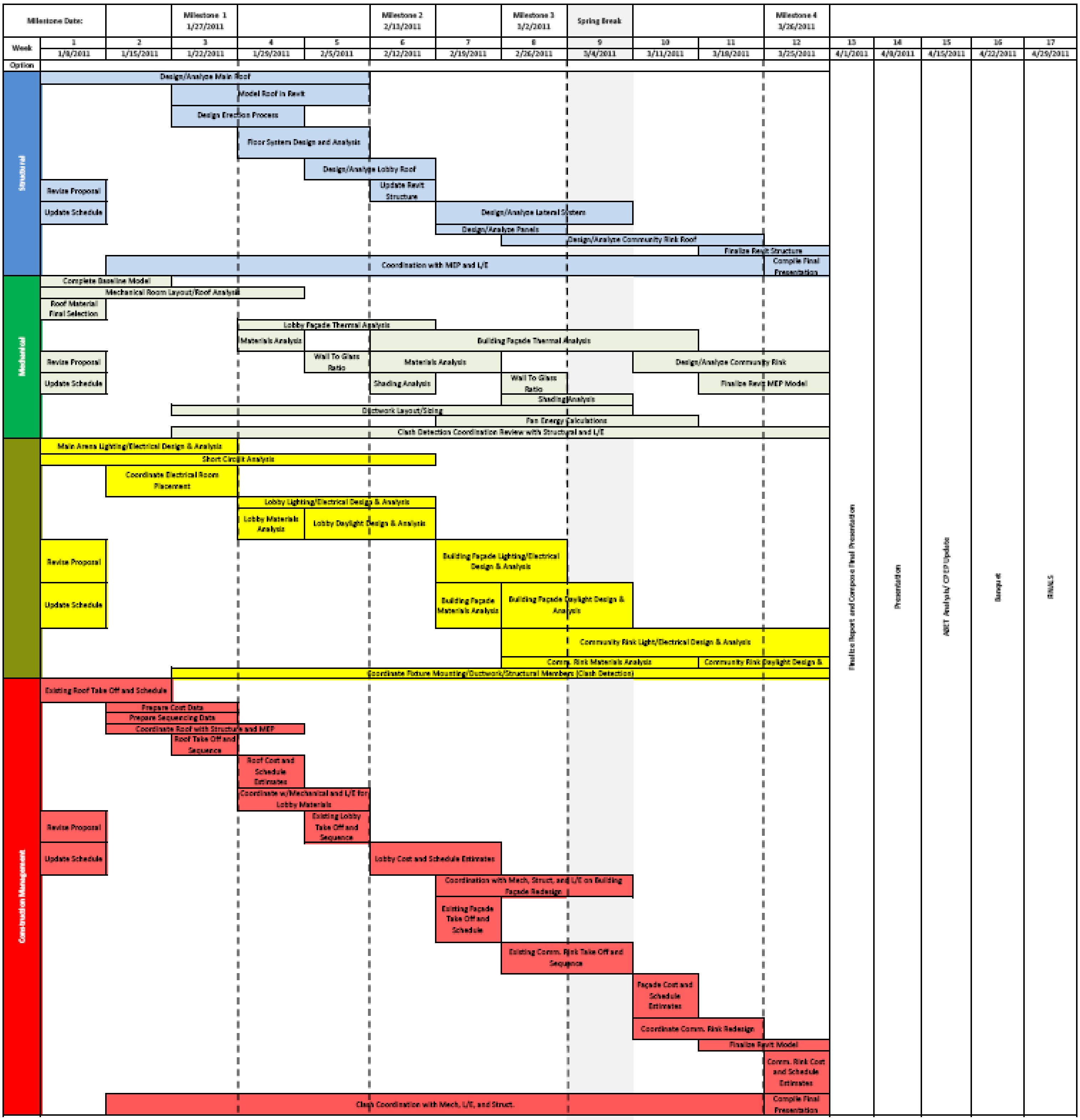
The goal of this proposal was to layout the steps that will be needed to perform the tasks and analysis for next semester to further our design of the Penn State Ice Hockey Arena. The objective is to, through these steps, create an iconic structure which will solidify Penn State NCAA Division 1 hockey culture as much as Beaver Stadium has done for Penn State football through the use of a cable-mast roof structure and lightweight glass-metal panel façade. In doing so, we must balance feasibility, energy consumption, cost, and, most importantly, prevent environmental factors from affecting the quality of ice.

The transformation of the Ice Hockey Arena from the design-development documents to our vision will be done through the three major areas of focus, the main arena roof, building façade, and community rink roof, as elaborated above in our proposal. BIM strategies and computer software will be extensively incorporated to ensure an optimized and energy responsible building while keeping in mind constructability and recognizing conflicts across disciplines to solve them before the project reaches construction.

Appendix

Appendix A: Proposed Schedule and Timeline

Overall Schedule

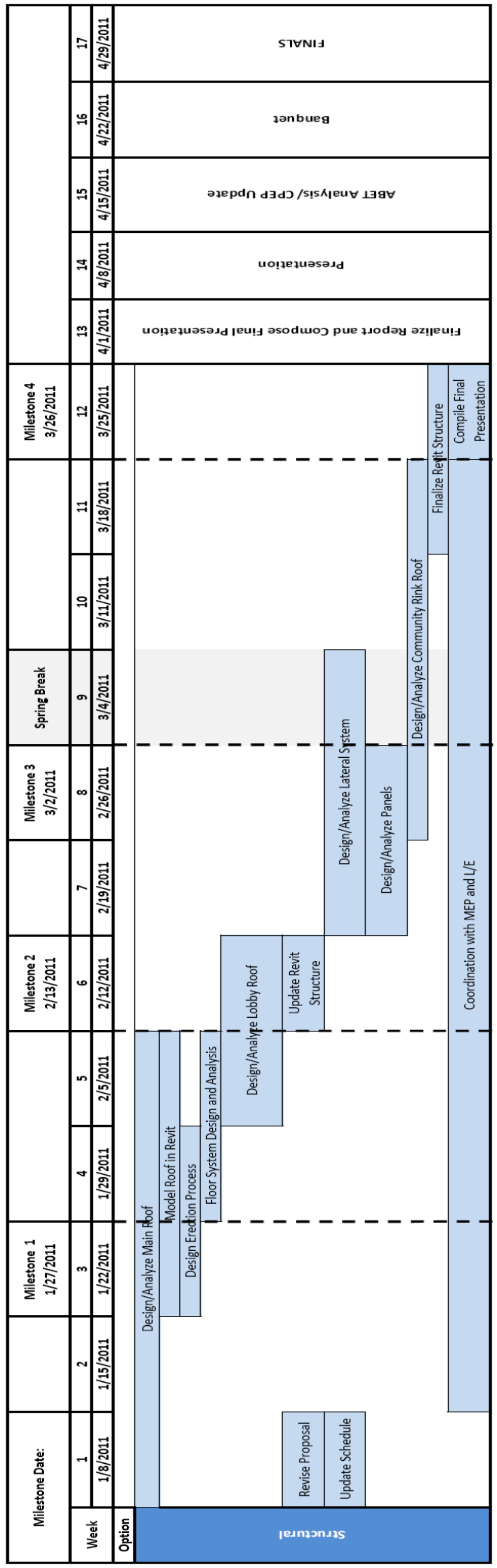


Week	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
	1/8/2011	1/15/2011	1/22/2011	1/29/2011	2/5/2011	2/12/2011	2/19/2011	2/26/2011	3/4/2011	3/11/2011	3/18/2011	3/25/2011	4/1/2011	4/8/2011	4/15/2011	4/22/2011	4/29/2011

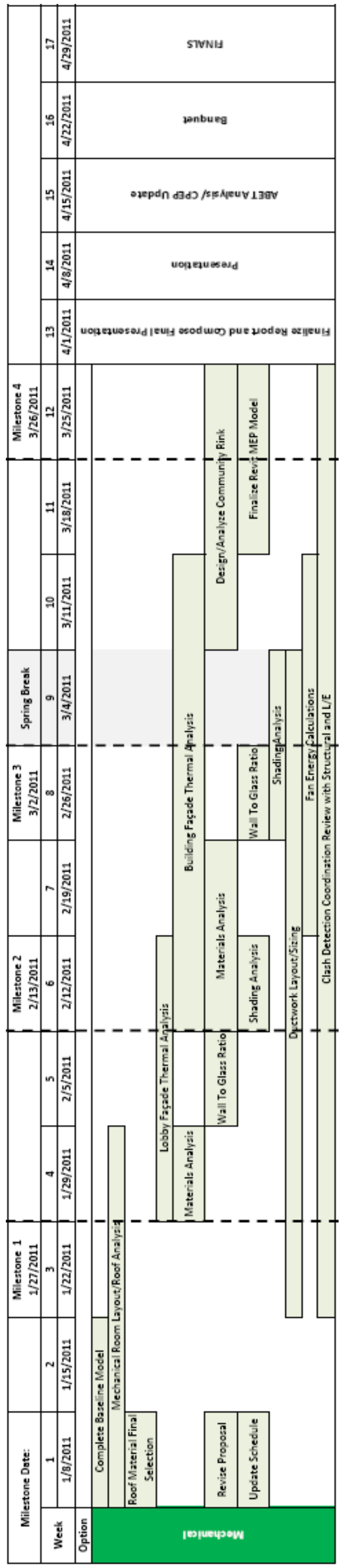
Milestones

Milestone 1:	**1/27/2011**			
Structural:	Cable-stayed Roof Design of Main Roof 75% Complete			
MEP:	Mechanical Room Layout/Roof Design Analysis Complete			
L/E:	Main Arena Lighting/Electrical Design & Analysis Finalized			
CM:	Existing Roof Cost and Schedule Estimates and Proposed Roof Take Off and Sequencing Complete			
Milestone 2:	**2/13/2011**			
Structural:	Floor System Framing Redesign Complete, Erection Process Complete			
MEP:	Lobby Façade Analysis/Lobby Energy Model Complete			
L/E:	Lobby Lighting/Electrical Design 75%			
CM:	Existing Lobby Façade Cost and Schedule Estimates and Lobby Design Complete			
Milestone 3:	**3/2/2011**			
Structural:	Façade Panel Strength Analysis Complete, Lateral System Model Complete			
MEP:	Building Façade/Building Ductwork Layout Complete			
L/E:	Lobby and Facade Lighting/Electrical Design & Analysis Finalized			
CM:	Lobby Cost and Schedule and Existing Façade and Community Rink Take Offs and Schedule Complete			
Milestone 4:	**3/26/2011**			
Structural:	All Structural Analysis Complete			
MEP:	Fan Energy Analysis/Community Rink Thermal Analysis Complete			
L/E:	Community Rink Design & Analysis Finalized			
CM:	Façade Cost and Schedule Estimates and Community Rink Redesign Complete			

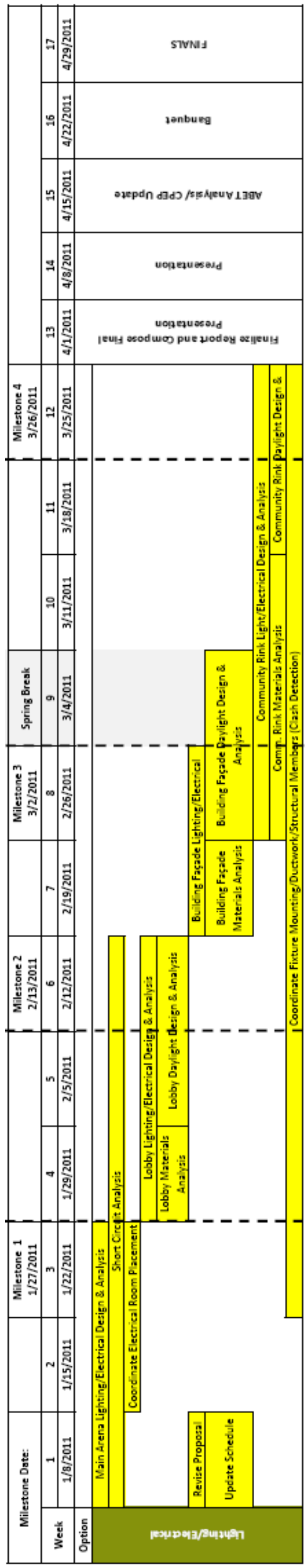
Individual Schedule: Structural



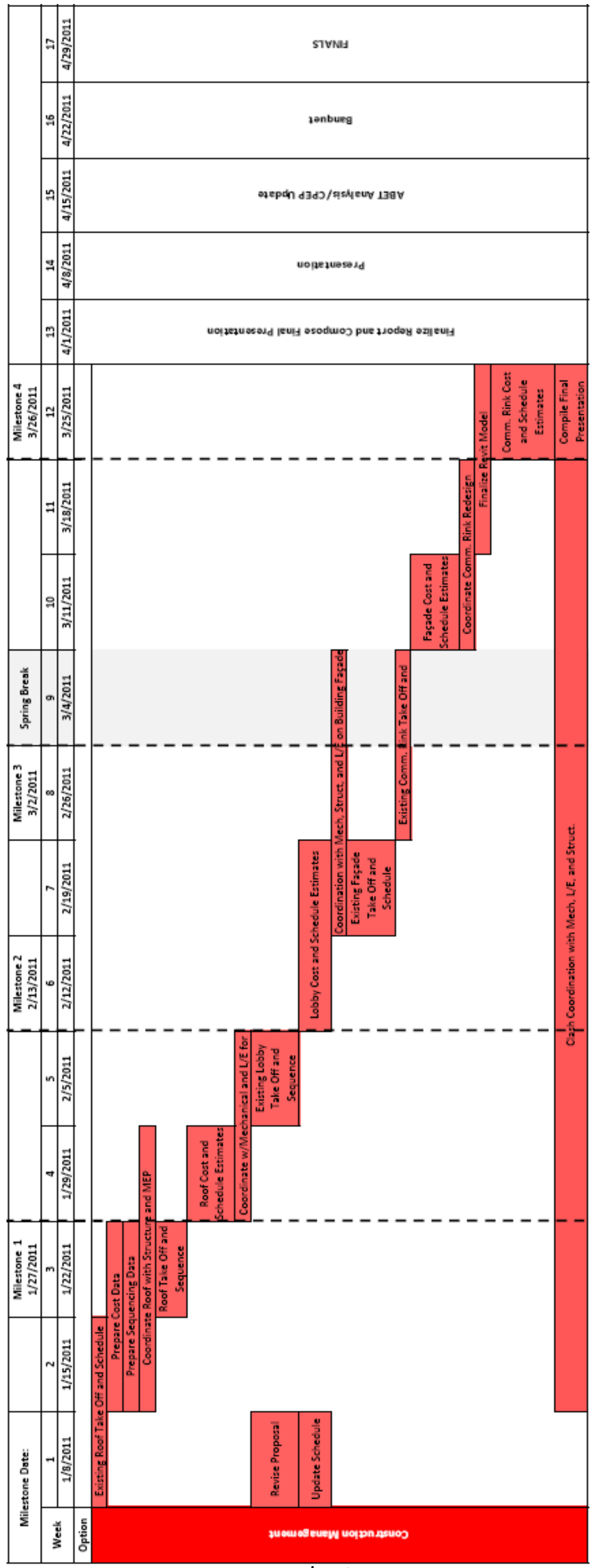
Individual Schedule: Mechanical



Individual Schedule: Lighting/Electrical



Individual Schedule: Construction Management



Appendix B: BIM Execution Planning

BIM Goals

Priority (1-3)	Goal Description	Potential BIM Uses
1-Most Important	Value Added Objectives	
1	Recognize design conflicts before they reach construction	3D Coordination, Design Review, Design Authoring
1	Create an energy efficient arena	Energy Analysis, Lighting Analysis, Building System Analysis, Site Analysis, Design Authoring, Sustainability LEED Evaluation
2	Design with constructability in mind	3D Coordination, 4D Modeling, Cost Estimation, Design Authoring
1	Optimize building performance	Building Systems Analysis, Cost Estimation, Structural Analysis, Energy Analysis, Mechanical Analysis, Design Authoring, 3D Coordination, Construction Systems Design

Appendix C: Individual Tasks and Tools Tables

Construction Management			
Primary Task	**Secondary Task**	**Programs to be Used**	**Resources**
Roof Redesign	Cost Analysis	Revit Architecture, Revit Structure, MS Excel	RS Means, Vendor(s)
	Schedule Analysis	Microsoft Project	RS Means, Vendor(s), Book
	Site Plan Analysis	AutoCAD, Adobe Acrobat, MS Excel	
	MEP Coordination	Navisworks, MS Project	
Façade Redesign	Cost Analysis	Revit Architecture, Revit Structure, MS Excel	RS Means, Vendor(s)
	Schedule Analysis	Microsoft Project	RS Means, Vendor(s)
	Site Plan Analysis	AutoCAD, Adobe Acrobat, MS Excel, Revit Architecture	Construction Manager
Community Rink	Cost Analysis	Revit Architecture, Revit Structure, MS Excel	RS Means, Vendor(s)
	Schedule Analysis	Microsoft Project	RS Means, Vendor(s)
	Site Plan Analysis	AutoCAD, Adobe Acrobat, MS Excel	Construction Manager
	MEP Coordination	Navisworks, MS Project	

Mechanical		
Primary Task	Second Task	Programs
	Wall Composition	H.A.M. Toolbox/Trane Trace 700
Façade	Wall To Glass Ratio	Trane Trace 700
	Shading	Trane Trace 700
	Roof Composition	H.A.M. Toolbox/Trane Trace 700
Roof Design	Mechanical Room Layout	Revit MEP 2012
	Main Bowl Ductwork Layout	Revit MEP 2012
	Shaft Coordination	Revit MEP 2012
	Roof Analysis	Trane Trace 700
Community Rink	Façade Analysis	H.A.M. Toolbox/Trane Trace 700
	Ductwork Layout	Revit MEP 2012

Lighting/Electrical			
Primary Task	**Secondary Task**	**Programs to be Used**	**Resources**
Roof Redesign	Arena Lighting Design	AGi32	NCAA Recommendations, ASHRAE 90.1
	Lighting Structural Loads Coordination	-	Coordinate with Structural Team Member
	Branch Circuit & Panel Redesign	Revit MEP	2011 NEC
Façade Redesign	Daylight Analysis	Revit Architecture, AGi32, Daysim, 3DS Max	IES 2011 Lighting Handbook
	Shading Analysis	AGi32, Revit Architecture, 3DS Max	IES 2011 Lighting Handbook
	Lighting Redesign	AGi32, Revit Architecture, Revit MEP, 3DS Max	IES 2011 Lighting Handbook, ASHRAE 90.1
	Branch Circuit & Panel Redesign	Revit MEP	2011 NEC
Community Rink	Daylight Analysis	AGi32, Daysim, Revit Architecture	IES 2011 Lighting Handbook
	Solar Thermal Gain Analysis	-	Coordinate with Mechanical Team Member
	Lighting Redesign	AGi32, Revit Architecture	NCAA Recommendations, ASHRAE 90.1

Structural			
Primary Task	**Secondary Task**	**Program(s) to be Used**	**Applicable Codes/Design Standards**
Main Roof Redesign	Design/Analyze Cable-stayed Mast, Cables, Roof Girder	SAP, Revit	ASCE 7-10, ASCE 19-96, AISC Steel Manual 13 Ed., ACI 318-08
	Adjust Interior Steel Framing	RAM, Revit	AISC Steel Manual 13 Ed.
	Design Erection Process	SAP, Navisworks	AISC Steel Manual 13 Ed.
Façade Redesign	Design Panels (wind, earthquake, gravity, etc)	ETABS, Excel	ASCE 7-10
	Lateral System Design/ Analysis	ETABS, RAM	ASCE 7-10, AISC Steel Manual 13 Ed.
Community Rink Redesign	Design/Analyze Lobby Roof for Mechanical Units	SAP, Revit	ASCE 7-10, ASCE 19-96, AISC Steel Manual 13 Ed.
	Design/Analyze Community Rink Roof	RAM, Revit	ASCE 7-10, AISC Steel Manual 13 Ed.

Appendix D: MAE Requirements

Mechanical MAE

Material from AE 542-Building Enclosure Science and Design will be used in the façade design analysis and for the roof design analysis. The redesign of the mechanical units supplying the main arena will be assisted by information from AE 555-Building Automation and Control. Principles from AE 558-Centralized Heating Production and Distribution Systems and AE 557-Centralized Cooling Production and Distribution Systems will be implemented into the relocation of the mechanical units. The indoor air quality of the main arena will be evaluated based on lessons learned in AE 552-Air Quality in Buildings.

Structural MAE

Knowledge gained in AE 537-Building Performance Failures and Forensic Techniques, AE 538-Earthquake Resistant Design of Buildings, and AE 597A-Computer Modeling of Building Structures will be used to fulfill the MAE requirements for BIM Thesis. Advanced computer modeling techniques learned in AE 597A will be used to accurately model and analyze both the gravity and lateral systems of the structure. The model will use proper assumptions and modeling techniques including connection rigidities, boundary conditions, and diaphragm assignments. Information about braced frames and moment frames discussed in AE 538 will be applied to the lateral system of the structure in order to properly resist lateral loads. Knowledge gained from discussions in AE 537 on snow loads and drifting will be utilized to properly calculate roof snow loads. The proper calculation of snow loads is important in long span structures due to lack of redundancy to ensure that members are not overstressed to failure.

Appendix E: Additional Requirements

Lighting/Electrical

Lighting Redesign

The lighting redesign will be done for 3 of the building's spaces: Exterior Façade, Lobby/Main Entrance and Club Lounge/Bar. These spaces will be designed according to schematic designs done previous with revisions made with respect to comments given by Dr. Mistrick and Lutron lighting panel. Equipment (luminaires, lamps, ballasts, etc.) will be specified and illuminance criteria will be selected according to IES recommendations.

Branch Circuiting Redesign

The proposed scope of the branch circuit redesign will include 4 distinct spaces: the Main Entrance/Lobby, Club Lounge/Bar, Main Arena and Community Rink. The circuiting will also be designed and modeled in Revit MEP

Short Circuit Analysis

A single path, beginning at the building service entrance and ending at a panelboard will be selected to perform a short circuit analysis. This analysis will include coordination of protective devices along the proposed path. Calculations of short circuit current and trip curves for each device will be shown. Due to the lack of existing information (power loads) some assumption may have to be made. The proposed path of analysis will begin at the service entrance → main 3000A switchgear → switchboard HD1-1 → panelboard HL1-1

Lutron Presentation Comments:

Lee:

- façade: some colors kind of weird, became a theme throughout, but became distracting sometimes
- more liveliness = more enthusiasm
- make renderings bigger
- show downlights in ceiling
  - consider other sources besides CFL
- be careful with perspective views: ceiling becomes huge which is a big black plane
- can't light glass
- façade: light is not perfect, it goes everywhere
- party /dance theme won't see blue, can't light glass

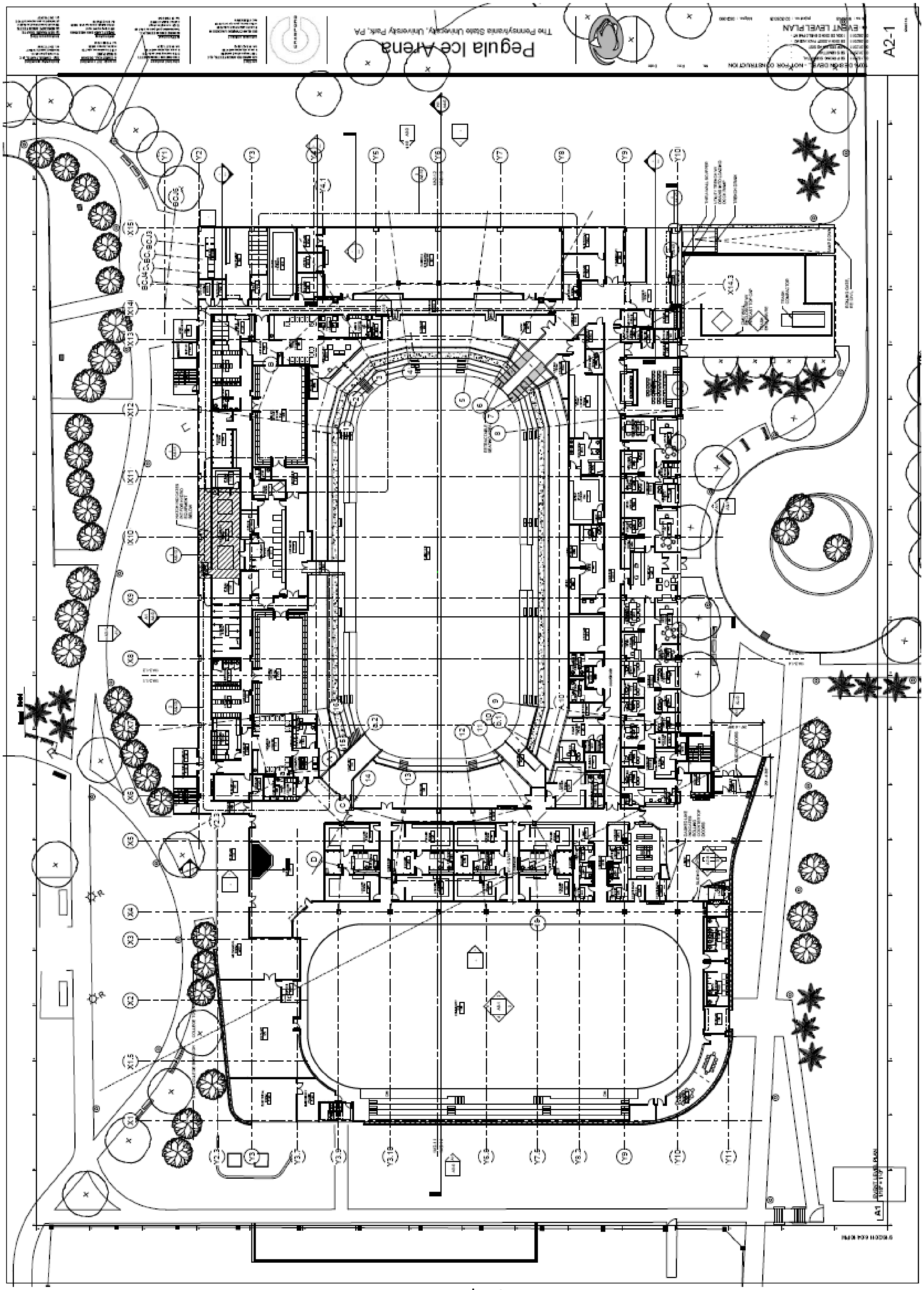
Andrea:

- ice arenas are always cold:
  - consider CCT more deeply, could change based on time of year
- watch your terminology
  - a wall washer doesn't throw light to the ceiling
- colored lighting should light an object, not air
- if you want to downplay the stairs, downplay them, don't accent architecture

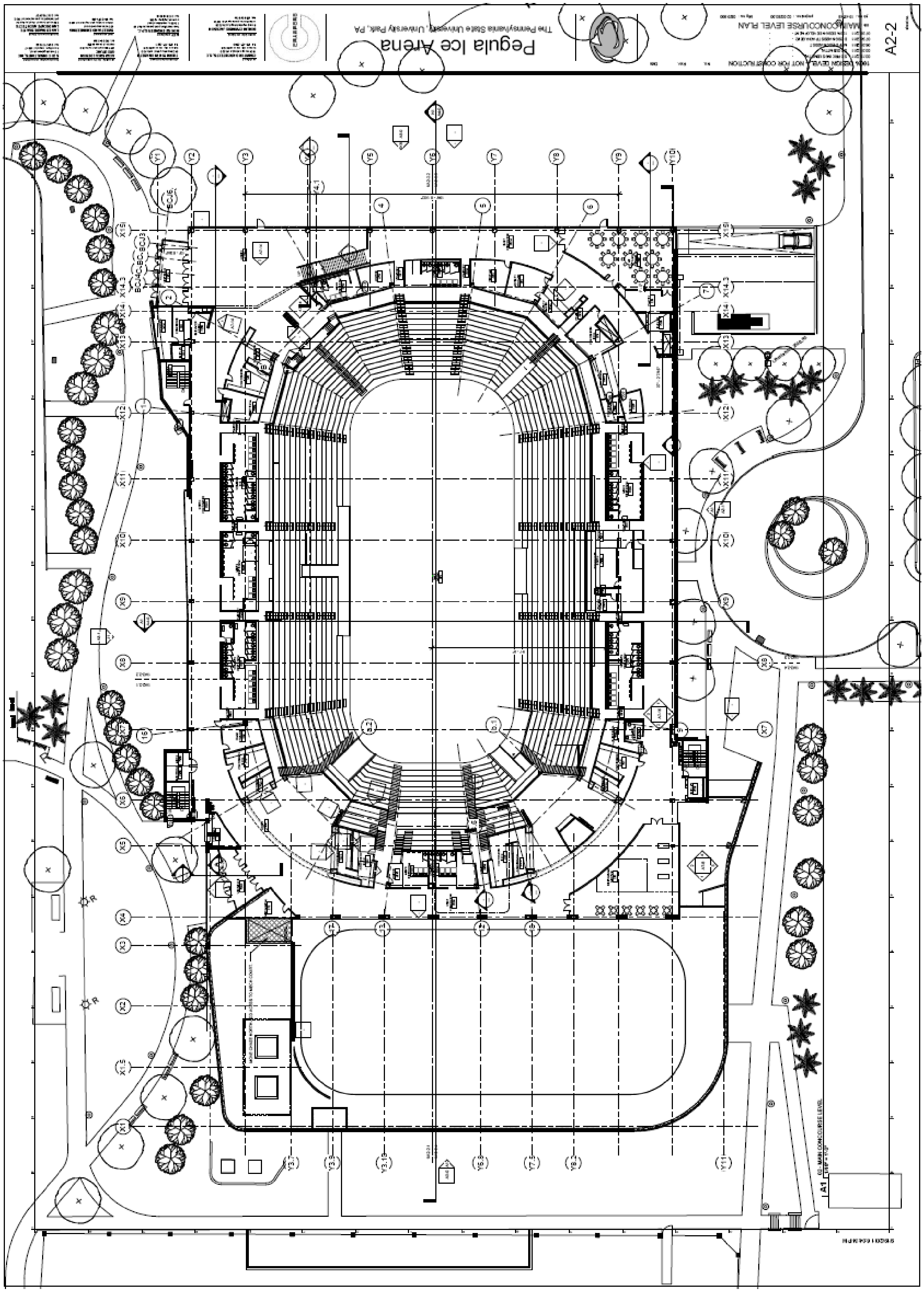
Brent:

- some of your renderings show more contrast than there would actually be
- façade rendering not accurate
- sometimes hard to tell where lighting would come from
- club level should be the focus, up-play it, not downplay

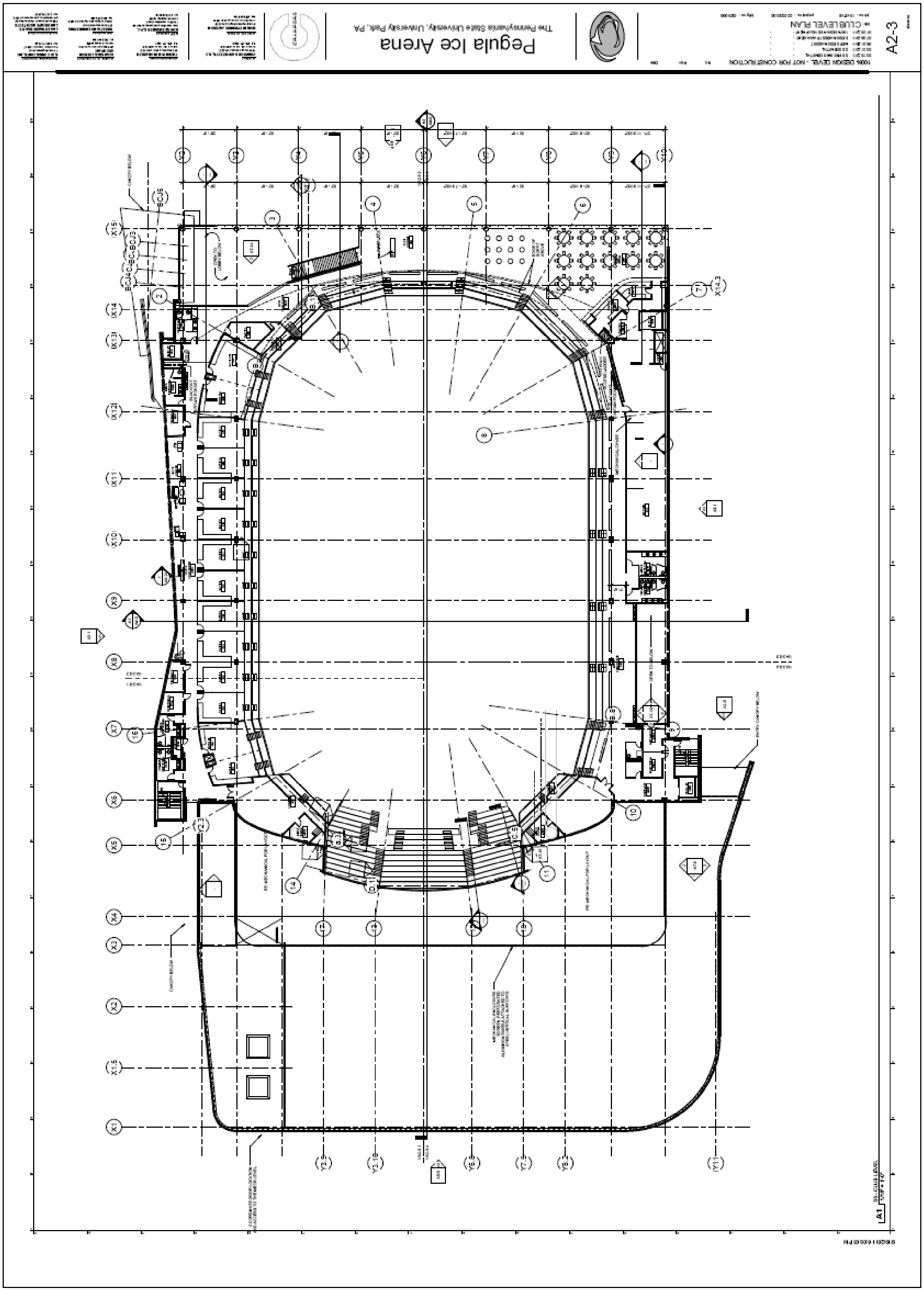
Appendix F: Selected Architectural Design Development Drawings



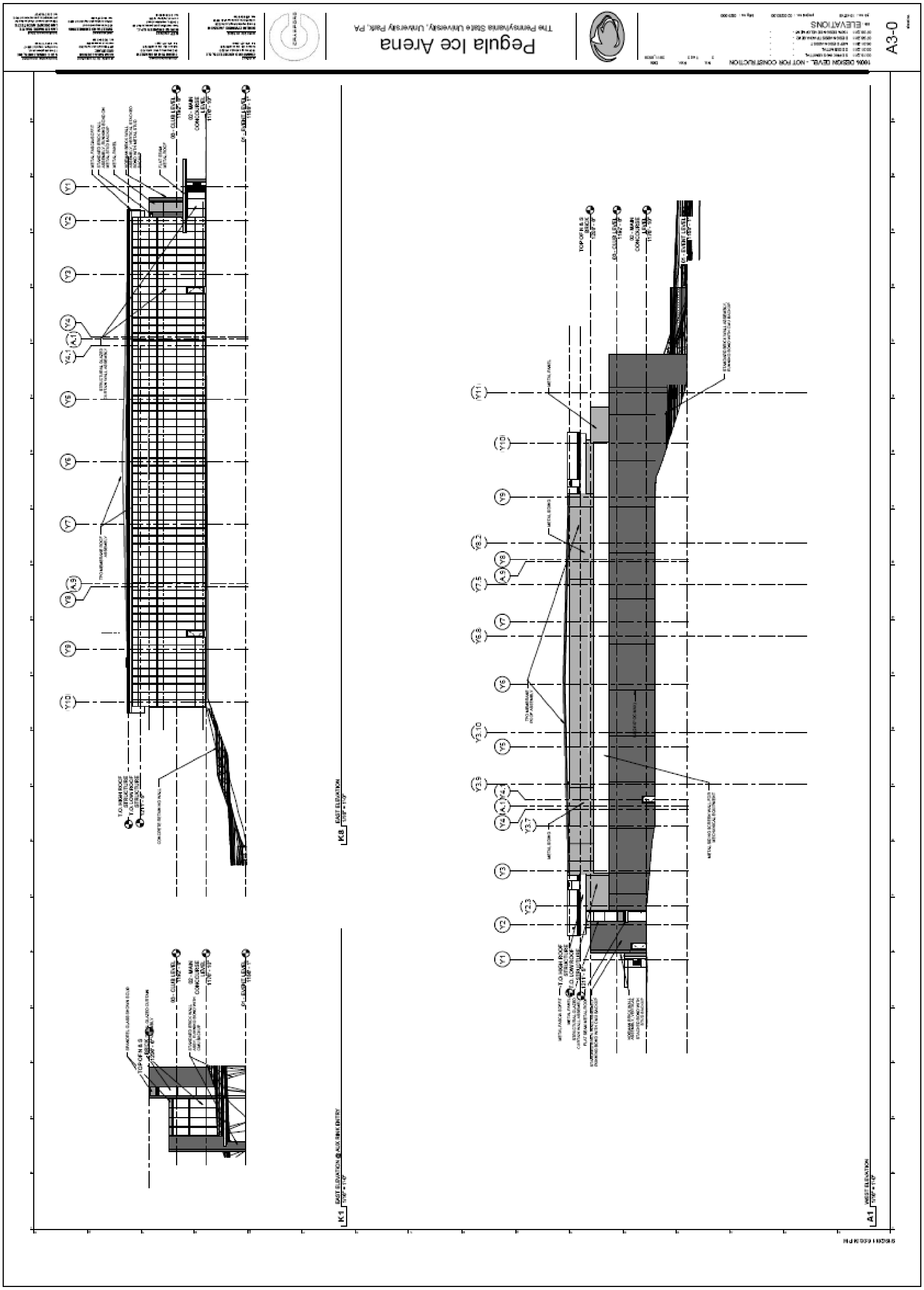
Event Level Plan (Courtesy of Crawford Architects)



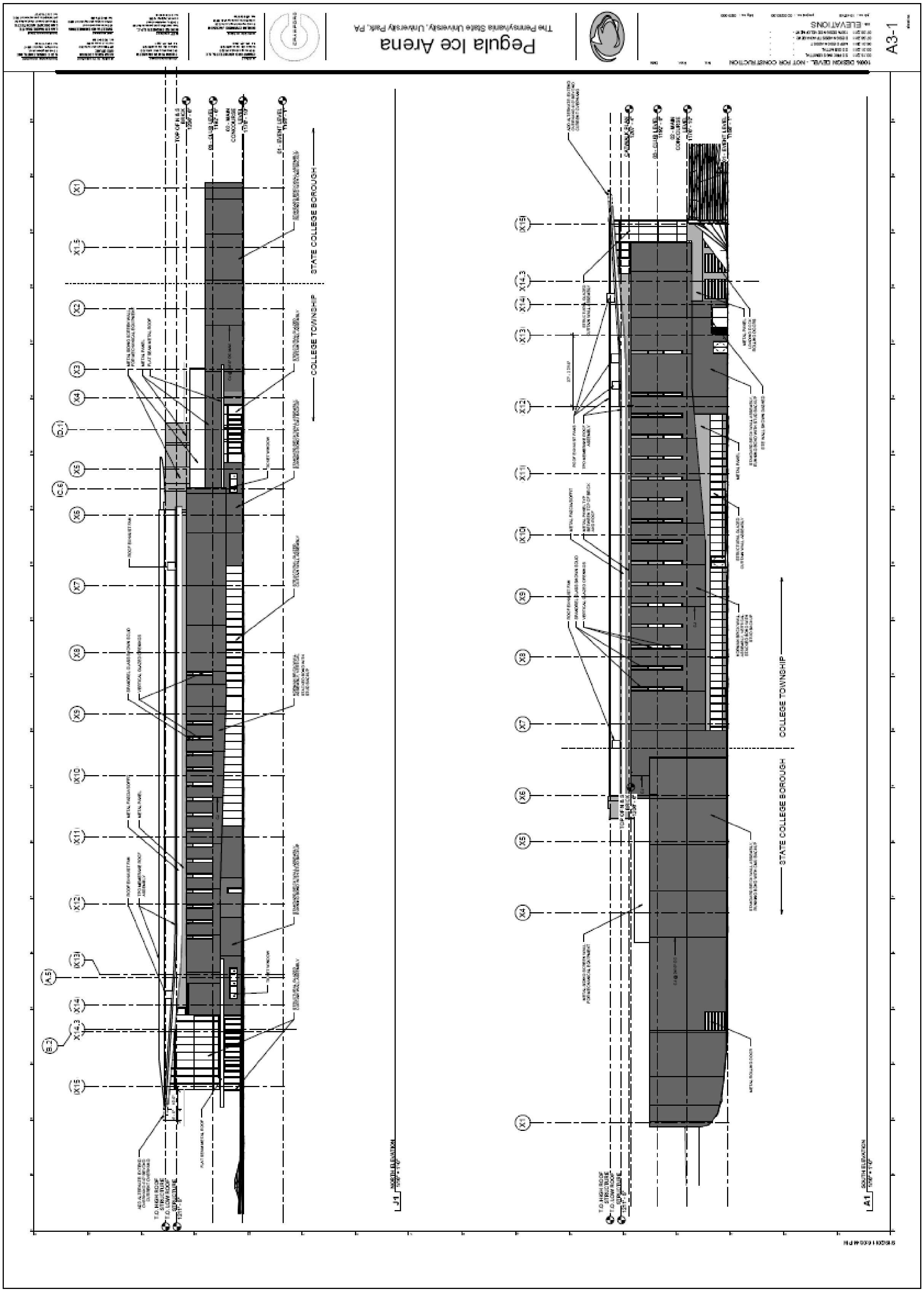
Main Concourse Level Plan (Courtesy of Crawford Architects)



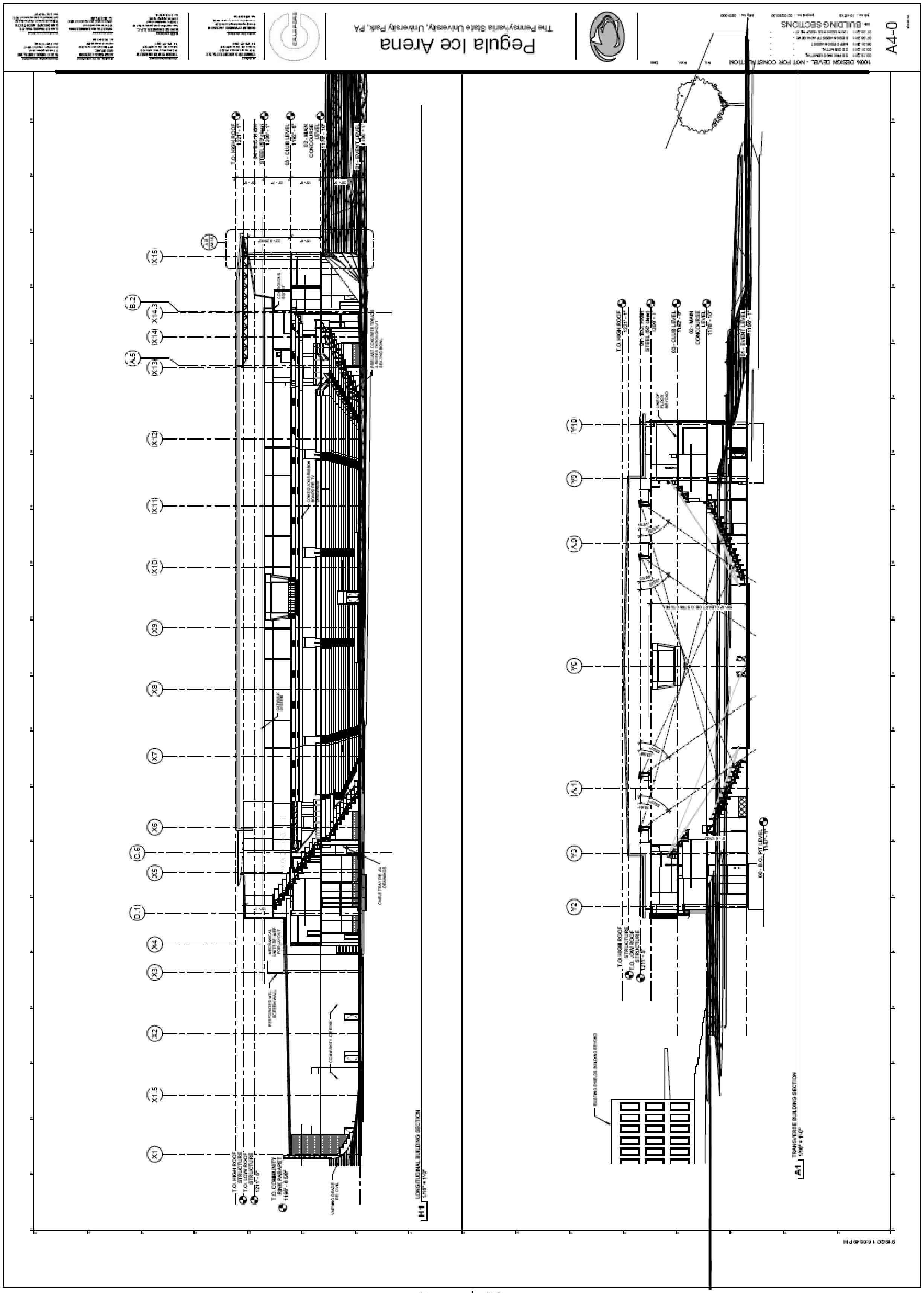
Club Level Plan (Courtesy of Crawford Architects)



Elevations (Courtesy of Crawford Architects)



Elevations (Courtesy of Crawford Architects)



Building Sections (Courtesy of Crawford Architects)