BIM Thesis Proposal

January 13th, 2012

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Courtesy of Crawford Architects

[Executive Summary]

The Penn State Ice Arena is the focus of the Integrated Project Delivery/ Building Information Modeling (IPD/BIM) Senior Thesis. This report will serve as a proposal for HPR Integrated Design's alternative design strategies to achieve more efficient building systems within each discipline. The goals of these strategies are to deliver a facility that will have the highest quality for the budget allotted, reduce building's energy usage and cost, create a fast tracked schedule, and develop a LEED Gold certified hockey arena.

HPR Integrated Design has chosen to focus on three areas of study during the spring 2012 semester. They are as follows:

- Raising of the Event Level – Design Focus 1
- Main Arena Roof System Design – Design Focus 2
- Façade Redesign – Design Focus 3

Raising of the Event Level:

The current design shows a floor to floor height between the event level and main concourse level of 20 foot 9 inches. With this height level, there is 10 foot plenum space. The driving force behind raising the event level is to reduce the amount of bedrock needed to be excavated from the site. In doing so, the plenum space will be reduced. HPR believes that by raising the event level approximately three feet, excavation costs will be reduced and plenum space that is otherwise wasted will be optimized. Savings from the reduction of excavation will then be reallocated to the main arena roof system design to give the Penn State University a facility of greater value for the same construction cost.

Main Arena Roof System Design:

When HPR received the drawings for the Penn State Ice Arena, the main arena roof system's design had not been completed. HPR's designers will coordinate and design a roof for the main arena that is iconic and that will support the overhead lighting and duct systems.

Façade Redesign:

With the design of the new roof system, the façade will have to be redesigned in order to coordinate in the efforts to design an iconic facility. As the façade is redesigned, materials will be selected and configured to maximize daylighting, reduce energy loads, and reduce construction and energy costs.

The raising of the event level and the main arena roof systems are very closely connected. As the volume of the main arena is increased by a new roof profile it is then reduced by moving the event level up. On a financial side, money saved in excavation by raising the event level can then be reallocated to the more prominent arena roof structural and MEP systems. This will provide the University with a higher valued product for a competitive cost to the original design.

This proposal will serve as a guide for the Architectural Engineering faculty to monitor and assess the progress that HPR Integrated Design will achieve in the spring 2012 semester. Building information modeling with integrated project delivery design processes will be used heavily in coordination of the design team throughout the semester to implement these design alternatives. All modeling will be done using BIM based software such as the Autodesk Revit platforms and Navisworks. Individual discipline design will be conducted in appropriate analytical programs that can be exported or imported into these interfaces. HPR is constantly aware of the collaborative nature of the design process and will monitor the lead and lag of each task.

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[Penn State Ice Arena Overview]

The Penn State Ice Hockey Arena will be home to the newly developed Penn State NCAA Division 1 men's and women's hockey teams. The new facility will be located on University Drive on the Penn State University Campus, between Holuba Hall and Shields Building (the location can be seen as the blue box in Figure 1). The facility is a 3-story, 220,000 square-foot arena containing 2 regulation sized ice sheets. A few features that are important to the facility are its proximity to the other major campus sports facility (the Bryce Jordan Center and Beaver Stadium) and its view of Mt. Nittany from the Mt. Nittany room. There is a footprint constraint for this site; a main campus utility artery runs parallel with the west side of the site depicted in Figure 1 as a yellow line.

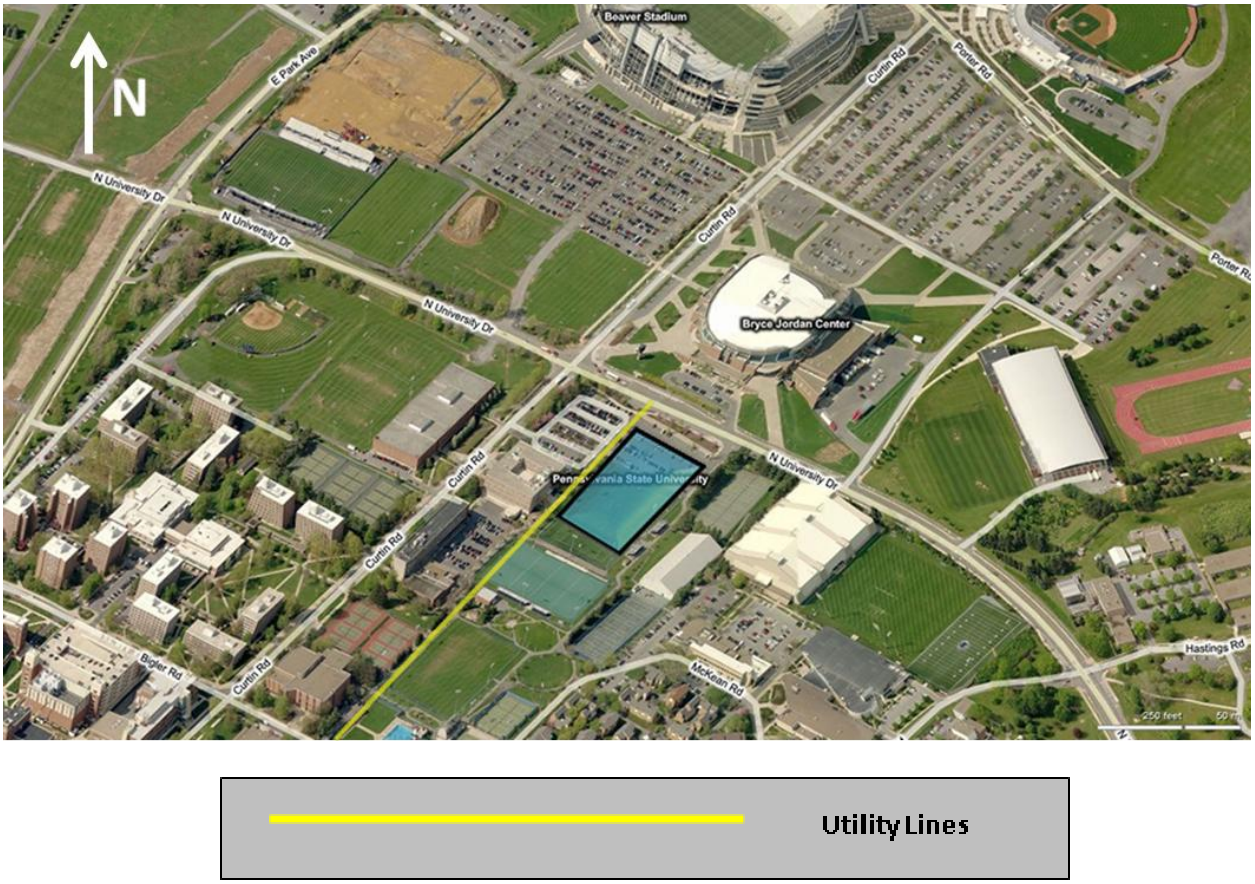


Figure 1: Site and Surroundings

Each floor is occupiable, with the event level hosting the ice sheets, office spaces, locker rooms, and training rooms. The main concourse level, where the main and student entrances are located, has restaurant services, concession stands, and the Mt. Nittany room. There are 14 suites and 2 lodge boxes for the Penn State President and donors. The main competition arena will be able to hold 6,000 spectators, while the auxiliary arena will hold 300 spectators.

Construction Management

In September 2010, a private donor provided Penn State with a gift and the opportunity to build a Penn State Ice Hockey Arena for its Division 1 men's and women's hockey teams. This donation was made in the amount of $88 million, with an additional private donor donating $1 million. Of the $89 million donation, $73 million has been budgeted for the development and construction of this project. Mortenson Construction has been selected as the project management firm. The teams will officially become a Division 1 program in the 2012 to 2013 hockey season, but the facility will not be completed until the 2013 to 2014 season. Preconstruction will begin in January 2012, with construction slated to begin in March 2012. Construction is expected to be completed by September 2013 in time for the first scheduled puck drop on October 11, 2013. The project is being delivered as a Design-Build project with a LEED Gold Certification.

Existing Architecture

The existing architectural style of the Penn State Ice uses many of the common building materials found on campus. It is mostly brick with a large glass eastern façade. The current design calls for a slightly pitched metal deck roof. Many features of the building are geared towards enhancing the audiences experiences while at a Penn State hockey game, large vomitories, panoramic views, and optimized viewing angles, among many others.

Both sheets of ice are on the event level (shown in Figure 2) along with building administration offices, visitor locker rooms, team locker rooms and team support areas. The main arena ice sheet plays host to the men and women varsity hockey program. The second sheet, the auxiliary rink, has been branded the "workhorse" of the facility and will service local patrons and other leagues. The entrance for the auxiliary rink side of the facility is located on the southeastern side of the building. The electrical, mechanical, and ice plant rooms are all located on the western corner of the event level.

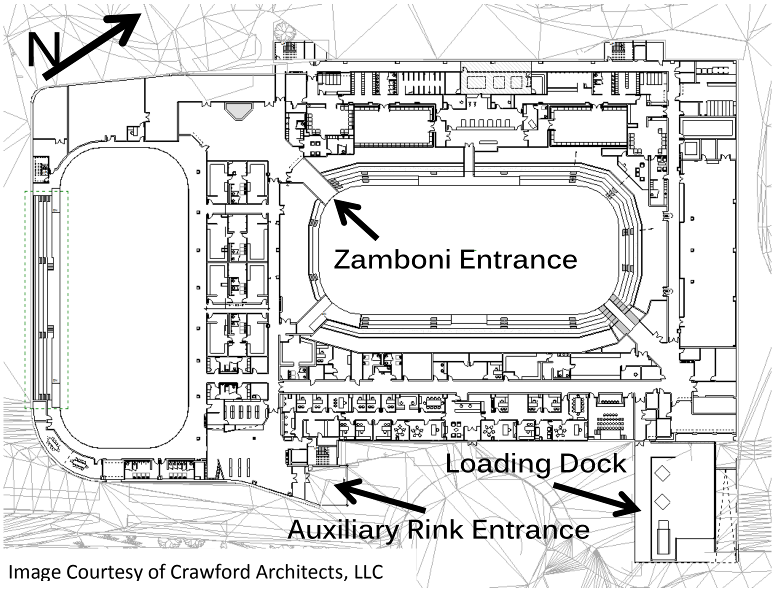


Image Courtesy of Crawford Architects, LLC

Figure 2: Event Level Floor Plan

The main concourse level, shown in Figure 3, will be the level in which the majority of patrons will occupy during a game. It holds all of the main vomitories to enter the arena bowl as well as restrooms and concessions. The main building entrance is located on the northern corner of the building; patrons of the building are greeted by a 2 story atrium which opens up to three options for traveling around the building, the main concourse which wraps the main bowl, a grand stair case to the club level and a large vomitory into the arena bowl. The main student entrance is located on the west façade.

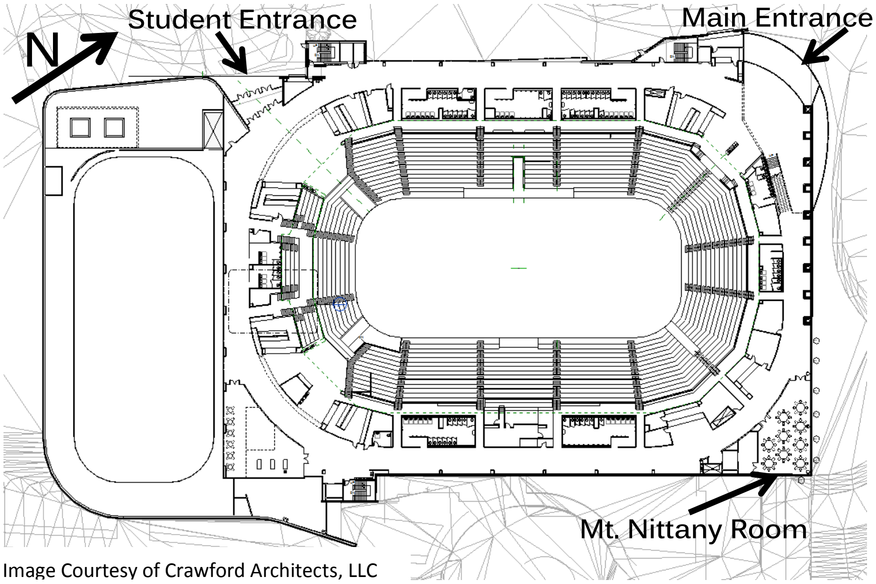


Image Courtesy of Crawford Architects, LLC

Figure 3: Main Concourse Level Floor Plan

The club level (Figure 4) is located on the top level. Located on this level are the club suites, club lounge, a dining space, and a kitchen to support the suites and the dining space.

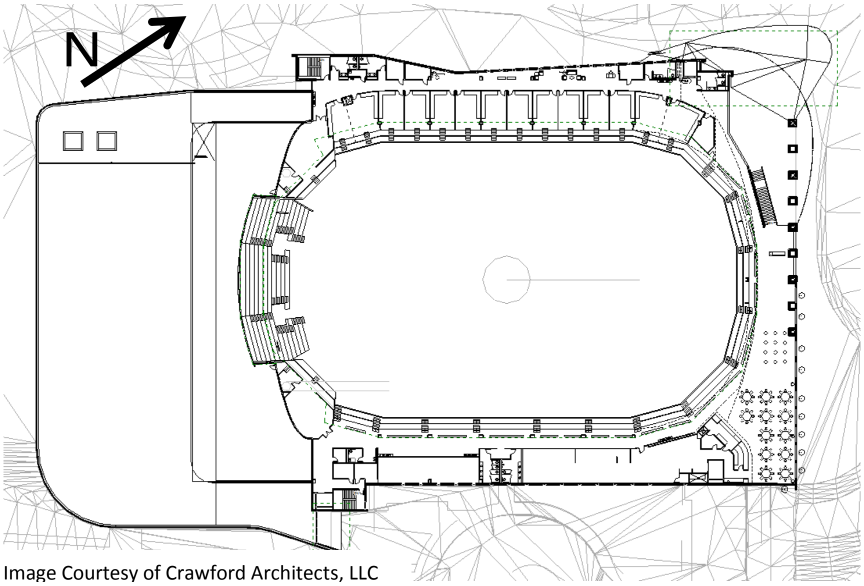


Image Courtesy of Crawford Architects, LLC

Figure 4: Club Level Floor Plan

Existing Façade & Building Enclosure

The existing exterior façade architectural style of the ice arena is one that has graced the Penn State campus for many years. Large facades made of mostly brick with penetrations coming from the windows. One exception to this standard is northeast façade. In the preliminary designs this façade is a large glass curtain wall spanning the entire width of the building and wrapping the corners.

Existing Mechanical System

The current design for the Penn State Ice Arena uses the campus chilled water plant to provide chilled water for space cooling and the campus steam plant to meet loads. The low pressure steam from the pressure reducing valve (PRV) station puts the steam through a heat exchanger and the building ultimately uses hot water.

The building is served by twelve air handling units (AHU 1-12) and two dehumidifying units (AHU 13, 14). The twelve air handling units can be divided in to three separate categories:

1. Energy recovery and dehumidification
2. Energy recovery
3. Economizer

Group 1 (AHU 10-12) serves the main competition bowl and the auxiliary ice rink where it is important to control humidity. These areas are also served by the two dehumidification units. Group 2 (AHU 5, 7, 8, 9) serves both of the varsity looker rooms, the community looker rooms, and the offices. The energy recovery is done with a heat pipe. Group 3 (AHU 1-4, 6) serves the concourses, kitchen, restaurant, and weight room. The economizer is important in these areas because the occupancy is transient; if the amount of outdoor air can be controlled based on both outside temperature and occupancy there can be drastic energy savings. The remaining spaces are served by separate fan coil units.

The air handling units are located on the roof above the concourse level. Supply ducts from the two units serving the main arena bowl are able to penetrate into the main arena while that of the other units must go down through mechanical shafts. AHU 7, 8, 13, 14 are located on the concourse level, not the roof.

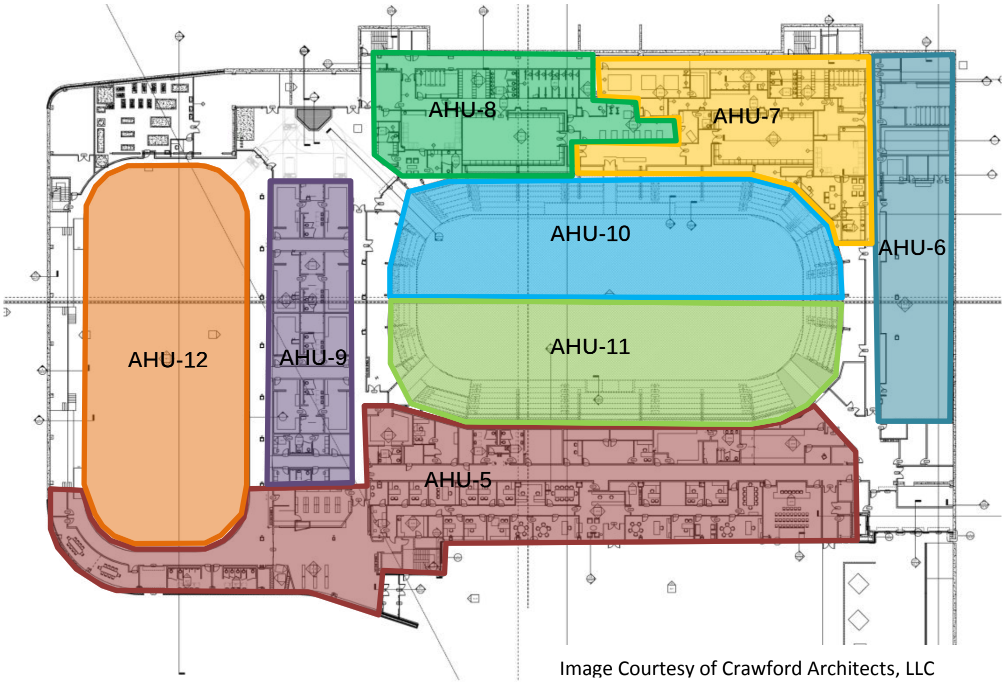


Image Courtesy of Crawford Architects, LLC

Figure 5: Existing AHU Zoning for the Event Level

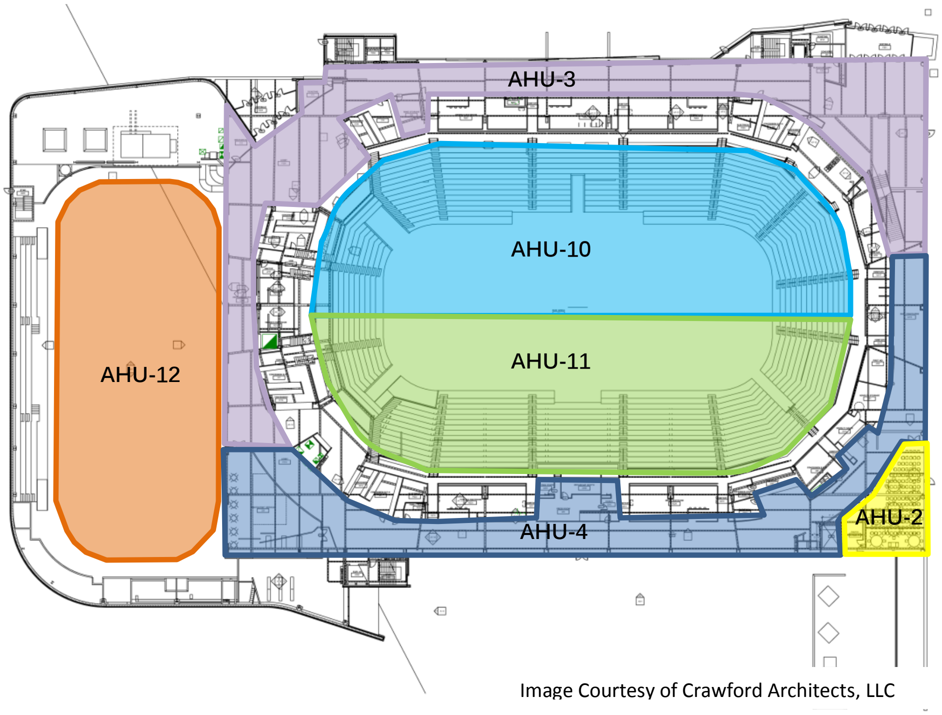


Image Courtesy of Crawford Architects, LLC

Figure 6: Existing AHU Zoning for the Concourse Level

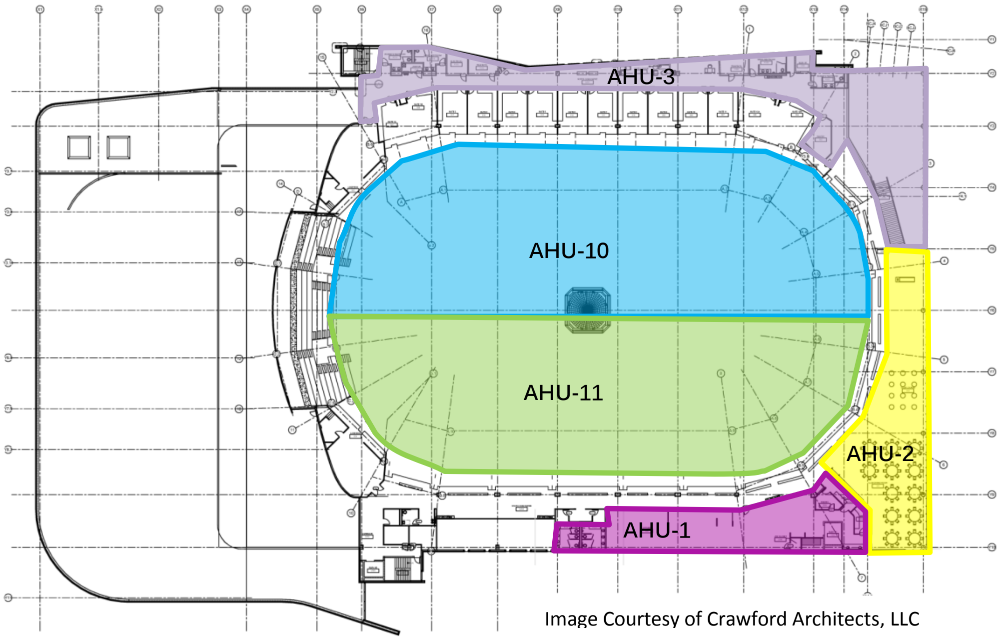


Image Courtesy of Crawford Architects, LLC

Figure 7: Existing AHU Zoning for the Club Level

Existing Lighting Systems

The lighting systems for the Penn State Ice Arena are all served on a 277V distribution system. The main arena has 1000 watt metal halide indoor sports lighting fixtures with black out shutters. An array of linear fluorescent high bays luminaries light the community rink. Other areas, including the concourse, lockers, concessions, restrooms, and lounges, of the building do not have lighting specified in the set of drawings provided at the beginning of the year. Site lighting is provided on both the northwest and the southeast side of the buildings by a pole mounted Louis Poulson fixture that is standard for Penn State. This fixture has a 100 watt metal halide lamp and is mounted at 12' above finished grade. Lighting in the parking lot is provided by Lumark Tribute Series, which contains a 250 watt high pressure sodium lamp mounted at 25'; this also is the Penn State standard.

Lighting controls for the building are not specified in the set of drawings provided at the beginning of the year.

Existing Electrical Systems

The normal building electrical service is provided by the Penn State campus loop and is rated at 12,470 Volts. Two pad mounted transformers reduce the voltage to the building operational voltage of 480Y/277 Volts. Each transformer is rated at 2,500 KVA and serves one side of the building's double-ended substation (main-tie-main). The substation consists of two main switchboards rated at 3000 Amps each. One of the main switchboards has service disconnects that feed the critical and equipment automatic transfer switches. Beyond the main switchboard lie distribution panels for both equipment and lighting rated at 480Y/277 Volts. An emergency automatic transfer switch is served from the equipment distribution panel. Step down transformers are also used throughout the building to service the receptacle load.

Emergency building electrical services are provided by the Penn State emergency campus loop and are rated at 4,180 Volts. A separate transformer is used to step down the primary voltage to 480Y/277 Volt. This transformer serves the emergency automatic transfer switch, rated at 200 Amps. The emergency distribution system has the same basic hierarchy as the normal system, with a distribution panel serving the load and step down transformers.

Existing Structural System

The foundation system for the Penn State Ice Arena consists of a combination of micropiles with pile caps, grade beams, isolated footings, and strip footings. Micropiles with pile caps are used west of the main competition arena where the elevation of top of bedrock may vary. Isolated footings are used on all interior columns around the main competition bowl while strip footings are utilized around the exterior walls of the arena. Figure 8 shows the current foundation system with the area around the main competition bowl that is anticipated to be micropiles with pile caps.

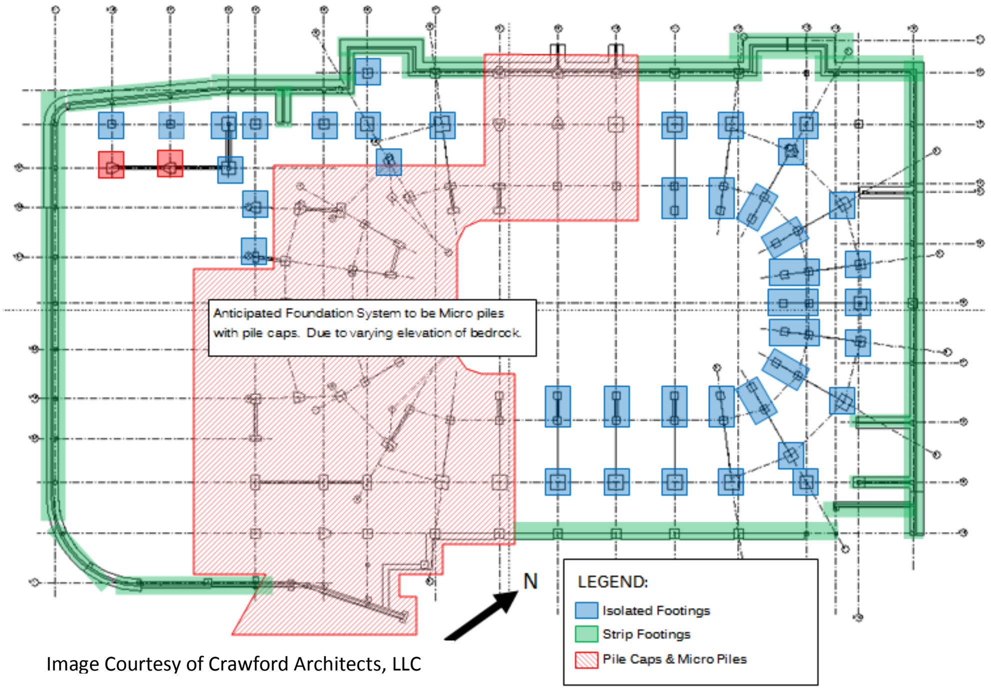


Image Courtesy of Crawford Architects, LLC

Figure 8: Existing Foundation Systems

The event level flooring systems are slabs on grade, all at the same elevation. In the northwest corner of the arena, between the event level and the main concourse level, is a depressed floor slab that is utilized for hiding mechanical equipment. This depressed slab consists of a 7 ½" normal weight concrete composite slab with W18 beams and W24 girders framing members.

All concrete used on the Penn State Ice Arena project will be 4,000 psi. Steel reinforcement both in the foundation system and throughout all other concrete walls will be 60 ksi.

The event level is on the same elevation and covers the entire footprint of the arena. There is a 20'-9" floor to floor height from the event level to the main concourse level. A 12" concrete foundation wall frames the full 20'-9" dimension from the northeast corner to the west corner of the facility. The east side of the building footprint has no foundation wall. Between the west corner and the south corner of the building, the foundation wall tapers down with the grade change.

Around the main competition sheet of ice, the main concourse level and club level consist of the typical one way, 4 ½" normal weight concrete composite slab on 3", 18 gauge VLI composite deck. The total slab thickness is therefore 7 ½". The composite slab is supported with framing members that consist of W18 beams and W24 girders. The beams and girders frame by W18 exterior columns and W24 interior columns at the intersection of grid lines. Typical bays on these levels range from 37'-2" by 28'-0" (largest bay) to 28'-8" by 28'-0" (smallest bay).

Special structural framing that is unique to the ice arena consists of the main competition bowl being made up of a precast "tub" which contains precast seating treads and risers supported on W30 sloped beams and intermediate HSS steel members. Additionally, both the competition and practice sheets of ice are installed over top of a 6" slab on grade that is insulated to avoid slab upheaval due to freeze/thaw cycles throughout the year.

Long span, simply supported steel trusses span 196'-0" from column line Y3 to Y9 running north-south with bracing trusses spanning 240'-5" from column line X6 to X13 running east-west. These bracing trusses are supported by the perpendicular main long span trusses. The top and bottom chords for all trusses are W14's with double angles utilized as the diagonals.

Figure 9 shows a simplified high roof framing plan. The high roof sits approximately 5'-11" above the flat lower roof covering the entire main sheet of ice and the surrounding lower seating bowl of the arena. The simply supported truss, shown in Figure 10, is sloped slightly to a high point in the middle. These trusses are 10'-0" deep at the exterior supports and 13'-9" at midspan. The bracing trusses, shown in Figure 11, are not sloped and are a constant 10'-0" deep. Bottom of the high steel is 50'-0" clear from the top of the ice, ideal for an ice hockey arena. Intermediate framing between these trusses support 3", 18 gauge roof deck.

Image Courtesy of Crawford Architects, LLC

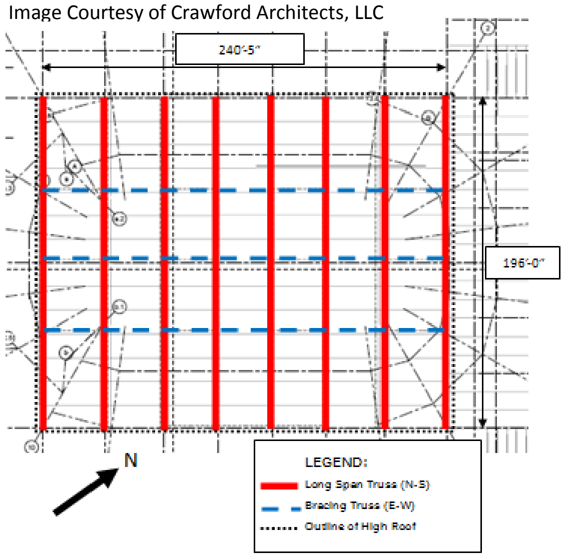


Figure 9: High Roof Framing Plan

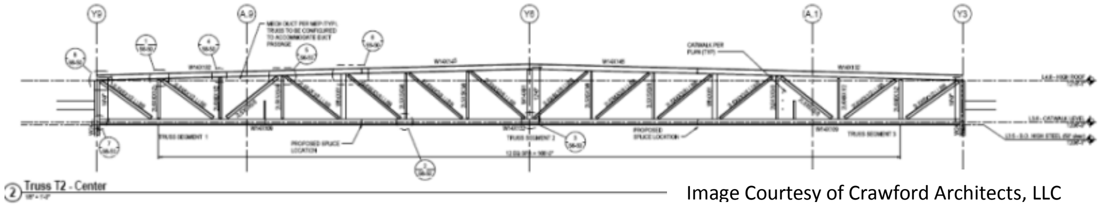


Image Courtesy of Crawford Architects, LLC

Figure 10: Simply Supported Existing Long Span Truss

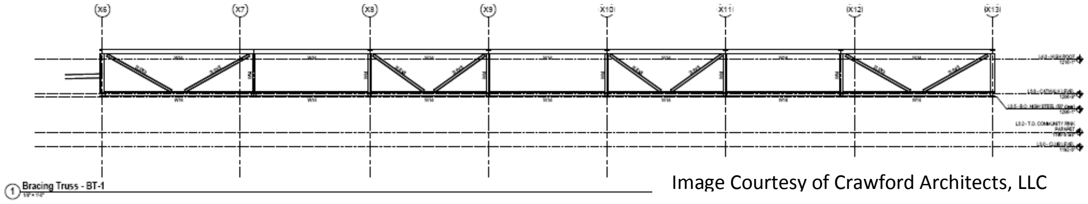


Image Courtesy of Crawford Architects, LLC

Figure 11: Bracing Truss

The lower flat roof wraps around the long span high roof covering the main lobby and exterior main vomitories that circle the main seating bowl. The lower roof spans the 28' wide north and south concourses around the competition arena with 24K8 bar joists. This low roof system slopes up on the north side of the building to meet the high roof top of steel to create a grand entry at the northern main entrance of the facility. Additionally, the auxiliary rink roofing system consists of sloped deep long span trusses that span the 110' wide space.

The lateral system for the arena consists of a combination of moment frames, braced frames and shear walls. Shear walls are designed starting from the event level and terminate at the main concourse level. The main concourse level has a small two bay braced frame running along column line D between column lines 12 – 13. This is the sole braced frame designed in the facility and extends up another level to the event level.

The majority of the lateral systems are designed as moment frames at the club level. Moment frames run the east-west direction above both the north and south concourse along column lines Y2.3 and Y10 ranging from column lines X7 to X12. Additional moment frames run north-south at these locations on all grids lines from X8 to X13. The lateral system for the Penn State Ice Arena is shown in Figure 12.

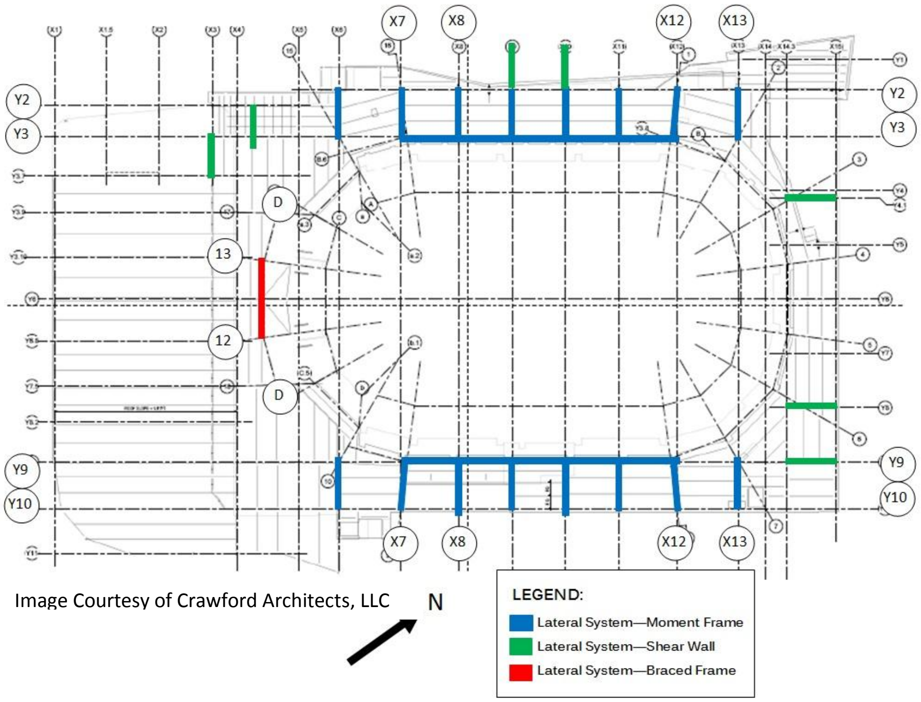


Image Courtesy of Crawford Architects, LLC

Figure 12: Existing Layout for the Arena Lateral Systems

[DESIGN FOCUS: Event Level Raising]

Problem Statement

The geotechnical report for the site chosen for the new Penn State Ice Arena concluded that the site has bedrock at a shallow depth below grade. Figure 13 gives a visual of the top of rock map for the site. Color scale for bedrock depth shows bedrock in the darkest red is 5 feet below the surface and steps down in increments of 5 feet with the yellow portions at 40 plus feet below grade.

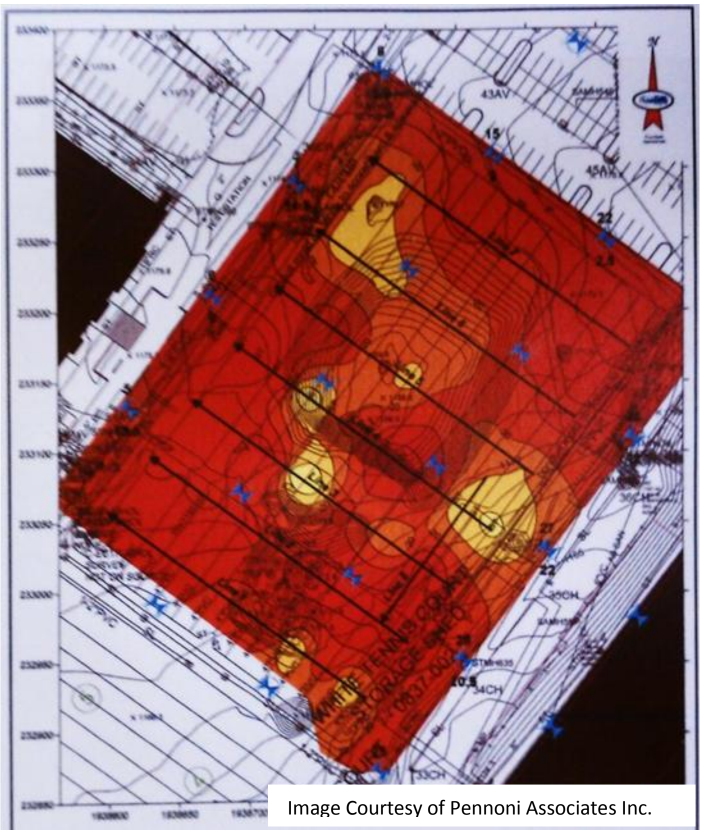


Image Courtesy of Pennoni Associates Inc.

Figure 13: Bedrock Depth

The amount of bedrock needed to be removed causes the cost of excavation to increase sharply, and also extends the schedule due to the laborious nature of rock removal. The bedrock will be removed by drilling into the bedrock and blasting.

HPR is proposing to raise the entire event level in elevation while keeping the concourse and club level at their respective elevations. Raising the event level in elevation will reduce the amount of rock needed removed. The distance that the event level would be raised will be determined based upon a number of variables.

Major design considerations are listed below:

- Egress logistics of the main arena bowl
- ADA seating
- Sight lines
- The number of seats at different price points
- Constructability
- Plenum space
- Grading on the southern side of the facility
- Loading dock logistics
- Other site restrictions such as building width

An alternative solution to raising only the event level elevation would be to raise the entire ice arena facility as a whole. This solution would also reduce the excavation scope and help to decrease costs, but would greatly impact the architectural intent of the main entrance to the facility. The architectural design for the main entrance to the ice hockey arena maintains a clean entry which allows customers to enter the arena on grade with the main concourse level. By raising the entire facility, the main concourse level would not be on grade and would require entrance steps and ADA compliant ramps at the main entrance. This would eliminate the clean entry that has been designed by the architect.

Additionally, site design by the civil engineer has been coordinated with the architectural intent through the use of “skate lines” in the concrete entrance plaza design. Control joints in the exterior concrete are mimicked in the main lobby with an architectural intent to connect the exterior and interior of the facility while also touching on the hockey architectural theme. Overall, without major site re-grading, HPR Integrated Design has decided to abandon this alternative as a viable option.

Figure 14 shows a sectional view of the proposed changes to the event level. The green lines represent the existing conditions while the yellow lines represent the proposed changes. Notice that the plenum below the concourse level is reduced and the slope of the arena seating stays the same. This reduction in plenum space will require a more closely coordinated plenum space. In these areas, BIM software like Navisworks will be vital in preforming clash detection to avoid any issues that could arise on the jobsite.

Model Courtesy of Crawford Architects, LLC

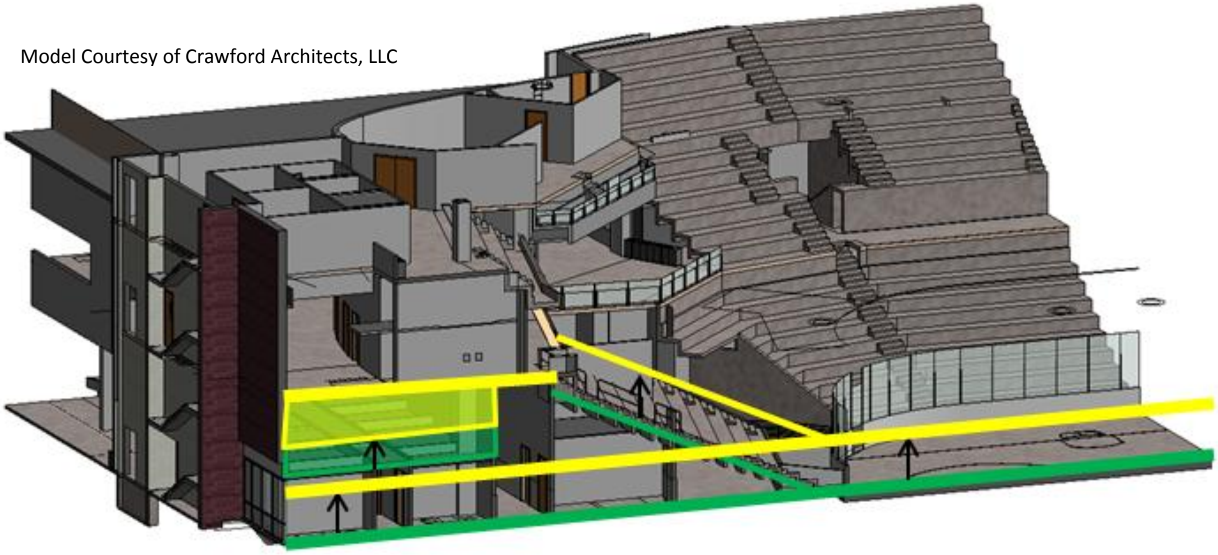


Figure 14: Three Dimensional Section of Southern Corner of Arena Bowl

Construction Approach

The construction manager's position will be to ensure that the facility will have the highest quality for the budget allotted, be completed on time, and achieve the desired level of LEED certification. The first thing that must be created is the baseline estimate and schedule of the existing design of the entire project. RSMeans Costworks and MC2 Ice Estimating Software will be utilized to help determine these values and schedule outputs.

Based on geotechnical reports, below the subsoil, much of the site that needs to be excavated consists of bedrock. HPR estimated 15,141 cubic yards of bedrock will need to be removed. The estimate taken was assuming that the rock to be excavated will be drilled and blasted with open faced rock costing at least $376,000, and about 61 eight-hour working days to complete. This is based on one crew working to remove the rock, equipment, blasting mats, a power shovel to remove the rock, and one 25-ton truck to haul the rock 3 miles away. This estimated cost does not take into account the excavation of soil, backfilling, or grading. Further research will need to be done to have a more accurate number for the amount of bedrock that needs to be removed for the baseline estimates.

Based on expert opinion of the geotechnical engineers, it has been determined that blasting of the rock is more cost effective than that of jack hammering. Though, there are vibrations to be considered, blasting will result in a less detrimental effect than that of jack hammering in the fact that jack hammering will have sustained vibrations for longer periods of time based on the geotechnical reports.

By raising the location of the event level, HPR will not only be able to save cost, but improve the schedule. The budget saved will be used for the development of an iconic and higher quality roof design. The construction manager will coordinate with each of the other disciplines to determine how much of the plenum space can be reduced based on the design of the equipment, utilities, and structural needs, before it can be determined how much budget and schedule will be saved.

Upon completion of the baseline estimate, schedule, and LEED score card the construction manager will update each based on the new designs from coordination of the other disciplines. As changes are made to the model, efforts will be made to ensure that new designs are meeting code, and are designed to achieve LEED Gold certification. Estimates will be kept in an excel file. The master model will be updated weekly in Revit. Navisworks will be used to perform initial clash detection and 4D modeling, and will continue weekly.

Mechanical Approach

The mechanical contribution to HPR Integrated Design's raising of the event level will consist of the design and layout of duct work for the offices, locker rooms, and training facilities; intense coordination with the structural and electrical disciplines regarding plenum space; and a potential system alteration in the training facilities area to reduce energy consumption.

Specific mechanical tasks will include: designing the air distribution system for the event level, coordinating reflected ceiling plans with lighting design in areas of interest, and a redesign for the system serving the training areas. Raising of the event level should have minimal to no effect on the loads in these spaces. A majority of the mechanical designer's task will be related to coordinating the utilities that must run in the plenum.

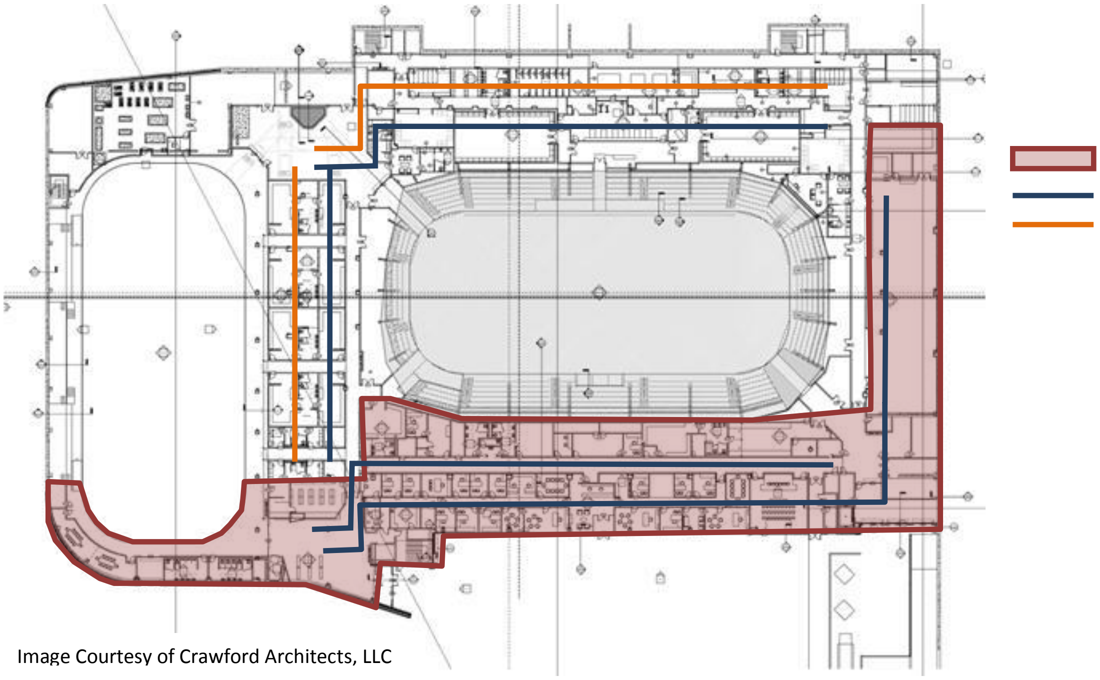


Image Courtesy of Crawford Architects, LLC

Figure 15: Potential Duct Layout on Event Level

With the raising of the event level, the main concourse and club levels will remain locked in place. The only thing changing is that the event level is moving up. The exact height that the event level will be raised will be a function of several constants including: plenum requirements, sight lines, head clearances, and egress concerns. HPR believes the optimal dimension will be approximately three feet; any less and the savings will be minimal, any more and the cost of relocating seats will start to overcome the excavation savings. Further investigation will be needed to finalize this dimension.

Aside from the design of the event level's mechanical systems, raising the event level also has impacts on the design of the main arena; it alters the volume and affects the return grille locations for the main arena system. To effectively design the return air system the mechanical designer and structural designer will need to work very closely. The air systems for the event level will be designed to a design development level. All spaces will have the high and medium pressure ducts modeled. If time permits key spaces will have the low pressure duct modeled as well. The return air system for the main arena bowl will be modeled to a schematic design level.

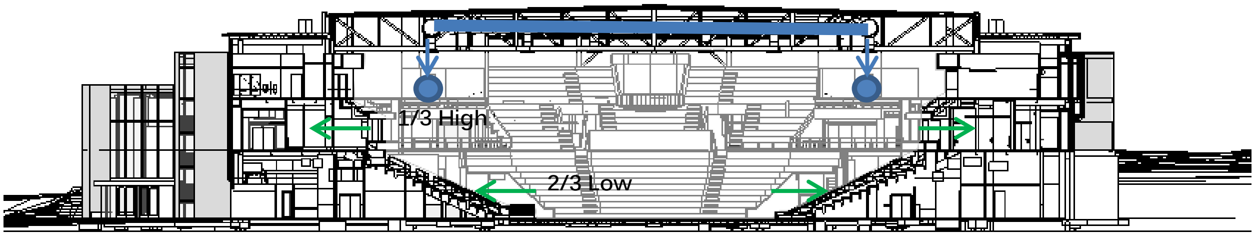


Figure 16: Potential Return Air Strategy

Lighting/Electrical Approach

The relocation of the event level creates a tighter plenum space which is where all the building systems are to be placed. Due to the fact that plenum space reduction is a crucial goal of this redesign the luminaires as well as the electrical coordination will be done in a way to optimize the plenum space for both design efficiency and maintenance considerations.

Luminaires that have a shallow recessed depth or are pendant mounted will be chosen to optimize the space in these locations. The lighting system design will utilize high efficacy sources, normal power factor electronic ballasts where applicable, and luminaires with high efficiency. In doing so, the total building lighting power density will reduce and help achieve the goals of LEED sustainability. The lighting control system will also be designed to reduce the energy consumption of the lighting systems. Controls such as occupancy sensors, vacancy sensors, and daylight sensors will be tied into the lighting system to turn off or dim lights to an appropriate level.

The offices located on the southern façade will be exposed to a large amount of direct sunlight during daylight hours. The lighting designer is proposing a shading device be in place to reduce or eliminate the amount of direct sun that enters the building and strikes the work plane in these spaces.

The electrical system on the event level needs to provide power to all the required spaces and also follow good design practice laid out in the relevant code manuals. Efforts will be made to reduce the amount of wiring and conduit needed by using the most efficient path for servicing the spaces.

Structural Approach

The structural contribution to HPR Integrated Design's raising of the event level will consist of redesign of the major structural systems (foundations, floor systems, etc.) and coordination with all the other disciplines for various system considerations.

Specific structural tasks will include redesign of the existing main concourse flooring system, redesign of the select gravity columns that frame between the event level and main concourse level, an analysis/redesign of foundations systems, and considerations for redesign of the new precast "tub" arrangement.

Assumptions include that the main concourse elevation will be held at its existing elevation and the entire event level will be raised in height. The dimension that the event level is raised will be based on major design considerations that are noted in the problem statement. This dimension will be determined through further investigation into the controlling design consideration.

The shear walls that are located between the event level and main concourse level will be decreased in height and will need to be assessed for capacity. This analytical process will be constrained in scope as this is a design consideration but not a primary focus of this redesign with a limited timeframe. A 12" exterior foundation walls' strength capacity will be assumed to be adequate as lateral earth pressures will be decreased.

Structural systems below the main concourse level will be redesigned to allow for maximum clearance for plenum coordination and allow for the event level to be raised to the optimum height. By creating efficient systems that maximize useable space and minimize the voids in the building, the excavation scope is decreased and therefore there are both cost and schedule savings for the project.

Accomplishing these goals will be done by changing the main concourse flooring system from a composite steel system to a two-way flat slab system. Redesign to a two-way flat slab system will be done to a construction level of detail to include reinforcement calculations and details along with deflection calculations. Integration within the team will be utilized with the construction manager for constructability review and schedule/cost analysis. Additionally, continuous MEP coordination with the MEP designers will be completed utilizing 3D coordination programs such as Navisworks with the BIM use led by the construction manager.

Preliminary design shows a decrease in overall system thickness from an existing 32" thickness to a reduced 19" thickness. Preliminary design for the concrete two-way flat slab system did not include the post-tensioned design element and it would be assumed that the structural flooring system depth could be decreased even further. Using a concrete system, HPR will propose fast-tracking the event level structure by erecting formwork and beginning concrete placement soon after foundations have been installed and foundations have reached 75% of its 28-day strength. HPR will offset the cost of formwork and labor associated with concrete placement with cost savings from the reduction of scope for additional fire protection.

The redesigned flooring system consists, primarily, of a 15" reinforced normal weight concrete slab with 4" thick drop panels. Reinforced concrete columns were assumed to be 18" by 18" square columns to match the dimensions of the existing steel columns for architectural considerations. The preliminary design for the two-way flat slab flooring system was conducted on the exterior main north and south concourses along column lines X6 and X15. Structural spans in these two areas range from 28'-8" to 37'-2". The thickness of the flooring system is controlled by deflection criterion from ACI Table 9.5.3, "Minimum Slab Thickness for Deflection Control." Drop panel thickness was derived from ACI 13.1.2 which dictates minimum nominal thickness of drop panels.

Two-way flat slab systems are not as effective at such large spans, which results in a thick slab which may have constructability issues. Multiple factors will be considered to further decrease the thickness of the flooring system:

1. The addition of a continuous drop panel which would act as a shallow beam.
2. Increase of drop panel thickness.
3. The addition of post-tensioning to the flooring system.
4. A combination of both post-tensioning and continuous drop panels.

Post-tension design would reduce the thickness of the slab from 15" down to 10" using a trial slab thickness equal to the average span divided by forty-five. An investigation into both post-tensioned design and a two-way flat slab without post-tensioning will be completed by HPR. Figure 17 shows a comparison between the two systems.

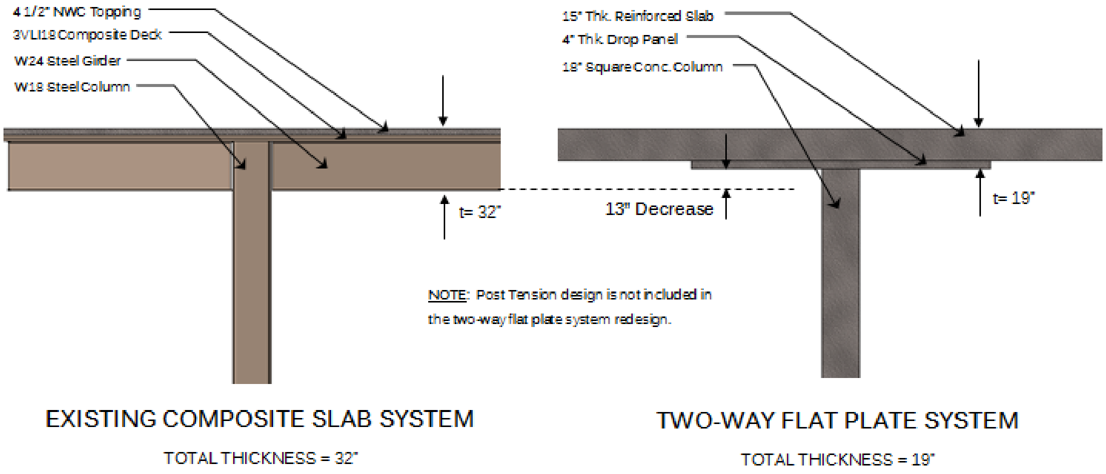


Figure 17: Comparison of Existing Versus Proposed Flooring System

Foundation systems will be analyzed and redesigned by the structural designer based on a new top of footing elevation. Foundation analysis will be conducted to account for the additional dead load that inherently accompanies the heavier concrete structural system. Shallow foundations will be re-evaluated for structural capacity and redesign will be completed if necessary.

This redesign process will be limited in scope to a few select typical foundation types and will be assessed for strength capacity through full structural design including reinforcement selection and any strength requirement calculations (wide beam, punching shear, etc.). Adequate design will then be assumed to be acceptable for similar situations. The structural designer will work with the construction manager on any foundation changes for schedule and cost impacts throughout the redesign process.

Another structural issue with relocating the entire event level is the design of slope steel for the precast “tub” in the main competition arena. Additional framing will be needed to accommodate the displaced seating in the lower bowl. Live loads will be derived similar to the actual structural engineer’s practices by “smearing” the live load requirements for the fixed seating and circulation aisles to account for the variability of function in this area. This design will be schematic in nature and will check for basic strength requirements.

A study on head clearance and fan sight lines will be conducted by HPR and may require alterations to the club level precast tub cantilevered framing. Any alterations to the club level precast tub seating will be conducted to a schematic level and will require coordination with the team. The HPR team will act together as the architect, to confirm that architectural elements of the building (sight lines, egress, ADA, etc.) will not be diminished. Figure 18 shows the relocated seating arrangement and the additional steel and precast design that must be completed for the proposed redesign.

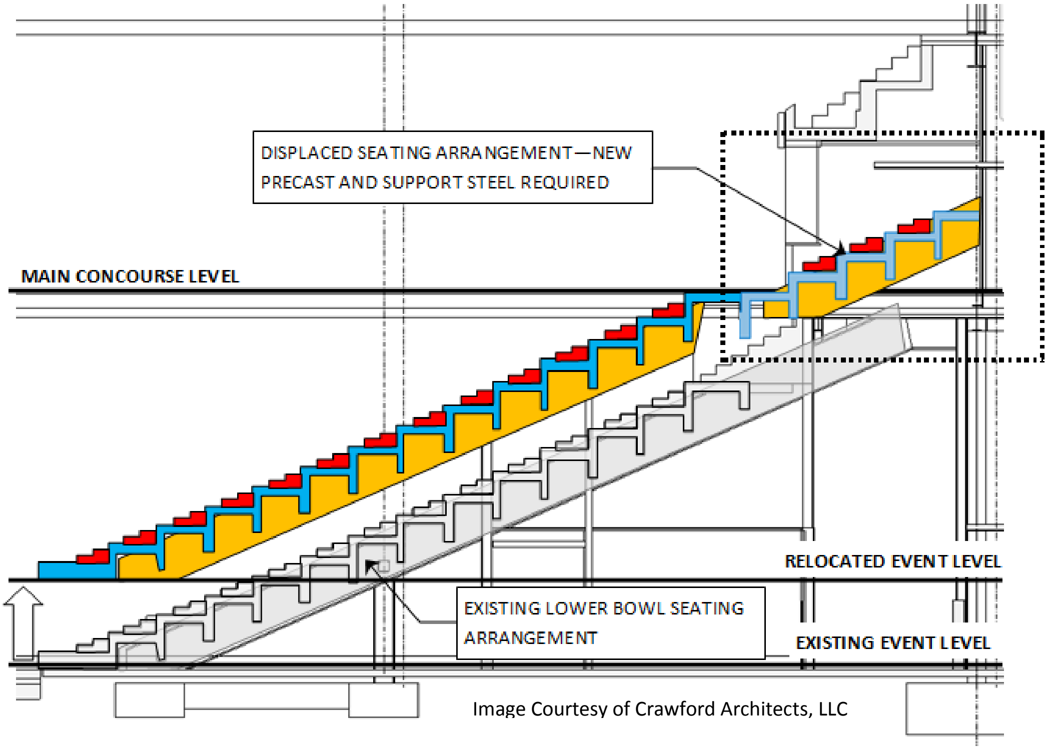


Image Courtesy of Crawford Architects, LLC

Figure 18: Section of Relocated Seating Arrangement

BIM and Interdisciplinary Approach

This study will initially be dominated by program requirements and balance between cost savings and added cost. Once an optimal dimension for the raising of the event level is determined the design authoring will commence. Updating the architectural model will be a team effort as each team member will help model the new event level elevation and seating location. Considerable time must be allocated to relocating seats and meeting ADA codes.

Once the architectural model is updated, the structural, mechanical, and electrical designers will determine the plenum requirements for each system and begin to lay out their individual systems. Further on into the process, the lighting and mechanical designers will have to coordinate the ceiling plans for key spaces. Preference will be given to the lighting designer where ever possible since lighting systems are more sensitive to location. This is an integrated process and as more design element moves forwards other disciplines may be impacted and revisions may be necessary.

The design authoring for this study will be done in Revit (Architecture, Structural, and MEP). Each discipline will also be creating an analytical model in the discipline specific software (Trace, spColumn, and AGI). This study will also require considerable clash detection so Navisworks will be utilized heavily. Further information on BIM goals and uses can be found in Appendix D. Deliverables can be found in Appendix A.

Event Level Relocation Conclusion

Given the site of the Penn State Hockey Arena and its characteristics, the excavation is a large portion of the schedule and the project budget. HPR Integrated Design, with the above proposed changes to the event level, can optimize the building volume while reducing the cost and schedule for the building.

There are a few consequences to raising the event level up. The biggest and most challenging to overcome is the reduction of seats in the main bowl. When the ice is raised, the seats will follow. The higher it is raised the more seats are lost from the top of the bowl's ring. HPR is proposing that these seats be replaced in the walk way around the top arena bowl and in the one of the three large vomitories in the corners of the concourse level without infringing on the original architectural intent.

The process of finding the optimum distance that the event level needs to be raised in elevation is going to be a collaborative team effort with input from all disciplines and impact from various design guidelines and codes. Ultimately, the end goal of this redesign is to provide a facility that will meet all of the current design goals and criteria, providing a high quality facility and within a shorter construction time.

HPR will measure the success of this redesign by adhering to all applicable codes, not affecting the quantity and price distribution of the seating bowl, making efficient use of the redesigned spaces, and not impacting the experience the fans will have when at an event.

[DESIGN FOCUS: Main Arena Roof System Design]

Problem Statement

HPR Integrated Design's alternative solution to the Penn State Ice Arena's main arena high roof systems will be a multi-disciplinary collaborative effort that results from the concurrent raising of the event level and redesign of the arena's building enclosure. Design constraints dictate that a 50 foot clear dimension between the playing surface and the bottom of high roof structural steel, ideal hockey regulations, must be maintained. As a result of the raising of the event level, the entire high roof system will also be raised in elevation to maintain this dimension. Additionally, the roof geometry must be designed to create a prominent, iconic facility which has been requested by the University.

With the assumption that the main arena roof geometry has not been established, HPR Integrated Design will investigate different design solutions that are both conscious of the campus sporting facility architecture and allows for optimization of the building's engineered systems. As this arena sits adjacent to the Bryce Jordan Center and in the shadow of Beaver Stadium, two major iconic Penn State sporting complexes, an architectural connection should be made.

This study will address this architectural connection and will be integrally connected to other design focuses such as the event level raising and façade redesign as a whole. Redesign of the structure's long span trusses that accommodate more pronounced roof geometry, consistent with the neighboring Bryce Jordan Center, will be accomplished and concurrently coordinate with alternative design solutions for both the lighting scheme of the arena and major mechanical systems. HPR's design focus is to create efficient engineered systems that accommodate changes to the high roof system.

Construction Approach

The construction manager will use the baseline estimates and schedule created in the first design focus and update them according to new designs from coordination of the other disciplines for the main arena roof system design.

It is important that the Penn State Ice Arena have an iconic presence on the University Park campus. Based on initial facility designs received from the architect, the drawings were at 50% completion without the roof drawings. However, rendered drawings show a completed roof design. Based on the current event level location design and the amount of budget used for excavation of the bedrock, the current roof design according to the architect is a result of lack of budget. With HPR's raising of the event level, money saved from excavation will be reallocated in the effort to creating a high quality, iconic roof.

HPR's new roof for the ice arena will require coordination between the construction manager and structural designer. Based on the sizes and design of the trusses, efforts will be made to ensure that the other disciplines' utility designs will be able to work with the trusses and new roof system. At this time, a crane analysis will be performed to determine what size cranes will be needed, the number of cranes that will be needed, and the type of cranes that can be accommodated based on a developed site logistics plan. Lead times will be acquired to determine at what point in the schedule the trusses can be installed. The construction manager will have the designers make changes to their systems based on coordination, quality, and cost.

In an effort to create a high quality, iconic roof, the design will include irregularly shaped roof panels. The construction manager will determine lead times for the roof panels to determine when the panels will be installed.

With having a more intricate roof design, completion of the roof system will take more time. Time saved in the schedule from the raising of the event level will help keep the new schedule on track and completed on time. Efforts will be made to shorten the schedule if possible.

As changes are made to the model, efforts will be made to ensure that new designs are meeting code requirements, and are designed to achieve LEED Gold certification. Estimates will be created from RSMeans Costworks and MC2 Ice Estimating Software and kept in an Excel file. The master model will be updated weekly in Revit. Clash detection and 4D modeling using NavisWorks will continue to be performed weekly.

Mechanical Approach

The mechanical contribution to HPR Integrated Design's roof systems integration will consist of duct design and layout along with diffusers locations within the truss network; continuous coordination with the structural and electrical disciplines regarding location of the utilities and structure; and a control structure that will allow for reduced supply air when the arena is under partial load. Initial coordination efforts, shown in Figure 19, will be continuously conducted with the other disciplines to ensure clashes with the duct layouts are avoided. This will be done through both verbal communication and clash detection in software programs like Navisworks.

The mechanical designer's tasks related to this change include a new volume calculation, load calculations, sizing and locating of ducts and diffusers while coordinating with the other disciplines, and the integration of a controls structure to reduce energy. This design will look into air handler selection and energy recovery strategies. The supply air system will be designed and modeled to an 85% construction document level.

The mechanical designer will perform a CFD analysis of the smoke exhaust system as part of requirements for the integrated master's program. If the current system does not meet code, changes will be proposed.

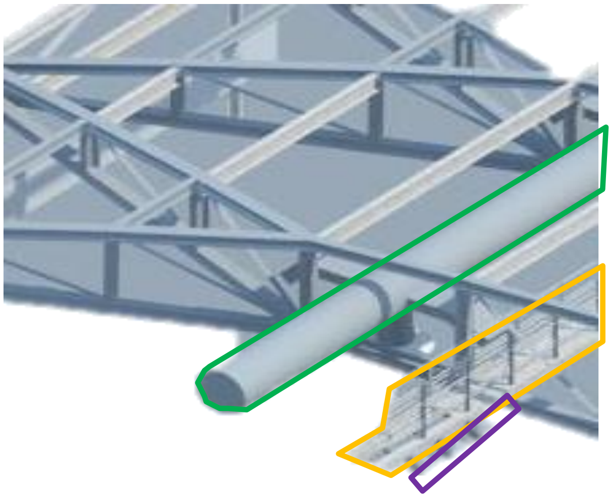


Figure 19: Perspective of Sample Roof Integration

Lighting/Electrical Approach

The competition arena poses a functional and illumination challenge. Producing a space that will align with HPR's project goals and design criteria will be a challenging task. The illumination criteria for Division 1 hockey is dictated by the NCAA. Illumination levels and uniformity requirements are the main criteria for televised events. The lighting/electrical designer is proposing a lighting system that conforms to the NCAA broadcasting criteria and also ASHRAE Standard 90.1 Section 9.

The seating area needs life safety illumination in case of an emergency. Either an array of fluorescent luminaires placed above the seating area or floodlights from the catwalk will be provided to give the space illumination in case of a power outage or during an emergency event. Figure 20 shows the preliminary proposed schematic lighting layout.

In preliminary lighting calculations for the main arena ice sheet, 46 indoor sports lights with 1000 watt metal halide lamps were needed to give the required illumination. This gives a power density of 2.6 watts per square foot, which is 83% of the total power density allowed by ASHRAE standard 90.1.

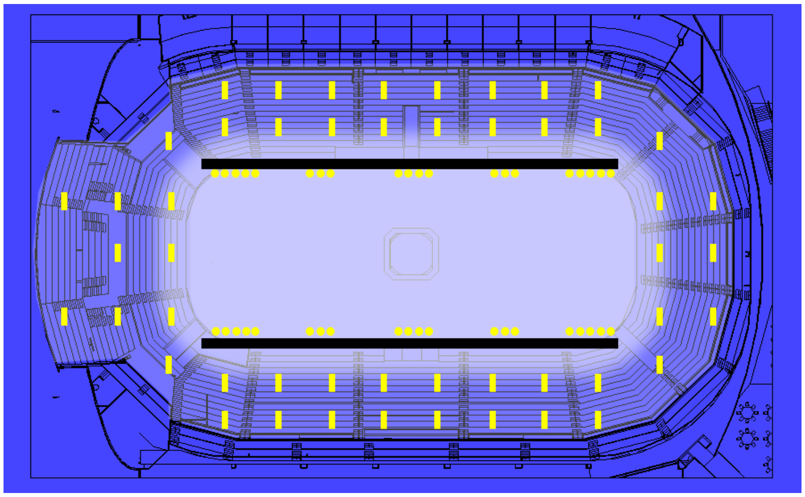


Figure 20: Schematic Lighting Layout for the Main Arena

The electrical systems in the main arena bowl will need to provide power for the lighting system, any smoke exhaust system that will be designed, the rigging points for events, the score board, and any other component that requires power.

Structural Approach

The structural contribution to HPR Integrated Design's alternative solution for the competition arena roofing system will focus on redesign of the long span trusses to accommodate more iconic roof geometries. The main goal for the roof systems integration is to design an efficient structural truss that allows for an aesthetically recognizable roof design. This successfully allows for coordination with the MEP systems to increase constructability in the field. The structural designer will coordinate with the construction manager to confirm or provide input into proposed erection procedures and sequencing of construction.

To accommodate the raising of the event level as an entire entity, the redesign of the simply supported long span trusses must be elevated to allow for the ideal 50 foot to 60 foot clear dimension between the bottom of steel and top of the ice playing surface. Raising of the entire facility as a whole, discussed in the event level raising problem statement has been eliminated as a viable alternative due to the architectural intent of the main entrance to the facility.

A 50 foot minimum clearance from the bottom of steel to top of the ice is a requirement to meet NCAA ice hockey gameplay regulations. Ideally, the bottom of steel could be as high as 60 feet high to allow for flexibility of the function of the arena. A bottom of steel dimension of 60 feet allows for alternative sports such as arena football to be accommodated. This is determined through research into the analysis of major sporting events where a sport rarely requires more than 60 feet of clear height to avoid disruption of gameplay.

To increase the efficiency of the long span truss, the structural depth of the trusses must be determined and coordinated with the other disciplines to avoid clashes in the field. Determining optimum dimensions will be led by the structural designer with specific input from all disciplines for key locations of major MEP systems, stemming from input from the MEP designers, and also constructability and cost/schedule impacts from the construction manager. The structural design will then be completed to a design document level of detail using computer analytical software described in Table 6: Structural Deliverables. If time allows, the structural designer will investigate and design typical connections at key locations on the truss to a construction level of detail.

The structural design of the long span trusses will be supplemented with input from all disciplines to allow for ease of coordination throughout the coordination process, led by the construction manager. Continuous discussion with the mechanical and lighting/electrical designers will be conducted to ensure the best location for all systems to create the optimum space in the main ice arena.

As a design alternative to the simply supported long span trusses proposed in the actual project's design, systems such as buttressed arch design, tied arch truss design, and a "Wishbone" split moment connected truss design were considered.

A pure arch structural element would require buttressing or large columns to counteract the large lateral thrust forces. With the premise that HPR has accepted the architectural floor plans and will not perform major redesign, the plans do not allow for the required large columns. Additionally, it is HPR's belief that buttressing could compromise the architectural intent.

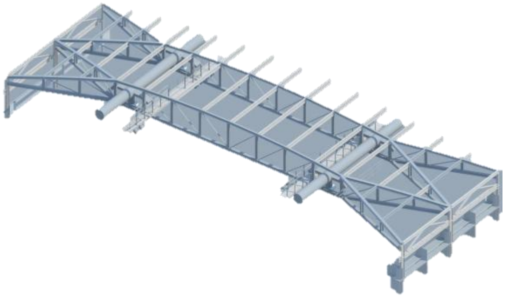


Figure 21: "Wishbone" Long Span Truss

Another alternative that was explored is shown above in Figure 21, which consisted of a wishbone support condition with moment connections to resist a part of the moment on the long span truss. The moment connections reduce structural member sizes by resisting more of the total static moment on the truss through creating a fixed-fixed condition rather than the simply supported condition that is currently designed. Optimization of this alternative solution requires an in-depth study in the balance of the additional cost of the moment connections and the addition of structural members against the material cost savings of reduced member sizes.

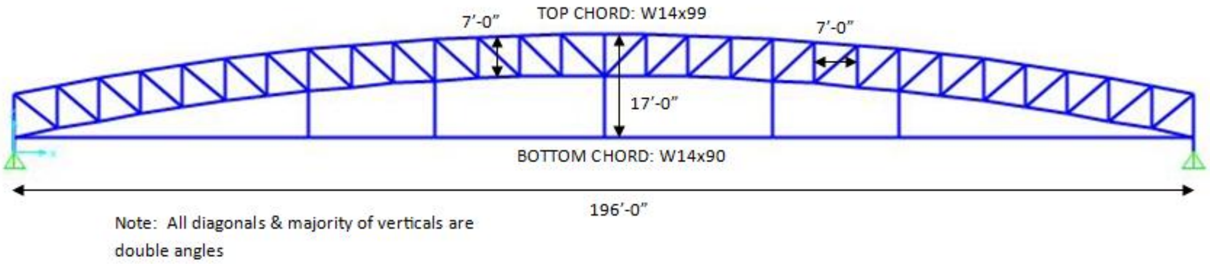
While the design was successful in reducing member sizes, the cost of the moment connections removed this as a viable alternative. The cost of a moment connection, according to the American Institute for Steel Construction (AISC), is equivalent to 800 pounds of steel per moment connection. A quick analysis of the wishbone truss yielded a 1.5% increase in material cost, even with the decreased member sizes. This increase in cost would be inflated by the laborious nature of moment connections and the additional vierendeel truss panels. The overall cost of this truss in both material and labor costs along with probable schedule delay removed this as an acceptable alternative solution.

Both, the architectural layout of the building and cost have dictated that the proposed long span truss must remain simply supported. An alternative proposed design solution is shown in Figure 22, consisting of a tied arch truss framing system with preliminary dimensions and member sizes. Not shown in Figure 22, are the additional members sizes listed below:

- Bottom chord of curved truss: W14x22
- Average diagonal member size: L3x3x1/4

The proposed truss design efficiency must be optimized by manipulating the depth of both the curved upper chord and overall truss depth. This design will also require further investigation into geometries to minimize the thrust forces on the exterior columns which are currently W27's. Possible solutions to reduce the large thrust forces that accompany an arched truss design include:

- Large bottom tie member sizes to accommodate both the thrust and bending considerations from midspan rigging loads.
- Alternative end support geometries such as x-bracing to resist trust forces.
- Bracing in adjacent bays that frame into the long span truss assembly.



Note: All diagonals & majority of verticals are double angles

Figure 22: Proposed Tied Arch Truss - Preliminary Design & Member Sizes

BIM and Interdisciplinary Approach

Redesign of the main arena roof systems will be initially led by the structural designer who will set a baseline for the geometry that has been established as a team decision. MEP designers will coordinate with the structural designer and provide input into the ideal locations for the HVAC and lighting systems to create the best atmosphere for the arena. Throughout the process, 3D coordination will be conducted by the construction manager who will provide the necessary clash detection data and also work closely with all disciplines for constructability considerations.

As the design process will be iterative, the design team will tweak the geometries of the roof profile to any changes with the exterior façade and allow for the required flexibility in function for the interior arena competition space. If changes are needed, the process will become cyclical with the structural designer making necessary changes followed by the changes made by the MEP designers, and coordinated with the construction manager. Life cycle, construction costs, and scheduling impacts will be analyzed throughout the redesign process, led by the construction manager.

HPR Integrated Design will use the Autodesk Revit Suite platform (Architecture, Structural, MEP) for the collaborative model throughout the design authoring portion of this redesign. Navisworks will be utilized as the primary 3D coordination tool and will produce clash detection reports as needed. Structural engineering will be conducted primarily using SAP2000 and hand calculations. The MEP designers will utilize analytical programs such as Trace (mechanical), AGI32 (L/E) and hand calculations which will then be modeled in the Revit platform. Finally, the construction manager will utilize RSMeans and Primavera P6 for cost and schedule impacts in that order. Further information on BIM goals and uses can be found in Appendix D. Deliverables can be found in Appendix A.

Main Arena Roof System Design Conclusion

HPR Integrated Design's alternative design solution for the main arena roof systems is aimed at creating an iconic roof geometry, consistent with architecture of Penn State's major sporting facilities and allows for the optimization of the building's engineered systems. The design team will be conscious of the concurrent alterations to the facility's façade and will establish a connection that is consistent with architectural elements from both the exterior and interior of the building.

The structural designer will be expected to lead this process with the generation and maintenance of the long span truss elements within the analytical and coordination model to be used as a baseline for coordination with the mechanical and lighting/electrical engineers. Cost analysis and erection planning will be derived by the construction manager through the use of the coordination model. Additionally, 4D coordination and clash detection will be completed throughout the coordination process by the construction manager.

HPR Integrated Design will not measure the success of the main arena roof systems design by comparing results to the existing facility design. Successes will be determined based on the overall system costs for the structural and MEP systems from a cost per square foot perspective compared to other similar sized ice hockey arenas.

The design team will strive to design a roof system that is competitive both in price and aesthetic to the proposed original design, but gives the University an architecturally enhanced product. Elevated design costs will be drawn from savings in excavation from the event level raising to ensure that the University is receiving a facility that is of greater value for the a similar competitive construction cost.

Architecturally, HPR Integrated Design will define a successful iconic and/or recognizable roof geometry profile consistent with the adjacent Bryce Jordan Center, and that can be argued that the architecture connects both architectural elements from the traditional academic campus to the more modern sporting facilities nearby the arena.

Locally, a successful iconic roof profile will be measured based on assimilation of the roof geometry with the façade redesign focus and architectural compliance from both the interior and exterior of the facility. The design team will strive to create a clean, architecturally appealing high roof overall system that accommodates "championship" ice performance and enhances the experience of the fans.

[DESIGN FOCUS: Façade Redesign]

Problem Statement

When HPR Integrated Design started to look at the existing plans for the Penn State Ice Arena, one of the areas that was determined that could be improved upon was the façade design. This included the material choices as well as the size and appearances of the entrances. The east façade's current design consists of a full length curtain wall that scales from grade to roof level. HPR Integrated Design believes that the intent of this design was to create and impressive view from University Drive as well as a view of Mt. Nittany and the Bryce Jordan Center. A new design solution can maintain these original goals while altering the architectural design to accomplish reduction of loads on the building, cutting cost and potentially shortening the schedule.

As part of the east façade, the main entrance will be altered. HPR Integrated Design will also aim to draw more attention to the student entrance. Although the student entrance is not the main entrance, it is still highly visible from the other sports fields and to the students on a daily basis.

Construction Approach

The construction manager will use the baseline estimates and schedule created in the first design focus and update them according to new designs from coordination of the other disciplines for the façade redesign. This will be done simultaneously with the roof system design.

In the effort in creating an iconic presence for the Penn State Ice Arena on the University Park campus, HPR will be developing a new roof system. HPR will redesign the façade to complement and blend with the new roof system. Based on coordinated efforts between the designers, HPR will redesign the façade to that of higher quality within the budget allotted.

The construction manager will work closely with the designers to determine the most cost effective materials to be used for the façade such as glazing, panels, brick, and structural materials. Along with creating an iconic façade, the important aspect here is to reduce energy costs in the building. The new materials selected for the façade will save budget the cost of different materials and installation, as well as decrease lead times. At this time, an analysis of heavy equipment needed for installation of the façade will be made. This is primarily an effort to determine if equipment needed for installation of the existing design can be eliminated reducing construction costs. Efforts will be made to reduce time in the schedule.

As changes are made to the model, efforts will be made to ensure that new designs are meeting code, and are designed to achieve LEED Gold certification. Estimates will be created from RSMeans Costworks and MC2 Ice Estimating Software and kept in an Excel file. The master model will be updated weekly in Revit. Clash detection and 4D modeling using NavisWorks will continue to be performed weekly.

Mechanical Approach

The mechanical contribution to HPR Integrated Design's redesign for the façade will be focused around load reduction and energy savings. The façade redesign is centered on reducing heat gain on the east façade along with improving the architecture and enhancing the prominence of the entrances.

The mechanical designer's role will be to drive the changes to the façade along with the lighting designer. The mechanical designer will then the changes effect on the loads, proposes changes additional changes that can help reduce heat gain while maintaining the views. Along with the structural and lighting/electrical designers, the mechanical designer will be responsible for selecting the appropriate glazing for the new façade. Once all architectural changes have been made and the mechanical and lighting design are completed, the mechanical designer will be preforming a full energy model to help predict the operating cost of the entire building throughout the year. The façade will be designed to a design development level. Materials and areas will be set, but limited details will be provided.

Lighting/Electrical Approach

The proposed changes to the eastern façade still allow a large amount of northern diffuse daylight into the spaces. This daylight can be used to reduce the amount of artificial light needed and reduce the energy consumption of the building. Photocell control or time of day switching can be used to give the required lighting control. Figure 23 shows a rendering of the main concourse. Additionally, the amount of illumination that the spaces see during the winter at noon can be seen in Table 1.

Figure 23: Rendering of Daylight into the Concourse

Table 1: Illuminance of Spaces on Winter Solstice at Noon

Space	Illuminance	
Lobby	1000 lx near perimeter	600 lx at interior
Concourse	800 lx on northern side	100 lx on southern side
Mt. Nittany Room	350 lx near perimeter	50 lx at interior

A proposed schematic design for lobby can be seen in Figure 24. Below is a list of relevant design criteria for the lobby space:

- 0.90 w/sf
- 100 lx horizontal
- 30 lx vertical

- Public psychological impression
- Architecturally appeal view from University Drive at night.

Figure 24: Lobby Schematic Lighting Design

Structural Approach

Structural contributions to the redesign of the façade system will be to focus on assisting the design team in creating an innovative, effective building envelope and façade that meets design goals for both energy efficiency and architectural intent. This will be accomplished specifically through proper analysis of the exterior columns for any change in loads based on alternative material selection, by providing proper support conditions in details, and the investigating the curtain wall glazing panels with considerations for wind pressures and construction loads.

Existing steel connections connecting façade panels and/or curtain wall systems will be considered in design, but will be assumed to be adequate for strength. Locations and sizes for these existing connections will not be evaluated unless the change in material properties is drastic. Connections will be designed to a schematic level if redesign is required. Additional miscellaneous steel needed for façade redesign will be considered and designed to a schematic scope.

The structural designer will attend all coordination meetings that involve the redesign of the façade. Currently, the east façade is completely a curtain wall system and redesign will involve changing this area into heavier materials that will require structural support and structural input for efficient design.

HPR Integrated Design will frame views along the east façade that will require analysis of the curtain wall mullions and glazing panels. Structural constraints will be investigated within these elements for strength and deflections from wind forces to a construction level of design. The structural designer's input will be required with all other disciplines throughout the redesign process to ensure the architectural design intent is constructible. Calculations for deflections from wind pressures will be completed as needed throughout changes in the curtain wall design process to ensure strength capacity once the assembly is installed.

Induced forces and loads from construction activities such as lifting, transportation and placement will also be investigated at a schematic level. This process will be completed with input from the construction manager for proposed lifting and placement procedures. The structural designer will be the liaison between the MEP design team and construction manager to ensure the proper placement of all curtain wall systems.

Additionally, the building envelope will be considered and monitored from the structural realm throughout the redesign process for waterproofing and performance issues. The building envelope design and sciences will be analyzed throughout redesign of the façade at a schematic level. The structural designer will provide input to the MEP designers who will lead this effort and will work with the construction manager on constructability of any changes structurally to the building envelope.

BIM and Interdisciplinary Approach

Due to the architectural and energy efficiency focus of this redesign the MEP designers will lead this process with the structural designer and the construction manager in a supporting role. The façade redesign will start with a comprehensive load calculation involving all disciplines; concurrently specific design criteria for the interior spaces affected will be defined. The mechanical designer will work with the lighting designer to create a comfortable and pleasant space, taking into consideration space temperature, humidity, lighting and daylighting schemes.

The structural designer will be advising the MEP designers on curtain wall loading. The construction manager will be performing clash detection using software as well as advising on cost, scheduling and constructability. The exterior architecture aesthetic will be tweaked as needed throughout the design process to reflect the engineering changes and decisions of the team.

Revit Autodesk software packages (Architecture, Structure, MEP) will be used for all 3D coordination and design authoring. The construction manager will use Navisworks for 4D coordination and clash detection. The mechanical designer will be using Trane Trace and DesignBuilder for load calculation. The lighting/electrical designer will be using AGI32 for lighting calculations, Autodesk 3DS Studio Max and Daysim for daylighting calculation. The structural designer will be completing calculations by hand as well as using SAP2000. Further information on BIM goals and uses can be found in Appendix D. Deliverables can be found in Appendix A.

Façade Redesign Conclusions

The façade redesign is a balance between architecture, cost and energy use. To find the compromise between these three factors the mechanical designer will create an energy model to track the effects of the changes in the façade. The lighting designer will be performing daylighting analysis and proposing changes to enhance natural light in the lobby and concourse. The construction manager will be preforming cost comparisons between different façade designs. The structural designer will investigate and complete glazing studies for structural considerations. The energy model as well as the cost analysis will be used to compare different designs to optimize a façade redesign that balances energy, cost, and architecture.

In conclusion of our first semester's work, HPR Integrated Design believes the design should emphasize the importance of the main entrance and magnify its presence on University Drive. Design considerations will heavily focus on whether or not the redesign reduces the load and cost for the building while maintaining important site specific elements like the view of Mt. Nittany. This redesign will be a success if HPR's design enhances the architectural appeal of the arena from University Drive, creates inviting entrances, reduces thermal load, and optimizes daylighting. It will be HPR's challenge to find the balance between these separate driving forces, but by keeping each in mind HPR can create an architectural pleasing design that is energy conscious.

[APPENDIX A: DELIVERABLES, SOFTWARE & CODES]

Table 2: HPR Integrated Design Team Deliverables

Design Alternative	Tasks	Program(s) To Be Utilized	Applicable Codes
Event Level Raising	Architectural Planning	Revit A/S/MEP, Hand Sketches	IBC 2009, ADAAG
	3D Modeling	Revit Architecture, AutoCAD	
	Code Compliance Investigation	Revit Architecture	IBC 2009, ADAAG
	Civil Site Investigation	Revit Architecture, Google SketchUp	
	Engineering Economics		
Roof Systems Integration	3D Modeling	Revit Architecture	
	Code Compliance Investigation	Revit Architecture	IBC 2009, Zoning, Local Codes
	Engineering Economics		
Façade Redesign	3D Modeling	Revit Architecture	
	Engineering Economics		
	Architectural Planning	Revit A/S/MEP, Hand Sketches	IBC 2009, ADAAG

Table 3: Construction Deliverables

Design Alternative	Tasks	Program(s) To Be Utilized
Event Level Raising	Baseline Estimate & Update	RSMeans, MS2 Ice, Excel, Hand Calcs
	Baseline Schedule & Update	RSMeans, MS2 Ice, Primavera 6, Hand Calcs
	3D Coordination & Clash Detection	Revit, Navisworks
	4D Modeling	Navisworks
Main Arena Roof System Design	Estimate Update	RSMeans, MS2 Ice, Excel, Hand Calcs
	Schedule Update	RSMeans, MS2 Ice, Primavera 6, Hand Calcs
	3D Coordination & Clash Detection	Revit, Navisworks
	4D Modeling	Navisworks
	Crane Analysis	RSMeans, MS2 Ice, Excel, Hand Calcs
	Site Logistics	Navisworks
Façade Redesign	Estimate Update	RSMeans, MS2 Ice, Excel, Hand Calcs
	Schedule Update	RSMeans, MS2 Ice, Primavera 6, Hand Calcs
	3D Coordination & Clash	Revit, Navisworks
	4D Modeling	Navisworks
Team	3D Coordination & Clash Detection	Revit, Navisworks
	4D Modeling	Navisworks

Table 4: Mechanical Deliverables

Design Alternative	Tasks	Program(s) To Be Utilized	Applicable Codes or Guidelines
Event Level Raising	System Analysis	Microsoft Excel	ASHRAE 62.1, ASHRAE 90.1
	Load Analysis	Trane Trace	ASHRAE 62.1
	Duct Layout and Sizing	Revit MEP	ASHRAE 62.1
	Clash Detection	Navis Works	
	Design Development	Revit MEP	
Roof Systems Integration	Machanical System Analysis	Microsoft Excel	ASHRAE 62.1, ASHRAE 90.1
	Duct Layout and Sizing	Revit MEP	ASHRAE 62.1
	Clash Detection	Navis Works	
	Design Development	Revit MEP	
Façade Redesign	Load Analysis	Trane Trace	ASHRAE 62.1, ASHRAE 90.1
	Glazing/Alternitve Material Investigation		ASHRAE 62.1, ASHRAE 90.1
	Schematic Design of Lobby and Concourse	Revit MEP	ASHRAE 62.1
	Energy Model	Trane Trace/Energy Plus	ASHRAE 62.1, ASHRAE 90.1
	Design Development	Revit MEP	
Team	BIM Modeling	Revit MEP	BIM Execution Plan
	Project Authoring	Revit MEP, Trane Trace, Microsoft Word	BIM Execution Plan

Table 5: Lighting/Electrical Deliverables

Design Alternative	Tasks	Program(s) To Be Utilized	Applicable Codes or Guidelines
Event Level Raising	System Analysis	Microsoft Excel	NEC 2011, ASHRAE 90.1
	Distribuition System Design	Revit MEP	NEC 2011, ASHRAE 90.1
	Schematic Lighting Design Planning	Adobe Photoshop, Revit MEP	NEC 2011, ASHRAE 90.1, USGBC LEED IESNA Lighting Handbook 10th ed.
	Daylighting Schematic Design	3DS Max Design, Revit MEP	USGBC LEED, IESNA Lighting Handbook 10th ed.
	Design Development	Revit MEP, AGI32, Daysim	
Roof Systems Integration	Electrical System Analysis	Microsoft Excel	NEC 2011, ASHRAE 90.1
	Distribuition System Design	Revit MEP	NEC 2011, ASHRAE 90.1
	Schematic Lighting Design Planning	Adobe Photoshop, Revit MEP	NEC 2011, ASHRAE 90.1, USGBC LEED,
	Design Development	Revit MEP, AGI32, Daysim	
Façade Redesign	Electrical System Analysis	Microsoft Excel	NEC 2011, ASHRAE 90.1
	Distribuition System Design	Revit MEP	NEC 2011, ASHRAE 90.1
	Schematic Lighting Design Planning	Adobe Photoshop, Revit MEP	NEC 2011, ASHRAE 90.1, USGBC LEED, IESNA Lighting Handbook 10th ed.
	Daylighting Schematic Design	3DS Max Design, Revit MEP	USGBC LEED, IESNA Lighting Handbook
	Daylight Calculation	AGI32, Daysim	USGBC LEED, IESNA Lighting Handbook
	Design Development	Revit MEP, AGI32, Daysim	
Team	BIM Modeling	Revit MEP	BIM Execution Plan
	Project Authoring	Revit MEP, AGI32, Microsoft Word	BIM Execution Plan

Table 6: Structural Deliverables

Design Alternative	Tasks	Program(s) To Be Utilized	Applicable Codes
Event Level Raising	Two Way Flat Slab without PT	SAP 2000, Hand Calcs	ACI318-08
	Two Way Flat Slab with PT	SAP 2000, Hand Calcs	ACI318-08
	Design Concrete Gravity Columns	spColumn, Hand Calcs	ACI318-08
	Explore alternative foundation design if feasible	SAP2000, RAM, Hand Calcs	ACI318-08
	Design misc. steel framing for additional seating in lower bowl	SAP2000, Hand Calcs	ACI318-08, AISC Steel Manual - 13th ed.
Roof Systems Integration	Design long span trusses	SAP 2000, STAAD	AISC Steel Manual - 13th ed.
	Design additional miscellaneous steel members for new roof geometry	SAP 2000, Hand Calcs	AISC Steel Manual - 13th ed.
	Evaluate lateral system with redesigned long span trusses	SAP 2000, RAM	ASCE7-05
Façade Redesign	Check exterior columns for strength requirements due to façade changes	SAP 2000, Hand Calcs	AISC Steel Manual - 13th ed.
	Design additional miscellaneous steel members	SAP 2000, Hand Calcs	ACI318-08, AISC Steel Manual - 13th ed.
	Analyze/Design exterior glazing and panels	Hand Calcs	
Team	Design Authoring	Revit Structure, AutoCAD, SAP2000	BIM Ex Plan
	Interdisciplinary Coordination	Revit Structure, Navisworks Manage	BIM Ex Plan

[APPENDIX B: Measures for Success]

Event Level Relocation

- Coordination amongst all of the disciplines throughout project design.
- Reduction in flooring system to allow for maximum plenum space while balancing optimum relocation of the entire event level.
- Reduction in cost for the redesign flooring system versus the existing flooring system.
- Reduce the cost of materials and resources needed for excavation.
- Reduce schedule by reducing amount of bedrock needing to be excavated.
- Optimize duct size balancing energy, cost, and space.
- Reduce the lighting power density of the level below ASHRAE Standard 90.1 Section 9.
- Reduce the cost of the electrical distribution system by optimizing the routing of conduit & wiring through the building.
- Ensure systems designed are achieving points necessary on LEED score card for Gold Certification.
- Maintain seating capacity of the arena within 5% of original design.

Main Arena Roof System Design

- Coordination amongst all of the disciplines throughout project design.
- Design a roof system consistent with the Bryce Jordan Center.
- Design a roof system that is consistent with façade redesign.
- Roof systems design is competitive in cost/sq. ft. cost analysis
- Roof system design increases or maintains constructability.
- Reduce cost with optimization of long span truss member size.
- Structural design maintains performance of lateral system with new truss system.
- Structural design allows for efficient lighting and mechanical designs while fully integrated.
- Determine proper crane size and amount of cranes needed to install roof system.
- Create a site logistics plan that allows smooth flow of operations.
- Create a controllable system that can be turned down when arena is not occupied which leads to a reduction of energy use.
- Reduce the lighting power density of the space below ASHRAE Standard 90.1 Section 9.
- Meet or exceed the lighting design guidelines laid out by the NCAA.
- Create an electrical distribution system that is versatile and provides the space with functional & logical points of connection.
- Ensure systems designed are achieving points necessary on LEED score card for Gold Certification.

Façade Redesign

- Coordination amongst all of the disciplines throughout project design.
- Along with the main arena roof system design, create an iconic façade design.
- Reduction or maintain the exterior column sizes while accommodating new façade materials with appropriate connections.
- Reduce thermal load to spaces along the east façade.
- Create more efficient air distribution in the lobby and concourse.
- Reduce project cost and energy cost by selecting optimum glazing panels for architectural and energy performance.
- Reduce resources needed for installation by changing the system of the façade from glass curtain wall to brick and glazing.
- Improve schedule for installation of new design.
- Reduce the lighting power density of the spaces below ASHRAE Standard 90.1 Section 9.
- Create an iconic building facade that balances architecture and engineering.
- Ensure systems designed are achieving points necessary on LEED score card for Gold Certification.

[APPENDIX C: Proposed Schedule and Timetable]

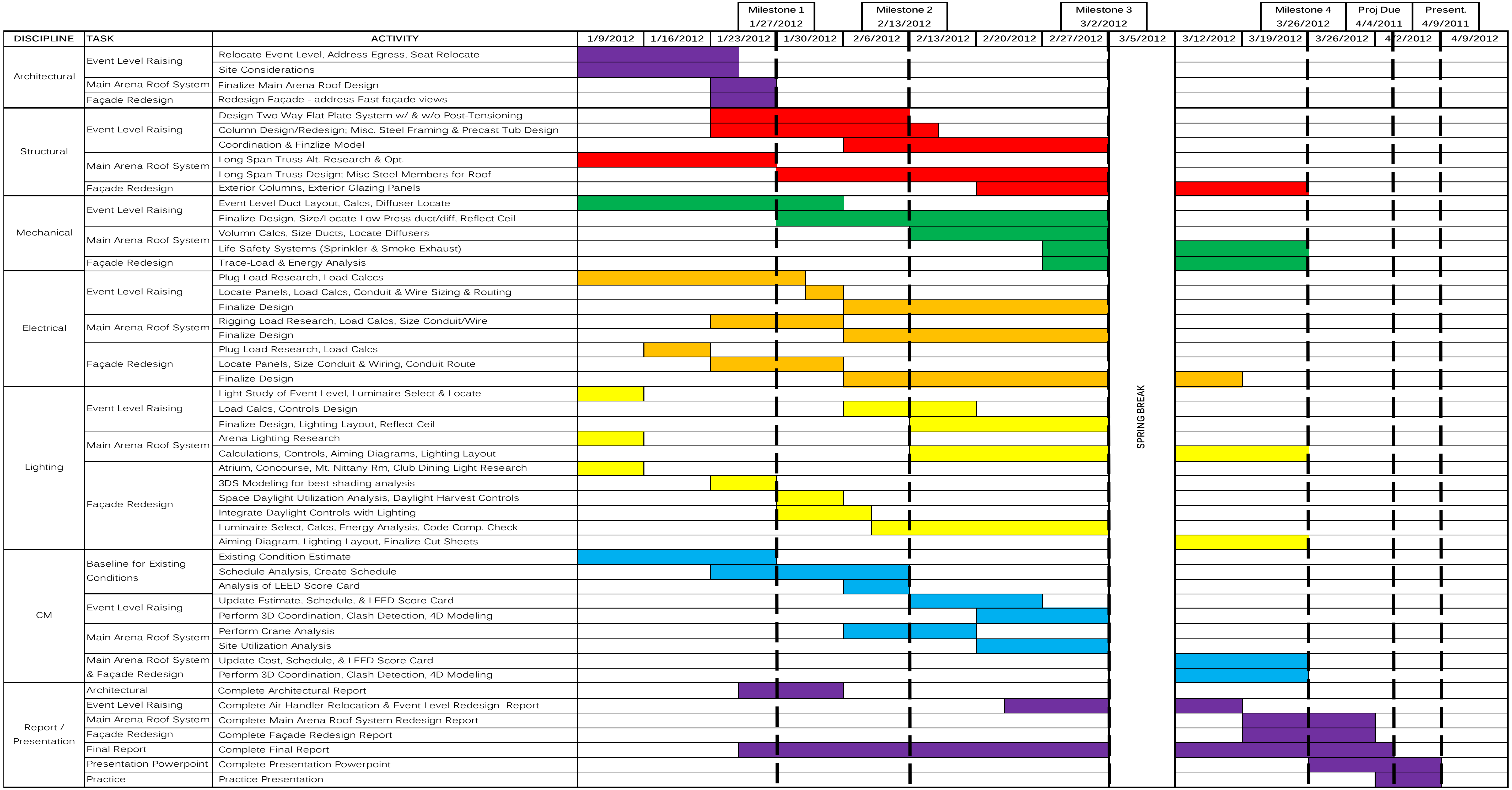
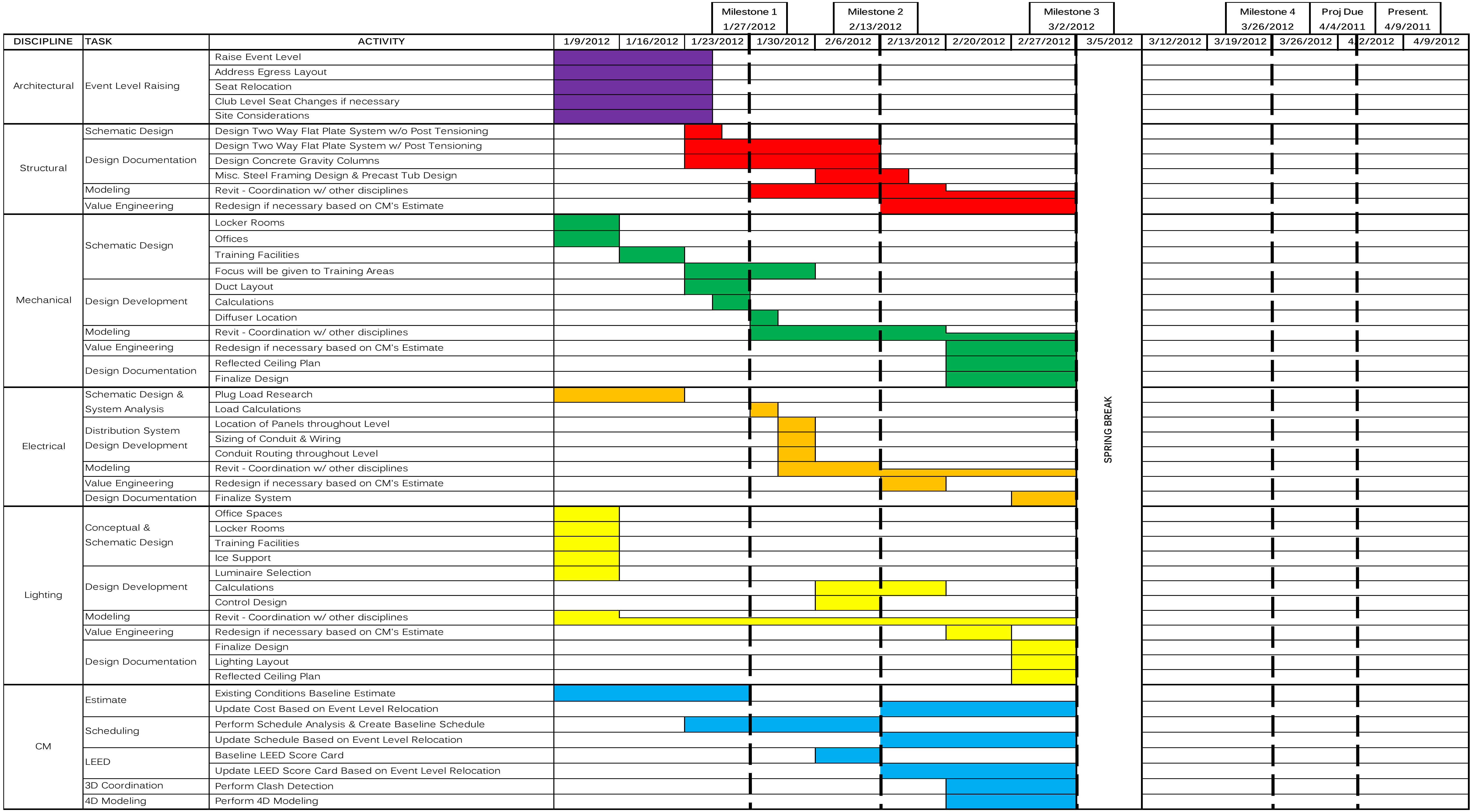


Figure 25: Proposed Schedule

Milestone 1 1/27/2012
Milestone 2 2/13/2012
Milestone 3 3/2/2012
Milestone 4 3/26/2012
Proj Due 4/4/2011
Present. 4/9/2011

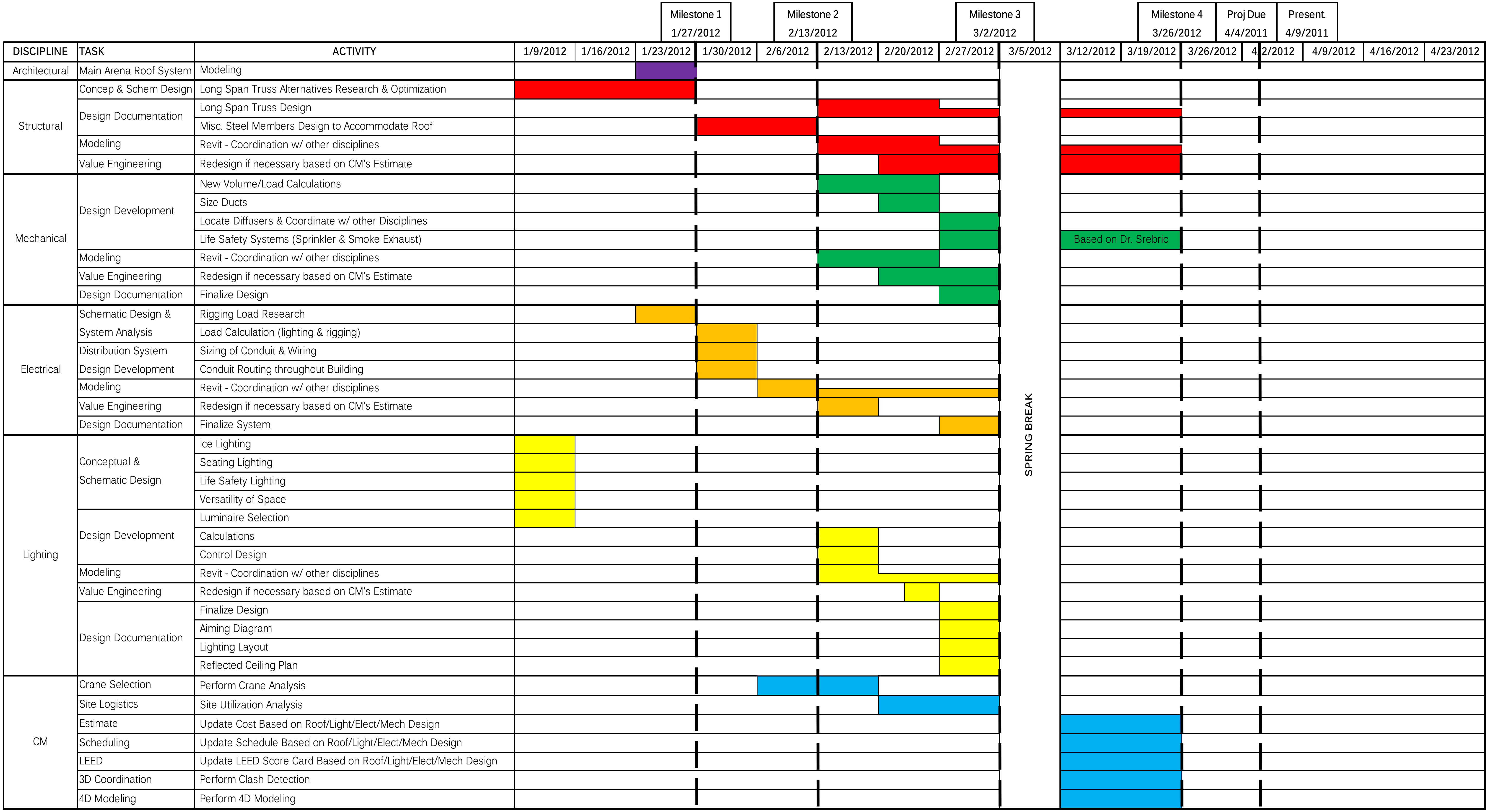
DISCIPLINE	TASK	ACTIVITY	1/9/2012	1/16/2012	1/23/2012	1/30/2012	2/6/2012	2/13/2012	2/20/2012	2/27/2012	3/5/2012	3/12/2012	3/19/2012	3/26/2012	4/2/2012	4/9/2012
Architectural	Event Level Raising	Relocate Event Level, Address Egress, Seat Relocate	🟪	🟪	🟪											
		Site Considerations	🟪	🟪	🟪											
	Main Arena Roof System	Finalize Main Arena Roof Design			🟪											
	Façade Redesign	Redesign Façade - address East façade views			🟪											
Structural	Event Level Raising	Design Two Way Flat Plate System w/ & w/o Post-Tensioning			🟥	🟥	🟥									
		Column Design/Redesign; Misc. Steel Framing & Precast Tub Design			🟥	🟥	🟥	🟥								
		Coordination & Finzlize Model					🟥	🟥	🟥	🟥						
	Main Arena Roof System	Long Span Truss Alt. Research & Opt.	🟥	🟥	🟥											
		Long Span Truss Design; Misc Steel Members for Roof				🟥	🟥	🟥	🟥	🟥						
	Façade Redesign	Exterior Columns, Exterior Glazing Panels							🟥	🟥		🟥	🟥			
Mechanical	Event Level Raising	Event Level Duct Layout, Calcs, Diffuser Locate	🟩	🟩	🟩	🟩										
		Finalize Design, Size/Locate Low Press duct/diff, Reflect Ceil				🟩	🟩	🟩	🟩	🟩						
	Main Arena Roof System	Volumn Calcs, Size Ducts, Locate Diffusers						🟩	🟩	🟩						
		Life Safety Systems (Sprinkler & Smoke Exhaust)								🟩		🟩	🟩			
	Façade Redesign	Trace-Load & Energy Analysis								🟩		🟩	🟩			
Electrical	Event Level Raising	Plug Load Research, Load Calcs	🟧	🟧	🟧	🟧										
		Locate Panels, Load Calcs, Conduit & Wire Sizing & Routing				🟧										
		Finalize Design					🟧	🟧	🟧	🟧						
	Main Arena Roof System	Rigging Load Research, Load Calcs, Size Conduit/Wire			🟧	🟧										
		Finalize Design					🟧	🟧	🟧	🟧						
	Façade Redesign	Plug Load Research, Load Calcs		🟧												
		Locate Panels, Size Conduit & Wiring, Conduit Route			🟧	🟧										
		Finalize Design					🟧	🟧	🟧	🟧		🟧				
Lighting	Event Level Raising	Light Study of Event Level, Luminaire Select & Locate	🟨													
		Load Calcs, Controls Design					🟨	🟨			SPRING BREAK					
		Finalize Design, Lighting Layout, Reflect Ceil						🟨	🟨	🟨						
	Main Arena Roof System	Arena Lighting Research	🟨													
		Calculations, Controls, Aiming Diagrams, Lighting Layout						🟨	🟨	🟨		🟨	🟨			
	Façade Redesign	Atrium, Concourse, Mt. Nittany Rm, Club Dining Light Research	🟨													
		3DS Modeling for best shading analysis			🟨											
		Space Daylight Utilization Analysis, Daylight Harvest Controls				🟨										
		Integrate Daylight Controls with Lighting				🟨	🟨									
		Luminaire Select, Calcs, Energy Analysis, Code Comp. Check					🟨	🟨	🟨	🟨						
		Aiming Diagram, Lighting Layout, Finalize Cut Sheets										🟨	🟨			
CM	Baseline for Existing Conditions	Existing Condition Estimate	🟦	🟦	🟦											
		Schedule Analysis, Create Schedule			🟦	🟦	🟦									
		Analysis of LEED Score Card					🟦									
	Event Level Raising	Update Estimate, Schedule, & LEED Score Card						🟦	🟦							
		Perform 3D Coordination, Clash Detection, 4D Modeling							🟦	🟦						
	Main Arena Roof System	Perform Crane Analysis					🟦	🟦								
		Site Utilization Analysis							🟦	🟦						
	Main Arena Roof System & Façade Redesign	Update Cost, Schedule, & LEED Score Card										🟦	🟦			
		Perform 3D Coordination, Clash Detection, 4D Modeling										🟦	🟦			
Report / Presentation	Architectural	Complete Architectural Report			🟪	🟪										
	Event Level Raising	Complete Air Handler Relocation & Event Level Redesign Report							🟪	🟪		🟪				
	Main Arena Roof System	Complete Main Arena Roof System Redesign Report											🟪	🟪		
	Façade Redesign	Complete Façade Redesign Report											🟪	🟪		
	Final Report	Complete Final Report			🟪	🟪	🟪	🟪	🟪	🟪		🟪	🟪	🟪	🟪	
	Presentation Powerpoint	Complete Presentation Powerpoint												🟪	🟪	
	Practice	Practice Presentation													🟪	

Figure 26: Detailed Schedule – Event Level Raising



DISCIPLINE	TASK	ACTIVITY
Architectural	Event Level Raising	Raise Event Level
		Address Egress Layout
		Seat Relocation
		Club Level Seat Changes if necessary
		Site Considerations
Structural	Schematic Design	Design Two Way Flat Plate System w/o Post Tensioning
	Design Documentation	Design Two Way Flat Plate System w/ Post Tensioning
		Design Concrete Gravity Columns
		Misc. Steel Framing Design & Precast Tub Design
	Modeling	Revit - Coordination w/ other disciplines
	Value Engineering	Redesign if necessary based on CM's Estimate
Mechanical	Schematic Design	Locker Rooms
		Offices
		Training Facilities
		Focus will be given to Training Areas
	Design Development	Duct Layout
		Calculations
		Diffuser Location
	Modeling	Revit - Coordination w/ other disciplines
	Value Engineering	Redesign if necessary based on CM's Estimate
	Design Documentation	Reflected Ceiling Plan
		Finalize Design
Electrical	Schematic Design & System Analysis	Plug Load Research
		Load Calculations
	Distribution System Design Development	Location of Panels throughout Level
		Sizing of Conduit & Wiring
		Conduit Routing throughout Level
	Modeling	Revit - Coordination w/ other disciplines
	Value Engineering	Redesign if necessary based on CM's Estimate
	Design Documentation	Finalize System
Lighting	Conceptual & Schematic Design	Office Spaces
		Locker Rooms
		Training Facilities
		Ice Support
	Design Development	Luminaire Selection
		Calculations
		Control Design
	Modeling	Revit - Coordination w/ other disciplines
	Value Engineering	Redesign if necessary based on CM's Estimate
	Design Documentation	Finalize Design
		Lighting Layout
		Reflected Ceiling Plan
CM	Estimate	Existing Conditions Baseline Estimate
		Update Cost Based on Event Level Relocation
	Scheduling	Perform Schedule Analysis & Create Baseline Schedule
		Update Schedule Based on Event Level Relocation
	LEED	Baseline LEED Score Card
		Update LEED Score Card Based on Event Level Relocation
	3D Coordination	Perform Clash Detection
	4D Modeling	Perform 4D Modeling

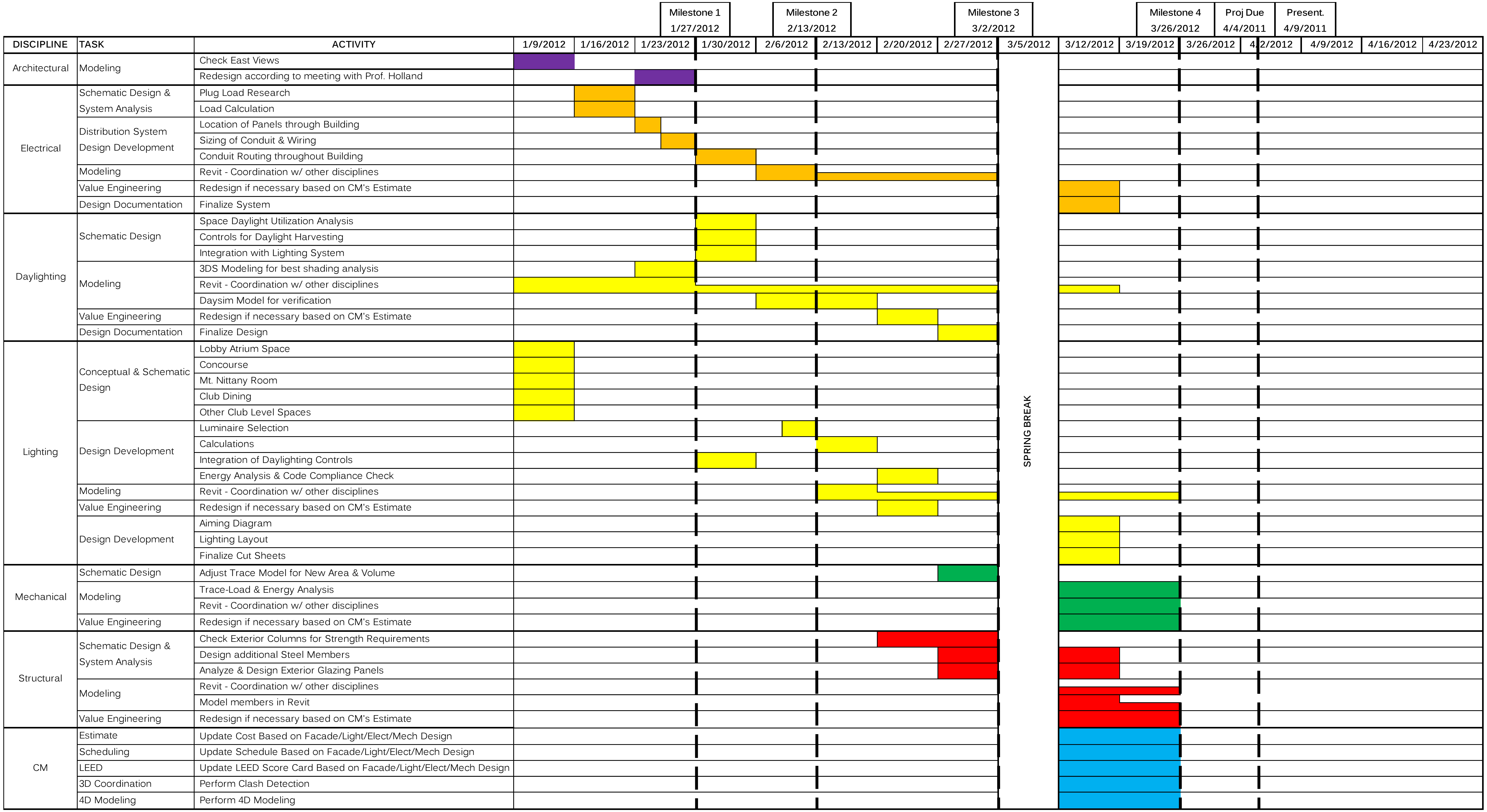
Figure 27: Detailed Schedule – Main Arena Roof System Design



Milestone 1 1/27/2012
Milestone 2 2/13/2012
Milestone 3 3/2/2012
Milestone 4 3/26/2012
Proj Due 4/4/2011
Present. 4/9/2011

DISCIPLINE	TASK	ACTIVITY	1/9/2012	1/16/2012	1/23/2012	1/30/2012	2/6/2012	2/13/2012	2/20/2012	2/27/2012	3/5/2012	3/12/2012	3/19/2012	3/26/2012	4/2/2012	4/9/2012	4/16/2012	4/23/2012
Architectural	Main Arena Roof System	Modeling			🟪						SPRING BREAK							
Structural	Concep & Schem Design	Long Span Truss Alternatives Research & Optimization	🟥	🟥	🟥													
	Design Documentation	Long Span Truss Design						🟥	🟥	🟥		🟥	🟥					
		Misc. Steel Members Design to Accommodate Roof				🟥	🟥											
	Modeling	Revit - Coordination w/ other disciplines						🟥	🟥	🟥		🟥	🟥					
	Value Engineering	Redesign if necessary based on CM's Estimate							🟥	🟥		🟥	🟥					
Mechanical	Design Development	New Volume/Load Calculations						🟩	🟩									
		Size Ducts							🟩									
		Locate Diffusers & Coordinate w/ other Disciplines								🟩								
		Life Safety Systems (Sprinkler & Smoke Exhaust)								🟩		🟩 Based on Dr. Srebric	🟩					
	Modeling	Revit - Coordination w/ other disciplines						🟩	🟩									
	Value Engineering	Redesign if necessary based on CM's Estimate							🟩	🟩								
	Design Documentation	Finalize Design								🟩								
Electrical	Schematic Design & System Analysis	Rigging Load Research			🟧													
		Load Calculation (lighting & rigging)				🟧												
	Distribution System Design Development	Sizing of Conduit & Wiring				🟧												
		Conduit Routing throughout Building				🟧												
	Modeling	Revit - Coordination w/ other disciplines					🟧	🟧	🟧	🟧								
	Value Engineering	Redesign if necessary based on CM's Estimate						🟧										
	Design Documentation	Finalize System								🟧								
Lighting	Conceptual & Schematic Design	Ice Lighting	🟨															
		Seating Lighting	🟨															
		Life Safety Lighting	🟨															
		Versatility of Space	🟨															
	Design Development	Luminaire Selection	🟨															
		Calculations						🟨										
		Control Design						🟨										
	Modeling	Revit - Coordination w/ other disciplines						🟨	🟨	🟨								
	Value Engineering	Redesign if necessary based on CM's Estimate							🟨									
	Design Documentation	Finalize Design								🟨								
		Aiming Diagram								🟨								
		Lighting Layout								🟨								
		Reflected Ceiling Plan								🟨								
CM	Crane Selection	Perform Crane Analysis					🟦	🟦										
	Site Logistics	Site Utilization Analysis							🟦	🟦								
	Estimate	Update Cost Based on Roof/Light/Elect/Mech Design										🟦	🟦					
	Scheduling	Update Schedule Based on Roof/Light/Elect/Mech Design										🟦	🟦					
	LEED	Update LEED Score Card Based on Roof/Light/Elect/Mech Design										🟦	🟦					
	3D Coordination	Perform Clash Detection										🟦	🟦					
	4D Modeling	Perform 4D Modeling										🟦	🟦					

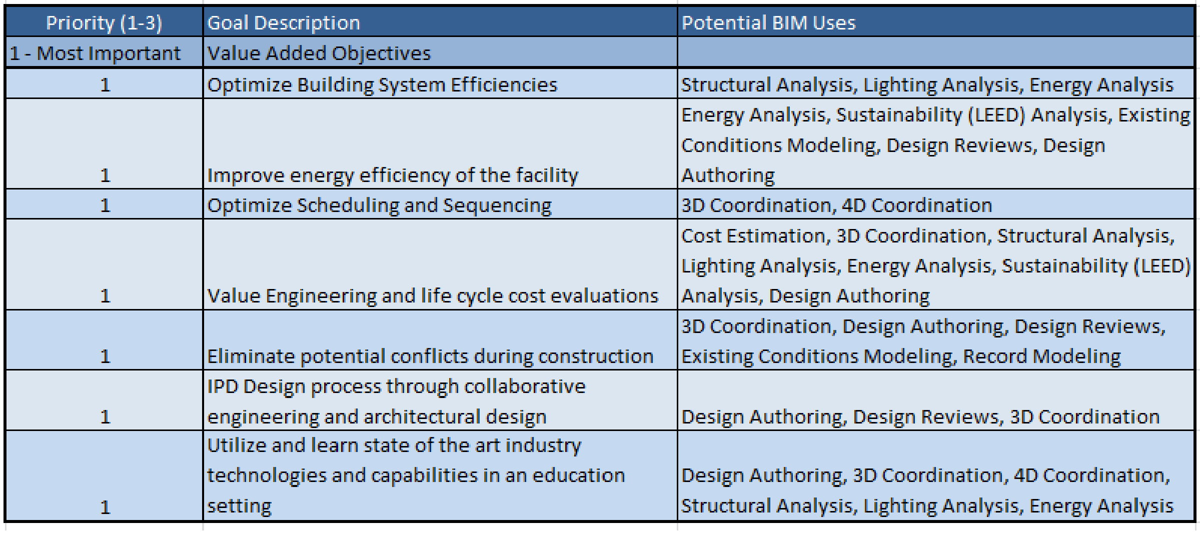
Figure 28: Detailed Schedule – Façade Redesign



					Milestone 1 1/27/2012		Milestone 2 2/13/2012		Milestone 3 3/2/2012			Milestone 4 3/26/2012	Proj Due 4/4/2011	Present. 4/9/2011		
DISCIPLINE	TASK	ACTIVITY	1/9/2012	1/16/2012	1/23/2012	1/30/2012	2/6/2012	2/13/2012	2/20/2012	2/27/2012	3/5/2012	3/12/2012	3/19/2012	3/26/2012	4/2/2012	4/9/2012	4/16/2012	4/23/2012
Architectural	Modeling	Check East Views	🟪								SPRING BREAK							
		Redesign according to meeting with Prof. Holland			🟪													
Electrical	Schematic Design & System Analysis	Plug Load Research		🟧														
		Load Calculation		🟧														
	Distribution System Design Development	Location of Panels through Building			🟧													
		Sizing of Conduit & Wiring			🟧													
		Conduit Routing throughout Building				🟧												
	Modeling	Revit - Coordination w/ other disciplines					🟧	🟧	🟧	🟧								
	Value Engineering	Redesign if necessary based on CM's Estimate										🟧						
	Design Documentation	Finalize System										🟧						
Daylighting	Schematic Design	Space Daylight Utilization Analysis				🟨												
		Controls for Daylight Harvesting				🟨												
		Integration with Lighting System				🟨												
	Modeling	3DS Modeling for best shading analysis			🟨													
		Revit - Coordination w/ other disciplines	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨		🟨						
		Daysim Model for verification					🟨	🟨										
	Value Engineering	Redesign if necessary based on CM's Estimate							🟨									
	Design Documentation	Finalize Design								🟨								
Lighting	Conceptual & Schematic Design	Lobby Atrium Space	🟨															
		Concourse	🟨															
		Mt. Nittany Room	🟨															
		Club Dining	🟨															
		Other Club Level Spaces	🟨															
	Design Development	Luminaire Selection					🟨											
		Calculations						🟨										
		Integration of Daylighting Controls				🟨												
		Energy Analysis & Code Compliance Check							🟨									
	Modeling	Revit - Coordination w/ other disciplines						🟨	🟨	🟨		🟨	🟨					
	Value Engineering	Redesign if necessary based on CM's Estimate							🟨									
	Design Development	Aiming Diagram										🟨						
		Lighting Layout										🟨						
		Finalize Cut Sheets										🟨						
Mechanical	Schematic Design	Adjust Trace Model for New Area & Volume								🟩								
	Modeling	Trace-Load & Energy Analysis										🟩	🟩					
		Revit - Coordination w/ other disciplines										🟩	🟩					
	Value Engineering	Redesign if necessary based on CM's Estimate										🟩	🟩					
Structural	Schematic Design & System Analysis	Check Exterior Columns for Strength Requirements							🟥	🟥								
		Design additional Steel Members								🟥		🟥						
		Analyze & Design Exterior Glazing Panels								🟥		🟥						
	Modeling	Revit - Coordination w/ other disciplines										🟥	🟥					
		Model members in Revit										🟥						
	Value Engineering	Redesign if necessary based on CM's Estimate										🟥	🟥					
CM	Estimate	Update Cost Based on Facade/Light/Elect/Mech Design										🟦	🟦					
	Scheduling	Update Schedule Based on Facade/Light/Elect/Mech Design										🟦	🟦					
	LEED	Update LEED Score Card Based on Facade/Light/Elect/Mech Design										🟦	🟦					
	3D Coordination	Perform Clash Detection										🟦	🟦					
	4D Modeling	Perform 4D Modeling										🟦	🟦					

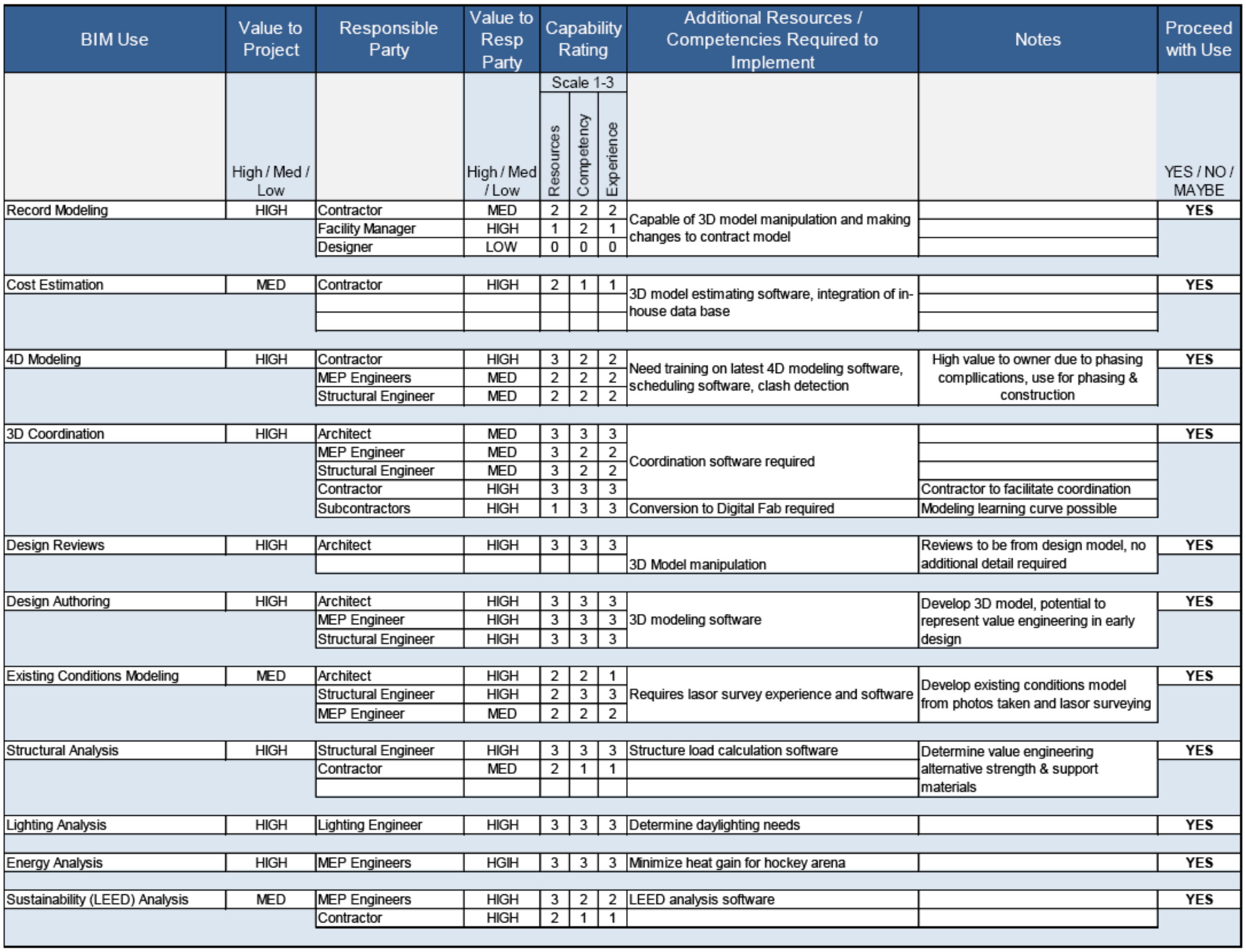
[APPENDIX D: BIM Execution Planning]

Table 7: BIM Goals



Priority (1-3)	Goal Description	Potential BIM Uses
1 - Most Important	Value Added Objectives	
1	Optimize Building System Efficiencies	Structural Analysis, Lighting Analysis, Energy Analysis
1	Improve energy efficiency of the facility	Energy Analysis, Sustainability (LEED) Analysis, Existing Conditions Modeling, Design Reviews, Design Authoring
1	Optimize Scheduling and Sequencing	3D Coordination, 4D Coordination
1	Value Engineering and life cycle cost evaluations	Cost Estimation, 3D Coordination, Structural Analysis, Lighting Analysis, Energy Analysis, Sustainability (LEED) Analysis, Design Authoring
1	Eliminate potential conflicts during construction	3D Coordination, Design Authoring, Design Reviews, Existing Conditions Modeling, Record Modeling
1	IPD Design process through collaborative engineering and architectural design	Design Authoring, Design Reviews, 3D Coordination
1	Utilize and learn state of the art industry technologies and capabilities in an education setting	Design Authoring, 3D Coordination, 4D Coordination, Structural Analysis, Lighting Analysis, Energy Analysis

Table 8: BIM Uses Worksheet



BIM Use	Value to Project	Responsible Party	Value to Resp Party	Capability Rating			Additional Resources / Competencies Required to Implement	Notes	Proceed with Use
				Scale 1-3					
	High / Med / Low		High / Med / Low	Resources	Competency	Experience			YES / NO / MAYBE
Record Modeling	HIGH	Contractor	MED	2	2	2	Capable of 3D model manipulation and making changes to contract model		YES
		Facility Manager	HIGH	1	2	1			
		Designer	LOW	0	0	0			
Cost Estimation	MED	Contractor	HIGH	2	1	1	3D model estimating software, integration of in-house data base		YES
4D Modeling	HIGH	Contractor	HIGH	3	2	2	Need training on latest 4D modeling software, scheduling software, clash detection	High value to owner due to phasing compllications, use for phasing & construction	YES
		MEP Engineers	MED	2	2	2			
		Structural Engineer	MED	2	2	2			
3D Coordination	HIGH	Architect	MED	3	3	3	Coordination software required		YES
		MEP Engineer	MED	3	2	2			
		Structural Engineer	MED	3	2	2			
		Contractor	HIGH	3	3	3		Contractor to facilitate coordination	
		Subcontractors	HIGH	1	3	3	Conversion to Digital Fab required	Modeling learning curve possible	
Design Reviews	HIGH	Architect	HIGH	3	3	3	3D Model manipulation	Reviews to be from design model, no additional detail required	YES
Design Authoring	HIGH	Architect	HIGH	3	3	3	3D modeling software	Develop 3D model, potential to represent value engineering in early design	YES
		MEP Engineer	HIGH	3	3	3			
		Structural Engineer	HIGH	3	3	3			
Existing Conditions Modeling	MED	Architect	HIGH	2	2	1	Requires lasor survey experience and software	Develop existing conditions model from photos taken and lasor surveying	YES
		Structural Engineer	HIGH	2	3	3			
		MEP Engineer	MED	2	2	2			
Structural Analysis	HIGH	Structural Engineer	HIGH	3	3	3	Structure load calculation software	Determine value engineering alternative strength & support materials	YES
		Contractor	MED	2	1	1			
Lighting Analysis	HIGH	Lighting Engineer	HIGH	3	3	3	Determine daylighting needs		YES
Energy Analysis	HIGH	MEP Engineers	HGIH	3	3	3	Minimize heat gain for hockey arena		YES
Sustainability (LEED) Analysis	MED	MEP Engineers	HIGH	3	2	2	LEED analysis software		YES
		Contractor	HIGH	2	1	1			

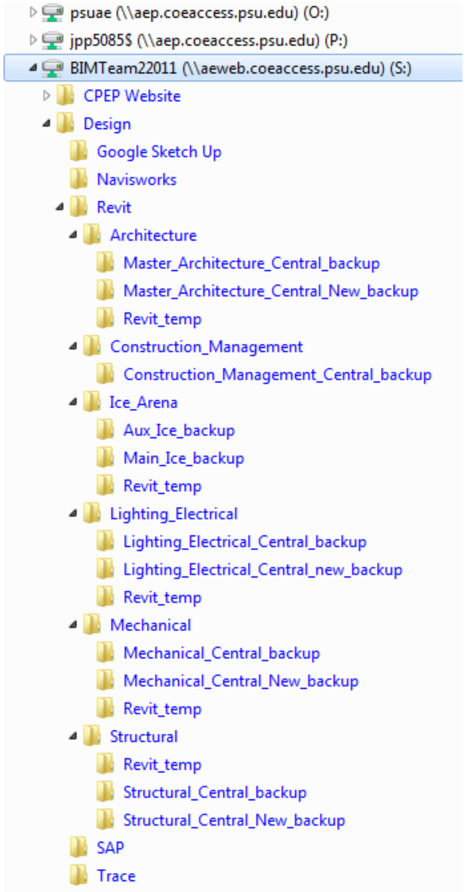
[APPENDIX E: BIM File Management]

Table 9: File Naming Structure

FILE NAMES FOR MODELS SHOULD BE FORMATTED AS: DISCIPLINE-PHASE-DATE.XYZ	
ARCHITECTURAL MODEL	ARCH-SCHEMATIC-DATE.RVT
MECHANICAL/PLUMBING MODEL	MECH-SCHEMATIC-DATE.RVT
LIGHTING MODEL	ELEC-SCHEMATIC-DATE.RVT
ELECTRICAL MODEL	LTG-SCHEMATIC-DATE.RVT
STRUCTURAL MODEL	STRUCT-SCHEMATIC-DATE.RVT
ENERGY MODEL	ENERGY-SCHEMATIC-DATE.RVT
CONSTRUCTION MODEL	CONST-SCHEMATIC-DATE.RVT
COORDINATION MODEL	COORD-SCHEMATIC-DATE.RVT

Table 10: BIM Model Storage Location

HPR Integrated Design will be storing all files, both current and back up models, on the S: drive through the Penn State network. The model is broken up by discipline and broken down as shown in the table below:

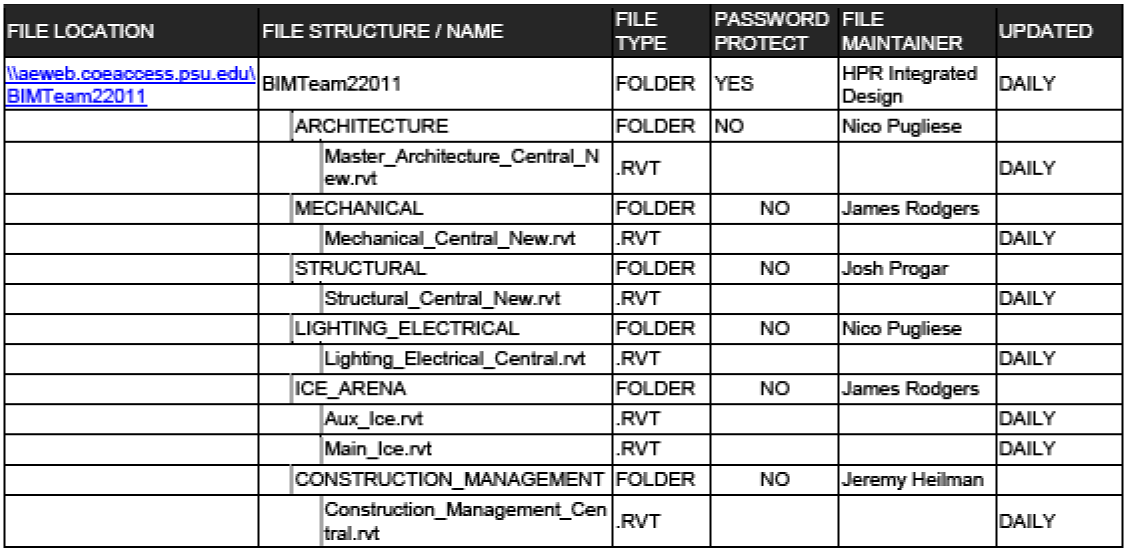


- psuae (\\aep.coeaccess.psu.edu) (O:)
- jpp5085$ (\\aep.coeaccess.psu.edu) (P:)
- BIMTeam22011 (\\aeweb.coeaccess.psu.edu) (S:)
  - CPEP Website
  - Design
    - Google Sketch Up
    - Navisworks
    - Revit
      - Architecture
        - Master_Architecture_Central_backup
        - Master_Architecture_Central_New_backup
        - Revit_temp
      - Construction_Management
        - Construction_Management_Central_backup
      - Ice_Arena
        - Aux_Ice_backup
        - Main_Ice_backup
        - Revit_temp
      - Lighting_Electrical
        - Lighting_Electrical_Central_backup
        - Lighting_Electrical_Central_new_backup
        - Revit_temp
      - Mechanical
        - Mechanical_Central_backup
        - Mechanical_Central_New_backup
        - Revit_temp
      - Structural
        - Revit_temp
        - Structural_Central_backup
        - Structural_Central_New_backup
    - SAP
    - Trace

Back up of models will be done on a bi-weekly basis to ensure the security of data.

Table 11: Electronic Communication Procedures – File Sharing

HPR Integrated Design will use the following structure for file sharing throughout the redesign process. Table 11 below represents the level of security and location for file storage procedures that have been adopted by the design team.



FILE LOCATION	FILE STRUCTURE / NAME	FILE TYPE	PASSWORD PROTECT	FILE MAINTAINER	UPDATED
\\aeweb.coeaccess.psu.edu\BIMTeam22011	BIMTeam22011	FOLDER	YES	HPR Integrated Design	DAILY
	ARCHITECTURE	FOLDER	NO	Nico Pugliese	
	Master_Architecture_Central_New.rvt	.RVT			DAILY
	MECHANICAL	FOLDER	NO	James Rodgers	
	Mechanical_Central_New.rvt	.RVT			DAILY
	STRUCTURAL	FOLDER	NO	Josh Progar	
	Structural_Central_New.rvt	.RVT			DAILY
	LIGHTING_ELECTRICAL	FOLDER	NO	Nico Pugliese	
	Lighting_Electrical_Central.rvt	.RVT			DAILY
	ICE_ARENA	FOLDER	NO	James Rodgers	
	Aux_Ice.rvt	.RVT			DAILY
	Main_Ice.rvt	.RVT			DAILY
	CONSTRUCTION_MANAGEMENT	FOLDER	NO	Jeremy Heilman	
	Construction_Management_Central.rvt	.RVT			DAILY

[APPENDIX F: Index of Figures and Tables]

Figures

Tables

[APPENDIX G: MAE Thesis Requirements]

Construction MAE

The construction management MAE requirements will be satisfied through knowledge gained in the following courses:

- AE 597G – Building Information Modeling Execution Planning
- AE 598C – Sustainable Construction Project Management.
- AE 570 – Production Management in Construction

Building Information Modeling (BIM) Execution Planning will help me along with my team to create and implement a BIM Execution Plan for this project. Along with that, I will use Sustainable Construction Project Management to help my team create Green ideas for the Ice Arena while ensuring the team stays within the guidelines of LEED in achieving LEED Gold certification.

I will use the Production Management course to help understand and build a short interval project schedule for the construction of the Ice Arena to ensure it will be constructed on time and within budget.

Mechanical MAE

The mechanical MAE requirements will be satisfied through knowledge gained in AE 559 in the spring of 2012. This class focuses on CFD modeling and as part of my deliverables for the roof integration I will be creating a CFD model that shows the effectiveness of the current buildings smoke exhaust system. I will also be using knowledge gained in AE 557 and AE 558 but knowledge gained in these classes doesn't directly lead to a deliverable like a CFD model.

Structural MAE

The structural MAE requirements will be satisfied through knowledge gained from two of the MAE electives that have been completed at the submission of this proposal. Structural 3D modeling techniques learned in AE597A – Advanced Computer Modeling of Building Structures, will be utilized to model gravity and lateral systems, long span truss designs, and conduct structural floor framing system evaluations, etc. These structural models will employ considerations for connection rigidities, key structural assumptions, boundary conditions, meshing of concrete lateral elements, and diaphragm assignments critical to accurate modeling outputs.

Additionally, information from curriculum taught in AE537 – Building Failures will be utilized to look deeper into performance issues in the façade. Flashing issues and control joint design for masonry facades will be investigated along with considerations for poor design details that lead to problems within the arena. Finally, another MAE elective that will be used for analysis will draw knowledge from is AE 542 – Building Enclosure, Science & Design to evaluate the performance for our redesigned façade. This course will be taken concurrent to the spring 2012 thesis semester and information will be used as it is taught throughout the semester.