BIM Thesis Proposal

December 9th, 2011

PENN STATE ICE HOCKEY ARENA
UNIVERSITY PARK, PA

H·P·R
INTEGRATED DESIGN

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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 reduce the overall project delivery costs, reduce energy usage and cost, create a fast tracked schedule, and develop a facility that is LEED Gold certified.

HPR Integrated Design has chosen to focus on three of four different areas of study during the spring 2012 semester. Of the following first two options, one is an alternate that will be not be an in depth study. At the beginning of the semester it will be determined as to which option will not be used.

- Event Level Relocation – Alternate Design 1
- Air Handler Relocation & Event Level Redesign – Alternate Design 2

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 relocating 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 able to be reduced. If initial research proves that it is not possible to reduce the plenum space, HPR will focus on the second alternative, relocation of the air handler units. This effort will be made in order to maximize the use of the plenum space. Along with both options, redesign of the event level to maximize daylighting and to reduce energy loads will take place.

The following focuses have also been chosen to be studied:

- Main Arena Roof System Design
- Façade Redesign

When HPR received the drawings for the Penn State Ice Arena, the main arena roof system's design had not been completed. HPR's engineers will coordinate and design a roof for the main arena that is iconic and that will support the overhead lighting and duct systems. 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 to maximize daylighting, reduce energy loads, and reduce construction and energy costs.

This proposal will serve as a guide for the AE 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 focused on throughout the semester to implement these design alternatives and be used heavily in coordination among the entire design team.

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[Penn State Ice Arena Overview]

The Penn State Ice Hockey Arena will be home to the new NCAA Hockey Facility for Penn State's 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.

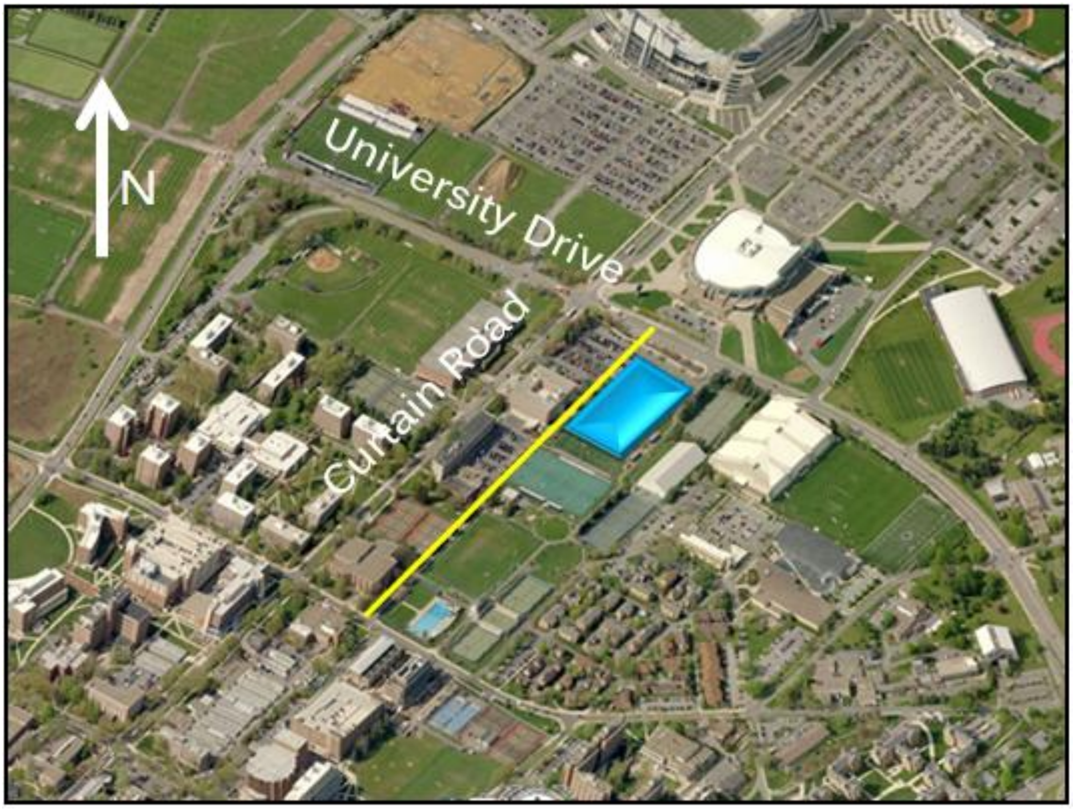


Figure 1: Site and Surroundings

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, $83 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. 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 Facility is utilitarian yet beautiful. It pays homage to the classic "hockey barn" and still has modern influences throughout the interior and exterior. Many features of the building are geared towards enhancing the audiences experiences while at a Penn State hockey game, large vomitories, panoramic vistas, 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 community rink, has been branded the "workhorse" of the facility and will service local patrons and leagues. The entrance for the community 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.

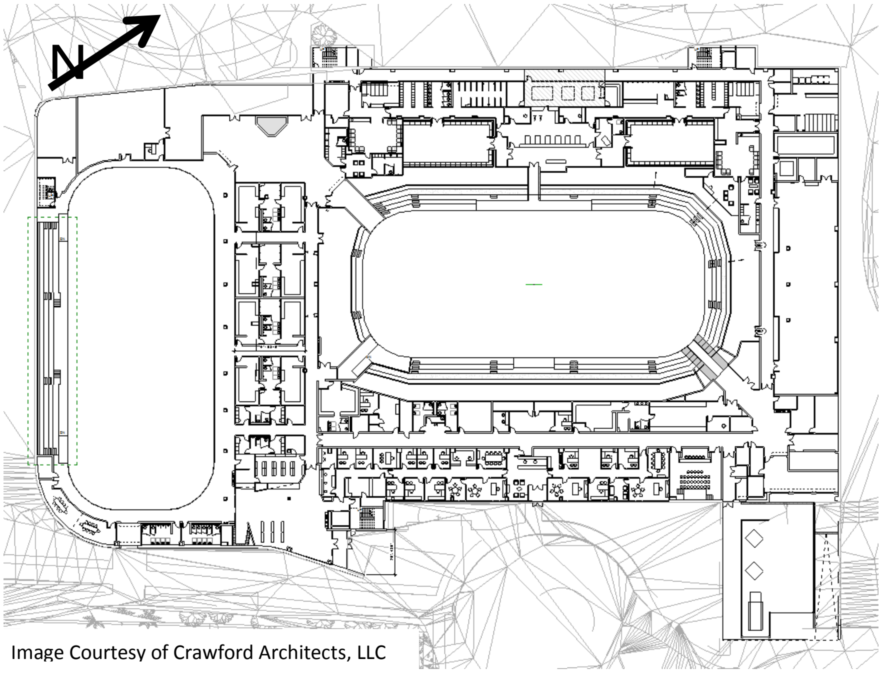


Image Courtesy of Crawford Architects, LLC

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 see 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.

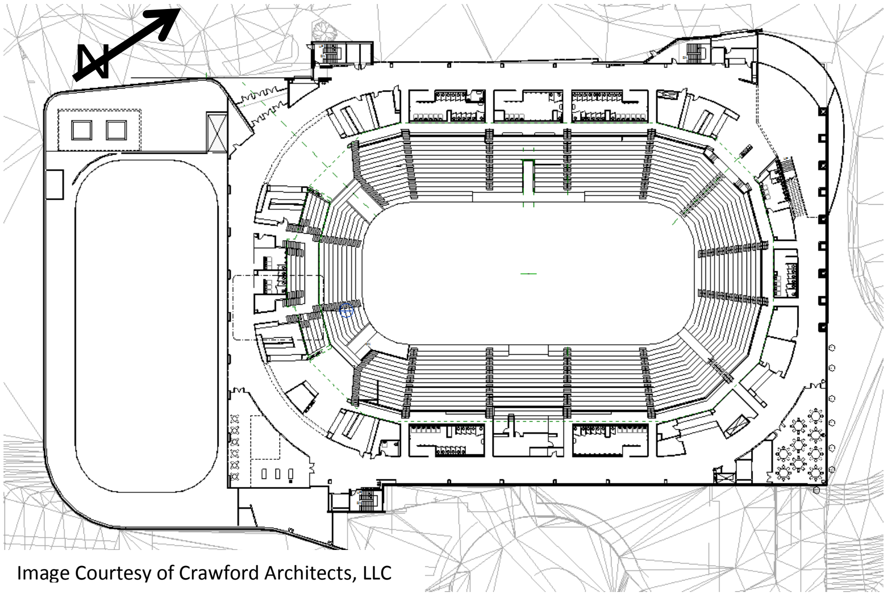


Image Courtesy of Crawford Architects, LLC

Figure 3: Main Concourse Level Floor Plan

Moving to the top level of the facility is the club level (Figure 4); within this level are the club suites, club lounge, a dining space and a kitchen to support the suites and the dining space.

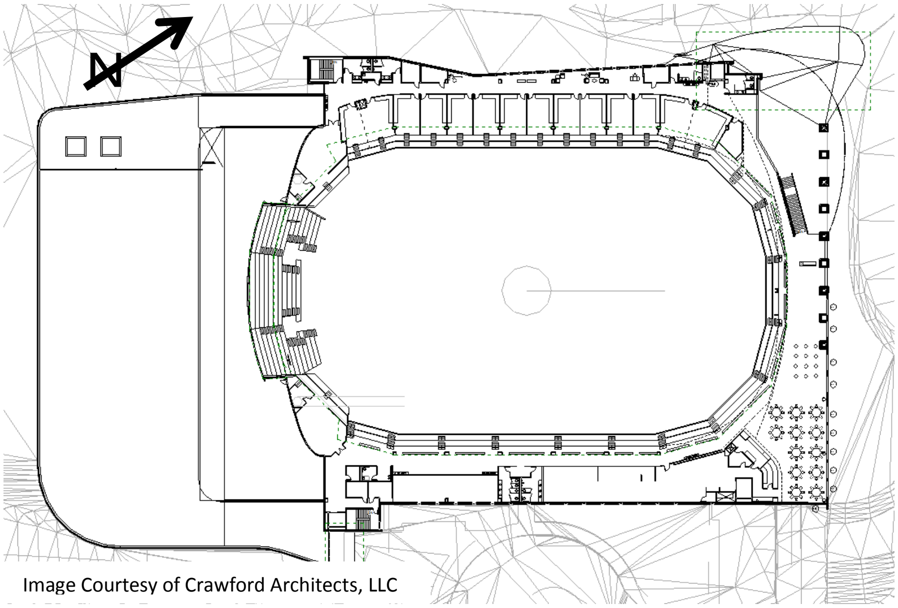


Image Courtesy of Crawford Architects, LLC

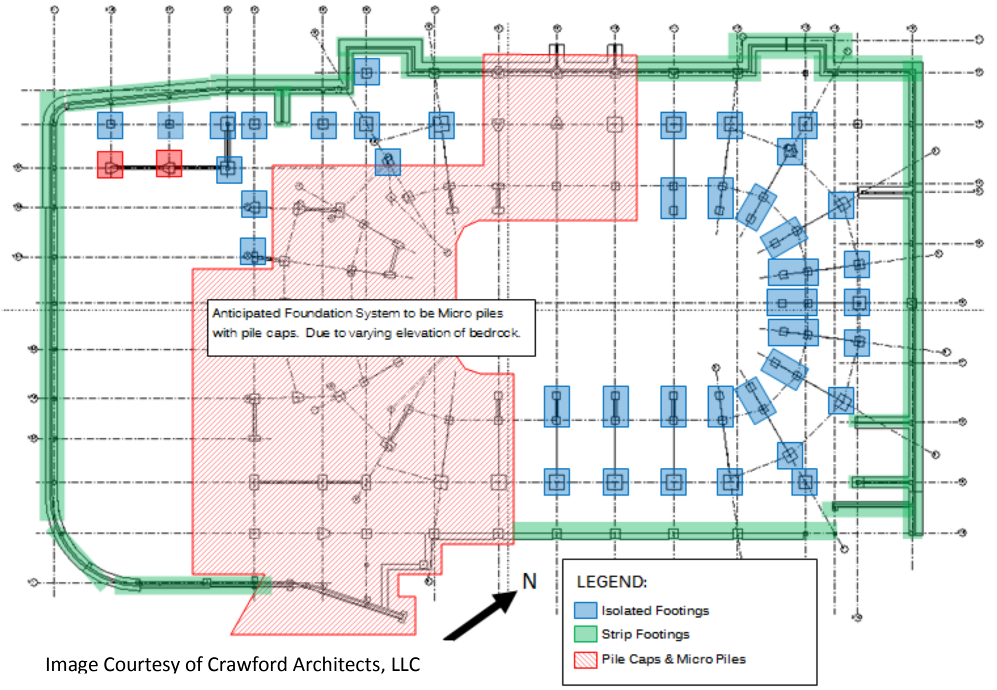
Figure 4: Club Level Floor Plan

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 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 and strip footings are utilized around the exterior walls of the arena. Figure 5 shows the current foundation system with the area around the main competition bowl that is anticipated to be micro piles with pile caps.



Anticipated Foundation System to be Micro piles with pile caps. Due to varying elevation of bedrock.

Image Courtesy of Crawford Architects, LLC

Figure 5: Existing Foundation Systems

The event level flooring systems are slabs on grade, all at the same elevation. In the plan 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" NWC composite slab with W18 beams and W24 girders framing members.

All concrete used on the Penn State Ice Arena project is 4,000 psi with the exception of formed slabs which utilizes 5,000 psi normal weight concrete. Steel reinforcement both in the foundation system and throughout all other concrete walls is 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 between the event level and main concourse level from the northeast corner to the west corner of the facility. The east side of the building footprint has no foundation wall and 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, 7 ½" NWC composite slab on 3 inch, 18 gauge VLI composite deck with W18 beams and W24 girders framing. The beams and girders frame into W18 exterior columns and W24 interior columns at the intersection of grid lines. Typical bays on these levels range from 37'-2" x 28'-0" (largest bay) to 28'-8" x 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 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. The top and bottom chords for all trusses are W14's with double angles utilized as the diagonals.

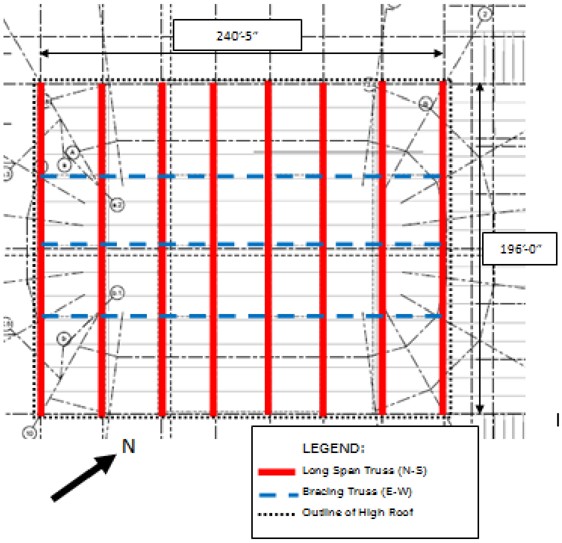


Image Courtesy of Crawford Architects, LLC

Figure 6: High Roof Framing Plan

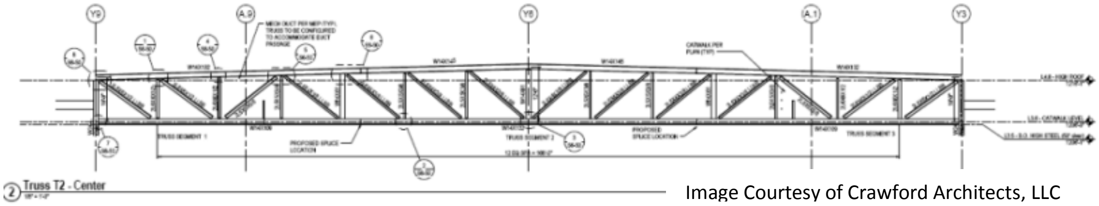


Image Courtesy of Crawford Architects, LLC

Figure 7: Simply Supported Existing Long Span Truss

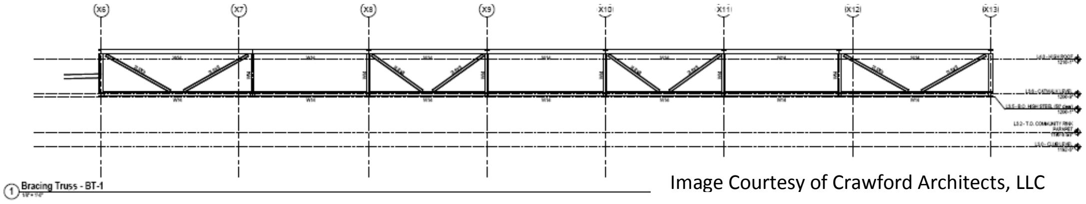


Image Courtesy of Crawford Architects, LLC

Figure 8: Bracing Long Span Truss

Figure 6 shows a simplified high roof framing plan. The high roof sits approximately 5'-11" above the flat lower roof. The simply supported truss, shown in Figure 7, 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 8, 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 inch, 18 gauge roof deck.

The lower flat roofs on either side of the long span high roof span 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 community 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 terminating 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 9.

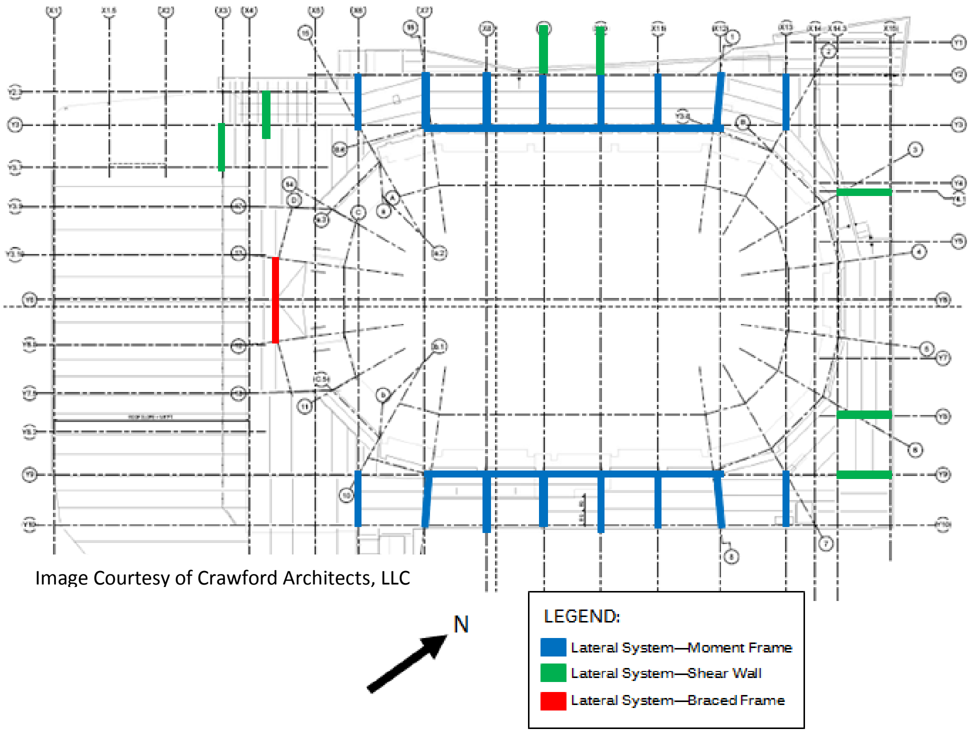


Image Courtesy of Crawford Architects, LLC

Figure 9: Existing Layout for the Arena Lateral Systems

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 community 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 and the community looker rooms as well as 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.

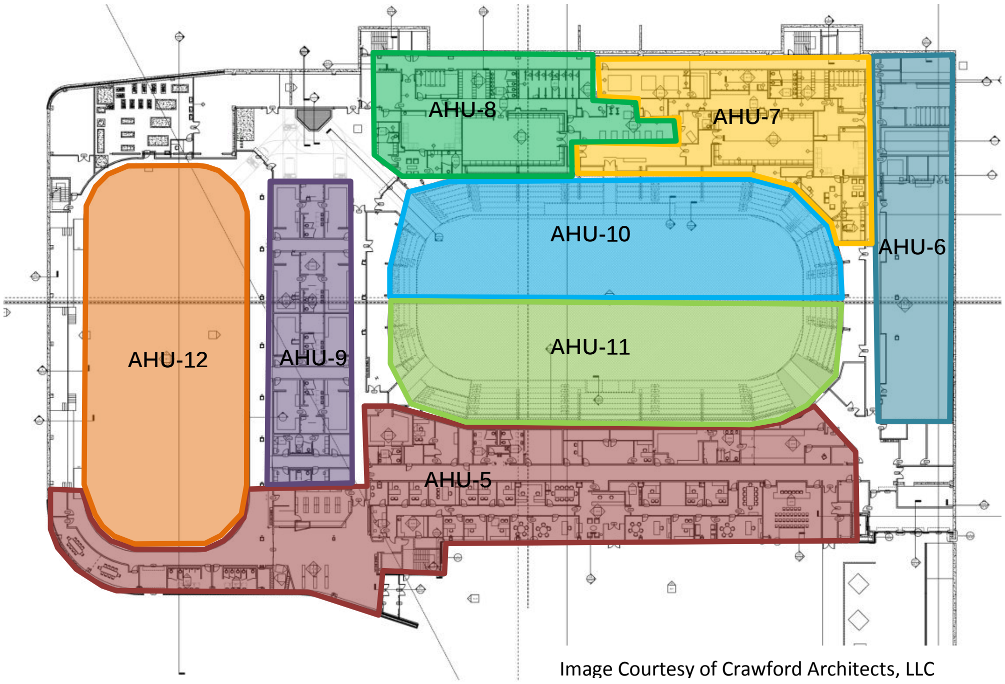


Image Courtesy of Crawford Architects, LLC

Figure 10: Existing AHU Zoning for the Event Level

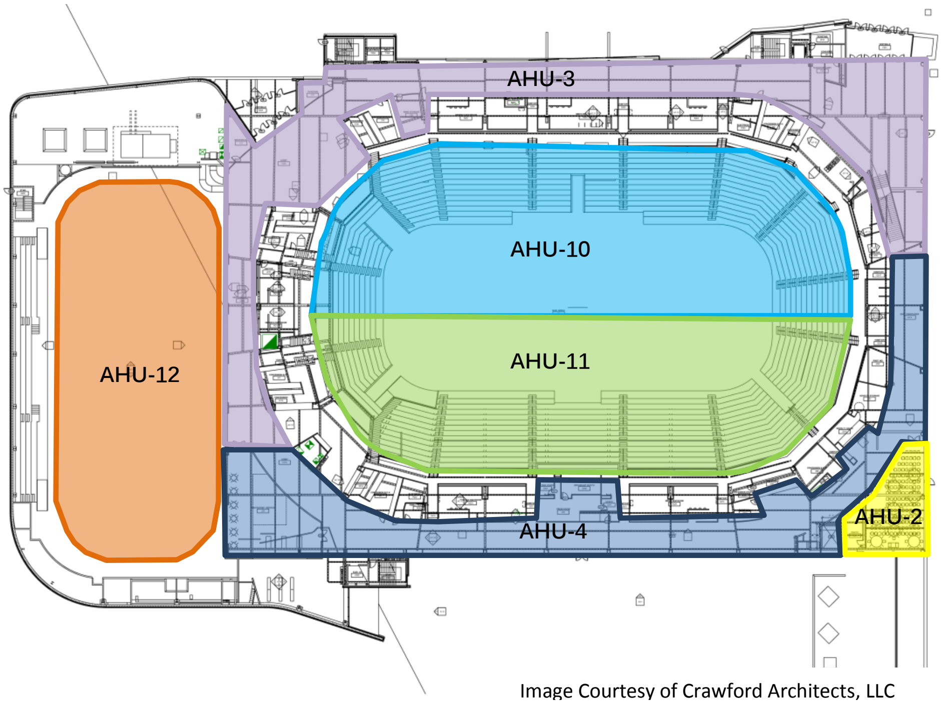


Image Courtesy of Crawford Architects, LLC

Figure 11: Existing AHU Zoning for the Concourse Level

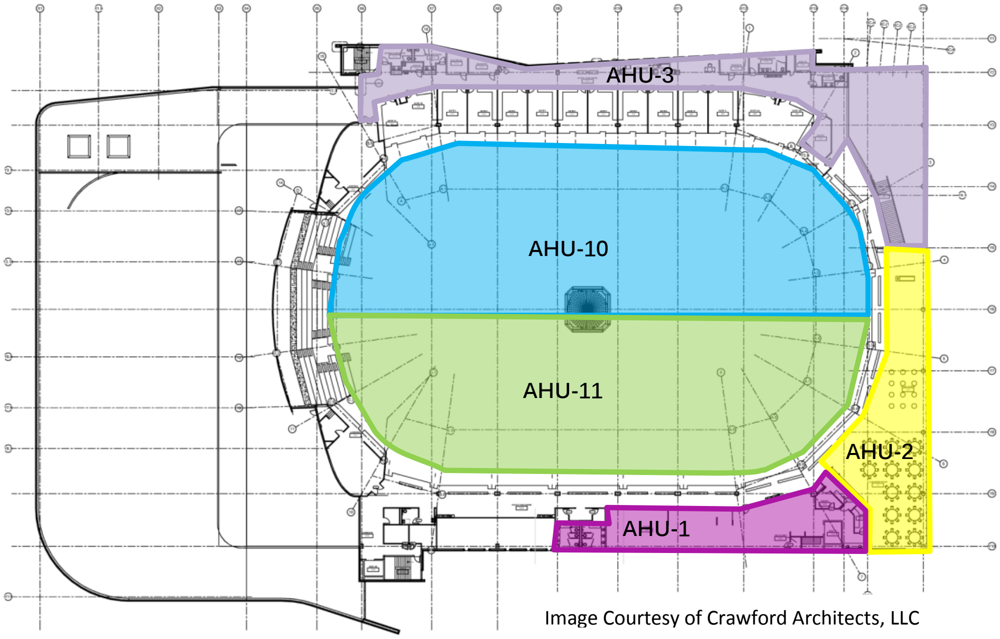


Image Courtesy of Crawford Architects, LLC

Figure 12: 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 given 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 given 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 of the transformers 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.

[DESIGN FOCUS: Event Level Relocation] – Alternative 1

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 surface and steps down in increments of 5 feet with the yellow portions at 40 plus feet below grade.

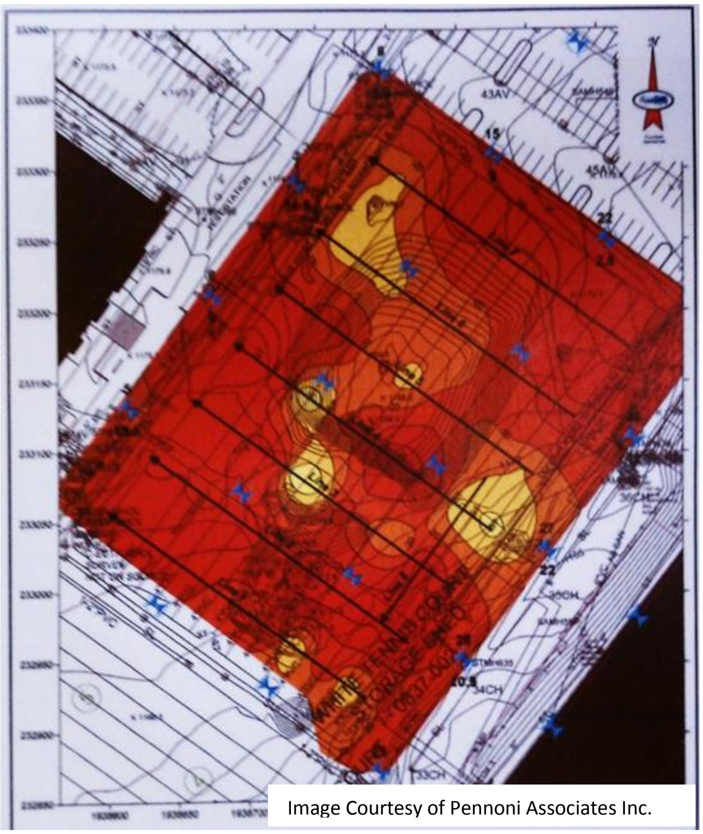


Image Courtesy of Pennoni Associates Inc.

Figure 13: Bedrock Depth

The amount of bedrock needed to be removed causes the cost of excavation increase sharply and also extends the schedule due to how laborious nature of rock removal through 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 need to be removed. The distance that the event level would be determined based upon a number of variables, some 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 building
- Loading dock logistics
- Other site restrictions such as building width

Below, Figure 14 shows a sectional view of the proposed changes to the event level, the green lines represent the existing conditions and the yellow represents the proposed changes. Notice that the plenum below the concourse level shrinks and the slope of the arena seating stays the same.

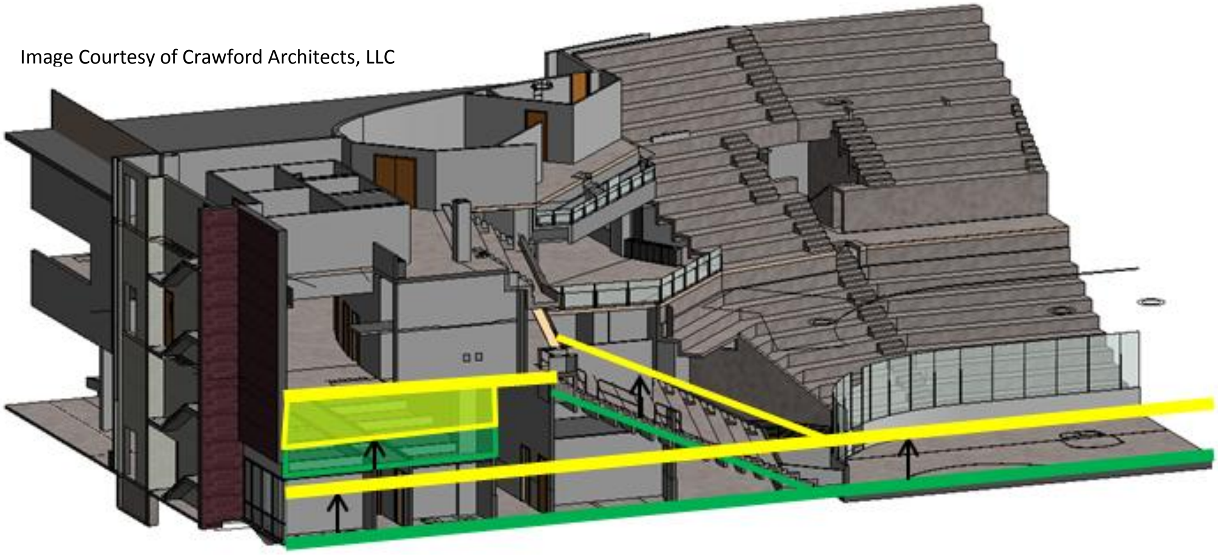


Image Courtesy of Crawford Architects, LLC

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

Construction Approach

The construction manager's position will be to ensure that the project will come under budget, be completed on time, and achieve desired LEED certification. First thing that must be created is the baseline estimate and schedule of the existing design of the entire project. RSMeans Costworks 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 rock to be excavated would be drilling and blasting with open faced rock costing at least $376,000, and about 61 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, we will not only be able to reduce the cost, but improve the schedule. 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 of the 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 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. Initial clash detection and 4D modeling will be performed and continued weekly.

Mechanical Approach

The mechanical contribution to HPR Integrated Design's relocation of the event level will consist of design and layout of duct work for the offices, lockers 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. Since the relocation will not be affecting the loads on these spaces a majority of the mechanical engineers task will be related to coordinating the utilities that must run in the plenum.

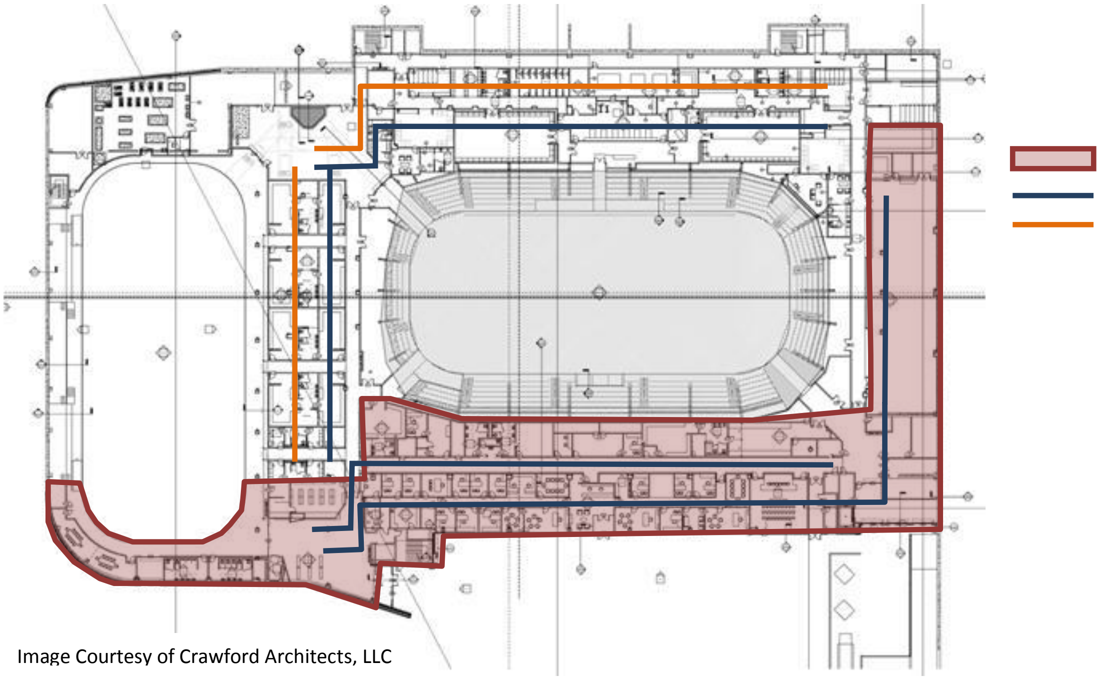


Image Courtesy of Crawford Architects, LLC

Figure 15: Potential Duct Layout on Event Level

With the relocation of the event level, the main concourse and club levels will remain locked in place. The only thing changing is the event level is moving up. The exact amount of the event level will be moved will be a function of several constants including: plenum requirements, sight lines, head clearances, and egress concerns.

Aside from the design of the event level's mechanical systems, moving the event level up 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 engineer and structural engineer will need to work very closely.

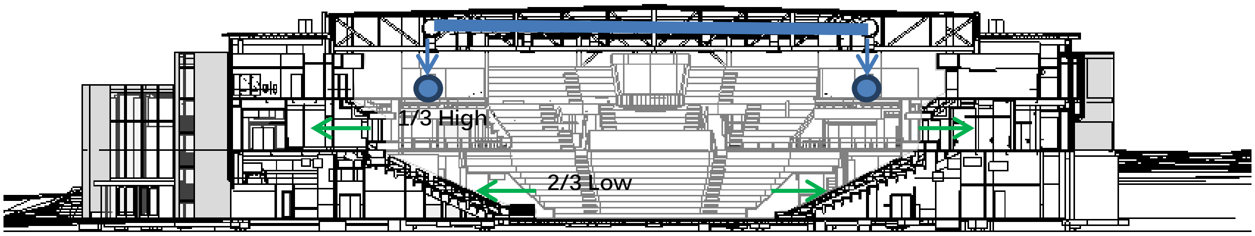


Figure 16: Potential Return Air Strategy

Lighting/Electrical Approach

The relocation of the event level creates a tighter plenum space for which all the building systems are to be placed. This makes the coordination and planning of these spaces a larger issue.

The lighting system design will utilize high efficacy sources, normal power factor electronic ballasts where applicable and luminaires with high efficiency. Doing so will reduce the total building lighting power density and helps achieve the goals of LEED. The lighting control system will also be designed to reduce the energy consumption of the lighting systems. Such controls 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. The lighting engineer is proposing a shading device be in place to reduce 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 books. Efforts will be made to reduce the amount of wiring and conduit need by using the most efficient path for servicing the spaces.

Structural Approach

The structural contribution to HPR Integrated Design's relocation of the event level will consist of redesign of 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 all gravity columns that frame between the event level and main concourse level, 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 elevation. The shear walls that are located between the event level and main concourse level will be decreased in size and will need to be assessed for capacity. The 12" exterior foundation walls outlining the building footprint 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 clear space for plenum coordination and allow for the event level to be raised to the optimum dimension. 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.

The structural engineer will redesign the existing main concourse level floor framing system. The current composite steel system will be replaced with a two way flat plate, post tensioned floor framing system. 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 consideration and it would be assumed that the structural flooring system depth could be decreased even further. The redesigned flooring system consists, preliminarily, of a 15" reinforced NWC slab with 4" thick drop panels. Reinforced concrete columns were assumed to be 18" x 18" square columns to match the dimensions of the existing steel columns for architectural considerations. Figure 17 shows a comparison between the two systems.

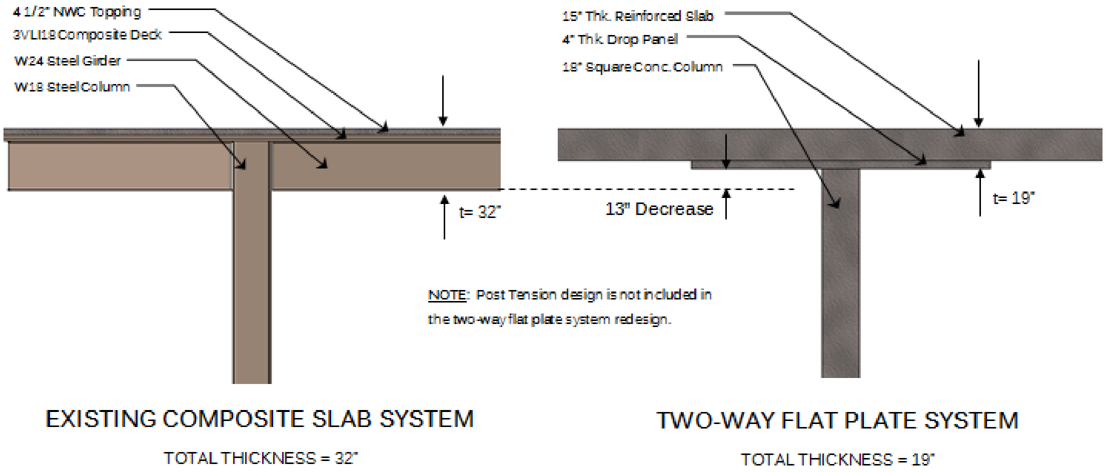


Figure 17: Comparison of Existing Versus Proposed Flooring System

Foundation systems will be analyzed and redesigned by the structural engineer based on a new top of footing elevation. The structural engineer will work closely with the construction manager to determine if changes need to be made at key locations where foundations may no longer be sitting on bedrock. Areas where micro piles are anticipated may be avoided with relocating the event level above top of bedrock which could minimize vibrations from micropiles installation during construction.

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. A study on clearance will be conducted by HPR and may require alterations to the club level precast tub cantilevered framing. Figure 18 shows the relocated seating arrangement and the additional steel and precast design that must be completed for the proposed redesign.

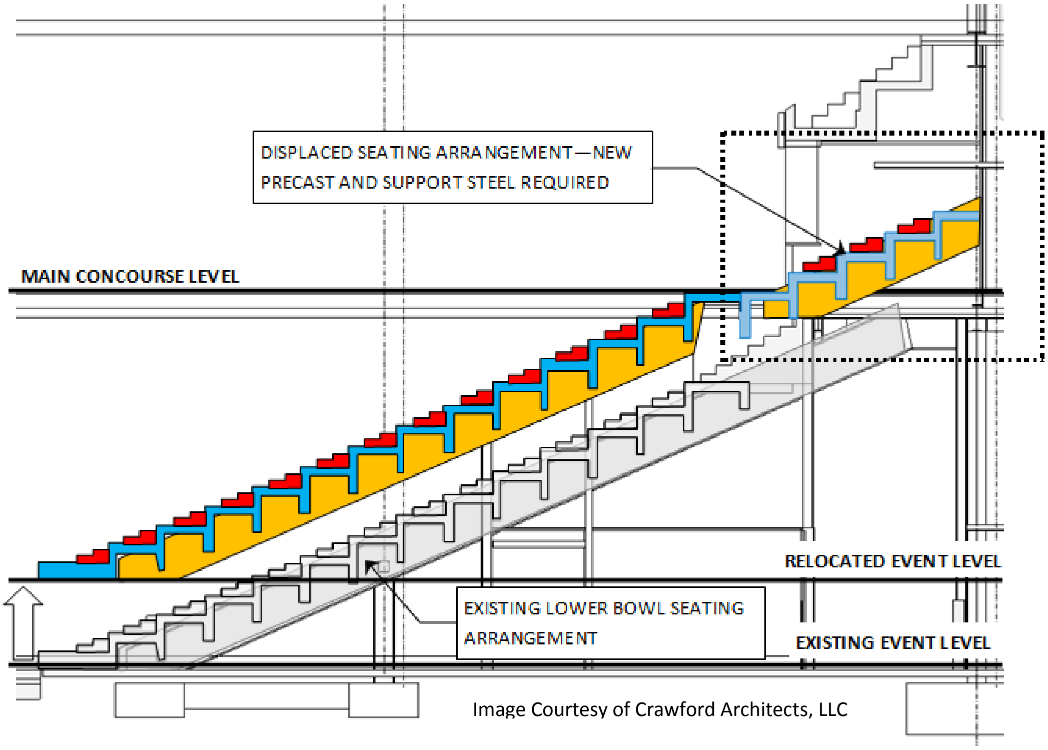


Image Courtesy of Crawford Architects, LLC

Figure 18: Section of Relocated Seating Arrangement

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.

The process of finding the optimum distance the level be raised in elevation is going to be a collaborative team based effort with influences coming from all disciplines and 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 but do so with a reduction in cost 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: Air Handler Relocation and Event Level Redesign] – Alternative 2

Problem Statement

When HPR Integrated Design first began studying the plans for the Penn State Ice Arena we immediately noticed the 20'-9" slab to slab dimension from the event level to the concourse level. We began to brain storm ideas on how to turn this potentially wasted space into a more useful space. We eventually arrived at the conclusion that we could relocate two air handlers from the roof to a mechanical mezzanine we would create in this 10' plenum space. Figure 19 shows the locations that each air handler unit serves. AHU 6 serves the training facilities shown in blue, while AHU 5 serves office spaces shown in red.

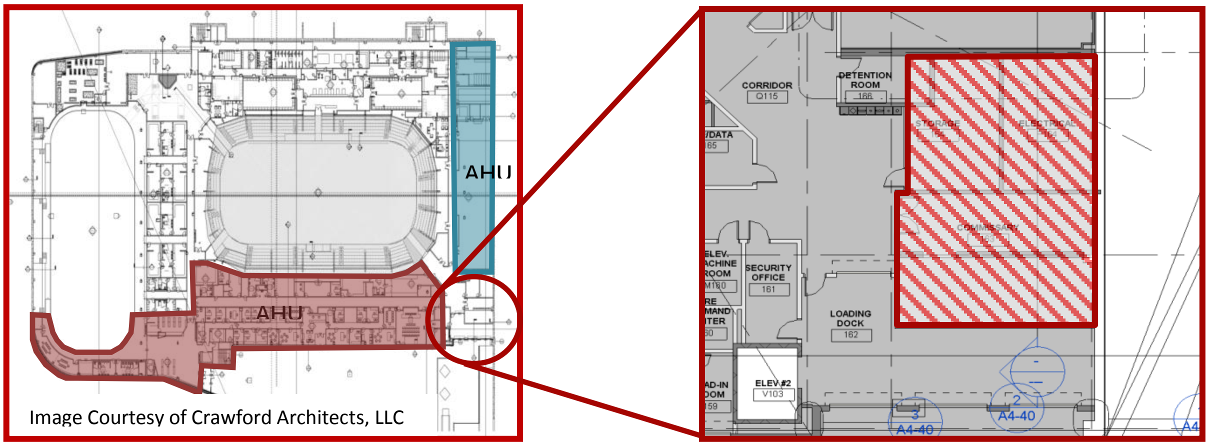


Image Courtesy of Crawford Architects, LLC

Figure 19: Perspective of Sample Roof Integration

The current design calls for AHU 5 and AHU 6, each located on the roof, to serve zones located on the far end of the event level. This design calls for a large mechanical shaft to penetrate the main concourse level and club level. The relocation of AHU 5 and 6 would reduce the shaft through the main concourse level and reduce the size of the shaft through the club level. The amount of duct will be reduced and the fan energy will be decreased.

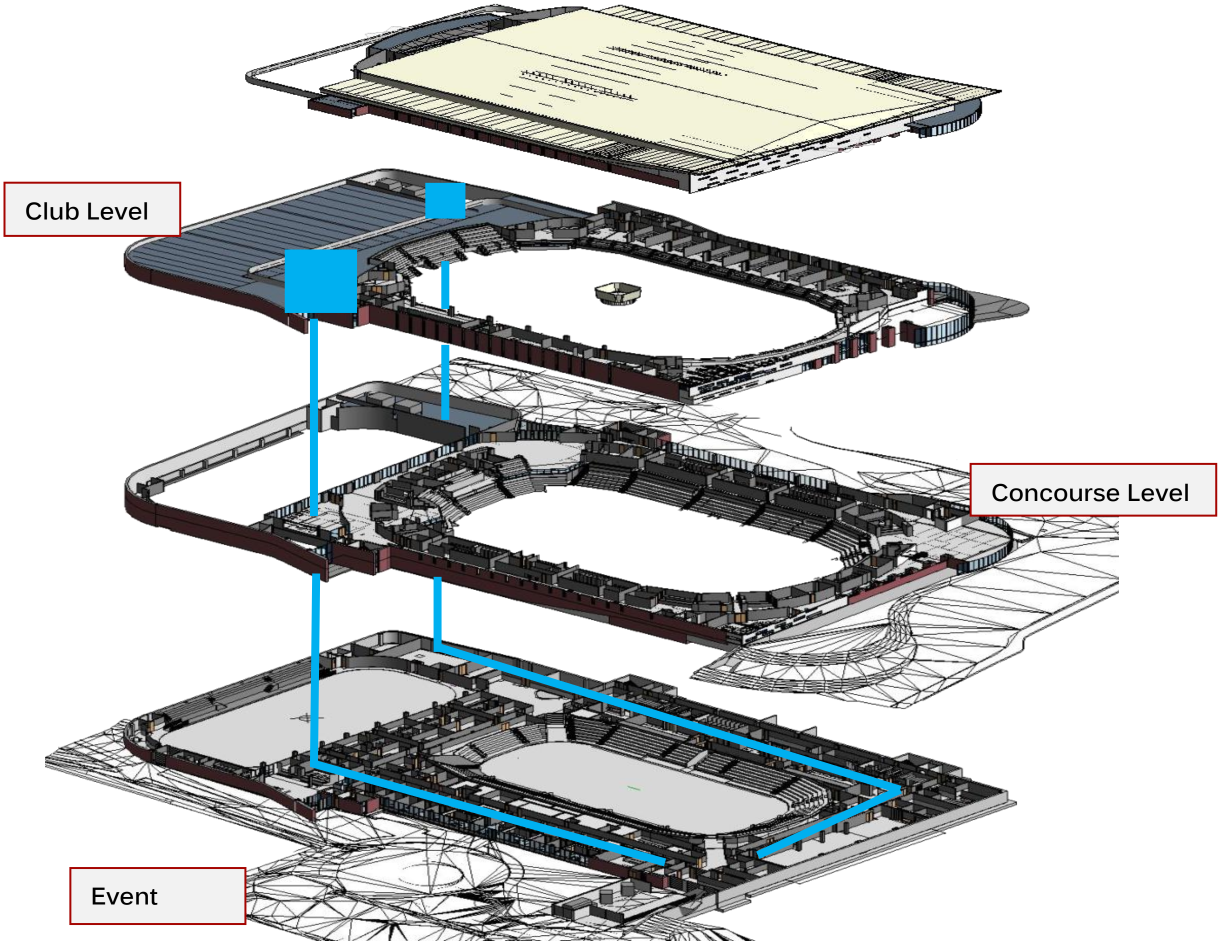


Figure 20: Perspective of Sample Roof Integration

Construction Approach

The construction manager's position will be to ensure that the project will come under budget, be completed on time, and achieve desired LEED certification. First thing that must be created is the baseline estimate and schedule of the existing design of the entire project. RSMeans Costworks will be used to help determine these values and schedule outputs.

Relocating the Air Handler Units from the roof will help reduce cost from reduced sizes and lengths of ductwork, the size of units needed, and the redesign of structural members needed for the roof. The cost of the design for the proposed location is minimal to that of what is currently designed. As the systems are installed the new location, workers can begin to work on installation of materials needed sooner reducing the schedule and labor needed than that of the existing schedule.

Upon completion of the baseline estimate, schedule, and LEED score card the construction manager will update each based on 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. Initial clash detection and 4D modeling will be performed and continued weekly.

Mechanical Approach

The mechanical contribution to HPR Integrated Design's relocation of the air handlers and event level redesign will be fairly involved. It will include the sizing and selection of the units, routing ducts to and from the unit as well as the piping for the chilled and hot water. There must be continuous collaboration between the mechanical electrical and structural disciplines to ensure there are no clashes in the tight plenum.

In addition to selecting the air handling units and coordinating the utilities that supply them, the mechanical engineer will be designing the system that serves the training facility. This will allow for a reduction in size of AHU 6 and will save space in the mechanical mezzanine along with a reduction of duct size and fan energy.

The mechanical engineer's tasks include but are not limited to: unit selection and sizing, louver location and sizing, 3D modeling and clash detection, load analysis, a required outdoor air analysis and difusser layout.

Lighting/Electrical Approach

The relocation of the air handler units reduces the plenum space above the electrical room, commissary, and storage room on event level. This makes the coordination and planning of these spaces a larger issue.

The lighting system design will utilize high efficacy sources, normal power factor electronic ballasts where applicable and luminaires with high efficiency. Doing so will reduce the total building lighting power density and helps achieve the goals of LEED. The lighting control system will also be designed to reduce the energy consumption of the lighting systems. Such controls 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. The lighting engineer is proposing a shading device be in place to reduce 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 books. Efforts will be made to reduce the amount of wiring and conduit need by using the most efficient path for servicing the spaces.

Structural Approach

Structural contributions for the alternative design solution to relocate rooftop air handlers AHU-5 and AHU-6 and event level redesign will focus on the main structural system below the main concourse level. The primary goals of this redesign focus are to increase daylighting on the plan south façade and enable the relocation of air handlers to a mechanical loft. The existing design has a floor to floor height of 20’-9” between the Event Level and Main Concourse levels. In most cases, this plenum is not fully utilized creating an inefficient void in the building. Utilization of this void space for a mechanical loft would allow for life cycle cost savings, construction savings and increase the efficiency of the above ceiling plenum.

Reducing the structural flooring system depth would accommodate the relocation of AHU-5 and energy recovery ventilator AHU-6. The structural engineer will redesign the flooring system from the existing composite steel system to a two-way post-tensioned flat slab system. Preliminary calculations, without post-tensioning, show that there will be a 13” reduction in overall system depth. A comparison of the existing versus proposed structural flooring systems is shown in Figure

21. With the addition of post tensioning, the structural system depth would be decreased optimizing the efficiency of the system and allowing for maximum clear space for the new mechanical loft.

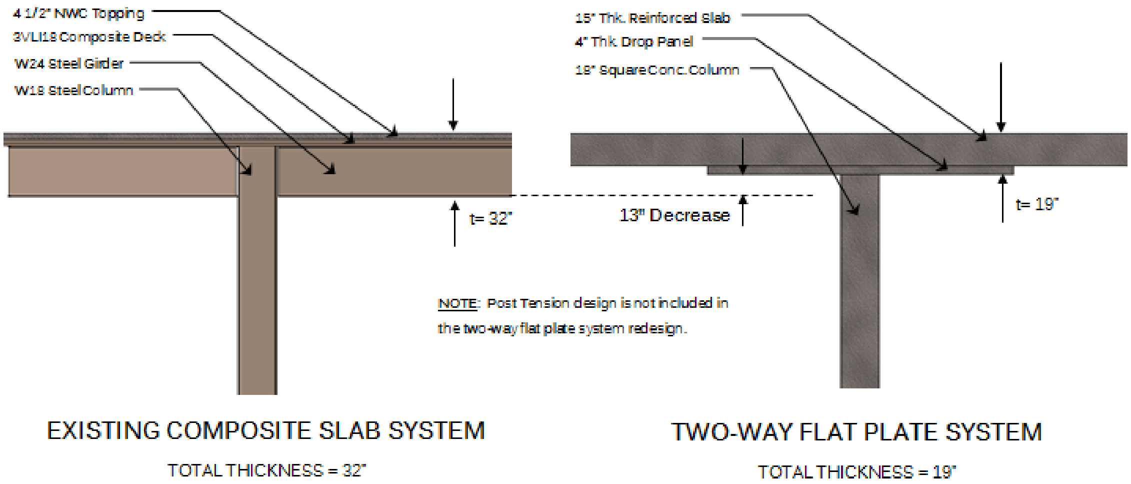


Figure 21: Comparison of Existing Versus Proposed Flooring System

The relocation of the mechanical equipment will require the design of a structural flooring system in the plenum space. A similar two-way post-tensioned flat slab will be design to decrease structural depth and therefore maximize the clear span within the loft. The location of the proposed mechanical loft slab is shown in Figure 22.

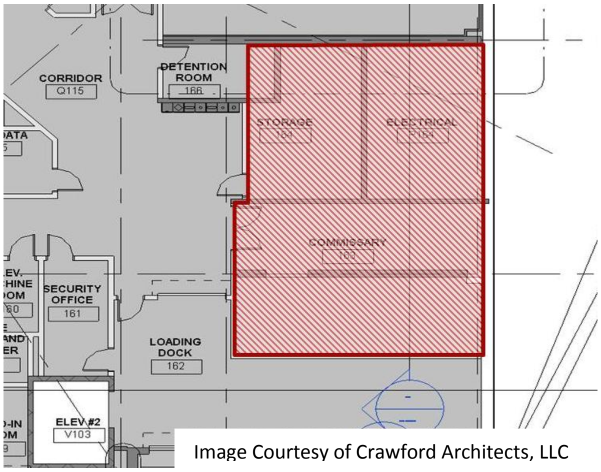


Image Courtesy of Crawford Architects, LLC

Figure 22: Proposed Location of the Mechanical Loft

An investigation into the requirement for additional gravity columns in this space will be done by the structural engineer and may require re-design of the surrounding columns if additional columns are deemed necessary. Foundation design will be included in this investigation.

Redesign for the event level will not be solely focused on the air handler relocation. The scope of redesign will be the entire main concourse structural floor system to increase the cost efficiency of the system and allow for a more aggressive construction schedule. Controlled daylighting coordination with the lighting/electrical engineer will be incorporated in this scope with a focus on the plan south façade.

Relocation of the air handlers into a tight mechanical loft will require full coordination with the mechanical and electrical engineers. The structural engineer will be present at all coordination meetings involving the relocation of these air handlers and/or the coordination of systems for optimized daylighting on the plan south façade.

Air Handler Relocation & Event Level Redesign Conclusion

All the disciplines will be working in close colaberation to create a comprehensive 3D models showing mechanical, electrical and structural systems. This will be done to eliminate clashes and decrease schedule durations. Because of the lead-lag nature of this design focus, it is important that each discipline sticks to their schedule and provides each other with the approrate information in a timely manner.

HPR Integrated Design will measure our suceess in three ways. We will be measuring the energy savings from the existing solution to the solution we are proposing. Energy savings is a major to contributor that would be considered a successful redesign. We will be tracking cost; if we are able to reduce cost that would also be a success. Lastly, if our 3D coordinated model has no clashes we will view that as a major success.

[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 relocation of the event level and redesign of the arena's building enclosure. Design constraints dictate that the 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 relocation 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 recognizable, iconic facility which has been requested by the Owner.

With the assumption that the main arena roof geometry has not been established, HPR Integrated Design will investigate different design elements 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 responsibility must be addressed to create unity between these facilities.

This study will address this architectural obligation and will be integrally connected to other design focuses such as the event level relocation and façade redesign as a whole. Redesign of the structure's long span trusses which accommodates more complex roof geometry, consistent with the neighboring Bryce Jordan Center will be accomplished and concurrently coordinated 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. RSMeans Costworks will be used to help determine these values and schedule outputs.

Through coordination efforts with the structural engineer, a crane analysis will be performed to determine the number of cranes and crane sizes needed based on the design of the roof profile. At this time, a site logistics analysis will also be performed. 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. Clash detection and 4D modeling 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 part load. Initial coordination efforts, shown in Figure 23, will be continuously conducted with the other disciplines to ensure clashes with the duct layouts are avoided.

The mechanical engineering tasks related to this change included: a new volume calculation, load calculations, sizing a locating ducts and diffusers while coordinating with the other disciplines, the integration of a controls structure to reduce energy.

The Mechanical engineer will perform a CFD analysis of the smoke exhaust system as part of requirements for the integrated master's program. If the current system doesn't meet code changes will be proposed.

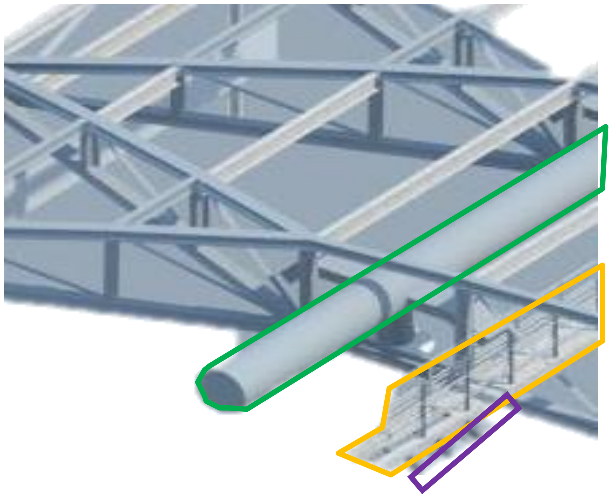


Figure 23: Perspective of Sample Roof Integration

Lighting/Electrical Approach

The competition arena poses a functional and illumination challenge. Producing a space that will align with our project goals and the design criteria will be a challenging task. The illumination criteria for Division 1 hockey is dictated by the NCAA broadcasting. Illumination levels and uniformity requirements are the main criteria for televised events. The lighting/electrical engineer 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 luminaries above the seating area or floodlights from the catwalk will be provided to give the space illumination in case of a power outage or emergency event. Figure 24 shows the preliminary proposed schematic lighting layout.

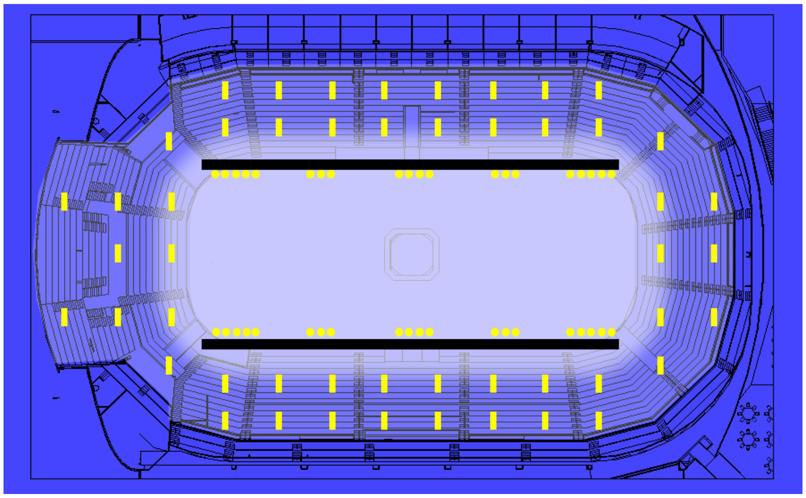


Figure 24: Schematic Lighting Layout for the Main Arena

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 design 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 both a more complex, aesthetically recognizable roof design and also coordination with the MEP systems to increase constructability in the field.

To accommodate the relocation 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. 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.

The structural engineer will therefore attend all coordination meetings regarding the roof systems integration and work closely with both the engineers and construction manager to avoid clashes between systems.

As a design alternative to the simply supported long span trusses, systems such as buttressed arch design, tied arch truss design and a "Wishbone" split moment connected truss design was considered.

A pure arch structural element would require buttressing or large columns to counteract the large 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 our team's belief that buttressing could compromise the architectural intent.

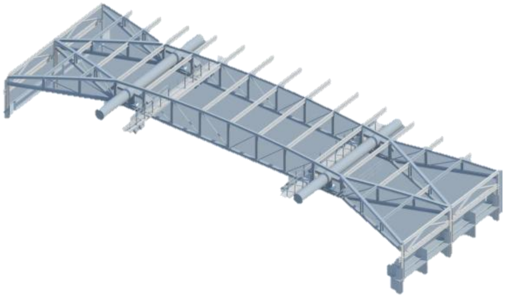
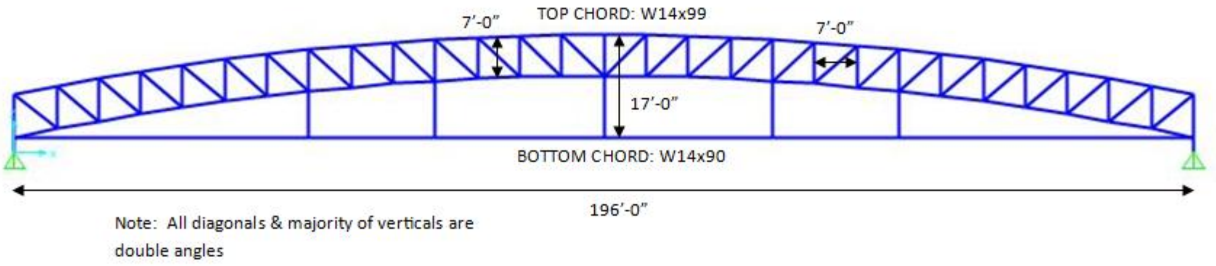


Figure 25: "Wishbone" Long Span Truss

Another alternative that was explored is shown above in Figure 29, which consisted of a wishbone support condition with moment connections to resist a part of the moment on the long span truss. While the design was successful in reducing member sizes, the cost of the moment connections removes this as a viable alternative.

Both the architectural layout of the building and cost has dictated that the proposed long span truss must remain simply supported. An alternative proposed design solution is shown in

Figure 26, consisting of a tied arch truss framing system with preliminary dimensions & member sizes. 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.



Note: All diagonals & majority of verticals are double angles

Figure 26: Proposed Tied Arch Truss - Preliminary Design & Member Sizes

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 can be felt from both the exterior and interior of the building.

The structural engineer 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 measure the success of the main arena roof systems design by not comparing to the existing facility design. Successes will be determined based on the 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 for "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 ground to roof. 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 can improve on these original goals with the 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. RSMeans Costworks will be used to help determine these values and schedule outputs.

Through coordination efforts with the other disciplines we will determine the proper materials and design for the façade in order to reduce energy costs and create an iconic look to the building. 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. Clash detection and 4D modeling will continue to be performed weekly.

Mechanical Approach

The mechanical contribution to HPR Integrated Design's for the façade redesign 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 Engineers role will be to monitor the changes and model their effect on the loads, proposes changes that can help reduce heat gain while maintaining the views. Along with the structural and electrical engineer, the mechanical engineer will be responsible for selecting the appropriate glazing for the new façade. Although not essential to the redesign of the façade, once all architectural changes have been made and the mechanical and lighting design are completed, the mechanical engineer will be preforming a full energy model to help predict the operating cost of the building throughout the year.

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 27 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 27: 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 28, and a schematic lighting design for the Mt. Nittany Room can be seen in Figure 29.

Figure 28: Lobby Schematic Lighting Design

Figure 29: Mount Nittany Room 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 architectural solution. This will be accomplished specifically through analysis of the exterior columns for any change in loads based on alternative material selection, provide proper support conditions in details, and investigation of curtain wall glazing panels with considerations for wind pressures.

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. Additional miscellaneous steel needed for façade redesign will be considered and designed to an appropriate scope.

The structural engineer will be involved in all coordination meetings that involve the redesign of the façade. The current East façade is completely a curtain wall system and redesign will involve changing this area into heavier materials which will require structural support and structural input. While the MEP engineers will lead this process, the structural engineer will have an equal level of input into design decisions.

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. Additionally, the building envelope will be considered and monitored from the structural realm throughout the redesign process for waterproofing and performance issues.

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 engineer will create an energy model to track the effects of the changes in the façade. The lighting design 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 engineer 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 & cost for the building while maintaining important site specific elements like the view of Mt. Nittany. This redesign will be a success if our design enhances the architectural appeal of the arena from University Drive, creates inviting entrances, reduces thermal load and optimizes daylighting. It will be our challenge to find the balance between these separate driving forces, but by keeping each in mind we can create an architectural aping design that is energy conscious.

[APPENDIX A: Index of Figures and Tables]

Figures

Tables

[APPENDIX B: DELIVERABLES, SOFTWARE & CODES]

Table 2: HPR Integrated Design Team Deliverables

	Design Alternative	Tasks	Program(s) To Be Utilized	Applicable Codes
Alternative 1	**Event Level Relocation**	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		
Alternative 2	**Air Handlers Relocation & Event Level Redesign**	Architectural Planning	Revit A/S/MEP, Hand Sketches	IBC 2009
		3D Modeling	Revit Architecture, AutoCAD	
		Code Compliance Investigation	Revit Architecture	IBC 2009, ADAAG
		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
Alternative 1	**Event Level Relocation**	Baseline Estimate & Update	RSMeans, Excel, Hand Calcs
		Baseline Schedule & Update	RSMeans, Primavera 6, Hand Calcs
		3D Coordination & Clash Detection	Revit, Navisworks
		4D Modeling	Navisworks
Alternative 2	**Air Handlers Relocation & Event Level Redesign**	Baseline Estimate & Update	RSMeans, Excel, Hand Calcs
		Baseline Schedule & Update	RSMeans, Primavera 6, Hand Calcs
		3D Coordination & Clash Detection	Revit, Navisworks
		4D Modeling	Navisworks
	Main Arena Roof System Design	Estimate Update	RSMeans, Excel
		Schedule Update	RSMeans, Primavera 6, Hand Calcs
		3D Coordination & Clash Detection	Revit, Navisworks
		4D Modeling	Navisworks
		Crane Analysis	RSMeans, Excel, Hand Calcs
		Site Logistics	Navisworks
	Façade Redesign	Estimate Update	RSMeans, Excel, Hand Calcs
		Schedule Update	SAP 2000, 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
Alternate 1	Event Level Redesign	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	
Alternate 2	AHU Relocation & Event Level Redesign	Mechanical System Analysis	Microsoft Excel	ASHRAE 62.1, ASHRAE 90.1
		Training Facility System Redesign		ASHRAE 62.1
		Air Handler Selection and Sizing	Internet	ASHRAE 62.1, ASHRAE 90.1
		Duct Layout and Sizing	Revit MEP	ASHRAE 62.1
		Piping 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
Alternate 1	Event Level Redesign	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	
Alternate 2	AHU Relocation & Event Level 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
		Daylighting Schematic Design	3DS Max Design, Revit MEP	USGBC LEED, IESNA Lighting Handbook
		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
Alternative 1	**Event Level Relocation**	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.
Alternative 2	**Air Handlers Relocation & Event Level Redesign**	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
		Foundation System Analysis/Redesign	SAP2000, RAM, Hand Calcs	ACI318-08
	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 C: 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.

Air Handler Relocation & Event Level Redesign

- Coordination amongst all of the disciplines throughout project design.
- Reduction of roof system members of previous location of relocated air handlers.
- Optimize plenum space above electrical room, storage room, and commissary.
- Reduce energy costs by designing and correctly sizing air handlers being relocated.
- Optimize duct size balancing energy, cost, and space.
- Reduce resources needed for installation of systems and duct, ultimately reducing cost.
- 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.
- Improve the schedule by moving installation of materials ahead of existing schedule.
- Ensure systems designed are achieving points necessary on LEED score card for Gold Certification.

Main Arena Roof System Design

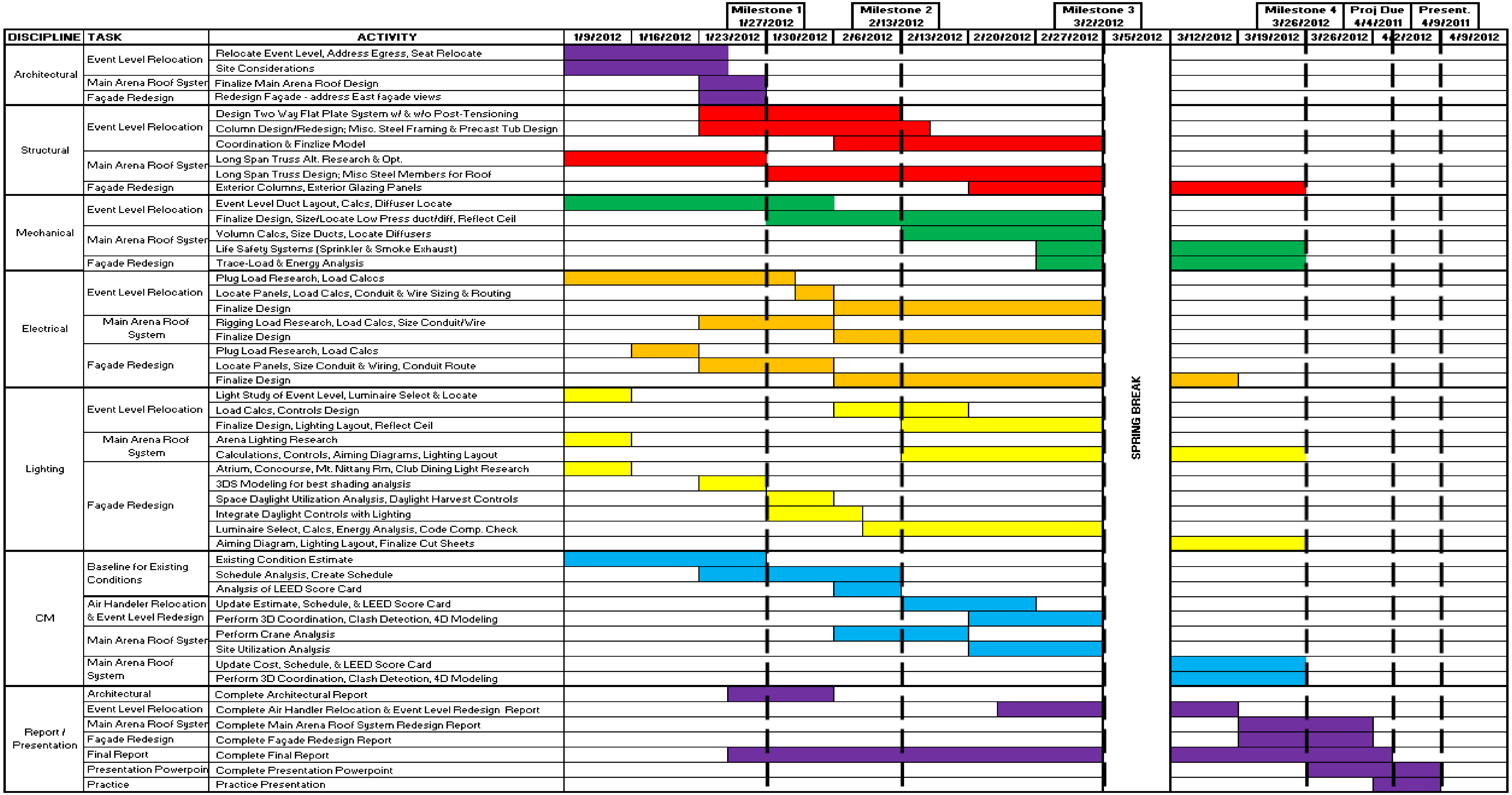
- Coordination amongst all of the disciplines throughout project design.
- Along with the façade redesign, create an iconic roof system.
- Roof system design increases or maintains constructability.
- Reduce cost with reduction of long span truss member size.
- Structural design maintains performance 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 D: Proposed Schedule and Timetable]

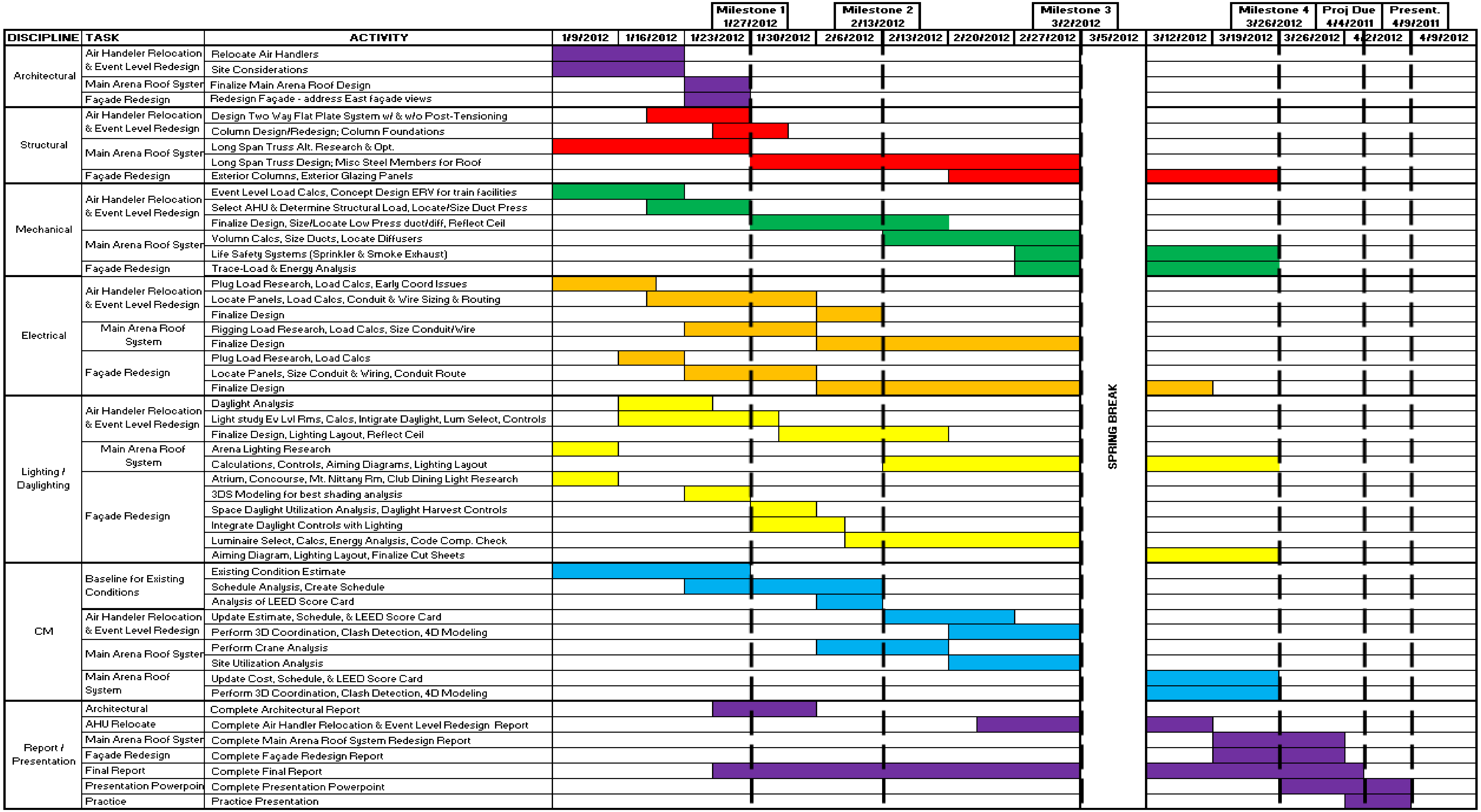


Milestone 1 1/27/2012
Milestone 2 2/13/2012
Milestone 3 3/2/2012
Milestone 4 3/26/2012
Proj Due 4/4/2011
Present. 4/9/2011

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 Relocation	Relocate Event Level, Address Egress, Seat Relocate	🟪	🟪	🟪											
		Site Considerations	🟪	🟪	🟪											
	Main Arena Roof Syster	Finalize Main Arena Roof Design			🟪											
	Façade Redesign	Redesign Façade - address East façade views			🟪											
Structural	Event Level Relocation	Design Two Way Flat Plate System w/ & w/o Post-Tensioning			🟥	🟥	🟥									
		Column Design/Redesign; Misc. Steel Framing & Precast Tub Design			🟥	🟥	🟥	🟥								
		Coordination & Finlize Model					🟥	🟥	🟥	🟥						
	Main Arena Roof Syster	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 Relocation	Event Level Duct Layout, Calcs, Diffuser Locate	🟩	🟩	🟩	🟩										
		Finalize Design, Size/Locate Low Press duct/diff, Reflect Ceil				🟩	🟩	🟩	🟩	🟩						
	Main Arena Roof Syster	Volumn Calcs, Size Ducts, Locate Diffusers						🟩	🟩	🟩						
		Life Safety Systems (Sprinkler & Smoke Exhaust)								🟩		🟩	🟩			
	Façade Redesign	Trace-Load & Energy Analysis								🟩		🟩	🟩			
Electrical	Event Level Relocation	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 Relocation	Light Study of Event Level, Luminaire Select & Locate	🟨								SPRING BREAK					
		Load Calcs, Controls Design					🟨	🟨								
		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					🟦									
	Air Handeler Relocation & Event Level Redesign	Update Estimate, Schedule, & LEED Score Card						🟦	🟦							
		Perform 3D Coordination, Clash Detection, 4D Modeling							🟦	🟦						
	Main Arena Roof Syster	Perform Crane Analysis					🟦	🟦								
		Site Utilization Analysis							🟦	🟦						
	Main Arena Roof System	Update Cost, Schedule, & LEED Score Card										🟦	🟦			
		Perform 3D Coordination, Clash Detection, 4D Modeling										🟦	🟦			
Report / Presentation	Architectural	Complete Architectural Report			🟪	🟪										
	Event Level Relocation	Complete Air Handler Relocation & Event Level Redesign Report							🟪	🟪		🟪				
	Main Arena Roof Syster	Complete Main Arena Roof System Redesign Report											🟪	🟪		
	Façade Redesign	Complete Façade Redesign Report											🟪	🟪		
	Final Report	Complete Final Report			🟪	🟪	🟪	🟪	🟪	🟪		🟪	🟪	🟪	🟪	
	Presentation Powerpoi	Complete Presentation Powerpoint												🟪	🟪	
	Practice	Practice Presentation													🟪	

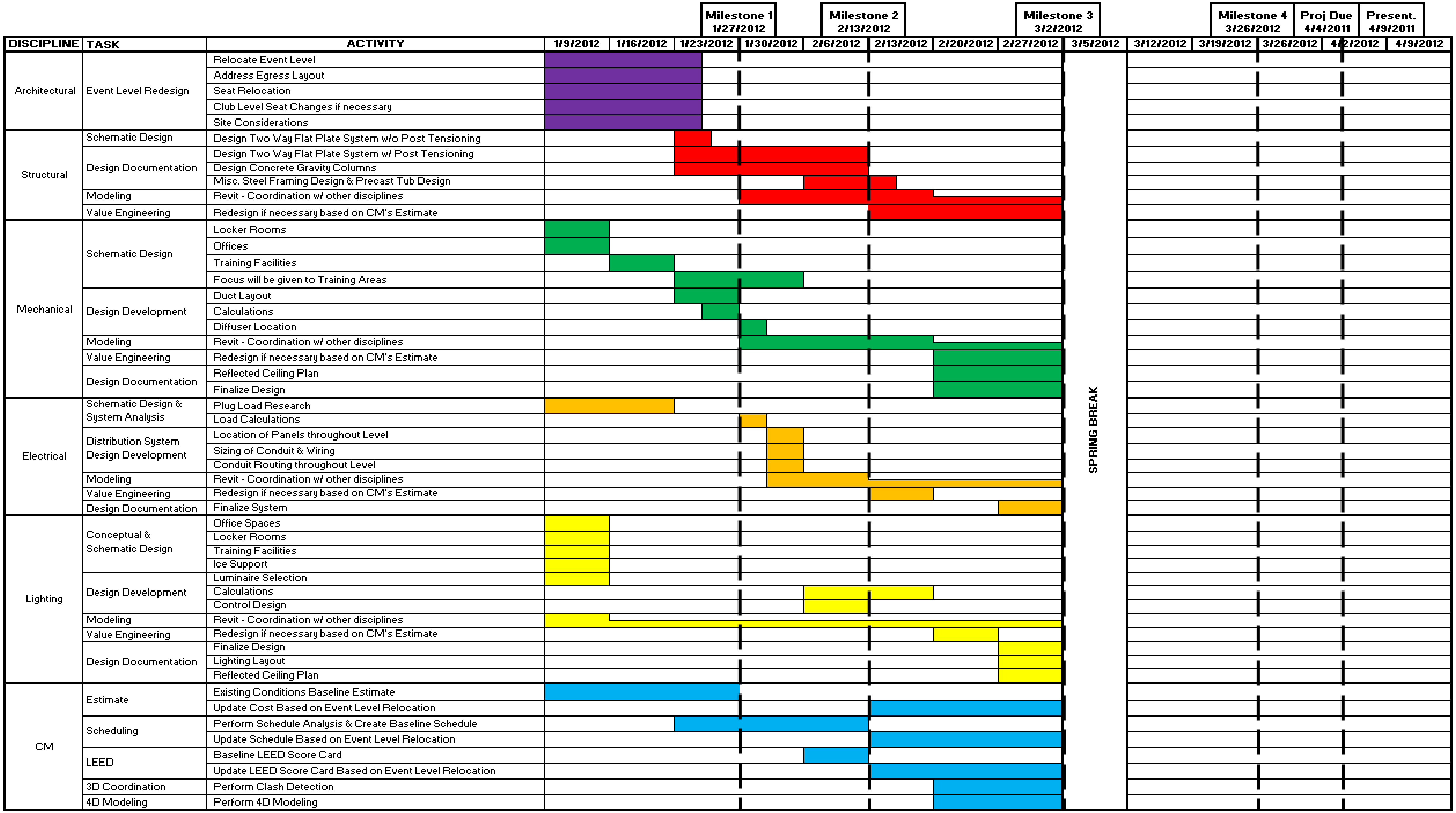
Figure 30: Proposed Schedule for Alternative Design 1

Figure 31: Proposed Schedule for Alternative Design 2



DISCIPLINE	TASK	ACTIVITY
Architectural	Air Handeler Relocation & Event Level Redesign	Relocate Air Handlers
		Site Considerations
	Main Arena Roof Syster	Finalize Main Arena Roof Design
	Façade Redesign	Redesign Façade - address East façade views
Structural	Air Handeler Relocation & Event Level Redesign	Design Two Way Flat Plate System w/ & w/o Post-Tensioning
		Column Design/Redesign; Column Foundations
	Main Arena Roof Syster	Long Span Truss Alt. Research & Opt.
		Long Span Truss Design; Misc Steel Members for Roof
	Façade Redesign	Exterior Columns, Exterior Glazing Panels
Mechanical	Air Handeler Relocation & Event Level Redesign	Event Level Load Calcs, Concept Design ERV for train facilities
		Select AHU & Determine Structural Load, Locate/Size Duct Press
		Finalize Design, Size/Locate Low Press duct/diff, Reflect Ceil
	Main Arena Roof Syster	Volumn Calcs, Size Ducts, Locate Diffusers
		Life Safety Systems (Sprinkler & Smoke Exhaust)
	Façade Redesign	Trace-Load & Energy Analysis
Electrical	Air Handeler Relocation & Event Level Redesign	Plug Load Research, Load Calcs, Early Coord Issues
		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 / Daylighting	Air Handeler Relocation & Event Level Redesign	Daylight Analysis
		Light study Ev Lvl Rms, Calcs, Intigrate Daylight, Lum Select, Controls
		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
	Air Handeler Relocation & Event Level Redesign	Update Estimate, Schedule, & LEED Score Card
		Perform 3D Coordination, Clash Detection, 4D Modeling
	Main Arena Roof Syster	Perform Crane Analysis
		Site Utilization Analysis
	Main Arena Roof System	Update Cost, Schedule, & LEED Score Card
		Perform 3D Coordination, Clash Detection, 4D Modeling
Report / Presentation	Architectural	Complete Architectural Report
	AHU Relocate	Complete Air Handler Relocation & Event Level Redesign Report
	Main Arena Roof Syster	Complete Main Arena Roof System Redesign Report
	Façade Redesign	Complete Façade Redesign Report
	Final Report	Complete Final Report
	Presentation Powerpoin	Complete Presentation Powerpoint
	Practice	Practice Presentation

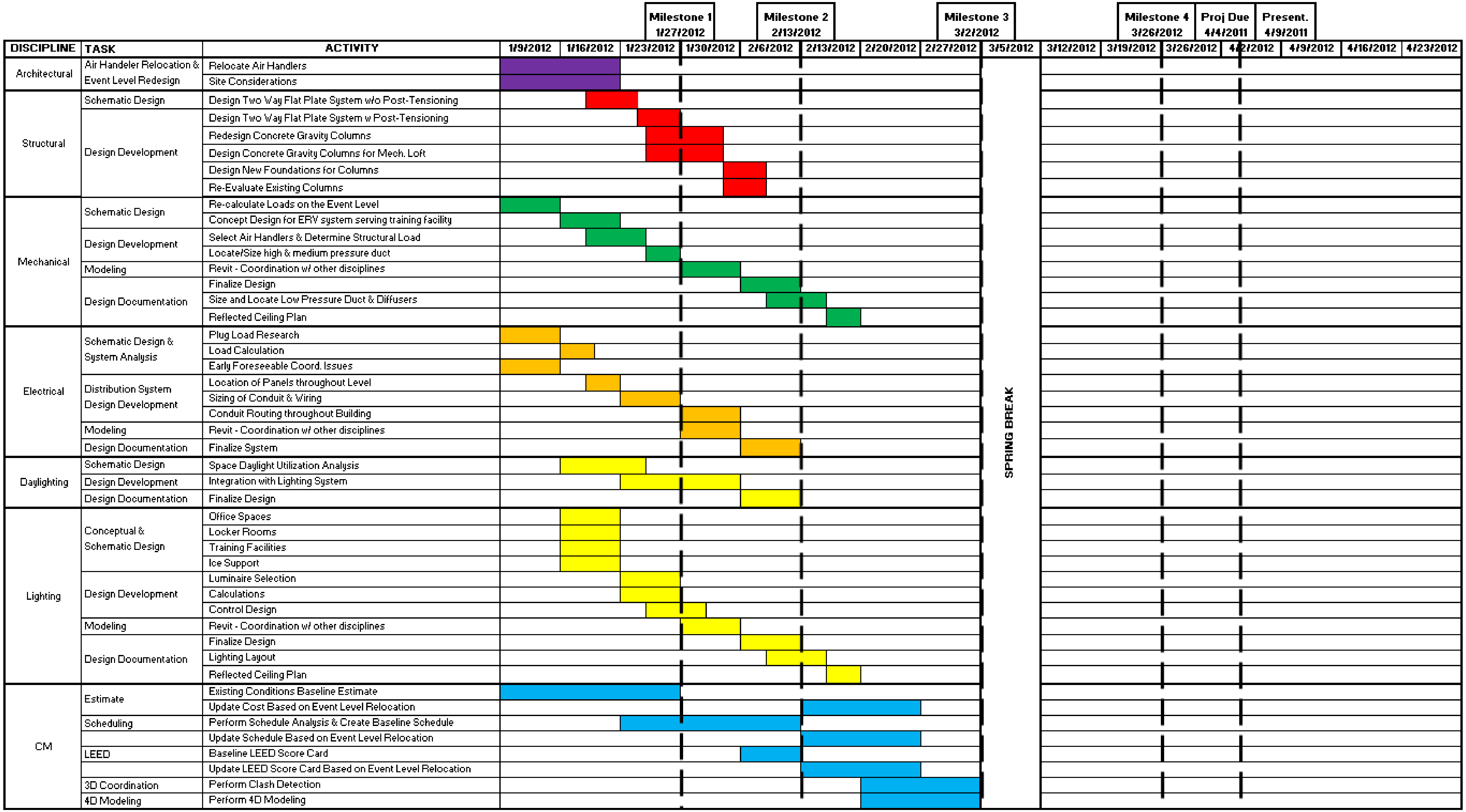
Figure 32: Detailed Schedule – Event Level Relocation



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 Redesign	Relocate Event Level	🟪	🟪	🟪						SPRING BREAK					
		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							🟦	🟦						

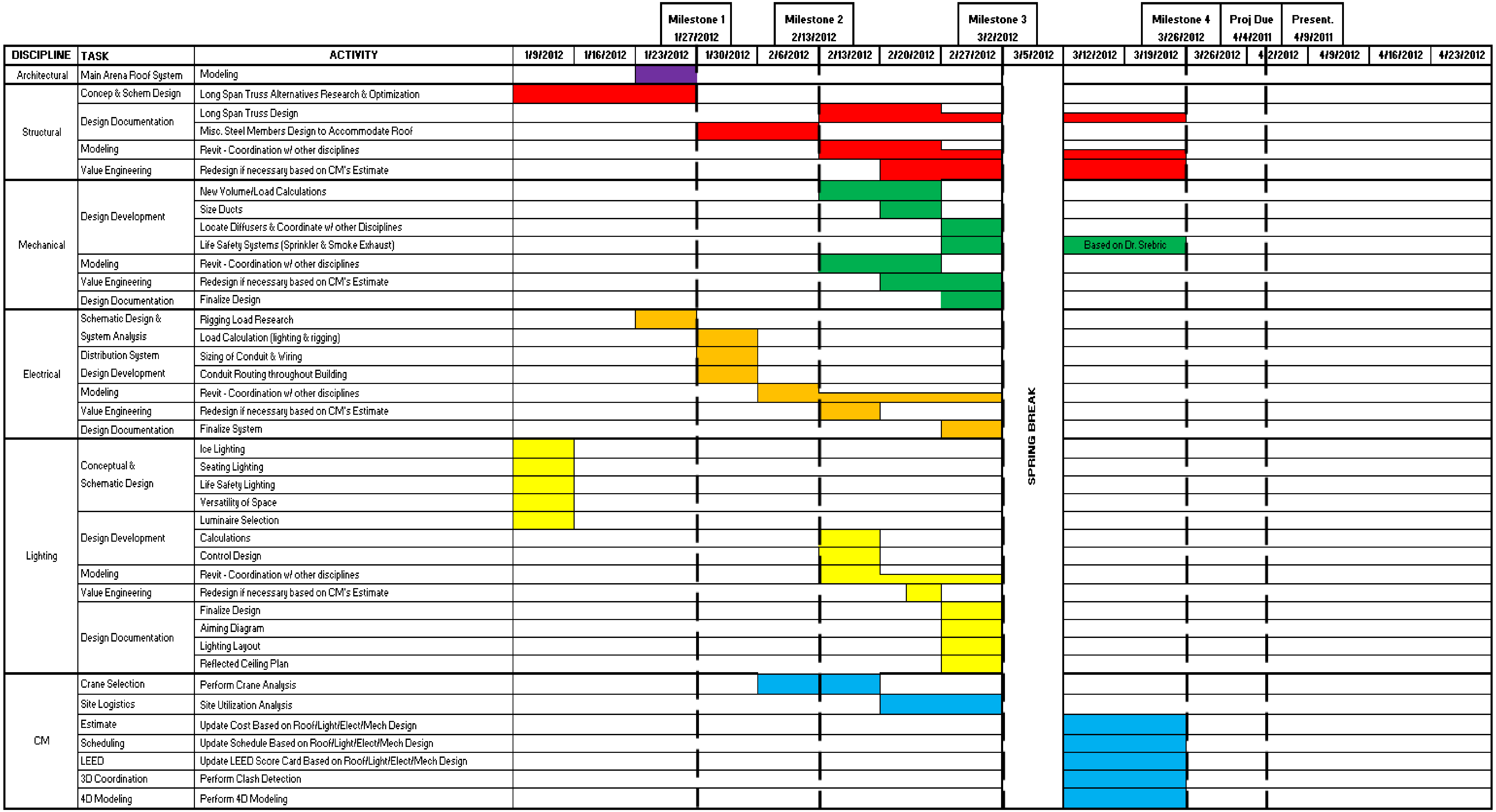
Figure 33: Detailed Schedule – Air Hander Relocation & Event Level Redesign



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

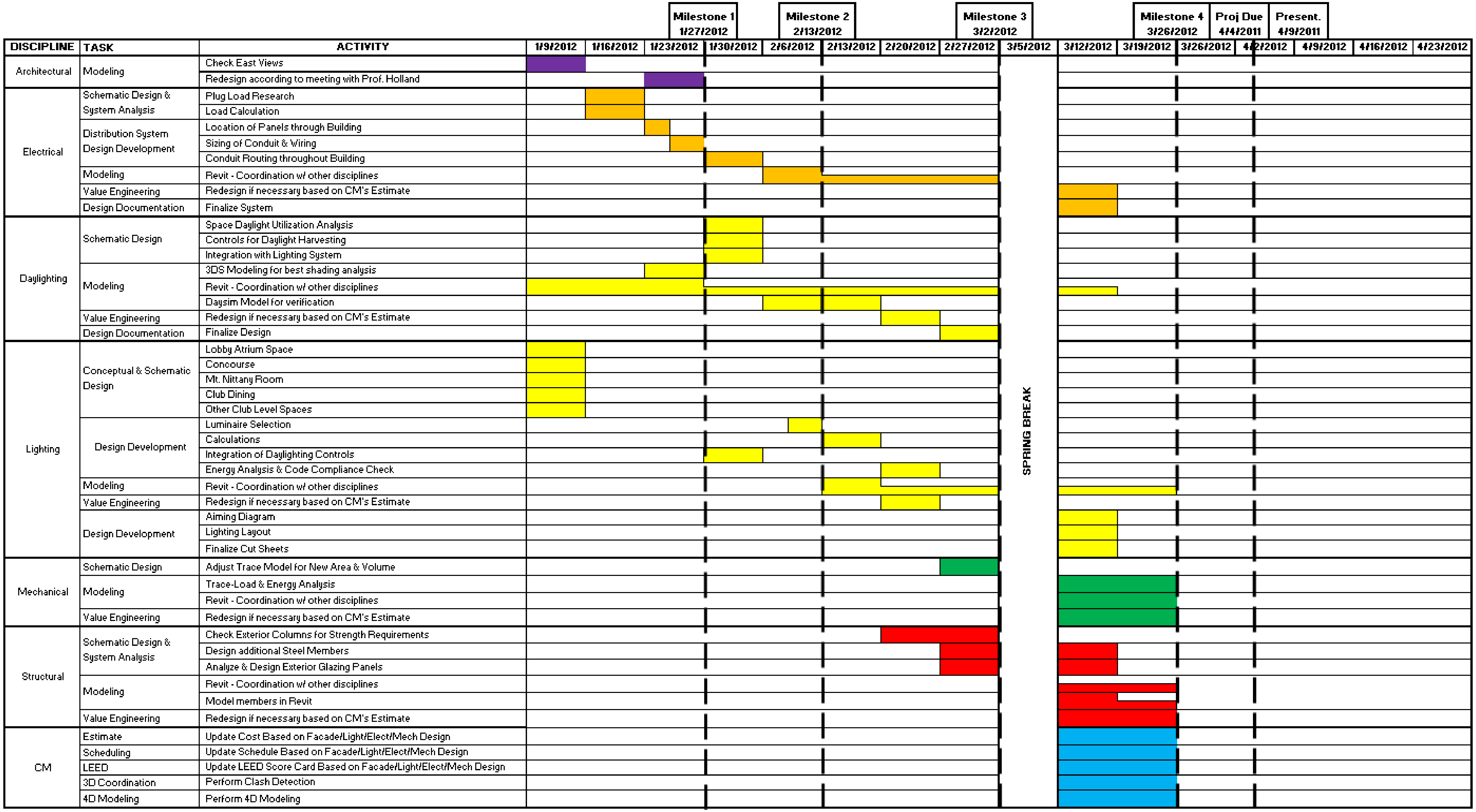
DISCIPLINE	TASK	ACTIVITY	1/9/2012	1/16/2012	1/23/2012	1/30/2012	2/6/2012	2/13/2012	2/20/2012	2/27/2012	3/5/2012	3/12/2012	3/19/2012	3/26/2012	4/2/2012	4/9/2012	4/16/2012	4/23/2012
Architectural	Air Handeler Relocation & Event Level Redesign	Relocate Air Handlers	🟪	🟪							SPRING BREAK							
		Site Considerations	🟪	🟪														
Structural	Schematic Design	Design Two Way Flat Plate System w/o Post-Tensioning		🟥	🟥													
	Design Development	Design Two Way Flat Plate System w Post-Tensioning			🟥													
		Redesign Concrete Gravity Columns			🟥	🟥												
		Design Concrete Gravity Columns for Mech. Loft			🟥	🟥												
		Design New Foundations for Columns				🟥	🟥											
		Re-Evaluate Existing Columns				🟥	🟥											
Mechanical	Schematic Design	Re-calculate Loads on the Event Level	🟩															
		Concept Design for ERV system serving training facility		🟩														
	Design Development	Select Air Handlers & Determine Structural Load		🟩	🟩													
		Locate/Size high & medium pressure duct			🟩													
	Modeling	Revit - Coordination w/ other disciplines				🟩												
	Design Documentation	Finalize Design					🟩											
		Size and Locate Low Pressure Duct & Diffusers					🟩	🟩										
		Reflected Ceiling Plan						🟩										
Electrical	Schematic Design & System Analysis	Plug Load Research	🟧															
		Load Calculation		🟧														
		Early Foreseeable Coord. Issues	🟧															
	Distribution System Design Development	Location of Panels throughout Level		🟧														
		Sizing of Conduit & Wiring			🟧													
		Conduit Routing throughout Building				🟧												
	Modeling	Revit - Coordination w/ other disciplines				🟧												
	Design Documentation	Finalize System					🟧											
Daylighting	Schematic Design	Space Daylight Utilization Analysis		🟨	🟨													
	Design Development	Integration with Lighting System			🟨	🟨												
	Design Documentation	Finalize Design					🟨											
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				🟨												
	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 34: 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 35: Detailed Schedule – Façade Redesign

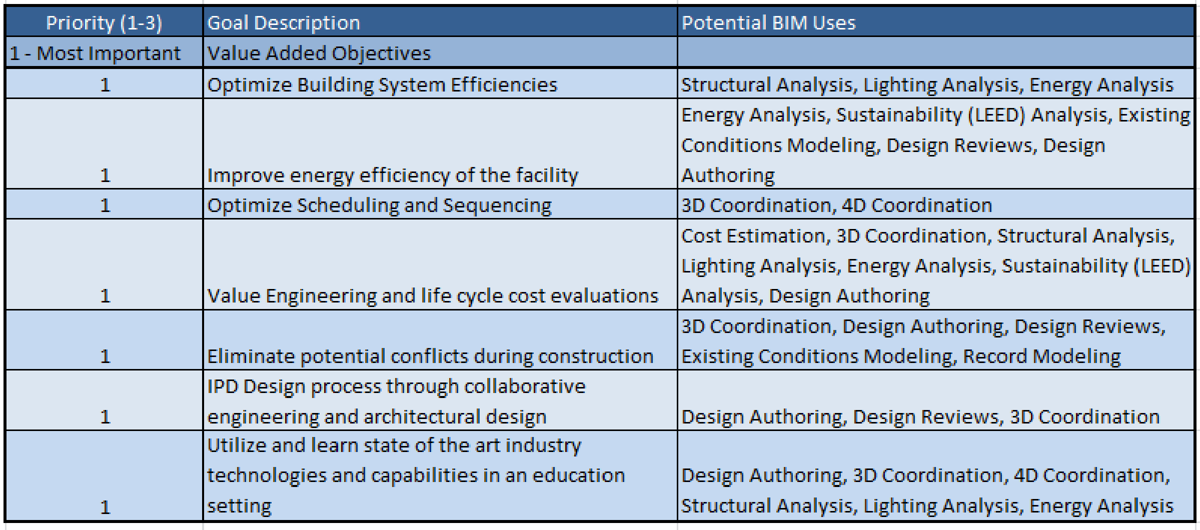


Milestone 1 1/27/2012
Milestone 2 2/13/2012
Milestone 3 3/2/2012
Milestone 4 3/26/2012
Proj Due 4/4/2011
Present. 4/9/2011

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 E: 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 F: 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 two of my other masters classes, both neither will lead directly to a deliverable like the 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.