December 6th 2010

IPD/BIM THESIS PROPOSAL

KGB
Maser
Management. Engineering. Consulting.

BIM/IPD TEAM #3

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EXECUTIVE SUMMARY

The following report contains a proposal of KGB Maser's strategy to research and redesign various aspects of The Pennsylvania State University's Millennium Science Complex. The team, which consists of Jason Brognano, Michael Gilroy, Stephen Kijak, and David Maser, will work in an integrated fashion using Building Information Modeling programs throughout the semester. The primary goal of KGB Maser's investigation is to reduce building energy consumption and offset initial increases in the cost of the building.

Three specific aspects of the analysis are:

- Decreasing the energy required by the mechanical distribution system and laboratory fume hoods
- Modifying the façade to benefit daylight delivery, structural efficiency, and mechanical system redesign
- Decreasing the structural cost to warrant upgrades within mechanical and electrical systems

The redesign of the mechanical system will include an analysis of replacing variable air volume systems in the office spaces and less dense fume hood lab spaces with a chilled beam and dedicated outdoor air system. Also, the face velocity of fume hoods will be analyzed for energy efficiency and operator safety.

The façade redesign will incorporate structural concerns, constructability issues, and impact the energy use of the building. Decreasing the weight of the precast panels will affect the structural system by reducing the bearing load on exterior columns. Each façade interacts differently with available daylight and will be examined for shading and daylight delivery. The cost and scheduling of newly designed panels will be tracked.

The existing structural system has been drastically affected by vibrational and architectural parameters. Changing the cantilever to include a single column could save on cost and coordination time. The proposed solution aims to provide a less costly structure that is aesthetically pleasing. Vibrational concerns have necessitated the use of larger, stiffer members in the floor and lateral systems. Castellated beams could be used to reproduce the stiffness needed for vibration and will provide an opportunity to enhance coordination with distribution systems.

Each member will be responsible for a portion of a collaborative building information model that will be used throughout the spring semester to coordinate and communicate system designs between team members and advisors. BIM use will be tracked and analyzed at the end of the semester for effectiveness during research and redesign efforts for the Millennium Science Complex.

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MILLENIUM SCIENCE COMPLEX OVERVIEW

Figure 1: Rendering of Millennium Science Complex, image from RVA

The Millennium Science Complex is a 275,000 SF science and research facility, specifically constructed for the Materials Science and Huck Institutes of Life Sciences at The Pennsylvania State University campus in University Park, PA. This state-of-the art research facility will be a signature building for Life Sciences and Material Sciences which will house interdisciplinary research between faculty and students.

The building consists of two perpendicular wings that meet to form the 155-ft cantilever. The 4-story laboratory facility also features stepping green roofs, stepping cantilevers, quiet lab spaces, and nano-clean rooms (Class 1000/100). The building is wrapped with a complex pre-cast panel system that blends the brick theme of the campus and the flowing continuous horizontal lines laid out by Rafael Vinoly Architects.

EXISTING FAÇADE & BUILDING ENCLOSURE

A complex pre-cast panel system comprises the majority of the Millennium Science Complex's building enclosure. Each of the 338 precast pieces were fabricated in York, PA and shipped to the site by flat-bed trailer. The exterior is clad in "Penn State" brick with bands of recessed dark-fired brick adhered to 6" of concrete. This panel is backed by 4" of rigid insulation and a vapor barrier.

Each nominal 22' panel is mechanically attached to the exterior column structure by a seat connection and a threaded rod. Between each precast section, two panes of glass are broken by an exterior shading device, meant to help control solar heat gain and glare while adding a valuable aesthetic feature. The lower vision lite wraps around the entire building providing views to the exterior, while the upper lite is fritted and meant to improve daylighting.

EXISTING MECHANICAL SYSTEM REVIEW

The Millennium Science Complex is equipped with an efficient, reliable, and energy conscious mechanical system. Campus steam and chilled water lines are used as the source of heating and cooling. This eliminates the need for spacious equipment such as boilers and chillers that consume large amounts of energy. Steam pressure is reduced from the incoming pressure of 140 psi to medium pressure steam at 60 psi and low pressure steam at 15 psi. Steam is used for sterilization, other process loads, and in heat exchangers that create the hot water used in VAV reheat-coils. Three variable speed split case pumps are used in junction with a jockey pump to deliver chilled water throughout the building.

Air is distributed to the laboratories from a 100% outdoor air VAV system. There are a total of five laboratory AHUs, each sized at 50,000 CFM. Laboratory spaces were required to have 100% outdoor air in order to help ensure that ongoing experiments were not altered or tainted by recirculated air. Similarly, the animal holding facility areas and clean room are served by 100% outdoor air AHUs to ensure proper indoor air quality. Phoenix venturi valves are used to ensure proper ventilation and pressurization with these systems.

Enthalpy wheels were used to recover energy from laboratory exhausted air and heat recovery coils were used on the animal holding and clean room AHUs. A dedicated fume hood exhaust system removes contaminated air from laboratory fume hoods and directs them straight out of the building. Three other 40,000 CFM VAV systems serve the supporting office and common area spaces. These areas do not require 100% outdoor air and therefore are specified to use 15% outdoor air.

An energy consumption analysis will explore alternate strategies aimed at enhancing the distribution system with chilled beams, improving the fume hoods, and incorporating the effect of the façade redesign on system sizing. It is anticipated that mechanical redesign efforts will decrease the overall energy usage of the building as well as decreasing maintenance efforts needed by chilled beams.

EXISTING LIGHTING AND ELECTRICAL SYSTEM REVIEW

Millennium Science Complex merges two buildings into one, a Life Science wing and a Material Science wing. The electrical system is a simple radial system with three service entrances. One service entrance feeds the normal double-ended switchgear, while one feeds emergency loads, and another feeds life-safety loads.

The main emergency system is run as a normal/emergency load, switching over to an emergency generator via eight automatic transfer switches located in the basement of the Material Science wing. A second emergency system, feeding all of the buildings life safety loads, is fed from an emergency generator switchboard located in the adjacent Life Science I Building.

After entering the Millennium Science Complex, the voltage system is stepped down to 480/277V. This voltage supplies all lighting loads, motor and HVAC equipment loads, and specialty equipment loads. Several transformers then step the voltage down to 208/120V to be used for receptacle loads, security system, and fire alarm.

Unique loads of the building include both the Clean Room in Material Science, and the Vivarium in Life Science. The clean room uses its own dedicated switchgear located in the basement of Material Science. Clean Room loads have not yet been designed, and are unknown as of now. The Vivarium loads are fed from multiple distribution panels located in the central hallway of the first floor of Life Science.

Typical office spaces have wall-mounted occupancy sensors located at the switch. The Conference and Seminar rooms have ceiling-mounted occupancy sensors. The controls also utilize four separate programmable zones, allowing for different scene selections. Perimeter open are zones have ceiling-mounted occupancy sensors tied into Lutron’s Ecosystem. This allows the fixtures in the zone to be integrated into the daylighting system. These fixtures have dimming capabilities that adjust depended on photo sensor readings.

EXISTING STRUCTURAL SYSTEM REVIEW

A composite floor system with typical 22 foot square bays constitutes the floor system of the Millennium Science Building. The typical floor layout of the wings contains a centralized corridor flanked by laboratories or offices on either side. The floor loads are handled by three types of composite floors used throughout the building, the most common of which is a 3 inch 18 gage deck with 3¼ inch light weight concrete topping. The concrete and composite decking is supported by W21 beams and W24 girders which frame into W14 columns. Beyond the typical dead and live loads, there are specialty loads from the green roof, mechanical equipment, and the pedestrian traffic at the entrance which call for increased slab strengths. The central bay in each wing is oriented perpendicular to the rest using W18 beams, rather than the typical W21 in order to save space for large mechanical equipment which runs underneath these beams. Plenum space is generally crowded with mechanical equipment and superstructure requiring an extra 7-8 feet of space above the ceiling. The gravity system is controlled by vibrational criteria in the wings. Vibrations are limited to 2000 micro inches/second in the Life Sciences wing and 4000 micro inches/second in the Material Sciences wing; due to these constraints, beams and girders are sized two to three times their required sizes to increase stiffness. A lightweight concrete is used for topping in the decking as well to reduce mass.

Two moment frames, several bays of braced frames, and two stairwell shear walls along with the concrete walls integral with the cantilever make up the lateral system for the building. These staggered frames and walls distribute the lateral forces over the entire building, preventing excessive localized stresses in the diaphragm. State College itself does not suffer from large wind or seismic loads given its geographical location and its lateral system more than suffices in resisting the design lateral loads.

To cope with the massive stresses induced by the 150 foot cantilever, a truss design was used to handle the gravity forces. Gravity loads start from the tip of the cantilever and are transferred into diagonal compression members. Continuing on the load path, the truss feeds into a 30” shear wall integral with the truss frame. The loads are then transferred into the foundation through enlarged pile caps connected by substantial grade beams. These enlarged pile caps and grade beams act in compression and tension on the soil, using micropiles as anchors. The trusses in the cantilever were designed to work alone, separate of the concrete shear walls which were later added to the project to prevent vibrational propagation through the trusses. These C-shaped concrete walls integral with the trusses serve only as massive dampers and are not critical to the structural integrity of the cantilever.

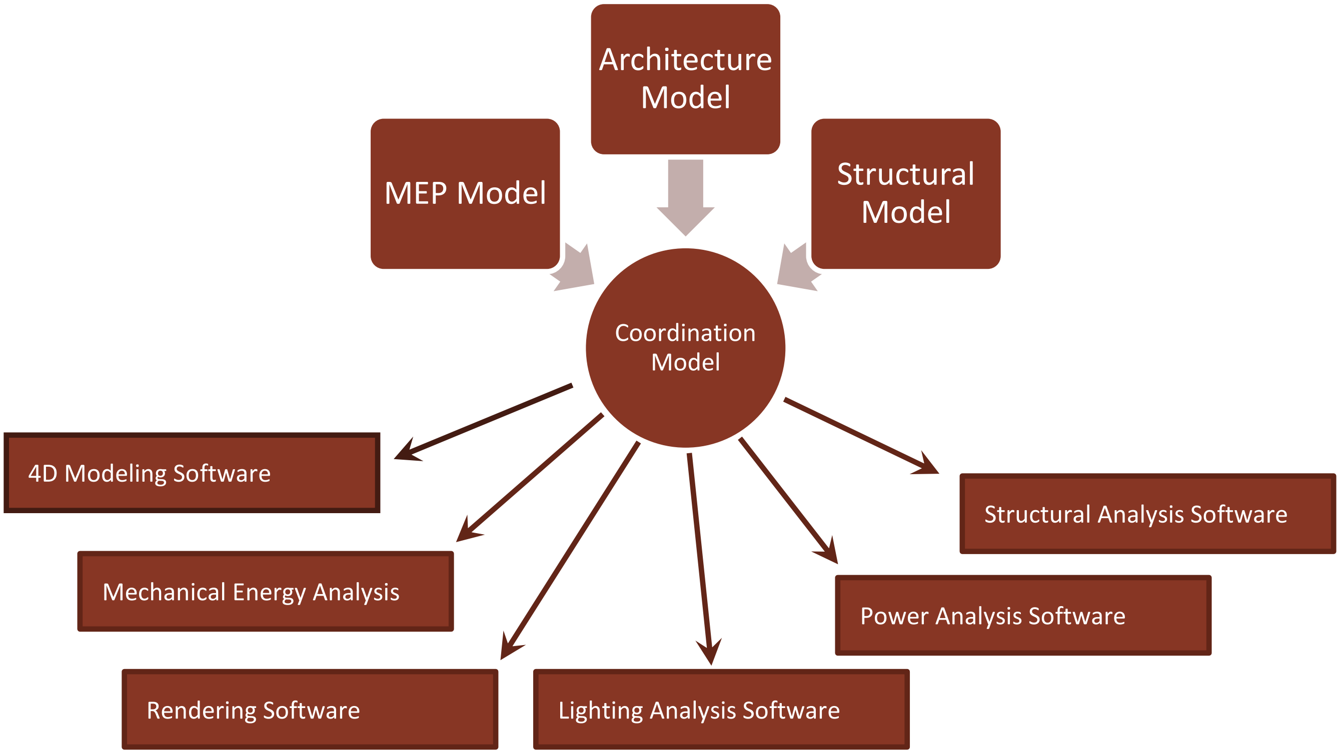
KGB-MASER’S OBJECTIVE

KGB Maser’s primary goal is to decrease energy consumption by 10% in comparison to the Millennium Science Complex as designed. The nature of space use in laboratory buildings causes large amounts of energy to be focused in the mechanical and electrical systems of the building. The mechanical system redesign will drive design changes for the entire building. Funding for the mechanical and electrical systems changes, as well as façade alterations will come from cost-saving redesign of the structural system, downsizing within the electrical distribution system, and resizing of façade panels.

KGB Maser has been working in the IPD/BIM environment throughout the year and will continue their endeavors with BIM programs into the next semester. Existing models of the MEP systems, structural system, and architecture are linked to one central Revit file that can be shared by all group members. Linked models have costs attributes linked to equipment that will be changed throughout the design process. Cost attributes allow the construction manager to perform more detailed take-offs and scheduling estimates in a timely manner. Other uses of BIM technologies include exporting models from Revit platforms to structural analysis, 3D rendering, HVAC analysis, and lighting analysis programs.

Redesign of the Millennium Science Complex systems will be considered successful with an overall energy use reduction for the building. Energy uses under scrutiny are the mechanical and power systems. Secondary to energy use will be cost impact with breaking even being the minimum level of acceptance. Additional initial costs associated with mechanical and electrical system upgrades will be offset with anticipated structural system savings.

Redesigns in the electrical and mechanical systems will be applied to the third floor of the Millennium Science Complex. This floor contains a diverse space set including laboratories, offices, conference rooms, student lounges, and service spaces. Upon analyzing completed design implications, these cost, schedule, and price changes will be applied to the rest of the building through square foot scaling. Success in analysis will be determined by the amount of operating cost savings and the net cost savings from all disciplines redesign.



ENERGY CONSUMPTION REDUCTION

The principal goal of KGB Maser's redesign of the Millennium Science Complex is the exploration and implementation of energy saving measures. The HVAC system of building typically accounts for the majority of energy use within any building. Laboratory buildings in particular are more energy-intense due to the extra requirements necessary for 100% outdoor air systems, fume hood exhaust, and other specialized process loads and equipment. KGB Maser proposes using active chilled beams in combination with a dedicated outdoor air system and supporting perimeter hydronic systems to heat and cool the majority of the building. The mechanical distribution redesign will replace the existing variable air volume system in those spaces. Also, fume hoods will be analyzed to find the optimum face velocity in order to further decrease the energy consumption.

Mechanical system changes will affect the electrical system in a large way. The power system is currently squeezed in to every corner of plenum spaces and shafts. The mechanical system power requirements yield very large equipment with very large lead times for installation. KGB Maser proposes mechanical changes that will downsize electrical equipment and eliminate some circuits. The proposed active chilled beam system also provides opportunity to integrate electric lighting with heating and cooling of perimeter office spaces, essentially combining two ceiling items into one.

MECHANICAL DISTRIBUTION SYSTEM REDESIGN

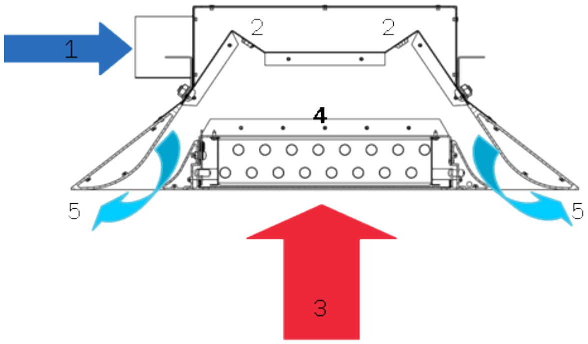


Figure 2: How Active Chilled Beams Work. From Dadanco

Chilled beams are an emerging technology in the United States but have been widely used in European countries. The active chilled beams that are being proposed in the redesign of the HVAC system will deliver ventilation air from a central AHU unit to distributed chilled beam units. Ventilation air will be sized to handle the latent and ventilation requirements. At each chilled beam, room air is induced up into the beam, mixed with fresh ventilation air while passing water coils, and discharged back into the room. Figure 2 depicts the way an active chilled beam will function.

In comparison to the existing VAV design, utilizing chilled beams will generate energy savings by downsizing AHUs, decreasing the amount of distribution ductwork needed, and avoiding zone level reheat energy. However, chilled beams cannot efficiently serve all spaces within the Millennium Science Complex. Areas that contain a large number of fume hoods increase the amount of ventilation air needed for exhaust requirements. In this case, the heat transfer properties of chilled beams may limit their use in areas where airflow needs are driven by numerous fume hoods. Chilled beams may drive up the initial cost of the mechanical system. Also, the indoor environment needs to be designed properly to ensure that condensation does not occur within the chilled beams at any operating condition. More time will be needed to effectively design and install these systems than the existing VAV system. This will need to be considered in the construction schedule and impact on design fee. In the case of the Millennium Science Complex, the concentrated fume hood areas may not be effectively served by chilled beams due to the high volume of air that needs to be delivered and the heat transfer characteristics of chilled beams. The new design will need to address this issue by effectively separating the chilled beam spaces from the VAV spaces to avoid unfavorable thermal conditions.

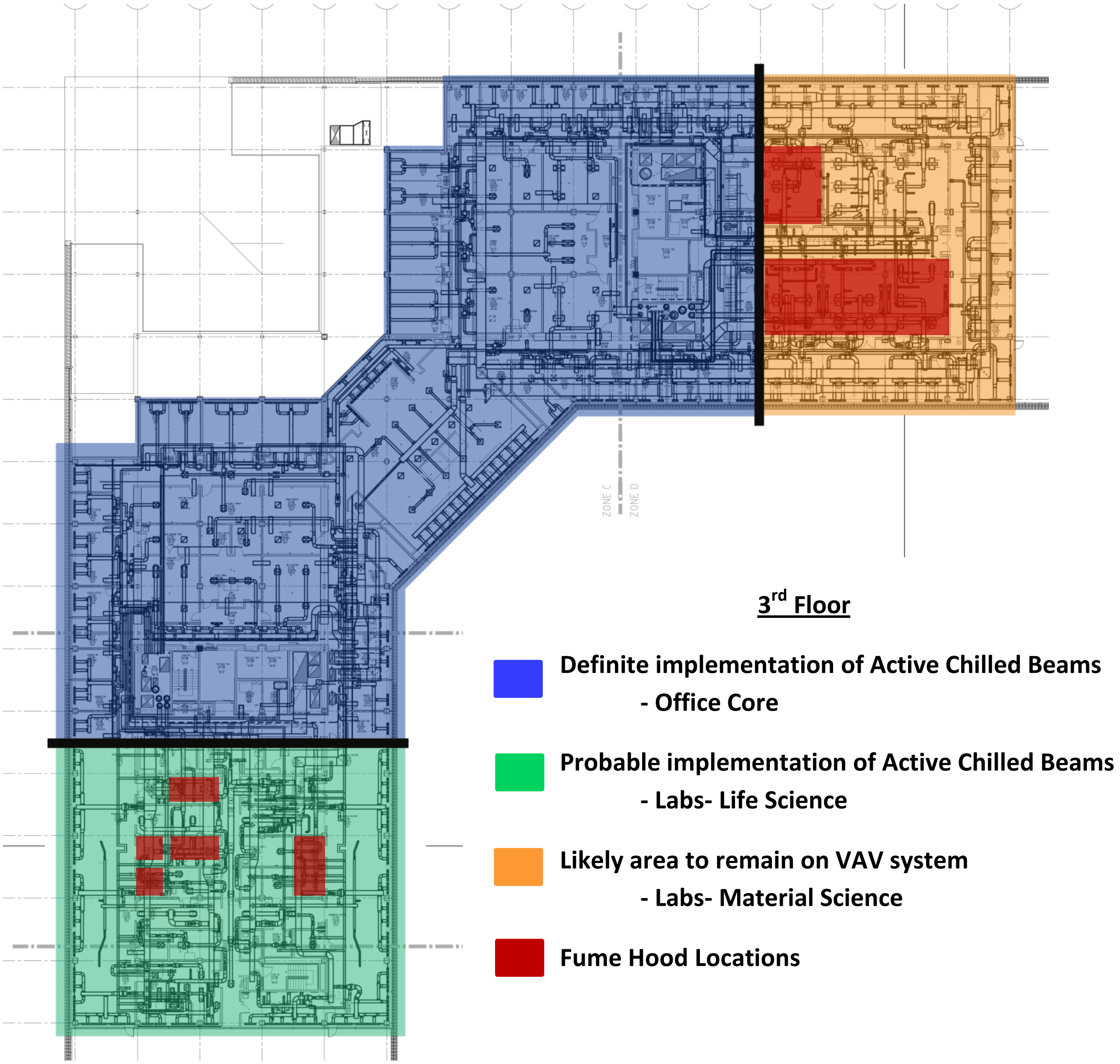


Figure 3: Chilled Beam Breakdown

As shown above in Figure 3, chilled beams are viable within the central office spaces because of smaller ventilation requirements. The laboratory wing of the Life Science appears to support use of chilled beams due to a low density of fume hoods. In comparison, the Material Science wing contains laboratory areas with a large number of fume hoods that could negate the energy saving effect of chilled beams. If the Material Science wing were to be served by a separate VAV system, doors would need to be installed to avoid pressurization issues during operation.

Two Trane TRACE models will be prepared to analyze the Millennium Science Complex's current and proposed redesign. A zone level model will be prepared to compare total energy use. For chilled beam sizing and dedicated outdoor air system design, a space by space model of the 3rd floor will be further developed from previous analysis.

The 3rd floor model will produce the sensible loads within the spaces that the chilled beams will need to accommodate. A product will be selected from a manufacturer will be selected and modeled in Revit MEP. Revit MEP and hand calculations will be used to size distribution ductwork and central air handling units, layout and coordinate ductwork with the structural redesign, and interface further with other disciplines' models.

The overall goal is to provide a "clean" mechanical distribution system that can save on operating costs, work with other systems to support the functions of the Millennium Science Complex, and can be easily maintained.

REDUCED FUME HOOD FACE VELOCITY

As previously mentioned, laboratory fume hoods are a major source of energy consumption because of the necessary exhaust requirements for operator safety. According to the specifications, all of the laboratory fume hoods are specified for a face velocity of 100 or 125 feet per minute which has been the design standard despite OSHA's allowance for face velocities to decrease to as low as 60 feet per minute. If the face velocity of Millennium Science Complex's fume hoods can be safely decreased, the amount of air that is required to be exhausted decreases. This not only results in fan energy savings but could also allow for further chilled beam coverage and more of the previously mentioned energy savings.

Ductless fume hoods, previously mentioned in earlier reports, will likely not be installed in place of conventional ducted exhaust fume hoods despite the potential for energy savings. Most other university and large scale research facilities do not permit the use of ductless fume hoods for a variety of reasons. Ductless fume hoods are considered unreliable by the National Institutes of Health for safe operation due to maintenance of filters and reliability of the technology itself.

An analysis of the vapor concentration utilizing CFD programs can be used to prove the safety of using lower face velocities. Figure 4 shows an example CFD analysis on contaminants within a fume hood. Airflows and the power to the fans for both the existing face velocities and lowered face velocities will be compared to determine ductwork savings and exhaust fan operating savings. 3rd floor fume hood ductwork will be incorporated into a Revit model for 3D coordination.

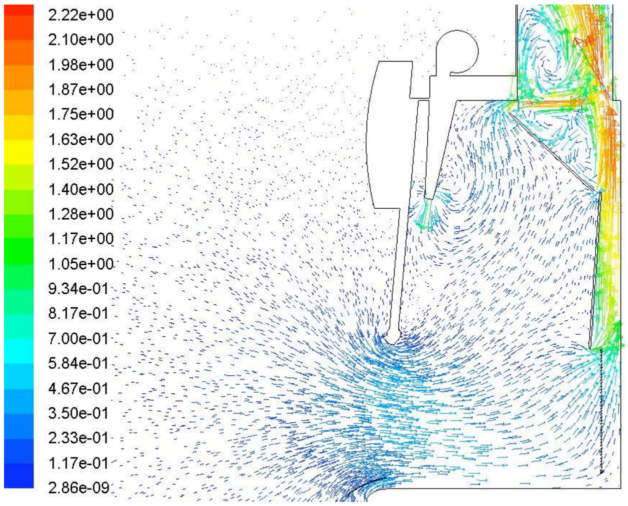


Figure 4: Example Computational Fluid Dynamics Fume Hood Analysis. From ESCO Micro Pte Ltd

ELECTRICAL SYSTEM IMPACT

The electrical system will be affected by the change in mechanical system delivery. With the possible reduction to air handling unit size and unit motors being moved to different circuits, KGB Maser will examine the possibility of reducing or changing sizes of elements in the power distribution system. Less air handling units will lead to less motors load and the cascading effect may allow for the removal or reduction of expensive equipment.

The goals for the electrical system redesign include reduction in size of at least one major piece of equipment (transformer, distribution panel, switchgear, capacitor bank, etc.), reduction in size of major feeders, and the removal of mechanical-specific distribution equipment through consolidation into a motor control center. Figure 5 below illustrates where system size reduction may take place.

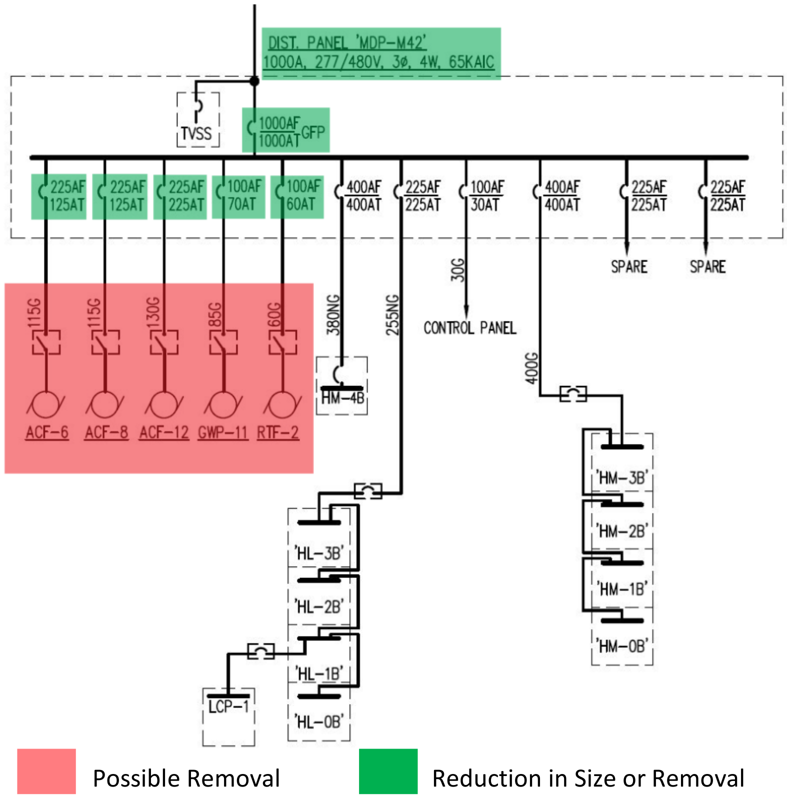


Figure 5: Single line diagram changes

By removing motor loads shown in red, the ability to remove five large breakers, downsize the main overcurrent protective device, and downsize the distribution panel frame are possible. There will be motor loads for chilled and hot water pumps, as well as exhaust and DOAS fans to still be included in the system. These extra loads will consolidated into a motor control center to save space within the penthouse.

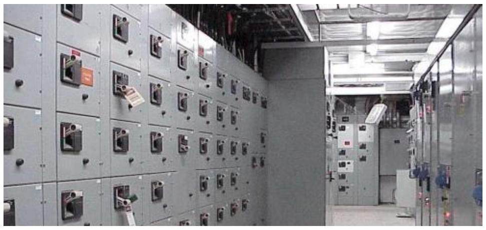


**Figure 6: Large-scale motor control center.
Image from www.powerstudies.com**

To analyze the impact of the mechanical system change, a portion of the existing power system will be modeled in SKM Power Tools. SKM analysis software allows for electrical engineers to construct single-line diagrams of a building's electrical system and perform short circuit capacity, arc flash, voltage drop, and other analyses to assure proper sizing of equipment. KGB Maser will limit this portion of the analysis to the third floor and its feeding components. Two models will be created throughout the semester:

- An existing third floor model with equipment sizes from construction documents as a baseline
- An updated third floor model with electrical equipment changes due to mechanical system changes

Successful redesign will be measured by reduction in cost of the electrical system. The new system model can be sized by SKM and component attributes will be analyzed side-by-side upon completion. Smaller transformers, smaller feeder wires, smaller capacitor banks, and smaller distribution panels will be considered achievements. Ultimately, the smaller equipment leads to less occupied space in electrical rooms, less occupied space in plenums, and less cost to the construction of the building. Maintenance and dependability will be unchanged as system components will be comparable in function and only changed in size.

OFFICE LIGHTING DESIGN INTEGRATION

The mechanical system provides opportunity for integration with lighting design. Currently, the offices along the perimeter of the Millennium Science Complex utilize recessed linear fluorescent luminaires. The acoustical tile ceiling must be coordinated with smoke detectors, supply air diffusers, return air grilles, perimeter heating diffusers, and luminaires. There are many aspects of offices that need to be addressed in lighting design. The particular office being designed by KGB Maser is a "Distinguished Office" for high-ranking faculty.

Figure 7: Active chilled beam with integrated lighting. Image from www.troxusa.com.

As the name describes, the office will be a standard above the rest. There will be accolades on the walls (degrees, awards, publications, etc.), extensive reference material on bookshelves, a computer terminal for communication purposes, and a large L-shaped desk for work. Each of these aspects will be addressed in lighting design.

Opportunities arise from the use of active chilled beams with integrated electric lighting. Chilled beams in combination with recessed linear fluorescent luminaires will provide ambient and direct light for the occupant. As the space has many tasks associated with its occupancy, task-specific lighting will be added for known activities within the space. These known tasks include bookshelf interaction and display of accolades on walls. Recessed linear fluorescent fixtures will keep thermal interaction with chilled beams to a minimum and will be selected to blend with the appearance of chilled beam surfaces.

Daylight integration will also be considered in this space. A further discussion of façade changes can be found in the daylighting topic in the façade redesign section of this document.

To achieve lighting design goals, KGB Maser will use BIM technologies to share geometric information across design platforms. Once chilled beams are modeled into the MEP model, it will be exported for design analysis in Daysim and AGI32, followed by rendering in 3D Studio Max Design. Lastly, a switching and circuiting diagram will be composed for the space.

A successful lighting design will be achieved if all design criteria are exceeded. These achievements include meeting uniform illuminance levels, seamless integration of electric light within the reflected ceiling plan, and performing better than ASHRAE Standard 90.1 for lighting power density.

STRUCTURAL IMPACT

The proposed floor system of the Millennium Science Building will utilize castellated/cellular beams and girders in its layout. It is anticipated to use the voids, which penetrate the beams, as spaces in which to run mechanical and electrical equipment. Whether or not mechanical ducts are changed in size will govern if the voids are in fact big enough to run sizable equipment through them. It will be a collaborative process between the structural and mechanical engineers to find a meeting ground which will economize the size of beam, and therefore the void through it, with the appropriate and necessary size of mechanical equipment. Currently, the ducts are slightly too big to fit through a 27” deep cellular beam and would therefore require a larger, deeper beam to accommodate the 24” by 14” ducts. Potentially, the mechanical system will be revised for maximum energy efficiency and may be able to utilize these voids without the need for excessively deep girders or beams; this would relieve congestion in the plenum space and reducing floor to floor height. The gain of energy efficiency would potentially result in a savings of structural materials, thereby reducing overall structural cost.

CONSTRUCTABILITY & COST INPUT

The proposed floor system of the Millennium Science Building will utilize castellated/cellular beams and girders in its layout. It is anticipated to use the voids, which penetrate the beams, as spaces in which to run mechanical and electrical equipment. Whether or not mechanical ducts are changed in size will govern if the voids are in fact big enough to run sizable equipment through them. It will be a collaborative process between the structural and mechanical engineers to find a meeting ground which will economize the size of beam, and therefore the void through it, with the appropriate and necessary size of mechanical equipment. Currently, the ducts are slightly too big to fit through a 27” deep cellular beam and would therefore require a larger, deeper beam to accommodate the 24” by 14” ducts. Potentially, the mechanical system will be revised for maximum energy efficiency and may be able to utilize these voids without the need for excessively deep girders or beams; this would relieve congestion in the plenum space and reducing floor to floor height. The gain of energy efficiency would potentially result in a savings of structural materials, thereby reducing overall structural cost.

FAÇADE REDESIGN

A second goal of KGB Maser's redesign strategy includes major changes to the skin of the building to reduce temperature moderation of spaces and reduce costs in structure and constructability. As the Millennium Science Complex interacts with the environment, the majority of thermal energy is exchanged through the exterior surfaces of the building – walls, glazing, roofs, etc. Details concerning the panels govern aspects of construction, structure, daylight delivery, and mechanical strategies. In construction, panel size governs number of deliveries, frequency of deliveries, site space requirements during construction, crane sizing and overall building cost. Structurally, the panels affect size of building members, stiffness of cantilever support systems, and vibration mitigation. Solar gains through the panels affect how occupants interact with the space and how much energy the building will consume in its lifetime. Specific changes to the glazing will include an increased light to solar gain ratio and the addition of shading devices tailored to each orientation of the façade.

The façade redesign strategy will address concerns outlined above. Currently, the panels enveloping the building skin are very thick, very heavy pre-cast concrete panels with face brick attached to their surface. Panel system changes include the following:

- Change of glazing above and below louvered overhangs
- Reduction in weight of panels
- Maximized size of panels for efficient delivery to the site
- Specific shading styles for each orientation of the façades
- Thermal optimization of the panels

DAYLIGHTING

Daylighting is intertwined with façade geometry and mechanical properties of the building glazing. The Millennium Science Complex utilizes tall window walls striping the building that are separated vertically by a louvered overhang. A combination of the overhang and wall thickness protects the interior spaces from high angle direct solar gain. The largest interaction between mechanical and lighting applications is facilitated by glazing. Currently, fritted glass is used to minimize gains in combination with top-down operating roller shades to minimize discomfort from direct glare from sunlight.

The first aspect of the daylight delivery system changes will be spectrally selective glazing in lower view glass. Spectrally selective glass maximizes light to solar gain ratio transmission through the glass. Figure 8 below shows how PPG Triple Silver Solar Control Low-e glazing operates relative to specific wavelength transmissions. Figure 9 outlines specific performance criteria relative to other glazing types. The spectrally selective glazing may also include slight tint to hide daylight control systems on the interior side of the glazing.

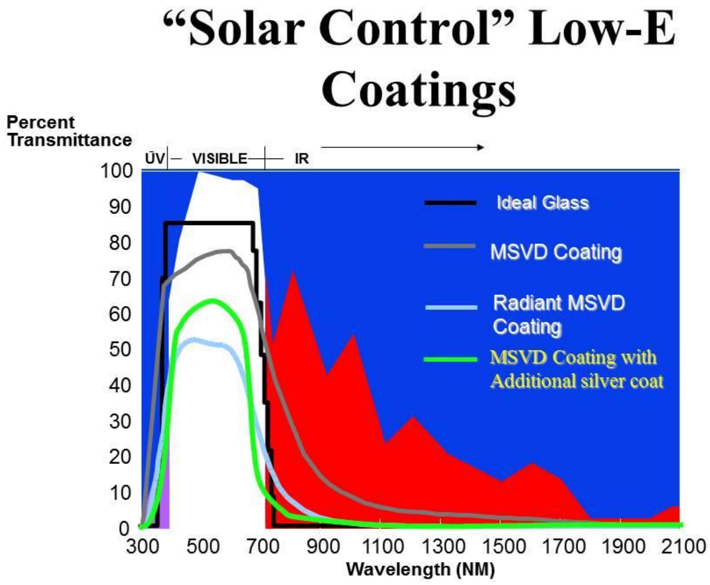


Figure 8: MSVD Coating performance graph courtesy of Darijo Babic, PPG

Glass Type	Winter U-Value	VLT	SHGC	LSG
Uncoated Glasses				
Clear Glass	0.47	79%	0.70	1.13
Ultra-Clear Glass (Low-iron glass)	0.47	84%	0.82	1.02
Blue/Green (Spectrally Selective) Tinted Glass	0.47	69%	0.49	1.41
Coated Glasses				
Pyrolytic Low-E (Passive Low-E) Glass	0.35	74%	0.62	1.19
Triple Silver Solar Control Low-E	0.28	64%	0.27	2.37
Tinted Solar Control Low-E	0.29	51%	0.31	1.64
Subtly Reflective Tinted	0.47	47%	0.34	1.39
Blue/Green Reflective Tinted	0.48	27%	0.31	0.87

Figure 9: Glazing Energy and Environmental Performance Data courtesy of Darijo Babic, PPG

With close cooperation between the lighting designer and mechanical engineer, an appropriate glass will be chosen to achieve both thermal and daylighting objectives for the space. Gratitude is expressed to Darijo Babic for the permission to use the above PPG research data.

Secondly, perimeter windows will be outfitted with shading devices specific for each orientation of the façades. Each side of the building interacts differently with the sun throughout the day and must be accounted for to assure occupant comfort. The shading will be interior to the glazing and, through cooperation with the glazing material, not interfere with the architect's expression of horizontality in the façade.

KGB Maser will analyze the effectiveness of the proposed shading practices in daylight delivery while changing from continuous dimming to switching algorithms. Ballast cost is lower in switching applications, but total energy savings may be hindered. To account for abrupt and noticeable light loss in switching, indirect-direct fixtures will be used while switching the direct portion of the lamps. Ambient light will still be present from indirect ceiling wash and lessen the effect of losing the direct portion of light output. This application will address desk tasks. Other tasks design criteria that will be addressed in this design include computer work at workstations and vertical reading tasks such as announcement postings.

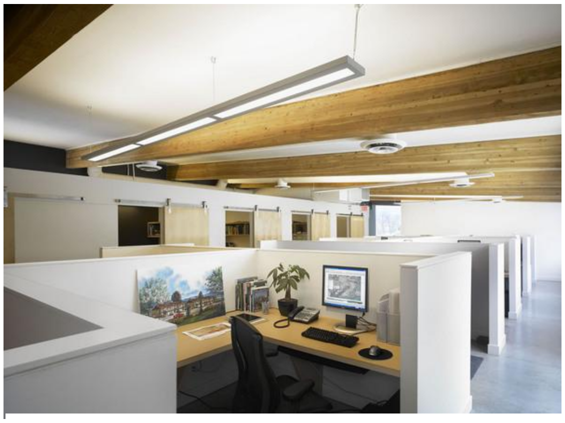


Figure 10: Indirect-direct lighting application, http://www.ledalite.com/products/sync

Figure 11: Task-specific lighting application, http://www.foiusa.com/SWAPPID/96/SubPageID/37960

Similar to the office space design, KGB Maser will use BIM technologies to share geometric information across design platforms. Phase change glazing will be modeled in the architecture model and be exported for design analysis in Daysim and AGI32, followed by rendering in 3D Studio Max Design. Finally, a switching and circuiting diagram will be composed for the lighting components in the space. This design is slightly different from the office space will not utilize switching or dimming.

A successful lighting design will be achieved if all design criteria are met. These achievements include meeting uniform illuminance levels and performing equal to or better than ASHRAE Standard 90.1 for lighting power density. Additionally, we will achieve success if the new switching algorithm combined with up-front costs will improve life cycle cost and payback of the lighting system.

ENVELOPE & PARTITION ANALYSIS

The envelope of any building is closely linked with the mechanical system requirements. The mechanical system must have the capability to overcome heat gains or losses through the envelope. As previously mentioned, KGB Maser will use two energy models will be developed in Trane TRACE. One model will analyze the third floor on a space by space basis. Another will break up the entire building into zones in order to calculate estimated energy usage building wide. These models will be run with inputs from potential envelope redesigns. Envelope loads from the model will determine the most efficient envelope construction. It is crucial that the façade redesign be resolved initially because of the direct impact the envelope has on mechanical system sizing.

Incorporating phase change material into the glazing and drywall within the Millennium Science Complex has the potential to provide more consistent room temperatures. However, after further thought, the information that is available on these products is not sufficient enough to provide valuable results.

The focus on the façade will shift to analyzing the effect of improving the insulation of the envelope and design changes desired based on construction, structural, and lighting recommendations and. Currently the facade contains a pre-cast panel system that contains 2" brick, a 6" concrete backing, and 4" of rigid insulation. The roof also contains areas of green roof on the lower levels and a rigid insulation and black EPM waterproofing membrane on the mechanical penthouse roof. These areas of the building envelope will be evaluated based on thermal and cost effectiveness. Software tools such as the HAM Toolbox and the previously mentioned zone-level Trane TRACE energy model will be used to determine the proper facade strategy.

STRUCTURAL IMPACT

Weight of the façade panels will be the biggest factor to take into account in terms of the structure. As it stands in the existing conditions, the panels generate large forces on the exterior columns requiring them to be sized as big as the interior columns which have twice the tributary area. Not only do these panels weigh heavily on the gravity system, they increase the weight of the entire superstructure which increases the seismic design forces. Decreasing the weight of the panels may require less lateral stiffness as the seismic design forces currently control over wind. The method of attachment to the columns and superstructure must also be considered for seismic conditions.

CONSTRUCTABILITY

A change to the existing design of the pre-cast panel façade will have to be investigated while taking multiple things into consideration. Initial cost, life cycle cost, maintenance scheduling, and the constructability of the façade redesign will all have to be considered while selecting a façade system. Given the nature of building usage at Penn State, longer payback periods relative to typical commercial buildings will be acceptable.

The precast panels of Millennium Science Complex cost $5.6 million, and are currently a substantial load on the structural system. The cost can easily be reduced by researching other cost effective designs and erection time of the building enclosure can be reduced by further prefabricating connections, or making each panel lighter. A 4D model could be produced for the erection duration of the existing façade design and KGB Maser's façade redesign for comparison. It will certainly be more of a challenge to achieve a redesign of the façade system that both performs better with respect to energy and daylighting while maintaining the architectural theme desired by Rafael Vinoly Architects and The Pennsylvania State University.

KGB Maser's main constructability concerns and possible benefits for our proposed façade redesigns include the fact that decreasing the weight of each panel could result in being able to ship more than one panel to the site at a time, however a lighter panel may be more prone to cracking during delivery. Another constructability issue being looked at is the size of each panel. If the panels can be lengthened, and made to a bigger nominal size of up to 60' in length, the number of deliveries and picks for the façade will be reduced.

STRUCTURAL REDESIGN

The existing structure is extremely costly amounting to just over $90 a square foot. In order to meet our goal of decreasing energy consumption, savings must be made in order to cover the cost of more expensive, more efficient mechanical and electrical systems. The easiest way to save money is to economize the systems that are already exorbitantly costly.

Vibrational and architectural parameters have drastically increased the cost of this building beginning with a purely architecturally purposed cantilever, and rounding out the bill with abnormally high vibrational requirements due to the building's laboratory environments. One solution to this building's great expenditures would be to revise its cantilever.

CANTILEVER STRATEGY

The existing cantilever costs an inordinate amount of money for purely architectural justifications. By trading architecture for energy efficiency, KGB Maser will meet two of its goals by allowing better, more economical energy systems to be implemented into the building by shifting money allocation from the cantilever to Mechanical and Lighting. In order to make this shift happen, the cantilever needs to be redesigned with value engineering in mind. As a solution, a column, or steel pipe filled with concrete and rebar, will be added to the end of the 150 foot overhang relieving the need for oversized, deflection-controlled members by splitting the load of the overhang between the base of each truss and the point at which the column meets it. Stresses are essentially halved requiring less strength and therefore less steel which will in turn decrease the cost of the structure.

There are several options to still be explored in this concept of adding a column. The process of design explained in the following paragraphs uses a single column at the end of the cantilever as illustrated in figure 12. Several other options are being explored centering around the idea of adding a "bird cage" underneath the cantilever, confined by the window box in the ceiling of the overhang, to add a piece of interest to the existing building while masking the presence of columns. Using more than one column will further alleviate stresses inside each truss, but will also affect the present layout of the basement isolation labs by piercing the vibrational sensitive rooms with columns. A new configuration of the labs will need drawn up, as will a solution to vibrational propogation through the isolation slabs from the columns.

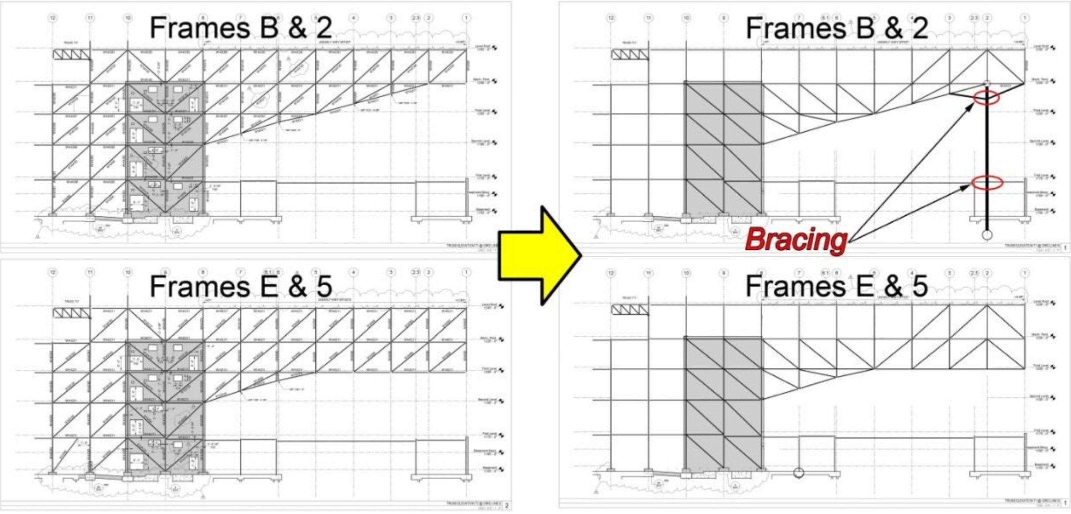


Figure 12: Column Example: One idea is to place the support for the cantilever at the intersection of the outside two trusses

In order to add a column to the cantilever, the existing structure must first be analyzed. An ETABS model will be created cooperatively between the structural students as it will benefit each of us to have an existing conditions analytical model. Using the drawings and Revit models given to us, a model will be built from the ground up using material properties and loads gathered from the plans and tech report one. Once complete, the model will be run and examined thoroughly for load paths in the trusses and throughout the rest of the cantilever. This initial process will provide vital information on member forces and the reasoning behind the current orientation of members.

Trial truss layouts with a column at the end, represented by a pin, will be created using the information garnered from the existing conditions model. These trusses will be drawn in SAP2000 and subjected to distributed loads similar to those seen in the current building. The objective of this exercise is to experiment with different layouts using the benefits of a computer program, which returns nearly immediate results, to perfect the orientation and layout of members. Once forces are found to be diluted enough throughout the truss, the layout will be noted and applied to a proper ETABS model. This step will be the first addition to the redesigned ETABS model.

After an initial sizing of members from existing load conditions, the cantilever will be run in ETABS as a whole and analyzed for strength in a gravitationally controlled scenario. The current cantilever is controlled by serviceability conditions, and it is presumed that the same will be so of the redesigned model. A deflection limit of 2 inches will be used and checked in the gravity analysis run. A re-assessment of loads will be conducted at this point in order to size the column. Assuming the column will be unbraced for a length of 15 feet due to the lateral support provided by our bird cage, an initial size will be found from strength requirements. A final run of the cantilever will be conducted and analyzed for strength and deflection.

The entire process should yield a building cheaper than that of the existing layout and would allow money to be reallocated elsewhere thereby satisfying the goals that KGB Maser has established. The structure should simplify coordination in the mechanical penthouse by eliminating braces and relieving the need to navigate around unfortunately placed members while maintaining a deflection limit of 2 inches.

FLOOR AND LATERAL SYSTEMS STRATEGIES

A second way to economize the building is in the floor system. Vibrational constraints have oversized the gravity members in the wings two and even three fold. Since the required stiffness necessitates beams and girders to be oversized, the only way to optimize the current floor system is by making it lighter. The current system employs normal W-flanges and lightweight concrete to meet vibrational requirements. Using castellated or cellular beams would satisfy stiffness constraints for a smaller amount of weight. This would in turn make the building marginally lighter and more efficient. The lighter superstructure could also benefit the lateral system as the lighter mass would be subjected to the same ground acceleration resulting in smaller seismic design forces.

The lateral system is positioned in a very conveniently staggered way throughout each wing of the building. An analysis of the existing system will be run. This analysis will include building a complete ETABS model of the existing design to which both wind and seismic loads will be applied. The results returned from the analysis will be used to check story drifts, torsional irregularity, and confirm presumed load paths of lateral loads through the lateral force resisting system. An explanation of the results will also be included, explaining potential inconsistencies with code requirements. The initial analysis will be done cooperatively between the three structural BIM students due to the similarity of their work; evaluation of the results will remain as an individual objective.

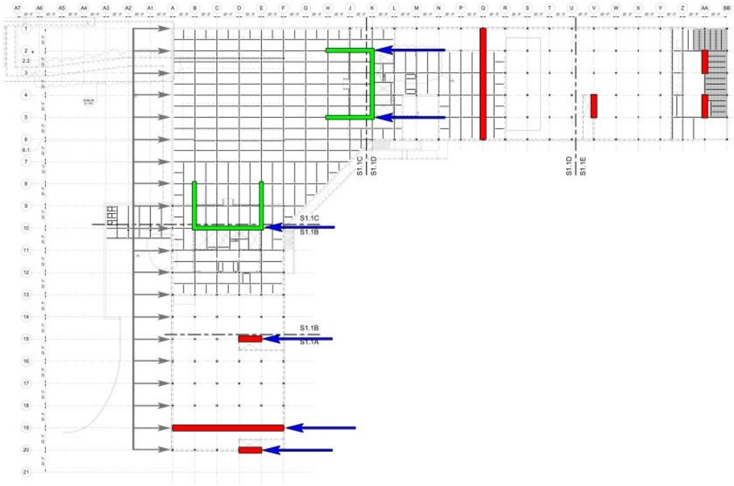


Figure 13: Existing Lateral System Placement

Designing the floor system falls at the beginning of the model building process. Before designing a preliminary cantilever, the floor system will be sized and checked starting with an assessment of existing loads. The metal decking, beams and girders will be sized based on vibrational criteria. Members not under vibrational constraints will be sized under normal strength requirements. A re-assessment of self-weight and gravity loads will be conducted and used to check strength and deflection.

The gravity and special systems will now have preliminary sizes. Each system will be entered into the ETABS model and run for a gravity analysis. Member strength and floor deflections will be checked in accordance with AISC and ASCE7, respectively, and iterations will be run as necessary. Finally the existing lateral system will be run in ETABS using loads acquired from Tech 1, and the analysis will be used to check story drift and torsional irregularity requirements.

Figure 14: Example castellated beams coordination with distribution systems. From ArcelorMittal

The final design should illustrate the benefits of using castellated beams and girders over normal W-flanges, providing a lighter, more efficient structure while still meeting vibrational requirements. Beams and girders would be sized comparably to the existing floor system using the voids and channels through which mechanical equipment may travel, an example of which is shown in figure 14, decreasing the necessary amount of plenum space and reducing floor to floor heights. The design would also be finished in a timely manner despite the complications of vibrational analysis, especially considering how recently the topic has been introduced to us. Constant collaboration with the MEP engineer will dictate the successful implementation of cellular beams, it being an ongoing and communicative process to coordinate each system efficiently and effectively. The lateral system would not need extra bracing, using moment connections instead to distribute the lateral forces.

CONSTRUCTABILITY & COST INPUT

The current structural system for Millennium Science Complex costs $24,559,974 or $90.06/SF. This cost is from the bid packages found Office of Physical Plant’s website. KGB Maser is investigating and developing multiple systems to support the 150-ft cantilever. Each design option will benefit the constructability and cost of Millennium Science Complex. The cost of the structure could have a significant decrease with the integration of columns placed underneath the cantilever, or other supporting methods. The use of other supporting systems will also help eliminate some on the truss bracing that is a concern for coordination on the 4th floor penthouse.

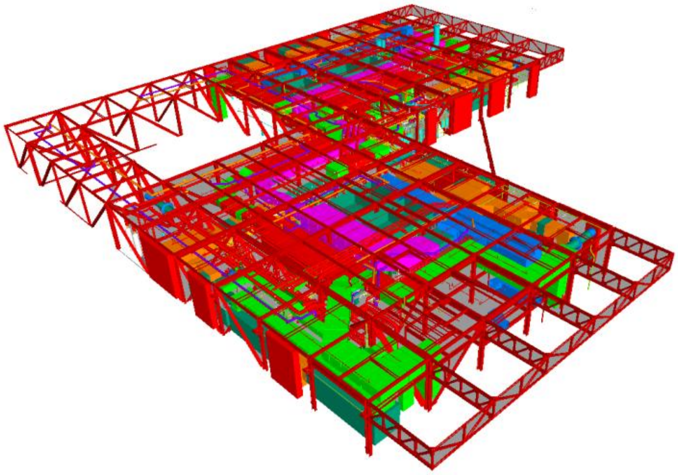


Figure 15: Coordination Model of 4th Floor Penthouse

Extensive resources were also allocated by Whiting-Turner and Thornton Tomasetti to the in depth sequencing and erection process planning that was necessary to construct the cantilever. With a column being placed for support under the 150-ft cantilever, the construction sequencing becomes much simpler.

The use of columns or other support methods, besides the current truss system, are expected to benefit the constructability by allowing more space for coordination, specifically on the 4th floor penthouse, and to reduce the total tons of steel for Millennium Science Complex. The cost of the structural system, erection duration, and the amount of planning and sequencing are all expected to be reduced, due to the reduction in the complexity of the structural system, specifically the 150-ft cantilever. A site logistics study and a crane study will also be completed to analyze whether a smaller crane can be used, or if the sequencing of the structural system can be changed to allow for less site congestion. With the addition of supports under the cantilever, it is expected that a smaller crane will be able to be used for steel erection. The site logistics study will also take into consideration the erection of the pre-cast panels.

BUILDING & SITE IMPLICATIONS

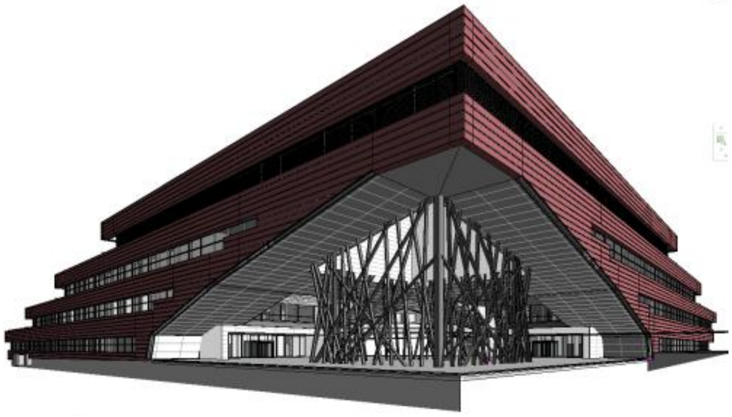


Figure 16: Rendering of proposed column concept

Adding a naked column to the building would clash with the architecture and take away from Rafael Vinoly's intention to make the building appear as if it were floating. In order to maintain the appearance of a lighter-than-air building, any addition to the cantilever must flow from the cantilever rather than to the cantilever; this will maintain disparity between the building and the ground. To accomplish this ideal while still using columns, the supports must become elements of the architecture. Using inspiration from the "Bird's Nest" stadium in Beijing, China, steel tubing will weave about and tie into the cantilever supports, thus blending into the architecture as seen in figure 16. The tubing will double as lateral bracing for the columns, reducing the unbraced length of the supports by twenty or more feet. By using multiple columns, stresses in the trusses would be reduced, but it require a new layout for the basement plan. Columns would continue through the plaza floor into the basement and the foundation and thereby penetrating the isolation slabs. This situation may allow vibrations to travel through the columns and into the slabs. One solution would be to place the column's pile cap deep beneath the thickened slab to preserve as much of the vibrational isolation that existed before. The isolation slab would be placed around the column allowing for a barrier of neoprene or some other material to limit vibrational propagation from the column.

A structural redesign that decreases the depth of members or utilizes castellated members could provide an opportunity to optimize the mechanical system distribution within the plenum space. Chilled beam systems typically need to deliver less amount of air and require smaller distribution ductwork. If floor to floor heights could be decreased, the building could have construction savings. However, due to the complexity of the distribution systems and the sizing of castellated members to accommodate distribution systems, it may not be possible to decrease floor to floor heights. In this case, smaller ductwork in the same plenum space could make the building easier to construct and maintain.

COURTYARD LIGHTING

The courtyard beneath the cantilever will be redesigned should the structural redesign prove to be feasible. A paradox exists in this space due to the sensitivity of spaces below. Paths within the landscape are designed to keep foot traffic away from disrupting nanotechnology labs below. A column, or columns, addition will provide an interesting architectural form to be lighted along with flowing paths within the courtyard. The new design as seen in Figure 17 will also include redesign of landscaping and path layout.

Design considerations for the courtyard include highlighting the locations of entrances beneath the cantilever, emphasizing paths for pedestrians to take, and keeping light levels sufficient for Penn State safety policies. Again, the space will be updated in the architectural, structural, and MEP models and exported to analysis platforms. In keeping with BIM processes, the cantilever will use an alternative file sharing path compared to other spaces.

Measures of success include power densities below the ASHRAE Standard 90.1 values and compliance with established IES design criteria.

MECHANICAL APPROACH REVIEW

ENERGY CONSUMPTION

I. Energy Modeling
  a. Zone Level Model- Trane TRACE
    i. Zone spaces by area, use
      1. Office
      2. Labs
      3. Interior
      4. Exterior (North, South, East, West)
    ii. Create load, airflow, construction and room templates
    iii. Model existing and redesign systems
    iv. Model plants
    v. Define Economics
    vi. Run model and compare results
  b. 3rd floor Model- Trane TRACE
    i. Update with system and façade changes
    ii. Run model and compare results
  c. Measures of Success: annual and monthly operating costs, maintenance costs, initial cost comparison

II. Cooling/Heating Strategy
  a. Obtain sensible loads from 3rd floor energy model
    i. Determine which areas can effectively utilize chilled beams
  b. Select manufacturer for chilled beams
    i. Download Revit family
  c. Place chilled beams in applicable spaces in Revit MEP
  d. Determine if additional perimeter system is needed based on peak loads
    i. Size and locate perimeter system in Revit MEP
  e. Determine additional pumping energy required

III. DOAS Design
  a. Determine the amount of ventilation air needed in each space for ventilation or latent loads
  b. Determine distribution strategy
  c. Size and layout ductwork
  d. Coordinate ductwork in plenum space
  e. Evaluate new air handler requirements and mechanical room layout

IV. Fume Hood Redesign
  a. Determine current CFM to each fume hood based on current face velocity and size of fume hood
  b. Calculate decreased CFM needed for fume hoods with decreased face velocity
  c. Size new exhaust ductwork and exhaust fans
  d. CFD analysis of vapor containment in low flow fume hoods

V. LEED/Labs 21 Analysis
  a. Evaluate the impact of the redesign efforts on both criteria

FAÇADE REDESIGN ANALYSIS

- I. Façade Energy Modeling
  - a. Analyze façade strategies
  - b. From façade redesign ideas, determine the U-factor of the wall and glazing
  - c. Run zone level energy model and determine best redesign strategy
  - d. Model if necessary in Revit, HAM Toolbox

STRUCTURAL REDESIGN

- I. Plenum Analysis
  - a. Relay desired ductwork layout to the structural engineer for appropriate sizing and use of castellated members
- II. Coordination
  - a. Coordinate mechanical distribution system redesign with other disciplines
    - i. Clash detect in Navisworks to avoid construction issues

ELECTRICAL APPROACH REVIEW

ENERGY CONSUMPTION

- I. Power system analysis
  - a. Short circuit hand calculation
  - b. Model existing power system
    - i. Gather information from construction documents and manufacturers
    - ii. Input information into SKM
  - c. Model changes to power system due to mechanical system changes
    - i. Gather power consumption and operating information from manufacturers
    - ii. Update SKM model to include motor control center design
    - iii. Input information into SKM
  - d. Run system analysis to automatically size system components
  - e. Side-by-side analysis of system size
  - f. Price out system changes with construction manager
- II. Motor control center design
  - a. Update single-line diagram and panel information from SKM output and mechanical redesign
  - b. Gather information on remaining mechanical equipment to be included in MCC
  - c. Design and layout MCC components
  - d. Locate MCC within mechanical penthouse

FAÇADE REDESIGN ANALYSIS

I. Student study area design
  a. Compose BIM model alongside mechanical engineer for export to AGI32
    i. Model chilled beams and façade geometry changes
    ii. Export to usable format in both AGI32 and Daysim through AutoCAD
  b. Select lighting gear to allow for design to meet established design criteria
  c. Utilize AGI32 analysis capabilities to assure design illuminances are met
  d. Use information from luminaires and illuminance analysis to model the space for Daysim
  e. Import room geometry into Daysim for switching analysis
    i. Add shading devices and material parameters
    ii. Model continuous dimming scenario
    iii. Record energy consumption tables
  f. Analyze cost difference between continuous dimming and switched operations
    i. Gather information from manufacturers
    ii. Perform cost analysis alongside construction manager
  g. Compose switching and circuiting diagrams for the space
II. Office lighting design
  a. Compose BIM model alongside mechanical engineer for export to AGI32
    i. Model chilled beams and façade geometry changes
    ii. Export to usable format in both AGI32 and Daysim through AutoCAD
  b. Select lighting gear to allow for design to meet established design criteria
  c. Utilize AGI32 analysis capabilities to assure design illuminances are met
  d. Use information from luminaires and illuminance analysis to model the space for Daysim
  e. Import room geometry into Daysim for switching analysis
    i. Add shading devices and material parameters
    ii. Model continuous dimming scenario
    iii. Record energy consumption tables
  f. Analyze cost difference between continuous dimming and switched operations
    i. Gather information from manufacturers
    ii. Perform cost analysis alongside construction manager
  g. Compose switching and circuiting diagrams for the space

CANTILEVER REDESIGN

I. Cantilever lighting design
  a. Compose BIM model alongside structural engineer for export to AGI32
    i. Export to usable format in both AGI32 and Daysim through AutoCAD
  b. Research outdoor lighting design practices
    i. IES lighting library recommended practices
    ii. IES handbook
  c. Select lighting gear to allow for design to meet established design criteria
  d. Utilize AGI32 analysis capabilities to assure design illuminances are met
  e. Export model to 3D Studio Max Design for rendering purposes
  f. Compose switching and circuiting diagrams for the space

STRUCTURAL APPROACH REVIEW

ENERGY CONSUMPTION

I. Coordination with Mechanical
   a. Beam depth and void size affected by mechanical equipment size
      i. Smaller equipment will feed through the beams
      ii. Larger equipment will need to pass underneath the beams
      iii. Beam depth can be altered to accommodate either mechanical scenario
   b. Beam orientation to be determined by duct layout
   c. Mechanical equipment weight on the 4th floor
      i. A reduction of energy will downsize mechanical equipment
      ii. Superimposed dead load may be decreased

FAÇADE REDESIGN ANALYSIS

I. Coordination with other disciplines
   a. A required thermal capacity of the façade may affect weight
   b. Reducing the weight of the panels for constructability
   c. Lighting Analysis requiring the addition of light shelves may add to weight
   d. Total weight change to affect exterior column size

STRUCTURAL REDESIGN

I. Cantilever Redesign
   a. Existing conditions analytical model
      i. Used to form a basis on which the redesign will be formed
      ii. Created using ETABS
         1. Collaborative effort between structural students
         2. Winter break project
      iii. Calculation of floor loads for existing conditions
      iv. A complete analysis of gravity systems
         1. Forces in cantilever used to create alternative truss design
         2. Preliminary members sized from existing conditions forces
   b. Truss Layout
      i. Comparison of existing conditions with trial truss layouts
         1. Using SAP2000
         2. Applied distributed loads based on existing conditions
         3. Analysis of member forces in preliminary layouts
         4. Evaluation of stress concentrations in truss areas
         5. Refinement of initial designs
            a. Secondary effect taken into consideration
      ii. Size members based on strength
      iii. Run analysis for deflection

1. Limiting deflection to 2 inches

iv. Size preliminary column
1. Based on kl/r with an unbraced length of 30 feet
2. Steel piping filled with concrete and rebar

v. Re-assess gravity loads and self-weight
1. Controlling factor will probably be deflection

II. Design Floor System and Lateral System
- a. Floor System
  - i. Evaluate gravity loads
  - ii. Size decking, beams and girders
    - 1. Size initially base on vibrational constraints
    - 2. Check strength and deflection
  - iii. Evaluate floor system for vibrational properties
    - 1. Check system meets vibrational requirements
  - iv. Assess weight of floor system
    - 1. Run gravity analysis for strength
    - 2. Check deflection limits
- b. Lateral System
  - i. Evaluate existing conditions lateral loads
    - 1. Taken from Tech. 1
  - ii. Position lateral force resisting elements
    - 1. Use the same layout as current system
    - 2. Calculate necessary stiffness based on distribution of loads
      - a. Check against drift and deflection limitations
  - iii. Size lateral system members
    - 1. Size base on required frame stiffness
    - 2. Use load combinations to check strength
  - iv. Check torsional irregularity

III. Combine all three systems
- a. Rerun analysis based on gravity loads
  - i. Check member strength
- b. Rerun analysis based on lateral loads
  - i. Check story drift

CONSTRUCTION APPROACH REVIEW

ENERGY CONSUMPTION

I. Track all equipment and duct sizing changes.
- a. Revit MEP will be used along with Microsoft Excel to compile equipment and duct run schedules.

II. Perform multiple cost analysis at varying levels of details for the 3rd floor and the entire building.
- a. The third floor of Millennium Science Complex will be completed with a detailed estimate of the building system redesigns.
- b. RS Means Costworks will be used along with contacting suppliers for pricing information to be used for the estimates.

III. Track the effect of design changes on the schedule.
  a. RS Means will also be researched for durations of specific tasks.

FAÇADE REDESIGN ANALYSIS

I. Track the effect of design changes on the architectural theme of Millennium Science Complex
  a. Revit Architecture will be used for viewing modeling content of design changes and creating renderings.

II. Perform multiple cost analysis at varying levels of details for the 3rd floor and the entire building.
  a. The third floor of Millennium Science Complex will be completed with a detailed estimate of the building system redesigns.
  b. RS Means Costworks will be used along with contacting suppliers for pricing information to be used for the estimates.
  c. Revit Architecture & Autodesk QTO will be utilized for detailed takeoffs.
    i. Possible direct link from Revit Architecture or Autodesk QTO to a model based estimating program.

III. Track the effect of design changes on the schedule.
  a. Research on similar spaces of the building will be completed to find durations for constructing similar spaces.
  b. RS Means will also be researched for durations of specific tasks.
  c. Precast paneling erection sequencing will be investigated and included in a Navisworks 4D model.

STRUCTURAL REDESIGN

I. Track the architectural effect of cascading columns underneath the 150-ft cantilever of Millennium Science Complex.
  a. Revit Architecture will be used for creating and viewing modeling content and creating renderings.

II. Perform a detailed structural estimate of the entire building to evaluate the design changes to the structural system.
  a. Revit Architecture & Autodesk QTO will be utilized for detailed takeoffs.
    i. Possible direct link from Revit Architecture or Autodesk QTO to a model based estimating program.
    ii. RS Means will also be consulted for cost data.

III. Track the effects of designs changes on the schedule.
  a. A Navisworks 4D model will be created to visualize the structural sequencing and erection process.

INDIVIDUAL TEAM MEMBER TASK BREAKDOWN

Appendix A contains a breakdown of tasks to be completed for each item mentioned in the team schedule. An estimated duration has been specified in order to compare to the actual duration as tasks are completed. The durations given express times that will be dedicated solely to individual task as opposed to the team schedule which stipulates the time-frames in which those tasks will be completed.

OVERALL TEAM SCHEDULE

Appendix B contains KGB Maser's agenda for the upcoming semester. Each discipline has provided their planned workflow. Information exchanges will occur throughout the semester to efficiently communicate between team members.

M.A.E. COURSE INTEGRATION

MICHAEL GILROY

To meet M.A.E. requirements during research and redesign, a study of the movement of particles within a fume hood will be completed. Information obtained from AE: 559 Computational Fluid Dynamics in Building Design will be beneficial in performing this analysis.

Information from AE 558: Centralized Heating Production and Distribution Systems and AE 557: Centralized Cooling Production and Distribution Systems will aid research and redesign efforts of the mechanical distribution systems. AE 552: Air Quality in Buildings will also be used if air quality issues arise during redesign.

STEPHEN KIJAK

Using the graduate AE courses taken in years 4 and 5, additional attention will be paid to seismic considerations, steel connections, and advanced computer modeling. Information on steel seismic design garnered from AE 538, specifically the design of ductile structures, will be applied to the lateral force resisting systems. Steel connections that see high gravity loads, especially those connecting the façade to the superstructure, and the connections which will experience high moments due to lateral forces will be examined and designed in accordance with the material learned in AE 534. Each system will be modeled in detail using ETABS by means of rigid end offsets, insertion points, diaphragms, panel zones, special constraints, mass definitions, and material definitions applied to the superstructure, as necessary, per AE 597a. The final structure will be detailed beyond that which was learned in the standard undergraduate course schedule resulting in a more accurate, more comprehensive structural solution.

LIST OF TABLES AND FIGURES

APPENDIX A: INDIVIDUAL TEAM MEMBER TASK BREAKDOWN

Stephen Kijak

Structural Engineer

			Coordination		
Task	**Expected Duration**	**Actual Duration**	**C.M.**	**L/E**	**Mech.**
Column Concept					
Model Column in 3D	1 Day				
Reconfigure Basement Layout	1 Day				
Check Aesthetics	1 Day		X	X	X
Existing Conditions Model					
Draw Members	4 Days				
Define Constraints	2 Days				
Assess Loads and Run Analysis	2 Days				
Truss Analysis					
Draw Trial Trusses in SAP	2 Days				
Gravity Analysis	3 Days				X
Refine layout and Size Members	4 Days				
Floor System Design					
Preliminary Sizing of Members	3 Days				X
Vibrational Analysis of System	5 Days				
Gravity Analysis	5 Days				X
Lateral System Design					
Assess Lateral Loads	1 Day		X		X
Calculate Necessary Stiffness	1 Day				
Lateral Analysis	3 Days				
Check Torsional Irregularity	1 Day				
Structural Model Assembly					
Assemble Systems	5 Days				
Gravity and Lateral Analysis	3 Days				
Export to Revit	1 Day		X	X	X

Construction Manager

			Coordination		
Task	**Expected Duration**	**Actual Duration**	**L/E**	**Mech.**	**Struc.**
Identify Constructability Concerns					
Façade Redesign	1 Week		X	X	X
Chilled Beam Integration	1 Week		X	X	
Cantilever Redesign	1 Week		X		X
Floor System Redesign	1 Week		X	X	X
Identify the Effect on Cost With Design Changes					
Façade Redesign					
Existing Conditions Estimate	Given				
Redesign Estimate	1 Week		X	X	X
Chilled Beam Integration					
Existing Conditions Estimate	Given				
Detailed Redesign Estimate (3rd Floor)	3 Weeks		X	X	
Final System Estimate	2 Weeks		X	X	
Cantilever Redesign					
Existing Conditions Estimate	Given				
Final Detailed System Estimate	3 Weeks			X	X
Floor System Redesign					
Existing Conditions Estimate	Given				
Final Detailed System Estimate	3 Weeks			X	X
Identify the Effect on Schedule With Design Changes					
Façade Redesign	2 Weeks		X	X	X
Chilled Beam Integration	2 Weeks		X	X	
Cantilever Redesign	2 Weeks			X	X
Floor System Redesign	2 Weeks			X	X
Construct 4D Model	3 Weeks		X	X	X
Coordinate System Redesigns	3 Weeks		X	X	X

Jason Brognano
Lighting/Electrical Engineer

Coordination

Task	Expected Duration	Actual Duration	C.M.	Mech.	Struc.
Existing Power System Model					
Input components from one-line	10 days				
Take-off feeder lengths	5 days				
Add loads to panels	5 days				
Daylight Energy Analysis/Design of Student Areas					
Create 3D model of space	2 days			X	
Luminaire selection and layout	3 days				
Analyze space in Daysim	2 days				
Compose 3D render of space	3 days			X	
Branch circuit redesign	1 day				
Office Lighting Design					
Establish design criteria	6 days				
Update 3D model of space	3 days				
Luminaire selection and layout	4 days				
Compose 3D render of space	3 days				
Branch circuit redesign	1 day				
***Laboratory Lighting Design**					
Establish design criteria	2 days				
Update 3D model of space	3 days				X
Luminaire selection and layout	3 days				X
Compose 3D render of space	3 days				
Branch circuit redesign	1 day				
Short Circuit Hand Calculation	5 days				
New Power System Analysis					
Model alternate layout in SKM	6 days			X	
Perform design analysis	2 days				
Compare equipment changes	4 days		X		
Design Motor Control Center for Mech. System					
Gather information from mechanical redesign	4 days			X	
Size components of MCC	2 days				
Layout components within MCC	2 days				
Locate MCC in building	1 day			X	X

Task	Expected Duration	Actual Duration	C.M.	L/E	Struc.
Façade Redesign					
Research and choose best envelope strategy	5 days		X	X	X
Model within energy model- U factors of construction	1 day				
Model within Revit model	2 days				
Energy Models					
Update existing 3rd floor model	2 days				
Create zone level building model	3 days				
Create load, airflow, construction templates	1 day			X	
Model campus utilities and economics					
Run model to obtain loads for distribution redesign	2 days				
Designate which spaces will be on ACB +DOAS vs. VAV	1 day				
Run both models to compare existing vs. redesign energy consumption	2 days			X	
Chilled Beam Design					
Select size based on loads from energy model	3 days				X
Identify Manufacturer	1 day		X	X	
Download Revit Chilled Beam model					
Perimeter heating sizing and locating	2 days			X	
Position for chilled beams for proper air flow (3rd floor)	2 days				X
Run ductwork and piping to ACBs within Revit model (3rd floor)	5 days				X
Analyze new pumping requirements	2 days			X	
Layout Dedicated Outdoor Air System					
Analyze latent load vs. 62.1 ventilation	2 days				
Analyze plenum space	4 days		X	X	X
Coordinate duct, piping runs with potential castellated beams	4 days				X
Size new AHU equipment	2 days			X	X
Coordinate space requirements in mechanical room	3 days				X
Reduce Fume Hood Velocities					
Tally current CFM exhausted from fans	1 day				
Calculate decreased CFM from reduced face velocity required	1 day				
Size new ductwork, fans and calculate initial and operating savings	3 days			X	X
CFD analysis to prove safety of reduced fume hood velocities	5 days				
LEED/Labs 21 Evaluation					
Evaluate redesign impact on LEED v3.0	2 days		X	X	
Evaluate redesign impact on Labs 21 EPC	2 days		X	X	

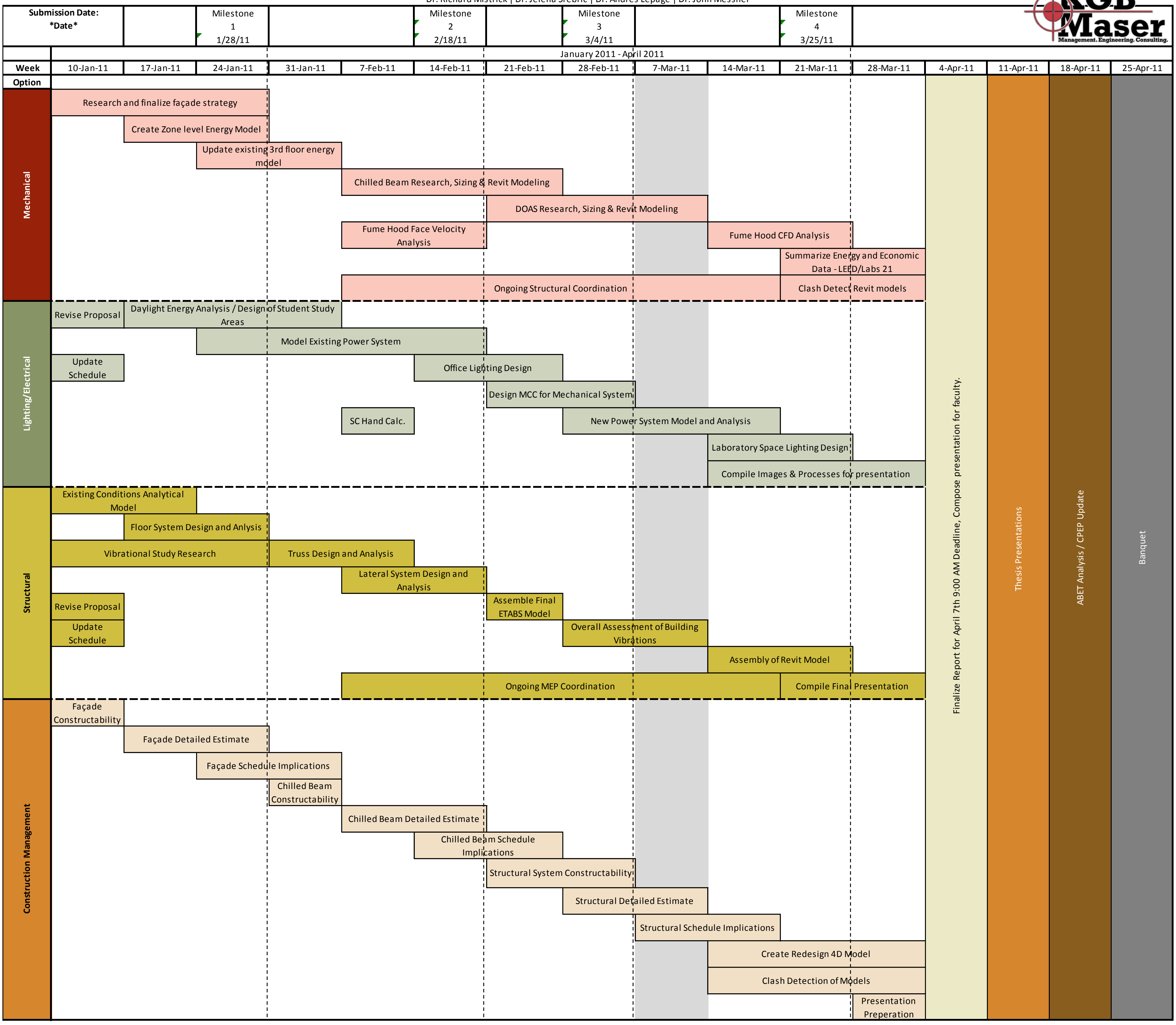
APPENDIX B: KGB MASER TEAM SCHEDULE

AE 481W/482 Senior Thesis

[Proposed IPD/BIM Spring Semester Schedule]

Jason Brognano (L/E) | Michael Gilroy (M) | Stephen Kijak (S) | David Maser (CM)
Dr. Richard Mistrick | Dr. Jelena Srebric | Dr. Andres Lepage | Dr. John Messner

Millennium Science Complex, University Park, PA



Milestone Activity List

▨ = Finished Activity

1. January 29, 2011
   Mechanical Finalize façade alterations after options evaluated for cost, constructability, and energy impacts
   Lighting Lighting design completed for student study area, 2 orientations, shading delivery complete, list of components and initial model of third floor SKM model.
   Structural Floor System designed in compliance with vibrational constraints and gravity loads
   Construction Detailed estimate of the changes to the façade system of Millennium Science Complex; Schedule Implications will be investigated.

2. February 18, 2011
   Mechanical Complete fume hood face velocity flow analysis (duct size and amount of exhaust CFM needed for each fume hood) and have available for electrical coordination. Estimate duct sizing to chilled beams for early structural coordination
   Lighting Complete SKM model of existing third floor system, short circuit hand calculation complete, lighting design and shading for office space in two orientations complete.
   Structural Lateral System design complete; Revit structure model is partially constructed with floor system and trusses in place
   Construction Chilled beam detailed estimate of the changes to the mechanical system; Schedule implications will be investigated.

3. March 5, 2011
   Mechanical Completed chilled layout on the 3rd floor spaces where applicable. Complete design of VAV systems where applicable.
   Lighting Complete office electrical design, complete motor control center design, list of components and initial SKM model of system changes in the third floor distribution.
   Structural Final ETABS model completely assembled and ready for final analysis; Vibrational analysis of entire structure begun
   Construction Structural system constructability and crane review will be completed and detailed take offs of the structural system will be completed for the estimate.

4. March 25, 2011
   Mechanical Complete CFD analysis of fume hoods for proof of operator safety. Complete 3rd floor structural coorindation in Revit.
   Lighting SKM analysis results complete, complete lighting and electrical design of laboratory space.
   Structural Revit structure model completely assembled; Final report started with all necessary material ready to be compiled
   Construction 4D model of design changes and clash detection of redesign 3D models will be taking place and design of the presentation will begin.

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