Proposal

Millennium Science Complex

University Park, PA

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Executive Summary

The Millenium Science Complex is a four story, 275,600 square foot, LEED Gold Certified laboratory and office facility for the Life and Material Sciences on The Pennsylvania State University, University Park campus. Located on the eastern end of campus, the Millennium Science Complex is the focus of the Integrated Project Delivery / Building Information Modeling Thesis (IPD / BIM Thesis). The building will house research facilities for the Material Science and Life Science departments. This report will serve as a proposal for design alternatives to be incorporated into the redesign of the Millennium Science Complex in order to achieve more efficiency in every discipline's design, with respect to reduced time, reduced cost, reduced energy use, and reduced use of resources. This proposal will serve as a guideline for faculty to follow the direction and progress that Building Stimulus will accomplish during the Spring 2011 semester. Alternative concepts will be implemented from an integrated project delivery design process and building information modeling will be used for coordination among group members.

Building Stimulus has decided to focus some of their efforts to redesigning the façade of the MSC. The use of a double skinned façade will be explored to provide benefits to the mechanical and daylighting design of the building. The two types of double skinned façades being explored are continuous and non-continuous. The continuous design will feature a single air gap along the entire face of the building; this will provide advantages in terms of thermal efficiency but difficulties in construction, integration, and analysis. The non-continuous design features a segmented air gap, compartmentalized by floor or building section to provide thermal efficiency to the building albeit not as efficiently as the continuous design, while also providing easier construction and possibly integration among disciplines. Through a thorough exploration of this façade type, the extent to which the double skinned façade will be implanted across the building will be determined. The current use of pre-cast panels will be reviewed and alternative lightweight materials will be considered for replacement. Specifically the panels will be redesigned to decrease weight, construction costs, and material costs.

In terms of the primary structural system of the MSC, the focus of the structural redesign will concern the 150-ft cantilever trusses. The truss system will be modified to define an alternative and efficient load path while optimizing the constructability of this complex structure. This will be carried out by reversing the direction of the braces from compression loading to tension loading while increasing the stiffness of the cantilever support by adding additional truss support in the form of added columns and added truss members above the current roof. These additional members will extend upward past the current support of cantilever, effectively adding stiffness and decreasing the unsupported length of the cantilever itself.

Lighting design will focus primarily on third floor spaces that include a student study area and a conference room. As the third floor consists of several types of spaces, it serves as a good representation of the spaces throughout the entire building. Therefore, the detailed analyses completed on the third floor for both mechanical and lighting design will be projected to the other floors and spaces. The student study area will include a daylight study that will be coordinated with the facade redesign. This aspect of the façade design will be incorporated throughout the building's entire façade, as the study areas occur throughout the building. A design of the plaza located under the cantilever will be completed as well. Electrical focuses will be to complete a Revit model of the third floor areas that includes circuiting components and modeling conduits and a select few branch circuits. An SKM Analysis will be completed to determine short circuit design criteria.

Collaboration among group members will be crucial to the success of the IPD/BIM Thesis project. The BIM Execution Plan along with this proposal will guide Building Stimulus through the Spring 2011 semester with a

schedule and outline of necessary tasks to ensure the project is completed on time with all the necessary information.

The Background of the Problem

The Millenium Science Complex is a four story, 275,600 square foot, LEED Gold Certified laboratory and office facility for the Life and Material Sciences on The Pennsylvania State University, University Park campus. Located on the eastern end of campus, the Millennium Science Complex is the focus of the Integrated Project Delivery / Building Information Modeling Thesis Project (IPD / BIM Thesis).

Figure 1 (Above) Bing image. (Right) RVA Rendering as seen from Pollock & Bigler intersection.

The L-shaped building will house research facilities for the Material Science and Life Science departments under one roof, where the two disciplines join at a monumental 150 ft cantilever connecting the 3rd and 4th floors of the building. The building consists of stepping, green roofed, cantilevers that extend over campus streets, and will surely become one of the most recognizable buildings on the University Park campus.

Structural System Background

Foundations

The foundation of the Millennium Science Complex utilizes a system of micropiles, pile caps, and grade beams. Each column is supported by a pile cap on grid lines spaced twenty two feet apart in a square pattern, as seen in Figure 2 :. Groups of micropiles continue from the pile caps and make their descent through the soil allowing friction to carry the load of the building. Each of these pile caps are connected by grade beams which help to reduce differential settlement, a crucial design consideration for a laboratory building.

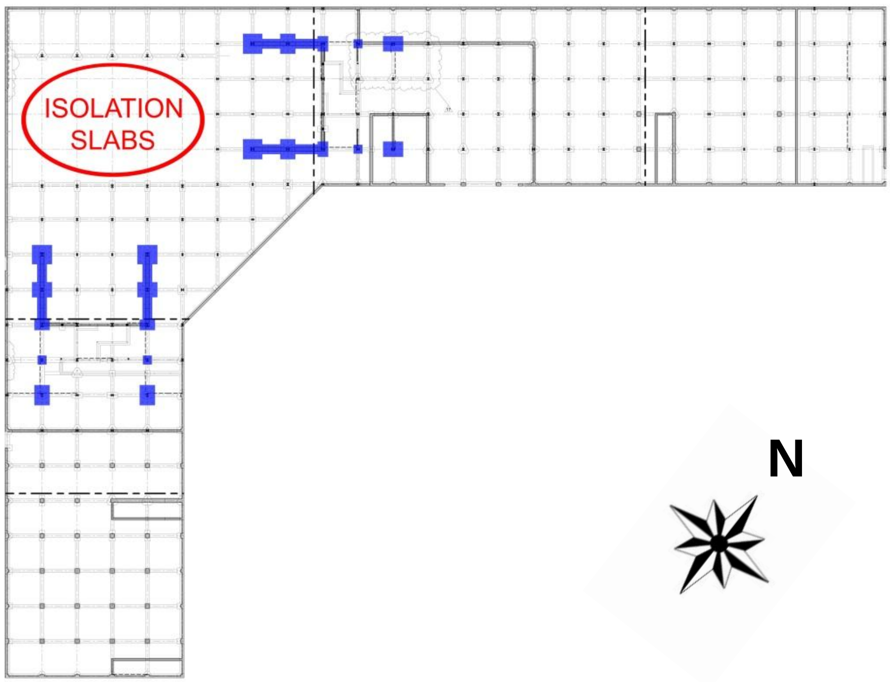

Figure 2 :

Seen here are pile caps positioned at every grid line corresponding to the location of the columns. Columns transfer their load into these pile caps and then into micropiles. Grade beams connect the pile caps in a grid pattern. Several of these pile caps are enlarged and highlighted in blue; they serve to distribute the load from the cantilever. Also seen here is a section circled in red which does not contain pile caps due to the presence of an isolation slab.

Forming the floor of the basement are four different slabs on grade in the occupiable area of the basement, shown in Figure 3:. The basement covers only a portion of the entire footprint of the building, the area colored in white indicates the presence of compacted fill filling the space between the basement level and first floor level. Columns and piers extend from the pile caps at the basement level up through the compacted fill, in this area of each wing, to the first floor. This was presumably designed in the event that the University would want to expand the basement level under each wing. Further evidence of this assumption can be found in the foundation walls called out in around the perimeter of the west wing, which enclose the compacted fill, and are in line with the exterior walls of the building. The accessible areas of the basement lie directly under the cantilever and extend to the edge of the compacted fill (indicated by color). Three isolation labs were placed at this level, designed to be completely disparate of the structural elements that make up the rest of the building. Slabs on grade, foundation walls, footings and piers use 4000 psi concrete; the pile caps are the only concrete items that use 6000 psi concrete. Reinforcement in the foundation and throughout the building is grade 60.

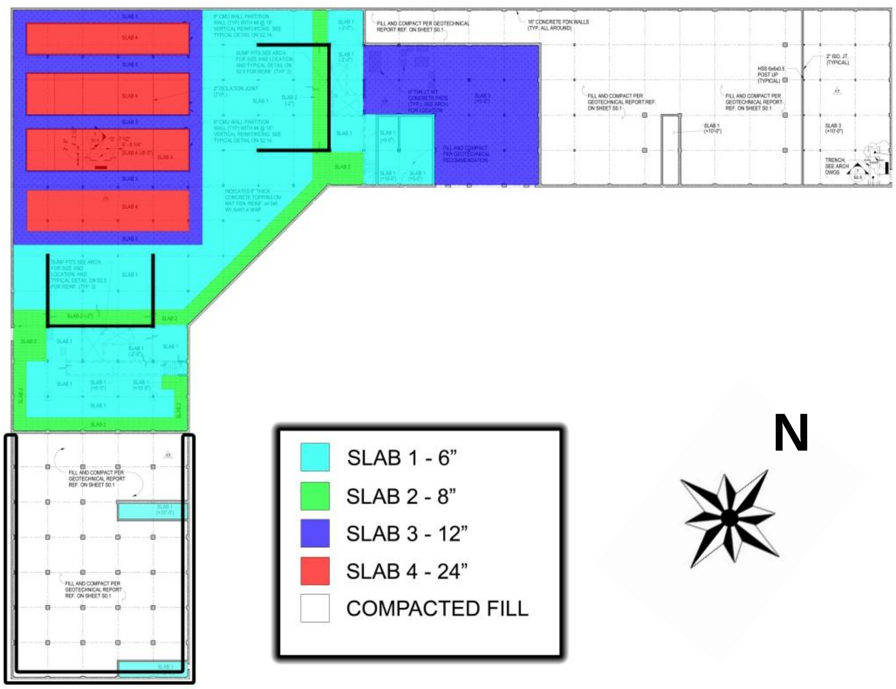

Figure 3:

This basement plan shows the occupiable areas in color, highlighting the four different slabs used in the basement level. This plan also shows areas where possible expansion could be made. The foundation walls in black show the bounds of this possible expansion area.

Floor System

A composite floor system with typical 22 foot square bays forms the floor system for the Millennium Science Building. A typical floor layout for the wings contains a centralized corridor surrounded by rooms on either side. Those perimeter spaces are generally divided into either laboratories or offices. The floor loads are handled by three types of composite decking used throughout the building, highlighted in Figure 4:, the most common of which is a 3 inch 18 gage deck with 3¼ inch light weight concrete topping. The concrete decking is supported by W21 beams and W24 girders which frame into W14 columns, at the intersection of each grid line. 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. A 3 inch metal deck is used with a 7 inch normal weight concrete topping immediately below the cantilever where pedestrian traffic is heaviest as people enter and exit the building, and a 4½ inch normal weight topping is used to support each green roof.

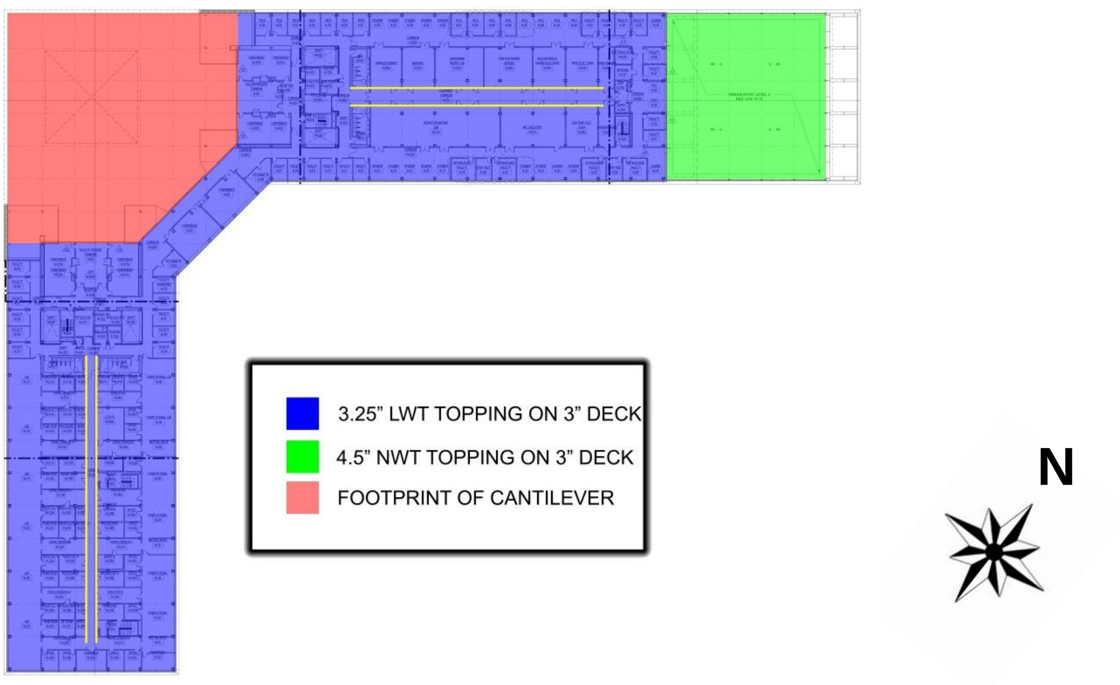

Figure 4:

Seen above is the second floor plan of the Millennium Science Building. Highlighted in green and blue are the different decks used on occupiable floors; they represent the green roof and interior floor, respectively. This plan is used as an example of a typical layout, being lightweight concrete used for the accessible spaces and normal weight concrete used for areas with specialty loads such as the green roof or mechanical penthouse. The area highlighted in red represents the plaza landscape under the cantilever. The yellow lines running through the center of each wing call out the central corridor.

Lateral System

Two moment frames, several bays of braced frames, and two shear walls located at the stairwells make up the lateral system for the building. The moment frames are located at grid lines Q and 19, which are midway and at the end of their respective wings. The location of these moment frames correspond with shear walls placed in either wing several bays away, as shown in Figure 5:. The objective of these staggered frames and walls is to distribute the lateral forces over the entire floor, preventing excessive localized stresses in the diaphragm. State College itself does not suffer from large wind or seismic loads given building height restrictions and geographical location. Along with the large span trusses and C-shaped shear walls that support the cantilever, the lateral system more than suffices in resisting the maximum lateral loads State College has to offer.

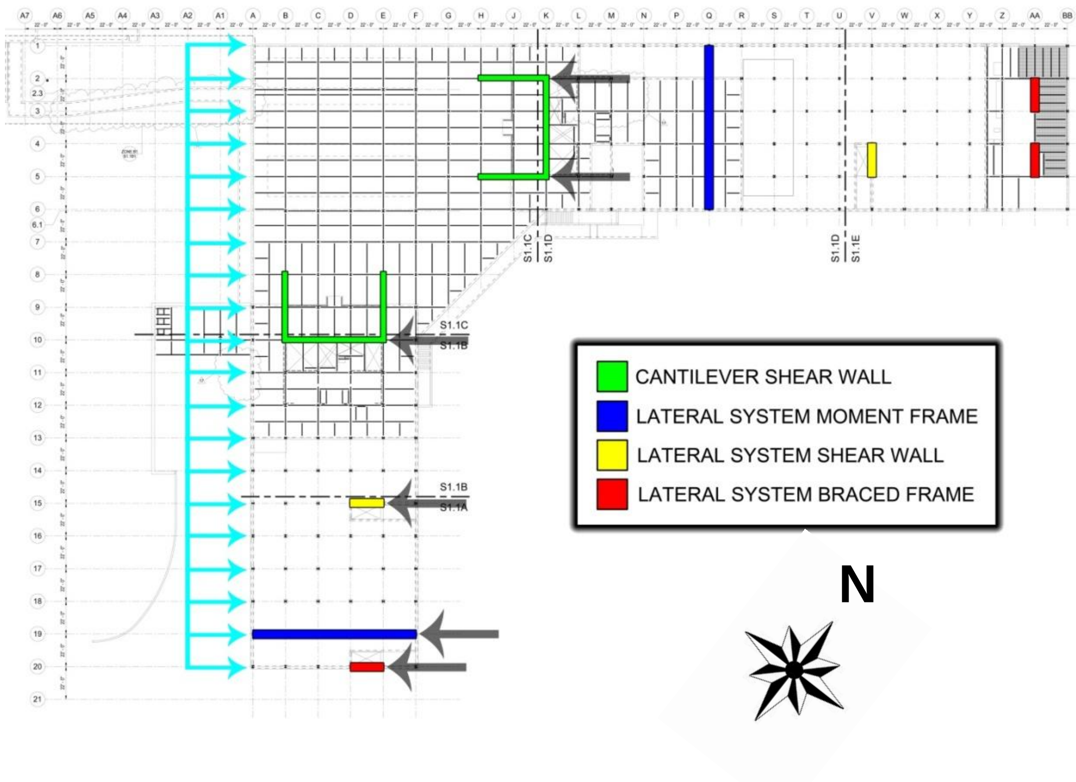

Figure 5:

As the wind is applied to the structure, loads are transferred from the exterior façade to the floors, acting as a diaphragm, which distribute the load to the lateral system.

Specialty Systems

To cope with the massive stresses induced by the 150 foot overhanging cantilever, a truss design was used to handle the gravity forces. Gravity loads start from the tip of the cantilever and are transferred into the diagonal compression members. Continuing on the load path, the truss feeds into a 30-inch thick shear wall integral with the truss frame. The loads from the diagonal compression members get carried into the shear wall and transfer into the foundation. The load is handled by 10 points in the foundation; one of the two identical frames is shown in Figure 6:. These enlarged pile caps and grade beams act in compression and tension on the soil, using the micropiles as an anchor. As revealed by a Thornton Tomasetti representative, the cantilever was originally designed to be supported solely by the steel truss system and the addition of the concrete shear wall was a necessity to dampen vibrations originating from the mechanical equipment located on the mechanical penthouse supported by the cantilever.

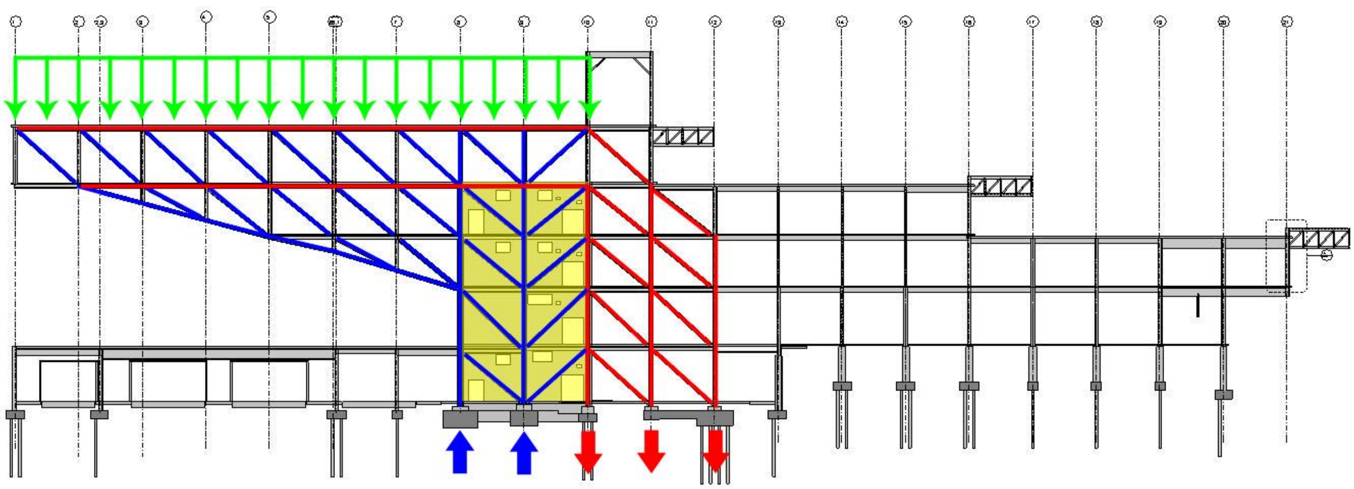

Figure 6:

Shown above is one of the four truss frames dedicated to supporting the cantilever. The members highlighted in blue are under compression; the red members are under tension. The shear wall is highlighted in yellow and provides added stiffness to the frame where foundational reactions change from positive to negative directions. The green distributed load represents gravity loads on the frame. This frame is located at grid line B.

Mechanical Background

The building's cooling and heating loads are serviced by Penn State's central plant, where chilled water and high pressure steam are supplied to the ground level mechanical room of the Millennium Science Complex. Chilled water is pumped via four variable speed horizontal split case chilled water pumps to the AHUs in the mechanical penthouse. From the AHUs, the chilled water is distributed throughout the floors to the VAV boxes to service the cooling coils. Low pressure steam is distributed to reheat and preheat coils at the AHUs and terminal devices, humidification and plate and frame hot water heat exchangers for perimeter finned tube elements in zones where the glass height is greater than 11 feet. Medium pressure steam is used in the building for laboratory equipment such as laboratory sterilization and domestic hot water heat exchangers, as well as for three clean steam generators in the mechanical penthouse.

Air distribution throughout the Millennium Science Complex is handled by variable air volume boxes for the interior and exterior zones. Hot water coils service the north perimeter offices for the VAV boxes. Air is supplied to the spaces through ceiling mounted low velocity radial diffusers to maintain room temperature setpoint using a traditional overhead ducted system. Carbon dioxide sensors were installed in both the return air and outside air ducts on each floor for demand control ventilation. In decreasing loads, the static pressure sensor in the longest duct run controls the variable frequency drive for the supply fans. The three 33,000 cfm non-laboratory AHUs, located on the fourth floor mechanical penthouse, utilize outdoor air economizers to save energy since they are not a dedicated outdoor air system. The laboratories and vivariums air distribution is serviced by (5) 50,000 cfm and (2) 25,000 cfm 100% outdoor air AHUs, respectively. To utilize energy, each unit includes an enthalpy heat recovery wheel and integral exhaust fan to operate concurrently with the supply. The exhaust system consists of manifold fume hood exhausts and the general room exhaust. The fume hood and vivarium exhaust fans are equipped with run around energy recovery coils that circulate glycol with two pumps to the preheat coils in the AHF AHUs, clean room AHU, and quiet lab AHU.

The energy and existing conditions analysis performed in Mechanical Technical Report 1 yielded results as shown in Figure 7 and Table 1. These determined values are only theoretical and relative, as the building is not currently occupied and operational due to construction. The second technical report for Building Stimulus investigated several facets of design areas that could be enhanced for each discipline. From the mechanical system perspective, studies were focused on alternative energy sources, air distribution, and façade redesign to determine parts of the design that yield greater opportunity to enhance performance for energy use and sustainability. In order to incorporate these possible design considerations into the redesign of the building, the third technical report explored the BIM/IPD execution plan to evaluate the roles and responsibilities of the mechanical engineer in this design process.

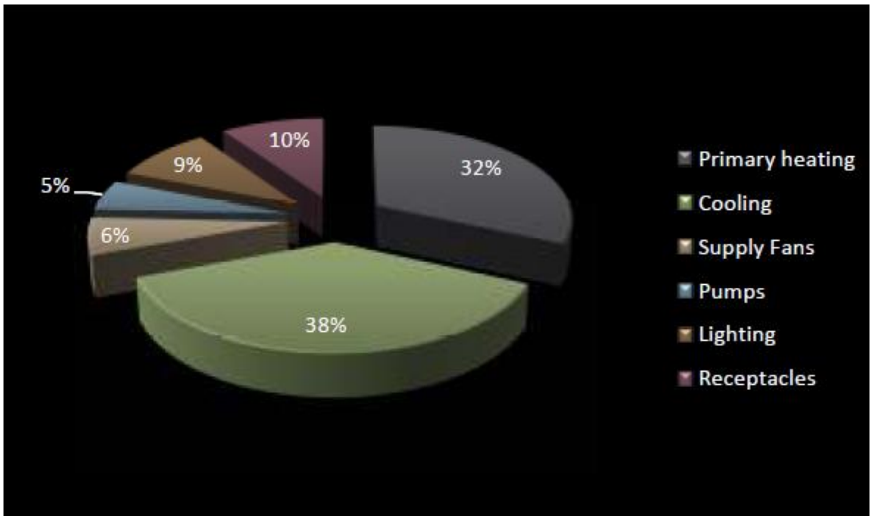

Figure 7: Energy Consumption

Table 1: Zones Load Summary

Zones	Cooling (tons)	Heating (MBtuh)	Supply Airflow (cfm)	Outside Air Percentage	cfm/ft^2
Laboratory	217.7	2,409.2	25,588	100	1.64
Office Spaces	97.2	513.9	28,974	22.5	1.01

Areas of Design Focus

Façade

According to the architect Rafael Vinoly, the intended design inspiration for the Millennium Science Complex was to give the appearance of a floating building. To accomplish this, the façade's original design intent was to enhance the linearity of the building by placing continuous horizontal glazing on all floors and stacked "Penn State" brick with bands of recessed dark-fired brick adhered to six inch thick pre-cast concretepanels along each face of the building.

As a team, this element of the building was determined to be a great opportunity for redesign due to its impact on each discipline. Currently, the precast concrete panels add a significant amount of weight to the structure. Each panel weighs approximately 1 Kip/LF. Along the building's perimeter of over 1800 feet, this load adds a significant amount of weight to the overall weight of the building and a large demand upon the structure; this is of particular importance in the area of the cantilever. Investigation into possible alternatives to the current precast panels to reduce the load on the structure can add potential time and cost savings to the construction of the Millennium Science Complex.

The glazing of the façade also provides several opportunities for improvement to the design with respect to daylighting and mechanical systems. The designed linear uniformity of the façade serves mainly as an architectural feature. Although there are solar louvers incorporated into the facade, they do not provide effective daylight control for each face of the building since it is one standardized system. This causes issues with glare in several of the spaces within the building, such as the computer labs. Due to this, the glazing requires the addition of solar shading devices that are designed to perform for each orientation of the façade. This adjustment will provide increased comfort for the occupants, both psychologically and thermally by reducing glare and solar heat gain. At present, the heat gain from the façade accounts for approximately 46% of the office space cooling loads. This significant percentage exhibits the need for optimization of the building envelope to decrease the solar heat gain and loads in the different zones. Through coordination with the lighting/electrical engineer, a new construction type for the glazing must be selected to increase the thermal performance of the material. As long as the modifications made decrease the heating and cooling needed, this will allow the HVAC system to save energy use in the building.

Design Efficiency

Structural System

The Structural Designer of the Millennium Science Complex, Thornton Tomasetti, is world renowned for developing creative solutions to meet the needs of complicated structures; the MSC is no such exception. Thus, the challenge becomes redesigning an already structurally efficient building. Through studying the existing systems possible areas for improvement of the building's structural system were identified and begun to be explored. The area of study for this proposal will be the 150 ft cantilever joining both wings of the building. The main cantilever is supporting two trusses extending from each wing and is configured in such a way that the braces are loaded in compression under the gravity loads of the structure. As will be discussed later in this report, it is being proposed to change the direction of the braces to explore how the trusses perform when the braces are loaded in tension. Secondly, the current floor system is metal framing with concrete on metal deck. As was presented to Building Stimulus by an engineer at Thornton Tomasetti, the current system is over-sized by 200% for gravity and deflection requirements due to the vibration sensitivity of the rooms occupying this floor space. A member check of the gravity system will be executed to confirm these values.

Mechanical System/Alternative Energy

Currently, the building's duct work is oversized due to the large pressure drops associated with very long runs in the building. Static regain was used to design the current ducts in order to regain velocity for what was lost due to static pressure. Therefore, the air distribution system offers an opportunity to be redesigned to reduce the duct sizes to provide better coordination in the plenum space with the electrical and structural systems and optimize the energy needed for distribution. This redesign opportunity was chosen by Building Stimulus due to its apparent coordination among the disciplines, but also to enhance the mechanical system efficiency and energy use. Decreased energy use in zones will allow a reduction in equipment sizes, such as air handling units in the penthouse, which in turn reduce the dead load on the structure.

The projected annual electricity energy use for the Millennium Science Complex is 684,280 kWh, which is a cost of approximately $51,500. To maintain its iconic stature and enhance the sustainability of building's performance, methods need to be investigated to reduce the primary energy use and source emissions, such as using alternative energy sources and more efficient design of the mechanical and electrical systems in the building. Table 2 summarizes the current projected annual emissions for the Millennium Science Complex.

Table 2: Millennium Science Complex Annual Emissions

Total Building Energy	172,158 BTU/ft^2-yr
Total Source Energy	280,932 BTU/ft^2-yr
CO_2	2,714,609 lb_m/yr
SO_2	20,988 g/yr
NO_x	4,219 g/yr

Alternative Designs

Sustainability

As part of Building Stimulus' goal to improve the overall efficiency performance of the Millennium Science Complex, sustainability and energy conservation will be a focus during the redesign. Since the Millennium Science Complex is an iconic building designed to be LEED Gold Certified, measures will be taken to adhere to LEED concepts throughout the design, as it was considered with the original design process of the building.

To decrease the dependence on fossil fuel consumption sources and reduce the carbon emissions produced by the Millennium Science Complex, rooftop mounted wind microturbines will be investigated as an alternative energy source for some of the building's electricity loads. The process heat load requirements in the laboratories are potential candidates for this on-site generation since energy needs of laboratories are immediate and intense. Since wind turbines usually produce intermittent energy that is not always reliable due to the weather, electricity from this renewable resource will be investigated for use in less critical equipment loads. The possibility of short-term storage will also be further pursued for design considerations. They will be assessed in terms of practicality, feasibility by means of lifecycle cost, and coordination with other disciplines in order to achieve the overall goals and scope of the design team.

Chilled beams will also make it possible to reduce the amount of energy needed in the building. Focus of the investigation and implementation of this system will be on load heavy spaces, such as office spaces and equipment corridors, which do not require as much air exchange. To evaluate the overall energy savings, Trane TRACE will be used. Reduced AHU and duct sizes will be key factors in the redesign to coordinate with structural system design, as well as the integration of luminaires into the chilled beams. A lifecycle cost analysis of the system will also be performed to determine the feasibility.

Double-skin Façade

Mechanical

To improve the thermal performance of the existing façade, a double skin façade will be designed to replace the existing structure. The large air cavity associated with the double skin provides a thermal buffer between the outside environment and the perimeter zones of the building, which will decrease the heating and cooling loads for these zones. Both a continuous double skin façade and non-continuous (story-high) double skin façades will be investigated to determine the best alternative.

Daylight Integration & Electrical Lighting

Each façade orientation faces differing challenges and opportunities for daylight integration. Individual façade orientations will be designed separately to allow for a system that is functional for different segments of the enclosure. These varying shading designs will allow for increased energy efficiency, as they will allow for a reduction in solar heat gain and possible electric light savings.

Introducing a double skin façade allows for more glazing options and designs and ultimately further customization of façade designs. The inhabitable space created between the two sets of glazing also allows for a place to locate shading devices while maintaining an overall uniform building enclosure viewed from the exterior. This façade system, which is new to Penn State, has been successfully applied to several buildings such as Loyola University Information Commons and Digital Library in Chicago, IL and Milstein Heart Hospital in New York.

The perimeter spaces that will incorporate daylighting integration are primarily comprised of offices and computer workspaces for students. These spaces will be analyzed for considerations that promote productivity and increase in psychological aspects of day to day life with the presence of daylight. Main criteria in the daylight design should include the reduction of glare while creating a visually uniform space. The reduction of glare will be most important in the student computer spaces. Direct solar glare on computer screens creates an unproductive workspace by reducing visual clarity.

Daylight and occupancy sensors are utilized in the computer workspaces, where offices use only occupancy sensors. This design will remain in the development of daylight integration with the façade. The absence of daylight sensors in offices will allow occupants to manually maintain a preferred light level and atmosphere. The public computer spaces will remain dimed via daylight sensors to maintain a uniform light level that is acceptable to the majority of users.

Structural

The application of a double-skin façade allows a unique opportunity for all disciplines to work closely on a specific system of the building. The design of the façade will rely heavily on coordination among team members to ensure the result is an efficient design. The structural engineer will be devoting the majority of his work regarding the façade to the redesign of the pre-cast concrete panels. A number of ideas will begin the process of further development. These include: an exterior insulation finishing system (EIFS) made to look like brick, one-way pan joist system backed with insulation formwork, carbon fiber reinforced pre-cast panels, etc. Further development of these ideas with input from other disciplines will influence whether to proceed with a continuous or non-continuous double skin façade. This decision must be made early on in the design process because the design of the panel must accompany a seamless air gap with the glazing for a continuous air gap to be of use. Proceeding further the panels will be designed for local wind forces and the connection to the structural system designed for applicable lateral and gravity loads and ease of construction. Uniformity of panels across the varying facade and weight of the panels will be of high priority to reduce material and fabrication costs.

Construction

The implementation of a double-skin façade on the Millennium Science Complex will require a significant amount of design time to ensure that its use is well warranted through life-cycle costs savings and mechanical system efficiencies and not a hindrance to the progression of the project and a liability to operational costs. It is the desire of the team to use a continuous double-skin façade if possible. This can only be done if certain changes are made to the design of the precast panels used in the enclosure to allow a continuous air gap behind the panels through multiple floors. If a continuous double-skin façade is not feasible, a non-continuous double-skin façade can be used, requiring very little redesign to the precast panels. During design phases, the extent to which a double-skin façade will be utilized shall be determined. The difference between focusing the double-skin façade on one or two faces versus universally throughout the facilities enclosure effects scheduling, sequencing, and costs drastically. It is understood that the complexity of construction for a double-skin façade is well above that of the current glazing system; therefore, it is important to research and monitor the construction duration of a double-skin façade. Increased delivery and construction time of a double-skin façade should be expected. It is vital to place orders as soon as possible in anticipation of lengthy lead times. It should also be noted that due to aforementioned increase in complexity, specialized contractors will be necessary. Double-skin façades are rarely found in North America. While Europe has designed double-skin facades dating to the early 1900's, North America did not construct one until 1980. Available contractors skilled in the construction of a double-skin façade in North America may be scarce. The hiring of an experienced designer and builder from abroad may be a potential necessity. A subcontractor experienced in double-skin facades should be preferred to those that lack experience in its construction, which may lead to higher construction costs. Potential vendors and suppliers will be pursued for future submittals. Another aspect that should be monitored when considering a double-skin façade is the life-cycle cost. The purpose of utilizing a double-skin façade is to take advantage of its ability to act as a thermal buffer between the exterior and interior of the building, as well as, the ability to extract heat from solar energy that warms this space to preheat the air used to condition the interior during winter months, thus reducing the loads on the mechanical equipment. Due to double-skin façade's higher upfront costs for materials and specialized labor it's vital to monitor operational cost savings to ensure life-cycle cost savings. An acceptable life-cycle between 50-100 years should be declared before any operational cost monitoring begins.

Structural System

Structural

The proposed redesign of the structural system will revolve around the design of the trusses supporting the 150-ft cantilever. The intent of the redesign is to switch the bracing of the trusses from compression to tension loading, with the end goal of designing a smaller member and efficient connection. This however is not without its limitations, to mitigate prophesized higher deflections at the tip of the cantilever the truss system will be increased above the current roof level and possibly extended an additional bay beyond the where the cantilever begins to span unsupported. Additionally, at the same point at which the new upper truss design extends beyond the current shear wall, three new columns will be introduced as further vertical support. This will increase the stiffness of the vertical truss supporting the cantilever while reducing the length of the structure that is unsupported. This will presumably decrease deflections and possibly add advantages in terms of constructability of the structure. Finally as an architectural detail to be refined as a result of the structural system, certain bracing members will be taken out to the refine the slope of the cantilever presenting a single slope as opposed to the current double slope of the angled cantilever. The addition of these extra members may potentially offset the possible benefit received from using smaller sized bracing members; however, this redesign is not without merit. The end goal of this exploration into the design of the cantilever system is to design the truss for an efficient load path and optimize the constructability of the structure.

Construction

The Millennium Science Complex currently uses 3557 tons of steel. At approximately $25 million, the structure costs over $90.00/SF and makes up 17.6 % of the budget. To support the facilities signature cantilever, the structure boasts an incredibly complex design. It was decided by team Building Stimulus that reducing Millennium Science Complex's structure was a primary goal. To do so, concurrent goals of façade redesign and alternative mechanical systems will contribute to reducing floor-to-floor height, total building height, and significant reduction in façade dead loads. While the structural redesign is in a very preliminary phase, it is Building Stimulus' aim to increase efficiency of construction while possibly reducing the amount of steel in the structural design; this in turn will reduce costs as well as offer potential scheduling relief.

With a new structural design, additional responsibilities and concerns arise for managing the construction process. Like any facility consisting of several cantilevers, deflections must be monitored frequently to ensure the structure is aligned properly and plumb. The redesign may not require a more frequent monitoring process, but expected deflections will surely be unique from the existing design. The Millennium Science Complex is also riddled with complex member connections and welds that required a significant amount of man-power and man-hours. Along with reducing material quantities, simplifying connections could significantly improve the construction process. When the structural redesign is determined, Building Stimulus will complete a construction sequence analysis to determine whether a sequencing of activities could result in a quicker finished product.

Methods & Tools

Mechanical Tasks & Tools

Table 3: Mechanical Tasks & Tools

Primary Task	Secondary Task	Program(s) to be Used
Air Distribution	Chilled Beams	TRANE Trace
	Energy Simulation	TRANE Trace
	BIM Modeling	Revit MEP 2011
Façade Redesign	Thermal Properties Model (CFD)	MS Excel,
	Glazing	TRANE Trace
	BIM Modeling	Revit MEP 2011
Wind Microturbines	Calculations	MS Excel
	CFD Model	
	BIM Modeling	Revit MEP 2011

Structural Tasks & Tools

Note: It is assumed all tasks will include hand calculations (written or MS Excel format) to facilitate or supplement design in addition to computer modeling.

Table 4: Structural Tasks & Tools

Primary Task	Secondary Task	Program(s) to be Used	Applicable Codes/Design Guides
Façade Redesign	Panel Design (Wind, Dead, Earth Quake, Connection Design, etc.)	pca Slab, ETABS	ASCE7-05
Cantilever Structure	Model Existing Cantilever Structure	SAP 2000, ETABS	
	Change Direction of Braces	SAP 2000, ETABS, RAM Connection	AISC Steel Manual 13ed
	Introduce Additional Columns	SAP 2000, ETABS, RAM SColumn	AISC Steel Manual 13ed
	Explore removing concrete shear walls	SAP 2000, ETABS	
	Explore introducing further verticality to truss	SAP 2000, ETABS, RAM SColumn, RAM Connection	AISC Steel Manual 13ed
Floor Systems	Investigate Current System Efficiency	ETABS	AISC Steel Manual 13ed, AISC Steel Design Guide 11
Model Redesigned Structure	Model in ETABS for potential import to Revit Structure	ETABS, Revit Structure	

Electrical & Lighting Tasks & Tools

Refer to "Appendix A: Mike Lucas Additional Research" for more detailed information.

Table 5: Electrical & Lighting Taks & Tools

Primary Task	Secondary Task	Program(s) to be Used
Lighting Redesigns	Layout & Performance	AGI 32
	BIM Modeling	Revit MEP 2011
Façade Redesign	Daylight Integration	AGi32, Daysim, and/or Ecotech
	Glazing	AGi32, Daysim, Trace
	BIM Modeling	Revit MEP 2011
Short Circuit Analysis	Calculations	MS Excel
Voltage Drop Calculations	Calculations	MS Excel
Branch Circuiting	Planning & Coordination	Revit MEP 2011

Construction Management Tasks & Tools

Table 6: Construction Management Tasks & Tools

Primary Task	Secondary Task	Program(s) to be Used	Sources of Information
Façade Redesign	Panel Modeling	Revit Architecture	-
	Cost Analysis	RS Means	RS Means, Information from vendor(s)
	Schedule Impact	Microsoft Project	Information from vendor(s)
Structural Redesign	Building Height Cost Analysis	Revit Architecture, Revit Structure	MSC Cost Information, Local Building Cost Information
	Schedule Impact	Microsoft Project	On-Site Production Rates
	Cost Analysis	RS Means	-
3D Coordination	Clash Detection	Navisworks	Revit Models
	4D Model	Navisworks, Microsoft Project	-

Design Development Schedule (Spring Semester 2011)

ID	Task Mode	Task Name	Duration	Start	Finish	Predecessors	Resource Names
1		**Begin Spring Semester**	**0 days**	**Mon 1/10/11**	**Mon 1/10/11**		
2		**Façade Design**	**38 days**	**Mon 1/10/11**	**Wed 3/2/11**	**1**	
3		Research	5 days	Mon 1/10/11	Fri 1/14/11	1	Team
4		**Glazing**	**11 days**	**Mon 1/10/11**	**Mon 1/24/11**	**1**	
5		Determine Glazing Properties	3 days	Mon 1/10/11	Wed 1/12/11	1	Mike,Sara
6		Shading Devices	4 days	Thu 1/13/11	Tue 1/18/11	5	Mike
7		Daylight Design	4 days	Wed 1/19/11	Mon 1/24/11	6	Mike
8		**Paneling**	**15 days**	**Mon 1/10/11**	**Fri 1/28/11**	**4SS**	
9		Develop potential panel designs	10 days	Mon 1/10/11	Fri 1/21/11	4SS	Team
10		Analyze wind load on panel	5 days	Mon 1/10/11	Fri 1/14/11	9SS	Paul
11		Design Panel Connections and Impact on gravity system	5 days	Mon 1/24/11	Fri 1/28/11	9	Paul
12		Cost Analysis	3 days	Mon 1/24/11	Wed 1/26/11	9,3	Jon
13		Determine Thermal properties	3 days	Mon 1/24/11	Wed 1/26/11	12SS	Sara
14		**Final Façade Design**	**25 days**	**Thu 1/27/11**	**Wed 3/2/11**	**13**	
15		Develop CFD Model	14 days	Thu 1/27/11	Tue 2/15/11	13	Sara
16		Energy Simulation	5 days	Fri 2/11/11	Thu 2/17/11		Sara
17		3D Coordination	5 days	Fri 2/18/11	Thu 2/24/11	16	Team
18		Façade Estimate	4 days	Fri 2/25/11	Wed 3/2/11	17,12	Jon
19		Develop Project Schedule	10 days	Thu 1/27/11	Wed 2/9/11	3SS	Jon
20		**Electrical**	**47 days**	**Thu 1/27/11**	**Fri 4/1/11**	**14SS**	
21		Model Electrical Equipment on 3rd Floor	5 days	Thu 1/27/11	Wed 2/2/11	15SS	Mike
22		Model Existing Feeders on 3rd Floor	5 days	Thu 2/3/11	Wed 2/9/11	21	Mike
23		Electrical Estimate	4 days	Thu 2/3/11	Tue 2/8/11	21,22SS	Jon
24		3D Coordination	3 days	Thu 2/10/11	Mon 2/14/11	22	Team
25		Short Circuit Analysis (Hand Calc.)	2 days	Thu 2/10/11	Fri 2/11/11	22	Mike
26		Electrical SKM Model	10 days	Mon 2/14/11	Fri 2/25/11	25	Mike
27		**Lighting Design**	**18 days**	**Thu 3/3/11**	**Mon 3/28/11**	**14SS**	
28		**Spaces**	**10 days**	**Thu 3/3/11**	**Wed 3/16/11**	**14SS**	
29		Under Cantilever Plaza	4 days	Thu 3/3/11	Tue 3/8/11	14	Mike
30		3rd Floor Conference Room Lighting	2 days	Wed 3/9/11	Thu 3/10/11	29	Mike
31		Electrical Lighting Design In Perimieter Rooms	4 days	Fri 3/11/11	Wed 3/16/11	30	Mike
32		Model Lighting Existing Components 3rd Floor	4 days	Thu 3/17/11	Tue 3/22/11	31	Mike
33		Recircuit & Model Lighting Redesigns	4 days	Wed 3/23/11	Mon 3/28/11	32	Mike
34		Model & Coordinate Branch Circuits in a block of 3rd Floor Offices	4 days	Tue 3/29/11	Fri 4/1/11	33	Mike

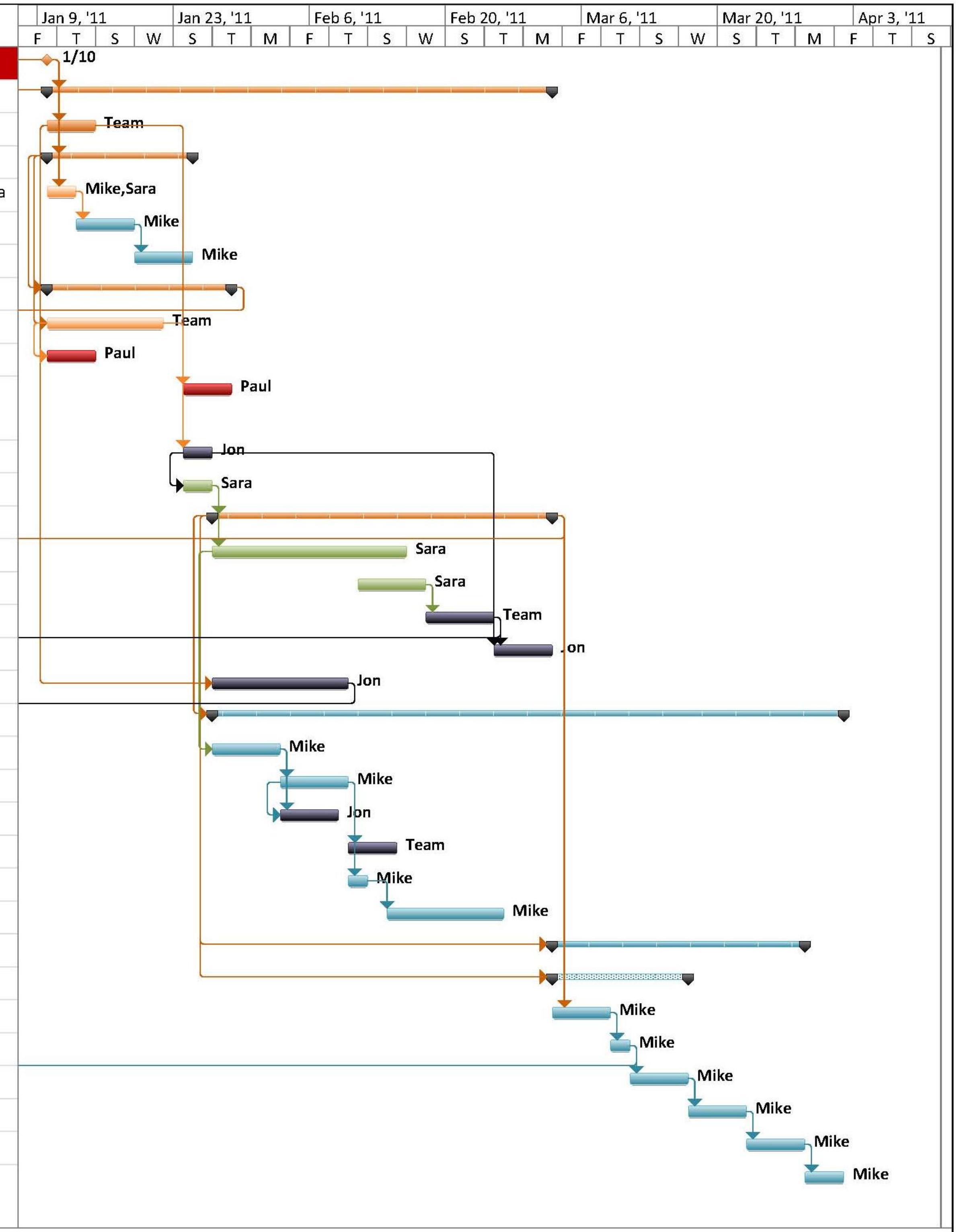

Figure 8: Spring Semester Schedule (1 of 2)

ID	Task Mode	Task Name	Duration	Start	Finish	Predecessors	Resource Names
35		**Structural Design**	**62 days**	**Mon 1/10/11**	**Tue 4/5/11**	**8**	
36		**Cantilever Structure**	**25 days**	**Mon 1/31/11**	**Fri 3/4/11**	**8**	
37		Model Existing Cantilever Structure	3 days	Mon 1/31/11	Wed 2/2/11	8	Paul
38		Change Direction of Braces	10 days	Thu 2/3/11	Wed 2/16/11	37	Paul
39		Introduce Additional Columns	5 days	Thu 2/17/11	Wed 2/23/11	38	Paul
40		Explore Introducing Vertical Towers	7 days	Thu 2/24/11	Fri 3/4/11	39	Paul
41		**Floor System Check**	**2 days**	**Mon 1/10/11**	**Tue 1/11/11**	**1SS**	
42		Check current system/justify member sizes and change if necessary	2 days	Mon 1/10/11	Tue 1/11/11	1SS	Paul
43		Model Structure in ETABS	7 days	Mon 3/7/11	Tue 3/15/11	40	Paul
44		Model in Revit Structure	7 days	Mon 3/7/11	Tue 3/15/11	40	Paul
45		3D Coordination Update	2 days	Wed 3/16/11	Thu 3/17/11	44,17	Team
46		Schedule Update # 1	5 days	Wed 3/16/11	Tue 3/22/11	45SS,19	Jon
47		Navisworks 4D Model	15 days	Wed 3/16/11	Tue 4/5/11	45SS	Team
48		Lateral System Check	5 days	Wed 3/16/11	Tue 3/22/11	44	Paul
49		**Mechanical Design**	**52 days**	**Mon 1/10/11**	**Tue 3/22/11**	**2SS**	
50		**Chilled Beams**	**14 days**	**Thu 3/3/11**	**Tue 3/22/11**	**14**	
51		Energy Simulations	5 days	Thu 3/3/11	Wed 3/9/11	14	Sara
52		Size Chilled Beams	1 day	Fri 3/11/11	Fri 3/11/11	51,30	Sara
53		Resize AHUs	1 day	Mon 3/14/11	Mon 3/14/11	52	Sara
54		3D Coordination Update	5 days	Wed 3/16/11	Tue 3/22/11	53,47SS	Team
55		**Microturbines**	**12 days**	**Mon 1/10/11**	**Tue 1/25/11**	**2SS**	
56		Research Microturbines/Location	5 days	Mon 1/10/11	Fri 1/14/11	2SS	Sara
57		Develop CFD Model	7 days	Mon 1/17/11	Tue 1/25/11	56	Sara
58		Determine # of Turbines (weight, vibration, etc.)	3 days	Mon 1/17/11	Wed 1/19/11	57SS	Sara
59		Determine Energy Storage, Type, Location	2 days	Thu 1/20/11	Fri 1/21/11	58	Sara
60		Develop Revit Family	2 days	Mon 1/24/11	Tue 1/25/11	59	Sara
61		**LEED Analysis**	**5 days**	**Wed 3/23/11**	**Tue 3/29/11**		**Team**
62		Life-Cycle Analysis	5 days	Wed 3/23/11	Tue 3/29/11	54	Team
63		Write Final Report	7 days	Wed 3/30/11	Thu 4/7/11		Team
64		Martin Luther King Jr. Day	0 days	Mon 1/17/11	Mon 1/17/11		Team
65		Spring Break	5 days	Mon 3/7/11	Fri 3/11/11		Team
66		Final Deadline	0 days	Mon 4/11/11	Mon 4/11/11		Team

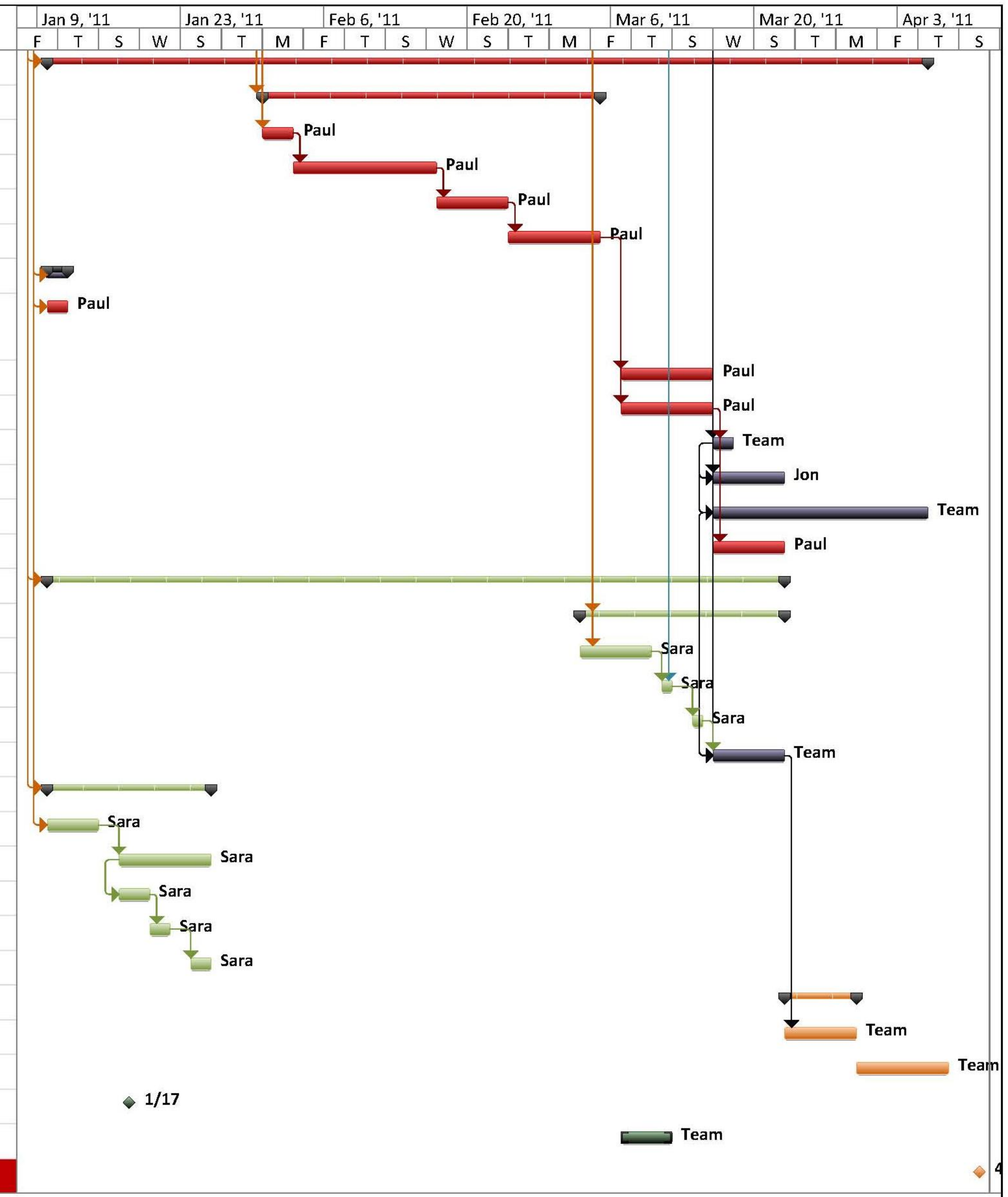

Figure 9: Spring Semester Schedule (2 of 2)

Metrics of Success

Mechanical

Façade Redesign:

- Peak envelope loads reduction
  - Cooling Load (BTU/hr)
  - Heating Load (BTU/hr)

HVAC Redesign:

- Primary Energy Use Reduction (MBtu/yr)
- Equipment Size Reduction
  - Decreased Dead Load
  - Decreased Plenum Space needed for mechanical systems
- Lifecycle Cost

Alternative Energy Source

- Annual Energy Produced
  - Reduced electricity need from Allegheny Power
- Associated Emissions Reduced (lb CO_2E)
- Lifecycle Cost

Structural

Façade Redesign

- Does the new panel design provide a reduction of:
  - Weight
  - Material
- Panel design provides advantages to constructability
- Panel design provides same or better thermal properties to current design

Structural Redesign

- Steel material reduced
  - If not reduced structural efficiency must be gained
- Less complex connection design

Electrical & Lighting

Lighting Design

- Meet Design Criteria
- Expand Architectural Features
- Provide Quality Lighting Design

Facade Design/Daylight Integration

- Minimalize Glare
- Reduced Heat Gain
- Increase Productivity & Personal Emotion

Construction Management

Façade Redesign

- Does proposed façade significantly reduce dead load on structure?
- Does double-skin façade reduce life-cycle costs?
- Does proposed façade present serious constructability issues?
- Will proposed façade lengthen the schedule?
- Is the architectural integrity of MSC compromised?

Structural Redesign

- Will steel erection and member connection time be reduced?
- Is structural weight of MSC reduced?
- Does proposed structural design present serious constructability issues?
- Does new design reduce costs?
- Does new structural design present more efficient construction sequencing opportunities?

Concluding Remarks

The overall goal Building Stimulus would like to achieve is increase the efficiency. This can be further narrowed down into the specific BIM Goals of Building Stimulus, found in Appendix D. As discussed in the preceding report this process will be accomplished by redesigning the cantilever structure, the building façade, identifying alternative energy sources, the mechanical devices (chilled beams) and as a result a combined chilled beam/luminaire. These areas of the building were identified as possible areas for improvement or redesign and will be the focus for the Spring 2011 semester.

The building enclosure offers a great opportunity for redesign and coordination between all disciplines. This was identified early in the selection process because of changes in technology and the University's renewed interest in saving energy. Thus, this particular area of focus will serve as an excellent source for all members of Building Stimulus to work together and utilize an Integrated Project Delivery approach with the use of Building Information Modeling. Using this as an example, each group member will have a hand in designing part of the façade. This will take place through initial design investigation and research leading into specific design and modeling and further progressing into 3D collaboration using Revit and Navisworks.

Appendices

Appendix A: Additional Research

MAE Requirements: Mechanical–Sara Pace

To fulfill the MAE requirements for BIM Thesis, knowledge learned in AE 559, “Computational Fluid Dynamics in Building Design,” will be used to complete CFD models and analysis of both the double skin façade and wind turbine additions to the structure. Also, AE 552, Air Quality in Buildings, will be used to ensure the zones that are replaced with chilled beams maintain the desired level of air quality in the space due to less air flow.

Paul Kuehnel - Additional Research

MAE Requirements: Structural – Paul Kuehnel

To fulfill MAE requirements for BIM Thesis, material explored in both Computer Modeling of Building Structures and Steel Connections will be used to complete the structural analysis of the Millennium Science Complex. ETABS and SAP 2000 will be used to model the lateral system of the building to perform a lateral system check for the redesigned structural system. Specifically the methods of placing rigid end offsets and panel zone analysis will be carried out for a thorough analysis of the cantilever. Also, steel connections will be redesigned where applicable to accommodate tension loading and different member shapes/sizing using the knowledge learned in the Steel Connections course.

Mike Lucas - Additional Research

Depth Proposal - Lighting

Lighting Design - Cantilever Plaza:

The main entrance of the Millennium Science Complex is located where each of the two wings meet. The cantilevered connection creates a plaza area that houses an entrance to each Material Science and Life Science wings. Under the square opening in the structure above, a pathway exist that sends walkers through a swirling pattern that leads from one entrance to the other. The design of the pathway was intended to be directionless to discourage use. The structure below is a quiet lab area has been deemed extremely vibration sensitive and heavy use will disrupt the research and experiments below.

Figure 10: Cantilever Plaza – Plan view

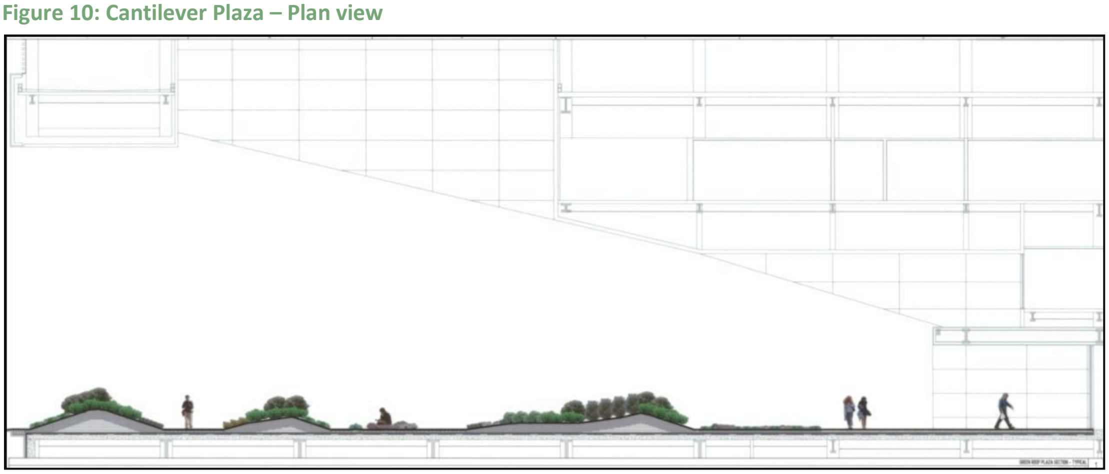

Figure 11: Cantilever Plaza – Section View

Lighting design of the cantilever plaza will take the function of the space and the vibration concerns of the quiet labs into consideration by creating private spaces while lighting the swirling pathway with minimal light. The main walkways will be lit uniformly to create safety, highlight architectural features, and brighter to create a contrast with the landscaped section of the plaza.

Lighting Design - 3rd Floor Conference Room:

A conference room on the third floor offers a chance to create a lighting designs with multiple scenes for the differing tasks in the space. Since tasks such as video conferencing, meetings and presentations will take place in this space, different scenes will be designed to accomadate all activities.

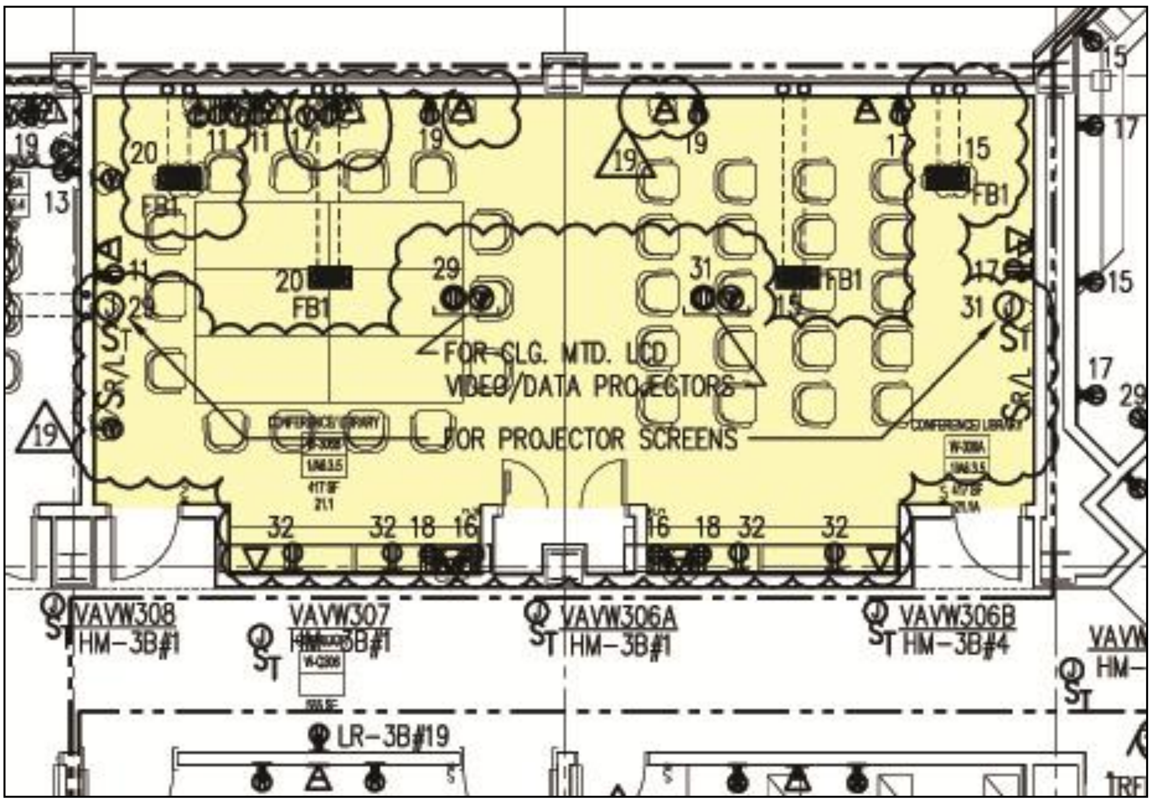

Figure 12: Conference Room Plan View

Table 7: Conference Room – IESNA & ASHREA 90.1 Criteria.

Tasks	IESNA Design Criteria	ASHREA 90.1 Allowable Power Density
Meeting Tasks	30fc (Horizontal); 5fc (Vertical)	1.3 W/ft^2
Video Conferencing	50fc (Horizontal); 30fc Vertical	1.3 W/ft^2

Lighting Design - Student Study Areas:

The Student Study Areas throughout the complex are located periodically along the perimeter of the science complex. Daylight integration into these spaces is a primary focus of the lighting design in this space, and will be coordinated with other disciplines to ensure the most efficient overall design of the system on all fronts. Electric light in this space will be designed to complement the daylight integration and work in tandem to create a visually uniform and appealing workspace. Since the Student Study Areas are opento the corridor, dimming ballasts for the circulation space will be a design consideration.

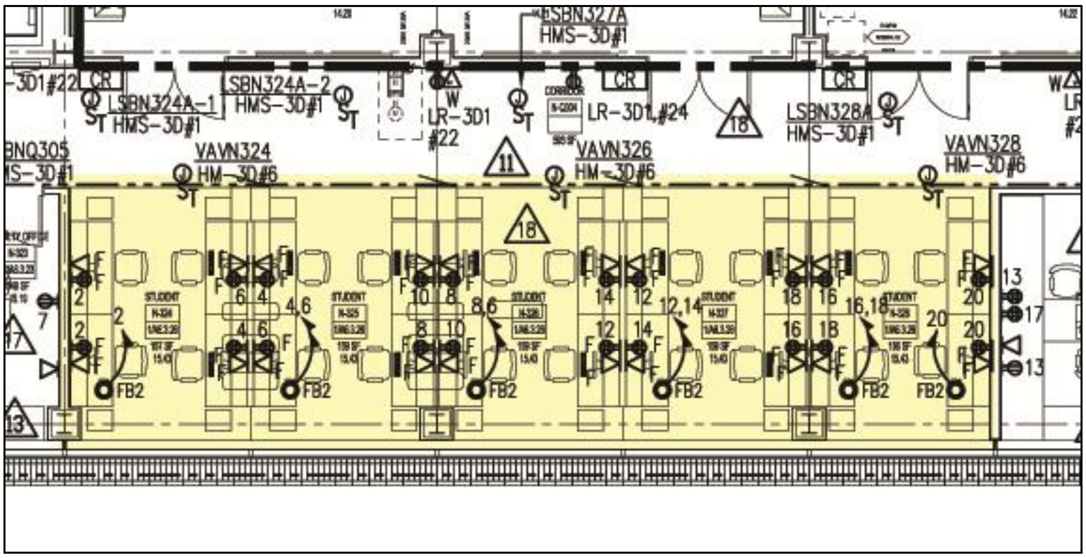

Figure 13: Computer Area – Plan View

Table 8: Computer Area – IESNA & ASHREA 90.1 Criteria.

Space	IESNA Design Criteria	ASHREA 90.1 Allowable Power Density
Computer Area	30-50fc (Horizontal); 3fc (Vertical)	1.2 W/ft^2
Corridor	5fc (Horizontal)	0.5 W/ft^2

Lutron Comments on Tech 3 Lighting Design Presentation (12.8.2010)

General Comments:

- Tell story of building architecture influence on lighting.
- Orientation of spaces in building and site.
- Think interior desing with material coors.
- Perhaps take a look at a lab space for lighting design.
- Don't Dance.
- Provide more Data (i.e. – proof that daylight will deviate cost and some energy).
- Use tools (AGi32 & Radiance) to provide story of daylight harvesting.

Louvers & Daylighting:

- Investigate study of louvers and daylighting into space more before bashing louvers.
- Be sure to investigate solutions that are feasible for all facades.
- If façade design is change, include exterior view of building to display new design from what a pedestrian would see.

Student Study Area:

- If uplighting were used, the corridor may not need lighting.
- Reinforce design for these spaces.
- High cabinets could be used for highlighting corridor wall.
- Balancing of space environment between exterior wall/glazing and corridor wall.
- Energy Savings: Control task lighting when no one is in the space.
- Night-Time control is important.
- Exterior view during evenings is important.

Conference Room:

- Provide source of research.
- Linear fixture is not viable solution for Video Conferencing.
- Don't wash a wall behind the user in the V.C. Situation.
- Make sure lighting and colors don't compete with necessary lighting for vertical illumination.
- Determine video camera location to design lighting appropriately.
- Look into materials and colors.

Cantilever Plaza:

- Unique features? Intent? Night-Time memorability?
- "Oculus" (i.e. – Void) is interesting in the space.
- By highlighting the Oculus, there is an opportunity to ambient light the plaza with a moon-like glow.
- Uplighting the cantilever would be wise.
- They do not believe that the meandering path was designed to discourage use.
  - It's like being drawn to the "Naughty Garden."

Depth Proposal –Electrical

Electrical Depth Topic 1: SKM Analysis

A short circuit analysis will performed using the software program SKM Systems Analysis. Multiple files will be maintained, as the software package available only allows the use of 100 buses, and the Millennium Science Complex contains over 250 branch panels, 27 switchboards and three switchgears.

Electrical Depth Topic 2: Detailed electrical model of 3rd Floor.

To collaborate with other disciplines, a 3-D RevitMEP model of the electrical components on the third floor will be provided. Items that will be included are panel-boards, switchgear, feeder conduit, receptacles, light switches. In addition to these coordination items, panel schedules will be created for the branch panels on the third floor by using the circuiting features provided in Revit MEP. Branch conduits in offices and student areas will be modeled and coordinated as well.

Appendix B: Proposal Summary

Sara Pace – Summary of Proposal Items

1) **Façade:**
   a. **Implement double skin façade:**
      i. Thermal Buffer:
         1. Glazing (for optical and solar properties):
            a) Collaborate with Lighting/Electrical Engineer to find most suitable glazing type(s) to minimize heat gainwhile optimizing daylight integration.
            b) Develop model to determine radiation contribution for sol-air temperature of air space
         2. Design optimal cavity space to be functional for each façade orientation.
            a) Study of a typical office and student study area that are present on each façade orientation.
         3. Develop CFD Model for convective heat transfer and air movement within façade:
            a) Study of a typical office and student study area that are present on each façade orientation.
         4. Run energy simulations to determine potential energy savings
2) **Air Distribution:**
   a. Chilled Beam Implementation:
      i. Study of typical office
      ii. Study of typical student computer lab
      iii. Study of typical equipment corridor
      iv. Study of 3rd floor conference room
   b. Run energy simulations to determine potential energy savings
   c. Determine reduced AHU sizes due to chilled beam use.
3) **Alternative Energy Sources:**
   a. Research wind energy use and microturbines
   b. Analyze the average wind speed reached at the roof system.
   c. Size appropriate number of microturbines needed to supply electricity to non-critical spaces.

4) **BIM/IPD:**
   a. Façade:
      i. Collaborate with other disciplines to model the façade redesign.
      ii. Provide technical information on glazing systems in Revit MEP model.
   b. Air Distribution:
      i. Model ductwork and chilled beams on the 3rd Floor.
         1. Provide technical information on air handling systems
         2. Devices and ductwork in Revit MEP model.
            a) Develop Revit Families for applicable chilled beams and mechanical equipment.
            b) Provide technical information on mechanical devices in Revit MEP model.
         3. Coordinate with Lighting/Electrical Engineer to receive Watts/SF information on a space by space basis for mechanical loads
         4. Coordinate with Structural Engineer
            a) Plenum space available and location of structural members
            b) Revised weight of AHUs in the mechanical penthouse
         5. Coordinate with Construction Manager for initial cost and installation of equipment

c. Alternative Energy Source:
   i. Model & coordinate all roof-mounted microturbines.
      1. Microturbine size
      2. Microturbine weight to give to structural engineer for added roof load
         a) Provide technical information on equipment in Revit MEP model
            (i) Develop Revit families for energy generation and storage devices
               1. Direct web-links to equipment cut-sheets
               2. Manufacturer and Model Numbers
      3. Energy produced from wind generators
      4. Coordinate with Electrical Engineer to determine optimal zones for energy supplied by microturbines
      5. Coordinate with Construction Manager for initial cost and installation of equipment

Paul Kuehnel - Summary of Proposal Items

1. **Cantilever Structure:**
    a. Change direction of braces from compression to tension, (compare internal forces using SAP)
        i. Redesign connections and members
    b. Introduce additional columns to support cantilever
        i. Initial ideas include 3 additional columns around each main entrance at column lines 7 and G
    c. Refine slope of the cantilever to be single sloped instead of the current double slope
    d. Introduce additional truss support above the height of the current cantilever. Develop a way to disguise the structure within the current architecture or assess architectural impacts with group
    e. Perform lateral system check following redesign of cantilever structure
2. **Floor System:**
    a. Check current floor system to compare with data presented by Thornton Tomasetti(ie. Members oversized by 200% for gravity and deflection requirements, to mitigate floor vibrations)
    b. Check floor system for any changes made by other disciplines to make sure structure is adequate
3. **Façade Panels and Connections:**
    a. Develop new precast panel
        i. Design to be lighter and more efficient to construct
            1. Pan joist panel with rigid insulation formwork
        ii. Design for use with continuous or non-continuous double skin façade
            1. Possible air gap
        iii. Analyze wind load capacity of panels using ASCE7-05
        iv. Design panel connections and impact on gravity system
        v. Develop Revit family for Revit Architecture model
4. **BIM/IPD:**
    a. Façade
        i. Coordinate panel design with Mechanical and Lighting/Electrical Engineering on placement of glass
        ii. Coordinate with Mechanical Engineer regarding use of continuous or non-continuous double skin façade
            1. Continuous requires an uninterrupted air gap to be located between the exterior façade and interior wall
            2. Design connections accordingly with input from the Construction Manager
        iii. Model panel Revit family for use in Revit Architecture model
    b. Structural System
        i. Model structural system in Revit Structure
            1. Clash detection using Navisworks
            2. Construction Manager to use for material takeoffs
        ii. Coordinate with Construction Manager for segmenting of structure to develop 4D Navisworks model

Mike Lucas - Summary of Proposal Items

1) **BIM/IPD:**
   a. Façade: Daylight Integration:
      i. Design shading devices to be functional for each façade orientation.
         1. Study of a typical office that is present on each façade orientation.
         2. Study of a typical student computer lab on each façade orientation.
      ii. Glazing:
         1. Collaborate with Mechanical Engineer to find most suitable glazing type(s) to minimize heat gain while optimizing daylight integration.
   b. Modeling:
      i. Electrical Lighting:
         1. Model lighting components on the 3rd Floor.
            a) Provide technical information on lighting devices in Revit MEP model.
            b) Provide Watts/SF information on a space by space basis for mechanical loads
   c. Electrical:
      i. Model & coordinate all feeder conduits on 3rd Floor.
         1. Conduit size
         2. Conduit type (i.e. RMT or EMT)
      ii. Model and coordinate all electrical Panels & Switchboards on 3rd floor.
         1. Provide technical information on electrical distribution devices in Revit MEP model.
2) **Electrical Lighting:**
   a. Under Cantilever Plaza:
      i. Redesign site lighting in this area.
   b. 3rd Floor Conference Room:
      i. Redesign lighting in this area to show three scenes.
         1. Conference
         2. Video Conference
         3. Presentation
   c. Student Computer Lab
      i. Redesign Lighting in this.
         1. Daylight Integration
         2. Chilled Beam integration
3) **Electrical:**
   a. Redesign branch circuit distribution of lighting redesigns.
   b. Short circuit analysis of distribution system (hand calculation).
      i. Specific feed to be from switchgear MDS-01B to switchboard SDP-2D1 to branch panel LB-3D1.
   c. Depth Topic #1: Electrical system SKM analysis.
   d. Depth Topic #2: Detailed 3-D coordination of lighting & electrical components on 3rd Floor.

Jon Brangan - Summary of Proposal Items

1. **Façade:**
    a. Design Double-Skin Facade
        i. Determine key constructability issues.
        ii. Research means of procurement.
        iii. Perform life-cycle cost analysis
    b. Precast Panels vs. Alternatives
        i. Perform cost analysis
            1. Contact potential vendors to determine cost of alternatives.
        ii. Procurement Study
            1. Contact potential vendors to determine lead times of alternatives
        iii. Constructability Study
            1. Determine potential hindrances to use of alternatives
            2. Determine required connections of alternatives
    c. Modeling
        i. Develop Revit model of final design
            1. Provide values and quantities of materials.
    d. Estimate
        i. Upon completion of design, prepare accurate estimate of façade
2. **Structural Redesign:**
    a. Modeling
        i. Develop Revit Model of final design
            1. Provide values and quantities of steel material to be used in estimates
    b. Create detailed estimate of proposed design
3. **3D Coordination:**
    a. Coordination of Models
        i. Create designed coordination meetings
            1. Along with each discipline member, update current Revit/Navisworks file
    b. 4D Modeling
        i. Create functional 4D model
            1. Upon completion of project schedule and Navisworks file, complete 4D model.
        ii. Upon completion of proposed designs, create detailed schedule of activities to be incorporated into 4D model
        iii. Research adjusted sequencing of facility
4. **BIM/IPD:**
    a. Façade
        i. Coordinate with structural and mechanical engineers to determine proper alternatives
        ii. Coordinate with Mechanical engineer on the use of continuous or non-continuous double-skin façade
            1. Inform Mechanical engineers on potential constructability issues or limitations.
        iii. Model panel Revit family for use in Revit Architecture model
    b. Structural System
        i. Coordinate with Structural engineer on sequence of construction
            1. Determine portions of building unable to stand-alone
            2. Determine lead times of members

Appendix C: Electric Company Info & Rates

The Millennium Science Complex is connected to the Penn State campus distribution system. The campus buys power from Allegheny Power for distribution throughout campus. The following information was obtained courtesy of Penn State Office of the Physical Plant and the website provided below:

Name: Allegheny Power, an Allegheny Energy company

Address: Allegheny Energy, Inc.
800 Cabin Hill Drive
Greensburg, PA 15601-1689

Website: http://www.alleghenyenergy.com

Utility Rate Schedule: **Tariff 37**

Distribution:
Demand Charge:
First 10,000kVA…………………………………………$0.91/kVA
Additional kVA…………………………………………$0.90/kVA
Energy Charge:
All kWh……………………………………………………$0.00277/kWh

Transmission:
Demand Charge:
First 10,000kVA…………………………………………$0.19/kVA
Additional kVA…………………………………………$0.18/kVA
Energy Charge:
All kWh……………………………………………………$0.00240/kWh

The University's demand shall not be less than the highest of the following:
50% of the kVA demand capacity of Tariff 37 agreement.
50% of the highest demand previously established during the term of Tariff 37.

Appendix D: Project Goals & BIM Uses

As a way to enhance the overall efficiency of the Millennium Science Complex, several design alternatives have been selected for each discipline and Building Stimulus as a group. The design alternatives will have a large impact on many facets of the building associated with the construction and implementation. With respect to redesigning the building envelope to accommodate a double-skin façade and redesign of the structural system for the cantilever and building as a whole, each BIM goal identified (see table below) for this Project Execution Plan is influenced. These alternative systems will rely heavily on the use of BIM for 3D coordination, simplifying cost estimation, and 4D modeling. Implementing BIM will allow Building Stimulus to locate design errors, serve as an initial model for material take offs, and allow for the generation of an accurate 4D model. In terms of alternative energy sources all BIM goals will be influenced except for Improve On-Site Coordination and Efficiency.

Table 9: BIM Goals and Objectives

PRIORITY (HIGH/ MED/ LOW)	GOAL DESCRIPTION	POTENTIAL BIM USES
H	Assess Cost Associated with Design Changes – compare money spent/saved vs. quantitative benefit of design change	Cost Estimation, Existing Conditions Modeling
H	Increase Effectiveness of Design – Increase efficiency of structural system, lighting/electrical system, and mechanical system	Design Authoring, Design Reviews, 3D Coordination, Engineering Analysis, Existing Conditions Modeling
H	Interdisciplinary Design Coordination – Effectively implement BIM through open communication and periodical design reviews	Design Reviews, 3D Coordination
M	Increase Effectiveness of Sustainable Goals – Increase thermal and lighting efficiency through implementation of double skin façade	Engineering Analysis, LEED Evaluation, Daylight Integration
M	Improve On-Site Coordination and Efficiency	Site Utilization Planning, 4D Modeling