April 7th, 2011

UNIT 2:
CONSTRUCTION REPORT

KGB Maser
Management. Engineering. Consulting.

IPD/BIM TEAM #3

JASON BROGNANO | MICHAEL GILROY | DAVID MASER | STEPHEN KIJAK

Dr. Mistrick | Dr. Jelena Srebric | Dr. John Messner | Dr. Andres Lepage

CONSTRUCTION EXECUTIVE SUMMARY

The Unit 2: Construction Report of KGB Maser's team report will cover the findings and the conclusions on the design analyses completed by KGB Maser on Millennium Science Complex. The Millennium Science Complex is a 275,000 SF Materials and Life Sciences Research Facility that contains 40,000 SF of quiet labs and 9,500 SF of nano-clean room lab space. This unit will cover existing conditions and evaluate the redesigns of KGB Maser in terms of upfront cost, architecture, and the implications to the schedule.

Structural Redesign:

The structural redesign of Millennium Science Complex utilized the placement of two W14X550 columns under the 150 FT signature cantilever and the utilization of castellated beams in the wings that are a separate system of the structure. The effect of the structural redesign is reflected in a significant savings of close to $2,300,000 between an existing conditions detailed structural system estimate and a redesign estimate. The two estimates were completed for the same floor plan, and the cost was applied per square foot to the entire building. The structural redesign will have minimal changes on the duration of the scheduling, but could change the phasing of the structure or the entire project significantly.

Architectural Redesign:

The architectural redesign of the courtyard beneath the cantilever involved the creation of a signature structure and a public gathering space. The existing courtyard plan consisted of an organic, curvaceous design that did not fit the rectilinear design of the rest of the building. The courtyard was redesigned to mask the cascading columns supporting the cantilever, and to also create an interesting public space that matched the buildings architecture. The existing courtyard and redesigned courtyard were estimated in detail; however a price for fabrication of the cage structure could not be acquired from Zahner Architectural Metals. The existing courtyard was estimated to cost $271,700 and the redesigned courtyard was estimated at $604,900 with an allowance built in for the cage structure.

Mechanical/Energy Savings Redesign:

The existing mechanical system and the façade system were both altered in this redesign and both had to be investigated. The existing mechanical system consisting of eight major AHU's was bid by the Farfield Company for $19,188,000, and the redesign of the mechanical system was estimated to be $21,040,000. This increase in upfront costs is funded from the savings on the structural system, and the mechanical system net present value analysis can be found in Unit 4: Mechanical Report. The mechanical system will also require a double crew for the installation of the chilled beams to remain on track with the original durations of the schedule.

The façade pre-cast paneling system was estimated in detail for the entire building to be $3,300,000, while the redesigned pre-cast paneling system was estimated to be $3,052,000 which is a savings of close to $248,000. This savings results from the reduction of the materials used in the façade panels, warranted by a structural study in Unit 5: Structural Report. The redesign of the panels will also have a minimal effect on the schedule due to the fact that the number of panels is not reduced.

TABLE OF CONTENTS

EXISTING CONDITIONS SUMMARY

SCHEDULE NARRATIVE

The Millennium Science Complex project summary schedule encompasses a selection of key activities, starting with the design, bidding and awarding of the project through building turnover to The Pennsylvania State University. Preconstruction for this project began in March 2008 and moved to primary coordination meetings by May 2009. By November 2010 the commissioning process will have begun and the building will be turned over to The Pennsylvania State University in July 2011.

The full summary schedule can be found in Appendix 2A. Below is a short summary made of several key construction activities, their durations, and the corresponding dates.

Construction Phase	Duration (Days)	Start	Finish
Notice to Proceed	1	8-12-2008	8-12-2008
Foundation/Substructure	270	2-16-09	2-26-10
Superstructure	274	7-7-09	7-23-10
Enclosure	303	11-9-09	1-5-11
Building Systems/Finishes	345	12-14-09	4-8-11
Construction Duration	758	8-12-08	7-7-11
Substantial Completion	1	7-7-11	7-7-11

Figure 2.1: Summary of Construction Scheduling

PROJECT COST EVALUATION

Considering the magnitude and complex nature of this project, it was assumed early on that the cost of this project would ultimately be high. While the exact total cost of the project is not known, an approximate total cost of $215 million has been obtained, and will be assumed as the total cost of the project. In addition, all construction and systems costs were obtained based on budgets provided by Whiting-Turner (dated July 3, 2008), and may not be up-to-date.

Total Cost	Total Cost Per Square Foot
$215,000,000	$788/SF

Figure 2.2: Total Cost Analysis

Construction Cost*	Construction Cost Per Square Foot
$139,176,843	$510/SF

***Construction Cost does not include contingency, general conditions, insurance and fees.**

Figure 2.3: Construction Cost Analysis

Building System	Percentage of Project Cost	Cost	Cost Per Square Foot
Structure	17.6%	$24,559,974	$90.06/SF
Plumbing	4.8%	$6,731,107	$24.68/SF
Fire Protection	1.0%	$1,362,000	$4.99/SF
HVAC	18.1%	$25,159,105	$92.26/SF
Electrical	8.9%	$12,313,658	$45.15/SF

Figure 2.4: Building Systems Cost Analysis

BUILDING & CONSTRUCTION SYSTEMS SUMMARY

ARCHITECTURE

Figure 2.5: Existing Architecture Rendering

The Millennium Science Complex is a 4-story LEED-Certified laboratory facility housing Life Sciences and Materials Sciences on The Pennsylvania State University, University Park campus. Located on the eastern end of campus at the corner of E. Pollack and Bigler Rd, the Millennium Science Complex is an L-shaped building with stepping cantilevers and expansive green roofs. Stepping green roofs allow for minimal intrusion on pedestrian areas while concentrating the heart of the building away from the street, maximizing green space. Designed by Rafael Viñoly Architects the building was designed with continuous horizontal glazing along each floor creating a plethora of natural light.

The building is composed of two wings joined with a 150-ft cantilever that stretches out over an open air public plaza. The cantilever allows for the addition of necessary isolated research laboratories to be located beneath the plaza without transferring vibrations through structural members. Over the plaza the wings of the building join at the 3rd and 4th floor to create the L-shaped research facility. The 3rd floor is composed of open meeting areas and lounge space, whereas the 4th floor is dedicated entirely to the mechanical space. Rafael Viñoly Architects have created a unique state of the art facility that compliments Penn State's faculty while providing the tools for research in the field of life and materials sciences.

STRUCTURAL SYSTEM

The sub structure is a cast in place reinforced concrete system consisting of localized groups of 7 in. diameter micro-piles, of ranging depths, under individual pile caps ranging from 36 to 72 inches in thickness and located at the intersection of the column grid lines. 24 and 36 in thick grade beams connect these pile caps along the grid lines.

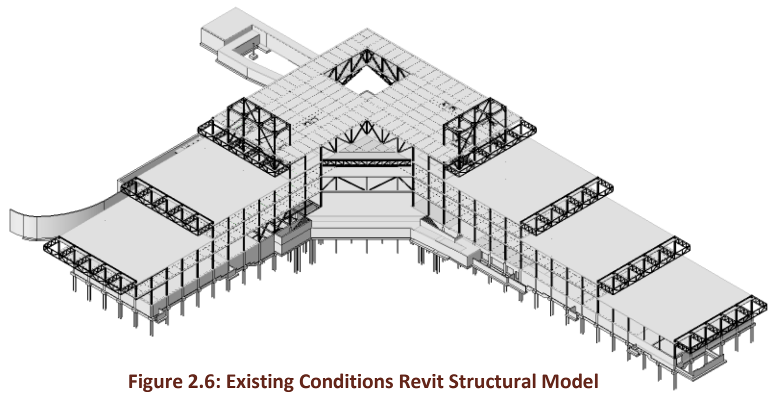

Figure 2.6: Existing Conditions Revit Structural Model

The super structure consists of a typical steel framed building with regular 22 feet square bays. The average floor to floor height is 19 feet. The typical construction for the two wings consists of steel wide flange columns and a concrete on metal deck floor system supported by steel wide flange beams and girders. Column and beam sizes range from W14X43 to W14X233 and W21X44 to W44X593, respectively. The typical floor system consists of 3 inch metal deck with 3 ¼ inch concrete topping.

The structure has to support the 150 foot cantilever at the intersection of the two wings. This is done through the use of a truss system consisting of wide flange members ranging from W14X90 to W14X283. This system is integral with a concrete shear wall extending from the foundation to the fourth floor level. This large c-shaped shear wall also contributes to the lateral force resisting system along with two moment frames and two smaller concrete shear walls at the stair wells.

The structural steel bid package for Millennium Science Complex has a contract value of $18,389,000.

MECHANICAL SYSTEM

The Millennium Science Complex combines both Materials Science and Life Sciences functions and spaces into one building. Each of these spaces contains offices, laboratories, and unique rooms such as a vivarium and a clean room. Different HVAC strategies are required to handle the varying requirements of this unique building.

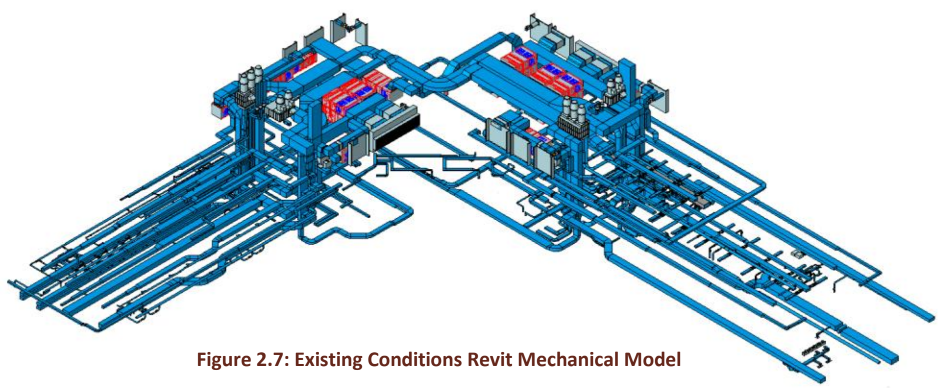

Figure 2.7: Existing Conditions Revit Mechanical Model

The laboratory areas of the building are served by five (5) 50,000 CFM VAV AHUs. Each of these AHUs contains a supply fan, cooling coils, heating coils, humidification equipment, and MERV-14 filters. All laboratory AHUs deliver 100% outside air. In an effort to save operating cost and energy in the DOAS systems, general laboratory exhaust air enters an enthalpy wheel with the incoming supply air. The laboratory fume hood exhaust is not included in the enthalpy wheel due to the potential contaminants within the exhausted fume hood air.

The office, lobbies, and common areas are served by three (3) 40,000 CFM VAV AHUs. These AHUs do not provide 100% outdoor air and instead contain a mixing box with CO2 sensors in the outdoor air, return air, and all conference rooms to ensure that the CO2 concentrations in these areas is maintained at appropriate levels by supplying enough outdoor air.

In addition to the main AHUs, cabinet unit heaters, electric heaters, fan coil units, and supplemental air conditioning units, other local equipment is used to address areas of the building where the main HVAC equipment cannot feasibly serve the area. It is necessary to have all of the previously mentioned components in order to effectively keep the building operating under optimum conditions for the various building occupants.

LIGHTING & ELECTRICAL

Power/Distribution

The electrical system for the Millennium Science Complex is a 12.47kV service feeding a set of dual 4000A, 480Y/277V switchgears (main-tie-main) through two pad mounted transformers. Distribution begins with 480Y/277V for lighting and other systems, and then stepped down at further locations to 208Y/120V for receptacle and equipment power. Emergency power is fed from two separate switchgears which feed multiple ATS's with both normal and emergency power. To limit the EMF from interfering with sensitive equipment, electrical closets are encased with aluminum shielding and in certain areas rigid conduit is used in place of standard conduit.

Lighting

All lighting is on 277V service. All building perimeter offices and laboratories are controlled by both occupancy and daylighting sensors with appropriate dimming ballasts. Typical internal laboratory and office rooms are controlled by the occupancy sensor. Three general types of ballasts are used. Class B quiet dimming ballasts are used in the quiet labs. Lutron's Hilume dimming ballasts are installed for rooms requiring less than 10% dimming from full power. Advance Mark7 dimming ballast is used in rooms with regular dimming conditions. A system of addressable ballasts is used in accordance with Lutron's GRAKIF Eye system.

ENCLOSURE

A complex pre-cast panel system comprises the majority of the Complex's building enclosure. Each of the 338 precast pieces were fabricated in York, PA and trucked to the site. 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 22' panel is mechanically attached to the exterior column structure by a threaded rod and gusset plate system. Between each precast section, two lites 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 day lighting. A system of metal panels and storefront glazing encloses the building around the landscaped exterior atrium.

PROJECT SITE LOGISTICS

Figure 2.8: Bing Maps View of Millennium Science Complex Site

The project site is located on The Pennsylvania State University campus at the corner of Bigler Road and Pollock Road, directly across from the Pollock Testing Center. Figure 2.8 above shows the site for Millennium Science Complex and some of the surrounding buildings. To the North of the project site is the Eisenhower Parking Deck, to the East is Nittany Apartments, to the South is the Pollock Testing Center, and to the West is the existing Life Sciences building.

The site was originally occupied by two roller hockey rinks, tennis courts, and intramural sports fields. The site for Millennium Science Complex is also surrounded by a variety of different building types, and vast amounts of student and vehicular traffic. To the East, across Bigler Road, is Nittany Apartments, where students must be easily able to arrive from and depart for class safely. To the North of the site, along Eisenhower Parking Deck, is a main artery of student travel in which safety is a main concern. On the South edge of the Life Sciences Wing, the building cantilevers over the pedestrian walkway, in which case a temporary structure has to be built in order to protect pedestrian safety.

Another main concern during the construction of Millennium Science Complex is the amount of vehicle traffic that is on Bigler Road and Pollock Road. CATABUS Community Service Lines use both Bigler Road and Pollock Road as part of their routes, and the Blue Loop also comes up Bigler Rd and turns onto Pollock Rd to continue its campus loop. Vehicle and pedestrian traffic are a main consideration in the Site Logistics planning for the Millennium Science Complex.

Aside from the complexities that Whiting-Turner had to deal with outside of the site, creating a site logistics plan for the building has also proved to be cumbersome. Whiting-Turner first began with a two phase site logistics plan. The first plan would cover from site preparation through the foundation being complete. The second phase site logistics plan would cover from steel erection to interior finishes. Both Site Logistics plans are shown on the next page.

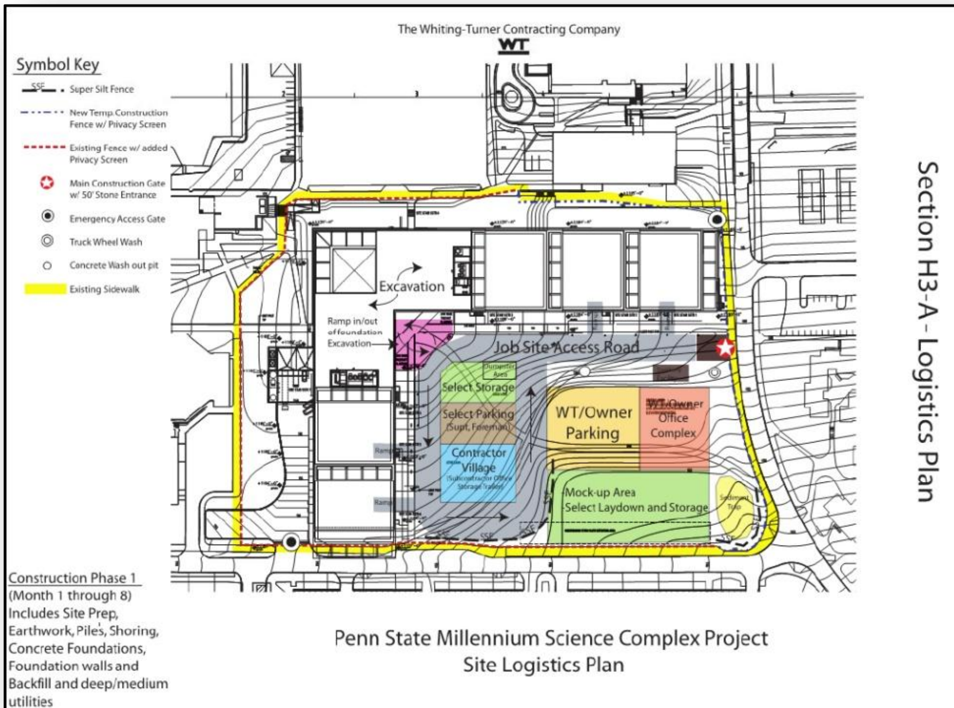

Figure 2.9: Phase 1 Site Logistics Planning

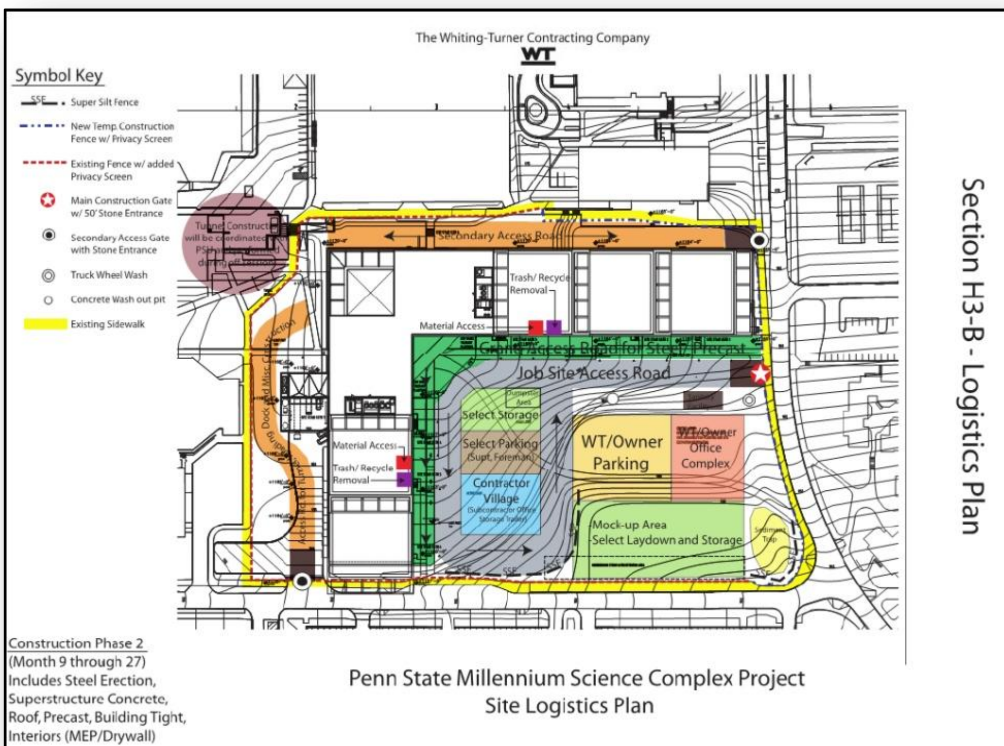

Figure 2.10: Phase 2 Site Logistics Planning

While the existing 2D site logistics plans from Whiting-Turner were beneficial, we were able to model the site logistics plans in 3D to get a better understanding of how project phasing would go, and how design changes could affect project phasing and delivery. Below is an image from the site logistics model that was created consisting of the various crane sizes and types that were used.

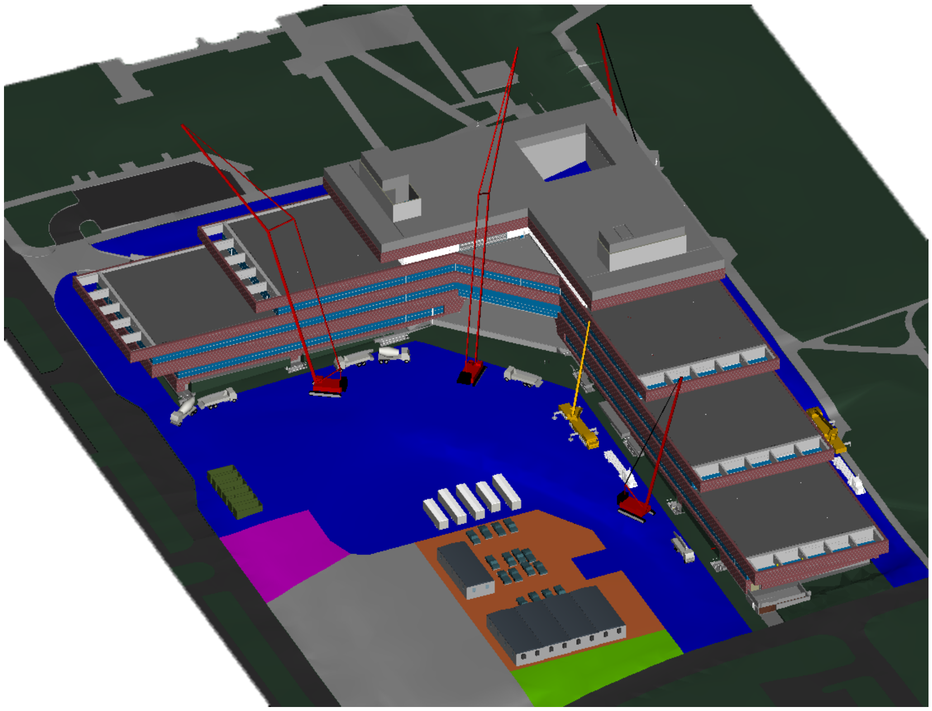

Figure 2.11: 3D Site Logistics Model in Navisworks Manage

PROJECT STAFFING & DELIVERY METHOD

PROJECT STAFFING

Whiting-Turner is staffing the project based on the project size and complexity. A simplified staffing plan is shown on the next page, and a full staffing plan is attached in Appendix 2.B. This particular project has two Sr. Project Managers, four Project Managers, a Sr. Superintendent, two Superintendents, and five Project Engineers. The project is overseen by Dick Tennant, an owner's representative Construction Manager. Both the project management and field supervision staff are placed on site in the trailer complex. Typically the management staff holds weekly subcontractor coordination meetings. The project management staff will handle all project submittals, most of the RFI's, and review the payment requisitions from the subcontractors. As for the Superintendents and their assistant, they handle all field installations using approved submittal and shop drawings. Superintendents also supervise the subcontractor's daily activities. Whiting-Turner's Safety efforts are in the mind of everyone on the staff; however Cesar Sastoque, a Safety Specialist Superintendent, is responsible to help create a safe environment by preventing dangerous practices on site. He is accountable for being aware of proper procedures and safe construction methods during the hours of construction.

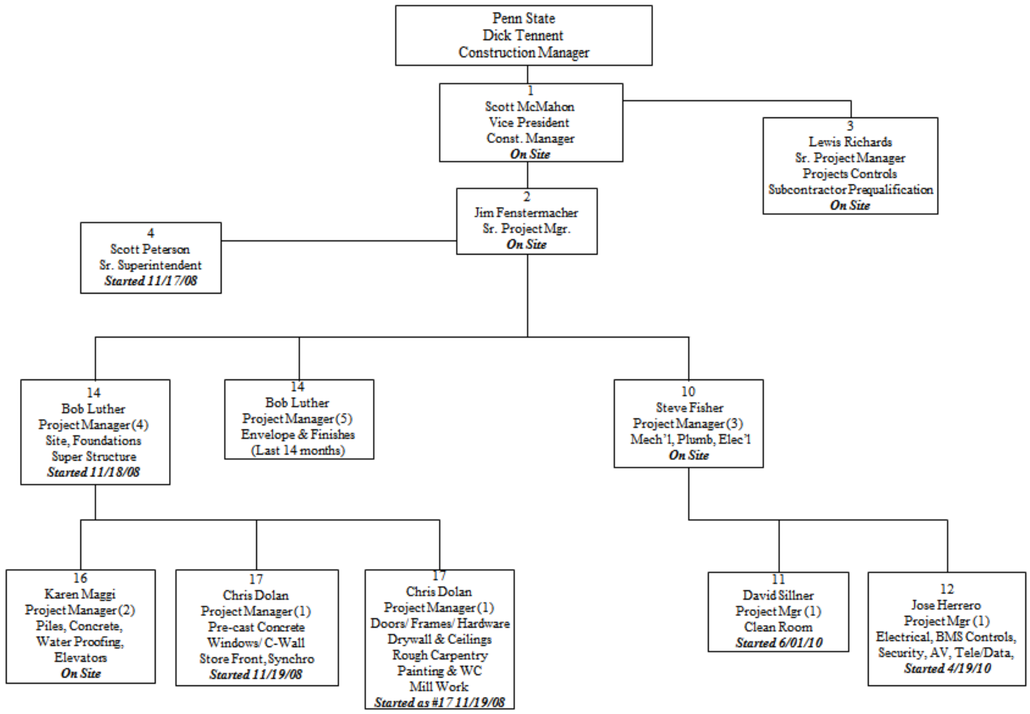

Figure 2.12: Simplified Project Staffing Plan

PROJECT DELIVERY

The Millennium Science Complex is primarily a Design-Bid-Build delivery system, with a form of Construction Management Agency and Fee in place with Whiting-Turner Contracting. Because this project has Department General Services (DGS) funding, Penn State University is required to hold the contracts which are publicly funded directly. These contracts include site demolition, underground utilities, micro-piles, structural steel, mechanical, and other early on activities. This project encompasses an interesting set up in that the owner, Penn State University, holds contracts with both a construction manager, as well as subcontractors.

Whiting-Turner, in effect, acts as a construction management agent to Penn State University, and is held responsible for overseeing, managing and coordinating the trades with which Penn State University holds contracts directly. At the same time, Whiting-Turning maintains contracts will all other subcontractors on site, and must maintain their responsibilities to manage their own subcontractors. Through their contract with Penn State University, Whiting-Turner performs their work for a fee.

ARCHITECTURAL REDESIGN STUDY

The architectural redesign of the cantilever courtyard was a multiple step process in which there were numerous iterations on the design. The existing design can be seen in the rendering to the right. Large open spaces and sweeping paths fill the courtyard. The ground cover consists of decorative grasses, stones, and plants. This design of the courtyard seemed to contrast the rigidity and linear design of the rest of the building. A free flowing layout of the courtyard was an organic design that could have reflected the Life Sciences aspect of the building, but contrasted with the strong lines of linearity of the rest of the building.

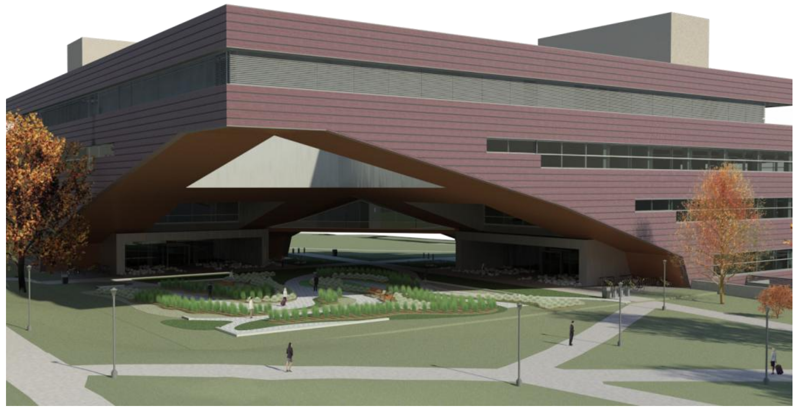

Figure 2.13: Existing Conditions Cantilever Courtyard Rendering

The first attempt at designing an architectural and structural column that would aid in supporting the cantilever was a single column placed at the North-West corner of the light well in the cantilever. For structural purposes, the column was placed at the intersections of grid lines B and 2. While this design worked well in terms of simplicity, structural capabilities, and had a minimal interference with the floor plan, it did not blend well with the design of the building and simply looked like an afterthought.

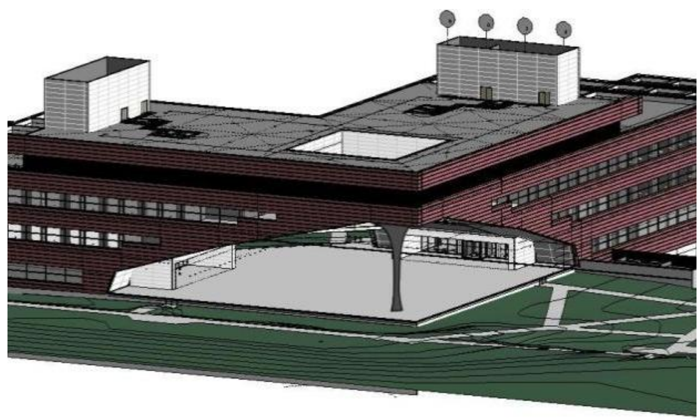

Figure 2.14: Cantilever Support Design #1

After going to the construction site and sketching other possible designs, KGB Maser began to develop a strong rigid design that utilized a cage structure to reduce the unbraced length of the column supporting the cantilever. To the right is one of the first renditions of the final design.

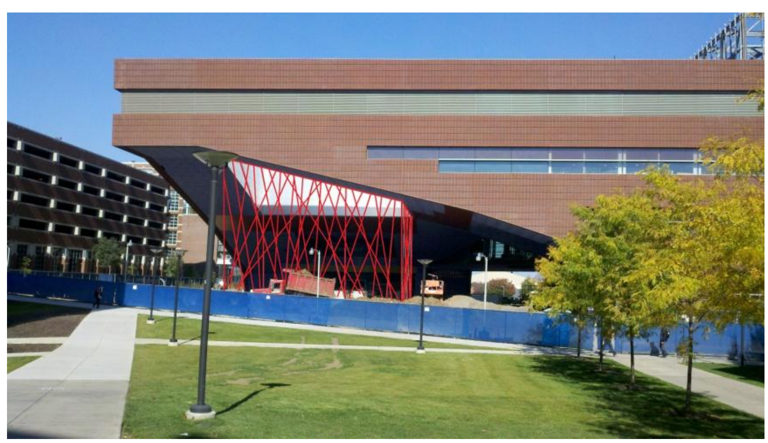

Figure 2.15: Preliminary Cage Structure Sketch

The first model with this design scheme consisted of a light, airy cage structure that didn't create a strong enough statement to still look like a featured aspect of a signature building like Millennium Science Complex. The cage structure was made much more significant with the increase in the size of each stick of the structure. Also to give the cage structure some depth and multiple aspects, a second layer was added with sticks ranging in size from six inches wide and a foot deep to one and a half feet wide and one and a half feet deep. The sticks are wrapped in two materials consisting of a blue brushed aluminum and a semi polished aluminum. The final design pictured to the left required significant coordination with the structural engineer to determine were cross bracing had to be placed for the columns supporting the cantilever, and also added a second column at the intersection of column lines E and 5. The final design is shown below in a rendering and the columns are shown in a basement floor plan to show the minimal effect that they will have on the floor plan of the lab spaces.

Figure 2.16: Final Cage Structure Design Rendering

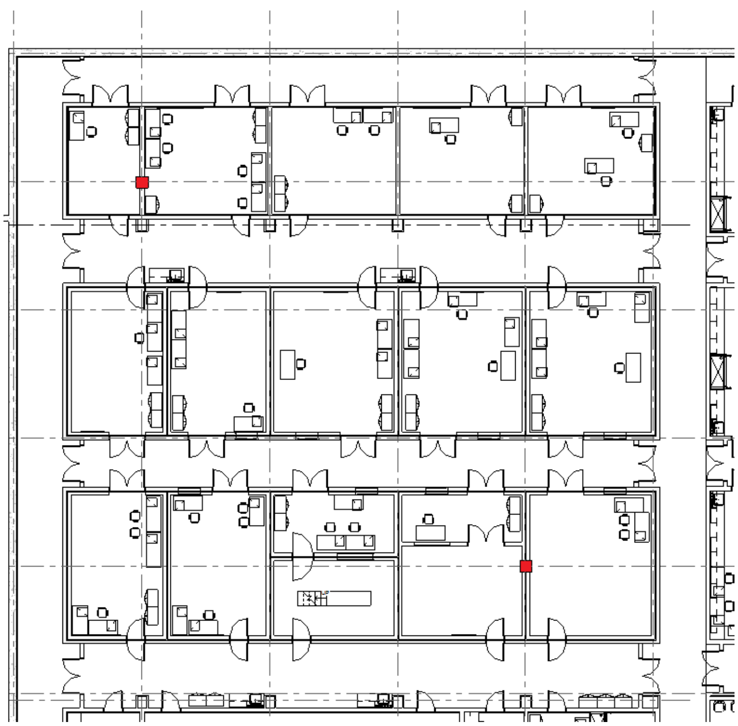

Figure 2.17: Basement Floor Plan with Cantilever Support Columns

FAÇADE REDESIGN COST IMPACTS

FAÇADE CONSTRUCTABILITY CONCERNS

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, maintenance scheduling, and the constructability of the façade redesign will all have to be considered while selecting a façade system.

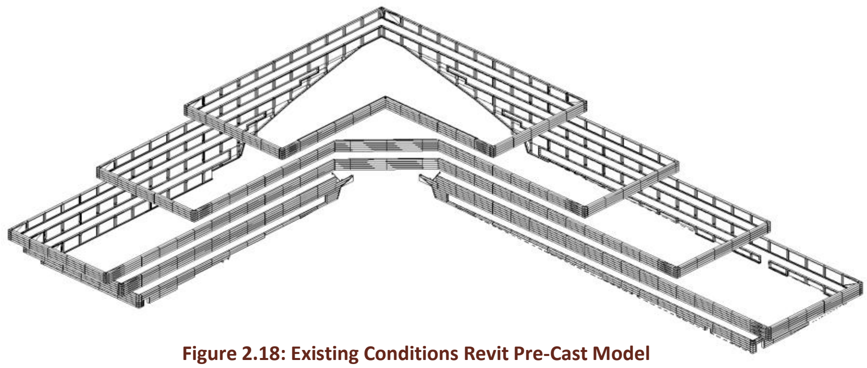

Figure 2.18: Existing Conditions Revit Pre-Cast Model

The precast panels of Millennium Science Complex cost $5.6 million, according to the bid packages available from Penn State's Office of Physical Plant, 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. 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 redesign 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.

DETAILED ESTIMATE

The pre-cast panels of the façade consists of over 330 brick faced "C" shape panels with 6" of concrete backing. RS Means had pricing information for a 20'X10' architectural panel with a 6" thickness. This panel pricing information was used for a baseline, but the volume of this panel was compared to the volume of the nominal pre-cast panels at Millennium Science Complex. The increased percent of volume was relayed to the material pricing that would be used for our detailed estimate. The total square feet of precast for the entire building was exported from Revit Architecture to Microsoft Excel, and the estimate was completed.

The total square feet of pre-cast panels will not change, but for each square foot of the panel, there will be less material used. The reduction in material is not enough to warrant a reduction in crane size or reduction of crew so the labor and equipment pricing will stay the same for the redesigned panel.

Existing Pre-Cast							
Total (SF)	Material	Labor	Equipment	Total	Cost	Time	O & P
72319.11	27.3	1.74	1.63	30.67	$2,218,027	$2,816,894	$3,295,766
			TOTAL COST =	$3,295,766.47			
Redesign Pre-Cast							
Total (SF)	Material	Labor	Equipment	Total	Cost	Time	O & P
72319.11	25.03	1.74	1.63	28.4	$2,053,862	$2,608,405	$3,051,834
			TOTAL COST =	$3,051,834.62			

Figure 2.19: Existing and Redesign Pre-Cast Estimate

MECHANICAL REDESIGN COST IMPACTS

EXISTING CONDITIONS COST BREAKDOWN

The mechanical system was going to be estimated from the mechanical Revit MEP model, which did not include everything to its entirety as a coordination model. Figures 2.20 and 2.21 below show the difference in detail from the coordination model to the Revit Mechanical Existing model.

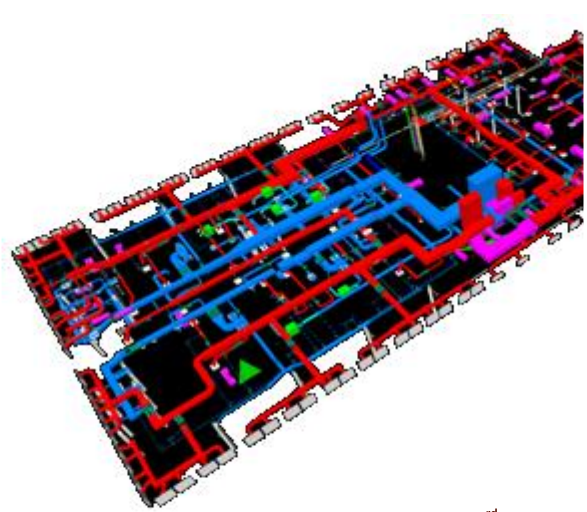

Figure 2.20: Mechanical Coordination Model – 3rd Floor LS

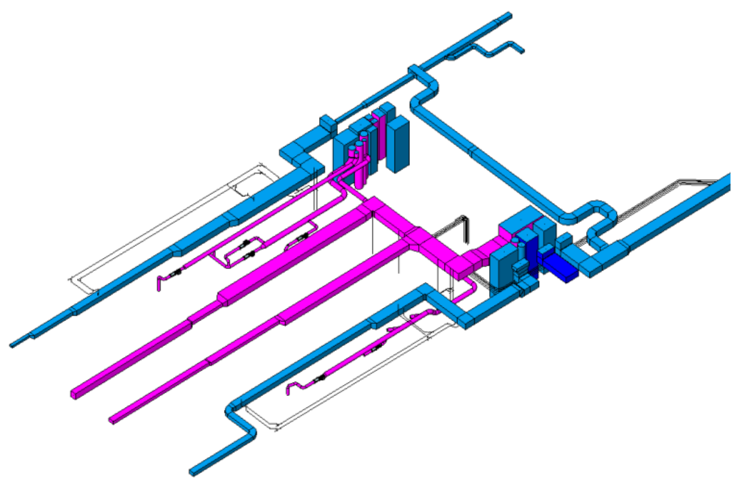

Figure 2.21: Revit Mechanical Existing Conditions Model – 3rd Floor LS

This lack of detail in the Revit Mechanical model required that assumptions be made for the estimate, which reduces the detail and precision of the estimate. Instead of doing a detailed estimate existing conditions estimate of the third floor for comparison, the entire building mechanical system had to be compared for the analysis. The Farfield Company was awarded the mechanical system, for the bid value of $19,188,000. This cost breaks downs to a cost per square foot of $78.38/SF.

COST IMPLICATIONS OF REDESIGN

The redesign of the mechanical system will include the use of two different types of chilled beams, each with extensive copper piping to be priced for the connections. Chilled beam prices have come from calling suppliers and researching labor output and labor pay rates. The redesigned system will have a cost reduction in AHU's of $452,924. Below is a summary of the cost of chilled beams, piping, and ductwork for the entire redesigned mechanical system. This cost is derived from a SF based estimate of the mechanical system, with the equipment and pumps being added.

The methodology behind this estimate is a detailed estimate of a predetermined area of the building. This predetermined area was modeled and estimated in detail, and the cost per SF was applied to the rest of the building. After the cost of these main categories was calculated, the pricing of the pumps was found through RS Means Mechanical Cost Data, and the AHU's were priced on a quote from SEMCO HVAC. The quote for this equipment is attached in appendix 2.C.

Chilled Beams	Ductwork	Piping	Pumps	AHU's	Total with GC & Crane Cost
$9,608,006.00	$2,966,422.00	$377,840.00	$165,484.00	$2,274,046.00	**$21,035,567.00**

Figure 2.22: Mechanical Estimate Breakdown Summary

The total cost of the redesigned mechanical system is expected to be around $21,040,000 based on a detailed square foot based estimate. This final cost includes general conditions and any crane costs for lifting mechanical equipment to the mechanical penthouse on the fourth floor. Detailed schedules are also attached in Appendix 2.D for the area that was detail estimated from the third floor.

ARCHITECTURAL REDESIGN OF COURTYARD

EXISTING CONDITIONS DETAILED ESTIMATE

The current design of the courtyard consists of sweeping paths with varying types of decorative grasses and gravels. Figure 2.23 to the right shows the existing design of the courtyard. This design was estimated in a detailed manner with takeoffs of major ground coverings, plantings, park benches, and bicycle racks. Pricing information was gathered from both RS Means and contacting vendors for specific plants.

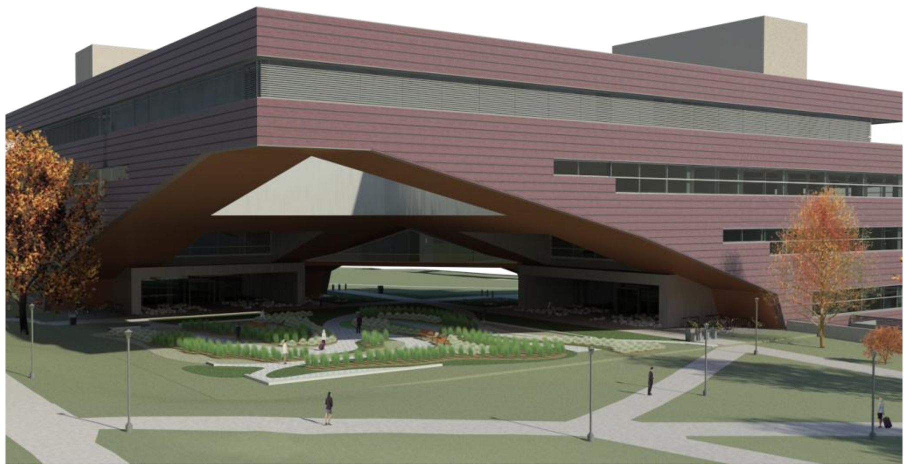

Figure 2.23: Existing Courtyard Rendering

Type	Total	Unit	Cost Total	Cost Unit	Cost
RPC Shrub: Century 1'-10"	244	EA	22	EA	$5,368.00
RPC Shrub: Switchgrass (2) 4'-0"	327	EA	17.1	EA	$5,591.70
Basic Wall: Concrete Panel Wall	214.5	FT	11.45	LF	$2,456.03
Custom Park Bench 6'-0"	5	EA	526.5	EA	$2,632.50
Bicycle Racks	8	EA	649	EA	$5,192.00
Stamped Stone Path	4271.75	SF	17.05	SF	$72,833.34
Mulch	4624.63	SF	2.91	SY	$498.43
Bermuda Ornamental Grass	1298.57	SF	50	SY	$2,404.76
Ground Cover Grass	8487.97	SF	220	MSF	$ 1,867.35
Fern/Boulder Area	1926.43	SF	46.3	SY	$3,303.47
Exposed Aggregate Concrete	1451.47	SF	18.18	SF	$26,387.72
Decorative Pea Gravel	4337.69	SF	7.1	SF	$30,797.60
Decorative Boulders	240	EA	28.85	EA	$6,924.00
					$166,256.90

Figure 2.24: Existing Courtyard Breakdown Summary

Total Including O & P, Waste, Delivery, & Time Modifications = **$271,745.24**

REDESIGN DETAILED ESTIMATE

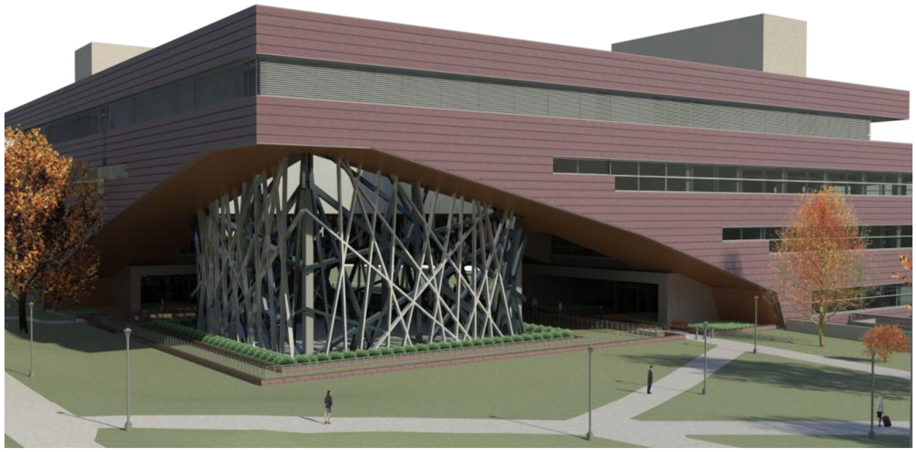

Figure 2.25: Redesign Courtyard Rendering

KGB Maser's redesign of the courtyard was necessitated by the integration of the W14X550 columns beneath the cantilever. The redesigned courtyard wraps the columns and the opening of the 66'X66' light well in the cantilever. This cage structure consists of two primary materials, brushed blue aluminum and a semi-polished aluminum. Due to the complex nature of estimating an artistic structure of this nature, Zahner was consulted for pricing information of a fabrication estimate of the cage structure. Zahner is experienced for over 110 years in working in an architectural metal industry.

The redesigned courtyard was estimated in the same manner as the existing courtyard. Ground covering, planting, site accessories, outstanding items were considered in the estimate.

Type	Total	Unit	Total	Unit	Cost
RPC Shrub: Acacia 3'-6"	101	EA	63.8	EA	$6,443.80
RPC Shrub: Fountain Grass 1'-6"	733	EA	21.01	EA	$15,400.33
Basic Wall: Courtyard Path Wall	1617.89	LF	12.34	LF	$19,964.76
Park Bench 6'-0"	16	EA	448.5	EA	$7,176.00
Courtyard Railing	486.5	LF	22.92	LF	$11,150.58
Mulch	14492.05	SF	2.91	SY	$1,561.92
Cage Structure(ALLOWANCE)	1	EA	0	EA	$ 1,000,000
Courtyard Sod	9356.29	SF	265.95	MSF	$2,488.31
					$ 64,185.70

Figure 2.26: Redesign Courtyard Breakdown Summary

Total Including O & P, Delivery, Waste, & Time Modifications =	**$1,104,910.88**

STRUCTURAL REDESIGN COST IMPACTS

STRUCTURAL CONSTRUCTABILITY CONCERNS

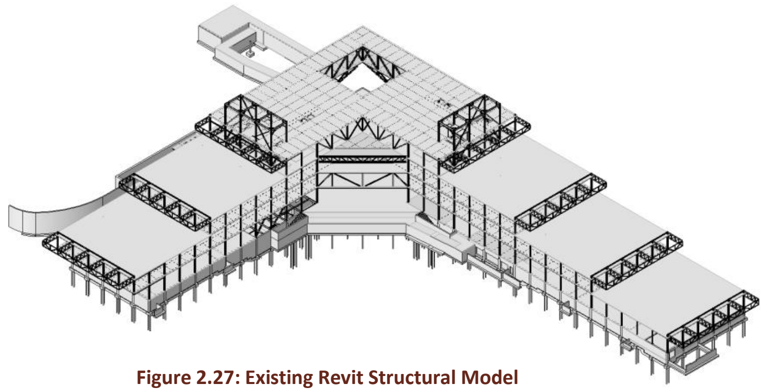
Figure 2.27: Existing Revit Structural Model

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. The structural redesign of the cantilever and floor systems will benefit the constructability and cost of Millennium Science Complex. The cost of the structure could have a significant decrease with the columns being placed underneath the cantilever. The use of other supporting systems will also help eliminate some on the truss bracing that is a concern for coordination on the 4^{th} floor mechanical 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 and easier to plan.

The use of columns under the cantilever should reduce the current truss system, and will 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 and the amount of planning and sequencing are both expected to be reduced, due to the reduction in the complex nature of the structural system, specifically the 150-ft cantilever.

A smaller crane size is not a likely possibility due to the fact that the crane will still have to be placed between the two wings to erect the courtyard/cantilevered area. Furthermore, the addition of the W14X550 columns under the cantilever will have to be placed from this location as well.

EXISTING DETAILED ESTIMATE

The existing structural steel was estimated in detail for both the entire building and the third floor with RS Means cost information. Autodesk Revit Architecture was used to create structural framing and structural column schedules for the entire existing structural steel, the existing and redesigned 3rd floor structural steel. Due to the irregularity of some of the W shapes used in the structure, linear extrapolation was used to determine pricing for some of the larger beam sizes that needed to be priced.

Existing Entire Structure				
	Framing Tons	Column Tons	Framing Cost	Column Cost
	3058.7 Tons	953.84 Tons	$8,179,891.34	$2,386,659.20
		Total =	$10,566,550.54	
Existing 3rd Floor Structure				
	Framing Tons	Column Tons	Framing Cost	Column Cost
	595.72 Tons	231.47 Tons	$1,848,680.85	$434,508.19
		Total =	$2,283,189.04	

Figure 2.28: Existing Conditions Structural Cost Breakdown Summary

REDESIGN DETAILED ESTIMATE

Our redesign for the floor system consists of castellated beams for the wings, and including W14X550 columns with bracing to support the cantilever. These changes to the structural system were estimated in detail for the third floor. With a cost for the third floor both in an existing conditions and a redesigned state, costs were compared and the savings per square foot was calculated. With a savings per square foot, we were able to apply the savings of our redesign to the entire building.

Redesign 3rd Floor Structure				
	Framing Tons	Column Tons	Framing Cost	Column Cost
	459.79 Tons	202.92 Tons	$1,310,896.61	$539,218.72
		Total =	$1,850,115.33	
Cost Implications to Entire Structure				
	Savings/SF	Total SF	Total Savings	Total Cost
	$8.3326/SF	274,922 SF	$2,290,815.05	**$8,275,735.48**

Figure 2.29: Redesign Structural Cost Breakdown Summary

It is estimated that the structural system redesign will save close to $2.3 million. The savings was taken off of the detailed structural steel estimate that was completed with cost information from RS Means, so that the savings was compared to an estimate that was constructed from the same manner and assumptions rather than comparing our savings and our detailed estimates to the structural steel package contract value of $18,389,000 for

Kinsley Construction. Attached in Appendix 2.E are the detailed take offs of the entire structure, existing third floor structural steel, and the redesigned third floor structural steel.

SCHEDULE IMPLICATIONS

FAÇADE REDESIGN

The façade redesign is very important to analyze with respect to the schedule because it could affect the duration until the building cane become water tight. However, the schedule implications due to the redesign of the pre-cast architectural panels are very minimal due to the fact that the number of panels and total square feet of the panels will not change. It is understood that also the redesign of the panels will not warrant a reduction in crane size. This may allow for a quicker pick time for each panel, with each panel being reduced in weight, but will reasonably take the same amount of time to set each connection for the panel.

MECHANICAL REDESIGN

The original duration of the mechanical system installation is 303 days from 12/24/09 to 2/9/11. This sequence of activities is an integral part of the critical path so it is necessary to try to maintain at the most this same duration. Chilled beams are very labor intensive and require a lot of field fabrication of connections. It is estimated based on our design that Millennium Science Complex will house roughly 3300 chilled beams to install. The installation of the chilled beam is what will change the schedule the most. From conversations and research through mechanical contractors, it has been found that a typical crew can install 5-6 chilled beams per day. This production rate would mean that the installation duration for the 3300 chilled beams would be around 600 days. With this extended duration, it would be necessary to add another crew to keep track with the original schedule duration of 300 days.

The mechanical penthouse will also have less equipment to be installed which will also lower the duration of the installation for the mechanical system. With less equipment and cross bracing in the mechanical penthouse as well, the installation of the ductwork and piping will take less time to coordinate and install. The mechanical system installation of the equipment and the chilled beams is expected to remain close to the existing duration through the use of a double crew to install the chilled beams.

STRUCTURAL REDESIGN

The erection of the structural steel is a critical task to analyze with respect to scheduling. The original structural steel erection duration was 274 days. It is believed that our redesign will have an erection duration of the same expected time, with a minor possibility to reduce this duration do to a reduction in the complex nature of the structural design, and a change in sequencing.

The existing structural sequencing begins steel erection with the East side of the Material Sciences wing works west through the wing, secondly moving to the South of the Life Sciences wing and working North. Finally the erection of the cantilever could be completed after the shear walls and moment connections were completed. With the reduction in moment connections and less detailed sequencing and coordination need for our redesign cantilever, the erection process can work from the East of Material Sciences to the West, construct the cantilever, and move on to the Life Sciences wing working from North to South.

While the structural redesign maintained the same number of pieces for structural framing, the additional two W14X550 columns will have to be set. This is again a minimal impact to the schedule. A standard steel erection crew (E-2) can set over 900 LF of columns per day. This makes a maximum to set the columns at half a day, which can be recovered by the reduction in complexness.

The Manitowoc 999 and 16000 cranes used for steel erection will primarily still be used, and will not be reduced in size due to the fact that there are still very large member sizes that need to be set for the vibration labs. (W40X593) These picks along with the enlarged W14X550 columns necessitate that the crane size can't be reduced.

SUMMARY AND CONCLUSION

The original interpretation of the team goals was to save money in some areas to provide for the upfront cost of the life cycle saving options. The cantilever, structural, and architectural redesign studies seemed to be areas to save money to fund higher efficient lighting fixtures and the mechanical redesign for energy savings.

The cantilever study of the structural system was a successful study in finding that there would be a savings of close to $2,300,000. This savings however covers the entire structural system, and not the percentage saved by simply placing the columns into the cantilever and seeing the savings from this redesign. KGB Maser believes that the cantilever is a successful option that could have been considered early in the design as another viable option to the cantilever. Along with the columns being placed for support KGB Maser was able to create an architectural study and believe that we have created an interesting courtyard space and a significant signature structure of the campus.

The chilled beam implementation for the mechanical system redesign will increase the current $19,188,000 mechanical system package by $1,852,000 or for a total new mechanical system with chilled beams of $21,040,000. This is a substantial increase in the upfront cost, but will have a lower net present value if inflation is considered. Reference Unit 4: Mechanical for further investigation on the net present value. KGB Maser believes that chilled beams are a viable option that can have an upfront cost increase, and will affect the schedule due to the labor intensive connections.

The façade was another area of improvement for KGB Maser's redesign as we saved $244,000 in the pre-cast paneling system by lessening the materials used. This results in a final pre-cast paneling contract value of $3,005,000 instead of close to $3,300,000 that was estimated for the existing conditions design.

KGB Maser believes that the designs and proposals that have been developed should have been strongly considered in the early stages of design. We have presented the results of our designs, and believe that as a whole our designs can still save close to $350,000 in upfront costs. This total analysis of savings is completed in Unit 1: IPD/BIM DISCUSSIONS.

REFERENCES

Bechtel, J. (2011, November). Office of Physical Plant, The Pennsylvania State University. (D.Maser, Interviewer)

Davis, Gary. (2011, February 23). Zahner Architectural Metal. (D. Maser, Interviewer)

Dolan, Chris. (2010-2011). Whiting-Turner. (D.Maser, Interviewer)

RSMeans Building Construction Cost Data. 60th ed. Kingston, MA: Construction publishers & Consultants, 2002.

RSMeans Interior Cost Data. 24th ed. Kingston, MA: Construction publishers & Consultants, 2007.

RSMeans Mechanical Cost Data. 30th ed. Kingston, MA: Construction publishers & Consultants, 2007.

RSMeans Site Work & Landscape Cost Data. 26th ed. Kingston, MA: Construction publishers & Consultants, 2007.

Taylor, M. (2011, February 28). Nitterhouse Concrete Products, Inc. (D.Maser, Interviewer)