Central Bed Tower Expansion

University of Virginia Charlottesville, VA

Final Report

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Construction Management

University of Virginia Health System

Central Bed Tower Expansion

Charlottesville, VA

Gilbane RUSSELL

Building Summary

Owner: UVA Health Systems
Building Name: Central Tower Bed Expansion
Function: Medical Center
Size: 60,000 Square Feet
Total Height: 7 floors
Duration: November 2008 – December 2011
Delivery Method: Design Assist -CM Agency
Cost: $55 Million

Architectural Features

- The Bed Tower Expansion will include a 2nd floor mechanical space and 6 patient occupied floors (3rd—8th)
- Each of the occupied floors will accommodate 12 patient rooms along the new façade.
- Façade is composed of metal wall panels, glass, and glazing
- Expansion will tie into existing hospital.

MEP Systems

- The Bed Tower Expansion will be serviced by the hospital wing's existing 8 air handler units
- 3,250 sqft of the new 2nd floor space will be dedicated to a relief air plenum
- The other 3,250 sqft of the new 2nd floor will accommodate a new 4000A, 480/270V transformer system and two new electrical rooms.
- A 25,000 and 45,000 CFM air plenum spaces will be added to the existing penthouse.

Structural System

- Bed Tower Expansion will sit on existing main lobby of hospital
- Select steel columns will need to be reinforced before construction can begin.
- Structure will consist of wide flange beams and columns
- Structural steel will support 4 1/2 lightweight concrete slabs poured on a 2" gage galvanized metal deck
- New addition will be bolted or welded into existing columns creating moment connections.
- Glass façade will be connected to the steel structure so weight will be self supported

Sarah L. Bell

Architectural Engineering | Construction Option
http://www.engr.psu.edu/ae/thesis/portfolios/2012/SLB5205/index.html

Acknowledgements

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Gilbane Russell Trust + Teamwork = Solutions

SmithGroup architecture engineering interiors planning

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Gilbane/Russell Project Team

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UVA Project Team

Bob Nashed at SmithGroup

PACE Industry Members

My Friends and Family

1.0 Executive Summary

This Senior Thesis Final Report is intended to discuss the findings, conclusions, and recommendations of the four analyses performed on the University of Virginia's Hospital Bed Expansion in Charlottesville, VA. This project features a 60,000 SF expansion along with a 70,000 SF renovation of the existing facility. The expansion/renovation will add 70 new private patient rooms across five floors. Each performed analysis has the intention of bettering the project design and construction through cost and schedule reduction, value engineer, and quality control.

Analysis #1 – Schedule Reduction via Acoustical Walls (*Breadth*)

The goal of this analysis was to find a means of reducing the construction schedule. Because the hospital is still an occupied facility, time restrictions have been implemented to reduce possible disturbances to the patients and staff due to high noise volumes, vibrations, and dust control. This analysis looked into the feasibility of utilizing prefabricated acoustical walls to isolate and suppress construction. The wall design proved beneficial in isolating the noise levels; however, a solution could not readily be found for vibrations traveling through the structure.

Analysis #2 – Quality Control and Schedule Reduction via BIM Implementation

The goal of this analysis was to find a means of reducing the construction schedule while also providing a more quality experience during construction for the hospital patrons. This analysis suggested that a phased schedule tied into a detailed 3D model would create a more organized sequence while providing more clarity for construction teams and hospital patrons. The phased schedule/model is believed to aid in the schedule savings and be a benefit to all parties; however, it was recommended that a more simplified 3D model be used do to the feasibility of creating a 3D model in detail.

Analysis #3 – Value Engineering via Energy Design of Photovoltaic Façade Change (*Breadth*)

The goal of this analysis was to add value to the hospital expansion by maintaining a unique façade that would help alleviate the electrical load. The Photovoltaic Glass Units (PVGU) were believed to provide efficient privacy for the patient rooms, maintain an excellent insulating value, and produce an efficient amount of power during the day. In order to follow the current façade design, a total of 576 windows were needed. The total power produced by these units is around 112.4 kW and would save around $3,310.48 per year.

Analysis #4 – Schedule Reduction via Prefabricated MEP Systems

The goal of this analysis was to find a means of reducing the construction schedule. Prefabrication has become a popular method to aid in schedule reduction on projects. The above ceiling MEP rough-in was altered to include prefabricated racks and individual units. After interviewing industry professionals, it was found that the implementation of prefabricated MEP systems could save between 50%-80% of total labor hours. Further calculations found that a 44% cost savings can be expected when utilizing prefabricated MEP on this project.

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Project Overview

Introduction

The University of Virginia Health System is expanding their hospital (the Hospital Bed Expansion) to accommodate the growing needs of the patients, visitors, and employees. With a total of 60,000 square feet of added space and 70,000 square feet of renovated space, the Hospital Bed Expansion will include six occupied floors repetitive in design. Each floor will feature seven patient rooms facing northwest. The 2nd floor is reserved for MEP space and will include a relief air plenum along with a transformer and electrical room. The project also includes the replacement of an existing ballasted Ethylene Propylene Dien Monomer (EPDM) roof with a new Thermoplastic Polyolefin (TPO) roof. An extensive green roof will be installed atop the first floor lobby.

Prior to the structural steel being erected, several existing columns will need to be strengthened. All of these columns exist in occupied areas of the hospital which will require Infection Control Risk Assessment (ICRA) walls to surround the work areas to ensure safety measures for patients are upheld in the hospital. ICRA walls will be required around all renovation areas including the major renovation space and individual waiting rooms which are to be renovated.

Before construction started, the project was already delayed. With the owner taking eight (8) months longer to move out than what was originally planned, the project was slated to have a delay on the substantial completion date. The owner delay along with unforeseen conditions on the existing building has pushed back the substantial date by four (4) months to April 2012 instead of December 2011.

Gilbane/Russell has been hired as a joint venture CM Agent to provide coordination and management services to the UVA Facilities Management team. SmithGroup has been hired solely as the architect via a lump sum contract; SmithGroup will hold contracts with the engineering and consulting firms. The UVA Facilities Management Team is holding a multiple prime contract with the subcontractors who are selected base upon prequalification data and a competitive bid.

The site is a tight area that is limited in space for material storage and parking. The Job Site trailers are located a block away from the actual site due to the congested area. While the Hospital Bed Expansion is being constructed, UVA has also begun the Emily Couric Cancer Center which will be built cattycorner to the current project site. This will complicate the area even more as two construction teams will attempt to keep traffic moving as smoothly as possible while still maintaining an efficient construction site. Gilbane/Russell will assist the project team and help reduce coordination issues.

Within the project site will be located portable toilets, dumpsters and a Manitowoc 888 crawler crane. The site will need to remain clean in order to allow concrete pump trucks, delivery trucks, and other vehicles to access the site safely. In order to create an efficient means of transportation to each floor, a hoist will be erected after the structural steel has topped out and before the glass façade is placed. See **Appendix A** for the site layout plan.

The original project cost was around $43 million and has since grown to roughly $55 million due to unforeseen conditions and schedule delays causing an added cost for the added time personnel will need to be on site.

Local Conditions

As mentioned previously, availability for construction parking is limited. Parking on site is only for utility vehicles performing work, and all other subcontractors must park in the 11th Street parking lot or Cherry Street lot. Parking is available in the parking decks, but either a permit or daily fee is necessary.

The obtained geotechnical report did not detail the types of soil existent on site. In 1984, a similar geotech test was performed with the actual soil data; however Schnabel Engineering South, LLC did include the historic data from 1984 in the report. However, Schnabel did report on previous boring tests revealing disintegrating rock in certain areas as well as rock refusal. After reviewing all historic data and performing their own tests, Schnabel recommended dewatering system at EL 478 for any excavation.

UVA attempts to incorporate SWaM (Small, Women, and Minority owned businesses) participation as much as possible.

Client Information

The University Health System (UHS) is the medical sector of UVA that offers learning opportunities to the relevant students of UVA, medical internships and fellowships for doctors, and premier health services for the residents of Charlottesville. With the growing population of Charlottesville, the hospital needed to expand their facilities in order to accommodate their growing number of patients. This addition will create 70 new private patient rooms while also updating the existing facility.

UVA has high standards for safety and quality. While cost and schedule play a role, UVA is willing to sacrifice a low budget and fast schedule for the safety of their doctors, patients, and visitors. While being a trailblazer in the new world of green technology, the University Health System also wants a home that will last them a 100 more years.

In the renovation side this expansion, an old Ballasted EPDM (Ethylene Propylene Diene Monomer) roof is causing problems with leakage. Not only is the roof allowing water to penetrate the building, but the system is outdated and hard to maintain. The UHS has decided to replace the Ballasted EPDM roof with a new energy efficient TPO (Thermoplastic Polyolefin) roof. This roof will reflect more heat from the sun keeping the rest of the hospital cooler with less energy.

Safety is the first consideration for any hospital system. In the design phase of the expansion, the architect was required to layout the patient rooms according to UVA's ADA regulations rather than the Federal Government's ADA regulations. The reason for this is because UVA has a much stricter set of rules in order to ensure the safety of their visitors.

Renovation of an occupied hospital proves to be incredibly challenging for not only the contractors, but also for the visitors and employees of the hospital as well. In order to maintain a sanitary area within the hospital, all construction areas are to be enclosed with ICRA walls. In the construction of HBE, many of these ICRA walls invaded patient rooms (for steel strengthening), waiting rooms (renovation of waiting rooms), and the main corridor. It is a dance to coordinate the interior renovations during the evening with the exterior construction during the day. The key here is to keep the visitors and patients happy.

Project Delivery Method

The project is being delivered as design-build. The interesting aspect of this project is that UVA Facilities Management is acting as the CM and Gilbane/Russell is acting as the CM Agent. In this situation the Facilities Management is holding all of the contracts for the subcontractors and architect, which creates a multiple prime contract between UVA and each subcontractor. The relationship between UVA and the Architect is a typical lump sum where the architect will still hold the contracts with the engineers/consultants. The contract between Gilbane/Russell is a lump sum contract where G/R is present more for the coordination and backup of UVA Facilities Management.

It isn't unusual to see a university maintaining a multiple prime contract with the subcontractors. As is typical with an experienced owner, UVA wants to control who is selected to work on their project, and maintain the working relationships with the subcontractors on site. Each of the subcontractors were chosen by first being pre-qualified and then by competitive bid. It is understandable, however in this situation where four or five projects are underway all at once with Gilbane/Russell being the CM Agent/CM on all of them, it seems as though it would be easier to hand the contract over to Gilbane/Russell where they control the coordination with every project team (see **Chart 1**.)

Staffing Plan

The staffing plan for the CM Agent is relatively simple. John Taylor is the District Manager for Gilbane out of Richmond, VA. Jeff Ferris (Gilbane) is considered to be the Project Executive, but is acting as a Project Manager at the same level as Chris Hoy who is the Project Manager for UVA. Under Mr. Ferris lie the Office Administrator, Tammy Pastelnick (Gilbane); the Sr. Project Engineer Mellonee Rheams (Russell) who controls submittal, transmittal, RFI, and change order processing; and the Sr. General Superintendant Gary Crosby (Gilbane) who controls the field activities. Office Engineer Brett Thompson reports to Mellonee Rheams, and Assistant Superintendent Mike Moubray reports to Gary Crosby (see **Chart 2**.)

Chart 1: Project Delivery Plan for HBE

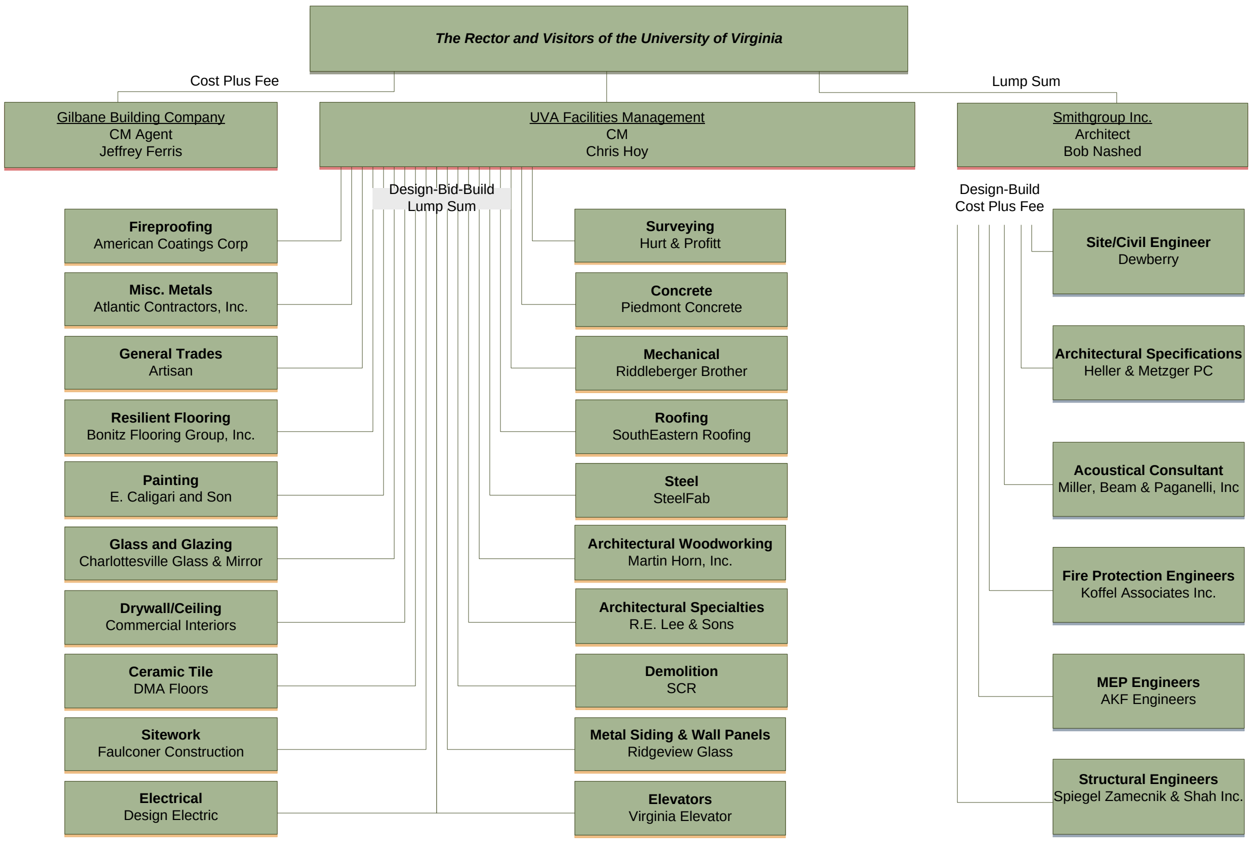
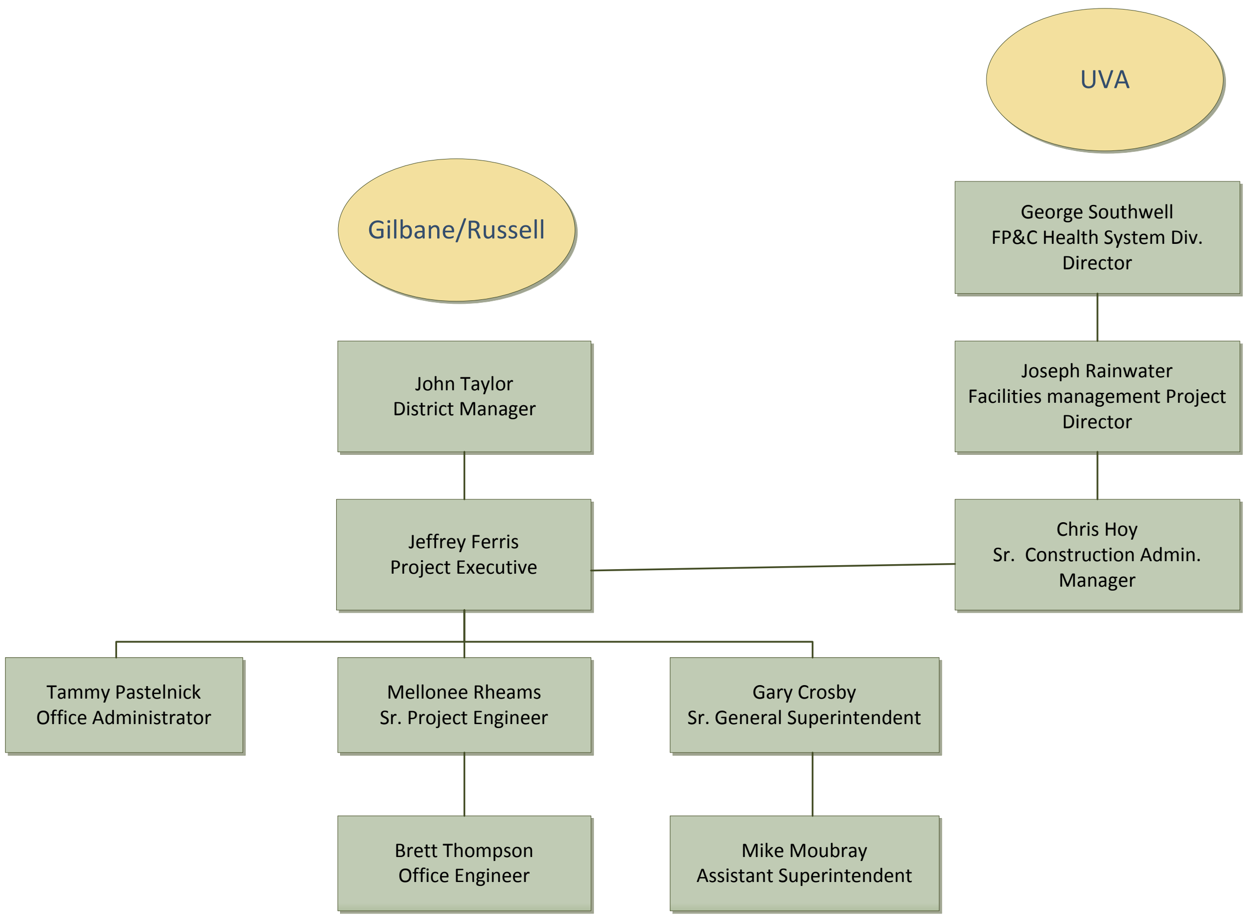


Chart 2: Staffing Plan of HBE



Building Systems Overview

Demolition

Hazardous materials are not thought to be contained within the existing hospital, resulting in a more simple demolition process. The renovation areas existing within the construction boundary are to be stripped to the bare bones leaving only the steel structure, concrete slabs, any masonry, and interior partitions to be exposed. The MEP systems are to be relocated until a new system pattern can be established for the future layout of the space. Throughout the demolition, waste management processes will be utilized to ensure materials are directed to the proper disposal sites. This will contribute to the LEED Silver rating expected to be attained. While gutting the interior renovation area, the concrete slabs will need to be checked for proper a proper level surface in order to ensure a level finished floor is stable and that a solid connection is made between the two adjoining structures.

Structural Steel

The superstructure is composed of a structural steel system with cast-in-place concrete floors. The structural system consists of typical 'W' beams that will tie into the existing structure with W10 x 12 beams and moment connections. The exterior framing also utilizes moment connections and includes W14x22 and W24x131 beams, where the interior framing is mainly comprised of shear connections with W12x14 and W12x6 beams. Concrete walls are not present in the new addition as the weight of the building will be carried by the steel exterior framing.

Before structural steel can proceed, a number of existing columns need to be reinforced in the hospital to ensure a stable new structure will work properly with the existing structure. The new steel will be welded into the existing columns, creating moment connections.

The new steel will be bolted or welded into the existing columns, creating moment connections. In order to erect the steel a Manitowoc 888 crane was brought to the site. The 888 can easily handle the largest piece of steel on site which is a W24 x 131, but the reason for such a large crane being used was the placement and height restrictions. There is barely enough room on site to fit the crane, but in leaving a nice 50' path right next to the hospital, this crane can easily lift the heaviest beam to the 8th floor. There is also heavy mechanical equipment that will need to be lifted to the penthouse, in which case the crane will have no issues in accomplishing the task.

Cast-in-Place Concrete

Cast in place concrete will mainly appear in the floor slabs; there will be some instances where a CMU firestop head wall will be seen in the corridors or stairwells. Because the new and existing structures will carry the entire load of the new addition, there will be no need for interior concrete walls. The floor system will consist of 4 ½" lightweight concrete poured on top of 2" gage galvanized metal deck making the total slab thickness 6 ½". The new patient bathrooms have been designed with a 4" depressed slab to allow space for the plumbing and fixtures within the room. Because the crane will be occupied with placing the steel, a crane and bucket method cannot be utilized. The most efficient means of pouring the concrete slabs is via concrete pumps.

Mechanical

Other than two new air handling units on the Penthouse Roof Level, the mechanical system does not undergo much of a major addition. The Penthouse will accept two new variable air volume (VAV) air handling units (AHU) with a capacity of 70,000 CFM; the fan type of these AHU's is a plenum space with a capacity of 45,000 CFM. Each patient room will contain a VAV box with an average supply load of 760 CFM and an average return load of 660 CFM. Along with additional AHU's the roof will also see an addition of relief air plenum space. The roof will see an addition of seven new relief air plenums that have a capacity of 24,000 CFM.

The second floor mechanical space will not see much of an addition in terms of mechanical equipment; however, with the hospital expansion adding 6,500 SQFT of space to the second floor mechanical room, nearly half of that will serve as ventilation and a relief air plenum space of 4,110 CFM with louvers being place on the exterior.

Existing ductwork will be demolished and removed from the 70,000 SQFT of area to be renovated. New ductwork and piping will be designed for both the renovation and expansion.

Electrical/Lighting

Along with the additional mechanical loads come added electrical loads. A total of three Doubled Ended Switchgears and one Medium Voltage Switchgear will be added to the hospital in order to support the new power and lighting loads of the hospital expansion along with future hospital expansions. Included with the new power requirements within the patient rooms, a new bank of elevators is being added to the hospital, which is considered to significantly add electrical loads.

The south end of the existing hospital will receive two new pieces of switchgear equipment. One of the switchgears is a 3-phase Medium Voltage Switchgear (MVS) with a nominal voltage of 15,000 Volts (V) and a 1200 Amp (A) main bus. The feeder size for this MVS will be a 4" Conduit with 3 #2/O wires and 1 #1/OG wire. The second switchgear is a Double Ended Switchgear which is identical with respect to voltage, ampage, and phase requirements as the other two Double Ended Switchgears. The primary of this switchgear is 3-phase with 12470 V, 3 wires, a 600 A main bus, and a 40,000 AIC Rating. The secondary of this switchgear is also 3-phase with 480/277 V, 4 wires, a 4,000 A main bus, and an 85,000 AIC Rating. Along with one of the Double Ended Switchgears being added to the south end of the existing hospital, one will be added to the east end of the existing hospital and the third will be placed in a designated area on the mechanical 2M floor.

The new equipment was supported by the power distribution that spanned from the South and East end of the existing hospital via a duct bank in the ground floor.

As each patient floor was repetitive, so is the lighting plan. The patient rooms were calculated to require an average of 41.0 footcandles (fc) with minimum of 13.2 fc and a maximum of 60.8 fc. Two direct/indirect linear fluorescent luminaires are called out to be installed above the patient beds. A surface mounted linear fluorescent color changing uplight luminaire is also called out to be installed above the dresser/closet space in each patient room. Each patient bathroom contains a linear fluorescent parabolic downlight. Each T5HO lamp required for these fixtures will consume 54 Watts (W).

The corridors needed an average of 20 fc, which led to 1'x4' recessed direct/indirect luminaires typically being used in the hallways and corridors.

Fire Protection

The fire protection system includes a wet-pipe sprinkler system throughout the new addition. The renovation area will also be fitted with the new sprinkler system. This system consists of automatic sprinklers attached to piping containing water that is connected to a water supply. These sprinklers are opened when heat melts a fusible link. The minimum spray density for this system in patient room is .20 gallons per minute (gpm) over a 1,500 sq. ft. area; with light hazards, the spray density is .10 gpm over 1,500 sq. ft. The maximum allow protection area per sprinkler for patient rooms is 225 sq. ft. meaning that every 225 square feet of space in a room must have at least one sprinkler head.

Façade

The Central Bed Tower Expansion is an addition to University of Virginia's existing primary care health center that will enhance the aesthetics of the hospital's already unique architecture. With a dissimilar facade constituted of white metal panels and periodic glass windows, the existing hospital is a standout amongst its neighboring brick facilities. While maintaining the design integrity of an existing campus, SmithGroup's design for the new hospital expansion brings a piece of the contemporary 21st century to a traditional 18th century university campus.

Figure 1: Curtainwall Mockup features “bullet” like supports

This new addition will feature an approximately 90' tall glass curtain wall system with metal tube supports placed on each floor stretching the entire length of the facade. White metal panels frame the glass, blending the new addition with the existing hospital. Louvers and corrugated metal panels will be utilized to cover the mechanical space on the 2nd floor and roof levels.

The support system is referenced to be the “bullets”. A hollow steel tube is attached to cantilevered steel beams at each level of the hospital. The actual glass panels will be attached to the hollow steel tube. Extending beyond the structural hollow tubes, are steel “bullet” like tubes. After the hoist is removed from the exterior of the building, the remaining glass panels can be installed. The curtain wall mockup can be found in **Figure 1** above.

LEED Features

The University of Virginia has designed the Hospital Bed Expansion to achieve a LEED Gold rating. Contributing to this accreditation are innovative design ideas and strict guidelines for construction waste.

The major sustainable features for this expansion/renovation are a new TPO (Thermoplastic Polyolefin) roof and a new extensive green roof. A diagram of a typical TPO roof can be found in **Figure 2**.

The TPO roof will replace the hospital’s existing Ballasted EPDM (Ethylene Propylene Diene Monomer) roof (see **Figure 3**.) TPO roofs are considered to help reduce the mechanical load in a building by reflecting solar heat emitted from the sun’s rays thus reducing the heat a building will take on. This roof also is also thought well of by maintenance crews since the light assembly makes is more simple to spot leaks and other construction issues over the building’s lifespan.

The extensive green roof is replacing the existing Ballasted EPDM roof on the ground level. Utilizing an extensive roof will provide an aesthetically pleasing landscape for hospital residents while reducing the use of environmentally harmful construction materials. Extensive green roofs have the benefit of a beautiful landscape without the maintenance issues of an intensive green roof. Intensive green roofs feature a more inclusive environment for residents, where patrons can actually walk on the roof and enjoy a garden environment. Intensive green roofs are thought to have more maintenance issues because there are more elements to consider and care for on the roof.

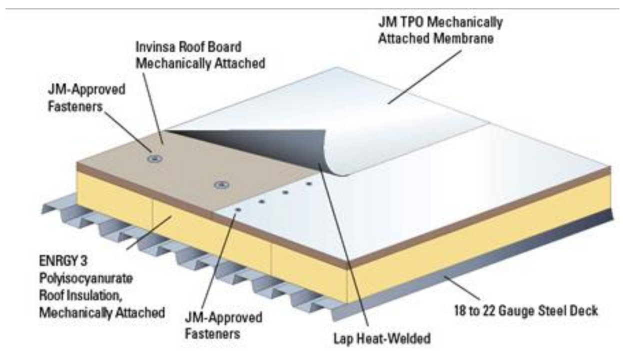


Figure 2: Diagram of a Thermoplastic Polyolefin (TPO) Roof

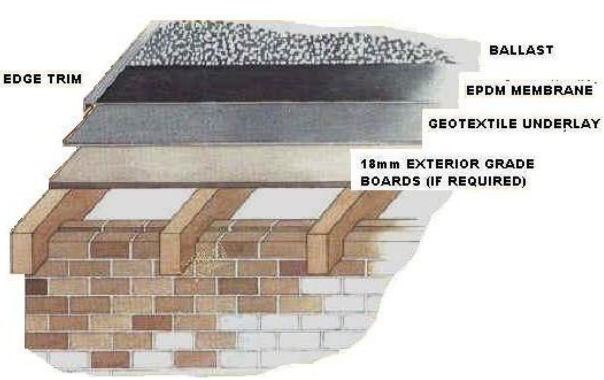


Figure 3: Diagram of a Ballasted Ethylene Propylene Diene Monomer (EPDM) Roof.

Construction Overview

Site Layout

Figure 4: Tight Site Layout at HBE

While HBE is being constructed, UVA also has two other projects in construction at the same time as HBE. The Emily Couric Cancer Center (ECCC) adjacent to this project will begin construction around the same time as HBE. Before ECCC can be built, an existing parking garage will need to be demolished, causing more traffic complications on Lee Street. The cancer center is considerably larger than the Hospital Addition, but unfortunately the ECCC construction team has an equivalent amount of lay out space as the HBE construction team. Towards the end of the Cancer Center construction, another project will be starting up. The “Connective Elements” mission is to create a transportation hub that will seemingly connect the Lee Street Parking garage, University Hospital, and Emily Couric Cancer Center. The issue with this project coming on board is that the lay out space available after ECCC closes out will no longer be available as Connective Elements will be taking over that area; this all results in a very small work area for the teams at HBE.

The site plan for this project is small and complicated. Because not much space is available for staging areas or material storage, each subcontractor will need to find their own area for storing materials, or limit the materials brought on site to only what is needed for each day’s workload (See **Figure 4**.)

Existing Conditions

The Hospital Bed Expansion will be built on top of the existing hospital lobby, thus relinquishing any need for excavation (see **Figure 5**.) The location of HBE is on the south side of Lee Street facing the Primary Care Center at Northwest. There is a small space in front of the future construction site that was used for hospital drop-offs. This area will be fenced off, and the paved pull-offs will be used for construction vehicle entrances.

Most of the utilities including chilled water, electrical cables, plumbing, etc. run under Lee Street. Because there is no excavation on site, there is not much worry of interference with these utilities. However, there will be more electrical lines added to the hospital service equipment on the south side of the emergency department.

The emergency department is connected to the University Hospital. The ED is on the south side of the hospital and north side of Crispell Rd. There is a helipad on the ground that brings frequent traffic to the

ED. Eventually this helipad will be relocated to the penthouse level of the hospital, allowing room for and Emergency Department expansion.

Lee Street is the main artery to the health system complex. With future construction on either side of this road, vehicular and pedestrian traffic will need to be heavily considered.

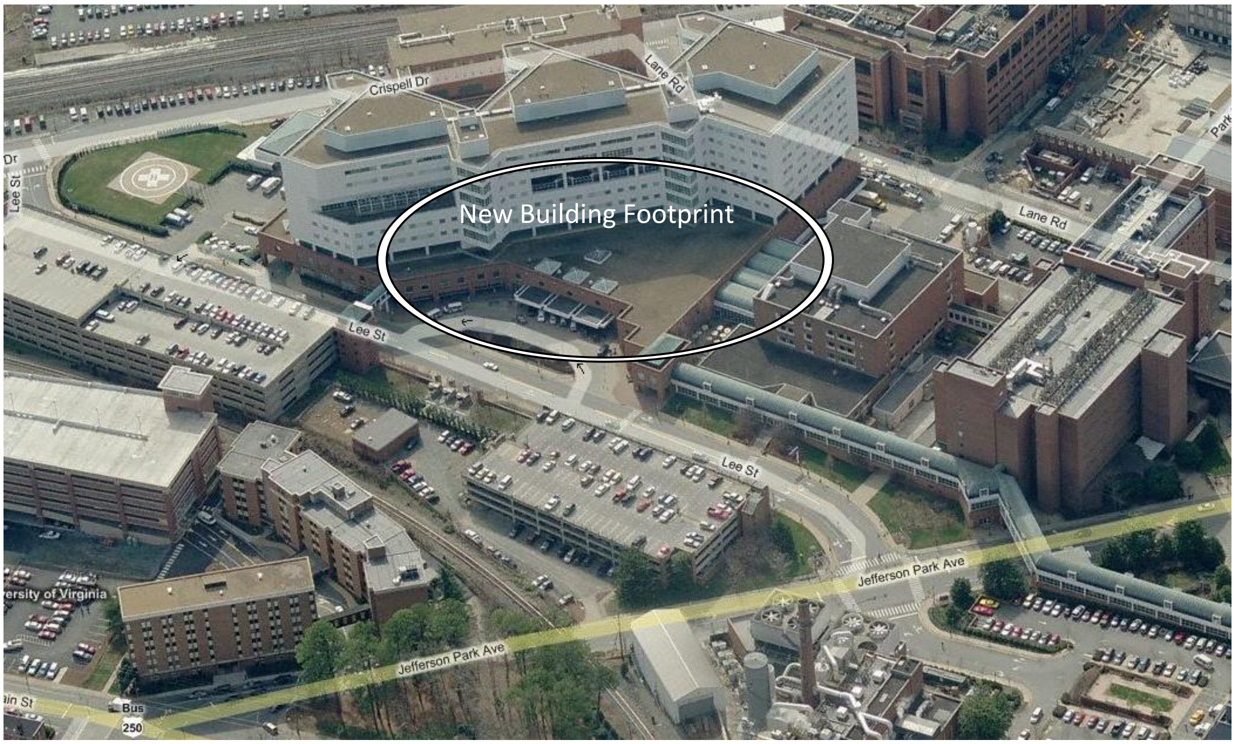


Figure 5: Location of new Hospital Expansion

Project Schedule

Because HBE involves renovations of the existing hospital, it is important to create an effective schedule that does not excessively inhibit the daily routines of hospital patrons. In order to avoid such hindrances for the hospital patients and staff, a phased schedule would be advantageous to use. Although the HBE Project Team did not utilize a phasing method for this project, the schedule has been reconstructed so as to effectively explore the possibilities of doing so. Creating a quality schedule is critical in creating a successful project where all parties are pleased.

Because HBE is being built directly on top of the existing hospital lobby, a foundation will not need to be established. However, several existing floors contain steel columns that will need to be reinforced with additional steel angles in order to support the future loads from the expansion and a newly renovated wing. After site mobilization, the project schedule specifies interior demolition of the renovation areas. Following the demolition of each floor will be the installation of steel strengthening. Before the new steel structure can be erected, the column reinforcing must be complete which makes it essential to have the reinforcing done before steel hits the site on September 14, 2009.

New construction primarily begins with the erection and placement of 2nd floor steel framing and elevated slabs. The steel framing begins at the 2nd floor and then works its way up to the penthouse which is then finished prior to the lower floors. Because steel members will be erected at night and picked from the trailers hauling them (there is no laydown room on site for steel), the concrete subcontractor will be able to pour the floor slabs during the day, maintaining a smooth uninterrupted schedule.

The construction team plans to create a real time schedule where the trades are beginning at the 8th floor and working their way down and out of the building so as to prevent the tradesmen from building themselves into a corner as well as preventing the interference of different trades. Before the real time schedule can work, the upper floors will need to finish shell framing before the lower floors.

As the structural framing is still in process, the mechanical and electrical equipment will be installed on the 2nd floor, where extra time will be necessary to create new wiring connections and alter the existing equipment. After hookup, this equipment can then generate power for the other trades on site.

Because the hospital's existing elevators will not be available for the tradesmen's use, a hoist will be installed during structural framing so as other construction workers can be transported vertically through the building and begin their work. Following the method of working from the top of the building to the bottom, tradesmen will begin their work as the 8th floor ends the structural framing process. While looking at the schedule, it may be more feasible to allow tradesmen to begin working from the bottom floors. Once the façade is erected on the respective floors, a faster schedule can be accomplished by releasing the subcontractors earlier rather than later.

After the building gap has been closed and before all of the new interiors are installed on each floor, the renovation process will begin in the existing hospital. Dust walls are placed on the limits of construction before demolition begins on the existing hospital. This schedule should result in the renovation area and bed expansion areas being in sync with their trade packages.

As the interiors are being finished, the elevators can then be installed. After the elevators are operational, the hoist can be removed so that the remaining pieces of curtain wall can be installed.

After interiors and mechanical connections are made, the commissioning process can begin on each floor. See **Appendix B** for the construction schedule.

Cost Evaluation

The RS Means estimated square foot cost associated with this project is significantly lower than the actual cost to build (See **Table 1**.) There are many factors in discussing this issue.

Table 1: SQFT Estimate Breakdown of HBE

Building Component	% of Total Building	RS Means SQFT Estimate	Actual SQFT Cost
Substructure	2.20%	$ 264,000.00	$ 1,210,000.00
Shell	23.00%	$ 2,760,000.00	$ 12,650,000.00
Interiors	2.02%	$ 242,400.00	$ 1,111,000.00
Elevators & Lifts	2.60%	$ 312,000.00	$ 1,430,000.00
Plumbing Fixtures	2.80%	$ 336,000.00	$ 1,540,000.00
Water Distribution	7.30%	$ 876,000.00	$ 4,015,000.00
Rain Water Drainag	0.75%	$ 90,000.00	$ 412,500.00
Energy Supply	1.40%	$ 168,000.00	$ 770,000.00
Heat Generating Systems	1.60%	$ 192,000.00	$ 880,000.00
Cooling Generating Systems	1.20%	$ 144,000.00	$ 660,000.00
Other Systems	11.60%	$ 1,392,000.00	$ 6,380,000.00
Sprinklers	1.00%	$ 120,000.00	$ 550,000.00
Standpipes	0.40%	$ 48,000.00	$ 220,000.00
Electrical Service/Distributior	5.90%	$ 708,000.00	$ 3,245,000.00
Lighting and Branch Wiring	7.70%	$ 924,000.00	$ 4,235,000.00
Communication and Security	0.80%	$ 96,000.00	$ 440,000.00
Equipment & Furnshings	7.40%	$ 888,000.00	$ 4,070,000.00
Total		$ 9,560,400.00	$ 43,818,500.00
Cost/SQFT		$ 200.00	$ 916.67

RS Means has estimated this project based upon the assumption that the building will be construction in an open field without any outside interferences. Reference **Appendix C** for R.S. Means Square Foot cost data. That is certainly not the case in this project. HBE is an expansion plus renovation. The costs are going to be hire due to dual occupancy challenges as well as OSHA requirements to maintain a sanitary environment in the hospital. The steel strengthening is also not considered in the RS Means Cost Estimate. This will have a huge impact on pricing for the steel package. If the columns needing steel strengthening are in occupied spaces, the ICRA requirements are also going to drive the cost up.

The percentages seem to be accurate. However, due to the small work for mechanical and electrical packages, it could be suggested that this pricing will be lower than what is estimated. The renovations which were not considered in this analysis will play a big role in the higher cost for construction simply because of the dual occupancy issue and labor.

General Conditions Estimate

The General Conditions Estimate includes items to be covered by Gilbane/Russell acting as the CM Agent for UVA. As the CM agent, Gilbane/Russell will include items into the general conditions that will only affect the current CM agent staffing. Because of this, the majority of general conditions' hard numbers for HBE will be composed of the field personnel salaries. The cost information taken from R.S. Means for field personnel adds up to $1,970,475 for the estimated 124 lined schedule duration. R.S. Means line items were chosen based upon the seniority of each field office personnel.

Other hard number line items included in the general conditions are the trailer rental, office equipment, office supplies, water, telecomm, lights & HVAC, small tools, barricades, fencing, signs, and site cleanup. Gilbane/Russell may not include some of these items in the actual general conditions as they typically would place these items with the general contractor on site. The general contractor may also own barricades and fencing for the jobsite.

Gilbane/Russell will carry insurance and bonding for the entire project and subcontractors.

There are aspects of the project that will be bought under the general contractor for HBE. Portable toilets, dumpsters, and site fencing will be included in the general contractor's bid package.

After the hard numbers have been calculated, and summed to equal $3,430,293.31, commissioning and contingency percentages were added into the subtotal. The percentages for commissioning and contingency were based upon the total project cost. Because a hard number for the total project cost could not be accurately determined, the square foot estimate cost was used. For the 130,000 ft^2 addition/renovation, R.S. Means estimated the project would cost around $23.5 million based upon historical data. The estimated percentages for Commissioning and Contingency were multiplied by $23.5 million and then added to the subtotal of $3,430,293.31. The total cost for General Conditions is then estimated to be $5,557,668.31.

After all of the percentages have been added into the general conditions, a total GC value is $5,557,668.31. Time and City Index adjustment factors have not yet been taken into consideration from R.S. Means Costworks. See **Appendix D** for the complete general conditions estimate.

Structural Systems Estimate

The structural system of HBE utilizes typical construction elements and design methods to achieve a stable foundation. Structural steel columns and members frame the new wing with cast-in-place (CIP) concrete acting as the floor system. Welded Wire Fabric (WWF) will serve as reinforcement for the flooring system, reducing the need for larger steel reinforcing bars (rebar). Hollow Steel Sections (HSS) frame the exterior of each floor slab which will later serve as the support system for a glass curtain wall. The HSS exterior frame was not included in this estimate due to the lack of consistency with the main steel structure.

As mentioned earlier, column reinforcing is an important aspect of this project as there is no new foundation being built. Column reinforcing is prevalent on the ground floor, 1^{st} and 2^{nd} floors, and the mechanical space 2M. Primarily, three different sizes of steel angles were used for column reinforcing: L8x8x1, L6x6x1, and L6x6x5/8. Although the columns have differing details that reference the method of installing new steel angles, the plate sizing will not vary outside of the three that were given. Using the steel manual, total weight in tons was found for each of these steel angles. A corresponding value could not be found in RS Means, therefore the total cost of these angles were not included in the total estimate.

Because the 2nd floor will be reserved for mechanical and electrical equipment, a different layout was assigned in order to carry the extra loading. The 2nd floor boasts the largest steel members for the project with sizes ranging from (2) W12x14 to (6) W36x441. The mechanical floor owns the title of "highest cost per floor" while possessing the heaviest/largest steel beams and a thick detailed floor system. The floor system consists of 6" normal weight concrete poured over a 3", 20 gage galvanized composite steel decking with 4x4 W4.0xW4.0 WWF utilized for tensile reinforcing. The floor consists of bays with the concrete sloping to a drain in the middle of each bay. This floor estimate was calculated as a flat slab to take into account expected concrete waste.

Floors 3-8 and roof are similar with a few variations. Floors 4,5,7,8 will be identical in reference to steel framing and floor systems. The steel members range a much smaller scale as compared to the 2nd floor. With the smallest beam being a W10x12 the largest beam only sizes to a W24x131 (small in comparison to W36x441). The elevated slab is 4 ½" lightweight concrete poured over 2", 20 gage galvanized composite steel decking with 4x4 W4.0xW4.0 WWF utilized for tensile reinforcing. Each floor contains five large and two small 4" depressed slabs to accommodate space for the bathrooms. Each main patient floor also has WT10.5x28.5 girders to reinforce the existing girders. These girder reinforcements were not considered in this estimate due to lack of cost information from RS Means.

The 3rd floor estimate only deviates from the typical floor estimate in the elevated slab. Rather than 4 ½" light weight concrete, the 3rd floor utilizes a 6" normal weight concrete poured over a 3",20 gage galvanized composite steel decking.

The 6th floor maintains the same characteristics of the typical floor framing but also includes an additional floor space. The 6th floor has an extra 5066 sq. ft. of floor space that is being framed. This space is an existing lobby that needs to be further framed and reinforced in order to accommodate the new patient program.

The steel columns are spliced at every 14' floor height.

There were a number of nontraditional beam and column sizes used throughout this project. In order to find an accurate cost from R.S. Means, the values were interpolated or averaged using information from supplied cost information, an assumed O&P percentage of 15% was used. Accessories such as concrete forming, steel bolts, and connection plates were not included in the estimate, as it was considered that these items would have a negligible cost associated with them.

Shear studs were not included in the estimate due to lack of cost information from R.S. Means.

A current estimated cost for the structural system is $2,011,444.76. If the steel angles, HSS framing, and WT reinforcing girders were to be included, it is expected that this dollar amount would increase above $2,300,000.00 which falls within 16% of the typical cost for shell construction on a 60,000 square foot hospital project. The current project cost for HBE well exceeds a typical hospital project of this size. It is anticipated that the actual cost for the steel package well exceeds the typical $2,760,000 value due to the phasing complications and work schedule requirements set forth by the hospital. See **Table 2** for the detailed structural estimate.

Summary			$ 2,011,444.76
Steel Strengthening			
Description	Weight	Quantity (tons)	Total O&P
L8 x 8 x 1	51 lbs/ft	45.696	10%
L6 x 6 x 5/8	24.2 lbs/ft	46.0768	10%
L6 x 6 x 1	37.4 lbs/ft	12.5664	10%
Level 2M			$ 282,673.14
Description	Units	Quantity	Total O&P
Steel Members	L.F.	923.5	$ 254,248.56
Steel Deck	S.F.	5376	$ 19,407.36
Concrete	C.Y.	150	$ 3,802.50
WWF	C.S.F.	54	$ 5,214.72
Level 4,5,7,8 (Typical)			$ 189,559.77
Description	Units	Quantity	Total O&P
Steel Members	L.F.	2304	$ 164,633.25
Steel Deck	S.F.	5661	$ 16,699.95
Concrete	C.Y.	94	$ 2,735.40
WWF	C.S.F.	57	$ 5,491.17
Level 3			$ 190,550.82
Description	Units	Quantity	Total O&P
Steel Members	L.F.	2304	$ 146,166.98
Steel Deck	S.F.	5661	$ 16,699.95
Concrete	C.Y.	147	$ 3,726.45
WWF	C.S.F.	57	$ 5,491.17
Level 6			$ 276,612.11
Description	Units	Quantity	Total O&P
Steel Members	L.F.	3245.5	$ 229,091.47
Steel Deck	S.F.	10727	$ 31,644.65
Concrete	C.Y.	188	$ 5,470.80
WWF	C.S.F.	107.27	$ 10,405.19
Columns			$ 313,809.84
Description	Units	Quantity	Total O&P
Columns	L.F.	1811	$ 313,809.84

Table 2: Detailed Structural Estimate

Values provided do not indicate the actual cost for structural systems

Constructability Challenges

Infection Control Risk Assessment (ICRA)

The UVA Health System recognizes that facility patrons are the number one priority, and the hospital administration has dedicated time and funds to ensure the safety of everyone visiting or staying at the hospital. In essence, the construction team has tried to maintain an "unseen" presence throughout the project to ensure the comfort and safety of all hospital occupants.

Because this work is being done to an occupied hospital, it is critical that the safety of patients, visitors, and staff take priority amongst all concerns of the construction management team. The largest risks take shape in the form of Infection Control and Interim Life Safety Systems. In order to reduce the risk of disrupting these systems and/or creating dangerous situations involving dust or heat, the management team used stringent requirements that mandated the use of Directive No. 723A/902A which outlines the health safety requirements for construction in occupied hospital facilities.

Directive No. 723A/902A categorizes activities of construction into Class I and Class II:

Class I address less invasive work such as minor plumbing, electrical, carpentry and duct work, aesthetic improvements and installation of phones, computers, medical gases, TV cable, etc. This class would pertain to the individual renovations of multiple lobby areas outside of the major construction zone. Some of the required procedures for this category include:

a. Water misting of surfaces to control dust while cutting.
b. Seal around doors for projects that produce large quantities of dust.
c. Block off and seal air vents and diffusers
d. Noise and vapor containment shall comply with Occupational Safety Hazard Association (OSHA) regulations
e. Construction waste shall be contained in sealed plastic bags
f. We mop and/or vacuum with HEPA filtered vacuum before leaving the work area
g. Place dust mat at entrance and exit of work area
h. Remove blockage and seal from air vents and diffusers.

Class II addresses major construction that will require barrier precautions and include asbestos removal, demolition of walls and ceilings, removal of windows, doors, casework, tiles, construction of wall, ceiling, new rooms, major utility changes, major equipment installation, etc. This class pertains to all construction areas within the hospital, which are Steel Strengthening, HBE expansion, and Lobby Renovations. Some of the required procedures for this category include:

a. All temporary construction barriers shall be completed of noncombustible materials before construction begins

b. Hospital Epidemiology may inspect the work site before construction beings.
c. All air vents shall be blocked off and sealed to prevent contamination of duct system before construction begins
d. Dust mats shall be used at entrances to the work area
e. All holes, pipes, conduits, punctures and exposures shall be sealed appropriately
f. Wet mop area with disinfectant
g. Work area shall be vacuumed with a HEP filtered vacuum
h. Construction waste shall be bagged or transported in covered carts

In addition to this directive, routine and random inspections will be required throughout the project to ensure compliance of all necessary procedures. Hospital Epidemiology may also visit the work site to ensure compliance with this directive and reserves the right to add requirements to a project on an individual basis.

The temporary construction walls have been denoted by the construction team as ICRA walls. These walls have strict requirements on how they are installed so as to reduce noise and dust penetration. The ICRA walls are also built as a 1-hour fire rated barrier to provide occupants on either side adequate time to evacuate the building.

Because these ICRA walls are temporary, much effort was taken by the construction management team to blend the walls with the existing facility to create the illusion of purposeful placement to direct hospital traffic. This also became a constructability concern for the management team.

Schedule Reduction via Acoustical Walls

Problem Identification

The Hospital Bed Expansion is combining new construction with renovations throughout the existing hospital that include separated waiting rooms and steel column reinforcing. With these renovations come noise and vibration restrictions that dictate the construction schedule in the designated areas so as to prevent excessive disturbance to patients and visitors. Rather than high-noise volumes being the source of work restrictions, the UVA Project Manager expressed concern over vibrations stemming from the equipment being used (pneumatic tightening, hammer drilling, concrete demo, etc.) in the renovation areas. Despite the local regulations providing guidelines for high-level noise and vibration operations in occupied buildings, alternative solutions such as acoustical barriers and vibration controls, have not been addressed in this area of renovation work.

Research Goal

The goal of this analysis is to perform a preliminary design of a vibration control and acoustical barrier wall system to analyze the cost and schedule impacts of implementing prefabricated acoustical walls to create the most efficient work schedule for this renovation area.

Approach

- Research the type of construction work activities being performed
- Contact Local Regulator for possible solutions to high-level vibrations
- Reschedule the construction activities to group high-noise and vibration operations together
- Consult Acoustical Design Professional about approaches to sound barrier walls
- Design a prefabricated acoustical wall
- Analyze noise volumes between acoustical walls and non-acoustical walls
- Analyze schedule, cost, and constructability of wall system

Introduction

Acoustical walls are used in many applications, construction and design. Acoustical panels are used in auditoriums, theatres, classrooms, churches, and other applications to reduce sound reverberation and increase the quality of sound for the receiving parties. In other applications, acoustical walls can be used to separate rooms that require sound isolation. In this instance, temporary acoustical walls will be used as a sound barrier between construction areas and occupied facilities.

Noise volume is measured in decibels (dB), named after Alexander Graham Bell (-*bel*) and the logarithmic function used in the mathematical formula (*dec*-). Small instruments and equipment can be used to find the noise intensity and noise volume of any noise source. A typical noise level of normal conversation is around 63 dB, whereas the typical noise level of large truck at 50’ is around 86 dB

Welding torches, pneumatic drills, air compressors, etc. are all used in renovations of the waiting rooms and steel columns. This type of equipment produces around the same noise levels a truck at 86 dB. In this application, the goal is to reduce the noise volume of construction to a normal conversation level of 63 dB or lower. In order to isolate the noise levels to a normal conversation a metal stud wall be introduced with a double layer of gypsum wall board such as seen in **Figure 6**. Along with the introduction of acoustical walls, it is recommended that the patient rooms be vacated next to construction areas and below construction areas. Only waiting room renovations will be reviewed in detail for this analysis.

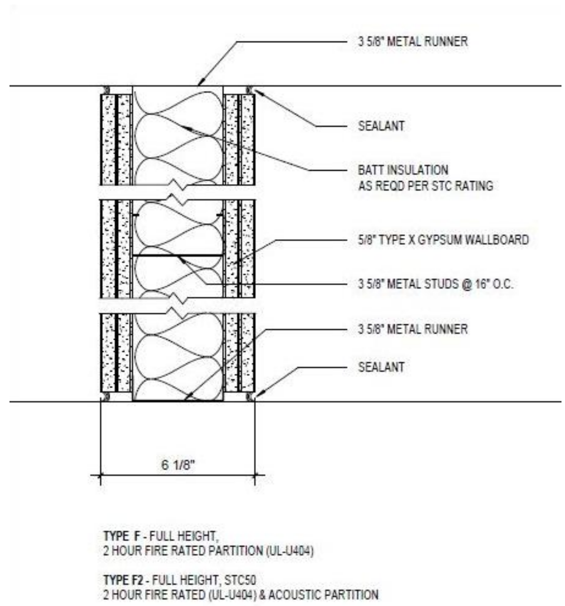


Figure 6: Proposed Acoustical Wall Construction

In order to achieve the best possible sound isolation in an acoustical wall, it is important to ensure that all cracks and seams are sealed at the bottom, top, and edges of the wall sections. It is also important in using acoustical barrier to extend the wall directly from the floor slab to the bottom of the next floor slab. If the wall stops below the mechanical plenum space in the ceiling, then sound can still travel over the wall into the adjoining room(s) thus rendering the acoustical walls useless.

Acoustical Wall Construction

It was originally believed that a double stud wall would be needed to reduce the construction noise levels to an acceptable level for the patients. However, after a detailed analysis, it was found that a single metal stud wall with two layers of gypsum wall board would suffice as an acoustical barrier. The Acoustical Barriers will include 3-5/8" metal studs, (4) total layers of Gypsum Wall Board, and 3-1/2" Fiberglass Insulation such as seen in **Figure 6** above. This wall construction is 11 lb/ft^2.

A calculation was done to find the noise reduction (NR) due to the acoustical barrier wall.

$$NR = TL + 10\log\left(\frac{a_2}{S}\right)$$

TL = Transmission Loss of Common Barrier (dB)

a_2 = absorption in receiving room (sabins)

S = surface area of common barrier (ft^2)

The TL of this wall is around 38 dB, which means that of the 86 dB produced by the construction equipment, only around 48 dB will pass through the wall, assuming all cracks and seams are sealed off. This would already bring the noise volume well below the goal of 63 dB. However, it is still important to run through the actual Noise Reduction calculation. The transmission loss in this application will be measured at a frequency of around 125 Hertz (Hz). Sound frequency is the rate of repetition for sound vibrations in a constant period of time. Lower frequencies correlate to a man's bass singing voice, whereas higher frequencies would correlate to a woman's high soprano voice. The type of construction equipment being used would fall into the lower frequency category of around 125 Hz.

The room absorption is measure in sabins and shows how much noise a wall can absorb. The calculation for this is:

$$a = \Sigma S\alpha$$

a = total room absorption (sabins)

S = surface area (ft²)

α = sound absorption coefficient at given frequency (decimal percent)

The surface area is the combination of all floor, ceiling, and wall areas of the receiving room (i.e. the vacated patient room.) The partitions between patient rooms are constructed similarly to the proposed acoustical walls and are rated with a .55 sound absorption coefficient. The summary of total room absorption can be found in the below **Table 3**.

Type	No. of Type	Size	Total Size (ft^2)	α (decimal percent)	a (sabins)
Wall	2	16'x14'	448	.55	246.4
	2	10'x14'	280		154
Ceiling	1	10'x16'	160	.38	60.8
Floor	1	10'x16'	160	.02	3.2
Total a_2	464.4 sabins				

Table 3: Composition of sound absorption in receiving room

With the room absorption and transmission loss coefficients now determined, the actual noise reduction can be found. The only thing left is to include the surface area of the barrier wall. The barrier wall will theoretically reach to the base of the next floor slab, making the dimension of this wall 12'x 14', or 168 ft².

$$NR = TL + 10\log\left(\frac{a_2}{S}\right)$$

TL = 38 dB

a_2 = 464.4 sabins

S = 168 ft²

$$NR = 38\ dB + 10\log\left(\frac{464.4\ sabins}{168\ ft^2}\right)$$

$$NR = 42.42\ dB$$

Using this type of wall construction will reduce the noise volume by around 42 dB bringing the noise levels in the adjoining rooms to around 44 dB. This is 19 dB under a normal conversation level, and will suffice for the work being done. The sound transmission class (STC) of this type of partition is around 50 STC. This value represents the performance of this constructed wall at absorbing sound through the materials. The higher the value is, the better the construction. This construction type meets requirements.

Schedule Analysis

Construction of these waiting rooms will begin on the 8th and 7th floor with demolition of the vacated renovation areas. Because these occupied floors will still be in use during construction, only one waiting room per floor will be renovated at any time. While renovations are being worked on the first two waiting rooms in the 7th and 8th floors, construction enclosures of the acoustical walls will begin on the next two waiting areas. As mentioned by the project management team, vibration control was a coinciding concern in these renovation areas. In considering this, it is thought that vacating the patient rooms underneath construction areas would be advantageous in avoiding any disruptions for the patients; however, this method will not be included in the cost analysis. The construction sequence for the waiting rooms can be seen below.

Color Key

Color Key	
Renovation in Progress	(green)
Enclosures Erected	(blue)
Complete	(red)

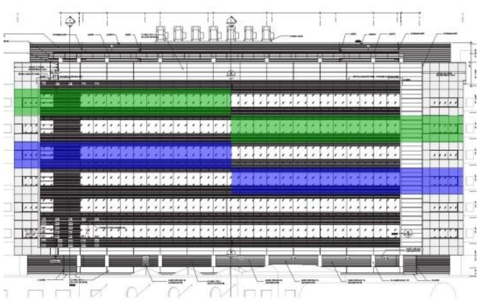


Figure 7:
Partial 8th and 7th floor being renovated. Partial 6th and 5th floor walls being erected.

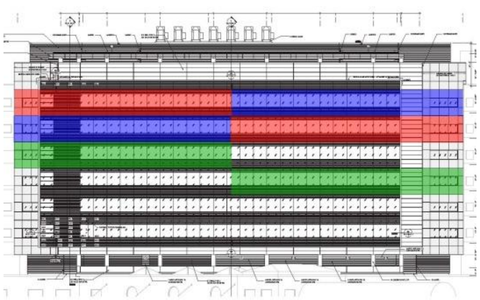


Figure 8:
Partial 8th and 7th floor complete. Partial 6th and 5th floor being renovated. Remaining 8th and 7th floor rooms are enclosed.

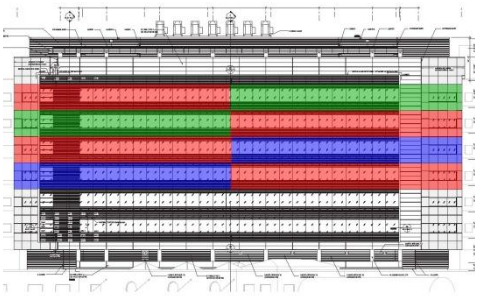


Figure 9:
Partial 8th, 7th, 6th, and 5th floors complete. Partial 8th and 7th floor being renovated. Remaining 6th and 5th floor rooms are enclosed.

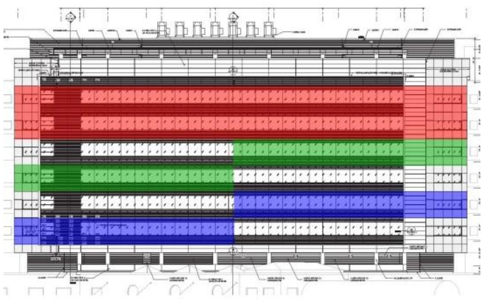


Figure 10:
8th and 7th floors complete. Partial 6th and 5th floor being renovated. Partial 4th and 3rd floor rooms are enclosed.

Figure 11:
8th, 7th, 6th, and 5th floors complete. Partial 4th and 3rd floor being renovated.

Figure 12:
8th, 7th, 6th, and 5th floors complete. Partial 4th and 3rd floor being renovated.

The original renovation schedule of the waiting rooms dedicated 50 days of construction until each was completed and a total of 300 days to complete all six floors of waiting rooms. It is very difficult to objectively reduce this schedule as there are many factors to consider. However, it is assumed in this analysis that the schedule can be reduced by 30% when using the prefabricated acoustical walls. This would bring the construction schedule down to 35 days per waiting room and a total of 210 days to complete all six floors of waiting rooms. In reducing this schedule, significant labor costs can be saved.

Cost Analysis

The cost benefit was determined by analyzing material cost, labor cost, and loss in hospital revenue. R.S. Means was used to determine the cost of these typical walls. It was determined that this wall construction would cost a total of $6.51/ft^2 after all adjustment factors were included (see **Table 4** below.)

Item	Quantity	Material($)	Installation($)	Sub-Total ($)	Total($)
Metal Stud	1	.67	1.01	1.68	1.68
5/8" GWB	4	.31	.53	.84	3.36
3-1/2" Fiberglass Insulation	1	.59	.39	.98	.98
Taping & Finishing	2	.10	1.06	1.16	2.32
Total Cost	$8.34 x (93.4/100) x .836 = $6.51			**$6.51/ft^2**	

Table 4: Composition of Acoustical Wall

It is expected that four sets of these wall assemblies will be in use at any given time. The length of wall required to enclose one waiting room is 48 ft., and the height of these walls will need to extend 14 ft. to the ceiling. This brings the total square footage of these walls to around 672 ft^2 and $4,376.11 for one set. The total material and installation cost of these walls would be around $17,504.45

In determining labor costs, it was assumed that three crews of **Crew L-4** were used for each waiting room renovation (a complete list of crew types used can be found in **Appendix K**. The original duration of 50 days per waiting room resulted in 4800 labor hours per room. The crew type used costs $51.08/labor hour. This cost per hour includes overhead and profit, but does not consider prevailing wages. Utilizing three crews at this price would result in a total of $431,440 after all adjustment factors were included. When using the modified renovation duration of 35 days per waiting room, the total cost is around $302,008 after all adjustment factors were included. This brings the cost savings of labor to around $129,431.85. See **Table 5** for full details.

	Duration	No. of Rooms	L.H.	Crew Cost/L.H.	No. of Crews	Subtotal	Historical Index	Location Factor	Total
Original	50	12	4800	$51.08	3	$735,552	93.4/100	.628	$431,439.50
Modified	35	12	3360	$51.08	3	$480,903.90			$302,007.65

Table 5: Expected Labor Costs

It is recommended that the adjacent patient rooms be vacated during waiting room renovations. There exist two private patient rooms next to each waiting room. Internet searches suggested that a typical private room can cost a patient between $795 and $2,200. It was determined that these patient rooms could possibly cost around 75% of the $2,200 which is $1,650 per day. This is not a straight profit for the hospital. Included in this cost are administrative fees, staffing costs, and equipment costs. It was assumed that a hospital could make a profit of around 30% off each room. A 30% profit of $1,650 would yield a $495 margin. Thus, if these patient rooms were to be vacated, the hospital could expect to lose around $1,980 per day.

Even with an accelerated schedule, such as what was previously proposed, the hospital would still need to vacate these rooms for seven weeks per floor (duration of renovations per waiting room.) By renovating two waiting rooms at a time, the hospital is sacrificing four patient rooms for seven weeks (or forty-nine days) at $495 per day. This yields a $582,120 total profit loss the hospital throughout renovations of all six floors. These values were not based on any specific year, thus cost adjustments were not made. See **Table 6** for a cost summary.

Type	Cost
Material	$17,504.45
Labor	
Modified Schedule	$302,007.65
Lost Revenue	
Modified Schedule	$582,120
Total	$901,632.1

Table 6: Expected Cost for Acoustical Wall Method

All hand calculations for this analysis can be found in **Appendix E**.

Constructability

An acoustical design professional was contacted to discuss the feasibility of creating a prefabricated wall system such as this. It was determined that a typical prefabricated wall section of 8'x14' at 11 lb/ft² could weigh well over 1000 lbs. This wouldn't be so much and issue if the walls were being transported via hoist; however, these walls are needed because of the noise created in an occupied facility, and it would not make sense to create more noise just to bring these walls in. It is not realistic to expect laborers to lift these walls from the facility entrance to the waiting rooms. It is also unrealistic to believe that walls of this size could fit through the existing doorways of the hospital.

Another important factor to remember is that these walls would need to extend from the floor slab to the metal decking of the floor above in order to reduce and isolate the noise sources. Due to complications in the ceiling space with MEP utilities, it is unrealistic to design a 14' high wall without expecting these complications. It would also be difficult to seal the seams at the top of the wall due in part of the above ceiling utilities.

While the acoustical walls work well to isolate sound, it is not expected that these walls will help much to prevent vibrations from traveling through the structure. Because of this, work restrictions would still be mandated by the hospital.

Recommendation and Conclusion

Based upon the information presented in this analysis, although an acoustical wall would be advantageous in the reduction and isolation of noise volumes, it is not believed that these walls will prevent the vibrations caused by construction in the waiting rooms. Because these walls will not prevent vibrations, work restrictions will still be in place by the hospital, rendering these walls useless. Even if the walls could help with vibrations, it is unrealistic to prefabricate walls and transport them through the hospital to the waiting rooms. Even then, it would be difficult to create a wall that can extend into the ceiling space, preventing sound from traveling over the barrier. Although hit would still be wise to implement some type of acoustical barrier for the patients' wellbeing, it is not recommended to use this method due to constructability issues and lack of cost benefit.

Schedule Reduction via BIM Implementation

Problem Identification

The Hospital Bed Expansion did not utilize any type of phasing on this project which could be a major factor in the current schedule delays throughout construction. A proper phasing model would have been advantageous in creating deadlines that prioritize construction sequences and owner move-out dates. Unforeseen conditions have also been a challenge in maintaining an accurate schedule. Construction issues arising in regard to existing conditions of the hospital may have been alleviated with the use of 3D laser scanning. Both Phase Modeling and 3D Laser Scanning are subcategories of BIM technologies that if implemented could dramatically improve the project's schedule and reduce the possibility of any delays.

Research Goal

The goal of this analysis is to create a 4D phased model that will assess the efficiency of a phased construction schedule. This analysis will assess the benefit of utilizing phased schedule and the implementation of BIM modeling.

Approach

- Interview the Project Manager to determine all contributing factors to project delays
- Request the use of current AutoCad from Architect and Project Owner
    - 3D drawings unavailable
- Create a 3D model of the Hospital Bed Expansion
- Create a phased construction schedule
- Link phased schedule to 3D model

Introduction

Building Information Modeling (BIM) has become an increasingly popular method in improving building design and construction. The technology and process has proven itself as a tremendous asset in the design of complicated systems, energy modeling, and other important design aspects. Along with beneficial design programs, BIM offers programs to analyze and model the cost and schedule outcomes of a design. Some of these software programs include Revit, Navisworks, Vasari, SIPPS, and many more. Although BIM includes many software programs to use as a tool on a building project, this process is often confused as software by itself.

Building Information Modeling is actually a process that involves an integrated team working to create digital representations of an architectural design. This process is often paired with Integrated Project Delivery (IPD) methods to create a cohesive team that works together from the conceptual design of a building. This is an advantageous approach to design and construction because the designers, engineers, and construction manager can all take part in creating a design that is efficient, cost effective, and beautiful while avoiding as many headaches as possible that may have occurred in the field.

By creating a more cohesive and integrated design, the construction schedule could potentially be decreased due to fewer design changes during construction. These modeling programs can easily find design conflicts when building systems are integrated. By depicting these clashes, design can easily be changed before the project enters into the construction phase. This process also helps to reduce cost over the construction period because of the fewer expected unforeseen conditions that inevitably occur in the field. Because the Hospital Bed Expansion did not implement any type of phased schedule, this analysis will determine the feasibility of a phased schedule via BIM methods to prove the benefit of this tool.

Because the project lacked 3D drawings and only utilized 2D drawings, a 3D scheduling model will not be created in this analysis. Instead, the phasing schedule will be shown through 2D drawings that incorporate color coordination to aid in the understanding of a phased schedule. If 3D Autocad drawings would have been readily available, then a model would have been prepared for the benefit of hospital occupants and construction teams. Within this model, a schedule would be attached so a real time construction sequence could be shown for the benefit of construction teams along with hospital staff and patients.

PHASE I

The Hospital Bed Expansion has undertaken an additional 70,000 square foot renovation of the existing structure. As this is an occupied facility, the owner must temporarily move out of the designated spaces before some construction can even begin. Although this is not construction related, if the owner does not move out by the agreed time period then the schedule will be affected by severe delays.

The owner was, in fact, eight (8) months late in moving out of the designated areas. This has severely affected the construction schedule, where the project was originally set for a November 2011 final completion date, the final completion date has now been pushed back to April 2012. If the time frame of this delay had been known, the project management team could have prioritized the areas needed to maintain a prompt schedule. Looking back on this phase of the project, the management team would have encouraged the owner to move out of the 8th floor first so preparations could be made for the new penthouse that was to be built on top of the new expansion/renovation.

Because the structural steel could not begin until the column reinforcing had a significant portion done, it became crucial for the project management team to push in getting this done. Fifty-eight (58) columns needed reinforcing to ensure a structurally stable building. If these columns were not completely reinforced by the dedicated date, then there was the potential of extending the project schedule more than it had already been delayed. The UVA management team lessoned the stress of finishing the steel reinforcement on time by planning ahead. A contractor was to begin the steel strengthening process before HBE was even sent out for bid. Around twelve (12) columns were reinforced before the Hospital

Bed Expansion went underway. It is unclear if the original contractor remained on site to finish the remaining column reinforcement as that information was not readily available.

These factors have been included in PHASE I along with, Demolition, and Penthouse Preparation. These four aspects are crucial to completing during the procurement of steel, façade, and penthouse AHU. If these items can completed on time, then the rest of the project should be able to run smoothly with little interference with hospital staff. Below is the sequence of phasing for Owner Move-Out, Steel Strengthening, Demolition, and the Penthouse.

The activities involved in Owner Move-Out include and the removal of all hospital equipment, supplies, and furniture. After the space has been vacated, the ICRA dust partition will begin to be erected so demolition of the space can begin as soon as possible.

Steel Strengthening will begin on the 2nd floor mechanical space. Steel columns in the basement and 1st floor of the hospital were previously strengthened by the UVA facilities management team. Each floor has around 10 columns that will need to be reinforced. In order to accomplish this according to regulations and codes, ICRA walls will need to be erected around the welding areas to control odors, dust, noise, vibrations, and any contaminations. The project team has set aside 10 – 16 days to complete this task on each floor.

Demolition will begin after the 7th floor has been vacated. This is to ensure there is as little disturbance from dust, noise, and vibration, as possible for the hospital staff who are still working on the levels beneath the construction area. According to this schedule, there should be a vacated floor between the construction area and the next occupied floor.

Preparation for the Penthouse can begin after the 8th floor has been vacated and the ICRA wall has been erected. The Equipment Pad must first be poured before the interior Penthouse MEP can begin. Upon completion of the interior MEP utilities, the crane will be used to install MEP risers and then lift the two new air handling units to the roof. Phase I will be completed with the installation of and connect of both air handling units on December 18, 2009.

The original schedule can be found in **Appendix B**, and the phased schedule can be found in **Appendix F**.

Color Key

Steel Strengthening

Owner Move Out

Demolition

Steel Strengthening and Move Out

Steel Strengthening and Demolition

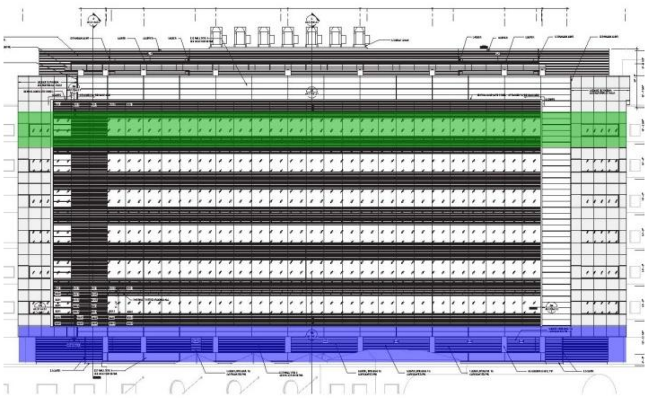


Figure 13:
The Owner will move out of the 8th Floor, and at the same time Steel Strengthening will begin in the Mechanical space on floor 2M.

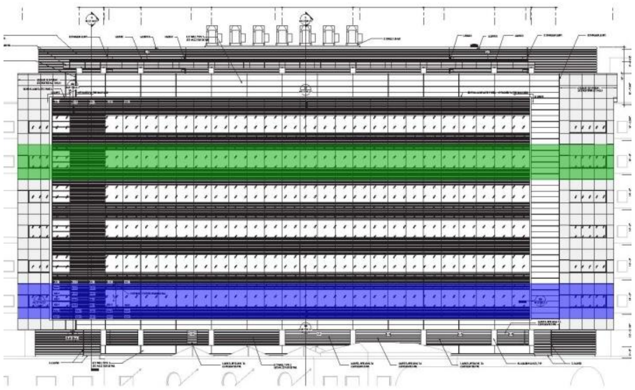


Figure 14:
As the steel strengthening work moves to the 3rd floor, the move out process will continue to the 7th floor.

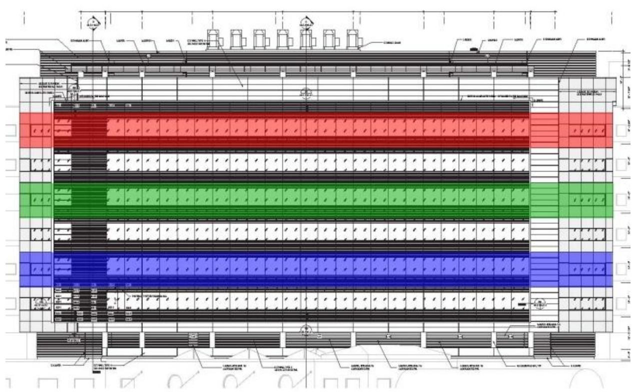


Figure 15:
When Steel Strengthening reaches the 4th floor, and the move out process comes to the 6th floor, demolition can begin on the 8th floor.

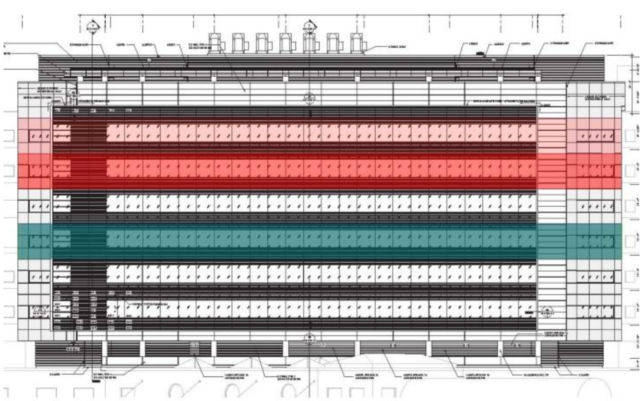


Figure 16:
Steel Strengthening and Move Out continue on to 5th floor, while the Demolition starts on the 7th floor.

Figure 17:
Steel Strengthening is now on the 6th floor, and the 4th floor is now being vacated while demolition begins on the 6th floor.

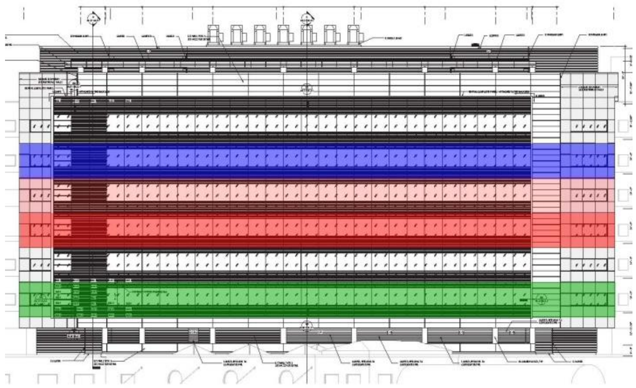


Figure 18:
Steel Strengthening is now on the 7th floor, and the 3rd floor is the last to be vacated while demolition begins on the 5th floor.

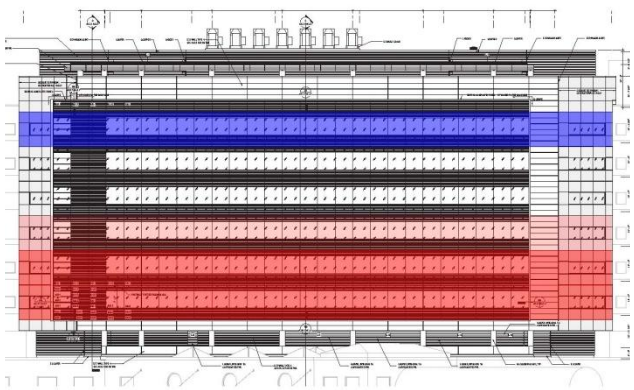


Figure 19:
Steel Strengthening is now on the 8th floor, while demolition can continue on the 4th and 3rd floors simultaneously.

PHASE II

The Project Management team noted that the steel erecting process went relatively smoothly and was completed within the directed time frame allowed. With this information, it is suggested that Phase II will be relatively simple and continue as previously designated by the Project Team. Phase II will include the erection of the superstructure, installation of façade, and installation of prefabricated MEP systems. Prefabricated MEP systems will not be addressed in detail for this analysis, but it is addressed later in this report.

The construction of the superstructure includes steel erection, metal decking, and concrete poured floors. Due to a lack of space on site and heavy traffic patterns during the day, steel erection will occur overnight with the crane making steel picks straight off of the flatbed trucks which are transporting the steel. Because the steel will be erected overnight, metal decking can be installed during the day, and the concrete floors can be poured during the day as well.

Before the façade can be entirely installed, a hoist will be installed after steel is erected for the high roof on March 3, 2010. The hoist will be used to transport materials and labor throughout the construction area. The hospital, rightly so, is not allowing construction labor to use the interior elevators. Also, prefabricated MEP systems will be brought in for installation before the façade can be installed for the respective floors. Installation of the prefabricated MEP systems will begin on December 2, 2009.

Color Key

Steel Erection

Above Ceiling Prefabricated MEP R/I

Façade Installation

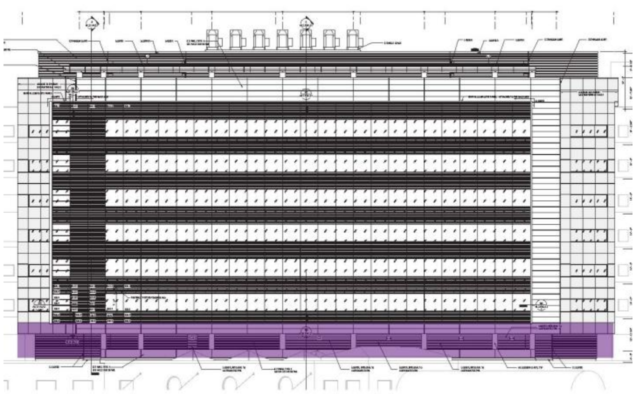


Figure 20:
The 2nd floor stub columns will be installed and the building pad will be prepared.

Figure 21:
Steel Erection for 3rd floor at night, metal decking installed, and concrete poured during day.

Figure 22:
Steel Erection for 4th floor at night, metal decking installed, and concrete poured during day.

Figure 23:
Steel Erection for 5th floor at night, metal decking installed, and concrete poured during day. Prefabricated MEP systems installed on 2nd floor.

Figure 24:
Steel Erection for 6th floor at night, metal decking installed, and concrete poured during day. Prefabricated MEP systems installed on 2rd floor.

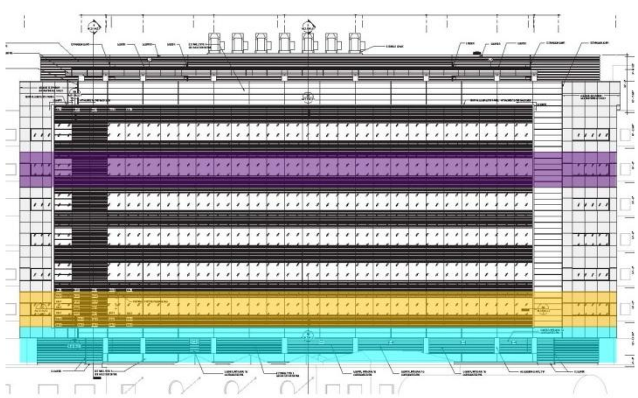


Figure 25:
Steel Erection for 7th floor at night, metal decking installed, and concrete poured during day. Prefabricated MEP systems installed on 3rd floor. 2nd floor façade installed.

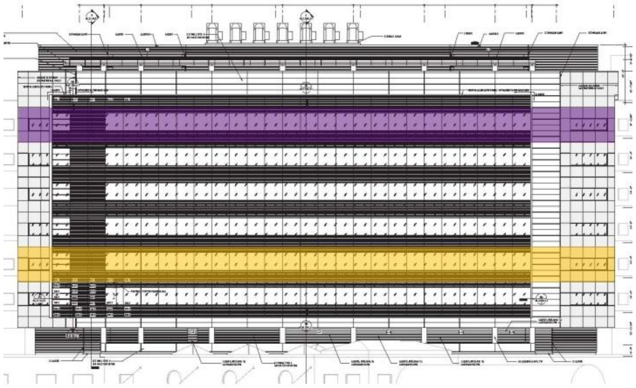


Figure 26:
Steel Erection for 8th floor at night, metal decking installed, and concrete poured during day. Prefabricated MEP systems installed on 4th floor.

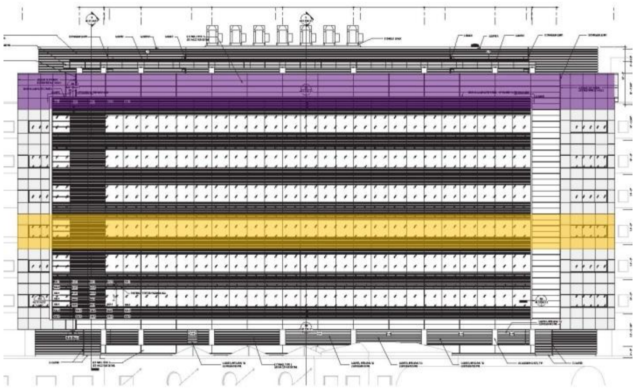


Figure 27:
Steel Erection for high and low roof at night, metal decking installed, and concrete poured during day. Prefabricated MEP systems installed on 5th floor.

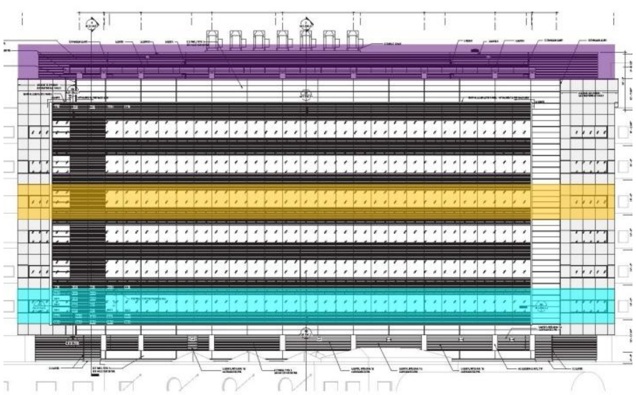


Figure 28:
Structural Steel has topped out. Material hoist installed. Prefabricated MEP systems installed on 6th floor. Façade installation begins on 3rd floor.

Figure 29:
Prefabricated MEP systems installed on 7th floor. Façade installation begins on 4th floor.

Figure 30:
Prefabricated MEP systems installed on 7th floor. Façade installation continues to 5th floor.

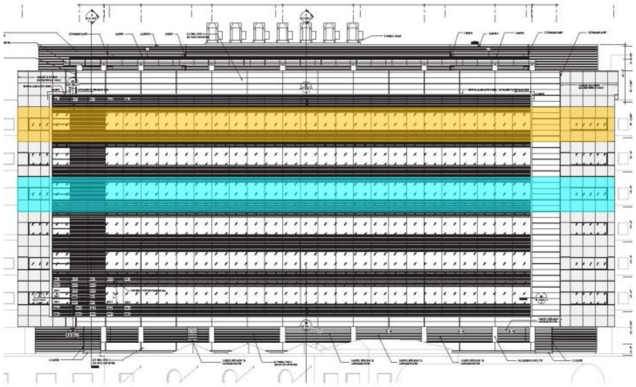


Figure 31:
Prefabricated MEP systems installed on 8th floor. Façade installation begins on 6th floor.

Figure 32:
Prefabricated MEP systems installed on 8th floor. Façade installation continues to 7th floor.

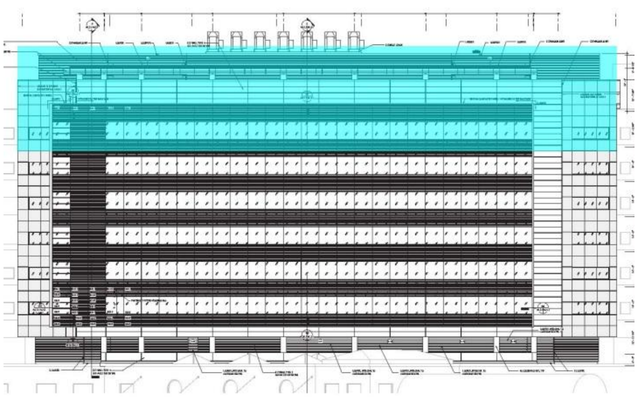


Figure 33:
Façade Installation from 8th floor – High Roof.

PHASE III

Phase III involves the construction of rough- in and finishes from floor 3 to floor 8. This construction will begin on the third floor and work up. By following this sequence, the construction for interiors can begin earlier and thus result in an earlier completion date. Originally, the schedule depicted the construction sequence beginning on the eighth floor and working downward. This method would be beneficial in keeping the work organized, however it would not contribute to any type of schedule reduction since interior construction on the eighth floor would be waiting on above ceiling MEP installation and façade installation. Because there is one hoist available to all 8 floors including the penthouse, it is important to avoid as much congestion as possible. However, with careful planning, congestion on the hoist can be avoided.

Color Key

3rd Floor Interiors

4th Floor Interiors

5th Floor Interiors

6th Floor Interiors

7th Floor Interiors

8th Floor Interiors

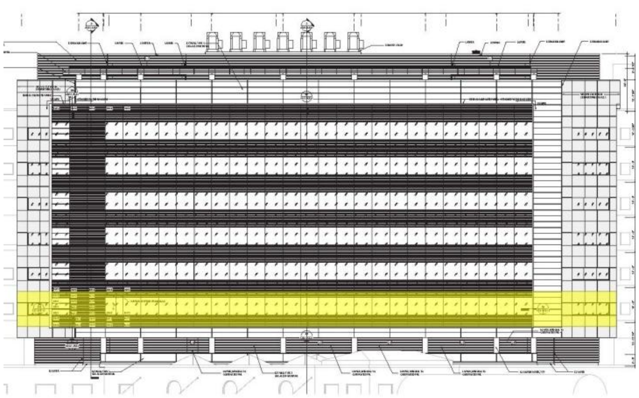


Figure 34:
3rd Floor Interior Construction

Figure 35:
3rd and 4th Floor Interior Construction

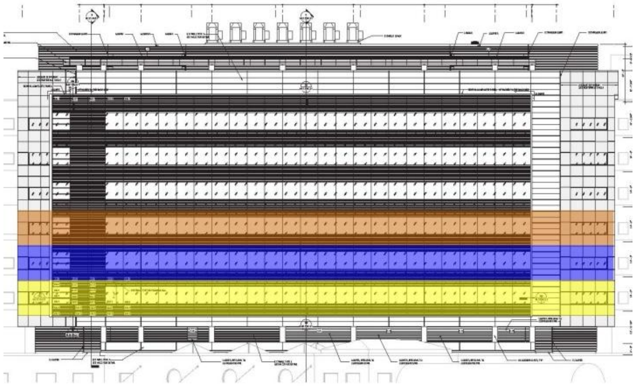


Figure 36:
3rd, 4th, and 5th Floor Interior Construction

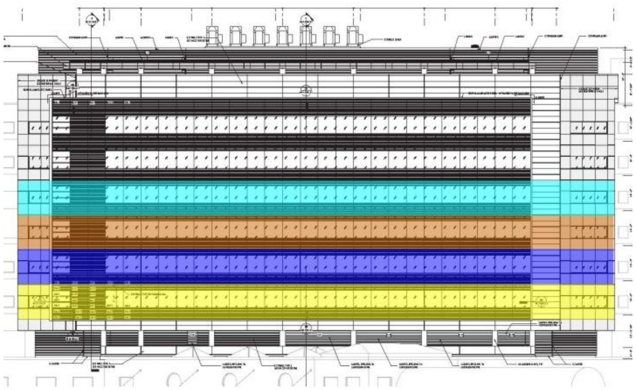


Figure 37:
3rd, 4th, 5th and 6th Floor Interior Construction

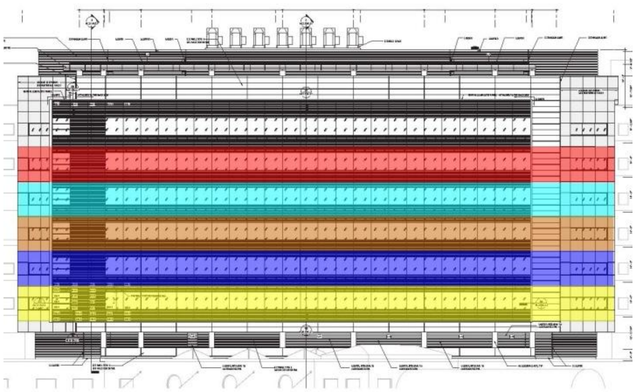


Figure 38:
3rd, 4th, 5th, 6th and 7th Floor Interior Construction

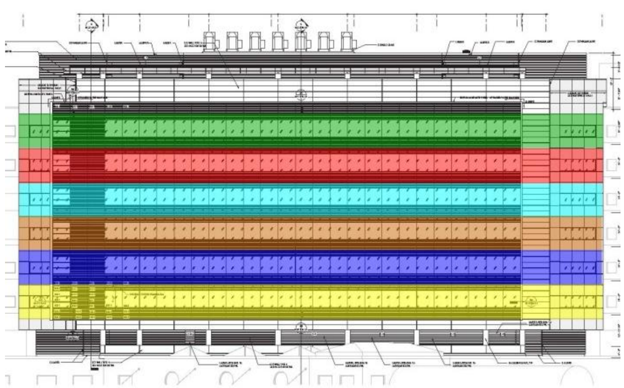


Figure 39:
3rd, 4th, 5th, 6th, 7th and 8th Floor Interior Construction

Techniques

In lieu of the significant time delay due to a late owner move out, it may be valuable to consider implementing BIM models to use for the benefit of hospital occupants. Simple phasing models can be on display in the lobby and other strategic areas of the hospital to help hospital occupants better understand the progress of construction in their facility. These models will also help the patrons better understand how they will be affected, when they will be affected, and in what areas the construction will be happening during that time period.

It is difficult to offer an estimate of how much time can be saved using the 3D and 4D models with a phasing schedule. However, it is believed that his technique will provide some type of schedule savings. The most useful portion of implementing BIM is the quality added to the project. There is a potential benefit of increased employee satisfaction with construction.

It is difficult and unrealistic to model every detailed area and phase in a computer modeling program. But it is highly useful to model general areas such as shown (and even areas on detailed floor plans) to use for the general understanding of all parties involved.

Along with the phasing model, an existing conditions model should be created to avoid unforeseen conditions such as was experienced in the hospital.

Recommendation and Conclusion

Based upon the information presented in this analysis, a phased schedule would improve quality of the construction schedule by creating a more clear and organized model for both the project team and hospital staff. It is believed that the implementation of phased 3D computer models would also increase the quality of experience for hospital staff and patients. By utilizing phased models within the hospital, staff and patients will be given the added benefit of a better understanding of construction sequencing and progress in their facility. This would increase the understanding of hospital patrons so to prevent confusion and frustration with the ever changing hospital environment in the midst of construction. It is recommended that the project team implement a phased schedule and general 3D model throughout construction. Implementing a detailed phased 3D model is not recommended due to the complexity and time that would be required to create such a model. A computer model can still be generated where general construction areas are highlighted according to each phase. This would still benefit hospital staff and construction teams without the investing unnecessary time and cost.

Energy Design via Photovoltaic Façade Change

Problem Identification

As mentioned earlier, this project is to feature an extensive green roof to be added atop the main lobby and a Thermoplastic Polyolefin replacement roof for the main hospital tower. These features will help the project team attain a LEED Silver Rating for the Hospital Bed Expansion. This expansion also features a North Facing 17,500 ft^2 glass façade, and although this façade may be aesthetically pleasing while contributing day-lighting to the patient rooms, there is concern over both the consequential mechanical loads and the potential lack of patient privacy that ensues glass facades. Because the UVA Health System desires to attain a sustainable building, a new façade detail may be worthwhile to investigate. While maintaining the aesthetically pleasing appearance of the current glass façade, a newly popular glazing system has been brought to attention by Penn State AE faculty. A photovoltaic glazing system will retain the same desired façade appearance with the benefit of adding privacy for the patients (through alternate panel transparency) and contributing to the sustainable features of the project.

Research Goal

The goal of this analysis is to perform a preliminary redesign of the glass façade and assess the effects on electrical, mechanical, and structural loads.

Approach

- Evaluate the constructability and schedule on installation of PV Glazing Systems
- Research various designs and costs for Photovoltaic Glazing Systems
- Redesign the façade
- Assess the effects on electrical and mechanical loads
- Assess the effect on structural load (time permitting)

Introduction

Photovoltaic (PV) Panels have been an increasingly popular source of renewable power for residential and commercial systems. Government incentives have made the purchase and installation of these panels more affordable to both the commercial builder and average homeowner. Incentives combined with the savings in electrical power will often bring the payback period under 25 years.

Despite having effective results in certain areas of the world, it can be difficult to find space to house the large PV arrays. With this in mind, modern technology and innovative engineers have begun to develop PV systems that can be used as windows on a building. These Photovoltaic Glass Units (PVGU) can be designed for most of any parameter that an owner would like to use them for.

Through research, a variety of PVGU's were found that featured colored glass backgrounds, opaque glass, and even clear glass. For the purposes in this analysis, a PVGU will be used from Pythagoras Solar based in Israel.

This PVGU unit has photovoltaic strips laminated between two pieces of translucent glass as seen in **Figure 40**. Although a figure could not be provided, an additional PVGU type will be used on this façade which will have an opaque interior glass to provide more privacy for the room occupant. The transparent PVGU can be seen in **Figure 41**.

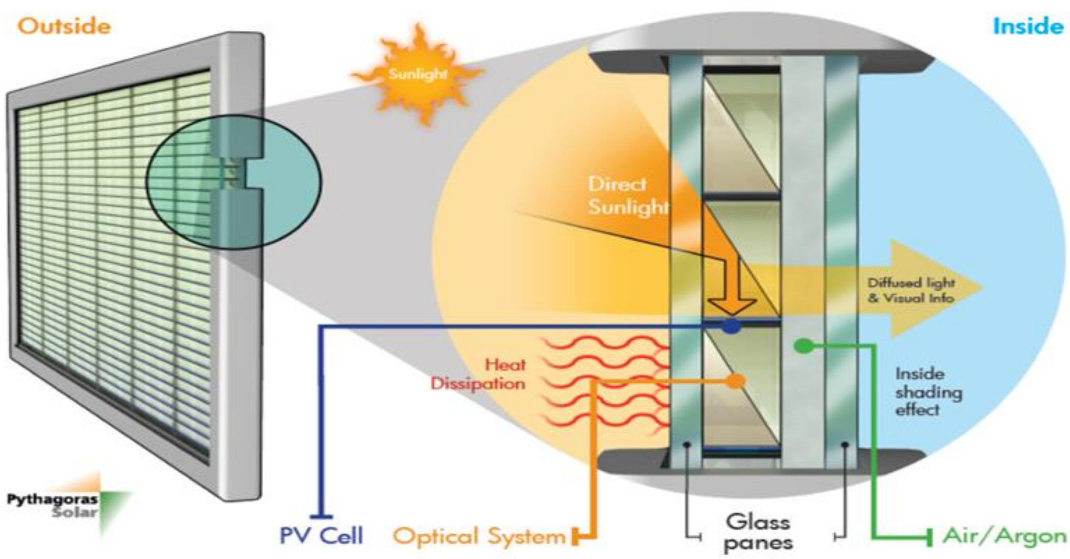


Figure 40: Diagram of proposed PVGU unit

The current façade utilizes several types of insulating fritted glass to provide privacy for the room occupants while also maintaining a unique façade design. The PVGU's are assumed to provide at least the same if not better insulating value as the current glass façade. The current glass unit features an air space to provide insulating value to the interior of the room such as seen in **Figure 42**. The PV glass unit also features a similar airspace, but also includes an additional insulating layer consequence of the PV cells (see above). Because of this, it is not believed that the insulating integrity of the PVGU will be an issue in this application. The product information for this system can be found in **Appendix F**.

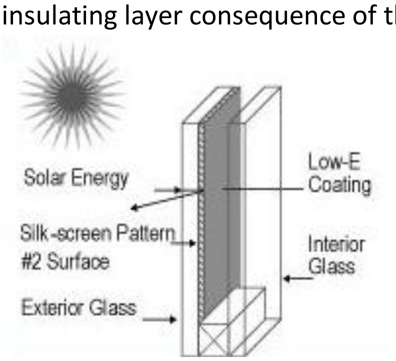


Figure 42: Diagram of existing glass panel

Figure 41: Picture of proposed PVGU unit

Orientation and Shading

Because the expansion will only feature one glass façade, the photovoltaic glass placement becomes limited to one option. The orientation of this expansion faces a non-optimal direction of NNW, but it is believed that this façade will still receive a small amount of sunlight to produce some energy. Expected sun hours were determined using the solar insulation map on Wholesale Solar's website. Data from Richmond, VA was used due to the lack of solar information being readily available for Charlottesville, VA. The expected number of sun hours during a clear sunny day was found to be around 4.5 hours while the amount of sun during an overcast day was found to be around 3.37. The Photovoltaic Glass Units will be designed for the minimum expected sun hours to ensure the system is not designed for an unrealistic load. The initial design parameters can be found in **Table 7** seen to the left.

PVGU Design Parameters	
Location	Charlottesville, VA
Latitude	38.03°N
Longitude	78.48°W
Elevation	594' (181m)
Façade Orientation	NNW
Total Area of Glass Facade	17,955 ft²
Area Covered by PVGU	10,080 ft²
Tilt Angle	90°
Sun Hours/Day	
High	4.5
Low	3.37
Average	4.13

Table 7: PVGU Design Parameters

The hospital is surrounded by other medical facilities that despite being less in stature, will still project shadows onto the proposed façade in the late afternoon. Although the surrounding buildings will project shadows onto portions of the glass façade, the entire PV glass system is not expected to be deemed unusable during this time of day. A general model of the façade was created using Google Sketchup. The Sketchup model depicts a simulation of the shadows and day lighting of the Hospital during the Spring/Fall Equinox, Summer Solstice, and Winter Solstice which can be seen in **Figures 43-48**.

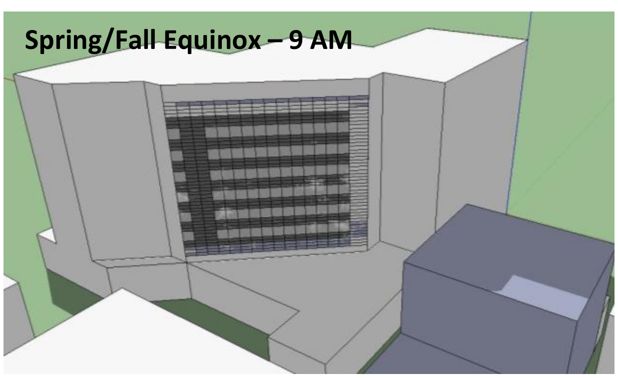


Figure 43

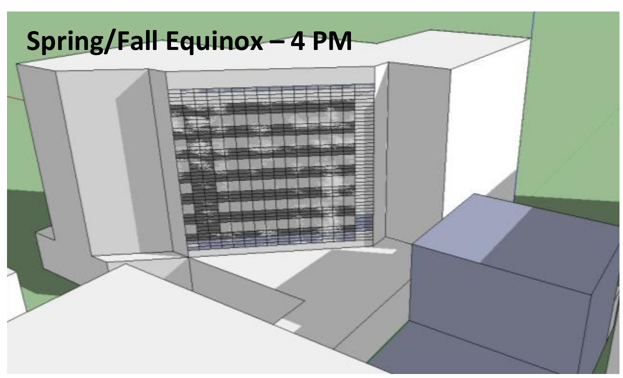


Figure 44

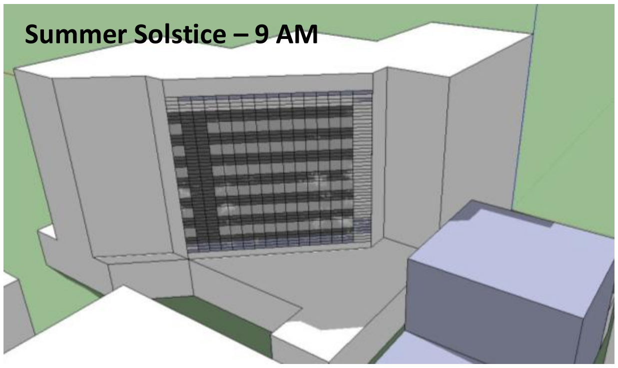


Figure 45

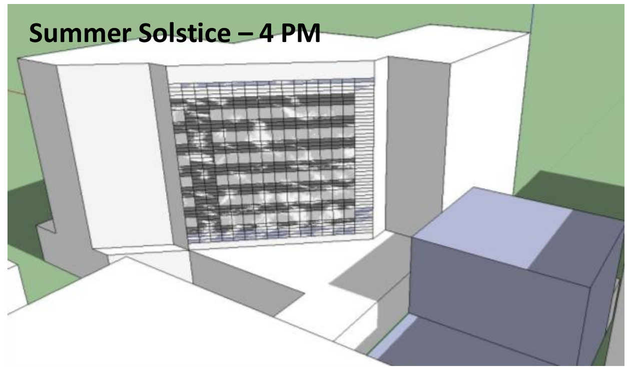


Figure 46

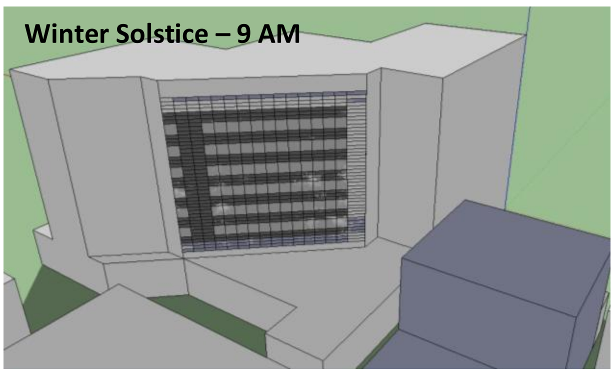


Figure 47

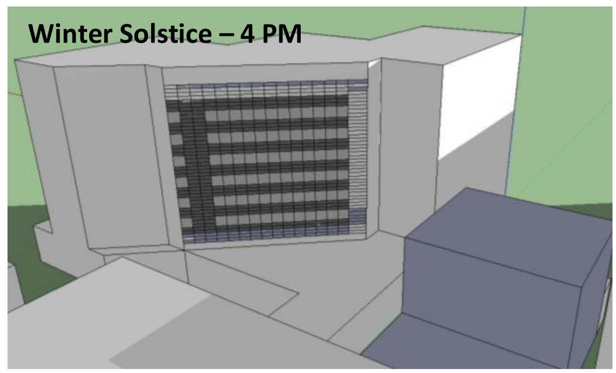


Figure 48

PVGU Layout

The current façade utilizes three patterns of insulated fritted glass unit to provide privacy for parts of the patient room exterior. The proposed PV glass units would replace the fritted glass pattern while providing equal if not more privacy and still maintain the insulating value of the fritted glass. Each patient room will use around six (6) Photovoltaic Glass Units to help support the lighting load of the appropriate patient room. The current and proposed PVGU layout can be seen to the right in **Figure 49**.

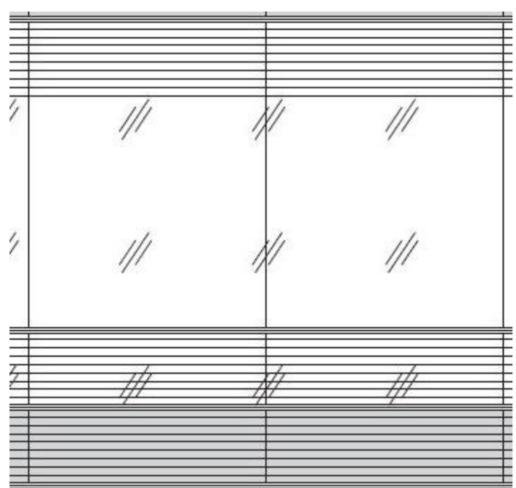


Figure 49: Typical Patient Room Layout

Following this pattern will allow room for a total of 576 PV glass units sized at 2'4" x 7'6". The square footage for a single unit is 17.5 ft². This area will be used to calculate the max power that a panel can produce. The pattern can be seen below in **Figure 50**.

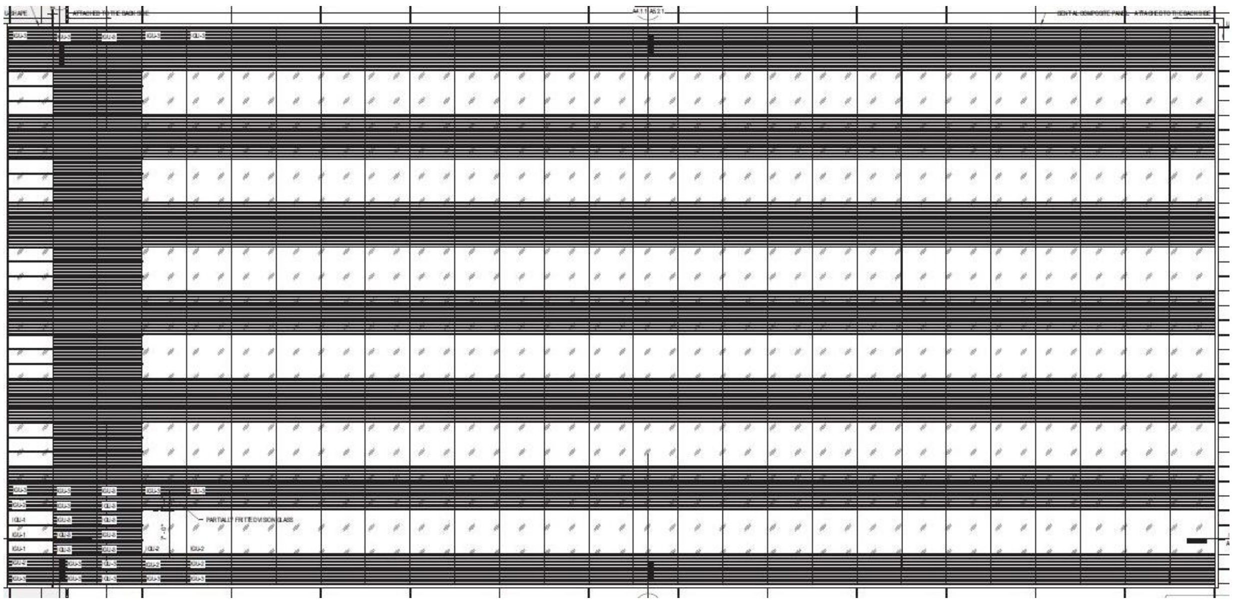


Figure 50: The PV Glass Units will replace the fritted glass shown

PVGU and Inverter Sizing

While determining what building loads the PV glass units could power, it was assumed that any load other than the lighting would be too high for the panels to keep up with. Thus only the lighting load of the current *expansion* was evaluated.

In determining the number of PVG units the building would require to power the lighting load, and analysis was done to find the lighting load for one day. To do this, the luminaire fixtures were counted for one typical floor in the hospital. This number was then multiplied by six (6) to determine the total number of lights and watt per hour (w/h) for the expansion. The results can be seen in **Table 8**.

Table 8: Required Power for Lighting Fixtures

Patient rooms				
Light Type	**Description**	**No. of Lamps**	**Wattage**	**Total Watts**
UBM-2	Fluorescent Wallwasher with Recessed Aperture	144	26	3744
UBM-3A	Metal Halide Adjustable Accent Luminaire	144	20	2880
UBM-4.1A	Linear Fluorescent Surface Mounted	72	24	1728
UBM-6A	Compact Fluorescent Shower Light	144	32	4608
UBM-6B	Pendent LED Fixture with Mono Point Canopy	144	3	432
UBM-9	Fluorescent Wall Sconce	72	17	1224
UBM-12A	Linear Fluorescent Parabolic Downlight	72	54	3888

UBM-14A	Surface Mounted Color Changing Uplight	72	54	3888
UBM-15A	Fluorescent Staggered Strip - Surface Mounted	216	54	11664
UBM-16	Linear Fluorescent Strip - Surface Mounted	72	39	2808
UBM-18	LED Recessed Wall Luminaire for Wet Location	144	3	432
UBM-20	Direct/Indirect Linear Fluorescent Luminaire	144	54	7776
UBM-22	Staggered Lamps Continuous Rows Fixture		54	0
UBM-23	Wall Mounted Plug-In With Gooseneck Arm Multi Direction Task Luminaire	72	3	216
	Total W/h for all patient rooms			45288

General Floors				
Light Type	**Description**	**No. of Lamps**	**Wattage**	**Total Watts**
UBM-20	Direct/Indirect Linear Fluorescent Luminaire	402	54	21708
UBM-22	Staggered Lamps Continuous Fluorescent Fixture	150	54	8100
A	2x4 Direct/Indirect Linear Fluorescent Luminaire	162	40	6480
B1/B2	2x2 Direct/Indirect Linear Fluorescent Luminaire	126	40	5040
C	36" Undercabinet Lighting Prismatic Diffuser	24	25	600
F	48" Undercabinet Lighting Prismatic Diffuser	18	32	576
G1/G3/G4	Vertical Compact Fluorescent Reflector Downlight	144	18	2592
G2	Vertical Compact Fluorescent Reflector Downlight	120	32	3840
H	1x4 Recessed Direct/Indirect	48	32	1536
J1/J2/J3	Vapor Tight Strip Lighting	66	32	2112
L1/L2/L3	Recessed LED Fixture	306	3	918
	Total W/h for renovated area			68982

Total W/h for occupied addition	114270

The total wattage needed to power the expansion's light load each *hour* is roughly 114.3 kW/h, and for an entire day the expected power need is 2742.5 kW. After a quick calculation for max power using the technical specific value of 11.15 Watts per square foot (w/ft²) multiplied by the area of a single PVGU (17.5 ft²) will result in a power production of 195 W/h. This number was then multiplied by 576 to determine the max power of the entire PV glass façade. The max power for this façade is around 112.4 kW/h, which is just short of the needed power to generate the hospital expansion's lighting load.

Even if the panels produced the same Wattage as the required lighting load, this still would not suffice to power the entire lighting load all day. As seen in the preliminary design **Table 9** the area of Charlottesville, VA only receives an average of 4.13 sun hours per day, which means that the PV glass units will only be charged for around 4 hours each day. If this is the only amount sun that can be expected each day, then the PVGU's will only supply 464.2 kW per day. This is only 17% of what is needed for the entire day, not nearly enough to be relied on for an entire day. If the owner would want to have their lighting supplied by the PVGU's then the façade would need to be made up of around 3504 glass units of the same size. See **Table 9** for this estimate.

PVGU Sizing Calculations (Full Lighting Load)		
Sun Hours/Day	4.13	Determined from Wholesale Solar's Solar Mapping Chart
Total Wh/Day	2743.2 kW	114.27 kW/h lighting load multiplied by 24 hours
Watts per Hour of Sunlight	664.21 kW	2743.2 kW/day divided by 4.13 Sun Hours/Day
Actual Produced Power	195.13 W/h	11.15 W/ft^2 (taken from tech specs) multiplied by 17.5 ft^2
# of Panels Required	3504	664.21 kW divided by 195.13 W
Total kW Panels can Produce	464.19 kW	(195. 13 W/h)x(576 panels)x(4.13 hours) divided by 1000
% of Required Power that can be Supplied	17%	464.19 kW ÷ 2743.2 kW

Table 9: PVGU Sizing (Full Lighting Load)

Because this is an unrealistic number of PV glass units to buy, a different lighting load requirement was looked at. Rather than powering the entire expansion's lighting load, only the patient rooms were looked at. The lighting load analysis can be seen in **Table 10** below.

Single Patient Room				
Light Type	**Description**	**No. of Lamps**	**Wattage**	**Total Watts**
UBM-2	Fluorescent Wallwasher with Recessed Aperture	2	26	52
UBM-3A	Metal Halide Adjustable Accent Luminaire	2	20	40
UBM-4.1A	Linear Fluorescent Surface Mounted	1	24	24
UBM-6A	Compact Fluorescent Shower Light	2	32	64
UBM-6B	Pendent LED Fixture with Mono Point Canopy	2	3	6
UBM-9	Fluorescent Wall Sconce	1	17	17
UBM-12A	Linear Fluorescent Parabolic Downlight	1	54	54
UBM-14A	Surface Mounted Linear Color Changing Uplight	1	54	54
UBM-15A	Fluorescent Staggered Strip - Surface Mounted	3	54	162
UBM-16	Linear Fluorescent Strip - Surface Mounted in Cove	1	39	39
UBM-18	LED Recessed Wall Luminaire for Wet Location	2	3	6
UBM-20	Direct/Indirect Linear Fluorescent Luminaire	2	54	108
UBM-22	Staggered Lamps Continuous Rows Fixture		54	0
UBM-23	Wall Mounted Plug-In With Gooseneck Arm Multi Direction Task Luminaire	1	3	3
Total W/h for one patient room				629

Table 10: Lighting Load of Single Patient Room

The total lighting load for a single patient room is around 629 W/h. A total of 72 patient rooms are being added in this expansion which would result in a load of 45,288 W/h needed to power the patient rooms and a total of 1087 kW for the entire day. The estimate can be seen below in **Table 11**.

PVGU Sizing (Patient Room Lighting Load)		
Sun Hours/Day	4.13	Determined from Wholesale Solar's Solar Mapping Chart
Total Wh/Day	1087 kW	45.29 kW/h lighting load multiplied by 24 hours
Watts per Hour of Sunlight	263.17 kW	1087 kW/day divided by 4.13 Sun Hours/Day
Actual Produced Power	195.13 W/h	11.15 W/ft² (taken from tech specs) multiplied by 17.5 ft²
# of Panels Required	1348.7	263.17 kW divided by 195.13 W/h
Total kW Panels can Produce	464.19 kW	(195. 13 W/h)x(576 panels)x(4.13 hours) divided by 1000
% of Required Power that can be Supplied	42.7%	464.19 kW ÷ 1087 kW

Table 11: PVGU Sizing (Patient Room Lighting Load)

If the PVGU panels are only to contribute to the patient room lighting loads, then the expected contribution is around 43%, much better than the previous expected contribution. Because of this, the design of the PVGU façade will be based upon the load required for patient rooms only.

After the design load was determined, inverters needed to be designed. Inverters convert the DC power, which the PV panels produce, into AC power which is the type of power that is consumed. Fronius inverters were used due to familiarity with the student.

Several options were available in consideration to the number of systems to use for the façade. Ultimately the selection was narrowed to two (2) different system options. The first was to divide the façade in half and place the associated PV glass units on 10 different Fronius 11.4-1 UNI inverters. This option was eventually discarded due to cost and feasibility reasons. Please reference **Appendix G, Appendix H** and **Appendix I** for the product information and full calculation.

The second option involved dividing each floor into its own system. This option would place (87) windows, or 1,522.5 ft² of PV glass space on the first five floors, and (141) windows, or 2,467.5 ft², of PV glass space on the sixth floor. This results in two different system types that will need to be calculated for inverter sizing.

In summary, the first system type would produce 16,976 W which can be safely divided onto two (2) separate Fronius 7.5-1 UNI inverters at 8,488 W each. The second system produces 27,512.63 W which can be safely divided onto four (4) separate Fronius 7.5-1 UNI inverters at 6,878.25 W. This system division was chosen because of lower costs for the sized inverters and also for the purposes of flexibility and efficiency on each floor. The full calculation for these two systems can be found in **Appendix I**.

Energy Production

Before it can be determined if this system is feasible, the yearly value of energy produced must be calculated using the design parameters of proposed PVGU system. Because it was believed the surrounding building would not have much effect on façade shading, an energy model was not created. However, the PV Watts calculator at nrel.org was utilized to find the energy value savings in one year of operation. The design parameters can be seen in **Table 12** below. Using these parameters, PV Watts estimated that a building could save up to 41,381kWh and $3,310.48 in a single year of operation. The estimated results from PV Watts can be found in **Table 13** seen below.

PV System Parameters	
Station Identification	
Location	Charlottesville, VA
Latitude	38.03°N
Longitude	78.48°W
Elevation	594’ (181m)
PV System Specifications	
DC Rating	112.4 kW
DC to AC Derate Factor	.77
AC Rating	83.5 kW
Array Type	Fixed Tilt
Array Tilt	90.0°
Array Azimuth	315.0°
Energy Specifications	
Cost of Electricity	8.0 ¢/kWh

Table 12: PV System Parameters

PV Watts Energy Production Results			
Month	Solar Radiation ($kWh/m^2/day$)	AC Energy (kWh)	Energy Value ($)
1	0.90	1450	116.00
2	1.09	1773	141.84
3	1.56	3448	275.84
4	2.17	4802	384.16
5	2.51	5805	464.40
6	2.76	5997	479.76
7	2.69	5996	479.68
8	2.23	4876	390.08
9	1.78	3640	291.20
10	1.20	2131	170.48
11	0.81	914	73.12
12	0.65	548	43.84
Year	**1.70**	**41381**	**3310.48**

Table 13: PV Watts Energy Production Results

This system will be grid connected. Because the façade does not receive many sun hours, it is unrealistic to have this system connected to the grid and have back-up batteries. These PV panels will connect directly to the grid, as seen the diagram below. The PVGU unit will provide DC power to the Inverter which converts the current to AC power. From here, the AC power is registered in the Meter Box and then transferred to the power grid.

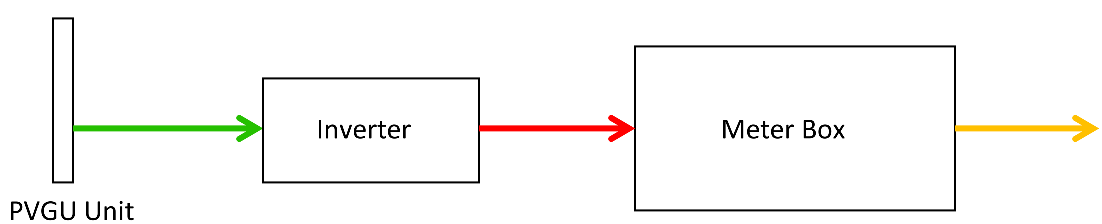


Diagram 1: Power supply from PVGU Unit

Cost and Payback

In an email with a Pythagoras representative, bare cost for the PV Glass Units was found to be around $125/ft². The Pythagoras representative also noted that this product is eligible for the 30% Federal Investment Tax Credit and also for the accelerated depreciation (MACRS) which would reduce the cost down to $75/sf. This would bring the subtotal for these panels up to around $756,000. At this time, there are no other incentive programs offered in Charlottesville, Va.

There is an assumed energy inflation rate of 1% every year. If this inflation rate is applied to the energy value savings predicted by PV Watts, then it is estimated that this system will take around 208 years to pay back the cost. The life expectancy of these PV units is around 25 years. In order to pay back the cost to install these units, the PV glass would need to save around $30,240/year.

Recommendation and Conclusion

Based upon the information presented in this analysis, Photovoltaic Glass Units will still maintain the façade's architectural integrity while providing more privacy for the patients. It was determined that this façade was not in the ideal location to take advantage of the PV units. Despite the units saving around $3,310.48/ year, the system itself would cost around $756,000 including incentives. The average life span of a system like this would be around 25 years, but the hospital could never recoup the cost to buy and install this system within the lifespan timeframe. Thus it is not recommended that these Photovoltaic Glass Units be implemented into the façade.

Schedule Reduction via Prefabricated MEP Systems

Problem Identification

As mentioned earlier, the Hospital Bed Expansion has had issues with schedule delays throughout the project. Along with the several other methods mentioned earlier, another way to alleviate the schedule strains is prefabricated systems. Because the hospital is being constructed as a structural steel system, prefabricated modular rooms would be impractical to use despite the repetitive floor layout. However, there are smaller assemblies that can still be manufactured as prefabricated systems. Ductbanks, electrical busways, telecommunications, and various other components are typically run together. These components can be manufactured offsite, where the correct size and length can be fabricated. After each designated component is fabricated offsite, the entire system can be combined and then installed together, potentially simplifying the installation time and process.

Research Goal

The goal of this analysis is to reduce the construction schedule by simplifying the process of fabricating and installing the major MEP and Telecommunications systems.

Approach

- Research the type of labor used on project (Union or Open Shop)
- Determine which components can be fabricated to fit together as an assembly
- Determine who is responsible for installing systems
- Assess the time required to fabricate and then install assemblies
- Evaluate the time and cost savings

Introduction

The typical fast pace lifestyle has carried over into the construction field where owners want their projects done faster so business can carry on as usual. Buildings that would have normally taken five years to construct are now expected to be completed in three years. Thankfully, emerging technologies have made it possible for construction teams to carry out such demanding tasks such as fast track schedules. As previously mentioned, BIM is one of the many new directions that this industry is taking as the 21st century is well on its way. Another new direction that is proving to be a benefit to construction teams is prefabrication.

Prefabrication has grown in popularity over the past few years due in part to the cost and schedule savings that often accompany prefabricated systems. This method is particularly helpful in building projects that are repetitive in design such as hotels, hospitals, office buildings, apartment buildings, etc. A Case study was done by Skanska on the Miami Valley Hospital in Dayton, Ohio which credited prefabrication as a major factor in the success of their project. This case study will be discussed later in this analysis.

Aside from the cost and schedule savings that can be accrued throughout a project, there exist many other added benefits in the use of prefabrication. This method improves worker safety because most of the work is being done offsite in a controlled environment. By working in a controlled environment offsite, employees can assemble these products under proper temperature and lighting conditions and at a height that puts limited strain on their physical health. Another benefit to this process is improved quality control and reduction of waste.

The project location will determine whether or not preliminary inspections can be done at the prefabrication site. State and local codes will dictate the requirements for on-site and off-site inspections. If the codes will allow for preliminary inspections, this will also lead to schedule reductions. Waste reduction is also an important factor in prefabrication. Because units are assembled in the same controlled environment, material waste is limited due to the easy access of tools, equipment, and material. This also reduces cost as compared to assembly in the field.

These benefits are all important factors in the decision to use prefabricate MEP's on the Hospital Bed Expansion. With safety being a major concern for both UVA and Gilbane/Russell on any project they are involved in, it makes sense to use prefabrication on this project to help reduce the cost and schedule.

Preliminary Design and Local Conditions

The MEP will feature two types of prefabricated units. The first type will be a modular unit that includes mechanical ductwork, electrical conduit, gas lines, plumbing lines, sprinkler lines, and cable trays such as seen in **Figures 51 & 52** These components will fit into 20' long modular units and be run through the main straight corridors of each floor. The main corridor running past the patient rooms is roughly 234' long and the connecting service and public corridors are roughly 34' long. Out of these straight modular units will be the individual branches of each MEP system. These individual branches will constitute the second type of prefabrication.

Because the MEP system is a complicated network of duct, plumbing, electrical, and sprinkler lines it would be difficult to prefabricate these pieces as modular units outside of the floor's straight corridors. Since it is impractical to fabricate the entire floor in modular units, the MEP branches will be prefabricated as individual units seen in **Figures 53 & 54**. These pieces will be constructed offsite at a separate facility where employees will still have the benefit of working in a controlled environment. When the assembly is ready to be installed, the prefabricated pieces will be shipped to the site and installed according to their proper location. This process could be equated to fitting pieces of a numbered puzzle together. Despite not being manufactured as a modular assembly, this process will still save time and money since the field workers will not have to cut, weld, and fit individual components in the field.

Because this project does not employee union workers there are fewer complications involved with installation and fabrication. If unions were to be employed on this project, there may be concerns as to who fabricates and installs the modular racks of utilities. In this case, the Project Labor Agreement would have to be researched more. As this is an open shop project, the most practical contractor can be chosen to install the prefab modular racks. In this case, the mechanical subcontractor would be chosen to install these racks since the modular units contain more ductwork and the mechanical subcontractor would probably have the best experience in hanging large units such as what these would be.

Figure 51: Prefabricated MEP Rack

Figure 52: Prefabricated MEP Rack

Figure 54: Prefabricated Piping

Figure 53: Prefabricated Piping

Case Study and Interview

In their case study of Miami Valley Hospital, Skanska reported a 300% increase in worker productivity at the prefabrication shop. While there is not solid research to support this statistic over a wide range of building projects, it can be expected that a project will expect a significant increase in worker productivity.

MEP Solutions, an MEP contractor in the UK, reported,

"On a general note you will save anywhere between 75 to 85% of the critical path labor hours by utilizing modules opposed to doing it traditionally."

This refers to the first type of prefabrication mentioned earlier in this analysis where several utilities are combined into a modular rack to be installed in straight corridors. Due to irregularities and design complexities, it is not believed that this statistic can be applied directly to individual prefabricated utilities. As mentioned earlier, the second type of prefabrication comes in the form of assembled utility pieces because of the complicated above ceiling network of utilities.

In an interview with a similar mechanical subcontractor, it was stated that the estimated time savings using the second type of prefabrication can be up to 50% of the critical path labor hours. The traditional method was used on the Hospital Bed Expansion, which took around 100 days to rough in all above ceiling utilities for one floor. Compared to the traditional method used, prefabrication is a significant amount of time saved.

Schedule Reduction

Upon receiving feedback from MEP subcontractors who work with prefabrication, calculations were made to determine the rough estimate of time to be saved. The percentages received were averaged to a rate of 65% and applied to the current scheduled durations for each utility (see **Table 14**.) The full hand calculations can be found in **Appendix J.**

	Original Duration (days)	Modified Duration (days)
Electrical R/I	80 x .65	28
Mechanical R/I	74 x .65	26
Plumbing R/I	64 x .65	23

Table 14: Modified Schedule Durations

Cost Savings

Cost will be evaluated according to labor hours only in this analysis. Cost of material savings will not be taken into account. In order to find the amount of money that could be saved, calculations must first be made of the labor required using the traditional method of fabrication and installation. After calculations are made using the traditional method, the labor hours required for prefabrication methods can then be determined. Full calculations can be found in **Appendix J**.

Traditional Method

Above Ceiling Utilities included were Electrical, Mechanical, and Plumbing. Durations were taken from the current construction schedule and can be seen above in **Table 14**. Only rough-in for the *patient floors* will be considered in this cost analysis. The designated crew types can be viewed in **Appendix K**.

The above ceiling electrical was assumed to utilize two crews of **Crew R-1**. One of these crews would produce 48 labor hours per day (L.H. /Day) at a cost of $59.51 per labor hour. This cost per hour includes Overhead and Profit (O&P) and does not account for prevailing wages. With the original duration for electrical rough-in being eighty days, the subtotal for one floor of electrical rough-in is around $457,037. If including the six patient floors of this expansion and cost adjustment factors, the total for electrical rough-in using the traditional method is around $1,608,455.10.

The above ceiling mechanical was assumed to utilize three crews of **Crew Q-11**. One of these crews will produce 32 L.H. /Day at a cost of $57.83 per labor hour. With the original duration for mechanical rough-in being seventy-four days, the subtotal for one floor of mechanical rough-in is around $410,825. If including the six patient floors of this expansion and cost adjustment factors, the total for mechanical rough-in using the traditional method is around $1,445,818.96.

The above ceiling plumbing was assumed to utilize three crews of **Crew Q-2**. One of these crews will produce 24 L.H. /Day at a cost of $57.70 per labor hour. With the original duration for plumbing rough-in being sixty-four days, the subtotal for one floor of plumbing rough-in is around $265,882. If including the six patient floors of this expansion, the total for plumbing rough-in using the traditional method is around $935,720.31.

The total cost for labor of electrical, mechanical, and plumbing using the traditional method of fabrication and installation is around $3,989,994.37.

Prefabrication Method

These calculations include the modified durations for each floor which can found in the schedule reduction section of this analysis. It was assumed that each floor's utilities would require thirty days of fabrication time in the shop. Because the crane will still be utilized by the steel workers at night, the cost of the crane was not included in this calculation. The cost of the crane is covered by the structural steel package. However, the cost for a crane operator was included in this calculation. Cost of the flat bed trucks used in prefabrication was assumed to be equivalent to the trucks used during the traditional fabrication method. Full hand calculations and assumptions can be seen in **Appendix J**. Crew numbers remained the same for in-field installation so as to maintain consistency across the analysis.

The In-Shop labor was assumed to utilize four crews of **Crew L-9**. One of these crews would produce 36 labor hours per day (L.H. /Day) at a cost of $53.64 per labor hour. This cost per hour includes Overhead and Profit (O&P) and does not account for prevailing wages. The assumption was made that each floor would require around twenty days of fabrication time to complete assembly of the above ceiling utilities. Using this duration, the subtotal for one floor of fabricated utilities is around $231,725. If including the six patient floors of this expansion and cost adjustment factors, the total for utility fabrication is around $815,511.87.

The above ceiling electrical was assumed to utilize two crews of **Crew R-1**. One of these crews would produce 48 labor hours per day (L.H. /Day) at a cost of $59.51 per labor hour. This cost per hour includes Overhead and Profit (O&P) and does not account for prevailing wages. With the modified duration for electrical rough-in being twenty-eight days, the subtotal for one floor of electrical rough-in is around $159,963. If including the six patient floors of this expansion and cost adjustment factors, the total for electrical rough-in using the prefabrication method is around $562,959.28.

The above ceiling mechanical was assumed to utilize three crews of **Crew Q-11**. One of these crews will produce 32 L.H. /Day at a cost of $57.83 per labor hour. With the modified duration for mechanical rough-in being twenty-six days, the subtotal for one floor of mechanical rough-in is around $144,344. If including the six patient floors of this expansion and cost adjustment factors, the total for mechanical rough-in using the prefabrication method is around $507,990.45.

The above ceiling plumbing was assumed to utilize three crews of **Crew Q-2**. One of these crews will produce 24 L.H. /Day at a cost of $57.70 per labor hour. With the modified duration for plumbing rough-in being twenty-three days, the subtotal for one floor of plumbing rough-in is around $95,551. If including the six patient floors of this expansion and cost adjustment factors, the total for plumbing rough-in using the traditional method is around $336,274.49.

It was assumed that the crane would be used to lift prefabricated units off the flat bed trucks around 50% of the total time required for utility installation. This percentage leads to around 15 days of crane operation per floor. The cost of a crane operator was found to be $60.70 per labor hour, which includes O&P and does not consider prevailing wages. The cost of supplying a crane operator for 15 days is around $7284. The total cost of supplying a crane operator for all six floors is $25,634.67.

The total cost for in-shop labor, the crane operator, and field crews to install the utilities using the prefabrication method is around $2,248,370.76.

Cost Comparison

To find the cost savings, the total labor cost using the prefabrication method ($2,248,370.76) was divided by the labor cost using the traditional method ($3,989,994.37). This fraction produces a decimal of .564. To find the percentage actually saved, .56 is subtracted from 1. The potential percentage of cost saving is around 44%. This is a conservative estimate, and actual cost savings can be expected to reach higher if including material cost savings. See **Table 15** for a Cost Comparison.

It is important to note that the above ceiling rough-in will interfere with firewalls throughout the patient floors. Although this is a concern, it is not a terrible complication. Rather than having the designated subcontractor build the firewalls first, it is possible to build the fire wall sections that will interfere with utility rough-in. These sections can be built and hung from the appropriate location so as not to delay the schedule any further.

	Traditional Method	Prefabrication Method
Electrical Rough-In	$1,608,455.10	$562,959.28
Mechanical Rough-In	$1,445,818.96	$507,990.45
Plumbing Rough-In	$935,720.31	$336,274.49
In-Shop Labor	N/A	$815,511.87
Crane Operator	N/A	$25,634.67
Total	$3,989,994.36	$2,248,370.75
Cost Savings	44%	

Table 15: Above Ceiling MEP Cost Comparison

Recommendation and Conclusion

Based upon the information presented in this analysis, the use of prefabricated MEP systems can reduce the installation time by 65% percent and has the potential to significantly reduce the overall construction schedule. This method can also help the owner save around 44% in his cost for the above ceiling MEP. This percentage translates to around $1,741,623.61. This percentage does not reflect the overall cost savings for individual Electrical, Plumbing, or Mechanical work packages. However, it is recommended that this method be used for the prescribed work, along with other construction applications. This method can also prove to be advantageous in prefabricated modular patient rooms where the owner can expect to see an increased cost savings amount.

Final Recommendations

Based upon the information presented in ***Analysis #1***, although an acoustical wall would be advantageous in the reduction and isolation of noise volumes, it is not believed that these walls will prevent the vibrations caused by construction in the waiting rooms. Because these walls will not prevent vibrations, work restrictions will still be in place by the hospital, rendering these walls useless. Even if the walls could help with vibrations, it is unrealistic to prefabricate walls and transport them through the hospital to the waiting rooms. Even then, it would be difficult to create a wall that can extend into the ceiling space, preventing sound from traveling over the barrier. Although hit would still be wise to implement some type of acoustical barrier for the patients' wellbeing, it is not recommended to use this method due to constructability issues and lack of cost benefit.

Based upon the information presented in ***Analysis #2***, a phased schedule would improve quality of the construction schedule by creating a more clear and organized model for both the project team and hospital staff. It is believed that the implementation of phased 3D computer models would also increase the quality of experience for hospital staff and patients. By utilizing phased models within the hospital, staff and patients will be given the added benefit of a better understanding of construction sequencing and progress in their facility. This would increase the understanding of hospital patrons so to prevent confusion and frustration with the ever changing hospital environment in the midst of construction. It is recommended that the project team implement a phased schedule and general 3D model throughout construction. Implementing a detailed phased 3D model is not recommended due to the complexity and time that would be required to create such a model. A computer model can still be generated where general construction areas are highlighted according to each phase. This would still benefit hospital staff and construction teams without the investing unnecessary time and cost.

Based upon the information presented in ***Analysis #3***, Photovoltaic Glass Units will still maintain the façade's architectural integrity while providing more privacy for the patients. It was determined that this façade was not in the ideal location to take advantage of the PV units. Despite the units saving around $3,310.48/ year, the system itself would cost around $756,000 including incentives. The average life span of a system like this would be around 25 years, but the hospital could never recoup the cost to buy and install this system within the lifespan timeframe. Thus it is not recommended that these Photovoltaic Glass Units be implemented into the façade.

Based upon the information presented in ***Analysis #4***, the use of prefabricated MEP systems can reduce the installation time by 65% percent and has the potential to significantly reduce the overall construction schedule. This method can also help the owner save around 44% in his cost for the above ceiling MEP. This percentage translates to around $1,741,623.61. This percentage does not reflect the overall cost savings for individual Electrical, Plumbing, or Mechanical work packages. However, it is recommended that this method be used for the prescribed work, along with other construction applications. This method can also prove to be advantageous in prefabricated modular patient rooms where the owner can expect to see an increased cost savings amount.

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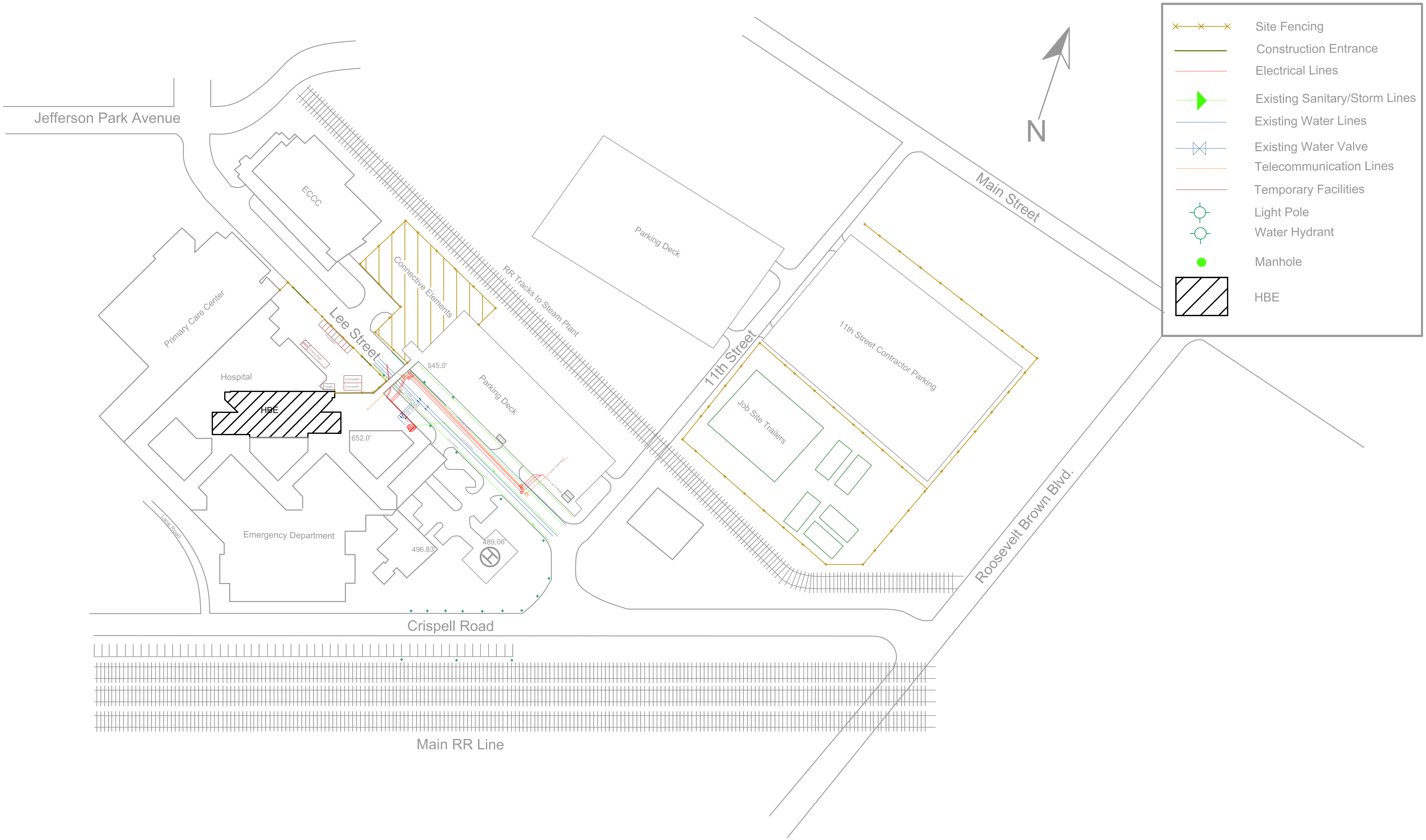
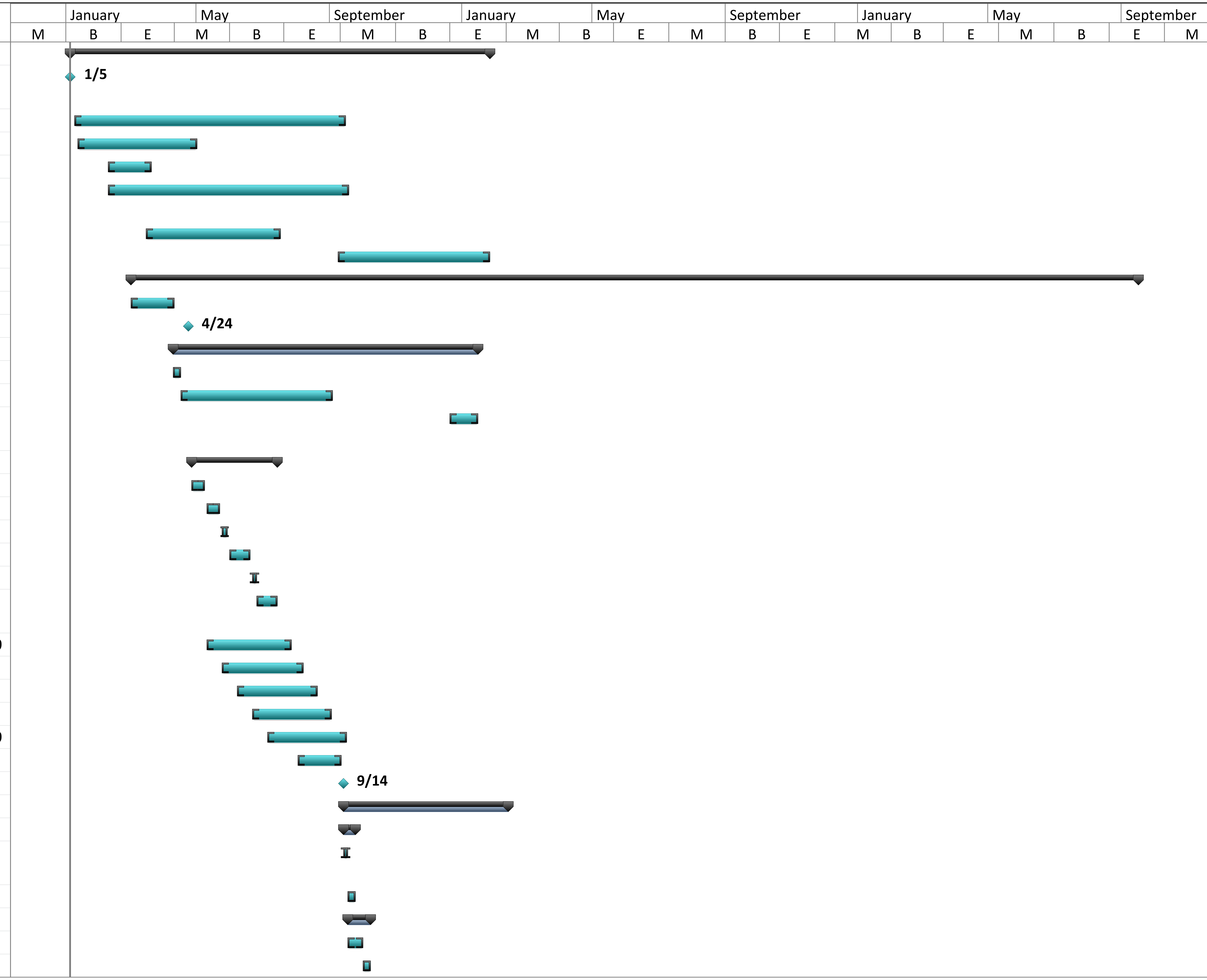
APPENDIX A – SITE LAYOUT PLAN



Jefferson Park Avenue
ECCC
Primary Care Center
Hospital
HBE
Lee Street
Connective Elements
RR Tracks to Steam Plant
Parking Deck
545.0'
652.0'
Emergency Department
496.83'
489.06'
Lane Road
Crispell Road
Main RR Line
Parking Deck
11th Street
Job Site Trailers
11th Street Contractor Parking
Main Street
Roosevelt Brown Blvd.
N
Site Fencing
Construction Entrance
Electrical Lines
Existing Sanitary/Storm Lines
Existing Water Lines
Existing Water Valve
Telecommunication Lines
Temporary Facilities
Light Pole
Water Hydrant
Manhole
HBE

APPENDIX B – CONSTRUCTION SCHEDULE

ID	Task Name	Duration	Start	Finish
1	**Procurement**	**277 days**	**Mon 1/5/09**	**Tue 1/26/10**
2	Structural Steel and Curtain Wall Purchased	0 days	Mon 1/5/09	Mon 1/5/09
3	Prepare Structural Steel Shop	178 days	Fri 1/9/09	Tue 9/15/09
4	Prepare CW Shops/Embed	80 days	Mon 1/12/09	Fri 5/1/09
5	Fabricate Trusses/Beams	30 days	Mon 2/9/09	Fri 3/20/09
6	Fabricate Deck/Misc. Structural Members	160 days	Mon 2/9/09	Fri 9/18/09
7	Approve Structural Steel Shop	90 days	Mon 3/16/09	Fri 7/17/09
8	Fabricate Curtain Wall System	100 days	Wed 9/9/09	Tue 1/26/10
9	**New Construction**	**665 days**	**Mon 3/2/09**	**Fri 9/16/11**
10	Job Set Up	30 days	Mon 3/2/09	Fri 4/10/09
11	Owner Move-Out	0 days	Fri 4/24/09	Fri 4/24/09
12	**Penthouse**	**201 days**	**Fri 4/10/09**	**Fri 1/15/10**
13	Set Equipment Pad	5 days	Fri 4/10/09	Thu 4/16/09
14	Interior Penthouse MEP	100 days	Fri 4/17/09	Thu 9/3/09
15	Install & Connect AHU-1, AHU-2	20 days	Mon 12/21/09	Fri 1/15/10
16	**8th Floor (Typical)**	**57 days**	**Mon 4/27/09**	**Tue 7/14/09**
17	Construct Dust Partition	10 days	Mon 4/27/09	Fri 5/8/09
18	Demo MEP/Cut N Cap	10 days	Mon 5/11/09	Fri 5/22/09
19	Demo Existing Exterior	5 days	Mon 5/25/09	Fri 5/29/09
20	Demo Existing Int.	15 days	Mon 6/1/09	Fri 6/19/09
21	Install Temp Electric	4 days	Mon 6/22/09	Thu 6/25/09
22	Install Structural Steel Reinforcing	13 days	Fri 6/26/09	Tue 7/14/09
23	**7th Floor (Typical)**	**56 days**	**Mon 5/11/09**	**Mon 7/27/09**
24	**6th Floor (Typical)**	**55 days**	**Mon 5/25/09**	**Fri 8/7/09**
25	**5th Floor (Typical)**	**54 days**	**Mon 6/8/09**	**Thu 8/20/09**
26	**4th Floor (Typical)**	**53 days**	**Mon 6/22/09**	**Wed 9/2/09**
27	**3rd Floor (Typical)**	**53 days**	**Mon 7/6/09**	**Wed 9/16/09**
28	Prepare Building Pad	30 days	Mon 8/3/09	Fri 9/11/09
29	Steel Hits Site	0 days	Mon 9/14/09	Mon 9/14/09
30	**Structure**	**110 days**	**Mon 9/14/09**	**Fri 2/12/10**
31	**2M Floor**	**9 days**	**Mon 9/14/09**	**Thu 9/24/09**
32	Install Stub Columns and Decking	4 days	Mon 9/14/09	Thu 9/17/09
33	Pour Deck 2M	5 days	Fri 9/18/09	Thu 9/24/09
34	**3rd Floor**	**15 days**	**Fri 9/18/09**	**Thu 10/8/09**
35	Steel Structure and Deck	10 days	Fri 9/18/09	Thu 10/1/09
36	Pour Deck	5 days	Fri 10/2/09	Thu 10/8/09



Project: Updated Schedule
Date: Fri 12/9/11

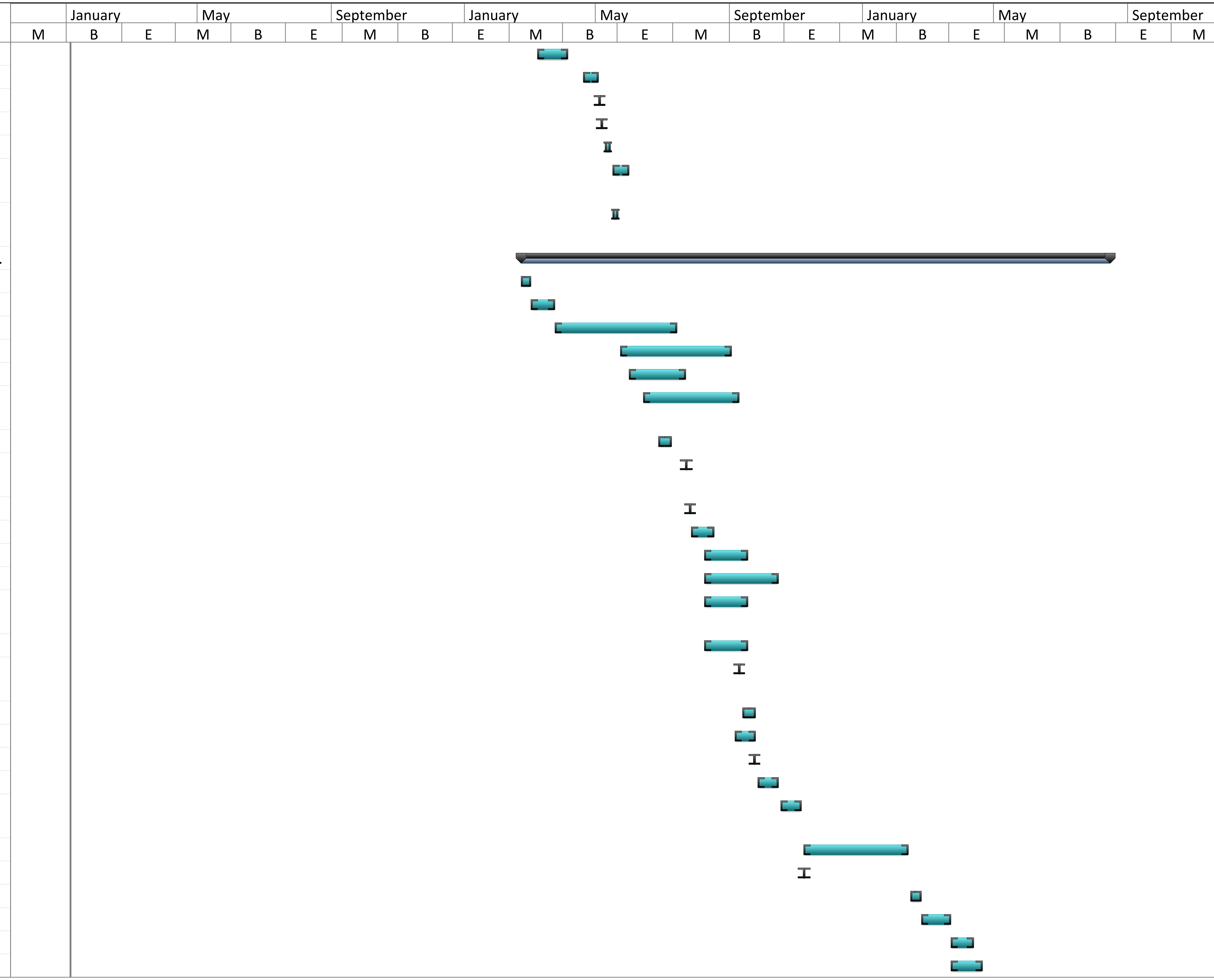
Task	Project Summary	Inactive Milestone	Manual Summary Rollup
Split	External Tasks	Inactive Summary	Manual Summary
Milestone	External Milestone	Manual Task	Start-only
Summary	Inactive Task	Duration-only	Finish-only
Deadline	Progress		

ID	Task Name	Duration	Start	Finish
37	**4th Floor (Typical)**	**17 days**	**Fri 10/2/09**	**Mon 10/26/09**
38	Steel Structure and Deck	10 days	Fri 10/2/09	Thu 10/15/09
39	Pour Deck	7 days	Fri 10/16/09	Mon 10/26/09
40	**5th Floor (Typical)**	**17 days**	**Fri 10/16/09**	**Mon 11/9/09**
41	**6th Floor (Typical)**	**16 days**	**Fri 10/30/09**	**Fri 11/20/09**
42	**7th Floor (Typical)**	**16 days**	**Thu 11/12/09**	**Thu 12/3/09**
43	Spray Fireproof	60 days	Mon 11/23/09	Fri 2/12/10
44	**8th Floor (Typical)**	**17 days**	**Wed 11/25/09**	**Thu 12/17/09**
45	**Penthouse (Typical)**	**10 days**	**Mon 12/7/09**	**Fri 12/18/09**
46	Install MEP Risers	30 days	Thu 12/17/09	Wed 1/27/10
47	**High Roof**	**28 days**	**Mon 12/14/09**	**Wed 1/20/10**
48	Steel Structure and Deck	23 days	Mon 12/14/09	Wed 1/13/10
49	Penthouse Roof Curbs	5 days	Thu 1/14/10	Wed 1/20/10
50	**Low Roof**	**13 days**	**Wed 1/13/10**	**Fri 1/29/10**
51	Steel Structure and Deck	8 days	Wed 1/13/10	Fri 1/22/10
52	Pour Deck	5 days	Mon 1/25/10	Fri 1/29/10
53	Top Out	0 days	Fri 1/22/10	Fri 1/22/10
54	**Façade**	**331 days**	**Mon 1/25/10**	**Mon 5/2/11**
55	Installation of Hoist	1 day	Mon 1/25/10	Mon 1/25/10
56	Curtain Wall Construction Front	57 days	Tue 1/26/10	Wed 4/14/10
57	Penthouse Façade	20 days	Thu 4/15/10	Wed 5/12/10
58	Install Metal Panels East corners	10 days	Mon 4/26/10	Fri 5/7/10
59	Install metals Panels West Corners	10 days	Mon 5/3/10	Fri 5/14/10
60	Removal of Hoist	1 day	Mon 4/11/11	Mon 4/11/11
61	Complete East/West Curtainwall	15 days	Tue 4/12/11	Mon 5/2/11
62	**Roof**	**30 days**	**Tue 1/26/10**	**Mon 3/8/10**
63	Roofing	30 days	Tue 1/26/10	Mon 3/8/10
64	**New Interior**	**510 days**	**Mon 10/5/09**	**Fri 9/16/11**
65	**2M Floor**	**171 days**	**Mon 10/5/09**	**Mon 5/31/10**
66	Layout for New Interior	1 day	Fri 10/9/09	Fri 10/9/09
67	Above Ceiling Mech R/I	50 days	Mon 10/12/09	Fri 12/18/09
68	Above Ceiling Elec R/I	70 days	Mon 10/12/09	Fri 1/15/10
69	Above Ceiling Plumbing R/I	17 days	Mon 10/12/09	Tue 11/3/09
70	FRP Equipment Pads	7 days	Mon 10/5/09	Tue 10/13/09
71	Set Switchgear	6 days	Mon 10/26/09	Sat 10/31/09
72	Ext. Framing for New Int.	12 days	Mon 12/14/09	Tue 12/29/09

Project: Updated Schedule
Date: Fri 12/9/11

Task	Project Summary	Inactive Milestone	Manual Summary Rollup	Deadline
Split	External Tasks	Inactive Summary	Manual Summary	Progress
Milestone	External Milestone	Manual Task	Start-only	
Summary	Inactive Task	Duration-only	Finish-only	

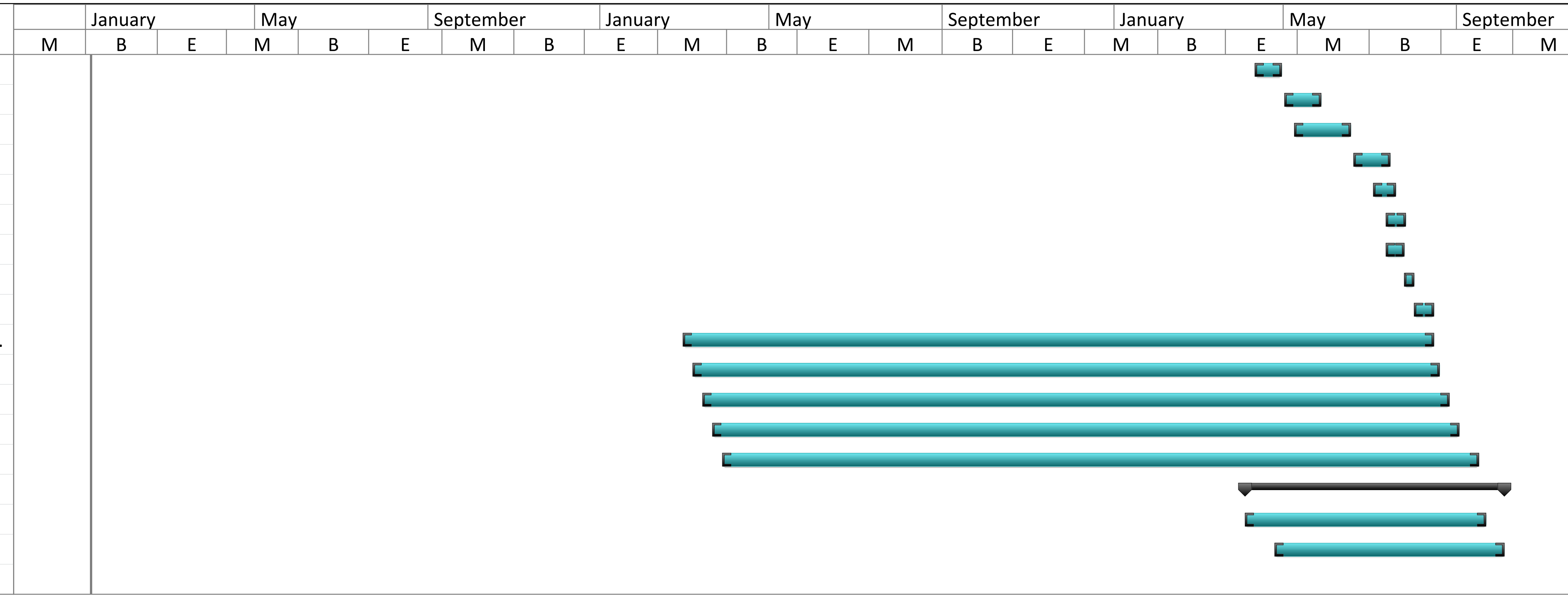
ID	Task Name	Duration	Start	Finish
73	In-Wall Elec R/I	20 days	Tue 3/9/10	Mon 4/5/10
74	Frame Drywall Partition	10 days	Tue 4/20/10	Mon 5/3/10
75	Framing Inspection	2 days	Tue 5/4/10	Wed 5/5/10
76	Close In- Inspection	2 days	Thu 5/6/10	Fri 5/7/10
77	Hang Sheet Rock	5 days	Mon 5/10/10	Fri 5/14/10
78	Frame/Hang Drywall Ceilings	11 days	Mon 5/17/10	Mon 5/31/10
79	Float, Tape & Finish Sheet Rock	5 days	Mon 5/17/10	Fri 5/21/10
80	**8th Floor (Typical)**	**386 days**	**Mon 2/22/10**	**Mon 8/15/11**
81	Layout for New Interior	7 days	Mon 2/22/10	Tue 3/2/10
82	Electric Feeders	16 days	Wed 3/3/10	Wed 3/24/10
83	Above Ceiling Elec R/I	80 days	Thu 3/25/10	Wed 7/14/10
84	Above Ceiling Mech R/I	74 days	Mon 5/24/10	Thu 9/2/10
85	Frame Drywall Partition	38 days	Tue 6/1/10	Thu 7/22/10
86	Above Ceiling Plumbing R/I	64 days	Mon 6/14/10	Thu 9/9/10
87	Install Pneumatic Tube	10 days	Mon 6/28/10	Fri 7/9/10
88	Install Hollow metal Door Frames	1 day	Fri 7/23/10	Fri 7/23/10
89	Framing Inspection	2 days	Mon 7/26/10	Tue 7/27/10
90	Frame Drywall Ceilings	15 days	Wed 7/28/10	Tue 8/17/10
91	In-Wall Mech R/I	30 days	Mon 8/9/10	Fri 9/17/10
92	In-Wall Elec R/I	50 days	Mon 8/9/10	Fri 10/15/10
93	In-Wall Plumbing & Med Gas R/I	30 days	Mon 8/9/10	Fri 9/17/10
94	Overhead M&P Insulation	30 days	Mon 8/9/10	Fri 9/17/10
95	Above Ceiling Inspection	2 days	Thu 9/9/10	Fri 9/10/10
96	Hang Drywall Ceilings	10 days	Mon 9/13/10	Fri 9/24/10
97	In-Wall M&P Insulation	15 days	Mon 9/6/10	Fri 9/24/10
98	Close In- Inspection	2 days	Thu 9/23/10	Fri 9/24/10
99	Hang Drywall	15 days	Mon 9/27/10	Fri 10/15/10
100	Float, Tape & Finish Sheet Rock	15 days	Mon 10/18/10	Fri 11/5/10
101	Elevators	70 days	Mon 11/8/10	Fri 2/11/11
102	Install Med Gas Manifold	1 day	Mon 11/8/10	Mon 11/8/10
103	Prime & First Coat Paint	8 days	Mon 2/14/11	Wed 2/23/11
104	Devices & Plates	19 days	Thu 2/24/11	Tue 3/22/11
105	Registers/Grilles/Diffusers	15 days	Wed 3/23/11	Tue 4/12/11
106	Light Fixtures	21 days	Wed 3/23/11	Wed 4/20/11



Project: Updated Schedule
Date: Fri 12/9/11

Task	Project Summary	Inactive Milestone	Manual Summary Rollup	Deadline
Split	External Tasks	Inactive Summary	Manual Summary	Progress
Milestone	External Milestone	Manual Task	Start-only	
Summary	Inactive Task	Duration-only	Finish-only	

ID	Task Name	Duration	Start	Finish
107	Ceramic Tile	15 days	Mon 4/11/11	Fri 4/29/11
108	Plumbing Fixtures	20 days	Mon 5/2/11	Fri 5/27/11
109	Casework/Countertops	30 days	Mon 5/9/11	Fri 6/17/11
110	Owner Systems	20 days	Mon 6/20/11	Fri 7/15/11
111	Install Flooring	12 days	Mon 7/4/11	Tue 7/19/11
112	Fire Alarm Devices	10 days	Wed 7/13/11	Tue 7/26/11
113	Install Doors & Hardware	9 days	Wed 7/13/11	Mon 7/25/11
114	Fire marshall Inspection	5 days	Tue 7/26/11	Mon 8/1/11
115	Punchlist	10 days	Tue 8/2/11	Mon 8/15/11
116	**7th Floor (Typical)**	**381 days**	**Mon 3/1/10**	**Mon 8/15/11**
117	**6th Floor (Typical)**	**380 days**	**Mon 3/8/10**	**Fri 8/19/11**
118	**5th Floor (Tyipcal)**	**380 days**	**Mon 3/15/10**	**Fri 8/26/11**
119	**4th Floor (Typical)**	**380 days**	**Mon 3/22/10**	**Fri 9/2/11**
120	**3rd Floor (Typical)**	**385 days**	**Mon 3/29/10**	**Fri 9/16/11**
121	**Commissioning**	**132 days**	**Mon 4/4/11**	**Tue 10/4/11**
122	Equipment Start-Up	123 days	Mon 4/4/11	Wed 9/21/11
123	Commissioning	117 days	Mon 4/25/11	Tue 10/4/11
124	**Substantial Completion**	0 days	Thu 12/1/11	Thu 12/1/11



Project: Updated Schedule
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Task	Project Summary	Inactive Milestone	Manual Summary Rollup	Deadline
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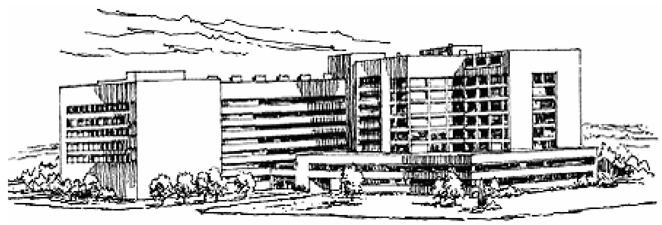
APPENDIX C – R.S. MEANS SQUARE FOOT ESTIMATE

Square Foot Cost Estimate Report

Estimate Name:	**HBE 2**
Building Type:	**Hospital, 4-8 Story with Precast Concrete Panels With Exposed Aggregate / Steel Frame**
Location:	CHARLOTTESVILLE, VA
Stories Count (L.F.):	**6.00**
Stories Height	**14.00**
Floor Area (S.F.):	**130,000.00**
LaborType	**Open Shop**
Basement Included:	No
Data Release:	**Year 2008 Quarter 3**
Cost Per Square Foot	**$181.82**
Total Building Cost	**$23,637,500**



Costs are derived from a building model with basic components. Scope differences and market conditions can cause costs to vary significantly

		% of Total	Cost Per SF	Cost
A Substructure		**2.3%**	**3.65**	**$475,000**
A1010	**Standard Foundations**		**2.30**	**$299,500**
	Strip footing, concrete, reinforced, load 44.0 KLF, soil bearing capacity 6 KSF, 24" deep x 96" wide			
	Spread footings, 3000 PSI concrete, load 400K, soil bearing capacity 6 KSF, 8' - 6" square x 27" deep			
	Spread footings, 3000 PSI concrete, load 500K, soil bearing capacity 6 KSF, 9' - 6" square x 30" deep			
	Spread footings, 3000 PSI concrete, load 600K, soil bearing capacity 3 KSF, 16' - 0" square x 35" deep			
	Spread footings, 3000 PSI concrete, load 600K, soil bearing capacity 6 KSF, 10' - 6" square x 33" deep			
	Spread footings, 3000 PSI concrete, load 800K, soil bearing capacity 3 KSF, 18' - 0" square x 39" deep			
A1030	**Slab on Grade**		**1.02**	**$133,000**
	Slab on grade, 6" thick, light industrial, reinforced			
A2010	**Basement Excavation**		**0.02**	**$2,000**
	Excavate and fill, 30,000 SF, 4' deep, sand, gravel, or common earth, on site storage			
A2020	**Basement Walls**		**0.31**	**$40,500**
	Foundation wall, CIP, 4' wall height, direct chute, .148 CY/LF, 7.2 PLF, 12" thick			
B Shell		**22.8%**	**35.92**	**$4,669,500**
B1010	**Floor Construction**		**15.14**	**$1,968,000**
	Steel column, W10, 200 KIPS, 10' unsupported height, 45 PLF			
	Floor, composite metal deck, shear connectors, 5.5" slab, 30'x30' bay, 26.5" total depth, 75 PSF superimposed load,			
	Fireproofing, gypsum board, fire rated, 2 layer, 1" thick, 10" steel column, 3 hour rating, 17 PLF			
B1020	**Roof Construction**		**1.32**	**$171,000**
	Floor, steel joists, beams, 1.5" 22 ga metal deck, on columns, 30'x30' bay, 28" deep, 40 PSF superimposed load, 62			
B2010	**Exterior Walls**		**12.34**	**$1,604,000**
	Exterior wall, precast concrete, flat, 8" thick, 10' x 10', white face, 2" rigid insulation, low rise			
B2020	**Exterior Windows**		**5.38**	**$700,000**
	Windows, aluminum, sliding, insulated glass, 5' x 3'			
B2030	**Exterior Doors**		**0.65**	**$84,000**
	Door, aluminum & glass, with transom, full vision, double door, hardware, 6'-0" x 10'-0" opening			
	Door, aluminum & glass, with transom, non-standard, double door, hardware, 6'-0" x 10'-0" opening			

		% of Total	Cost Per SF	Cost
	Door, steel 18 gauge, hollow metal, 1 door with frame, no label, 3'-0" x 7'-0" opening			
B3010	**Roof Coverings**		**1.07**	**$139,000**
	Roofing, single ply membrane, reinforced, PVC, 48 mils, fully adhered, adhesive			
	Insulation, rigid, roof deck, composite with 2" EPS, 1" perlite			
	Roof edges, aluminum, duranodic, .050" thick, 6" face			
	Flashing, copper, no backing, 16 oz, < 500 lbs			
B3020	**Roof Openings**		**0.03**	**$3,500**
	Roof hatch, with curb, 1" fiberglass insulation, 2'-6" x 3'-0", galvanized steel, 165 lbs			
C Interiors		**21.0%**	**33.00**	**$4,290,000**
C1010	**Partitions**		**5.32**	**$692,000**
	Metal partition, 5/8" vinyl faced gypsum board face, 5/8"fire rated gypsum board base, 3-5/8" @ 24",s ame opposite			
	Gypsum board, 1 face only, 5/8" with 1/16" lead			
C1020	**Interior Doors**		**8.79**	**$1,142,500**
	Door, single leaf, kd steel frame, hollow metal, commercial quality, flush, 3'-0" x 7'-0" x 1-3/8"			
	Door, single leaf, kd steel frame, metal fire, commercial quality, 3'-0" x 7'-0" x 1-3/8"			
C1030	**Fittings**		**0.85**	**$111,000**
	Partitions, hospital curtain, ceiling hung, poly oxford cloth			
C2010	**Stair Construction**		**1.18**	**$154,000**
	Stairs, steel, cement filled metal pan & picket rail, 12 risers, with landing			
C3010	**Wall Finishes**		**4.98**	**$648,000**
	Glazed coating			
	Painting, interior on plaster and drywall, walls & ceilings, roller work, primer & 2 coats			
	Vinyl wall covering, fabric back, medium weight			
	Ceramic tile, thin set, 4-1/4" x 4-1/4"			
C3020	**Floor Finishes**		**7.16**	**$931,000**
	Composition flooring, epoxy terrazzo, maximum			
	Terrazzo, maximum			
	Vinyl, composition tile, maximum			
	Tile, ceramic natural clay			
C3030	**Ceiling Finishes**		**4.70**	**$611,500**
	Plaster ceilings, 3 coat prl, 3.4# metal lath, 3/4" crc, 12"OC furring, 1-1/2" crc, 36" OC support			
	Acoustic ceilings, 3/4"mineral fiber, 12" x 12" tile, concealed 2" bar & channel grid, suspended support			
D Services		**44.7%**	**70.26**	**$9,134,000**
D1010	**Elevators and Lifts**		**5.58**	**$725,000**
	Traction, geared hospital, 6000 lb, 6 floors, 12' story height, 2 car group, 200 FPM			
D2010	**Plumbing Fixtures**		**5.35**	**$695,500**
	Water closet, vitreous china, bowl only with flush valve, wall hung			
	Urinal, vitreous china, stall type			
	Lavatory w/trim, wall hung, PE on CI, 19" x 17"			
	Kitchen sink w/trim, raised deck, PE on CI, 42" x 21" dual level, triple bowl			
	Laundry sink w/trim, PE on CI, black iron frame, 48" x 21" double compartment			
	Service sink w/trim, PE on CI, corner floor, wall hung w/rim guard, 22" x 18"			
	Bathtub, recessed, PE on CI, mat bottom, 5'-6" long			
	Shower, stall, baked enamel, terrazzo receptor, 36" square			
	Water cooler, electric, wall hung, wheelchair type, 7.5 GPH			
D2020	**Domestic Water Distribution**		**7.23**	**$940,500**
	Electric water heater, commercial, 100< F rise, 1000 gal, 480 KW 1970 GPH			
D2040	**Rain Water Drainage**		**0.63**	**$82,500**
	Roof drain, CI, soil,single hub, 5" diam, 10' high			
	Roof drain, CI, soil,single hub, 5" diam, for each additional foot add			

		% of Total	Cost Per SF	Cost
D3010	**Energy Supply**		**2.51**	**$326,000**
	Hot water reheat system for 200,000 SF hospital			
D3020	**Heat Generating Systems**		**0.32**	**$42,000**
	Boiler, electric, steel, steam, 510 KW, 1,740 MBH			
D3030	**Cooling Generating Systems**		**2.44**	**$317,500**
	Chiller, reciprocating, water cooled, standard controls, 100 ton			
	Chiller, reciprocating, water cooled, standard controls, 150 ton			
	Chiller, reciprocating, water cooled, standard controls, 200 ton			
D3090	**Other HVAC Systems/Equip**		**21.03**	**$2,734,000**
	Ductwork for 200,000 SF hospital model			
	Boiler, cast iron, gas, hot water, 2856 MBH			
	Boiler, cast iron, gas, hot water, 320 MBH			
	AHU, rooftop, cool/heat coils, VAV, filters, 5,000 CFM			
	AHU, rooftop, cool/heat coils, VAV, filters, 10,000 CFM			
	AHU, rooftop, cool/heat coils, VAV, filters, 20,000 CFM			
	VAV terminal, cooling, hot water reheat, with actuator / controls, 200 CFM			
	AHU, rooftop, cool/heat coils, VAV, filters, 30,000 CFM			
	Roof vent. system, power, centrifugal, aluminum, galvanized curb, back draft damper, 1500 CFM			
	Roof vent. system, power, centrifugal, aluminum, galvanized curb, back draft damper, 2750 CFM			
	Commercial kitchen exhaust/make-up air system, rooftop, gas, 5000 CFM			
	Plate heat exchanger, 400 GPM			
D4010	**Sprinklers**		**1.53**	**$198,500**
	Wet pipe sprinkler systems, steel, light hazard, 1 floor, 10,000 SF			
	Wet pipe sprinkler systems, steel, light hazard, each additional floor, 10,000 SF			
D4020	**Standpipes**		**0.53**	**$68,500**
	Wet standpipe risers, class III, steel, black, sch 40, 4" diam pipe, 1 floor			
	Wet standpipe risers, class III, steel, black, sch 40, 4" diam pipe, additional floors			
	Cabs, hose rack assembly, & extinguisher, 2-1/2" x 1-1/2" valve & hose, steel door & frame			
	Alarm, electric pressure switch (circuit closer)			
	Escutcheon plate, for angle valves, polished brass, 2-1/2"			
	Fire pump, electric, with controller, 5" pump, 100 HP, 1000 GPM			
	Fire pump, electric, for jockey pump system, add			
	Siamese, with plugs & chains, polished brass, sidewalk, 4" x 2-1/2" x 2-1/2"			
	Valves, angle, wheel handle, 300 lb, 2-1/2"			
	Cabinet assembly, includes. adapter, rack, hose, and nozzle			
D5010	**Electrical Service/Distribution**		**5.26**	**$684,000**
	Service installation, includes breakers, metering, 20' conduit & wire, 3 phase, 4 wire, 120/208 V, 2000 A			
	Feeder installation 600 V, including RGS conduit and XHHW wire, 2000 A			
	Switchgear installation, incl switchboard, panels & circuit breaker, 2000 A			
D5020	**Lighting and Branch Wiring**		**12.77**	**$1,659,500**
	Receptacles incl plate, box, conduit, wire, 20 per 1000 SF,2.4 W per SF, with transformer			
	Wall switches, 5.0 per 1000 SF			
	Miscellaneous power, 1.2 watts			
	Central air conditioning power, 4 watts			
	Motor installation, three phase, 460 V, 15 HP motor size			
	Motor feeder systems, three phase, feed to 200 V 5 HP, 230 V 7.5 HP, 460 V 15 HP, 575 V 20 HP			
	Fluorescent fixtures recess mounted in ceiling, 1 watt per SF, 20 FC, 5 fixtures @40 watts per 1000 SF			
D5030	**Communications and Security**		**1.33**	**$172,500**
	Communication and alarm systems, includes outlets, boxes, conduit and wire, fire detection systems, 100 detectors			
	Internet wiring, 8 data/voice outlets per 1000 S.F.			

		% of Total	Cost Per SF	Cost
D5090	**Other Electrical Systems**		**3.75**	**$488,000**
	Generator sets, w/battery, charger, muffler and transfer switch, diesel engine with fuel tank, 100 kW			
	Generator sets, w/battery, charger, muffler and transfer switch, diesel engine with fuel tank, 400 kW			
	Uninterruptible power supply with standard battery pack, 15 kVA/12.75 kW			
E Equipment & Furnishings		**9.2%**	**14.54**	**$1,890,000**
E1020	**Institutional Equipment**		**10.51**	**$1,366,500**
	Architectural equipment, laboratory equipment glassware washer, distilled water, economy			
	Architectural equipment, sink, epoxy resin, 25" x 16" x 10"			
	Architectural equipment, laboratory equipment eye wash, hand held			
	Fume hood, complex, including fixtures and ductwork			
	Architectural equipment, medical equipment sterilizers, floor loading, double door, 28"x67"x52"			
	Architectural equipment, medical equipment, medical gas system for large hospital			
	Architectural equipment, kitchen equipment, commercial dish washer, semiautomatic, 50 racks/hr			
	Architectural equipment, kitchen equipment, food warmer, counter, 1.65 KW			
	Architectural equipment, kitchen equipment, kettles, steam jacketed, 20 gallons			
	Architectural equipment, kitchen equipment, range, restaurant type, burners, 2 ovens & 24" griddle			
	Architectural equipment, kitchen equipment, range hood, including CO2 system, economy			
	Special construction, refrigerators, prefabricated, walk-in, 7'-6" high, 6' x 6'			
	Architectural equipment, darkroom equipment combination, tray & tank sinks, washers & dry tables			
E1090	**Other Equipment**		**0.00**	**$0**
E2020	**Moveable Furnishings**		**4.03**	**$523,500**
	Furnishings, hospital furniture, patient wall system, no utilities, deluxe , per room			
F Special Construction		**0.0%**	**0.00**	**$0**
G Building Sitework		**0.0%**	**0.00**	**$0**
Sub Total		**100%**	**$157.37**	**$20,458,500**
Contractor's Overhead & Profit		**6.0%**	**$9.44**	**$1,227,500**
Architectural Fees		**9.0%**	**$15.01**	**$1,951,500**
User Fees		**0.0%**	**$0.00**	**$0**
Total Building Cost			**$181.82**	**$23,637,500**

APPENDIX D – GENERAL CONDITIONS ESTIMATE

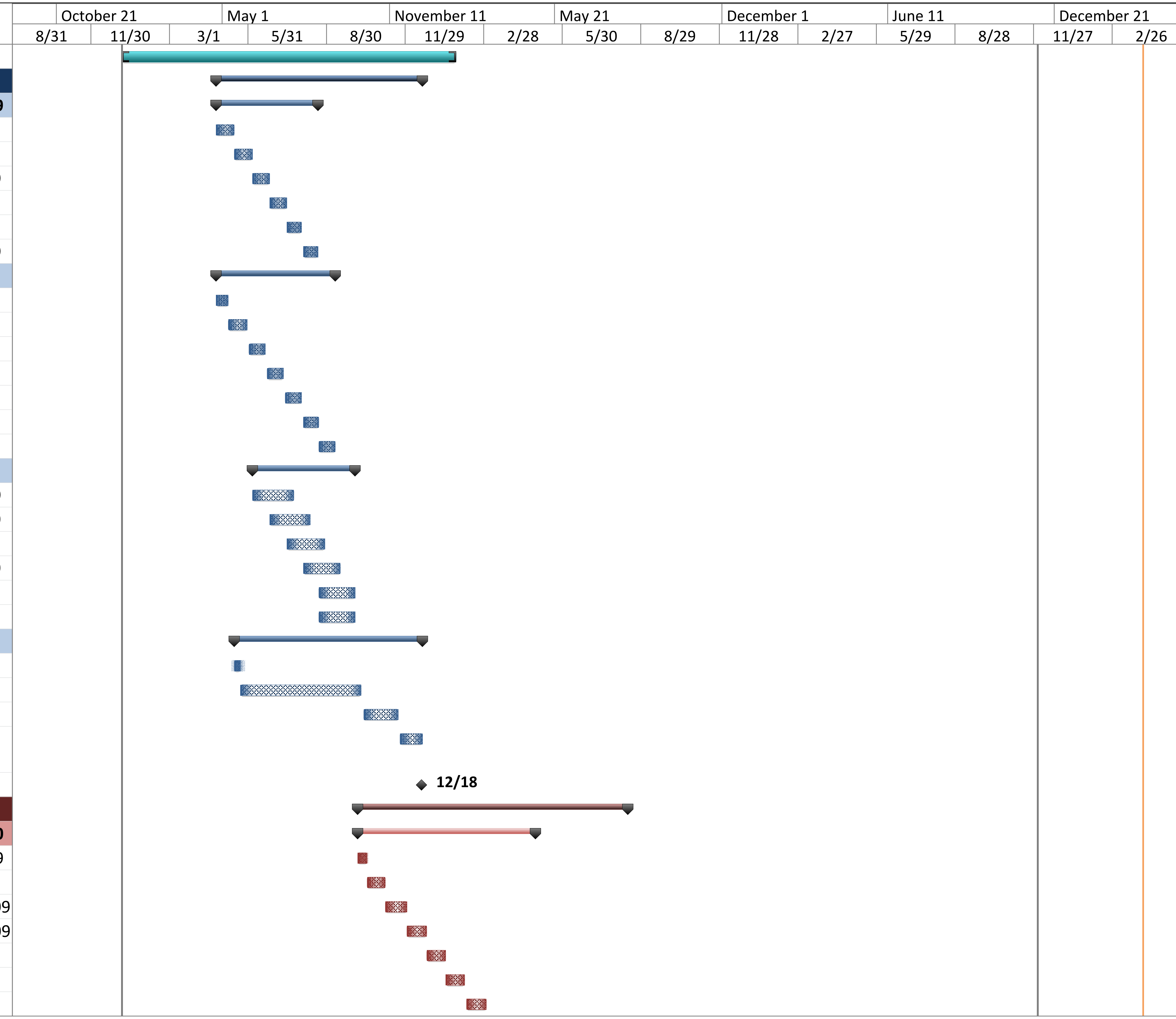
General Conditions									
Category	**Item**	Units	Quantity	Material	Labor	Equip	Total Cost	Total Inclu. O&P	Subtotal
Project Coordination									
Field Personnel	Field Engineer (Avg)	Week	129		$ 1,215.00		$ 1,215.00	$ 1,875.00	$ 241,875.00
Field Personnel	Field Engineer (Max)	Week	129		$ 1,400.00		$ 1,400.00	$ 2,150.00	$ 277,350.00
Field Personnel	Project Manager (Max)	Week	129		$ 2,275.00		$ 2,275.00	$ 3,500.00	$ 451,500.00
Field Personnel	Superintendent (Avg)	Week	129		$ 1,850.00		$ 1,850.00	$ 2,850.00	$ 367,650.00
Field Personnel	Superintendent (Max)	Week	129		$ 2,100.00		$ 2,100.00	$ 3,225.00	$ 416,025.00
Field Personnel	Timekeeper (Avg)	Week	129		$ 1,085.00		$ 1,085.00	$ 1,675.00	$ 216,075.00
Temporary Electricity									
Water Bill/month	Average	Month	28	$ 62.00			$ 62.00	$ 68.00	$ 1,904.00
Field Offices and Sheds									
Trailer	32'x8' Rented	Month	28	$ 193.00			$ 193.00	$ 213.00	$ 5,964.00
Office Equipment	Rental Average	Month	28	$ 155.00			$ 155.00	$ 171.00	$ 4,788.00
Office Supplies	Average	Month	28	$ 85.00			$ 85.00	$ 93.50	$ 2,618.00
Telephone Bill	Average	Month	28	$ 80.00			$ 80.00	$ 88.00	$ 2,464.00
Lights & HVAC		Month	28	$ 150.00			$ 150.00	$ 165.00	$ 4,620.00
Construction Equipment									
Small Tools	Maximum	Total							$ 70,000.00
Temporary Barricades									
Barricades	W/ Reflective tape	Each	30	$ 525.00			$ 525.00	$ 580.00	$ 17,400.00
Temporary Fencing									
Chain Link	11 ga, 6' high	L.F.	300	$ 3.25	$ 1.77		$ 5.02	$ 6.50	$ 1,950.00
Temporary Project Signs									
Signs	High Intensity Reflected	S.F.	150	$ 26.50			$ 26.50	$ 29.50	$ 4,425.00
Progress Cleaning									
Cleanup of floor area	Continuous per day	M.S.F.	20000	$ 1.70	$ 37.00	$ 3.75	$ 42.45	$ 67.00	$ 1,340,000.00
Final by GC	End of job	M.S.F.	39.627	$ 2.71	$ 51.50	$ 5.20	$ 59.41	$ 93.00	$ 3,685.31
								Subtotal	$ 3,430,293.31

Square Foot Project Estimate = $23,637,500									
General Commissioning									
Commissioning	O&M, Training, Minimum	Project						1.00%	$ 236,375.00
Contingency Allowances									
Contingency	Construction Phase	Project						8.00%	$ 1,891,000.00
								Total	$ 5,557,668.31

APPENDIX E – ACOUSTICAL WALL HAND CALCULATIONS

APPENDIX F – PHASED CONSTRUCTION SCHEDULE

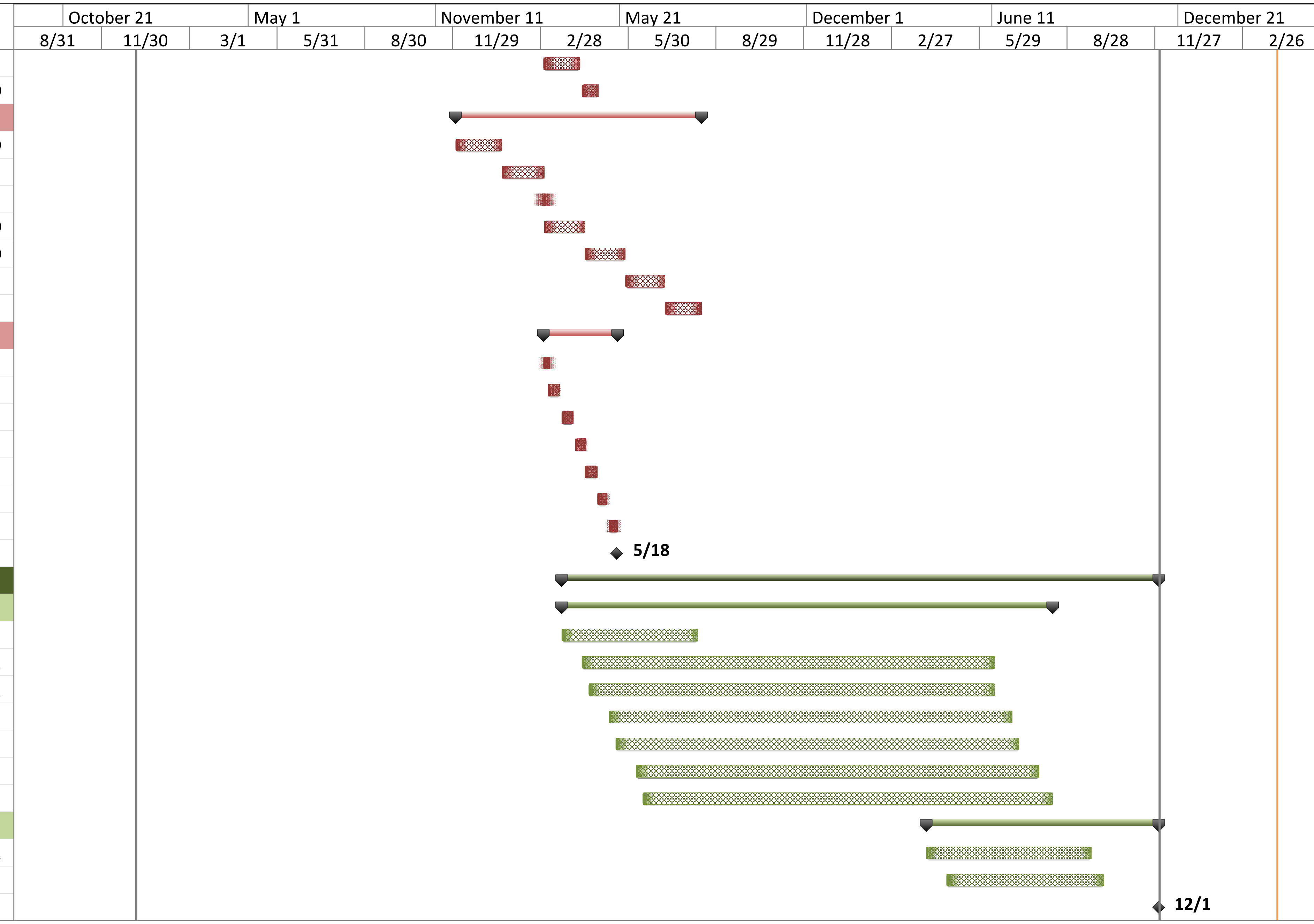
ID		Task Mode	Task Name	Duration	Start	Finish
1			Procurement	277 days	Mon 1/5/09	Tue 1/26/10
2			**PHASE I**	**171 days**	**Fri 4/24/09**	**Fri 12/18/09**
3			**Owner Move-Out**	**84 days**	**Fri 4/24/09**	**Wed 8/19/09**
4			8th Floor	15 days	Fri 4/24/09	Thu 5/14/09
5			7th Floor	15 days	Fri 5/15/09	Thu 6/4/09
6			6th Floor	14 days	Fri 6/5/09	Wed 6/24/09
7			5th Floor	14 days	Thu 6/25/09	Tue 7/14/09
8			4th Floor	13 days	Wed 7/15/09	Fri 7/31/09
9			3rd Floor	13 days	Mon 8/3/09	Wed 8/19/09
10			**Steel Strengthening**	**98 days**	**Fri 4/24/09**	**Tue 9/8/09**
11			2M	10 days	Fri 4/24/09	Thu 5/7/09
12			3rd Floor	16 days	Fri 5/8/09	Fri 5/29/09
13			4th Floor	15 days	Mon 6/1/09	Fri 6/19/09
14			5th Floor	15 days	Mon 6/22/09	Fri 7/10/09
15			6th Floor	15 days	Mon 7/13/09	Fri 7/31/09
16			7th Floor	14 days	Mon 8/3/09	Thu 8/20/09
17			8th Floor	13 days	Fri 8/21/09	Tue 9/8/09
18			**Demolition**	**85 days**	**Fri 6/5/09**	**Thu 10/1/09**
19			8th Floor	34 days	Fri 6/5/09	Wed 7/22/09
20			7th Floor	33 days	Thu 6/25/09	Mon 8/10/09
21			6th Floor	32 days	Wed 7/15/09	Thu 8/27/09
22			5th Floor	31 days	Mon 8/3/09	Mon 9/14/09
23			4th Floor	30 days	Fri 8/21/09	Thu 10/1/09
24			3rd Floor	30 days	Fri 8/21/09	Thu 10/1/09
25			**Penthouse**	**156 days**	**Fri 5/15/09**	**Fri 12/18/09**
26			Set Equipment Pad	5 days	Fri 5/15/09	Thu 5/21/09
27			Interior Penthouse MEP	100 days	Fri 5/22/09	Thu 10/8/09
28			Install MEP Risers	30 days	Mon 10/12/09	Fri 11/20/09
29			Install and Connect AHU-1, AHU-2	20 days	Mon 11/23/09	Fri 12/18/09
30			End PHASE I	0 days	Fri 12/18/09	Fri 12/18/09
31			**PHASE II**	**225 days**	**Mon 10/5/09**	**Fri 8/13/10**
32			**Superstructure**	**148 days**	**Mon 10/5/09**	**Wed 4/28/10**
33			2M	9 days	Mon 10/5/09	Thu 10/15/09
34			3rd Floor	15 days	Fri 10/16/09	Thu 11/5/09
35			4th Floor	17 days	Fri 11/6/09	Mon 11/30/09
36			5th Floor	17 days	Tue 12/1/09	Wed 12/23/09
37			6th Floor	16 days	Thu 12/24/09	Thu 1/14/10
38			7th Floor	16 days	Fri 1/15/10	Fri 2/5/10
39			8th Floor	17 days	Mon 2/8/10	Tue 3/2/10



Project: Phased Schedule
Date: Mon 4/2/12

Task		Project Summary		Inactive Milestone		Manual Summary Rollup		Deadline	
Split		External Tasks		Inactive Summary		Manual Summary		Progress	
Milestone		External Milestone		Manual Task		Start-only			
Summary		Inactive Task		Duration-only		Finish-only			

ID		Task Mode	Task Name	Duration	Start	Finish
40			High Roof	28 days	Wed 3/3/10	Fri 4/9/10
41			Low Roof	13 days	Mon 4/12/10	Wed 4/28/10
42			**Above Ceiling MEP R/I**	**183 days**	**Wed 12/2/09**	**Fri 8/13/10**
43			3rd Floor	34 days	Wed 12/2/09	Mon 1/18/10
44			4th Floor	32 days	Tue 1/19/10	Wed 3/3/10
45			Installation of Hoist	1 day	Wed 3/3/10	Wed 3/3/10
46			5th Floor	30 days	Thu 3/4/10	Wed 4/14/10
47			6th Floor	30 days	Thu 4/15/10	Wed 5/26/10
48			7th Floor	29 days	Thu 5/27/10	Tue 7/6/10
49			8th Floor	28 days	Wed 7/7/10	Fri 8/13/10
50			**Façade**	**55 days**	**Wed 3/3/10**	**Tue 5/18/10**
51			2M	4 days	Wed 3/3/10	Mon 3/8/10
52			3rd Floor	10 days	Mon 3/8/10	Fri 3/19/10
53			4th Floor	10 days	Mon 3/22/10	Fri 4/2/10
54			5th Floor	9 days	Mon 4/5/10	Thu 4/15/10
55			6th Floor	9 days	Thu 4/15/10	Tue 4/27/10
56			7th Floor	8 days	Wed 4/28/10	Fri 5/7/10
57			8th Floor	7 days	Mon 5/10/10	Tue 5/18/10
58			End PHASE II	0 days	Tue 5/18/10	Tue 5/18/10
59			**PHASE III**	**443 days**	**Mon 3/22/10**	**Thu 12/1/11**
60			**Interior**	**365 days**	**Mon 3/22/10**	**Fri 8/12/11**
61			2M	101 days	Mon 3/22/10	Mon 8/9/10
62			3rd Floor	306 days	Mon 4/12/10	Mon 6/13/11
63			4th Floor	301 days	Mon 4/19/10	Mon 6/13/11
64			5th Floor	300 days	Mon 5/10/10	Fri 7/1/11
65			6th Floor	300 days	Mon 5/17/10	Fri 7/8/11
66			7th Floor	300 days	Mon 6/7/10	Fri 7/29/11
67			8th Floor	305 days	Mon 6/14/10	Fri 8/12/11
68			**Commissioning**	**173 days**	**Mon 4/4/11**	**Thu 12/1/11**
69			Equipment Start-Up	123 days	Mon 4/4/11	Wed 9/21/11
70			Commissioning	117 days	Mon 4/25/11	Tue 10/4/11
71			Substantial Completion	0 days	Thu 12/1/11	Thu 12/1/11



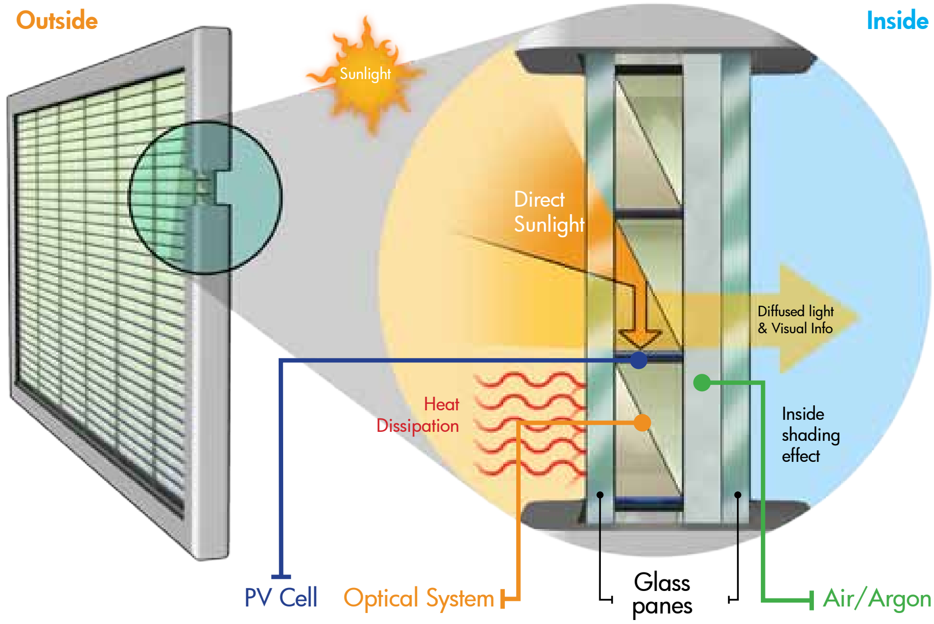
Project: Phased Schedule
Date: Mon 4/2/12

Task		Project Summary		Inactive Milestone		Manual Summary Rollup		Deadline	
Split		External Tasks		Inactive Summary		Manual Summary		Progress	
Milestone		External Milestone		Manual Task		Start-only			
Summary		Inactive Task		Duration-only		Finish-only			

APPENDIX G – PYTHAGORAS PVGU TECHNICAL SPECIFICATIONS

Photovoltaic Glass Unit (PVGU)

> TECHNICAL SPECIFICATION



Solar windows: a world of benefits

Pythagoras Solar's photovoltaic glass units (PVGUs), or more simply solar windows, are designed to replace conventional insulated glass units (IGUs) in curtain wall, window and skylight systems. It is the first product to simultaneously provide energy efficiency, solar energy generation, and optimized daylighting. This is achieved through patent-pending optics, high-efficiency crystalline silicon solar cells, advanced materials science, and proprietary software design tools.

The PVGU is designed around the form factor of a standard insulated glass unit (double paned window). A system of optics and photovoltaic cells is adhered to the inner surface of the outer glass pane (surface #2). The optical elements are designed to separate light according to the angle at which it hits the glass, concentrating all direct sunlight onto PV cells which are mounted perpendicular to the glass panes. At the same time, diffused light is transmitted through the unit and into the building. This allows the PVGU to simultaneously provide a high level of energy generation (up to 12.0% efficiency) while acting as a high-performance shading device (SHGC as low as 0.14).

PVGU:

- Transforms building facades into energy generating assets
- Seamlessly integrates into conventional curtain wall, window, and skylight systems

Key Technical Metrics

- Solar Heat Gain Coefficient (SHGC) as low as 0.14
- Module Efficiency as high as 12.0%

PVGU Windows

Questions?
contact@pythagoras-solar.com
Main number: (650) 357-9093
Toll-free: (855) 357-9093

Visit us Online:
pythagoras-solar.com

Turning Facades Into Generating Assets™

Designing PVGU Projects

Architects and building owners looking for value-added architectural glass products need to choose between BIPV glass products and various "tunable" or "smart" windows, which provide energy efficiency without power generation. Current BIPV products suffer from low power conversion efficiencies and low light transmission and inacceptable aesthetics, which have kept them from becoming a mainstream architectural product. Smart windows have long held the promise of delivering excellent insulation and optimized daylighting, but their inability to produce power reduces the economic benefit and prevents them from fully addressing the Net-Zero-Energy challenge. In contrast, the PVGU delivers an unmatched combination of energy efficiency, power generation and daylighting.

Pythagoras' PVGUs are custom made per project just as an IGU would be. The units can be made in any size required. The standard window units come with a ¼" ultra-clear outer lite and a ¼" low-e inner lite, but can be made with any glass specified (see technical specifications below).

Pythagoras Solar has teamed up with a number of leading glass manufacturers, glazing contractors, and solar integration firms to develop a seamless integration process of its products into existing building design and construction practices. We can work with a contractor who is already involved in a project or recommend one of our industry partners. A typical project requires a glazing contractor to provide the design and installation of the glazing system and a solar contractor to design and integrate the electrical system including wiring and inverters.

PVGU Window

Scalable high-power photovoltaic glass unit (PVGU) delivers triple-value benefit

- Energy efficiency
- High-density solar power generation
- Optimized daylighting

PVGU Skylight

General PVGU Window Specifications

ELECTRICAL SPECIFICATIONS	
Maximum Power Density	120 Wp/m^2 (11.15 Wp/ft^2)
Module Efficiency	up to 12.0%
Tested Operating Temperature	-40°C – 85°C
Maximum System Voltage	600 V DC
Maximum Series Fuse Rating	15 amps
Power Tolerance	+/- 5%
TEMPERATURE COEFFICIENTS	
Nominal Operating Cell Temperature (NOCT)	53°C
Temperature Coefficient of P_{mpp}	-0.55%/°C
Temperature Coefficient of V_{oc}	-0.36%/°C
GLAZING SPECIFICATIONS	
Outer Glass**	6mm (1/4") ultra-clear
Inner Glass**	6mm (1/4") low-e coated
U-Value*	0.30
Solar Heat Gain Coefficient (SHGC)***	0.14 (for angles > 25° above normal) 0.41 (for angles < 25° above normal)
Visual Light Transmittance (VT)***	0.00 (for angles > 25° above normal) 0.49 (for angles < 25° above normal)
UV Transmittance (UVT)***	0.00 (for angles > 25° above normal) 0.28 (for angles < 25° above normal)
MECHANICAL CHARACTERISTICS	
Solar Cells	mono crystalline PV cells
Weight/unit area*	~41.6 kg/ m^2 (~8.5 lb/ ft^2)
Junction Box (see figure below)	Top edge mounted
Output Cables (see figure below)	Length per requirements – MC3 connectors
Unit Thickness**	28mm-36mm (1 1/8" – 1 7/16")
LOCATION	**ANNUAL ENERGY YIELD (KWH/FT² (KWH/M²))******
Atlanta	9.63 (97.99)
Chicago	9.50 (96.70)
Denver	11.97 (121.84)
Los Angeles	10.41 (105.93)
New York City	9.51 (96.77)
Phoenix	11.85 (120.61)
San Francisco	10.57 (107.61)
Seattle	8.37 (85.17)

*Determined by unit thickness and glass type
**Determined by unit dimensions and project requirements
***See Glazing Transmission Specification

****Estimates only: Based on south orientation. Will change based on project specifics and final unit design.

Questions?
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Turning Facades Into Generating Assets™

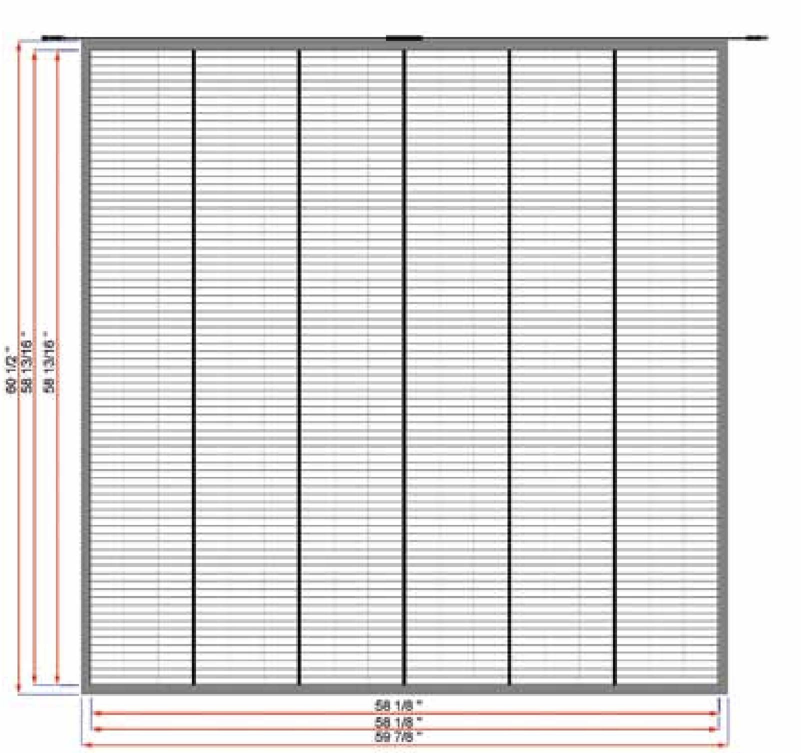
Typical PVGU Window Specification

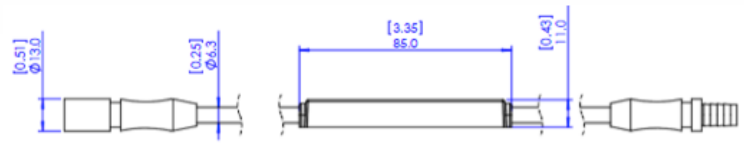
UNIT MECHANICAL SPECIFICATIONS	
Length	60" (1524mm)
Width	60" (1524mm)
Thickness	1 ¼" (32mm)
Weight	209 lbs (95 kg)

UNIT ELECTRICAL SPECIFICATIONS	
$Power_{mpp}$	252.8 W
V_{mpp}	48.4 V
V_{oc}	58.2 V
I_{mpp}	5.2 A
I_{sc}	5.6 A
Tested Operating Temperature	-40°C – 85°C
Maximum System Voltage	600 V DC
Maximum Series Fuse Rating	15 amps
Power Tolerance	+/- 5%

UNIT GLAZING SPECIFICATIONS	
Outer Glass	1/4" (6mm) ultra-clear
Inner Glass	1/4"(6mm) low-e coated
U-value*	0.30
SHGC***	0.14 (for angles > 25 above normal)
VLT***	0.49 (for angles < 25 above normal)
UVT***	0.28 (for angles < 25 above normal)
Maximum System Voltage	600 V DC
Maximum Series Fuse Rating	15 amps
Power Tolerance	+/- 5%

ELECTRICAL COEFFICIENTS	
Nominal Operating Cell Temperature (NOCT)	53°C
Temperature Coefficient of Pmpp	-0.55%/°C
Temperature Coefficient of Voc	-0.36%/°C
Temperature Coefficient of Isc	0.03%/°C

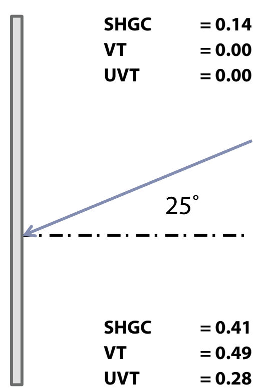




Junction Box Dimensions: mm (inches)

Glazing Transmission Specifications

The PVGU's patented optical design accepts light from a range of angles and concentrates it onto solar cells. This unique ability allows the PVGU to obtain glazing transmission metrics unlike any product on the market today. For angles where direct sunlight would be incident on the window the PVGU blocks all direct sunlight thus creating a very low solar heat gain coefficient (SHGC). At the same time diffused light is transmitted at a rate corresponding to the visible transmittance (VT) of the glass specified. It is this optimization of SHGC and VT that allows the PVGU to achieve an effective light-to-solar-gain (LSG) unmatched by any glazing product on the market today.



**Glazing metrics are a function of angle and are generalized by the above drawing for illustration purposes.*

Questions?
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Pythagoras Solar

APPENDIX H – INVERTER PRODUCT INFORMATION

Fronius **IG Plus** PV Inverter

The first complete solution. Reliable. Proven. Smart.

An outstanding addition to the family: The next generation Fronius IG Plus inverter builds on a successful model with multiple enhancements, including maximum power harvest, a built-in six circuit string combiner, integrated, lockable DC Disconnect, significantly improved efficiency, and unbeatable reliability. New, larger power stages expand the proven Fronius IG family from 2 to 12 kW in a single inverter.

Fronius

POWERING YOUR FUTURE

INPUT DATA Fronius IG Plus	3.0-1 UNI	3.8-1 UNI	5.0-1 UNI	6.0-1 UNI	7.5-1 UNI	10.0-1 UNI*	11.4-1 UNI	11.4-3 Delta	12.0-3 WYE277
Recommended PV-Power (Wp)	2500-3450	3200-4400	4250-5750	5100-6900	6350-8600	8500-11500	9700-13100	9700-13100	10200-13800
MPPT-Voltage Range	230 ... 500 V								
DC Startup Voltage	245 V								
Max. Input Voltage (at 1000 W/m^2 14°F (-10°C) in open circuit operation)	600 V								
Nominal Input Current	8.3 A	10.5 A	13.8 A	16.6 A	20.7 A	27.6 A	31.4 A	31.4 A	33.1 A
Max. usable Input Current	14.0 A	17.8 A	23.4 A	28.1 A	35.1 A	46.7 A	53.3 A	53.3 A	56.1 A
Admissible conductor size (DC)	No. 14 - 6 AWG								
Number of DC Input Terminals	6								
Max. Current per DC Input Terminal	20 A; Bus bar available for higher input currents								

OUTPUT DATA Fronius IG Plus	3.0-1 UNI	3.8-1 UNI	5.0-1 UNI	6.0-1 UNI	7.5-1 UNI	10.0-1 UNI*	11.4-1 UNI	11.4-3 Delta	12.0-3 WYE277
Nominal output power ($P_{AC\ nom}$)	3000 W	3800 W	5000 W	6000 W	7500 W	9995 W	11400 W	11400 W	12000 W
Max. continuous output power 104°F (40°C) 208 V / 240 V / 277 V	3000 W	3800 W	5000 W	6000 W	7500 W	9995 W	11400 W	11400 W	12000 W
Nominal AC output voltage	208 V / 240 V / 277 V							208 V / 240 V	277 V
Operating AC voltage range (default) 208 V	183 - 229 V (-12 / +10 %)								
240 V	211 - 264 V (-12 / +10 %)								
277 V	244 - 305 V (-12 / +10 %)								
Max. continuous output current 208 V	14.4 A	18.3 A	24.0 A	28.8 A	36.1 A	48.1 A	54.8 A	31.6 A**	n.a.
240 V	12.5 A	15.8 A	20.8 A	25.0 A	31.3 A	41.7 A	47.5 A	27.4 A**	n.a.
277 V	10.8 A	13.7 A	18.1 A	21.7 A	27.1 A	36.1 A	41.2 A	n.a.	14.4 A**
Admissible conductor size (AC)	No. 14 - 4 AWG								
Max. continuous utility back feed current	0 A								
Nominal output frequency	60 Hz								
Operating frequency range	59.3 - 60.5 Hz								
Total harmonic distortion	< 3 %								
Power factor	1								

GENERAL DATA Fronius IG Plus	3.0-1 UNI	3.8-1 UNI	5.0-1 UNI	6.0-1 UNI	7.5-1 UNI	10.0-1 UNI*	11.4-1 UNI	11.4-3 Delta	12.0-3 WYE277
Max. Efficiency	96.2 %								
CEC Efficiency 208 V	95.0 %	95.0 %	95.5 %	95.5 %	95.0 %	95.0 %	95.5 %	95.0 %	n.a.
240 V	95.5 %	95.5 %	95.5 %	96.0 %	95.5 %	95.5 %	96.0 %	95.5 %	n.a.
277 V	95.5 %	95.5 %	96.0 %	96.0 %	96.0 %	96.0 %	96.0 %	n.a.	96.0 %
Consumption in standby (night)	< 1 W								
Consumption during operation	8 W		15 W			22 W			
Cooling	Controlled forced ventilation, variable fan speed								
Enclosure Type	NEMA 3R								
Unit Dimensions (W x H x D)	17.1 x 24.8 x 9.6 in.		17.1 x 36.4 x 9.6 in.			17.1 x 48.1 x 9.6 in.			
Power Stack Weight	31 lbs. (14 kg)		57 lbs. (26 kg)			82 lbs. (37 kg)			
Wiring Compartment Weight	24 lbs. (11 kg)		26 lbs. (12 kg)			26 lbs. (12 kg)			
Admissible ambient operating temperature	-4 ... 122°F (-20 ... +50°C)								
Compliance	UL 1741-2005, IEEE 1547-2003, IEEE 1547.1, ANSI/IEEE C62.41, FCC Part 15 A& B, NEC Article 690, C22. 2 No. 107.1-01 (Sept. 2001)								

PROTECTION DEVICES Fronius IG Plus	3.0-1 UNI	3.8-1 UNI	5.0-1 UNI	6.0-1 UNI	7.5-1 UNI	10.0-1 UNI*	11.4-1 UNI	11.4-3 Delta	12.0-3 WYE277
Ground fault protection	Internal GFDI (Ground Fault Detector/Interrupter); in accordance with UL 1741-2005 and NEC Art. 690								
DC reverse polarity protection	Internal diode								
Islanding protection	Internal; in accordance with UL 1741-2005, IEEE 1547-2003 and NEC								
Over temperature	Output power derating / active cooling								

* Complies with Canadian standard C22.2 No. 107.1-01 (Sept. 2001).

** per Phase

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www.fronius-usa.com

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APPENDIX I – PVGU HAND CALCULATIONS

Appendix J – Prefabricated MEP Hand Calculations

Appendix K – Crew Types

APPENDIX L – COST FACTORS