Devin Learn

Construction Management Option

Lancaster General Hospital 5th and

6th Floor Fit-Out & Cardiac

Elevator Addition

Spring 2007

Dr. Messner

Lancaster General Hospital
Lancaster, PA

5th & 6th Floor Fit-Out
Cardiac Elevator

PRIMARY PROJECT TEAM:

Owner: Lancaster General Hospital, www.lha.com
General Contractor: Benchmark Construction Company Inc., www.benchmarkgc.com

5th and 6th Floor Fit-Out:
Architect: RTKL Associates Inc., www.rtkl.com
MEP Engineering: Barton Associates, Inc. www.ba-inc.com

Cardiac Elevator:
Architect: IKM Inc.
Structural Engineering: Atlantic Engineering Services

PROJECT FEATURES:

Total Cost - GMP $11,719,050.00
Project Delivery method: Design-Bid-Build, GC
Occupancy or Function Type: Medical/Hospital
Square Feet – 50,192
Number of Stories Above Grade - 9

CONSTRUCTION:

5th & 6th Floor: Fit-Out of existing shell space
Cardiac Elevator: Steel and cast-in-place construction of new elevated elevator shaft
Tie-in to existing corridors

STRUCTURAL:

5th & 6th Floor: Existing Steel Frame: cast-in-place slab-on-deck to remain
Cardiac Elevator: New Steel Frame: cast-in-place slab-on-deck

MECHANICAL, LIGHTING & ELECTRICAL:

3 AHU's totaling 41,060 CFM,9400 CFM O.A.
Medical Gas/Vacuum piping
Plumbing and sanitary piping
Electrical 4-480v 75KVA transformers serving 8-120/208V panels Normal Branch
3-480V 75KVA transformers serving 6-120/208V panels Critical Branch
2-480V 15KVA transformers serving 2-120/208V panels Life Safety Branch

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Construction Management

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Executive Summary

The beginning of this report is meant to provide a brief background of the Lancaster General Hospital 5th and 6th floor Fit-Out and Cardiac Elevator Addition. This section of the report includes a project overview, project team overview, project cost summary, project schedule summary, and project logistics detail. This information was compiled during the fall semester of this senior thesis course.

The depth study section of this report contains industry research on commissioning of new construction and retro-commissioning of existing building equipment. In order to complete this research a survey was developed and distributed to industry personnel. These survey results along with interviews and research from industry reports on commissioning were summarized to develop recommendations for the use of commissioning processes.

The first breadth study analyzes the proposed use of pre-cast concrete floor planks in place of the designed cast-in-place concrete on composite metal decking for the Cardiac Elevator Addition. In order to complete this analysis calculations were completed to determine the size of pre-cast concrete floor plank required to replace the cast-in-place system. Additionally cost and schedule reduction analyses were completed to determine what impact the switch in structural system had on cost and schedule. These analyses showed a $1,612.00 increase in cost and a 2 day reduction in schedule. The final part of this section contains a constructability review of the Cardiac Elevator Addition.

The second breadth study analyzes the mechanical connections used at the Infection Control Risk Assessment (ICRA) partitions. Focusing on the selection of mechanical connections that reduce rework at the partition locations saving unnecessary costs and schedule impacts.

The final section of this report contains a summary and conclusions of the work conducted in this senior thesis.

Acknowledgments

I would like to thank the following people for all of their help in the development of this senior thesis:

- Penn State Architectural Engineering Faculty
    - Dr. John Messner
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    - Chris Zamilski
    - Terri Hungarter
- Lancaster General Hospital
    - Mark Matuzak
    - John Hartman
- Building Commissioning Association and its members
- Fellow AE students

Project Introduction

Lancaster General Hospital, located at 555 North Duke Street Lancaster, PA 17604, is an existing facility serving Lancaster County and surrounding region. The 5^{th} and 6^{th} floor Lime Street infill project is the fit-out of 44,600 ft^2 of existing shell space located in the 9 story above grade Lime Street Building of the hospital. The 5^{th} floor which is 14,700 ft^2 will be fit-out into the Nero Trauma Intensive Care Unit and the 6^{th} floor consisting of 29,900 ft^2 will be fit-out into the Intensive Care Unit. The design for these two spaces was completed by RTKL Associates Inc.

The Cardiac Elevator Addition is being constructed along the outside of the Lime Street Building in order to serve the newly fit-out 5^{th} and 6^{th} floors. The design for the 1,600 ft^2 Cardiac Elevator Addition was completed by IKM Inc. Structural engineering was performed by Atlantic Engineering Services and MEP engineering was performed by Barton Associates, Inc.

The general contractor for both projects was Benchmark Construction Company, Inc., Brownstown, PA.

Project Background

A. Client Information

The owner of this project is Lancaster General Hospital, a non-profit hospital with multiple facilities throughout the Lancaster region. This project is part of their pre-planned growth, using existing shell space within the hospital. This project is one of several currently in progress within the hospital and the second shell space fit-out that Benchmark Construction Company Inc. has worked on in the last year. The first of which was a fit-out of a 30,000 ft^2 shell space on the 1^{st} floor.

Since LGH is a non-profit hospital, the cost of projects is very important to them. Once a budget for a given project is created and is approved the construction costs must not exceed that budget. This can be difficult in a very-high tech project such as this, with high quality standards and tight schedule restrictions. Quality of finishes and equipment are very important to the hospital due to the manner of work that will take place in this space once completed. They hold strict requirements on flooring finishes and wall protection due to the near constant rolling of beds and medical equipment throughout the hospital. Schedules are fast paced and face stoppages due to emergency situations that may arise at the hospital as well as by the helicopters landing on the landing pad located on the roof adjacent to the shell space and cardiac elevator sites. These are coordinated via radio with hospital staff and Lancaster County Communications. However on-time completion of work is still expected and penalties can be

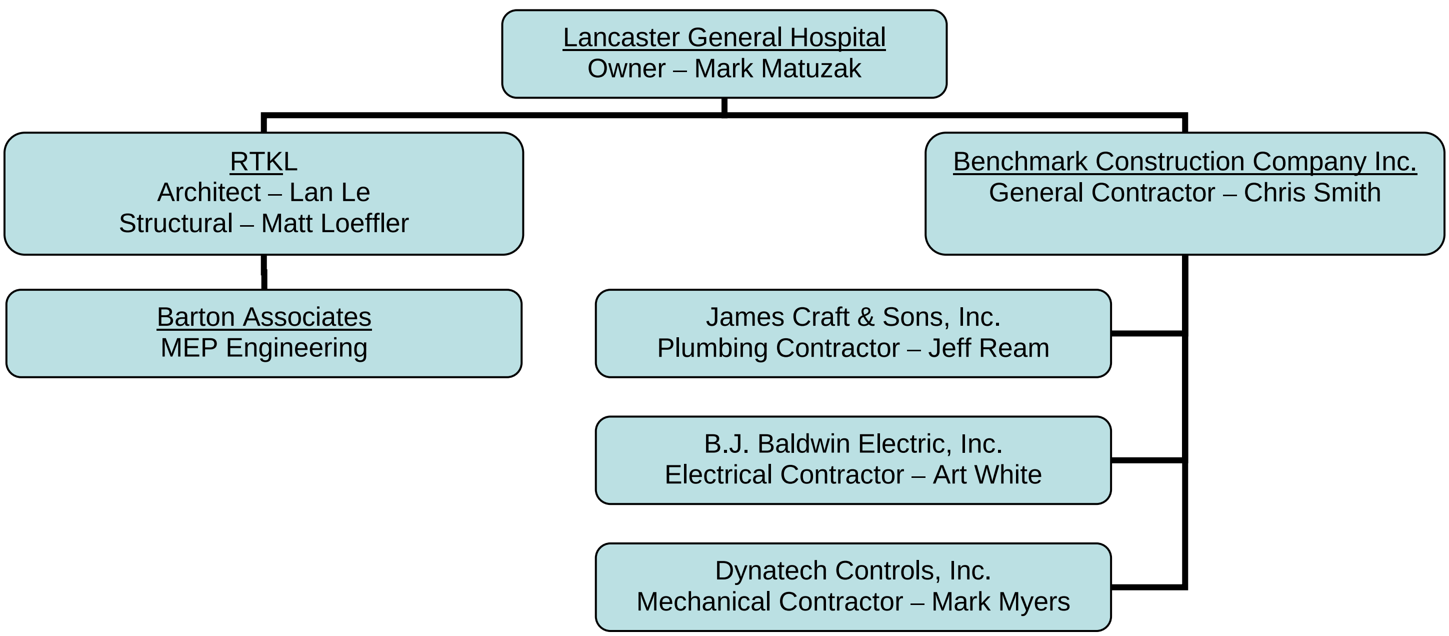
applied for late finishes as per the contract. Safety expectations are extremely high when working in the hospital. Safety concerns not only apply to the construction workers on site but also to the patients and staff that are often in close proximity to construction sites. These safety requirements are monitored by hospital safety staff as well has Department of Health safety inspections. Some requirements include Infection Control Risk Assessment (ICRA) partitions creating a barrier between construction space and occupied space. As well as creating negative pressure in construction spaces so that no dust or possible air born contaminants are pushed out into the occupied spaces. This is done by using negative air machines inside the construction space equipped with hepa filters that draw air from the space and force it outside.

This project is being completed inside an occupied, active hospital leading to the fact that there are dual occupancy requirements throughout the entire project. This is further complicated by the fact that there are occupied patient rooms directly below the 5th floor making through slab electrical and mechanical tie-ins even more complicated. Having this dual occupancy leads to restrictions of noise and vibration that would disturb patients or doctors and the sensitive equipment that they use. The hospital also restricts construction personnel traffic from entering the occupied corridors whenever possible. It is the hospitals wishes to make it appear that there is no construction going on at the hospital whenever possible.

The keys to completing this project to the owner's satisfaction go along with their expectations discussed in the previous paragraph. They expect the highest quality facility that can be created in a short period of time within the given budget. This is a common expectation of most owners' but is complicated by high-technology requirements. There are outside agencies that are involved in the construction process of healthcare facilities and they must also be satisfied in order for this project to be considered a success.

B. Project Delivery System

This project is being delivered through a design-bid-build method, utilizing a general contractor that works with the internal project managers from the hospital. This approach is used due to the experience of the owner in construction and the budget, schedule and quality constraints. Benchmark Construction Company Inc. was the only GC to bid the job due to their longtime experience and relationship with the owner; however it was competitively bid to subcontract/vendor marketplace.



The architect was hired by the owner for design and engineering services and held a contract directly with the owner. The architect utilized an in house engineer to complete the small amount of structural design for the project; however they subcontracted out the design of the MEP systems to Barton Associates. The

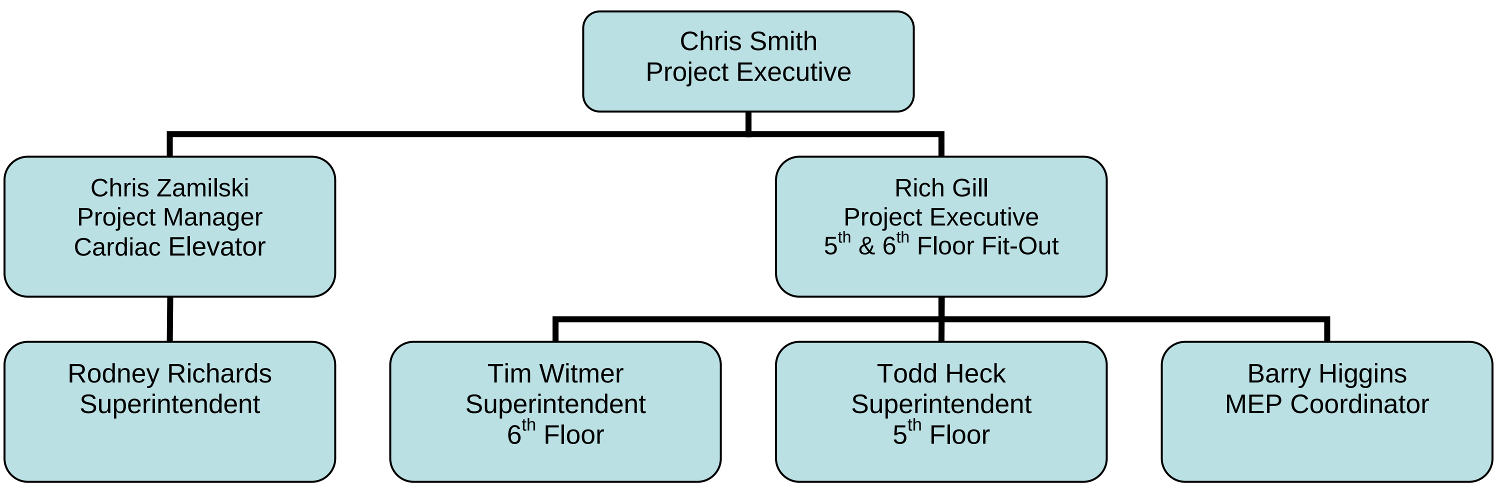
general contractor was selected due to their experience and relationship with work for the owner through a negotiated bid. They hold a guaranteed maximum price (GMP) contract (AIA A121) and (AIA A201) with the owner. The general contractor competitively bid the subcontractor/vendor marketplace. The subcontractors and vendors selected hold a typical AIA 111 contract directly with the general contractor.

There are no bonds required by the owner for this project. Insurance requirements are as follows contractor's liability insurance including workers compensation, comprehensive or commercial general liability, contractual liability, personal injury, business auto liability and umbrella excess liability. Owner's liability insurance including bodily injury, property damage and personal injury. All insurance coverage's shall be provided by insurance companies having policy holder ratings of no lower than "A" and financial ratings not lower than "XII" in the Best's Insurance Guide, latest edition in effect as of the date of the contract.

These contract types seem to be appropriate for this project allowing for less risk to be taken by the general contractor with a GMP contract meaning that there will be less contingency built into the price. This type of contract also allows for any savings on the project to go to the owner at which time he can decide who if anyone to share them with. A design-bid-build delivery method also benefits the owner in this type of high-technology high quality project, allowing for competitive bidding on a nearly complete design package.

C. Staffing Plan

The organizational structure for the general contractor starts with Chris Smith a project executive who oversees all projects with Lancaster General Hospital allowing for a strong working relationship to be developed. The two projects, 5th and 6th floor fit-out and cardiac elevator, are then split with Chris Zamilski a project manager running the cardiac elevator project and Rich Gill a project executive running the 5th and 6th floor fit-out project. Under Chris Zamilski is Rodney Richards who is a superintendent and will be responsible for any laborers and subcontractors on-site. Rich Gill has two superintendents under him one for each of the two floors as well as Barry Higgins who is the on-site MEP coordinator for Benchmark.



D. Local Conditions

The preferred method of construction in the region for commercial construction is steel structure with cast in place concrete slab on composite metal deck. This is the method of choice on the existing building containing the shell space that will be fit-out during this project as well as the rest of the hospital. This method fits into the local preferences for construction and also allows for open floor plans that are required for a hospital setting. Layout of the space can be easily changed by moving partition walls as the requirements of the hospital change allowing them to adapt to current needs.

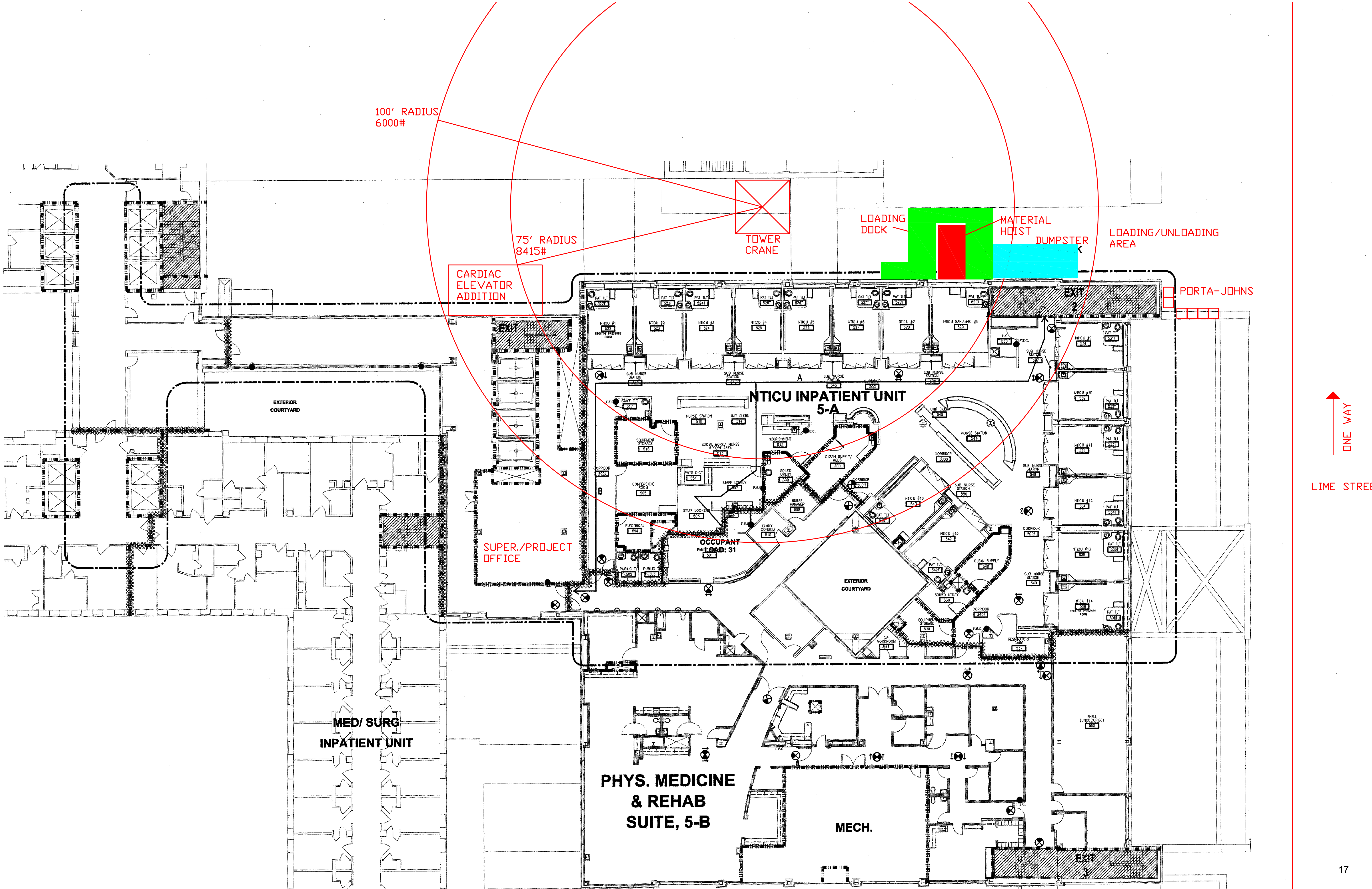
Construction parking is not readily available in this urban site that is surrounded on three sides by tightly grouped residential row homes. Offsite parking has been acquired several blocks away at a local business and construction personnel are bused in using a construction van furnished by the general contractor. There are several parking garages on-site including one on the ground floor below the project site, however these spaces are reserved for hospital staff and no construction vehicle are allowed.

Trash and recycled materials are placed in dumpsters located at ground level below the material hoist. This allows for the waste to be removed directly from the project site without having to travel through the occupied space of the hospital. Since eliminating the spread of dust and construction debris to occupied areas is extremely important to the hospital and its patients this means of waste removal is crucial to owner satisfaction.

The only phase of this project that does not take place in an existing shell space is the construction of the cardiac elevator. Due to this, soil and subsurface water conditions only apply to this phase. The soil that will be excavated for the concrete footing that will support the elevated elevator shaft is clean fill that was backfilled against the existing building. Ground water levels are located below the excavation depth and will have no impact in this project. The only concern during this excavation would be underground utilities and sanitary lines that run to and from the existing building, however, these concerns were alleviated by plant engineering documents from the hospital and by the local municipality identifying no existing obstructions.

E. Site Layout Planning

The map above shows a large scale layout of the project location and surrounding areas including the off site construction parking lot that will be used for the duration of the project. Located below on ***page 17*** is a scaled site plan drawing. This view allows the location of the material hoist, dumpsters, loading/unloading zone, tower crane and cardiac elevator to be shown in relation to the 5th and 6th floor fit-out. As you can see the site is surrounded by streets and existing buildings hindering maneuverability. Deliveries are further complicated because Lime Street runs directly in front of the project site is a one way street.



100' RADIUS
6000#
75' RADIUS
8415#
TOWER
CRANE
LOADING
DOCK
MATERIAL
HOIST
DUMPSTER
LOADING/UNLOADING
AREA
PORTA-JOHNS
CARDIAC
ELEVATOR
ADDITION
EXIT
1
EXIT
2
EXIT
3
NTICU INPATIENT UNIT
5-A
EXTERIOR
COURTYARD
SUPER./PROJECT
OFFICE
OCCUPANT
LOAD: 31
MED/ SURG
INPATIENT UNIT
PHYS. MEDICINE
& REHAB
SUITE, 5-B
MECH.
ONE WAY
LIME STREET

The site for this project is condensed to the small area between two existing buildings with access to the loading/unloading area coming from a one way street. Another complicating factor is the location of the helicopter landing pad for the hospital on one of the adjacent rooftop which can be seen in Figure 1.

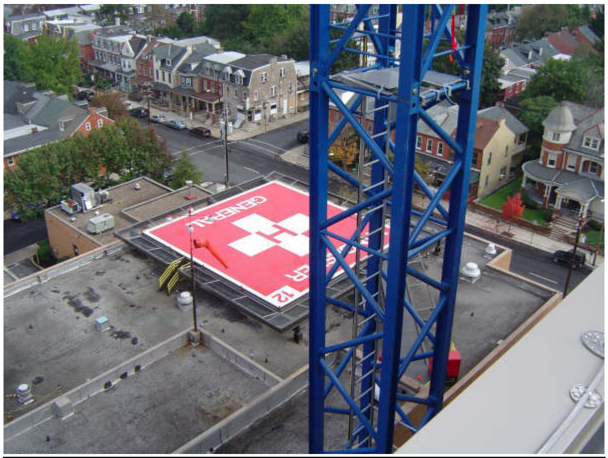


Figure 1 - Tower Crane w/ Helicopter Pad

Figure 2 - Material Hoist/Loading Dock

Site Layout:

Because construction personnel and material are prohibited from using the occupied areas of the hospital a material hoist is utilized for access to the spaces on the 5th and 6th floor. This makes transporting labor and materials easier but takes up valuable space in this restricted site. In Figure 2 you can see the placement of the material hoist and loading dock as well as some material storage behind the material hoist. Because the hoist traveled past occupied patient rooms on its way to the project floors hours of operation were restricted to 7am – 7pm.

Due to the lack of space on site and since the general contractor does a large amount of work at the hospital they are allocated a large room in the basement of the hospital that has been split into a conference room and two small offices for on site personnel. For superintendent office space the mechanical rooms on the 5th and 6th floors are utilized due to their close proximity to the project space.

Figure 3 - Loading/Unloading Zone (1)

Figure 4 - Loading/Unloading Zone (2)

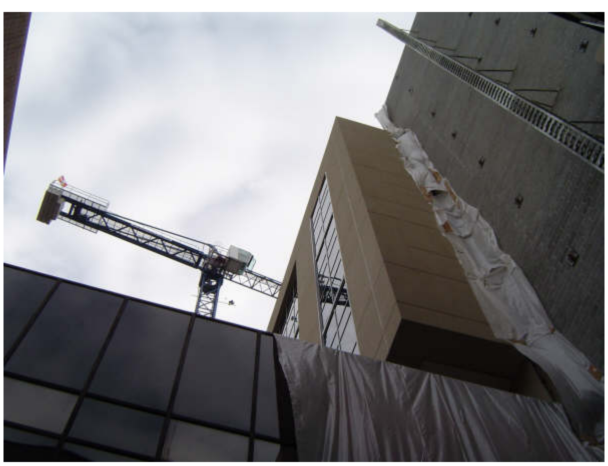


Figure 5 - Cardiac Elevator Addition Site

In Figures 3 & 4 you can see the loading/unloading zone that is set up just off of Lime St. which is a one way street. This tight space is made smaller by the placement of the dumpster just off the loading dock. Figure 4 shows a drywall delivery being made using a boom truck to set the drywall on the loading dock. Deliveries must be coordinated so that there is no more than one large truck making a delivery at any time because there is no staging area available.

Figures 5 & 6 show the location of the cardiac elevator addition behind the loading dock area with several elevated walkways, one on either side of the elevator. Figure 5 is a picture shows were the façade of the existing building has been removed in preparation of the elevator construction. Figure 6 shows the self climbing scaffold that was used to remove the façade. The scaffold will need to be removed for the structural phase of the elevator addition but will be brought back in for the placement of the EIFS panels.

Figure 7 shows the location of the porta-johns that are used by all construction personnel on site. The use of these facilities requires workers to travel

down the material hoist taking excess time. This is not an optimum set up but do to the restricted site options for placement was limited as well as the inability to use the facilities located in the hospital caused this to be the only option available.

Figure 6 - Self Climbing Scaffold

Figure 8 and Table 1 shoe the tower crane and crane load chart respectively. The tower crane will be used for construction of the elevator as well as placement of air handling units. The tower crane stands 146’ tall and has a swing that travels over the helicopter landing pad.

Figure 7 - Porta-Johns

Coordination for helicopter landings is conducted via radio with the communications center advising when the crane needs to be moved out of the way and shut down for landings. This happens on average of 2-3 times a week with only one or two of those happening during normal working hours. To protect against issues at night the crane is secured to the roof of the adjacent building to stop the crane from swinging over the helicopter pad. The limited occurrence will have limited impact on the overall project schedule so minimal time was figured into the schedule for these delays. If it were a more common situation time would need to be figured in for delays.

Figure 8 – Tower Crane

CRANE OPERATION LOAD CHART	
Distance Trolly (Ft.)	Hook Radius (Ft.)
	123.0
45.9	11023 lbs.
49.2	11023 lbs.
52.4	11024 lbs.
55.7	11025 lbs.
59.0	11026 lbs.
62.3	10438 lbs.
65.6	9854 lbs.
68.8	9325 lbs.
72.1	8840 lbs.
75.4	8410 lbs.
78.7	8013 lbs.
82.0	7638 lbs.
85.2	7309 lbs.
88.5	6988 lbs.
91.8	6701 lbs.
95.1	6437 lbs.
98.4	6183 lbs.
101.6	5952 lbs.
104.9	5731 lbs.
108.2	5522 lbs.
111.5	5335 lbs.
114.8	5147lbs.
118.0	4982 lbs.
121.3	4817 lbs.
123.0	4739 lbs.

Table 1 – Crane Load Chart

F. Detailed Project Schedule

The detailed project schedule for this project is made up of six major parts general items, 5th floor, 6th floor, connecting corridors 5 & 6, cardiac elevator and site work. All of these parts are being conducted simultaneously but are broken down into separate schedules for clarity. Please find a detailed schedule attached below on ***pages 27, 28, 29, and 30***.

Key Project Dates:

Start 5th & 6th Floor	August 11, 2006
Start Cardiac Elevator	September 5, 2006
Tower Crane Erection	September 20, 2006
Corridor Connection 5th & 6th Floor	September 5, 2006
DOH Life Safety Inspection	December 29, 2006
DOH Licensure Inspection	January 15, 2007

Structural Steel Frame:

All structural steel frames shall be securely braced until all floor slabs, roof decks and shear walls have been installed and become capable of stabilizing the frames. Bracing used is steel angle welded to columns and floor beams. Composite metal decking shall be used for all elevated floor slabs. A tower crane will be utilized for all steel erection. Crane will be located between the two elevated walkways directly adjacent to the elevator shaft. Crane swing is above helicopter pad for the hospital and will have to be shut down and boom swung out of the way whenever use of the pad is required. Coordination for this is done through radio contact with the hospital and Lancaster County Communications.

Cast in Place Concrete:

Cast-in-place concrete will be placed on composite metal decking in the cardiac elevator project. No formwork is required due to the metal decking. Edge stops will be permanently placed continuous bent plates 3/8”x4”x5-1/2” welded to

the top of the steel floor beam with a ¼ 3@12 fillet weld. Concrete slab on deck will be 4” in depth light weight 4000psi (110 PCF Maximum). Other concrete to be used for foundation will be placed in footing excavation requiring no other formwork. This concrete shall be 3000psi normal weight concrete.

Mechanical System:

Mechanical rooms are located on the 4th and 5th floor of the hospital directly outside the shell space on the 5th floor with the 4th floor mechanical room located directly underneath. Air handling units are forced air systems with distribution through ductwork utilizing smoke and fire dampers wherever a fire or smoke rated wall is penetrated. All areas of the hospital are fully sprinkled and the sprinkler system in the shell space are existing however drops will have to be added and main lines relocated to match floor plan layout. Sprinklers for the new elevator lobbies will be run by tapping into the main branch lines running down the corridor being tied into.

Electrical System:

Electrical service comes from 4-480V 75KVA transformers serving 8-120/208V panel’s normal branch. 3-480V 75KVA transformers serving 6-120/208V panel’s critical branch and 2-480V 15KVA transformers serving 2-120/208V panel’s life safety branch. Also the floors are supplied with nurse call systems, alarm systems and emergency lock down systems.

Masonry:

Masonry system will be a brick veneer located on the base of the elevator shaft. Adjustable masonry ties to be attached to 6” metal stud wall. Climbing scaffold will be utilized for the masonry work and EFIS system installation.

Shell Space:

The 5th and 6th floor fit-out project is part of hospital expansion utilizing existing space inside the hospital that was previously used as storage space.

Figure 9 – 6th Floor Shell Space

Figure 10 – 5th Floor MEP Rough-in

Figure 11 – 5th Floor MEP

Because they will be utilizing existing shell space no structural work will be required for this part of the project, which means that work on these two floors began with floor layout and MEP rough-in. In Figure 9 you can see the open layout of the 6th floor shell space with the orange lines designating hollow metal frame wall layout. In the picture you can also see that the sprinkler lines have already been run in a standard layout that will have to be revised after the floor layout is complete.

MEP Rough-in:

MEP rough-in on the 5th and 6th floor consisted of tying into existing piping and ductwork in the adjacent corridor as well as to new units in the mechanical room located directly outside the shell space. As can be seen in Figures 10 and 11 once floor layout and hollow metal framing is complete MEP rough-in begins with ductwork, piping and electrical conduit being placed. In figure 11 you can also see that there were some coordination issues with existing

sprinkler piping and the ductwork that was being installed. These issues were resolved when sprinkler pipe relocation occurred. A very sensitive part of the MEP rough-in occurs when tie-ins are being made to systems located in the 4th floor ceiling plenum space because the 4th floor is occupied with patient rooms. This requires coordination with the hospital to move patients around during tie-in operations as well as cleaning rooms after work is completed so that patients can be moved back in.

Figure 12 – 5th Floor Patient Room Finishes

Finishes:

Finishes for all projects at the hospital are high end and are designed to tie into existing finishes in adjacent spaces. In Figure 12 you can see the wall paneling that is being placed in the patient rooms on the 5th and 6th floors. This is a honey oak finish that has been selected and will be continued throughout the space and adjoining corridors. Figure 13 shows a rendering of a finished patient room and in the background you can see the finishes carrying over into the corridor with the nurse's station. This rendering also shows the VCT flooring pattern that is being utilized in the project. The high qualities of the finishes require longer schedule durations for these phases of

Figure 13– 5th Floor Patient Room Rendering

the project. As long as this is realized up front there should not be any negative effects on the overall project completion. This is one of the many things that should be looked at during all project schedule developments because if not identified could cause problems later in the project.

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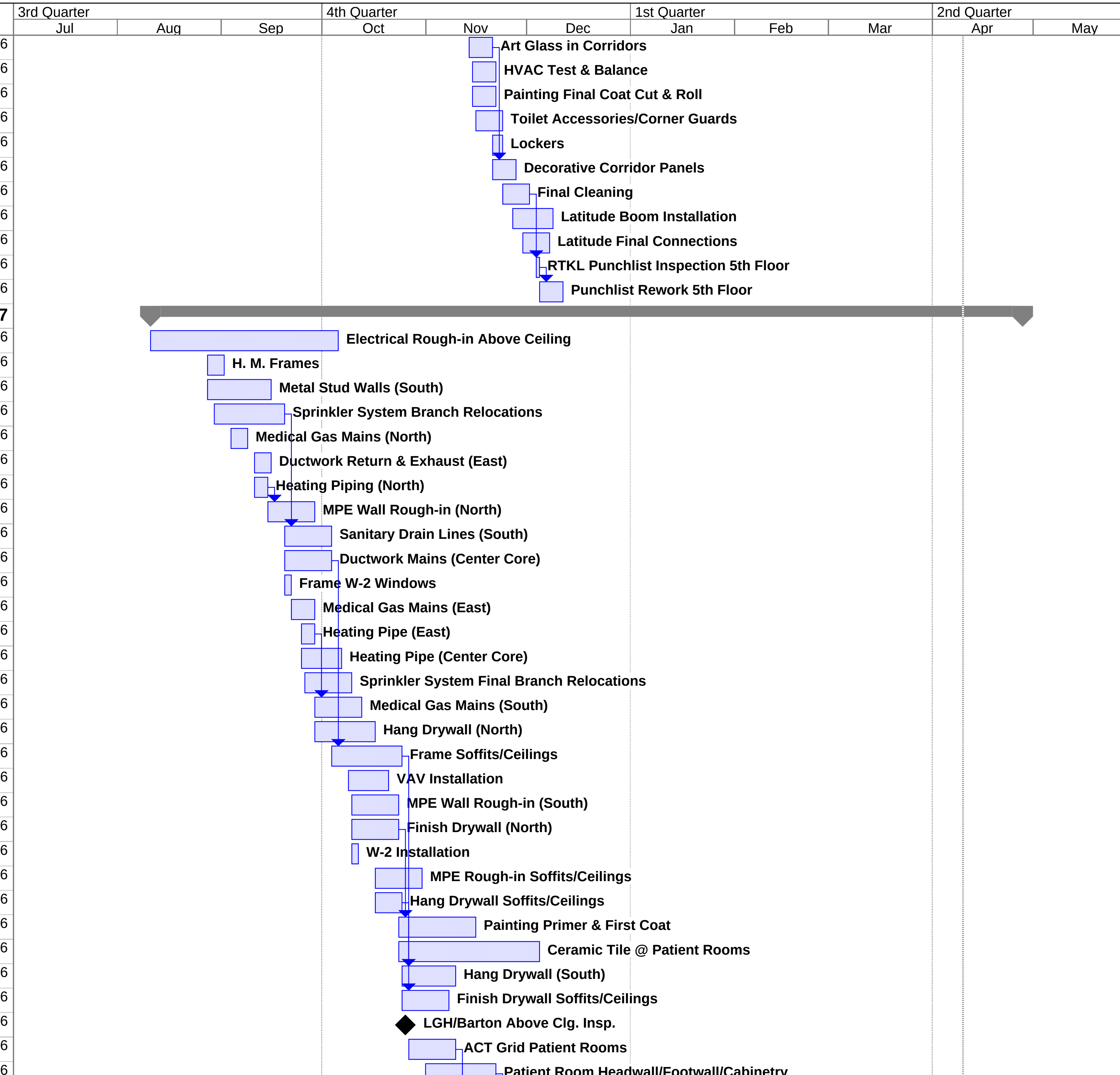
ID	Task Name	Duration	Start	Finish
1	**General Items**	**11 days**	**Fri 12/29/06**	**Mon 1/15/07**
1	DOH Life Safety Inspection	0 days	Fri 12/29/06	Fri 12/29/06
2	Plant Engineering In-Service Training	2 days	Tue 1/2/07	Wed 1/3/07
3	DOH Licensure Inspection	0 days	Mon 1/15/07	Mon 1/15/07
2	**5th Floor**	**186 days**	**Fri 8/11/06**	**Fri 4/27/07**
1	Electrical Rough-in Above Ceilings	40 days	Fri 8/11/06	Thu 10/5/06
2	Frame Soffits/Ceilings	10 days	Mon 8/28/06	Fri 9/8/06
3	Sprinkler System Final Branch Relocations	10 days	Fri 9/1/06	Thu 9/14/06
4	Sanitary Drain Lines 4 Lime (South&Core)	5 days	Tue 9/5/06	Mon 9/11/06
5	Hang Drywall (North & East)	4 days	Thu 9/14/06	Tue 9/19/06
6	MPE Rough-in Soffits/Ceilings	7 days	Fri 9/15/06	Mon 9/25/06
7	Hang Drywall Soffits/Ceilings	4 days	Thu 9/21/06	Tue 9/26/06
8	Finish Drywall (North & East)	7 days	Mon 9/25/06	Tue 10/3/06
9	Hang Drywall (Center Core)	5 days	Wed 9/27/06	Tue 10/3/06
10	Finish Drywall Soffits/Ceilings	6 days	Fri 9/29/06	Fri 10/6/06
11	VAV Installation	5 days	Mon 10/2/06	Fri 10/6/06
12	Painting Primer & First Coat	15 days	Wed 10/4/06	Tue 10/24/06
13	Ceramic Tile @ Patient Rooms	10 days	Wed 10/4/06	Tue 10/17/06
14	Finish Drywall (Center Core)	7 days	Fri 10/6/06	Mon 10/16/06
15	Patient Room Headwall/Footwall/Cabinetry	6 days	Wed 10/18/06	Wed 10/25/06
16	ACT Grid Patient Rooms	5 days	Thu 10/19/06	Wed 10/25/06
17	Column Wraps	4 days	Wed 10/25/06	Mon 10/30/06
18	LGH/Barton Above Clg. Insp.	0 days	Wed 10/25/06	Wed 10/25/06
19	ACT Grid Center Core	5 days	Thu 10/26/06	Wed 11/1/06
20	Casework @ Nurse Stations	5 days	Thu 10/26/06	Wed 11/1/06
21	Flooring	18 days	Wed 10/18/06	Fri 11/10/06
22	Wood Doors & Hardware	12 days	Thu 10/26/06	Fri 11/10/06
23	Ceiling Tile Patient Rooms	5 days	Wed 10/25/06	Tue 10/31/06
24	Ceramic Tile @ Nurse Stations, Corr.	10 days	Mon 10/30/06	Fri 11/10/06
25	Light Fixtures	10 days	Tue 10/31/06	Mon 11/13/06
26	GRD's	5 days	Tue 10/31/06	Mon 11/6/06
27	Sprinkler Head Turn Down Patient Rooms	5 days	Tue 10/31/06	Mon 11/6/06
28	Medical Gas Devices	2 days	Tue 10/31/06	Wed 11/1/06
29	Electrical Devices/Finishes	15 days	Tue 10/31/06	Mon 11/20/06
30	Corian Sinks	7 days	Tue 10/31/06	Wed 11/8/06
31	Casework Center Core	8 days	Thu 11/2/06	Mon 11/13/06
32	ACT Grid Corridors	5 days	Fri 11/3/06	Thu 11/9/06
33	Sprinkler Head Turn Down Center Core	5 days	Fri 11/3/06	Thu 11/9/06
34	Patient Room Breakaway Doors	4 days	Thu 11/9/06	Tue 11/14/06
35	Plumbing Fixtures	5 days	Thu 11/9/06	Wed 11/15/06
36	Corian Wall Protection	4 days	Fri 11/10/06	Wed 11/15/06
37	Ceiling Tile Corridors and Center Core	7 days	Tue 11/14/06	Wed 11/22/06
38	Corian Tops @ Casework	6 days	Tue 11/14/06	Tue 11/21/06

Project: Project Schedule.mpp
Date: Tue 4/10/07

Task	Milestone	Rolled Up Task	Rolled Up Progress	External Tasks	Group By Summary
Progress	Summary	Rolled Up Milestone	Split	Project Summary	Deadline

ID	Task Name	Duration	Start	Finish
39	Art Glass in Corridors	5 days	Tue 11/14/06	Mon 11/20/06
40	HVAC Test & Balance	5 days	Wed 11/15/06	Tue 11/21/06
41	Painting Final Coat Cut & Roll	5 days	Wed 11/15/06	Tue 11/21/06
42	Toilet Accessories/Corner Guards	6 days	Thu 11/16/06	Thu 11/23/06
43	Lockers	3 days	Tue 11/21/06	Thu 11/23/06
44	Decorative Corridor Panels	5 days	Tue 11/21/06	Mon 11/27/06
45	Final Cleaning	6 days	Fri 11/24/06	Fri 12/1/06
46	Latitude Boom Installation	10 days	Mon 11/27/06	Fri 12/8/06
47	Latitude Final Connections	6 days	Thu 11/30/06	Thu 12/7/06
48	RTKL Punchlist Inspection 5th Floor	1 day	Mon 12/4/06	Mon 12/4/06
49	Punchlist Rework 5th Floor	5 days	Tue 12/5/06	Mon 12/11/06
50	**6th Floor**	**186 days**	**Fri 8/11/06**	**Fri 4/27/07**
1	Electrical Rough-in Above Ceiling	40 days	Fri 8/11/06	Thu 10/5/06
2	H. M. Frames	5 days	Mon 8/28/06	Fri 9/1/06
3	Metal Stud Walls (South)	15 days	Mon 8/28/06	Fri 9/15/06
4	Sprinkler System Branch Relocations	15 days	Wed 8/30/06	Tue 9/19/06
5	Medical Gas Mains (North)	5 days	Mon 9/4/06	Fri 9/8/06
6	Ductwork Return & Exhaust (East)	5 days	Mon 9/11/06	Fri 9/15/06
7	Heating Piping (North)	4 days	Mon 9/11/06	Thu 9/14/06
8	MPE Wall Rough-in (North)	10 days	Fri 9/15/06	Thu 9/28/06
9	Sanitary Drain Lines (South)	10 days	Wed 9/20/06	Tue 10/3/06
10	Ductwork Mains (Center Core)	10 days	Wed 9/20/06	Tue 10/3/06
11	Frame W-2 Windows	2 days	Wed 9/20/06	Thu 9/21/06
12	Medical Gas Mains (East)	5 days	Fri 9/22/06	Thu 9/28/06
13	Heating Pipe (East)	4 days	Mon 9/25/06	Thu 9/28/06
14	Heating Pipe (Center Core)	10 days	Mon 9/25/06	Fri 10/6/06
15	Sprinkler System Final Branch Relocations	10 days	Tue 9/26/06	Mon 10/9/06
16	Medical Gas Mains (South)	10 days	Fri 9/29/06	Thu 10/12/06
17	Hang Drywall (North)	12 days	Fri 9/29/06	Mon 10/16/06
18	Frame Soffits/Ceilings	15 days	Wed 10/4/06	Tue 10/24/06
19	VAV Installation	10 days	Mon 10/9/06	Fri 10/20/06
20	MPE Wall Rough-in (South)	10 days	Tue 10/10/06	Mon 10/23/06
21	Finish Drywall (North)	10 days	Tue 10/10/06	Mon 10/23/06
22	W-2 Installation	2 days	Tue 10/10/06	Wed 10/11/06
23	MPE Rough-in Soffits/Ceilings	10 days	Tue 10/17/06	Mon 10/30/06
24	Hang Drywall Soffits/Ceilings	6 days	Tue 10/17/06	Tue 10/24/06
25	Painting Primer & First Coat	17 days	Tue 10/24/06	Wed 11/15/06
26	Ceramic Tile @ Patient Rooms	30 days	Tue 10/24/06	Mon 12/4/06
27	Hang Drywall (South)	12 days	Wed 10/25/06	Thu 11/9/06
28	Finish Drywall Soffits/Ceilings	10 days	Wed 10/25/06	Tue 11/7/06
29	LGH/Barton Above Clg. Insp.	0 days	Thu 10/26/06	Thu 10/26/06
30	ACT Grid Patient Rooms	10 days	Fri 10/27/06	Thu 11/9/06
31	Patient Room Headwall/Footwall/Cabinetry	15 days	Wed 11/1/06	Tue 11/21/06



Task | Milestone | Rolled Up Task | Rolled Up Progress | External Tasks | Group By Summary
Progress | Summary | Rolled Up Milestone | Split | Project Summary | Deadline

ID	Indicators	Task Name	Duration	Start	Finish
32		Casework @ Nurse Stations	20 days	Tue 11/7/06	Mon 12/4/06
33		Flooring	30 days	Tue 11/7/06	Mon 12/18/06
34		Ceramic Tile @ Nurse Stations, Corr.	15 days	Thu 11/9/06	Wed 11/29/06
35		Finish Drywall (South)	15 days	Fri 11/10/06	Thu 11/30/06
36		ACT Grid (Center Core)	10 days	Fri 11/10/06	Thu 11/23/06
37		Light Fixtures	20 days	Fri 11/10/06	Thu 12/7/06
38		GRD's	10 days	Fri 11/10/06	Thu 11/23/06
39		Sprinkler Head Turn Down Patient Rooms	10 days	Fri 11/10/06	Thu 11/23/06
40		Decorative Corridor Panels	10 days	Tue 11/14/06	Mon 11/27/06
41		Art Glass in Corridors	10 days	Thu 11/16/06	Wed 11/29/06
42		Casework (Center Core)	15 days	Thu 11/16/06	Wed 12/6/06
43		Electrical Devices/Finishes	30 days	Thu 11/16/06	Wed 12/27/06
44		Corian Sinks	6 days	Thu 11/16/06	Thu 11/23/06
45		Patient Room Breakaway Doors	20 days	Tue 11/21/06	Mon 12/18/06
46		Ceiling Tile Patient Rooms	15 days	Wed 11/22/06	Tue 12/12/06
47		Medical Gas Devices	20 days	Wed 11/22/06	Tue 12/19/06
48		ACT Grid Corridors	15 days	Fri 11/24/06	Thu 12/14/06
49		Sprinkler head Turn Down (Center Core)	10 days	Fri 11/24/06	Thu 12/7/06
50		Plumbing Fixtures	12 days	Fri 11/24/06	Mon 12/11/06
51		Painting Final Coat Cut & Roll	10 days	Mon 11/27/06	Fri 12/8/06
52		Column Wraps	6 days	Fri 12/1/06	Fri 12/8/06
53		Wood Doors & Hardware	20 days	Fri 12/1/06	Thu 12/28/06
54		Corian Tops @ Casework	10 days	Thu 12/7/06	Wed 12/20/06
55		Ceiling Tile (Corridors and Center Core)	12 days	Fri 12/8/06	Mon 12/25/06
56		Toilet Accessories/Corner Guards	10 days	Tue 12/12/06	Mon 12/25/06
57		Corian Wall Protection	10 days	Fri 12/15/06	Thu 12/28/06
58		Final Cleaning	6 days	Fri 12/15/06	Fri 12/22/06
59		Lockers	6 days	Tue 12/19/06	Tue 12/26/06
60		HVAC Test & Balance	8 days	Tue 12/19/06	Thu 12/28/06
61		RTKL Punchlist Inspection 6th Floor	1 day	Tue 12/26/06	Tue 12/26/06
62		Punchlist Rework 6th Floor	5 days	Wed 12/27/06	Tue 1/2/07
63		**Connecting Corridors 5 & 6**	**169 days**	**Tue 9/5/06**	**Fri 4/27/07**
1		Demolition	5 days	Mon 10/16/06	Fri 10/20/06
2		Flooring	7 days	Mon 10/23/06	Tue 10/31/06
3		Casework	10 days	Wed 11/1/06	Tue 11/14/06
4		Wall Patching	4 days	Wed 11/1/06	Mon 11/6/06
5		Ceiling Grid	4 days	Wed 11/15/06	Mon 11/20/06
6		MPE Devices	7 days	Tue 11/21/06	Wed 11/29/06
7		Vynil Wallcovering	10 days	Tue 11/21/06	Mon 12/4/06
8		Handrail/Wall Protection	6 days	Tue 12/5/06	Tue 12/12/06
9		Ceiling Tile	4 days	Wed 12/13/06	Mon 12/18/06
10		**Cardiac Elevator**	**169 days**	**Tue 9/5/06**	**Fri 4/27/07**
1		Close Off Work Area	4 days	Tue 9/5/06	Fri 9/8/06

Project: Project Schedule.mpp
Date: Tue 4/10/07

Task	Milestone	Rolled Up Task	Rolled Up Progress	External Tasks	Group By Summary
Progress	Summary	Rolled Up Milestone	Split	Project Summary	Deadline

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Construction Management

ID	Task Name	Duration	Start	Finish
2	Install ICRA Partitions	9 days	Tue 9/5/06	Fri 9/15/06
3	Tower Crane Foundation	3 days	Fri 9/15/06	Tue 9/19/06
4	Tower Crane Assembly	3 days	Wed 9/20/06	Fri 9/22/06
5	Install Scaffold Platform	4 days	Wed 9/20/06	Mon 9/25/06
6	Select Interior Demo (Floors 5 to 8)	8 days	Mon 9/18/06	Wed 9/27/06
7	Removal of Windows (Floors 5 to 8)	2 days	Tue 9/26/06	Wed 9/27/06
8	EIFS Panel Removal	7 days	Thu 9/28/06	Fri 10/6/06
9	Curtainwall Removal @ 2nd Floor Link	1 day	Mon 10/9/06	Mon 10/9/06
10	Install Expansion Bolts in CMU for Steel	3 days	Mon 10/9/06	Wed 10/11/06
11	Install "Chase" EIFS Panels	2 days	Thu 10/12/06	Fri 10/13/06
12	Romove Scaffold Platform	2 days	Mon 10/16/06	Tue 10/17/06
13	Foundation Work	5 days	Mon 10/16/06	Fri 10/20/06
14	Concrete Structure	8 days	Thu 10/19/06	Mon 10/30/06
15	Structural Steel	19 days	Tue 10/31/06	Fri 11/24/06
16	SOD Pours (Floors 5 to 8)	5 days	Wed 11/22/06	Tue 11/28/06
17	Install Shaftway Scaffold System	3 days	Wed 11/22/06	Fri 11/24/06
18	EIFS Panels	5 days	Mon 11/27/06	Fri 12/1/06
19	Reinstall Windows	3 days	Mon 12/4/06	Wed 12/6/06
20	Exterior Caulking	3 days	Thu 12/7/06	Mon 12/11/06
21	Drywall Shaftwalls	15 days	Mon 12/4/06	Fri 12/22/06
22	Install Elevator Machine Room Beams	3 days	Mon 11/27/06	Wed 11/29/06
23	Pour Elevator Machine Room	2 days	Thu 11/30/06	Fri 12/1/06
24	Set Elevator Motor	1 day	Mon 12/4/06	Mon 12/4/06
25	Install Roof Steel	2 days	Tue 12/5/06	Wed 12/6/06
26	Roofing	5 days	Thu 12/7/06	Wed 12/13/06
27	Elevator Construction	40 days	Tue 12/26/06	Mon 2/19/07
28	Remove Scaffold System	2 days	Fri 12/29/06	Mon 1/1/07
29	Elevator Lobby Metal Studs	10 days	Mon 12/4/06	Fri 12/15/06
30	MEP Rough-ins	10 days	Fri 12/8/06	Thu 12/21/06
31	Hang and Finish Drywall	15 days	Fri 12/15/06	Thu 1/4/07
32	Paint and Vinyl Wall Covering	7 days	Thu 1/4/07	Fri 1/12/07
33	Flooring	7 days	Wed 1/10/07	Thu 1/18/07
34	Wall Protection	5 days	Mon 1/15/07	Fri 1/19/07
35	**Sitework**	**110 days**	**Mon 11/27/06**	**Fri 4/27/07**
1	Exterior Curtain Wall Replacement	5 days	Mon 11/27/06	Fri 12/1/06
2	Hoist Removal	10 days	Mon 12/4/06	Fri 12/15/06
3	Loading Dock Demo.	10 days	Mon 12/18/06	Fri 12/29/06
4	Sitework Demo.	5 days	Wed 1/3/07	Tue 1/9/07
5	Sitework Renovation	5 days	Wed 1/10/07	Tue 1/16/07
6	Landscaping	10 days	Mon 4/16/07	Fri 4/27/07

Project: Project Schedule.mpp
Date: Tue 4/10/07

Task	Milestone	Rolled Up Task	Rolled Up Progress	External Tasks	Group By Summary
Progress	Summary	Rolled Up Milestone	Split	Project Summary	Deadline

G. Project Cost Summary

Since this project takes place inside an existing building the construction costs are the same as the total project costs with no land costs, or site work included. However the project is broken down into two separate parts with the cost of the fit-out and cardiac elevator being separate. The construction costs for the 5th and 6th Floor Lime Street Fit-Out are $9,720,090 for 48,592 ft^2 leading to a cost per square foot of $200.04. The construction costs for the Cardiac Elevator Addition are $1,998,973 for 1,600 ft^2 leading to a cost per square foot of $1,249.36.

Lancaster General Hospital 5th and 6th Floor Fit-Out	
Description	Cost
General Conditions	$650,881.00
Demolition/Landscaping	$82,448.00
Concrete	$25,549.00
Steel	$48,496.00
Carpentry	$1,101,130.00
Thermal/Moisture	$39,252.00
Doors & Windows	$768,344.00
Finishes	$1,526,672.00
Specialties	$123,140.00
Equipment	$51,862.00
Furnishings	$28,400.00
Conveying/Hoisting	$61,566.00
MEP	$5,000,100.00
Contingency and Fee	$212,250.00
Total	$9,720,090.00

Lancaster General Hospital Cardiac Elevator	
Description	Cost
General Conditions	$167,519.00
Demolition/Landscaping	$154,765.00
Concrete	$87,174.00
Masonry	$17,827.00
Steel	$527,297.00
Carpentry	$8,782.00
Thermal/Moisture	$284,954.00
Doors & Windows	$8,954.00
Finishes	$183,653.00
Specialties	$11,696.00
Furnishings	$1,141.00
Conveying/Hoisting	$433,698.00
MEP	$75,520.00
Contingency and Fee	$35,993.00
Total	$1,998,973.00

H. General Conditions Estimate

The general conditions estimate shows all project and staffing costs associated with the coordination and running of the 5th and 6th floor fit-out and cardiac elevator addition projects. These projects are Guaranteed Maximum Price, negotiated contracts. The costs shown in the estimate do not include home office overhead. General conditions costs are meant only to show the costs directly associated with the project.

Estimate Break Down:

This break down shows the categories of the general conditions estimate that can be found below on ***page 33***.

- Project Coordination
- Building Layout
- Regulatory Requirements
- Progress Schedules
- Temporary Utilities
- Temporary Construction
- Construction Aids
- Temporary Controls
- Traffic Regulation
- Contract Closeout

GENERAL CONDITIONS ESTIMATE LGH 5th & 6th FLOOR FIT-OUT								
Phase	Description	Takeoff Quantity	Material Amount	Labor Amount	Sub Amount	Euip. Amount	Total Cost/Unit	Total Amount
1000.400	Project Coordination	6 - Months		$292,000.00		$2,763.00	$49,129.20 /Month	**$294,763.00**
1000.540	Building Layout	6 - Months	$3,895.00	$42,952.00		$1,000.00	$7,974.50 /Month	**$47,847.00**
1000.600	Regulatory Requirements	6 - Months			$55,210.00		$9,201.67 /Month	**$55,210.00**
1300.100	Progress Schedules	6 - Months	$5,895.00				$982.5 /Month	**$5,895.00**
1500.100	Temporary Utilities	6 - Months	$650.00	$6,420.00	$3,450.00	$6,500.00	$2,836.67 /Month	**$17,020.00**
1500.200	Temporary Construction	6 - Months	$190.00	$670.00		$3,450.00	$718.33 /Month	**$4,310.00**
1500.250	Construction Aids	6 - Months	$2,400.00	$33,600.00	$16,300.00	$39,600.00	$15,316.70 /Month	**$91,900.00**
1500.600	Temporary Controls	6 - Months	$7,050.00	$17,530.00	$32,000.00		$9,430 /Month	**$56,580.00**
1500.700	Traffic Regulation	6 - Months		$42,000.00	$13,000.00		$9,166.67 /Month	**$55,000.00**
1700.100	Contract Closeout	48,592 Sq.Ft.	$300.00	$10,250.00	$12,600.00		$.48 /Sq.Ft.	**$23,150.00**
	GENERAL CONDITIONS		**$20,380.00**	**$445,422.00**	**$132,560.00**	**$53,313.00**	**$108,613 /Month**	**$651,675.00**

GENERAL CONDITIONS ESTIMATE LGH CARDIAC ELEVATOR								
Phase	Description	Takeoff Quantity	Material Amount	Labor Amount	Sub Amount	Euip. Amount	Total Cost/Unit	Total Amount
1000.400	Project Coordination	5 - Months		$75,250.00			$15,150 /Month	**$75,250.00**
1300.100	Progress Schedules	5 - Months	$2,680.00				$536 /Month	**$2,680.00**
1400.100	Testing & Inspections	5 - Months	$25.00	$1,310.00	$2,135.00	$842.00	$862.40 /Month	**$4,312.00**
1500.100	Temporary Utilities	5 - Months		$11,413.00		$4,267.00	$3,136 /Month	**$15,680.00**
1500.250	Construction Aids	5 - Months			$31,215.00	$725.00	$6,388 /Month	**$31,940.00**
1500.300	Barriers & Enclosures	5 - Months	$1,246.00	$3,812.00		$417.00	$1,095 /Month	**$5,475.00**
1500.400	Security	5 - Months	$3,768.00	$645.00			$882.60 /Month	**$4,413.00**
1500.600	Temporary Controls	5 - Months	$2,422.00	$7,800.00	$9,770.00	$300.00	$4,58.40 /Month	**$20,292.00**
1500.700	Traffic Regulations	5 - Months			$180.00		$36 /Month	**$180.00**
1700.100	Contract Closeout	1,600 Sq.Ft.	$600.00	$6,354.00	$2,555.00		$5.94 /Sq.Ft.	**$9,509.00**
	GENERAL CONDITIONS	**5.00 Months**	**$10,741.00**	**$106,584.00**	**$45,855.00**	**$6,551.00**	**$33,946.20 /Month**	**$169,731.00**

I. Assemblies Estimate

The assemblies' estimate that was developed for this section is for the building enclosure system for the cardiac elevator addition. The estimate was created using R.S. Means 2005 data. Location factors had to be taken into account in order to give an accurate depiction of costs for the region of construction. Location factors for Lancaster, Pennsylvania are .95 for materials, .88 for labor and .92 total cost. Equipment costs were taken at a direct rate from R.S. Means with the major equipment cost for this phase coming from the self climbing scaffolding shown earlier in Figure 6. A 27% O&P factor was used in calculating the total cost.

Assembly:

The assembly was broken down into the following sections.

- Exterior Insulation Finish System (EIFS)
- Fireproofing
- Single Ply Membrane Roofing
- Sheet Metal Flashing/Trim

ASSEMBLY ESTIMATE - BUILDING ENCLOSURE
LGH CARDIAC ELEVATOR ADDITION - PREPARED BY: DEVIN LEARN

Phase	Description	Takeoff Qty.	Material Cost	Labor Cost	Equip. Cost	$ Per Unit w/.92 Location Factor	27% O&P	Total Cost
7240.100	Exterior Ins./Finish System	25,000 Sq.Ft.	$64,600.00	$118,800.00	$11,750.00	$7.90 Sq.Ft.	$10.03	$250,750
7250.255	Fireproofing	9,500 Sq.Ft.	$5,595.50	$4,514.40	$855.00	$1.15 Sq.Ft.	$1.48	$14,060
7500.300	Single Ply Membrane Roofing	5.4 Sq.	$630.00	$194.83	$30.51	$156.08 Sq.	$195.04	$1,053
7600.200	Sheet Metal Flashing/Trim	1,800 Sq.Ft.	$3,146.40	$2,566.08	$0.00	$3.18 Sq.Ft.	$4.41	$7,938
Total			$73,971.90	$126,075.31	$12,635.51	$13.79 Sq.Ft.		$273,801

J. Detailed Structural Estimate

The detailed structural systems estimate for this section was completed using the structural system for the cardiac elevator addition because the 5th and 6th floor fit-out project is inside an existing shell space requiring no structural work. The structural system estimate required a structural member takeoff that can be found along with the detailed structural systems estimate blow on ***pages 36 and 37***. The costs for the estimate were based on a price per unit basis.

Structural Systems Estimate Summary:

Below is a structural systems estimate summary to compliment the attached detailed structural systems estimate.

PROPOSED STRUCTURAL ESTIMATE - SUMMARY LGH CARDIAC ELEVATOR							
Description	Takeoff Quantity	Material Amount	Labor Amount	Sub Amount	Euip. Amount	Total Cost/Unit	Total Amount
CONCRETE FORMWORK							
	1,249.00 Sq.Ft.	$4,940.00	$11,795.00	$0.00	$0.00	$13.40 /Month	$16,735.00
REINFORCING BAR							
	4.24 Ton	$5,965.00	$7,540.00	$0.00	$0.00	$3,185.14 /Ton	$13,505.00
REINFORCING WIRE MESH							
	1,996.00 Sq.Ft.	$530.00	$415.00	$0.00	$0.00	$.47 /Sq.Ft.	$945.00
CONCRETE ACCESSORIES							
		$1,905.00	$2,735.00	$0.00	$0.00		$4,640.00
CAST IN PLACE CONCRETE							
	210.60 Cu.Yd.	$29,015.00	$7,820.00	$7,030.00	$7,500.00	$243.90 /Cu.Yd	$51,365.00
MASONRY							
	535.00 Sq. Ft.	$0.00	$0.00	$17,850.00	$0.00	$33.36 /Sq.Ft.	$17,850.00
STRUCTURAL STEEL							
	1600.00 Sq.Ft.	$0.00	$0.00	$522,600.00	$0.00	$326.63 /Sq.Ft.	$522,600.00

STRUCTURAL STEEL TAKEOFF LGH CARDIAC ELEVATOR			
Wide Flange Columns	Qty.	Length	Weight
W14 x 132	1	52'	6864#
W14 x 90	1	38'	3420#
W14 x 90	1	44'	3960#
W12 x 87	1	52'	4524#
W12 x 87	1	38'	3306#
W12 x 87	1	44'	3828#
Total	6	268'	25,902#
Wide Flange Beams	Qty.	Length	Weight
W24 x 55	1	14'	770#
W21 x 44	1	15'	660#
W16 x 26	2	15'	780#
W16 x 26	1	6'	156#
W10 x 12	9	15'	1620#
W10 x 12	4	4'	192#
W12 x 16	8	16'	2048#
W12 x 16	11	15'	2640#
W24 x 68	4	16'	4352#
W24 x 68	4	14'	3808#
W14 x 22	1	16'	352#
W14 x 22	5	15'	1650#
W14 x 22	1	12'	264#
W27 x 84	1	16'	1344#
W27 x 84	1	15'	1260#
W16 x 50	1	16'	800#
W16 x 50	1	14'	700#
Total	56	793'	23,396#
Tube Steel Beams	Qty.	Length	Weight
HSS12 x 6 x 3/8	9	15'	
HSS12 x 6 x 3/8	3	14'	
HSS12 x 6 x 3/8	2	6'	
Total	14	189'	
Steel Joists	Qty.	Length	Weight
12K1	2	16'	
10K1	1	16'	
10K1	3	14'	
Total	6	90'	
Metal Floor Decking		Area	Weight
2"-20GA. Comp. Steel Deck		1320 Sq.Ft.	3036#
1-1/2"-20GA. Galv. St. Roof Deck		360 Sq.Ft.	792#
Total		1680 Sq.Ft.	3828#

STRUCTURAL ESTIMATE LGH CARDIAC ELEVATOR								
Phase	Description	Takeoff Quantity	Material Amount	Labor Amount	Sub Amount	Euip. Amount	Total Cost/Unit	Total Amount
CONCRETE FORMWORK								
3100.010	Strip Footer Formwork	142.00 Sq.Ft.	$160.00	$600.00			$5.35 /Sq.Ft.	**$760.00**
3100.050	Peir Cap Formwork	336.00 Sq.Ft.	$540.00	$1,700.00			$6.67 /Sq.Ft.	**$2,240.00**
3100.080	Foundation Pier Formwork	171.00 Sq.Ft.	$270.00	$1,350.00			$9.47 /Sq.Ft.	**$1,620.00**
3100.120	Elevator Wall Formwork	708.00 Sq.Ft.	$1,200.00	$3,000.00			$5.93 /Sq.Ft.	**$4,200.00**
3100.240	Elevated Slab Formwork	746.00 Sq.Ft.	$2,680.00	$4,870.00			$10.12 /Sq.Ft.	**$7,550.00**
3100.390	Frost Wall Formwork	69.00 Sq.Ft.	$90.00	$275.00			$5.29 /Sq.Ft.	**$365.00**
	CONCRETE FORMWORK	**1,249.00 Sq.Ft.**	**$4,940.00**	**$11,795.00**	**$0.00**	**$0.00**	**$13.40 /Month**	**$16,735.00**
REINFORCING BAR								
3210.010	Strip Footer Re-Bar	1.00 Ton	$1,400.00	$1,500.00			$2,900 /Ton	**$2,900.00**
3210.050	Peir Cap Re-Bar	2.50 Ton	$3,600.00	$4,700.00			$3,320 /Ton	**$8,300.00**
3210.080	Foundation Pier Re-Bar	0.32 Ton	$475.00	$750.00			$3,828 /Ton	**$1,225.00**
3210.240	Flat Plate Re-Bar	0.34 Ton	$390.00	$450.00			$2,470 /Ton	**$840.00**
3210.390	Frost Wall Re-Bar	0.08 Ton	$100.00	$140.00			$3,000 /Ton	**$240.00**
	REINFORCING BAR	**4.24 Ton**	**$5,965.00**	**$7,540.00**	**$0.00**	**$0.00**	**$3,185.14 /Ton**	**$13,505.00**
REINFORCING WIRE MESH								
3220.230	Slab on Deck Wire Mesh	1,700.00 Sq.Ft.	$450.00	$340.00			$.46 /Sq.Ft.	**$790.00**
3220.330	Stoop/Pad Wire Mesh	126.00 Sq.Ft.	$35.00	$40.00			$.59 /Sq.Ft.	**$75.00**
3220.530	Sidewalk Wire Mesh	170.00 Sq.Ft.	$45.00	$35.00			$.47 /Sq.Ft.	**$80.00**
	REINFORCING WIRE MESH	**1,996.00 Sq.Ft.**	**$530.00**	**$415.00**	**$0.00**	**$0.00**	**$.47 /Sq.Ft.**	**$945.00**
CONCRETE ACCESSORIES								
3250.080	Foundation Pier Accessories		$190.00	$140.00				**$330.00**
3250.135	Misc. Concrete Accessories		$1,050.00	$1,600.00				**$2,650.00**
3250.230	Slab on Deck Accessories		$580.00	$820.00				**$1,400.00**
3250.240	Plate Slab Accessories		$5.00	$15.00				**$20.00**
3250.330	Stoop/Pad Accessories		$10.00	$30.00				**$40.00**
3250.530	Sidewalk Accessories		$70.00	$130.00				**$200.00**
	CONCRETE ACCESSORIES		**$1,905.00**	**$2,735.00**	**$0.00**	**$0.00**		**$4,640.00**
CAST IN PLACE CONCRETE								
3300.005	Concrete Bulk				$1,375.00			**$1,375.00**
3300.010	Strip Footers	11.00 Cu.Yd.	$1,300.00	$500.00			$163.63 /Cu.Yd.	**$1,800.00**
3300.080	Pier Foundation	68.00 Cu.Yd.	$8,350.00	$4,140.00	$15.00	$1,250.00	$202.28 /Cu.Yd.	**$13,755.00**
3300.120	Elevator Wall	16.00 Cu.Yd.	$2,175.00	$750.00			$182.81 /Cu.Yd.	**$2,925.00**
3300.135	Misc. Concrete	85.00 Cu.Yd.	$10,920.00	$1,925.00		$1,250.00	$165.82 /Cu.Yd.	**$14,095.00**
3300.215	Elevator Slab					$1,250.00		**$1,250.00**
3300.230	Slab on Deck	24.00 Cu.Yd.	$3,940.00		$4,725.00	$2,500.00	$465.21 /Cu.Yd.	**$11,165.00**
3300.240	Flat Plate Slabs		$875.00	$385.00	$150.00	$1,250.00		**$2,660.00**
3300.330	Stoops/Pads	2.00 Cu.Yd.	$525.00		$290.00		$407.50 /Cu.Yd.	**$815.00**
3300.390	Frost Wall	2.50 Cu.Yd.	$280.00	$120.00			$160 /Cu.Yd.	**$400.00**
3300.510	Curb		$10.00					**$10.00**
3300.530	Sidewalk	2.10 Cu.Yd.	$640.00		$475.00		$530.95 /Cu.Yd.	**$1,115.00**
	CAST IN PLACE CONCRETE	**210.60 Cu.Yd.**	**$29,015.00**	**$7,820.00**	**$7,030.00**	**$7,500.00**	**$243.90 /Cu.Yd**	**$51,365.00**
MASONRY								
4200.100	Masonry Accessories	535.00 Sq.Ft.			$17,850.00		$33.36 /Sq.Ft.	**$17,850.00**
4200.110	Brick	535.00 Sq.Ft.						**$0.00**
4200.130	Precast Copings & Sills							**$0.00**
4200.210	Foundation Block	535.00 Sq.Ft.						**$0.00**
	MASONRY	**535.00 Sq. Ft.**	**$0.00**	**$0.00**	**$17,850.00**	**$0.00**	**$33.36 /Sq.Ft.**	**$17,850.00**
STRUCTURAL STEEL								
5100.100	Steel Fab. & Erection	47 Ton			$470,000.00		$10,000.00 /Ton	**$470,000.00**
5100.110	Wide Flange Columns							**$0.00**
5100.210	Wide Flange Beams							**$0.00**
5100.220	Tube Steel Beams				$52,600.00			**$52,600.00**
5100.315	Standard Angles							**$0.00**
5200.210	Steel Joists							**$0.00**
5300.210	Metal Floor Decking							**$0.00**
	STRUCTURAL STEEL	**1600.00 Sq.Ft.**	**$0.00**	**$0.00**	**$522,600.00**	**$0.00**	**$326.63 /Sq.Ft.**	**$522,600.00**

Depth Research: Commissioning Vs. Retro-Commissioning

A. Executive Summary

The industry research performed in this section focuses on the differences in the processes for commissioning of new construction and retro-commissioning of existing building equipment.

In the first part of this section a survey was developed in order to be distributed to industry personnel including owners, architects, contractors, and commissioning agents. The goal of the survey was to obtain the opinion of industry personnel on the use of commissioning and retro-commissioning processes.

The second part of this section contains the summary of the survey responses from the previous section along with interviews conducted with industry contacts. Responses depended on the persons experience with commissioning. The general opinions of those contacted were owner's cost savings on operation and maintenance of building systems, the contractor's reduction in call backs for warranty and comfort issues, and commissioning agents stress on the early introduction of the commissioning processes on a project.

Research of industry papers was conducted in the third section in order to obtain more information on the differences in the steps of the commissioning of new construction and retro-commissioning of existing building equipment. The commissioning process is broken down into five steps and the retro-commissioning process is broken down into four steps which are detailed in this section.

The summary and recommendation section includes a summary of the research conducted in this section along with recommendations for the use of commissioning processes and how this research related to the focus project for this report.

B. Overview

The commissioning of fit-out projects in existing facilities and retro-commissioning of existing facilities is the focus of the research conducted in this section. Commissioning of fit-out projects follow much the same process of that of new construction in that many of the same steps are followed; however the retro-commissioning process used to commission existing facilities that were originally constructed without the use of the commissioning process follow somewhat different steps. The processes of each of these styles of commissioning will be discussed in this section. The steps used to complete this research include:

1. Development of a survey to obtain the opinions of industry personnel on commissioning.
2. Compile information from this survey.
3. Research published material on commissioning and retro-commissioning.
4. Summarize research information to develop commissioning use recommendations for what types of projects would benefit the most from the commissioning and retro-commissioning processes.
5. Bibliography of sources utilized throughout research for this section.

C. Survey

My name is Devin C. Learn; I am an Architectural Engineering, Construction Management Option Student at Pennsylvania State University. I am conducting research on the commissioning process for construction, specifically looking at Healthcare construction. Below is a short word document survey developed to access the pros and cons of commissioning in projects within a healthcare facility. This survey is being released to Mechanical Contractors, Owners, General Contractors and Independent Commissioning Agencies. Your response will be compiled into a decision matrix to determine what type of projects will benefit the most from commissioning applications. Responses will be confidential and used solely for the academic purposes of my senior thesis research. Form of response can be hand written or typed scanned and emailed to dcl146@psu.edu or mailed to Devin C. Learn, 338 Reynolds Ave. Bellefonte, PA 16823. Results will be compiled and analyzed in mid March. Your response is greatly appreciated.

Sincerely
Devin C. Learn
Pennsylvania State University
Architectural Engineering
Construction Management

1. Your Name:
2. Current Company:
3. Role in Company:
4. Have you ever been involved in the commissioning process?
5. If so what type of projects were they used in?
6. How do you feel commissioning affected the outcome of the project?
7. What do you feel could have been done differently in respect to the commissioning process?
8. Have any of the projects that you have worked on or have knowledge utilized the commissioning process in an existing facility such as a hospital were previous projects did not utilize the commissioning process?

9. If so how do you feel commissioning affected the outcome of these projects versus projects involving new construction of facilities?
10. In your opinion what are some of the pros of utilizing commissioning?
11. In your opinion what are some of the cons of utilizing commissioning?
12. Do you feel that current and future project within existing facilities would benefit from the implementation of commissioning?
13. What issues do you think effect the decision to utilize commissioning?
14. Who do think should be involved in the decision process to decide to what extent commissioning should be implemented in a project?

D. Survey Results

Due to limited response to the actual survey most of the information obtained for this section comes from personal conversations with industry contacts. While not the planned method for compiling information a broad spectrum of opinions was still acquired for the purposes of this research. The summary of information in this section has been broken down into three sources owners, contractors, and commissioning agents.

Owners-

An owner's opinion on commissioning depends greatly on their experience and knowledge of the commissioning process. Owners that have limited experience with commissioning often have unrealistic expectations when someone comes to them and says that they can save them money on life-cycle costs of their building. Once an owner understands the commissioning process and begin to comprehend its benefits they can more easily weight the decision on whether or not it fits into their goals and financial plan. Type of facility can affect the benefits of commissioning, specifically whether or not the facility has its own maintenance staff such as a university or healthcare facility or if they outsource their maintenance.

The intended use of a building also plays heavily on an owner's willingness to consider implementing the commissioning process. For owners such as developers the commissioning process may be less desirable because it comes with a higher initial cost of which they will not own the building long enough to benefit from the life-cycle cost savings. However, depending on the final use of the building being constructed by a developer they may choose to utilize the commissioning process and use it as a marketing tool in obtaining tenants. A building that will be used for labs or healthcare facilities tend to benefit more from the commissioning process due to the complexity of the systems used and there requirements.

Commissioning when implemented successfully is a definite advantage over the long term and is a sound investment. The major benefits are reduced operation and maintenance costs, less comfort complaints from tenants, and incentives.

Contractors-

Contractors have mixed feelings about commissioning due to some of the impacts that it has on a project. As with owners some of these feelings come from the fear of the unknown. Contractors and subcontractors that do not have experience with commissioning fear that having another outside consultant looking over their shoulder will interfere with their construction methods and stretch out schedules that are often very limited on extra time. Even though having a commissioning professional within the contractor's own company is an option most fear that the additional cost of having someone dedicated to just commissioning services will not be utilized enough to offset the cost, as they may not always have projects under construction that are utilizing commissioning. This may change in the future as more projects begin to use the commissioning process to some extent but until that happens this may not be a feasible option for many companies.

Contractors that do have experience with commissioning are starting to see some of the benefits of the process. These benefits include higher owner satisfaction rates and reduced expenses with fewer call backs for warranty work. All contractors represented in this research utilized outside commissioning consultants but verified that as commissioning becomes more widespread hiring a commissioning professional at their company will become a more feasible option.

Commissioning Agents-

Commissioning agents have seen a steady increase in the use of commissioning processes in construction over the past few years as more owners are starting to realize the long term benefits. With the increase in the use of commissioning repeat clients are starting to involve the commissioning agents earlier on in the design and pre-design planning phases. This is one of the things that commissioning agents stress as an important issue in helping to reduce

commissioning costs as a whole on a project due to the reduction in design rework. If the use of commissioning on a project is identified early on then the commissioning agent can be involved in the initial design which has been found to make the process more efficient.

E. Research

The intent of the commissioning vs. retro-commissioning research is to compare and contrast the process for commissioning of new construction and the retro-commissioning of facilities that were originally constructed without the use of the commissioning process. The information contained in this section comes from various published documents of the commissioning and retro-commissioning processes. The intent of the research performed is to formulate a decision matrix for what types of projects would benefit the most from each of these types of commissioning processes. The summary and decision matrix developed from this research will be presented in part 4 of this section under research summary.

a. Introduction to Commissioning/Retro-Commissioning-

Building commissioning is a method of risk reduction for new construction projects. Commissioning activities for new construction follow the construction process from pre-design through construction and acceptance. ASHRAE Guideline 1-1996 defines commissioning as the process of ensuring that systems are designed, installed, functionally tested, and capable of being operated and maintained to perform in conformity with the design intent.

Retro-commissioning a term used to define existing building commissioning, is an event in the life of a building that applies a systematic investigation process for improving and optimizing a building's operations and maintenance. Retro-commissioning occurs after construction, as an independent process that usually focuses on energy using equipment such as mechanical equipment, lighting, and related controls. Depending on the needs of the owner it may or may not emphasize bringing the building back to its original intended design. This also depends on whether the original design documentation exists or is still relevant. Retro-commissioning is applied to buildings that have not previously been commissioned to ensure system functionality. Depending on the current needs of the owner, the budget, and the condition of the equipment the retro-commissioning process most often focuses on the dynamic energy using systems

with the goal of reducing energy waste, obtaining energy cost savings, and identifying and fixing existing problems.

In general commissioning and retro-commissioning are used to ensure that the building meets the owner's needs in terms of functionality of systems that ensure occupant comfort, energy use, and operation and maintenance costs. Regardless of what type of commissioning is applied the extent to which it is applied depends on several variables such as complexity of building systems, type of facility, and intended use.

b. Process Steps-

Since the final outcome of any form of commissioning is to obtain a building with efficient system operation, the biggest difference between commissioning of new construction and retro-commissioning of existing buildings are the steps performed in the process. The steps for these two different forms of commissioning will be detailed below. It is important to remember that these are basic guidelines as some steps may vary depending on specific project requirements.

Commissioning of New Buildings:

Commissioning of new construction projects is broken down into 5 steps conception or pre-design phase, design phase, construction/installation phase, acceptance phase, and post-acceptance phase.

Step 1- The first step conception or pre-design phase is not always performed during the pre-design phase of the project but it is in the opinion of industry professionals that if at all possible the decision to commission a building should be made early so that this step can be performed early to reduce rework and additional cost of redesign. Early involvement of commissioning professionals also aids in selection of a design team that is experienced in the commissioning process which will help ensure a successful project. Items to be completed in the first step of the commissioning process for new construction include the development of commissioning objectives for the project, hiring of

commissioning provider, development of design phase commissioning requirements and selection of the design team.

Step 2- The second step is the design phase of the commissioning process. This step is important to receiving accurate bid information from contractors and subcontractors because specifications for bid documents are developed. If this step is not completed before the project goes out for bid the budget developed will not be accurate, therefore acquiring realistic project budget information for funding will not be possible. Another important reason for the development of specifications is so the contractors preparing a bid can identify equipment that will have long lead times so they can be ordered immediately after awarding of the project. Items to be completed in this step of the process include a commissioning review of the design intent, writing the commissioning specifications for bid documents, awarding of job to contractor, and development of commissioning plan.

Step 3- The construction/installation phase is a phase in which design, commissioning, and contractor personnel will be required to work closely together to ensure that all specifications are being met as far as procurement of equipment and installation procedures. For this reason it is important to maintain a free flow of information between the team members from all of these areas as well as hold meetings in which all teams are represented. Items to be completed in the construction/installation phase include gathering and reviewing documentation, holding commissioning scoping meetings and finalize plan, development of pre-test checklists, and start up equipment or perform pre-test checklists to ensure readiness for functional testing during acceptance.

Step 4- The acceptance phase includes executing functional tests and diagnostics, fixing deficiencies, retesting and monitoring as needed, verifying operator training, review of operation and maintenance manuals, and building/retrofit acceptance by owner. This phase is intended to verify that all steps leading up to this point have been completed in an acceptable manor and that all equipment is functioning to design specifications.

Step 5- The post-acceptance phase includes preparing and submittal of final report, performing deferred tests (if needed), and development of re-commissioning plan/schedule. At this point substantial completion of the project has been reached and the goal now is to develop a plan to periodically verify that the systems are still operating efficiently.

Retro-Commissioning of Existing Building Equipment:

Retro-commissioning of existing building equipment is broken down into 4 steps the planning phase, investigation phase, implementation phase, and project hand-off and integration phase. The biggest difference between the steps in the commissioning of new building and the retro-commissioning of existing buildings and equipment is the lack of the design phase. This occurs for an obvious reason there is already equipment in place, however this equipment must be analyzed to determine how it is functioning.

Step 1- The first step in the retro-commissioning process is the planning phase. This phase is very similar to the conception or pre-design phase in the commissioning of new building process; however, it is made more complicated due to the often incomplete documentation from the original system components. Items to be completed in this phase are development of commissioning objectives, hiring of commissioning provider, review of available documentation and obtain historical utility data, and development of the retro-commissioning plan.

Step 2- The investigation phase includes performing site assessments, obtain or develop missing documentation, develop and execute diagnostic monitoring and test plans, develop and execute functional test plans, analyze results, develop master list of deficiencies and improvements, and recommend most cost-effective improvements for implementation. During this phase the real scope of work will be developed and a realistic feasibility analysis can be performed based on the information obtained. It is difficult to assume what changes will need to be made before the actual tests of the existing equipment are performed.

Step 3- The implementation phase of the retro-commissioning process can be a complicated step depending on several variables which include accessibility of

existing equipment and how downtime of equipment will affect building tenants among others. Items to be completed during this phase include implementation of repairs and improvements, retest and re-monitor for results, fine-tune improvements if needed, and revise estimated energy savings calculations.

Step 4- The project hand-off and integration phase of the retro-commissioning of existing buildings and equipment include all the same items as the post-acceptance phase of commissioning new buildings, which are preparation and submittal of the final report, performing deferred tests (if needed), and development of re-commissioning plan/schedule. However, one difference in these two forms of commissioning is that the owner of a building that has utilized the retro-commissioning process can easily document the cost savings with the updated systems. This makes it important to review realistic savings goals early in the project to avoid negative feelings by the owner once the process has been completed.

The steps for commissioning of new construction and retro-commissioning are illustrated below in Table 2.

Table 2. New-construction commissioning vs retrocommissioning

New-construction commissioning	Retrocommissioning (existing equipment)
1. Conception or pre-design phase (a) Develop commissioning objectives (b) Hire commissioning provider (c) Develop design phase commissioning requirements (d) Choose the design team	**1. Planning phase** (a) Develop commissioning objectives (b) Hire commissioning provider (c) Review available documentation and obtain historical utility data (d) Develop retrocommissioning plan
2. Design phase (a) Commissioning review of design intent (b) Write commissioning specifications for bid documents (c) Award job to contractor (d) Develop commissioning plan	**[No design phase activities]**
3. Construction/installation phase (a) Gather and review documentation (b) Hold commissioning scoping meeting and finalize plan (c) Develop pre-test checklists (d) Start up equipment or perform pre-test checklists to ensure readiness for functional testing during acceptance	**2. Investigation phase** (a) Perform site assessment (b) Obtain or develop missing documentation (c) Develop and execute diagnostic monitoring and test plans (d) Develop and execute functional test plans (e) Analyze results (f) Develop Master List of deficiencies and improvements (g) Recommend most cost-effective improvements for implementation
4. Acceptance phase (a) Execute functional tests and diagnostics (b) Fix deficiencies (c) Retest and monitor as needed (d) Verify operator training (e) Review O&M manuals (f) Building/retrofit accepted by owner	**3. Implementation phase** (a) Implement repairs and improvements (b) Retest and remonitor for results (c) Fine-tune improvements if needed (d) Revise estimated energy savings calculations
5. Post-acceptance phase (a) Prepare and submit final report (b) Perform deferred tests (if needed) (c) Develop recommissioning plan/schedule	**4. Project hand-off and integration phase** (a) Prepare and submit final report (b) Perform deferred tests (if needed) (c) Develop recommissioning plan/schedule

(A Practical Guide for Commissioning Existing Buildings; By Tudi Haasl, Portland Energy Conservation Inc. and Terry Sharp, Oak Ridge National Laboratory)

c. Benefits and Costs-

There are many variables to the benefits and costs of commissioning and retro-commissioning many of which have to do with the needs of owner's and project specific requirements. Some key factors that can have a direct impact in developing a commissioning budget include:

- When the commissioning process starts (during design, construction, or post construction)
- The number and complexity of systems to be commissioned
- Complexity of the systems
- The level of detail required during the commissioning process (does it include documenting and witnessing all equipment start-up, verification tests, spot checking the balancing report, etc.?)
- Deliverables (design intent document, number of design reviews, commissioning plan, O&M manual review, final report, etc.)
- Allocation of costs (will the budget allow for increased design fee, increased contractor bids, training time for O&M personnel, the commissioning consultant's fee, etc.)
- Type of project (design-build, plan and spec, retrofit, etc.)

(Whole Building Design Group webpage; http://www.wbdg.org/project/plan_comm_process.php)

For this reason each project should be looked at on an individual basis. Below is a summary of average costs and standard benefits of commissioning and retro-commissioning.

Commissioning costs for new buildings average about $1 per square foot and the payback period averages 4.8 years. These costs vary widely with scope and supply/demand of commissioning providers. Paybacks also vary depend on these variables as well as the quality of the commissioning provider. Direct and indirect benefits of commissioning buildings that factor into payback periods and return on investment include:

- Savings in energy cost and improved building performance
- Improved indoor air quality, comfort and increased productivity by building users
- Early detection of potential problems (the sooner problems are resolved, the less expensive they are to fix)
- Fewer change orders to the owner during construction
- Precise tune-up and operation of systems and applicable controls
- Better building documentation
- Trained building operators and maintenance staff
- Shortened occupancy-transition period
- Reduced maintenance, operation, and equipment replacement cost

(Industry Pages: Two Steps to Commissioning Success; By James H. Shoop, CCP Secretary, Building Commissioning Association)

Retro-commissioning of existing building costs vary in much the same way as commissioning for new buildings including complexity of systems, number of pieces of equipment, and the objectives or scope of the retro-commissioning project rather than by building type. In a study of 44 existing buildings showed a cost of between $10,000 and $52,000, resulting in whole-building energy savings of 5-15%. These costs resulted in a square foot cost of $.05 to $.43. Retro-commissioning of existing buildings delivers simple paybacks on investments that rarely exceed 4 years, and were often 2 years or less. Benefits of retro-commissioning existing buildings include:

- Identifies system operating, control, and maintenance problems
- Aids in long-term planning and major maintenance budgeting
- Helps ensure a healthy, comfortable, and productive working environment for occupants
- Reduces energy waste and ensures that energy-using equipment operates efficiently
- Provides energy cost savings that often pay back investment

- Reduces maintenance costs; reduces premature equipment failure
- Provides complete and accurate building documentation; expedites troubleshooting
- Provides appropriate training to operating staff to increase skill levels; increases staff effectiveness in serving customers and tenants
- Reduces risk and increases the asset value of the building

(A Practical Guide for Commissioning Existing Buildings; By Tudi Haasl, Portland Energy Conservation Inc. and Terry Sharp, Oak Ridge National Laboratory)

F. Summary

The research conducted above in part 3 of this section will be summarized and a commissioning use recommendation for what types of building will benefit most from the commissioning and retro-commissioning processes. The recommendations given for use of commissioning given are not intended to be the final decision makers for the implementation of commissioning or retro-commissioning, instead a simple basic guideline that can be implemented in the early stages of the decision making process. Other project and owner specific issues will need to be accounted for on a project by project basis in order to determine if these processes should be implemented.

a. Summary of Research-

The research conducted in part 3 of this section was conducted with the intent of determining the differences in the processes of commissioning new construction and retro-commissioning of existing facilities. This is meant to be a summary of basic principles and standards as each project may vary from the normal procedure depending on specific need or specifications.

The first and most obvious difference between commissioning and retro-commissioning is at what stage they begin. Commissioning of new buildings begins as stated in its description at some point in the planning/design through construction of a new building. Retro-commissioning however is a term used to define the commissioning process performed on an existing building that has not previously utilized commissioning. This obvious difference plays a major role in what steps are performed in the commissioning process.

As most buildings are designed, built and occupied before there is a plan in place for their operation and maintenance this can lead to premature equipment failure and higher energy costs if poor operation and maintenance is present. Commissioning can benefit these buildings by verifying that equipment is installed and operating properly, resulting in a longer lifespan, increased operating reliability and fewer repairs. As well as ensuring that building documentation is accurate and complete. This benefits the owner as well as the contractor with

lower operating and maintenance costs for the owner and fewer call backs to the contractor.

The commissioning of fit-out spaces that would be implemented for Lancaster General Hospital 5th and 6th floor fit-out project would follow the method for commissioning of new building systems. This is because even thought the project takes place within an existing building all of the mechanical systems that will support the 5th and 6th floor shell space will be new units installed during construction.

The first step of the commissioning process which includes development of commissioning objectives, hiring of commissioning provider, development of design phase commissioning requirements, and choosing the design team would remain the same for the most part except the selection of the design team. This is because Lancaster General Hospital uses the same design team for almost all of their work to maintain a level of consistency. An outside commissioning consultant would have to be identified as neither the design team or contractor for the project has a commissioning professional on staff.

The second step of the commissioning process would also remain mostly the same with commissioning review of design intent, writing of commissioning specifications for bid documents, awarding of job to contractor, and development of commissioning plan. The changes would in awarding of job to contractor because Benchmark Construction Company, Inc. bids jobs for the hospital on a negotiated bid basis. Therefore the commissioning specifications for bid documents would needed to be coordinated with Benchmark in order to obtain a budget for the project.

The remaining three steps in the commissioning process would remain mostly intact with training of operators and maintenance personnel being conducted with the plant engineering staff for Lancaster General Hospital who conduct all operation and maintenance work for the hospital and their facilities.

Some issues with utilizing commissioning on this project would be the learning curve involved with the inexperienced owner, contractor and subcontractors for the project. The design team also has minimal experience with

the commissioning process. Some of these issues could be minimized by holding meetings with the commissioning agent to explain the process in detail and answer any questions. However, since hospitals utilize many complex systems commissioning could help improve the long-term efficiency of the spaces being fit-out in this project.

b. Commissioning Use Recommendations-

Based on the research conducted in the creation of this report there are several items that should be considered while making the decision to utilize commissioning or retro-commissioning on a project. These items include the intended use of the building, complexity of systems used in the building, owner's goals, and availability of commissioning personnel.

Buildings that contain laboratory spaces or healthcare facilities tend to have more complex mechanical, electrical and piping systems. For this reason these types of buildings may benefit more from the commissioning process than buildings such as warehouses. These types of facilities also tend to have complicated control systems that need to function properly in order for the systems to meet their potential. At least on a general basis it is safe to say that these types of buildings would benefit from the testing and documentation that comes with the commissioning process to ensure that the systems are operating as specified which will help them run more efficient, therefore reducing operating costs and comfort issues.

The goals of the owner also play into the decision making process of whether or not to utilize the commissioning process. If an owner such as a developer is constructing the building they may be more interested in first cost because they will not own the building long enough to recoup the savings. Also depending on the owner's budget for construction and yearly operation and maintenance it may be easier for them to absorb the increased yearly costs than the first cost increase.

The availability of experienced commissioning personnel can have an affect on the cost of commissioning a project; therefore this may also play into the decision making.

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Breadth 1 Structural Analysis: Cast-In-Place Vs. Pre-Cast Floor System

A. Executive Summary

In the structural analysis performed in this section a change in the floor system for the Cardiac Elevator Addition is proposed. The designed floor system consists of cast-in-place concrete on composite metal decking and the proposed new system is pre-cast concrete floor planks.

Calculations were performed in the first section of this analysis to determine what size pre-cast concrete floor plank would be required to replace the 3 1/2" thick 4000psi lightweight concrete slab on 2"-20Ga. composite metal deck. The pre-cast floor plank selected based on load and span capacities was a (T6-E23) 6" x 24" pre-cast concrete plank with 2" leveling top coat.

A supplier for pre-cast concrete floor planks was identified and availability was checked in the second section of this analysis. A possible supplier for the pre-cast concrete floor planks is Strescon Industries, Inc. located in Langhorne, PA. Langhorne, PA is located northeast of Philadelphia with an estimated travel time from Langhorne to Lancaster of 2 hours.

A detailed cost analysis was performed to determine what cost savings if any would be possible with the switch to the proposed system. The design system costs approximately $10,530.00 with the proposed system coming in approximately $1,612.00 more expensive at $12,142.00.

A schedule reduction analysis was then performed to determine any schedule savings with the proposed system. The estimated schedule savings is 2 days with the use of the proposed system.

The next section of this analysis contains a constructability review for the Cardiac Elevator Addition project. There are several site characteristics that make this a complicated site. These items are identified and accommodations are described in this section.

B. Overview

The focus of this section is the analysis of the structural system in place for the Cardiac Elevator Addition at Lancaster General Hospital, specifically looking at the benefits and restriction of switching from a cast-in-place concrete on composite metal decking to pre-cast concrete planks for the elevator lobbies. While structural analyses will be completed in this section a cost analysis and schedule reduction will be the main contributing factors to the final recommendation. Also included in this section will be a brief constructability review to address the extremely condensed site for the elevator addition and to address the air intake vents for the hospital that are located directly adjacent to the site.

In order to analyze the switch in structural system from cast-in-place concrete on composite metal decking to pre-cast concrete planks several items will need to be addressed. These items include

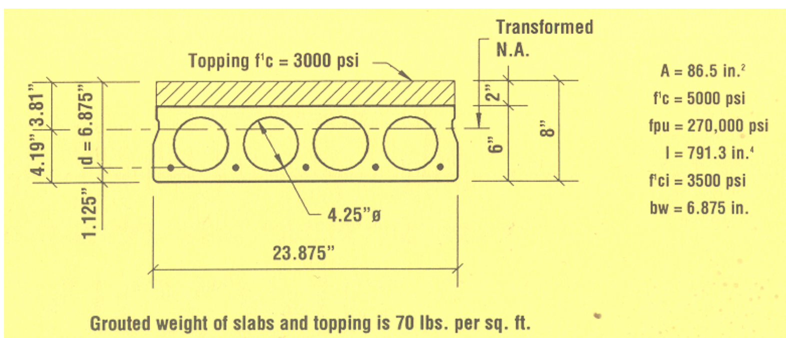
1. Calculations to verify design requirements for the proposed pre cast members
2. Determining a supplier and availability of pre-cast members
3. Cost comparison between the two systems
4. Identification of possible reduction in schedule with the proposed new system.
5. Constructability Review
6. Conclusions

C. Calculations

The span of the pre-cast concrete plank would be 14' for all applications. By evaluating the load chart included below for the (T6-E23) 6" x 24" pre-cast concrete plank with 2" leveling top coat we can see that the allowable load is 294 lbs. per square foot. Using the standard live load of 150lbs. per

Standard Designation	7-Wire P/S Strand Combination	P/S Strand Area Sq. In.	Ultimate Bending Moment, ø Mn in Kip. Ft. per Unit	SIMPLE SPAN IN FEET																	ø Vcw in Kips per Unit
				12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	
T6-E35	3-7/16	.345	41.7						282	246	214	188	165	145	128	113	100	88	77	68	12.43
T6-E31	2-1/2	.306	37.7					289	249	216	188	164	144	126	110	96	84	74	64	56	11.88
T6-E23	2-7/16	.230	29.3			294	249	211	181	155	133	115	99	85	73	62	53	44			11.60
T6-E17	2-3/8	.170	22.2		251	209	174	146	123	103	87	73	61	50							11.38

* INCLUDES THE LIVE LOAD PLUS ANY DEAD LOAD THAT IS ADDITIONAL TO THE WEIGHT OF THE BARE GROUTED SLABS & TOPPING



square foot designated for hospital use it is determined that this member is acceptable.

Several assumptions were made in order to complete this analysis. The first assumption is that the originally designed structural steel frame is capable of supporting the weight of cast-in-place system as approximately 145lbs. per sq. ft. as the weight of the pre-cast concrete hollow deck planks is lighter at 70lbs. per sq. ft. For the purposes of this analysis any possible reductions in structural steel frame were not determined due to the assumption that the weight and bracing requirements for the elevator equipment controlled design. Other assumptions include the camber and deflection of the pre-cast concrete hollow core deck planks are within the allowable limit.

D. Supplier/Availability

A possible supplier for pre cast concrete planks is Strescon Industries, Inc. located in Langhorne, PA. Langhorne, PA is located northeast of Philadelphia with an estimated travel time from Langhorne to Lancaster of 2 hours. They feature a Flexicore pre cast concrete plank that will adequately replace the cast in place concrete slab. Availability of these planks as in all pre-cast concrete members is something that needs to be evaluated as they present a longer lead time than cast-in-place lead time as time for design and fabrication in an off-site plant is required. Since the selected member is a standard size and design availability will not be an issue for this application.

E. Cost Analysis

In order to complete the cost comparison between the two structural systems the cost for the cast-in-place concrete system must be broken out of the original estimate. This was completed by using project cost data as well as RSMeans construction cost data to fill in any of the amounts that were included in subcontractor costs for the project. A worksheet of this information has been prepared and is included below. From this worksheet we can see that the total cost for the cast-in-place concrete system on floors 5-8 is $10,530.00. The detailed cost break down can be found on ***page 63***.

Construction Cost for Cast-in-Place Concrete on Composit Metal Deck				
Reinforcing Wire Mesh				
Description	Quantity	Labor $	Material $	Total $
6x6-6/6 w1.4	270 sqft	$47.00	$60.00	$107.00
6x6-6/6 w1.4	270 sqft	$47.00	$60.00	$107.00
6x6-6/6 w1.4	270 sqft	$47.00	$60.00	$107.00
6x6-6/6 w1.4	270 sqft	$47.00	$60.00	$107.00
SOD Wire Mesh	1080 sqft	$188.00	$240.00	$428.00
Slab on Deck Accessories				
Description	Quantity	Labor $	Material $	Total $
Drilled Dowels				
24" #4 epoxy filled	9 each	$119.00	$80.00	$199.00
24" #4 epoxy filled	9 each	$119.00	$80.00	$199.00
24" #4 epoxy filled	9 each	$119.00	$80.00	$199.00
24" #4 epoxy filled	9 each	$119.00	$80.00	$199.00
SOD Accessories	36	$476.00	$320.00	$796.00
Cast in Place Concrete				
Description	Quantity	Labor $	Material $	Total $
4000psi litewt conc	3.75 cuyd	$0.00	$453.00	$453.00
4000psi litewt conc	3.75 cuyd	$0.00	$453.00	$453.00
4000psi litewt conc	3.75 cuyd	$0.00	$453.00	$453.00
4000psi litewt conc	3.75 cuyd	$0.00	$453.00	$453.00
Slab on Deck	15 cuyd	$0.00	$1,812.00	$1,812.00
Place/Finish Slab on Deck				
Description	Quantity	Labor $	Material $	Total $
Place/Finish	270 sqft	$419.00	$0.00	$419.00
Place/Finish	270 sqft	$419.00	$0.00	$419.00
Place/Finish	270 sqft	$419.00	$0.00	$419.00
Place/Finish	270 sqft	$419.00	$0.00	$419.00
Conc. Boom Pump	1 day	$0.00	$0.00	$1,850.00
Slab on Deck		$1,676.00	$0.00	$3,526.00
Composite Metal Decking				
Description	Quantity	Labor $	Material $	Total $
2" 20ga.	270 sqft	$92.00	$540.00	$632.00
2" 20ga.	270 sqft	$92.00	$540.00	$632.00
2" 20ga.	270 sqft	$92.00	$540.00	$632.00
2" 20ga.	270 sqft	$92.00	$540.00	$632.00
Metal Decking	1080 sqft	$368.00	$2,160.00	$2,528.00
Structural Steel Beam				
Description	Quantity	Labor $	Material $	Total $
W12 x 16	16 lf.	$43.00	$317.00	$360.00
W12 x 16	16 lf.	$43.00	$317.00	$360.00
W12 x 16	16 lf.	$43.00	$317.00	$360.00
W12 x 16	16 lf.	$43.00	$317.00	$360.00
Beam	64 lf.	$172.00	$1,268.00	$1,440.00
Total Cost for Cast-in-Place Concrete slabs floors 5-8				**$10,530.00**

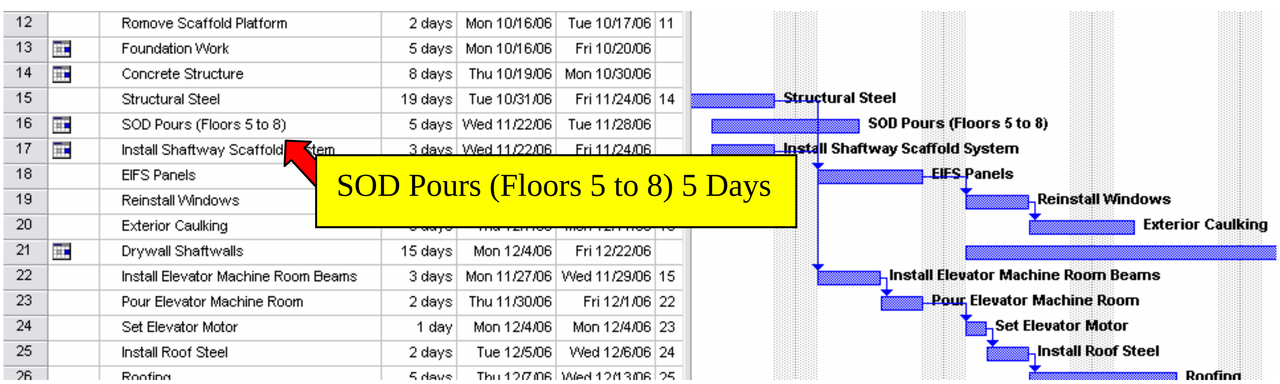
The next step is to formulate a worksheet for the cost of the pre-cast concrete plank system. This was complete by using project cost data as well as RSMeans construction cost data to fill in any of the amounts that were included in subcontractor costs for the project. There are several items that are no longer required for this system that were included in the cost for the cast-in-place system. These items include the reinforcing wire mesh, slab on deck accessories, composite metal decking and structural steel beam. The structural steel beam was used to support the cast-in-place system but is no longer needed for the pre-cast system. There is still a need for cast-in-place concrete to be used with the pre-cast system in order to provide the 2” topping slab over the pre-cast planks. This will also cause the placement and finishing costs to be included with the pre-cast system. Even with the reduction of several items from the cast-in-place system the pre-cast system still comes in more expensive at $12,142.00. This represents an increase in cost of $1,612.00 which is not a large increase and would not make a substantial impact on the outcome of the project; however, it does not indicate the desired reduction in cost that would justify a switch in structural systems from the cast-in-place concrete system to the proposed pre-cast concrete system. The detailed cost break down can be found on ***page 65***.

Construction Cost for Pre-Cast Concrete Planks				
Pre-Cast Planks				
Description	Quantity	Labor $	Material $	Total $
T6-E23	270 sqft	$261.00	$1,693.00	$1,954.00
T6-E24	270 sqft	$261.00	$1,693.00	$1,954.00
T6-E25	270 sqft	$261.00	$1,693.00	$1,954.00
T6-E26	270 sqft	$261.00	$1,693.00	$1,954.00
Pre-Cast Planks	1080 sqft	$1,044.00	$6,772.00	$7,816.00
Cast in Place Concrete				
Description	Quantity	Labor $	Material $	Total $
4000psi litewt conc	1.67 cuyd	$0.00	$200.00	$200.00
4000psi litewt conc	1.67 cuyd	$0.00	$200.00	$200.00
4000psi litewt conc	1.67 cuyd	$0.00	$200.00	$200.00
4000psi litewt conc	1.67 cuyd	$0.00	$200.00	$200.00
Slab on Deck	7 cuyd	$0.00	$800.00	$800.00
Place/Finish Topping Slab				
Description	Quantity	Labor $	Material $	Total $
Place/Finish	270 sqft	$419.00	$0.00	$419.00
Place/Finish	270 sqft	$419.00	$0.00	$419.00
Place/Finish	270 sqft	$419.00	$0.00	$419.00
Place/Finish	270 sqft	$419.00	$0.00	$419.00
Conc. Boom Pump	1 day	$0.00	$0.00	$1,850.00
Topping Slab		$1,676.00	$0.00	$3,526.00
Total Cost for Pre-Cast Concrete Planks floors 5-8				**$12,142.00**

F. Schedule Reduction

Schedule reduction will not be a large contributing factor in this analysis due to the relatively small quantity of concrete being replaced. The on-site tower crane will be used for the setting of the pre cast concrete planks in substitution for the concrete boom pump application of the cast-in-place slabs. The setting of the pre-cast planks will take approximately the same amount of time as placing the wet concrete, however, any delays in placement due to weather or need of the helicopter landing pad adjacent to the site requiring the crane to shut down for a period of time will not lead to spoils of material as would occur if shut downs were required during placement of cast in place concrete. These occurrences are few but often come with little warning and as there are no accessible areas to dump large quantities of waste concrete could cause a serious problem.

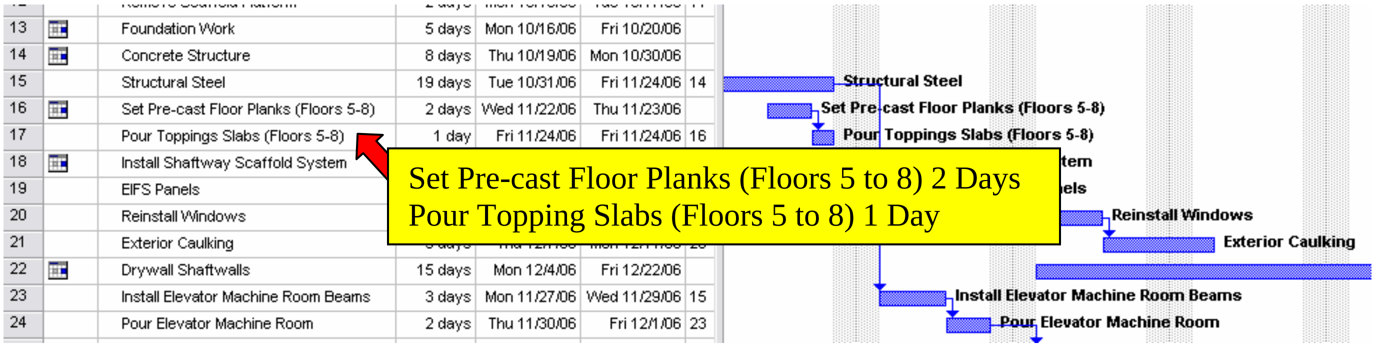
The original schedule shown below indicates 5 days for the slab-on-deck concrete pours for floors 5 to 8 which are the slabs proposed to be replaced by pre-cast concrete planks in this section. These 5 days include the placement of 2" – 20Ga. composite steel deck that is used as the support and bottom formwork for the cast-in-place concrete.



12	Romove Scaffold Platform	2 days	Mon 10/16/06	Tue 10/17/06	11
13	Foundation Work	5 days	Mon 10/16/06	Fri 10/20/06	
14	Concrete Structure	8 days	Thu 10/19/06	Mon 10/30/06	
15	Structural Steel	19 days	Tue 10/31/06	Fri 11/24/06	14
16	SOD Pours (Floors 5 to 8)	5 days	Wed 11/22/06	Tue 11/28/06	
17	Install Shaftway Scaffold [illegible]tem	3 days	Wed 11/22/06	Fri 11/24/06	
18	EIFS Panels	[illegible]	[illegible]	[illegible]	[illegible]
19	Reinstall Windows	[illegible]	[illegible]	[illegible]	[illegible]
20	Exterior Caulking	[illegible]	[illegible]	[illegible]	[illegible]
21	Drywall Shaftwalls	15 days	Mon 12/4/06	Fri 12/22/06	
22	Install Elevator Machine Room Beams	3 days	Mon 11/27/06	Wed 11/29/06	15
23	Pour Elevator Machine Room	2 days	Thu 11/30/06	Fri 12/1/06	22
24	Set Elevator Motor	1 day	Mon 12/4/06	Mon 12/4/06	23
25	Install Roof Steel	2 days	Tue 12/5/06	Wed 12/6/06	24
26	Roofing	5 days	Thu 12/7/06	Wed 12/13/06	25

A negligible reduction in the 19 day structural steel erection will be applicable due to the elimination of the W12x16 steel beam on each of the 4 floors. The schedule for the concrete placement on floors 5 to 8 was reduced by 2 days with the proposed new system. This does not represent a large

savings in the scale of the project and therefore is not a justifiable proponent to switch to the new pre-cast concrete plank system.

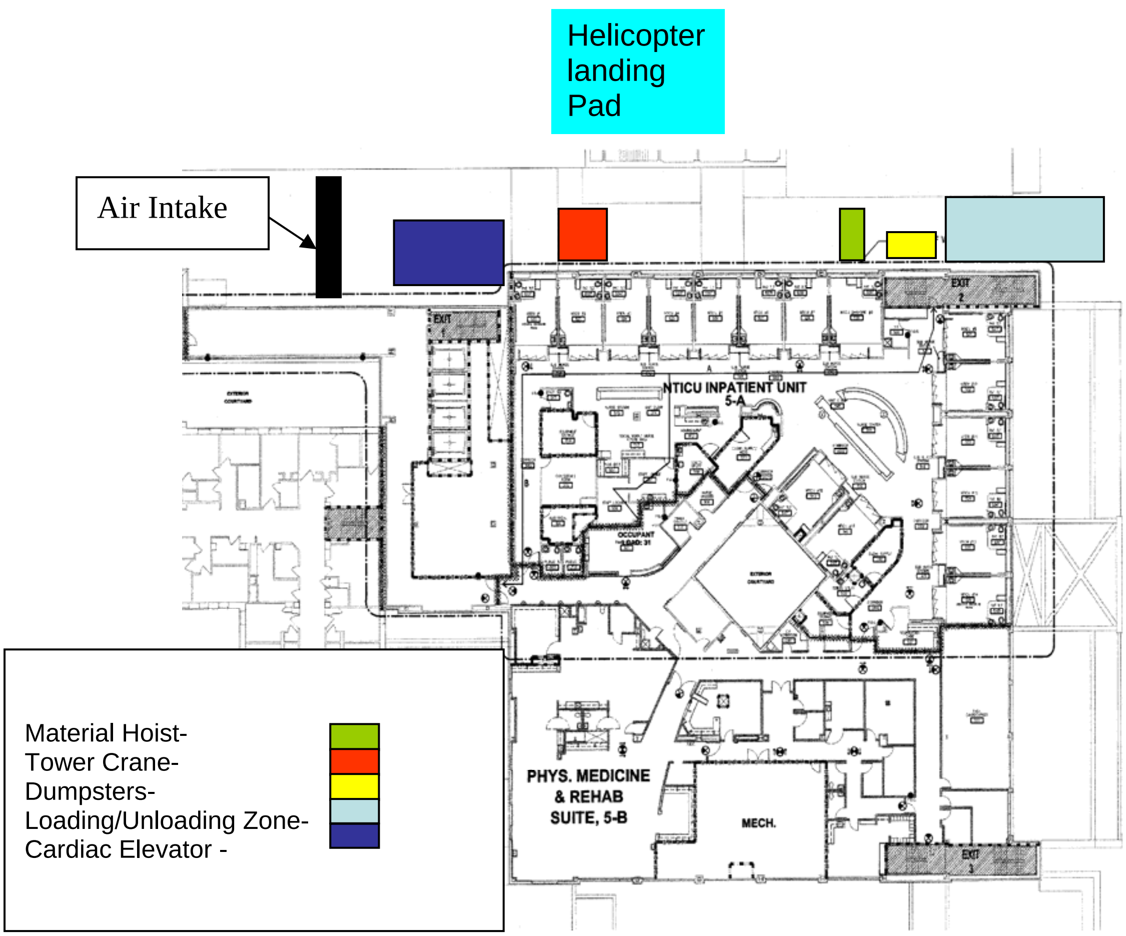


G. Constructability Review

There are several issues with the site that the Cardiac Elevator Addition is located on. These include very limited access to the actual location of the Elevator, small work area within the site, very limited material and equipment storage, and the main air intakes for the hospital being located on the wall directly adjacent to the site. Other complications include the helicopter landing pad for the hospital being located on the roof of the building directly adjacent to the site.

a. Site Plan-

The site for this project is extremely constricted. The items that must be located on this site include a tower crane, material hoist, loading/unloading zone, loading dock, dumpsters, material and equipment storage, and portable toilets. These items are places as depicted in the site plan below.



b. Site Access-

Site access to the cardiac elevator addition site is limited to the opening pictured below from the parking lot located under the Lime Street Building of the hospital. All materials and equipment had to either come through this opening or be lifted into the site by the tower crane. This meant that any items that were not to be lifted into the site by the tower crane had to be unloaded from trucks in the loading/unloading zone and carried into the site through the garage. This can become a tiring and tedious process but there are limited options for this site.

Figure 14 - Access to Elevator Site

c. Material & Equipment Storage-

There is a small amount of space for storage of materials and equipment around the base of the tower crane as well as a small fenced off area in the parking lot located under the Lime Street Building adjacent to the elevator site. The lack of storage and lay-down area on this project leads to the implementation of just-in-time delivery methods. However, even this method proves challenging due to the small loading and unloading zone with room for just one truck to unload at a time located off lime street which is a one way street with limited parking on either side. All equipment that cannot be fit into these small spaces must be stored off site when not in use.

Figure 15 – Material Storage

d. Air Intakes-

The air intakes for the hospital are located directly adjacent to the site for the construction site for the cardiac elevator addition. These air intakes had to be protected throughout the duration of the project. In order to help alleviate any exhaust or dust from entering the vents during construction shafts were constructed and placed around the intakes with an opening at the top so that all air drawn into the intakes came from well about the construction taking place. Along with this shaft there was also construction filters placed on the intakes in order to filter out any dust that made its way into the intakes. These filters were changed upon completion of the project.

Figure 16 – Air Intake (1)

Figure 17 – Air Intake (2)

E. Helicopter Landing Pad-

The helicopter landing pad is used for the transport of patients that are in critical condition in and out of the hospital. On average the landing pad is used 2-3 times per week. Whenever the landing pad is in use the tower crane must be shut down and swung out of the way since the swing of the crane travels over top of the pad, this is coordinated via radio with the communications center in the hospital. Little warning is often given for shut downs which can cause a problem when the crane is in use and a precise plan must be put into place for these instances.

H. Conclusions

After completing this analysis it is evident that the proposed system did not provide the desired cost and schedule savings that were hoped for. The proposed system was determined to be more expensive than the designed system making it undesirable as far as cost savings is concerned and a schedule savings of only 2 days which is not enough to justify the additional cost. However, if this were a larger project that was schedule driven the proposed pre-cast system may have been a better fit. Another factor is if the crane that was located on site would have only been required for the construction of the elevator structure and could have been removed after the placement of concrete there may have been enough savings recouped from the crane rental costs to justify the switch in floor systems.

Based on the data provided above in this analysis it is recommended that the originally designed cast-in-place concrete floor system be utilized for the Lancaster General Hospital Cardiac Elevator Addition.

Breadth 2 Mechanical Analysis: Mechanical Connections at ICRA Partitions

A. Executive Summary

The mechanical analysis performed in this section focuses on identifying mechanical connections that can be used at Infection Control Risk Assessment partitions and help eliminate rework. While mechanical equipment will be looked at the main purpose of this analysis is to reduce cost and schedule by avoiding rework.

In the first section the mechanical connection requirements for ICRA partitions will be researched in order to develop specifications used to develop a list of standard connection types. The requirements in this section are based on ICRA guidelines.

Using the information from the previous section a list of standard connection types will be generated based on the type of partition requirements. Such as fire and smoke rated connections to go with partitions that require fire or smoke ratings.

The cost and schedule impact of the rework required if the correct connection is not used in the beginning of the project are discussed in this section. An example cost and schedule analysis is completed in order to illustrate the impact of building new partitions in order to replace the connections.

B. Overview

The mechanical breadth section of this report focuses on the mechanical connections that are made at the Infection Control Risk Assessment (ICRA) partitions for the Lancaster General Hospital 5th and 6th floor Fit-Out project. This analysis has been completed with the hopes of reducing costs and minimizing schedule impacts that occur when rework is required to move or build new ICRA partitions in order to install mechanical connections. In order to complete this analysis the following steps will be taken:

1. Identify the requirements for mechanical connections at ICRA partitions.
2. Identify some standard sized connection types that satisfy these requirements.
3. Evaluate how this could impact construction costs and schedule.
4. Conclusions

C. Mechanical Connection Requirements

Based on the Infection Control Risk Assessment Guidelines the 5th and 6th floor fit-out project at Lancaster General Hospital is Type D High Risk because it involves new construction in a facility that deals with immunocompromised patients. These ratings dictate class V required infection control precautions being utilized. Class V requires the following precautions be taken during construction project:

i. Construct gypsum board/metal stud dust partition, extend and seal to ceiling.
ii. Isolate HVAC system within work areas to prevent contamination of duct system.
iii. Seal doors opening to adjacent areas with duct tape.
iv. Block off and seal HVAC registers, grills and any openings in ductwork to remain.
v. Maintain negative pressure within work site utilizing HEPA equipped air filtration units.
vi. Place dust mat at entrance and exit of work area.
vii. Cover construction waste before transport in covered containers.
viii. All work associated with a major project that has an approved ICRA authorization form will be assessed on an individual basis.

Upon completion of the project the following steps must be taken:

i. Cover construction waste before transport in covered containers.
ii. Do not remove barriers from work area until a Health System responsible person inspects completed project.
iii. Remove barrier materials carefully to minimize spread of dirt and debris associated with construction.
iv. Wet mop and vacuum with HEPA filtered vacuum before leaving work area.
v. Remove isolation of HVAC system in areas where work was being performed.

vi. Housekeeping to wipe work surfaces with disinfectant.

The most important items for mechanical systems are isolating the construction site from the occupied space by closing off the ducts and all ductwork openings in the space. Since the space above the drop ceiling were all of the ductwork and piping is located must be sealed to the deck above there is limited access to make connections once sealed. This is the focus of the analysis in this section; making sure that the proper connections are put in place avoiding rework. Using the proper connection such as a smoke or fire damper with an access panel will allow for the sealing of duct space without having to remove the damper and therefore the ICRA partition.

The requirements for mechanical connections are dictated by the wall that the partition is built in or between. For example if the partition is in a wall that has a 2 hour fire rating the ICRA partition must also have a 2 hour fire rating and therefore the duct must have a fire damper located at that position. For a similar example if the wall is a smoke barrier then a smoke damper is required.

D. Standard Connection Types

The basic types of connections used are fire dampers, smoke dampers, and combination smoke/fire dampers. There are also two functionally different HVAC systems; static and dynamic. Static HVAC systems are those required to shut down automatically during fire emergencies. Dynamic HVAC systems are those that continue to operate during the early phases of a fire emergency and, by doing so, provide smoke control functions. To go along with static HVAC systems there are dampers that are static rated and for dynamic HVAC systems there are dampers that are dynamic rated, as well as dampers that are made to work with either system.

Fire and smoke damper requirements are dictated by building codes along with Underwriters Laboratory (UL) Standard 555 Fire Dampers, and UL Standard 555S Smoke Dampers. Within the requirements are standards for temperature ratings, airflow velocity rating levels of 2000, 3000, 4000 fpm, and pressure rating levels of 4, 6, and 8 in. wg.

Examples of static and dynamic fire rated dampers are shown below.

Model FD: Static Rated
Model FDR: Round Static Rated

UL 555 rated models for use in HVAC systems that are automatically shut down in the event of a fire emergency. Available in three frame widths: standard, narrowline, and ultra thin, with optional sleeves and transitions.

Catalog: ***Dynamic and Static Rated Fire Dampers, Ceiling Radiation Dampers***

Model DFD: Dynamic Rated
Model DFDR: Round Dynamic Rated

UL 555 rated models tested to close under airflow, and rated for use in HVAC systems that are operational in the event of a fire emergency. Fire dampers can be mounted either vertically or horizontally with airflow in either direction.

Catalog: ***Dynamic and Static Rated Fire Dampers, Ceiling Radiation Dampers***

In order to gain access to the damper after duct installation is completed access panels can be installed adjacent to damper. This is recommended for inspection and testing purposes but in the case of dampers located at ICRA partitions it allows for the access to seal the duct during construction and removal of seal after construction is complete without having to remove any sections of ductwork.

Model HAD: *Hinged Style*
Model CAD: *Cam Style*
Model RAD: *Round Style*

E. Cost and Schedule Impact

The cost and schedule savings are difficult to calculate on a general basis as they will depend on the quantity and complexity of the ICRA partitions utilized. However, the cost and schedule savings will come from elimination of rework involved in moving and constructing new partitions in order to complete the connection of mechanical systems. On the 5th and 6th floor fit-out at Lancaster General Hospital even though the systems servicing the fit-out space are new systems they are located in an existing mechanical room located outside of the construction zone. This required the tying in of the pre-run piping and ductwork in the occupied space of the hospital to the newly fit-out space. Since the proper connections were not utilized from the start there were several instances in which rework was required.

The additional cost of rework includes the cost of several laborers and at least one carpenter plus any additional material costs. With the laborers costing on average $50 an hour and carpenters at an average of $70 an hour billable rate. An example of additional costs is shown below:

Additional Cost of Rework

Description	Hours	$/Hr.	Total
Laborer	4	$50	$200
Laborer	4	$50	$200
Carpenter	4	$70	$280
Total Labor	12	$170	$680
Misc. Material			$500
Total			$1,180

This is a simple example as actual costs will vary depending on complexity of partition, but it is easy to see that if a number of partitions are utilized on a project that the cost can quickly add up.

Similar to cost the schedule is also impacted in the same manner. As additional rework and partitions are needed the schedule will be impacted in addition to the workers required to perform rework being pulled from their other duties causing further delays.

If these additional costs and impacts to the schedule are not planned for in the beginning of the project they can potentially have a serious impact on the final outcome. However, even if planned for the term “work smarter not harder” comes into play that with a little thinking ahead this unnecessary work can be eliminated. Having to build additional ICRA partitions can also add to the risk of posing a health risk as they would need to be built outside of the existing partition.

F. Conclusions

From the analysis completed above it is easy to see how much of an impact neglecting the mechanical connection requirements for a project can have on the cost and schedule. Rework was required in several locations on the Lancaster General Hospital 5th and 6th Floor Infill project in order to make the mechanical connections above ceiling. This can very easily happen as it is required that the ICRA partitions be up before major construction activities commence. With some pre-planning, however, the mechanical connections required can be ordered before construction begins and be ready to put in place when the ceiling space is being sealed.

Summary and Conclusions

The information and research contained in this report has been developed and conducted over the fall and spring semesters of the 2006/2007 thesis course. The goal of this report is to convey the knowledge gained about the Lancaster General Hospital 5th and 6th Floor Fit-Out and Cardiac Elevator Addition project as well as industry research on the commissioning and retro-commissioning processes.

The first analysis focused on the differences in the steps of the commissioning of new construction and retro-commissioning of existing equipment processes, and to determine the types of projects that would benefit the most from there use. A survey was developed to obtain industry personnel’s opinions on the use of commissioning including the benefits and issues with implementing it in projects. Additionally research of industry papers was conducted to gain a greater understanding of the costs, benefits, and steps used to complete the two forms of commissioning. This information was then summarized in order to develop recommendations for the use of commissioning and retro-commissioning.

The second analysis looked to reduce the cost and schedule of the Cardiac Elevator project by proposing the replacement of the cast-in-place concrete floor system with a pre-cast concrete system. Calculations were performed to identify the size of pre-cast concrete floor plank required to replace the cast-in-place concrete on composite metal deck floor slab. Cost and schedule analyses were performed to determine what impact the switch in floor system would have on the cost and schedule of the project. It was found that the cost increased by $1,612.00 and the schedule was reduced by 2 days leading to the recommendation that the originally designed floor system be used.

The third analysis was intended to determine the type of mechanical connection that should be used at ICRA partitions in order to reduce rework. Connection requirements were identified by the ICRA guidelines and a list of standard connection types was developed. A cost and schedule analysis was performed to determine the affect of rework on the project cost and schedule.