Human Genome Sciences' Large Scale Manufacturing Facility

Rockville, MD

Aaron Trout

The Pennsylvania State University
Construction Management
Spring 2005

HUMAN GENOME SCIENCES
LARGE SCALE MANUFACTURING FACILITY

John Hopkins Belward Research Campus - Rockville, MD

Project Team

Owner: Human Genome Sciences
Architect: Lockwood Greene
CM / GC: Gilbane Building Company
Mechanical Contractor: Heffron
Electrical Contractor: Mona
Concrete Contractor: Miller and Long

Project Overview

Size: 290,000 Square Feet
Total Levels: 3(Including cellar)
Cost: Under $233,400,000
Delivery Method: General Contractor

Electrical System

11.4 MW Capacity
13.2 kVA stepped down to 277/480 Y
1200 amp double end switchgear

Mechanical System

3 1500 Ton HVAC Chillers
2 800 Ton Glycol Chillers
3 800 hp Boilers
19 AHU to feed majority of building
9 small units for specific areas

Structure / Envelope

8 in. slab on grade
Below grade: 18 in. reinforced concrete wall
Above grade: N, W, and E faces are enclosed by 2 in preformed metal wall panels
S face is enclosed by 4 in facing brick

Project Background

Human Genome Sciences is a mid-stage development biopharmaceutical company with a significant product pipeline derived from proprietary genomic technology. They focus their internal research and development efforts on novel protein and antibody drugs and on new long-acting versions of existing drugs by coupling then with their albumin fusion technology. HGS is also constructing a large-scale manufacturing facility to support their increasing needs for protein and antibody drug production related to the continuing progress of their product candidates and, eventually, the initial commercialization of their products.

Aaron Trout *Construction Management*

http://www.arche.psu.edu/thesis/2005/amt903

Table of Contents

Introduction

The following report is a senior thesis project for the Architectural Engineering at The Pennsylvania State University. This report will focus on Human Genome Sciences' Large Scale Manufacturing Facility in Rockville, MD. The analysis performed is centered on the following four topics: value engineering, schedule reduction, constructability, and research of developing methods.

The initial part of this thesis will focus on the existing construction conditions, an analysis of key construction features, and alternate system and method analysis. This portion of the report will give a basic overview of the LSM Facilities' building systems, schedule, construction cost, project delivery method, owner information, and other basic project information.

The first research analysis focuses on implementing a 4D model to assist with project coordination. This model depicts the first floor of the LSM Facility and various construction sequences on that floor. These sequences include installation of metal wall panels and structural support, equipment pads and air handling units, metal studs and drywall, and epoxy flooring for the MER room and the "clean rooms". The purpose of the model is to assist with constructability and sequencing of crews and materials.

The second analysis deals with value engineering to reduce cost and or schedule for the exterior wall system. Three different systems were analyzed including the specified metal wall panels, an exterior insulation and finishes system, and architectural precast concrete panels. Each system was broken down into total cost and installation time, and then analyzed for the best option. A major consideration was to improve the aesthetic value as well as the schedule and cost. A heat transfer calculation was performed in order to see how much the heating and cooling load could be reduced in order to find additional cost savings.

The third analysis also deals with value engineering to reduce the total cost and or schedule for the floor covering for the "clean rooms". Three systems were analyzed including the specified quartzite epoxy, bonded conductive terrazzo, and conductive epoxy terrazzo. Each floor coating was split up into total cost and installation time, and once again analyzed to determine the best system.

Existing Construction Conditions

Project Delivery System

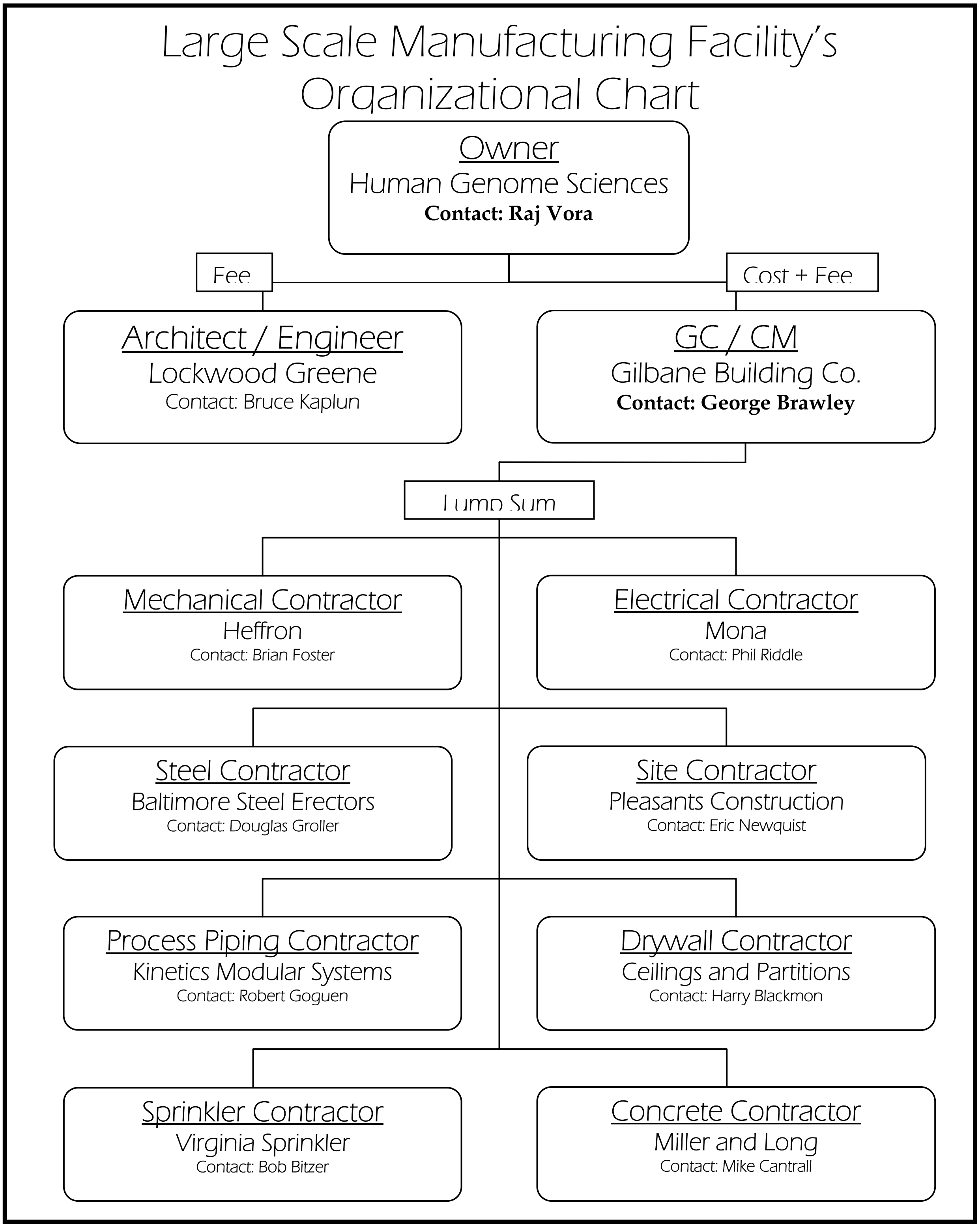
Description

Human Genome Sciences procured this project as a General Contractor with multiple subcontractors. The project was not fully designed when it was procured and some aspects of the building are still currently under design. Value Engineering was also conducted on the building and the exterior skin of the building and structural system for the first and second floors was changed.

HGS hired Lockwood Greene as the architect and engineer for the project with whom they hold a fee based contract. Lockwood Greene does not hold any contracts with any of the equipment suppliers or subcontractors. Gilbane was chosen as the General Contractor for the project; hence they hold contracts with all of the contractors and most of the equipment suppliers. Though Gilbane is the General Contractor, they do not self perform any construction. At the current time the contract held between HGS and Gilbane is cost plus a fee, but Gilbane is in the process of creating a GMP which is to be accepted by the owner. Most of the subcontractors do not hold a direct contract with the owner; instead they hold a lump sum contract with Gilbane.

On this specific project, the owner has chosen to have an OCIP, which is an owner controlled insurance program. This is becoming more and more common with larger construction projects. The main reason why HGS chose to have this type of insurance program is due to a reduction in the total project cost. An owner can reduce the total cost of the project by 1–2% as compared to traditional, fragmented insurance programs.

Organizational Chart


Large Scale Manufacturing Facility's Organizational Chart

Building Systems Summary

Demolition Required:

- There was no demolition required on this project.

Structural Steel Frame:

Bracing:

- There was no permanent bracing used on site
- Cables and turnbuckles were used for erection and plumbing purposes

Crane Information:

- The cranes used on site ranged from 200 ton truck cranes to 400 ton Manitowoc crawlers
- The cranes were located on the east and west sides of the building.
- The 400 ton Manitowoc crane was moved from the west side to the east
- A 200 ton truck crane was then used to complete the west side

Cast in Place Concrete:

Formwork Type:

- The formwork used on site was 25k scaffolding with aluminum beams and 5/8" forming plywood

Placement Method:

- Concrete was placed using a concrete pump truck and a tower crane

Precast Concrete:

- There was no precast concrete used on this project.

Mechanical System:

Location:

- Chillers and boilers are located in the northern part of the cellar
- The majority of the AHU's are located in the MER rooms, which are on the eastern end on the building on the first and second floors

System type:

- For cooling three 1500 ton chillers are used to supply chilled water via steel piping
- There are also two 800 ton glycol chillers that feed only process equipment

- For heating three 800 hp boilers provide steam serving both process and utility needs. Four hot waster skids provide hot water service for the building.

Distribution Types:

- All supply and return air is distributed via galvanized ductwork
- Custom AHU's that feed only the "clean" rooms contain HEPA filters that remove 99.99% of all particles

Fire Suppression:

- The system used is pressurized water that is powered by a diesel fire pump which is located in the cellar

Electrical System:

System Size:

- 11.4 MW capacity
- 13.2 kVA stepped down to 277/480 Y, three phase
- 6.7 MW standby emergency power, powered by diesel generators
- 1200 amp double end switchgear
- 1,200 kVA UPS system

Redundancy:

- Two separate PEPCO (electrical service) feeders feed the building
- Any one alone can run the facility

Masonry:

Type:

- The exterior of the building consists of standard brick with relief angles on the second floor
- There are load bearing masonry walls in the cellar supporting 10" cast-in-place slab mezzanine decks

Scaffolding:

- Scaffolding used for erection was a combination of hydraulic platforms and scaffolding and planks

Curtain Wall:

-Glass curtain wall at main lobby entrance

- Exterior glass consists of punch windows

Support of Excavation:

Type of Support System:

- Banked slopes complying with OSHA standards were used for excavation
- The site was carpet blasted then hogged out
- Additional blasting was required as project designs changed

Dewatering System:

- Dewatering was accomplished by surface pumping as required

Project Cost Evaluation

Building, Project, and Design Costs

Building Construction Cost:

Total: $233,400,000

* This can be found on HGS's annual report at http://www.hgsi.com

Unit Cost: $800/S.F.

Total Project Cost:

This value is to be kept confidential as per Human Genome Sciences request.

Design Cost:

The design cost of the project is roughly less than 10% of the construction cost.

All direct costs related to specific contractors are to remain confidential as per Gilbane's request.

Parametric Estimate

Code	Division Name	%	Sq. Cost	Projected
00	Bidding Requirements	0.38	1.66	480,864
01	General Requirements	1.81	7.89	2,287,037
02	Site Work	5.77	25.10	7,279,693
03	Concrete	9.60	41.72	12,097,840
04	Masonry	2.54	11.03	3,199,506
05	Metals	6.36	27.64	8,015,185
06	Wood & Plastics	0.27	1.17	340,123
07	Thermal & Moisture Protection	2.78	12.10	3,510,309
08	Doors & Windows	0.84	3.66	1,062,593
09	Finishes	3.44	14.96	4,339,506
10	Specialties	0.38	1.66	480,864
11	Equipment	3.39	14.72	4,269,136
12	Furnishings	1.65	7.15	2,074,753
13	Special Construction	0.58	2.51	727,969
14	Conveying Systems	0.16	0.70	204,074
15	Mechanical	43.88	190.78	55,325,670
	Mechanical	25.41	110.45	32030651.34
	Process Piping	18.48	80.33	23295019.16
16	Electrical	16.17	70.29	20,383,142
	Total Building Costs	100.00	434.75	126,078,265

Comparison:

Using the D4 Cost Estimating program, a parametric estimate was developed that partially resembles the LSM facility. The main reason why there is such a difference in total project cost ($54,000,000) is due to certain machinery and equipment that is to be kept confidential and I do not have access to the costs.

A smart average was not performed due to the nature of the project. There were very few buildings that closely resembled to the LSM project with respect to size, cost, or functionality. The Bryce Jordan Center was used to develop a parametric estimate. In order to have the estimate relate more closely to the LSM project some of the costs were altered. The mechanical cost was increased to 22 million, the electrical to 14 million, and site work to 5 million. It was difficult to determine what other costs needed to be altered with the information provided. The date was also changed to April 2003, the location to Rockville, MD, and the building size to 290,000 S.F.

Square Foot Estimate

Reference:

R.S. Means Construction Cost Data 2004 Edition

Assumptions:

- The LSM project most closely resembles a Research Lab with reference to the building itself not the equipment
- Cost / SF = $127
- Size = 19,000 SF

Calculations:

Total project cost: 290,000 SF * $127/SF = $36,830,000

Size Adjustment: 290,000 SF / 19,000 SF = 15.26
Use default vale of 0.9
$36,830,000 * 0.9 = $33,147,000
Subtracting adjustment = -$3,683,000

Location Adjustment: Rockville, MD was not available so Baltimore will be used
Factor of 91.4
$36,830,000 * 0.914 = $33,662,620
Subtracting adjustment = -$3,167,380
R.S. Means Cost: $36,830,000
- $3,683,000
- $3,167,380
= $29,979,620

Comparison

Due to the fact that there was no building that resembled a pharmaceutical manufacturing facility in the R.S. Means book, there is a distinct difference in the building cost estimate.

There are many factors that can be linked to this difference. The most evident distinction is the high tech machinery and equipment that is required for the LSM facility. This cost is to remain confidential as per HGS's request. Some other factors that cause this estimate to be off are is the spray on fireproofing required in the “clean” rooms which is very expensive, they epoxy floor covering which is expensive and time consuming to install. There is also an enormous amount of process piping inside the building which feed the process equipment.

The R.S. Means estimate proved to be insufficient in providing an accurate estimate for the Large Scale Manufacturing Facility.

Local Conditions

Being close to Washington D.C. there is a large labor force available for use. A major issue with this location is the amount of construction continually at work in the Maryland, D.C., and Virginia areas. This makes it hard at times to find qualified contractors to work on such a high profile project. Many of the contractors on site (i.e. process piping and rigging contractors) were not from the local area and were temporarily relocated to the area. This posed some issues during construction when workload was low. Certain contractors has to send some of their workers home because there was not enough work to perform, and when the workload increased there were problems getting enough workers back to the project.

Some other issues that developed are due to the site location and the area where it is being constructed. Parking became an issue due to the fact that there was no room to park on site, and there were also no trailers for the contractors. Gilbane rented out the top floor of an office building and was only allotted a certain amount of parking spaces. Fortunately a mile down the road Gilbane was finishing up another job for HGS, their corporate headquarters, and contractors were allowed to park there. Busses were provided in the morning and late afternoon to provide the commute from the parking area to the site.

The site, other than being quite confined, did not have many difficult subsurface conditions. The water table was low enough that surface pumping to a temporary pond was sufficient during excavation. The only times when it became difficult was during heavy rains, which this area receives a lot of. Along with that, there was a lot of stone where the excavation of the cellar was located. This was a known fact, so Gilbane obtained blasting permits to eliminate the stone. There turned out to be an excessive amount of stone that was unknown, which provided setbacks in the schedule. The rain also caused some other problems with mud being tracked into the building. All subcontractors are required to complete a daily cleanup since the building is required to be in a "clean" state. As construction progresses the building is required to reach certain clean protocols which are specified in the spec sections. To give a brief overview, it states that daily cleanup must be completed; no food, drink, or tobacco products are permitted inside the building; and at later protocols contractors are required to use clean tools/equipment and wear gloves. The rainy conditions make cleanup difficult and also time consuming, which in the overall scheme of things delays the schedule.

Client Information

Human Genome Sciences is a relatively new pharmaceutical company founded in 1992, which is located in Rockville, MD. Their overall goal is to discover, develop, and marker gene-based drugs to cure and treat diseases. Currently HGS has expanded the company vastly with construction of a new a Corporate Headquarters, a Pilot Production Facility, a Quality Building, a Biological Sciences Facility, and the LSM Facility.

With construction of the Large Scale Manufacturing Facility, HGS will be able to produce multiple drugs at once in a state of the art facility. Many drugs recently discovered are undergoing clinical trials in patents, and upon approval will enter the development stages at the facility.

Gilbane enforces safety on the construction site, which is also a substantial concern to the owner. All contractors are required to go through safety training before allowed on site, which entails all OSHA standards as well as standards Gilbane enforces. Quality construction is a major factor that HGS will be following closely. They have personnel that are to be present at all first deliveries, inspections, mock-ups, and construction set in-place. Gilbane has incorporated a quality plan that requires all entities involved with the specific process to be present and to sign off on the subject at hand.

Cost is always an issue with any construction project, and though it is the highest importance to HGS, they would like this project to be completed under budget, on time, and with a high level of quality. At times this poses difficulty due to the materials and special construction processes that are required to construct this building in a "clean" state. HGS has set forth project milestones as with most construction projects. In order for this building to be beneficial to the fullest extent, the LSM building needs to be completed on the date set forth. With multiple long lead items, delivery issues, and changes in the building, updating the schedule is a detailed ongoing process.

With hopes of a successful project, HGS plans on becoming a major force in the pharmaceutical market. Only by following the project schedule, completing the project within the allotted budget, and creating a quality facility can they achieve this goal. Gilbane plans of attaining this feat and hopes to continue their relationship with HGS.

Analysis of Key Construction Features

Contracts

Contract Description

Owner – A/E:

Lockwood Greene was hired on by HGS as the architect and engineer with whom they hold a fee based contract. Lockwood Greene does not hold any contracts with the subcontractors or the equipment suppliers.

As per HGS's request; I am not able to discuss any further details of the contract held between HGS and Lockwood Greene.

Owner – CM:

Gilbane Building Company was hired on as the Construction Manager for the LSM project. They hold all of the contracts with the subcontractors and some equipment suppliers. Though Gilbane is considered the General Contractor, they do not self perform any construction.

In respects to the contract held between the CM and the Owner, the Pre-GMax phase of the project is similar to a cost plus fee where everything is considered in scope. When the project is 60% complete Gilbane is to submit a GMP which is to be approved by HGS. Once they approve the GMP any change in scope will be an out-of-scope change.

In order to select subcontractors for the project, Gilbane has a procedure they must follow. First a bid list is prepared by Gilbane and then sent to HGS for approval with a minimum of three subcontractors. After the bid list is approved by HGS, Gilbane will prepare a Request for Proposal for the approved bidders and send it out for bids. There is a form that the contractors must return to Gilbane to acknowledge that they received all of the bid documents (i.e. drawings, specifications, safety plan, quality plan, etc.). If the subcontractors have any questions during the bidding process, Gilbane will answer and distribute the answers/solutions in the form of a Supplement.

CM – Subcontractors:

As stated earlier, Gilbane holds contracts with all of the subcontractors. Like most projects the contract type is a lump sum contract, where all of the work is placed under a given budget.

In reference to payment, all subcontractors are required to send Gilbane a pencil copy of what they intend to bill by the 25th of the month, which is submitted on AIA Document A703. This pencil copy is reviewed by the Project Executive and the General Superintendent for percent complete, and if the value is correct the Requisition for Payment is sent to the owner for approval. The Trade Contractor then resubmits the notarized Requisition for Payment, which is due back to Gilbane on the 5th of the following month. Gilbane then submits their bill to the Owner by the 8th of the following month. Within five days of receiving payment from HGS, Gilbane will pay their subcontractors.

Changes in the work are handled by each discipline Engineer within Gilbane. As they are received, the documents are disseminated to the Engineer who will then open a Change Request in JDE assigning a number to the change. A RFQ (Request for Quotation) is then prepared and sent to the appropriate subcontractor with any drawings or specs which resulted in the Change Order. The Trade Contractor has 10 days to quote the work and if they ask for a time extension, their request must be accompanied with a schedule showing the impact the extra work has on the job. Gilbane will then process each quotation within 35 days.

Insurance and Bonds:

On this specific project, the Owner has chosen to have an O.C.I.P. insurance program where HGS will carry the insurance for all of the subcontractors. In order for this to work, all of the subcontractors must give back a credit from their bid which would have covered their own insurance for the project. The O.C.I.P. covers everything except automotive liability for the subcontractors, and they have to provide this coverage which is stated in the General Conditions for the project.

Gilbane includes a copy of their boilerplate contract in their Request for Proposal. This allows the subcontractors to review the commercial terms and conditions to help decide if they want to enter into a contract with Gilbane based upon the requirements of the document. It is very rare that a subcontractor will want to alter the document presented to them.

Gilbane is required to obtain a bond waiver from Gilbane Legal in order to cover the cost of Labor, Payment, and Performance Bonds. Sometimes the Owner will also request that certain subcontractors be bonded considering the scope of work they will be performing, and that cost needs to be included in the total bid price. The purpose of the Payment Bond is to ensure that Gilbane will pay all of the subcontractors the full amount required, and that payments will be received on time. The Performance Bond ensures that Gilbane will complete the project in accordance with the contractual documents and HGS's standards.

Assessment of Findings:

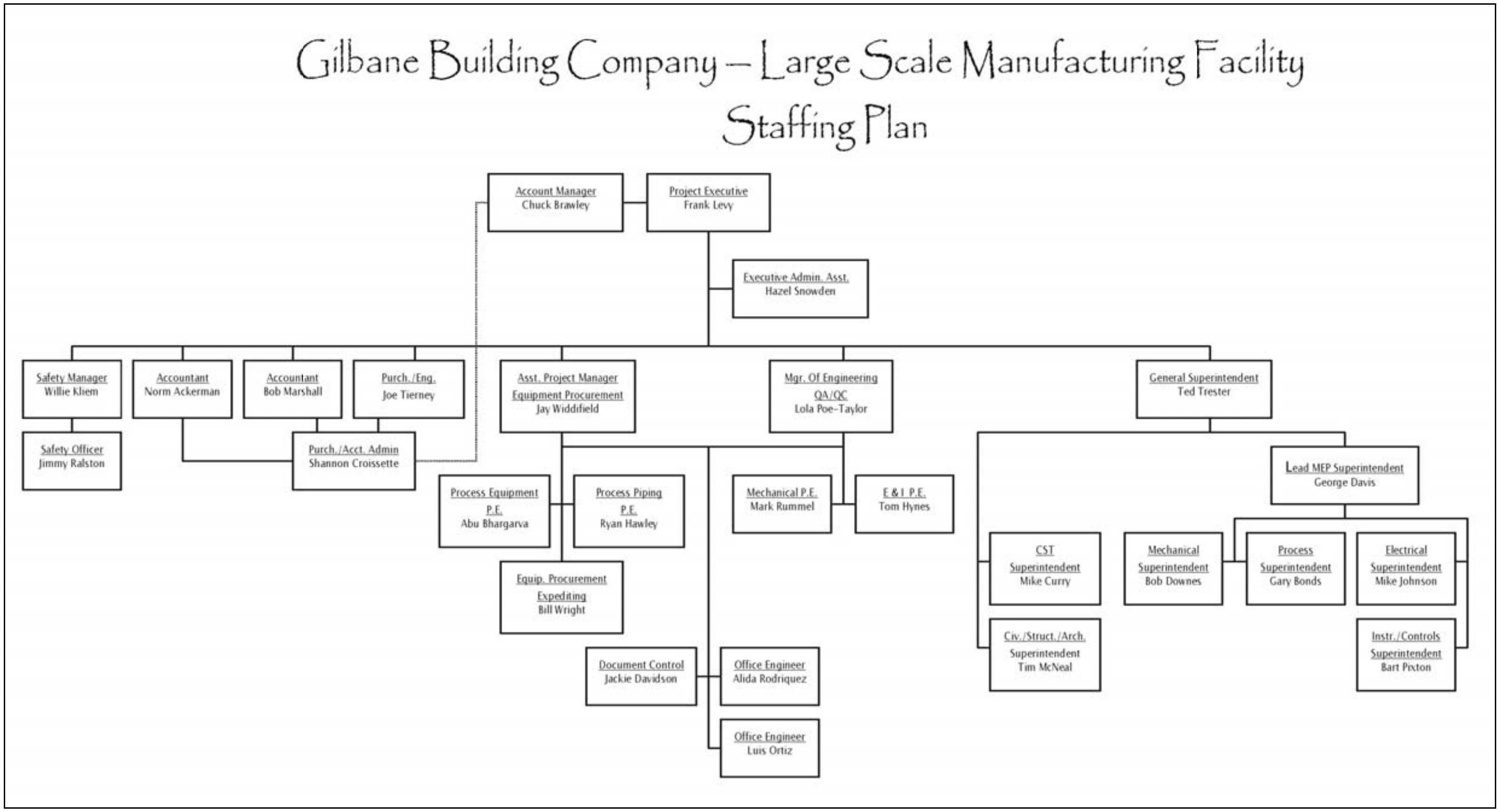
I feel that the approach HGS took with the contract type they selected and the insurance program is best suited for the project. This is a very large scale project and a GMP contract is the safest way to build this building with minimal cost issues.

By having Gilbane as the Construction Manager this helps out with coordination and scheduling of the project. If HGS would have chosen a Multiple Prime system there could be issues with trade contractors conforming together to coordinate early possibly pointing out issues early in the construction process. Also, by having a Construction Manager the Owner only needs to consult with one firm instead of multiple which can make the process much easier on the owner.

HGS also chose the O.C.I.P. Insurance Program, which provides cost savings for them. An owner can reduce the total cost of the project by 1–2% as compared to traditional, fragmented insurance programs.

Staffing Plan

Staff Organizational Chart



Description

By looking at the Gilbane's staffing chart it is evident that there is a lot of manpower that was assigned to the project (27 staff members). This project requires such a large staff due to the specialized equipment, construction techniques, and quality of construction required. Due to the restrictions of available space on the site, Gilbane has rented out a section of an office building to take the place of a site trailer.

At the top of the chart are the Account Manager and Project Executive whom work in close correlation. The Account Manager deals primarily with the accounting portion of the project and the Project Executive deals mainly with the site issues.

Below the Project Executive the staff is split up into smaller sections dealing with: Safety, Accounting, Equipment, Quality Control, and Site work. There are eight superintendents on site and each one has a specific trade that they work along side with. This is essential because the building is so specialized that a high level of detail needs to be placed on each specific trade. This does cause some issues with coordination within the company since each superintendent deals only with their area of expertise.

There are also two safety managers on site. Gilbane strives to have a safe workplace, and due to the size of the building and amount of workers in the field it is necessary to have this much management available.

Unlike most job sites, Gilbane has provided a document control section of the office. All incoming and outgoing paperwork passes through document control where it is entered into Prologue and then dispersed to the appropriate people. This is essential because without this intermediate stage, many processes such as change orders, submittals, and payment requisitions would be delayed due to confusion with their current state and where they are to be sent next.

There is a large staff that is assigned specifically to the equipment on the project. This is a very concise process due to the nature of the equipment; much of it is being delivered from long distances and also has a long lead time. It is up to this group to coordinate the delivery of the equipment with all of the field staff. On top of they have to ensure that the equipment ordered is exactly what the owner requires, and that it will physically fit inside the space designated.

Quality control is an important issue on this project due to all of the "clean" spaces. On top of that the building is to be validated to proper paperwork needs to be organized and kept on file. This person is responsible for multiple on site inspections, equipment delivery inspections, and equipment-in-place inspections.
As the project progresses less staff will be required on the project, and some people will move on to other projects that are just beginning construction.

Design Coordination

Scope of Coordination

The LSM project incorporates a large highly detailed MEP system that requires an extensive amount of coordination. There is a large amount of ductwork located on all three floors which is located primarily in the plenum spaces. Throughout the rest of the plenum space a majority of the sprinkler lines, electrical raceways, plumbing lines, and some process pipes that have to be coordinated properly so that they can be placed within the ceiling space. There are mechanical chases located throughout the building that service the "clean rooms" where mainly process piping, conduit, and other mechanical piping exist.

There are primarily three main MEP systems that require this extensive coordination to alleviate as many issues as possible.

1) Mechanical systems and all branches for the "dirty " sections of the building. This includes mechanical equipment and piping for utilities, chilled water, condensing water from the cooling towers, and HVAC heating & cooling duct.
2) Power distribution required for the mechanical equipment to support all of the utilities. This also includes the power requirements for the Building Automation System that controls the operation of the mechanical equipment.
3) Process systems and branches which include the same systems as the "dirty" sections. The installation of the equipment and piping for this system is more stringent due to the fact that it has to be installed in a clean state and kept clean during all of the construction activities. A different control system, the Mechanical Execution Controls) is installed for the Process Operation which is required for manufacturing a pharmaceutical product.

All contractors involved in there three main MEP systems have to perform coordination with each other and all of the other trades, including the designers, detailers, and the field workers. This is to ensure that all of the equipment, piping, and ductwork installation do not conflict with systems being installed by other trade contractors. As stated in the specifications: Each contractor is required to coordinate their work of systems installation with all other trades as to not impact or conflict with the installation of the other contractors.

Development of Coordination Plan

In order to create a coordinated MEP construction plan, a constructability review for the project was performed. For this, the architectural and equipment arrangement drawings were used to create a sequence of events that showed the move in path for all of the equipment. This also included placing piping and ductwork to a general location that was near its respective piece of equipment. In the field the piping and ductwork would stop in this general location until the equipment was set in place, and then the systems final connections can be made.

The use of 3D CAD was also incorporated into the design coordination process. These 3D models were developed for areas consisting of a large amount of equipment and piping. By using these models, they were able to determine equipment move-in pathways as well as determining sections of piping or ductwork that needed to be left uninstalled until the equipment was set in place.

Challenging Areas & Field Conflicts

The largest challenge that Gilbane experienced on the project was the process of moving all of the equipment into the building. This had to be coordinated with all of the architectural activities (i.e. flooring, concrete pouring, metal studwork, etc.). For example, certain walls could not be erected until a piece of equipment was received and set in its respective place. There is a section of prefabricated metal wall panels that cannot be installed until some heat exchangers are received, which will leave roughly a 20 ft. by 20 ft. section of the building open to the environment. This causes issues with keeping the building clean and also with temporary heat for the winter months the building will be left open. Another given challenge is with all of the mechanical chases. There is a large amount of work and to be completes that requires multiple trades to be involved at once.

There were some instances where structural members, mainly steel, had impacts on the actual setting of the equipment. Certain elevations on the equipment arrangement drawing were unable to be attained, so the elevations needed to be modified. This also resulted in modifications to the mechanical piping connections.

Critical Industry Issues

This year I attended the 12th Annual PACE Roundtable Meeting. This event is held for PACE members and Penn State faculty and students to interact in a learning environment on current issues in the industry. There are multiple sessions pertaining to different issues and topics in the construction that are held to allow industry members and students to interact and gain some new information and concepts prevalent today.

This year at the PACE Roundtable Meeting I was able to attend three discussion groups with industry members and student peers. The three I chose to attend were: Integrating Distributed Teams, Constructability and VE in Design, and Leadership Jump-Start for Entry Level/Undergraduates. Only the Constructability and VE in Design will be discussed in this report.

Constructability and VE in Design

Summary:

Constructability reviews and Value Engineering are prevalent throughout the construction industry; every company performs these to some extent. We discussed these two topics in detail during our session; pertaining to when these are performed and the benefits.

Constructability reviews are the most simple for of a drawing check. They are typically performed when a new set of drawings are released. The basic function of a constructability review is to see if the building can actually be built the way it is designed.

Value Engineering is a tool used for two purposes: to reduce the overall cost of the project or to add value to the building. Before any suggestions should be made it is important to take the owner's needs and wants into account.

The most beneficial way to apply value engineering would be to reduce the initial cost of the building while improving the long term performance of the building (hence reducing life cost). This is what the Green Value Engineering hopes to incorporate with all aspects of "Building Green". Some helpful hints to promote good Constructability reviews and Value Engineering methods are to simply ask questions, get the CM involved early, and always have the owners needs taken into account.

Interesting Topics:

I was very interested in the discussion on how much excess cost is incurred on numerous projects on simple items such as cable trays, facing brick, and carpeting. On many projects oversized cable trays are designed, and on larger projects where there are hundreds of thousands of linear feet of cable tray a lot of money can be saved by reducing the size or using a different system. Another example is in reference to carpet tile and broadloom. It costs more to install carpet tile, but if the carpeting is in an area where it will undergo a lot of wear or damage by using carpet tile small sections can be replaced instead of the entire carpet. This will reduce the life cost of the building and also help keep the aesthetic appeal of the building in tact longer.

Application to Thesis

During the session the comparison of VCT and terrazzo flooring came up concerning initial cost to life cost. This subject fostered the idea of changing a certain floor type in the LSM project to terrazzo flooring. A large portion of the flooring on the first and second floors is epoxy flooring, and by taking into account the initial cost and life cost of these two flooring systems the terrazzo flooring could prove to be more beneficial. On top of being more durable and possibly cheaper, it provides a smoother and more aesthetically appealing finish.

If I chose to research this topic more I will be in touch with Mike Arnold from the Foreman Group, whom I interned for last summer. They perform a lot of school work, and flooring is a major part in that type of construction.

Alternate System and Methods Analysis

Site Layout Planning

Description of Key Features

*Note these site plans can be found in Appendix B

Excavation Site Plan:

For the excavation of the LSM building, the building perimeter was excavated roughly 24 feet below finish grade. The sides of the excavation pit were sloped according to OSHA standards for soil retention, and a temporary fence was placed around the pit. The access roads only encroach the site a little due to the extensive amount of traffic. There are two temporary stockpiles located on the western and eastern sections of the site which are used to store dirt that will be used as fill. There are three ramps which dump trucks can enter the pit and collect dirt to be hauled off site. The excavation proceeded in a northern direction. There was no excavation site plan provided by Gilbane to compare to.

Superstructure Site Plan:

For construction of the superstructure, concrete pump trucks were used to pour the slab on grade and the cellar walls. The trucks were located in the areas where the cranes are shown on the drawing. These were not shown in order to eliminate confusion on the drawing. Three cranes were utilized to install the structural steel. Two 400 ton crawler cranes were used to install the majority of the structural members on both ends of the building. The crane on the western side of the building was later moved to the eastern side of the building to assist the other crane. A 200 ton truck crane was used to complete the western side of the building. There are two steel storage/lay down areas located on the eastern and western sides of the building. If required there was an extra material storage area on the northern end of the site for steel. The steel was installed in the southern end of the building first and then moved towards the north. There was no excavation site plan provided by Gilbane to compare to.

Finishes Site Plan:

The finishes plan was difficult to depict in a general site plan for the building. Each floor was laid out in a specific manner to meet the floors extents and demands. The general flow of finish work flowed in a northern direction. Most of the materials are brought into the building from the southern entrances. Large deliveries that contain materials to service the northern end of the building are delivered to the northern end of the building on the loading dock.

Also scaffolding was placed on the eastern side of the building to deliver heavy materials and equipment to the first and second floors. Materials are placed throughout the building where space is available. There were no specific storage places inside the building; many times these materials needed to be moved for the flooring contractor and still will need to be moved at a later time. There was no excavation site plan provided by Gilbane to compare to.

Detailed Systems Estimate

Description/Assumptions

*Note the estimate can be found in Appendix C

Description:

The charts displayed on the following pages show a detailed estimate of the Large Scale Manufacturing Facilities superstructure. In order to develop the estimate, the 2004 R.S. Means Cost Works program was used to acquire unit costs for materials used in constructing the LSM Facility.

The detailed estimate includes concrete spread footings, cast in place cellar walls, a slab on grade, two slabs on deck, elevated slabs, concrete and steel columns, concrete and steel beams, and metal decking. A location factor was also used so that appropriate unit costs could be obtained for material, equipment, and labor costs. Rockville, MD was not listed in the database; College Park, MD which is the closest location to Rockville, MD was selected.

Assumptions:

- Since actual location was not listed a location that closely resembled market costs was used
- If items were not specified exactly in the Unit Costs, an alternative was chosen that would closely resemble the specified product
- For beams and columns that were not listed in the Unit Costs, the correct value was interpolated from given costs
- If correct dimensions were not listed, alterations to total unit cost or quantity were made to make up the difference
- Due to the large size of the building and varying beam layouts, a common layout was devised between two column lines and copied in the east-west direction. (For example if between column lines J and K there are multiple W24x55 beams and a few W21x62 beams, the assumption was made that all of the beams are W24x55)
- Not all beams and girders were taken into account, only large structural members were included in the estimate.
- For all concrete columns, reinforcement was considered to be average
- Structural steel for pipe racks was not taken into account

Analysis 1 – 4D Coordination Model

Description of 4D Modeling

The traditional means of design and construction planning consist of 2D drawings and network diagrams. These tools are still widely used today, but they do not support the timely and integrated decision making necessary to accelerate projects. Due to the extensive MEP systems, structural steel, and site layouts, a type of coordination model is required. The traditional means of design do not provide the visualization, information modeling, and analysis of the environment necessary to support the rapid and integrated design and construction of facilities.

The initial step taken to assist with better visualization of construction projects was 3D models. 3D models are a tool used to visualize all aspects or specified sections of a facility. Typically these models are used to depict areas with extensive MEP equipment. This assists with the coordination required to alleviate issues in the field. By developing these models, the CM or GC is able to properly layout ductwork, piping, conduit, and raceways so that they do not interfere with each other or with structural steel members. The 3D models are typically created using Auto CAD. Typically the floor plans are already created in CAD, and from these drawings the elevations can be devised.

These models have been further developed into 4D models by the addition of a schedule. These schedules can be created in Primavera, Microsoft Project, or any other scheduling tool. By adding a schedule, a construction sequence can be determined, which allows out of sequence activities to be eliminated. A common application of 4D modeling is used with the construction of structural steel. Steel is typically installed in phases, and a 4D model can be used to show subcontractors the proper sequence to install the steel members. 4D models can be used for many other applications such as: foundations, finishes sequence, concrete slab pours, MEP equipment, and various construction processes. A common platform used to create 4D models is Common Point. With this program, an Auto CAD drawing is first imported into the program by either the entire drawing or by layers. A schedule is then imported whose line items directly coincide with the specific layers in the 3D model. Then each line item in the schedule it attached to its corresponding layer. From this a video can be played showing the exact sequence of the construction process.

The basic benefits of 4D models are as follows:

- Understand the relationship between construction activities and facility operation or projects
- Understand and improve the use of work, access, and tagging areas over a period of time
- Identify spatial conflicts among crews and other production elements
- Analyze activity sequencing
- Improve constructability
- Improve work flow for subcontractors
- Visualize the construction work to be done for a work zone, time period, or subcontractor

Model of LSM Facility

Description of Model

The model created of the LSM Facility only incorporates the first floor. Only the first floor is shown due to the immense size of the facility. Also, the sequence depicted for the first floor can be applied to the second floor. The specific construction sequences shown on the model are the installation of the metal wall panels, pouring of equipment pads, installation of air handling units, application of the epoxy flooring for the MER room and the "clean rooms", and metal stud and drywall installation for the MER room and the "clean rooms". Only these specific rooms are shown because these are the rooms requiring the most attention and coordination.

*Note sequence pictures of the LSM 4D model can be found in Appendix D.

Coordination of Activities

Exterior walls:

In order to install the 2" preformed metal wall panels, the steel support system needs to be installed. The 8" x 2" steel tubes are installed at 7' o.c., and they take 6 weeks to install. In order to speed up the process, a week after the steel tubing installation has started; the metal wall panels will begin installation. The subcontractor will begin on the eastern side of the building and work in a counterclockwise direction until all of the panels have been installed on the western side of the building.

One thing to notice on the model is that a section of the panels and steel tubing has been left out between column lines F.9 and H on the eastern side of the building. This is because there are pieces of equipment that are being delivered at a later date, and cannot be loaded in through doorways or other conventional entrances. Once the pieces of equipment arrive, the additional steel tubing will be installed the next day, and the metal wall panels will be installed once all of the steel tubing is up.

Metal Studs and Drywall:

Three weeks after installation of the steel tubing, metal studs for the "clean rooms" and MER room will begin. This process will take approximately 5 weeks to complete. The subcontractor will begin in Equipment Room A-1 at the northwest end of the building and work towards the southern end of the building. Once the subcontractor is done with the first row of rooms, installation of metal studs will begin at Equipment Room E-1 and work in the same direction. Metal studs for the MER room which is located on the eastern side of the building will also begin installation at the same time as the metal studs for Equipment room A-1.

Installation of the drywall will begin once the metal wall panels have been installed on the western side of the building. This is to ensure that there will be no mold problems with water entering the building. The drywall subcontractor will complete the rooms in the same process that the metal studs were installed.

Equipment Pads, Air Handling Units, and Epoxy Flooring for MER room:

Equipment pads, which are located in the MER room, for the air handling units will be poured concurrently with the installation of the metal studs. All of the pads will be poured except for two pads which are located between column lines F.9 and H on the eastern side of the building. This is because of the equipment that is going to be delivered at a later date. There are four different sets of air handling units that will be delivered, including the two that will be delivered at a later date. Five days after the pads are poured the epoxy flooring will be installed on the equipment pads. Two days after the epoxy is set on the pads, the first set of air handling units will be delivered. Once these are delivered the second set will be delivered, and a day later the third set will be delivered. Once the equipment that is going to be fed in through the opening on the eastern side of the building is delivered, the equipment pads can be poured for the remaining two air handling units, and the same process will follow for the epoxy and delivery of the AHU. Once the final two air handling units are delivered, the epoxy flooring will be set in the MER room.

Epoxy for “clean rooms”:

Once drywall has finished being installed in the first two “clean rooms”, the epoxy flooring will begin in Equipment Room A-1. The installation process takes 3 days per room since each layer takes a day to cure. The epoxy flooring subcontractors will also move in a southern direction following the installation of the drywall. The reason why the floor is installed after the drywall is because the flooring it placed up to the drywall and then curved so that there in not a 90 degree corner between the floor and the wall. The epoxy flooring is then extended 4in above the finished floor on the face of the drywall.

Conclusion / Recommendation

4D models are becoming more and more prevalent throughout the construction industry. They have numerous benefits that assist with coordination, work flow, sequencing, and visualization.

For the LSM facility, a 4D model was created for the first floor only depicting the installation of the exterior metal wall panels and structural support, metal studs and drywall, equipment pads and air handling units, and epoxy floor covering for MER room and "clean rooms". The model would be a useful tool for numerous subcontractors as well as the Construction Manager.

By viewing the model, it will be easy to determine where there could be crowded areas if numerous crews are working in the same area at once. Also, it will assist with the equipment delivery schedule. The CM and subcontractors will be able to tell when the air handling units will be delivered so that the equipment pads and epoxy flooring will have enough time to cure. Also, the opening in the side of the building will need to be clear during these times so that the air handling units can be moved in through the building.

The model also shows the sequencing of metal studwork, drywall, and epoxy flooring inside the building. This will assist with temporary material storage areas, subcontractor coordination, and crew allocation.

Overall, the model could prove to be a useful tool for the LSM Facility. The model can also be duplicated and manipulated easily to closely resemble the second floor.

Analysis 2 – Exterior Wall System

Background

When the Large Scale Manufacturing Facility first was designed, Human Genome Sciences' intent was to have the building resemble the neighboring buildings at the John's Hopkins Belward Campus. These buildings are all owned by HGS and have been built within the past two decades. The existing buildings consist of 4in. red facing brick with a multicolored helix pattern (Figure 1) towards the top of the building along with punch windows.

Figure 1: Brick Helix Pattern

Value Engineering was performed on the project early in the design phase to help reduce the total project cost. One decision made was to change the exterior wall system on three of the building's facades. All of the facades except for the front, or southern face, of the building were changed to a 2in. preformed metal wall panel with steel tube support framing. This helped reduce the overall cost of the project as well as reduce the schedule.

Value Engineering is defined as: "An organized approach to optimizing both cost and performance in a facility or to eliminating items that add cost without contributing to required function. In evaluating the quality, use, life, appearance, and required features of a facility, the consultant attempts to achieve value without reducing quality below required levels while at the same time maximizing function, cost, and worth in design."

When performing Value Engineering; the building envelope, building's structure, and the foundation system are typically analyzed first. Though there were obvious benefits to their decision, one aspect of the building was jeopardized. The main issue that arose from changing the brick to the metal wall panels (Figure 2) was maintaining the aesthetics of the building, which Human Genome Sciences is interested in. The metal wall panels provide no aesthetic value and take away from the surrounding environment.

Figure 2: Exterior Facade

The purpose of this analysis was to identify and evaluate different wall systems that could maintain the aesthetic value without impacting the schedule or cost in a negative manner. There are other types of wall systems that can be utilized such as: Exterior Insulation and Finishes System (EIFS) and Architectural Precast Concrete Panels. Both of these systems are desirable on facilities such as industrial buildings, commercial buildings, institutional facilities, and hotels.

Description of Wall Systems

Preformed Metal Wall Panels

Description:

Figure 3: Metal Wall Panel

The preformed metal wall panels that are being used on the Large Scale Manufacturing Facility are a custom wall panel manufactured by Centria. The specified product is the Formwall Dimension Series Flat Panels with concealed fasteners (Figure 3).

Then panels are made in 3' high sections and can be cut to a specified length. To provide a more appealing finish, the panels are produced with surface rolls which leave the pattern visible on both the interior and exterior faces. The embossed finish on the panels incurs a higher cost as well as a longer lead time. The support system for the panels is a 2" x 8" x ¼" steel through-tube which is offset at 7'. These steel tubes are attached to the building's floor slab and structural steel above.

The exterior faces of the panels are made with ASTM A653 22 gage stainless steel. For exposed surfaces, three coats of thermosetting fluoropolymer enamel (PVDF) are to be applied, which is highly resistant to environmental impacts. The unexposed surfaces are to be coated with a DFT polyester finish topcoat. The interior insulation consists of a urethane foam core with a density of 2.7 PCF and a compressive strength of 20 psi. To provide a weather tight seal, all vertical joints are required to have a continuous back-up flash with two beads of sealant. All of the components of the metal wall panel provide a thermal resistance for conduction, or an R-value of 14.5.

Advantages:

There are many benefits to using this type of system, especially when being compared to the brick wall system initially specified. This type of system can be installed very easily and efficiently. A pulley hoist system that is attached to the roof parapet can be used to lower the panels down the façade of the building. A small scale truck crane can also be used for easier installation. In order to achieve the insulation value and weather resistance, this system is less costly as compared to a brick wall system.

Metal wall panels are designed so there is minimal maintenance required, hence resulting in a long service life. The panels are designed so that they are highly resistant to impact and damage as well as the elements.

Disadvantages:

Some of the drawbacks to this system are that due to the custom design of the panels there is a long lead time. If any panels are damaged or the wrong size it could impact the project schedule if there are deadlines for building enclosure. If damage occurs to the panels during its life, it can become costly to replace and install them. Depending on the panels that are being used, there is a specified distance that must be left between the panels during installation. If there is not enough space left between the panels, they could buckle and cause damage while the building settles.

Exterior Insulation and Finishes System

Description:

EIFS is another type of cladding system that is becoming more prevalent throughout the construction industry due to its aesthetic appeal and low cost. Today, EIFS accounts for 17% of the commercial exterior finish market and 4% of the residential market. There are two different types of EIFS systems, drainable and non-drainable.

The non-drainable system, also known as synthetic stucco, has become less and less common. This is due to the fact that it does not have a drainage cavity or a weather-resistive barrier, and there is a limited drying potential. This allows water to become stuck inside the system damaging the materials, which can cause mold. In order to prevent this, the system must be installed perfectly which is never the case.

The drainable EIFS system (Figure 4) consists of::

- 2" x 4" framing stud wall
- Substrate (plywood, OSB, or cement board)
- Adhesive
- Insulation w/adhesive (extruded polystyrene - EPS)
- Base coat with reinforcing mesh
- Finish coat (Acrylic)

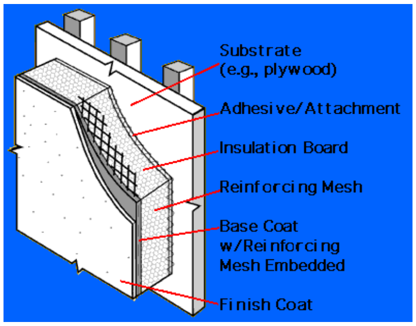


Figure 4: EIFS System

The EIFS system would also require the steel tubing that the metal wall panels require in order to meet the 90 lb/sf wind load.

Advantages:

Figure 5: EIFS Brick Facade

This system is preferred over the non-drainable system for the simple purpose of providing a water resistant exterior surface. The EIFS system has become popular because the continuous insulation board not only prevents water penetration but improves energy efficiency. Also, the insulation board allows easy construction of architectural details like corners. The exterior finishes are very versatile allowing various textures and colors, and is less prone to surface cracking then traditional stucco. Figure 5 shows a detailed example of a building that uses an EIFS system, and the exterior finish was designed to look like facing brick.

EIFS is a high-end product which has installation prices similar to those of basic brick veneer. Drainable EIFS can cost anywhere between $4.50 and $7.50 per square foot depending on insulation type and detail of exterior finish.

Though many materials go into constructing an EIFS wall system, it is one of the lightest forms of cladding. A typical EIFS system can impose a 4 psf. load on a buildings foundation as compared to brick veneer which can impose a load of 40 psf. This can allow for a smaller foundation design as well as reduce the size of a buildings beams and columns.

Disadvantages:

There are also disadvantages to this system. Since there is no drainage cavity on the interior of the system, care must be taken during application to prevent moisture from being captured inside which can cause mold. EIFS systems are more susceptible to damage than other cladding systems. They are typically dented rather than shattered or cracked, but can be easily repaired.

Architectural Precast Concrete Panels

Description:

Figure 6: Precast Building

Precast concrete wall systems provide designers, owners, and managers a solid wall construction system. These systems consist of three basic product types: sandwich wall panels (which will be analyzed), hollowcore, or double tees for walls. Since the panels are manufactured in a shop, they can be produced to an exact tolerance in a wide variety of dimensional choices to meet buildings specifications. The precast wall systems come with a limitless variety of finishes, varying colors, and textures. Precast wall systems have demonstrated high value and versatility in serving the food processing, warehousing and distribution, industrial / commercial / manufacturing and retail markets, which would make it an ideal system for the LSM Facility. Figure 6 shows and example of a building that incorporates architectural precast concrete panels.

The sandwich wall panels are manufactured in 20' x 10' sections with a smooth gray finish. The panels consist of 2" on concrete, then 2" of polystyrene insulation, and then another 2" of concrete.

Advantages:

There are numerous benefits associated with this type of wall system. In climates where there are issues with rain and cold temperatures there are no delays in the schedule due to the fact that the concrete is not poured on site. The panels are shipped to the site and are then installed with a crane. With proper coordination the panels can be cast simultaneously with site preparation, and can then be delivered to site at the exact time required. This can greatly reduce a project's schedule. Another benefit associated with the panels being manufactured in a plant has to do with quality assurance; the panels can be made with minimal to no defects and meet the exact project specifications. Any finish can be applied in the plant to meet the architects and owners needs, which cannot easily be done on site. Plus, precast wall systems can be load-bearing which opens up a whole new range of opportunities for designers to reduce foundation and framing costs. This wall system is also more durable than the previous wall systems, and requires little to no maintenance over the life of the building.

Disadvantages:

A major disadvantage of this system has to do with the cost of manufacturing the product. One of the most costly aspects of a precast system is the initial cost of making the forms. Once the forms are made, each additional piece becomes less expensive. Another issue has to do with bringing the product onto site. The wall planks must be shipped to site, so the cost of trucking them could drive up the total cost. Along with that, if the building is on a constricted site there could be difficulty getting the planks close to the building to eliminate crane movement. If the building requires special sizes there could be issues with lead time, and if a panel is damaged or the wrong size the project could be delayed.

Cost and Schedule Comparison

In order to compare the impacts of each wall system on the LSM project, an estimate was performed using the appropriate materials for each system. The values used for the preformed metal wall panels were obtained from Centria and A.C. Delovade whom are the manufacturer and contactor for the project respectively. In order to obtain cost and duration values for the EIFS and Precast Concrete Wall Systems, values were obtained from the R.S. Means Assemblies Estimate and Building Construction Costs Data books.

Located below in Table 1 are the overall cost, duration, and R-Values for each of the wall systems. At this point the R-Value is irrelevant; it will be discussed later in this analysis. A detailed estimate can be found in Appendix E.

Table 1 - Analysis of Exterior Wall System

Preformed Metal Wall Panel			
Description	Total Cost	Total Weeks	R - Value
Wall Panel	$892,500	12	14.5
Steel Tubing	$357,000	12	0
Total	$1,249,500	24	14.5
Exterior Insulation and Finishes System			
Description	Total Cost	Total Weeks	R - Value
EIFS System 4" EPS	$335,580	24	16.83
Premium Finish	$65,331	6	0
Steel Tubing	$357,000	12	0
Total	$757,911	42	16.83
Architectural Precast Concrete Panels			
Description	Total Cost	Total Weeks	R - Value
Insulated Precast Concrete	$910,350	4	10.4
Steel Tubing	$73,661	1	0
Metal Studs	$71,370	9	0
Total	$1,055,381	14	10.4

The only value located in the table which can be manipulated with proper coordination is the "Total Weeks" column.

- For the metal wall panels, the steel tubing is installed first and then the wall panels. The wall panel installation can begin 1 -2 weeks after the steel tubing is installed to speed up the process if needed. This would reduce the total duration to 14 weeks.

- For the EIFS system, the steel tubing is installed first and then a week later the EIFS can be installed reducing the schedule to 25 weeks. The premium finish can be installed in a manner so that the last section of EIFS installed can receive the finish the next day, hence keeping the schedule to 25 weeks. The EIFS system itself could be sped up by increasing the crew size, which in turn would increase the total cost to $901,425. This would reduce the schedule to 13 weeks.
- The concrete panels can be coordinated so that the steel tubing is installed first and once the first two columns are installed the precast panels for that section can be installed. Once the panels are installed the metal studs can be set into place. This would reduce the schedule to approximately 10 weeks.

The EIFS system clearly will take the most time to install. This is not an issue because the exterior wall system was installed during the warmer months, so there was no rush to have the building enclosed. Along with that, there was no pressure to have the building enclosed early to assist with indoor air quality because the clean rooms were not yet constructed.

Cost is the biggest concern to Human Genome Sciences, and if this is taken into account the EIFS system is the most efficient. If there was some issue with closing up the structure and more crews were needed to install the system, the cost would still be noticeable less than the other two systems.

Below is a cost and schedule relationship between the proposed metal wall panels and the other two systems. (+ is more, - is less)

EIFS:
Cost impact: -$491,589
Schedule impact: + 11 weeks

Precast Concrete Panels:
Cost impact: -$194,119
Schedule impact: - 4 weeks

The EIFS system provides a great cost savings, but will increase the schedule by more than 2 months. As stated earlier, the schedule is not of importance to an extent for enclosing the building. If there were to be an issue the crew size could be increased and still provide a cost saving of $348,075 and reduce the schedule by 1 week. The precast concrete panels provide advantages in both cost and schedule, but the EIFS system could save HGS approximately $350,000 and be under schedule by 1 week if the crew size is doubled.

With respect to cost and schedule the EIFS system would provide great savings to the owner as well as not impact the overall project schedule.

Heat Transfer Comparison

Description

In order to further research the benefits of the EIFS system, the operating cost of the building can be evaluated. Each type of wall system has a respective R - Value, which is the resistance to heat transfer. This number is derived by taking each component of the wall system and adding up each respective R - Value. This rating is very useful when comparing exterior envelopes because the higher the R - Value, the more effective the insulator.

Taking a look at Table 1, the R - Value for the preformed metal wall panel is 14.5. The EIFS system has a higher R – Value of 16.83 due to the thickness of the insulation used.

Calculations

The R - Value (R_{tot}) is used with the outside ($T_{\infty 1}$) and inside ($T_{\infty 2}$) ambient air temperatures and the surface area of the wall to determine the heat transfer rate (q_x). The equation for heat transfer rate is:

$q_x = (T_{\infty 1} - T_{\infty 2}) * A / R_{tot}$

<u>For metal wall panel:</u>

Heating: $q_x = ((70 - 8) * 35{,}700) / 14.5 =$ 152,648 Btu/h

Cooling: $q_x = ((94 - 70) * 35{,}700) / 14.5 =$ 59,090 Btu/h

<u>For EIFS:</u>

Heating: $q_x = ((70 - 8) * 35{,}700) / 16.83 =$ 131,516 Btu/h

Cooling: $q_x = ((94 - 70) * 35{,}700) / 16.83 =$ 50,909 Btu/h

In order to find the amount that both the heating and cooling loads can be reduced the difference in the heat transfer rates for the metal wall panel and EIFS system must be calculated. The total heating load is 8,000,000Btu/h, and the total cooling load is 3,000 tons.

Heating: 152,648 Btu/h - 131,516 Btu/h = 21,132 Btu/h

Cooling: 59,090 Btu/h - 50,909 Btu/h = 8,181 Btu/h = 0.68 tons

The total heating load can be reduced by 21,132 Btu/h, which is 0.26% of the total heating load.

The total cooling load can be reduced by 0.68 tons, which is 0.02 % of the total cooling load.

Conclusion

By changing the exterior wall system, the savings that could be achieved in cooling and heating are very miniscule. Over a span of 50 or more years there could be some cost savings related to the reduction of the heating and cooling load, but when compared to the operation costs of the building and the amount of money HGS makes annually, these saving would not benefit HGS substantially. In order to efficiently analyze which system would be the most desirable, the cost and schedule impacts should be looked at instead of the mechanical impacts.

Conclusion / Recommendation

Originally the LSM Facility was designed to have an exterior wall system consisting of facing brick only. Through the process of Value Engineering, all of the facades excluding the front facade were then changed to use a 2" preformed metal wall panel. The purpose of this analysis was to research different exterior facades in order to increase the aesthetic value while reducing the overall cost and or reducing the installation as compared to the preformed metal wall panels.

From my research it is evident that the preformed metal wall panels used is not the best system that HGS could have chosen. Both the architectural precast concrete panels and the EIFS system would benefit HGS in terms of their needs and wants. There are advantages and disadvantages to both systems, but there needs to be a one that will benefit HGS the most.

I feel that the EIFS system is the best exterior wall system for the LSM Facility. With EIFS the architect would be able to design the exterior coating to resemble that of the surrounding buildings and the front façade of the building. This was the initial intent of the architect, until the building was VE'd to reduce costs. By using an exterior insulation and finishes system the aesthetic value of the building will once again be renewed.

Along with aesthetic value, the EIFS system also will provide a great reduction in total project cost. It would cost roughly $500,000 less to install the EIFS than the metal wall panels. There is one disadvantage linked with this low cost. The building would not be enclosed for another 11 weeks as compared to the metal wall panels. If the project remains on schedule this would not be a great issue because there is no immediate need to get the building enclosed any earlier than this date.

If for some reason the EIFS system would need to be installed at a faster rate, the crew size would be doubled. The resulting effects would be a cost savings of approximately $350,000, and reduce the schedule to 1 week less than that of the metal wall panels. By implementing the EIFS system with either one crew size or by doubling the crew size the advantages are much better than that of the metal wall panels or the architectural precast concrete panels.

Though the wall system has more insulation and hence having a higher resistance to heat transfer through the wall, the savings that HGS could obtain from heating and cooling are very miniscule. The major savings are in the total cost of the exterior wall system itself.

In conclusion the Exterior Insulation and Finishes System would aesthetic value to the building while reducing the total project cost and not impacting the project schedule. This system will perform the same functionally, and hence not take away from the building's performance.

Analysis 3 – Floor Covering for Clean Rooms

Background

The primary purpose of the LSM Facility is to produce and store large amounts of pharmaceutical products. There are specific rooms containing specialized pharmaceutical equipment that are designated for mixing chemicals to create these pharmaceutical products. These rooms are called "clean rooms", which are defined as a manufacturing and inspection area that is temperature and humidity controlled and has continuously filtered air specifically designed to reduce particulate contamination.

Clean rooms differ from containment rooms in that they are intended to keep particles out of the room instead of containing them inside. Clean rooms are given a class depending on the particle count that is specified for the room. The clean rooms in the LSM Facility are a Class 10,000. This means that there exist no more than 10,000 particles larger than 0.5 microns in any given cubic foot of air. For example, in a Class 100 there exist no more than 100 particles larger than 0.5 microns in any given foot of air. In order to achieve this, the air in a clean room is repeatedly filtered to remove dust particles and other impurities that can damage the production of highly sensitive technologies.

Along with keeping the air clean, a major issue with clean rooms is keeping the floor surface clean. In order to prevent particles to become stuck to the floor, the surface needs to be smooth and joint free. Depending on what types of chemicals and products being used in the rooms, the floor must also be resistant to certain chemicals.

This is a very delicate matter because these floors are required to be highly durable to reduce the amount of cracks and nicks in the floor. These damages could retain dust and particles, which can contaminate the equipment or all of the products being produced.

In the LSM Facility, HGS chose to use a quartzite epoxy flooring system. This system is installed in 3 different coats: a primer coat, a base coat, and then a finish coat. The epoxy system is very common in pharmaceutical buildings, but it is a very expensive system to use. There is also a lot of time allotted to the installation because each layer requires a day to cure, and it must be kept relatively clean. I plan on researching different floor systems that could possibly reduce the installation time and or cost of the project. Some other types of floor coverings are terrazzo, epoxy terrazzo, or a plain epoxy floor.

Description of Floor Coverings

Quartzite Epoxy Flooring

Description:

For all of the clean rooms in the LSM facility Epo-Rok Quartz (Figure 7), a product manufactured by the Valspar Corporation, is specified to be the floor covering. The Valspar Corporation has been in business for over 80 years, and the Epo-Rok Quartz is just one of the products they manufacture for industrial purposes.

Figure 7 – Epo-Rok Quartz

The Epo-Rok Quartz flooring system is a 100% solid decorative floor resurfacer. It was designed to be used in light duty areas where slip resistance, and ease of maintenance and cosmetics are of a major consideration. This system is ideally suited for applications in hospitals, research and educational facilities, and pharmaceutical facilities. A unique feature of this system is that it is seamless, which makes it ideal for areas where sanitary needs are required.

This specific system is only ¼" thick, and is installed in three different layers. An epoxy shop floor resurfacer is applied directly to the concrete, which serves as the base coat. The next layer consists of the aggregate, which is the quartz aggregate. This can come in various colors, and the color used in the LSM can be seen above in Figure 7. The final layer of the system is a heavy coat epoxy resurfacer, which serves as the top coat. Each layer of the system requires 24 hours to cure, and must be protected from all traffic whether it be foot or equipment. On top of that, the existing concrete that the system is to be applied to must be no less than 60 days old to prevent cracking of the epoxy floor covering. The only temperature requirements for the system are that it must be applied between 60°F and 90 °F. This could cause some problems if the building is not enclosed and maintained at a constant temperature or provided temporary heating.

Advantages:

Epoxy floor systems are the most widely used in pharmaceutical and health care facilities and in most cases are the most beneficial. Located in Figure 8 is an example of a finished product in a pharmaceutical facility. These floors provide a seamless surface that is very resistant to chemicals, damage, slip, and dust collection. These are all very important attributes of the system because of the nature of the rooms in which they are used. As stated earlier in this analysis, cleanliness is a very important issue since pharmaceutical drugs are being produced in these rooms and can not be contaminated in any way. They also possess a compressive strength around 9,000 psi., which makes the surface very durable and hence requires very little maintenance.


Figure 8 – Example of finished product

Disadvantages:

There are no physical disadvantages to the system itself. Only if the surface was damaged, which would require a lot of force, the area would need to be sanded down and then reapplied. There would be some visible distinction between the original floor finish and the new, but it would be very minimal. The only issue with the system is related to its application time. Each layer needs to be applied no earlier than 24 hours before the previous. This could lead to delays in a project if contractors need to get into that area to work. This can be avoided with proper coordination by the contractors and the Construction Manager. This floor covering is also more expensive than most other coverings, but many of these other coverings do not possess the same attributes as the epoxy.

Bonded Conductive Terrazzo

Description:

Along with the epoxy system, terrazzo can also be a type of seamless floor coating depending on the floor slab below. Terrazzo is typically used in health care facilities, lobbies, educational facilities, retail, and hotels. Terrazzo is known traditionally as an expensive decorative floor covering that is very durable. Figure 9 shows a simple example of what a finished terrazzo floor looks like in a pharmaceutical building in Rockville, MD. This floor is not located in a clean room, but rather displays the aesthetic value of terrazzo. There are many different types of terrazzo floor systems including: precast, structural, monolithic, epoxy, conductive, and bonded. In this section, bonded conductive terrazzo will be analyzed further for reasons to be explained.

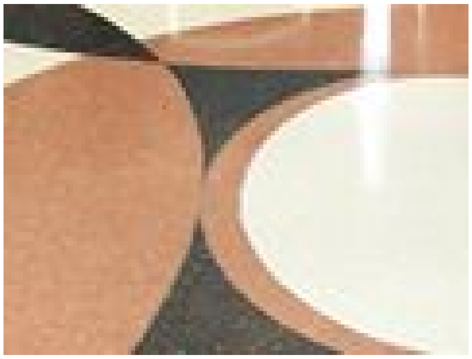


Figure 9 – Genetic Therapy Bldg.

Terrazzo is a composite material which is typically poured in place. It consists of a cementitious binder, instead of epoxy, and an aggregate which is spread throughout the mix creating at heterogeneous coating. The aggregate can be marble, quartz, granite, or glass. The terrazzo is then cured, ground down, and then polished and sealed to a smooth finish. Terrazzo is one of the thickest floor coatings due to the aggregates used in the bonding material. The average thickness of a terrazzo floor is 2", with the terrazzo topping being roughly ½". If terrazzo is used, it must be taken into account during the design phases of the project because the floor slabs will need to be recessed to account for the thickness of the terrazzo system.

Due to the fact that this floor is going to be used in a manufacturing facility, many things need to be taken into consideration. First is the fact that cleanliness and resistance to chemicals is a primary concern of Human Genome Sciences in the clean rooms, and this is the reason why conductive terrazzo must be used. Conductive terrazzo will conduct electricity within prescribed resistance levels. It eliminates the buildup of static electricity and is therefore a safe floor for use in areas subject to explosive hazards. Another issue is that there are a large number of floor drains within the building that require the floor to be sloped. This will require the floor covering to be bonded to the concrete floor slab, hence bonded terrazzo must be used in comparison to monolithic which requires a flat surface.

Advantages:

There are numerous advantages to bonded conductive terrazzo flooring. This flooring is very resistant to impact damage and daily wear and tear. It is also resistant to many chemicals due to its conductive nature. Terrazzo has always been known as a very decorative floor covering depending on the type of aggregate used in the binder. The cost of terrazzo is also very comparative to all other floor systems when maintenance cost is taken into effect instead of just initial cost.

Disadvantages:

Terrazzo can also become a very expensive product when areas need replaced. It can become difficult to get the same exact mix or a mix relatively close to the original. Also, depending on the aggregate, there can be a long lead time to get the appropriate materials. This can also become an issue during initial application. If the wrong amount is ordered, the schedule could fall behind if more material needs to be ordered. Another issue with terrazzo is that it is not 100% resistant to liquids. If proper maintenance is not taken on the surface it could retain some chemicals causing issues with flammability. One major issue with all terrazzo floor systems is the need for dividers to prevent cracking. Typically the dividers are placed over control joints located on the buildings concrete floor slabs, but they can also be placed in areas to separate different terrazzo mix designs. This would not be an issue in the LSM facility because the floor slabs are so thick and highly reinforced that there are no control joints throughout the slab. There is simply one main control joint running east to west in the southern portion of the building, and there is no need for special flooring in that section of the building.

Conductive Epoxy Terrazzo

Description:

The epoxy terrazzo floor system is a smooth seamless floor covering which is much thinner than your typical terrazzo. Epoxy terrazzo has taken more than 70% of today's terrazzo market due to its thin application, multicolor ability, and greater durability. Figure 10 shows an example of an epoxy terrazzo floor with an aesthetic design. This system is very comparable to that of the quartzite epoxy flooring. The main difference is in the aggregates used.

Figure 10 – Epoxy Terrazzo

Epoxy terrazzo floors are typically installed in a ¼" thickness, and in two different layers. The first layer is just an epoxy primer that takes no less than an hour to cure. The epoxy system is then set into place and trowel finished. Once the floor is allowed to cure for a little, the surface is then grouted with an epoxy terrazzo grout to fill in all of the voids. The final step is to then polish and seal the surface like typical terrazzo floors.

Advantages:

The advantages of the epoxy terrazzo floor are quite similar to that of the quartzite epoxy floor. This modern-day terrazzo is excellent for multicolored patterns and designs because the epoxy resin matrix can be pigmented, like paint, to achieve an unlimited spectrum of colors. And it can accommodate a wider variety of richly colored aggregates, including chips of marble or granite, recycled glass, mother of pearl, and various synthetic materials. Epoxy terrazzo offers outstanding durability and wear, making it tough enough for use in high-traffic commercial and industrial environments. Because the binder is 100% epoxy, the finished floor surface provides greater resiliency, chemical resistance, compressive strengths, and flexibility than cement-based systems.

Disadvantages:

This is one of the most expensive floor systems in the market today. This would be a big issue to Human genome Sciences because cost is a major factor in constructing the LSM facility. Though it has many attributes that are required for a clean room, the quartzite epoxy floor coating has the same attributes, so the added cost would not add any extra value to the facility. This system has only one physical disadvantage, and that comes into play if the floor is damaged. There can be a lot of time and cost associated with replacing the damaged section of the floor. There can be a lead time associated with the marble or granite aggregate used in the terrazzo mix. If it is a rare stone or a high demand stone there could be high costs and schedule delays to get the proper stone chips in time.

Cost and Schedule Comparison

In order to compare the impacts of each floor covering on the LSM project, an estimate was performed using the appropriate materials for each system. In order to obtain cost and duration values for the quartzite epoxy, bonded conductive terrazzo, and the conductive epoxy terrazzo, values were obtained from the R.S. Means Assemblies Estimate and Building Construction Costs Data books.

Located below in Table 2 are the overall cost and duration values for each of the floor coverings. A detailed estimate can be found in Appendix F.

Table 2 - Analysis of Floor Coverings

Quartzite Epoxy		
Description	Total Cost	Total Weeks
Epoxy with quartz chips	$450,500	22
Total	$450,500	22
Bonded Conductive Terrazzo		
Description	Total Cost	Total Weeks
Bonded Conductive Terrazzo	$742,000	118
Total	$742,000	118
Conductive Epoxy Terrazzo		
Description	Total Cost	Total Weeks
Conductive Epoxy Terrazzo	$617,450	53
Total	$617,450	53

These values obtained from the R.S. means are only approximations. As you can see the value for the total weeks varies greatly. This can be manipulated by adding extra crews which in turn would increase the labor cost of the product. By looking at the values obtained, it would be useless to perform this action.

The values for total cost and total weeks clearly show that the quartzite epoxy floor covering is the most beneficial system. Below is a cost and schedule relationship between the proposed quartzite epoxy and the other two systems. (+ is more, - is less)

Bonded Conductive Terrazzo:

Cost impact: +$291,500

Schedule impact: + 96 weeks

Conductive Epoxy Terrazzo:

Cost impact: +$166,950

Schedule impact: + 31 weeks

The only system that closely compares to the quartzite epoxy flooring is the conductive epoxy terrazzo. The only way to have the values more closely resemble each other would be to increase the crew size. This would change the total duration to 27 weeks, which would still impact the schedule by 5 more weeks. It would also add an additional $118,720 to the total cost.

By analyzing the cost and schedule impacts of all of the floor systems, the proposed quartzite epoxy flooring is the superior system.

Conclusion / Recommendation

The LSM Facility consists of multiple "clean rooms" in which pharmaceutical products will be produced. These rooms have a Class 10,000 rating which means that there exist no more than 10,000 particles larger than 0.5 microns in any given cubic foot of air. In order to keep this condition there needs to be an extensive HVAC system as well as a floor that is resistant to collecting dust and particles that could contaminate the pharmaceutical products being produced.

For all of the "clean rooms" a quartzite epoxy floor covering was specified. This floor covering is installed in three coats and each coat takes 24 hours to cure. This type of flooring is required due to its resistance to chemicals, durability, and relatively smooth surface.

Three different systems were researched in this analysis, including the specified floor covering, a bonded conductive terrazzo floor, and a conductive epoxy terrazzo floor. In terms of durability and chemical resistance all of the floor coverings are relatively the same. Each floor system has one disadvantage, and that is related to damage to the product itself. It can take a lot of time as well as money to replace a section of flooring depending on how it is damaged.

In terms of cost and schedule impact, the quartzite epoxy terrazzo floor is superior. The other two systems not only cost more money but they also will take more time to install. It is evident that for "clean room" applications a quartzite epoxy floor is the premier floor covering to use. It is not only aesthetically pleasing, but it is durable, resistant to chemicals, cheap, and takes less time to install than its counterparts.

Credits and Acknowledgements

I would like to thank the following people for their assistance and support throughout my senior thesis experience:

The Architectural Engineering Department

- Dr. John Messner, Dr. Michael Horman, and Dr. David Riley

Human Genome Sciences

- Raj Vora, P.E.
- Joe Morin

Gilbane Building Company

- Andy Faber
- Chuck Brawley
- Ted Trester
- Mike Curry
- Tim McNeal
- Mark Rummel
- Lola Poe Taylor
- Shannon Croissette

Family and Friends

- My Mom and Dad
- My roommates Jason and Joe
- My fellow peers in AE
- And whoever else I forgot…..my brain is fried

References

Exterior Wall System Analysis

2005 R.S. Means Building Construction Cost Data

2005 R.S. Means Assemblies Cost Data

Mechanical & Electrical Equipment in Buildings (MEEB), 9th Edition by Benjamin Stein and John S. Reynolds

http://www.toolbase.org/tertiaryT.asp?DocumentID=2043&CategoryID=1017

Floor Covering Analysis

2005 R.S. Means Building Construction Cost Data

2005 R.S. Means Assemblies Cost Data

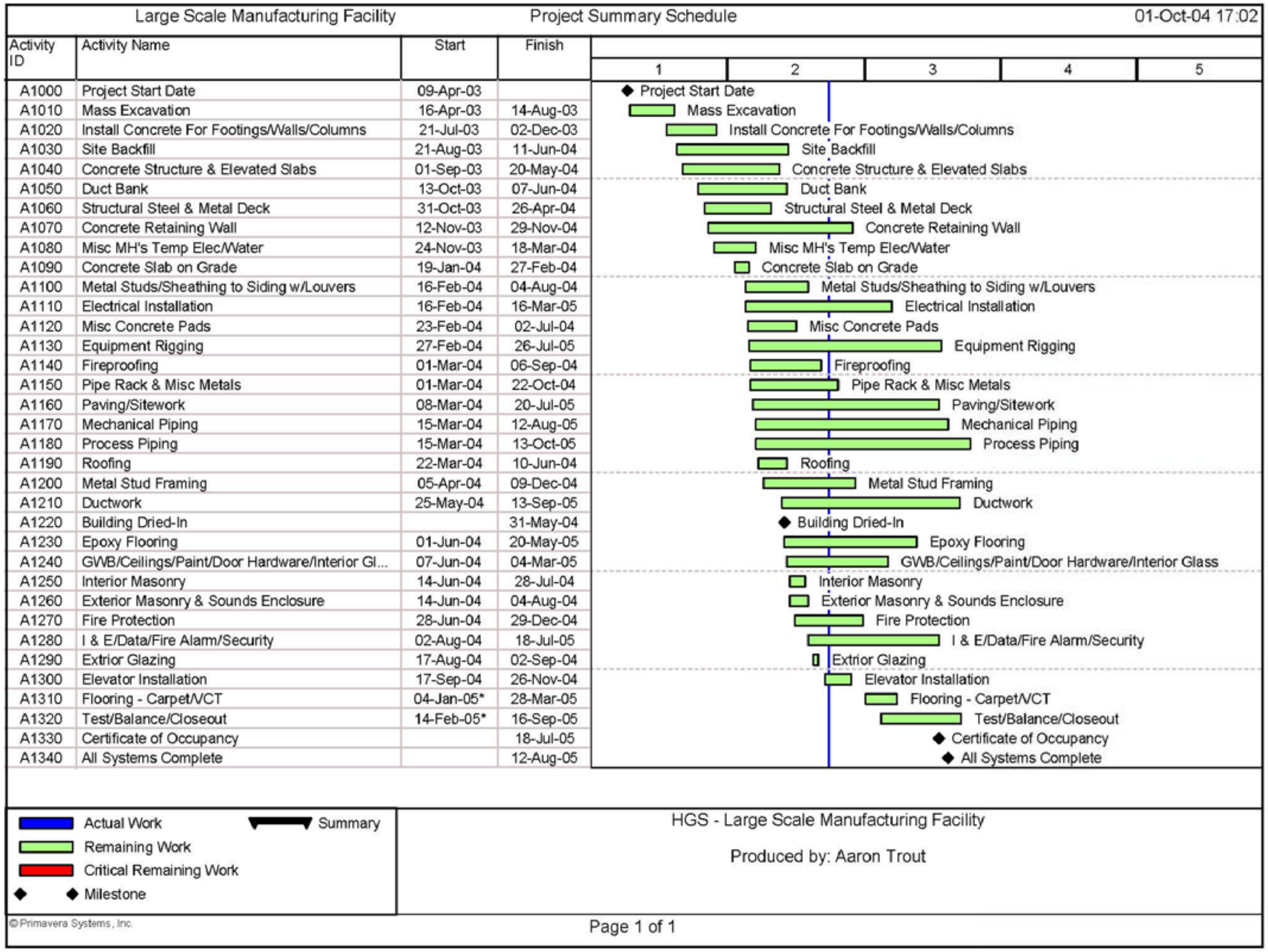
http://www.ntma.com/

4-D Coordination Model

http://www.new-technologies.org/ECT/Other/4d.htm

Appendix A – Schedule Information

Summary Schedule



Large Scale Manufacturing Facility Project Summary Schedule 01-Oct-04 17:02

Activity ID	Activity Name	Start	Finish
A1000	Project Start Date	09-Apr-03	
A1010	Mass Excavation	16-Apr-03	14-Aug-03
A1020	Install Concrete For Footings/Walls/Columns	21-Jul-03	02-Dec-03
A1030	Site Backfill	21-Aug-03	11-Jun-04
A1040	Concrete Structure & Elevated Slabs	01-Sep-03	20-May-04
A1050	Duct Bank	13-Oct-03	07-Jun-04
A1060	Structural Steel & Metal Deck	31-Oct-03	26-Apr-04
A1070	Concrete Retaining Wall	12-Nov-03	29-Nov-04
A1080	Misc MH's Temp Elec/Water	24-Nov-03	18-Mar-04
A1090	Concrete Slab on Grade	19-Jan-04	27-Feb-04
A1100	Metal Studs/Sheathing to Siding w/Louvers	16-Feb-04	04-Aug-04
A1110	Electrical Installation	16-Feb-04	16-Mar-05
A1120	Misc Concrete Pads	23-Feb-04	02-Jul-04
A1130	Equipment Rigging	27-Feb-04	26-Jul-05
A1140	Fireproofing	01-Mar-04	06-Sep-04
A1150	Pipe Rack & Misc Metals	01-Mar-04	22-Oct-04
A1160	Paving/Sitework	08-Mar-04	20-Jul-05
A1170	Mechanical Piping	15-Mar-04	12-Aug-05
A1180	Process Piping	15-Mar-04	13-Oct-05
A1190	Roofing	22-Mar-04	10-Jun-04
A1200	Metal Stud Framing	05-Apr-04	09-Dec-04
A1210	Ductwork	25-May-04	13-Sep-05
A1220	Building Dried-In		31-May-04
A1230	Epoxy Flooring	01-Jun-04	20-May-05
A1240	GWB/Ceilings/Paint/Door Hardware/Interior Gl...	07-Jun-04	04-Mar-05
A1250	Interior Masonry	14-Jun-04	28-Jul-04
A1260	Exterior Masonry & Sounds Enclosure	14-Jun-04	04-Aug-04
A1270	Fire Protection	28-Jun-04	29-Dec-04
A1280	I & E/Data/Fire Alarm/Security	02-Aug-04	18-Jul-05
A1290	Extrior Glazing	17-Aug-04	02-Sep-04
A1300	Elevator Installation	17-Sep-04	26-Nov-04
A1310	Flooring - Carpet/VCT	04-Jan-05*	28-Mar-05
A1320	Test/Balance/Closeout	14-Feb-05*	16-Sep-05
A1330	Certificate of Occupancy		18-Jul-05
A1340	All Systems Complete		12-Aug-05

🟦 Actual Work
🟩 Remaining Work
🟥 Critical Remaining Work
◆ ◆ Milestone
Summary

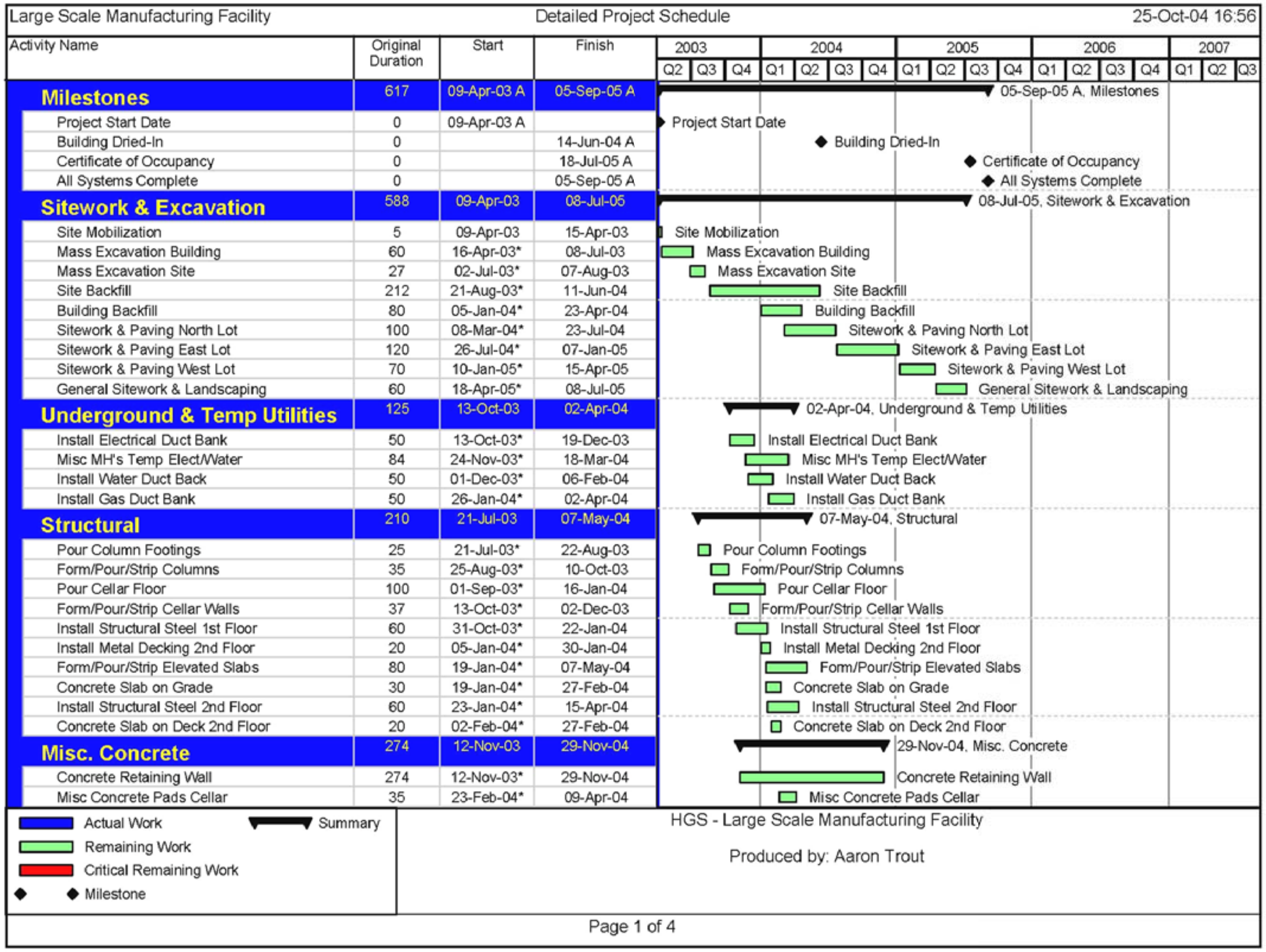
HGS - Large Scale Manufacturing Facility

Produced by: Aaron Trout

© Primavera Systems, Inc.

Page 1 of 1

Detailed Project Schedule



Large Scale Manufacturing Facility Detailed Project Schedule 25-Oct-04 16:56

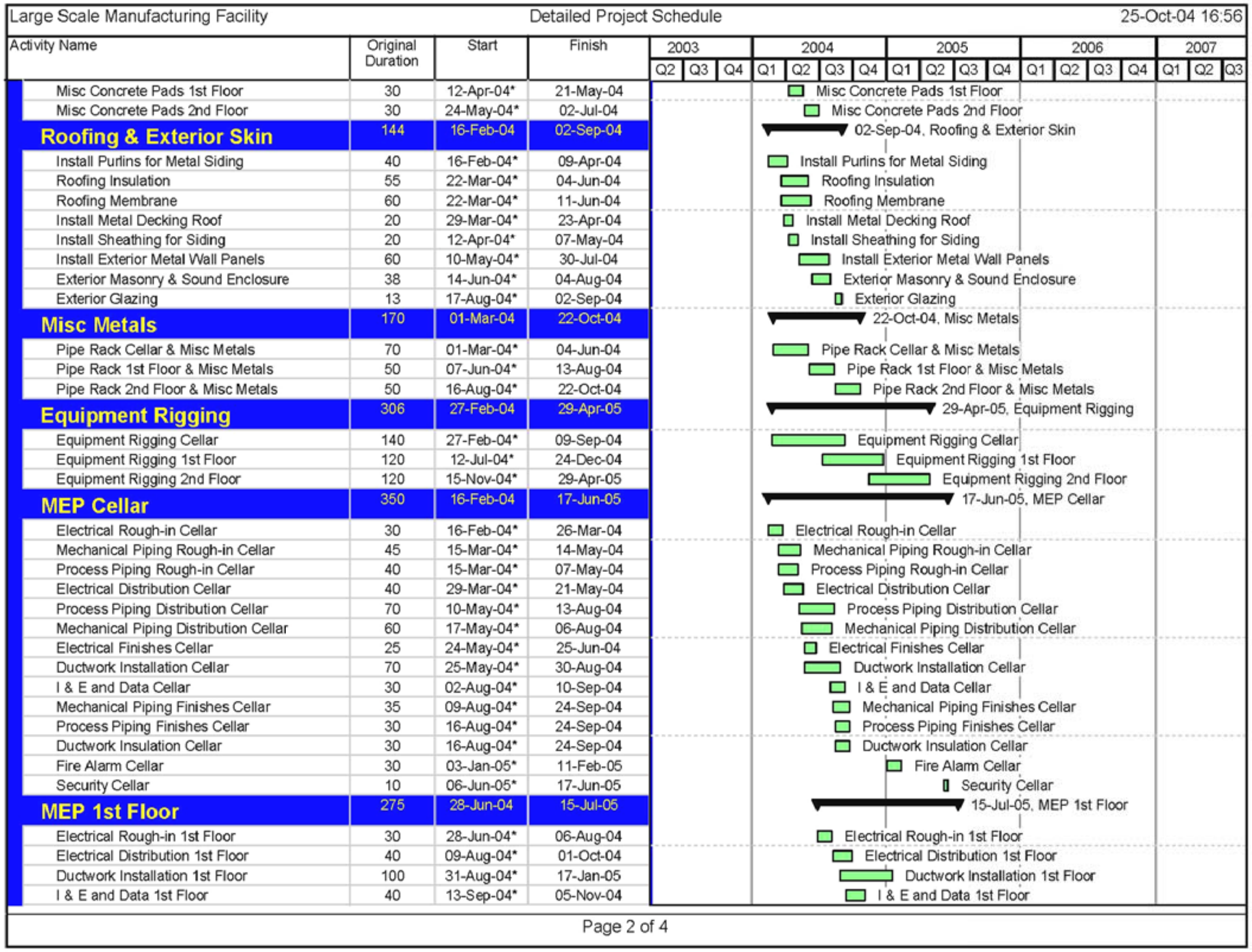
Activity Name	Original Duration	Start	Finish
Milestones	617	09-Apr-03 A	05-Sep-05 A
Project Start Date	0	09-Apr-03 A	
Building Dried-In	0		14-Jun-04 A
Certificate of Occupancy	0		18-Jul-05 A
All Systems Complete	0		05-Sep-05 A
Sitework & Excavation	588	09-Apr-03	08-Jul-05
Site Mobilization	5	09-Apr-03	15-Apr-03
Mass Excavation Building	60	16-Apr-03*	08-Jul-03
Mass Excavation Site	27	02-Jul-03*	07-Aug-03
Site Backfill	212	21-Aug-03*	11-Jun-04
Building Backfill	80	05-Jan-04*	23-Apr-04
Sitework & Paving North Lot	100	08-Mar-04*	23-Jul-04
Sitework & Paving East Lot	120	26-Jul-04*	07-Jan-05
Sitework & Paving West Lot	70	10-Jan-05*	15-Apr-05
General Sitework & Landscaping	60	18-Apr-05*	08-Jul-05
Underground & Temp Utilities	125	13-Oct-03	02-Apr-04
Install Electrical Duct Bank	50	13-Oct-03*	19-Dec-03
Misc MH's Temp Elect/Water	84	24-Nov-03*	18-Mar-04
Install Water Duct Back	50	01-Dec-03*	06-Feb-04
Install Gas Duct Bank	50	26-Jan-04*	02-Apr-04
Structural	210	21-Jul-03	07-May-04
Pour Column Footings	25	21-Jul-03*	22-Aug-03
Form/Pour/Strip Columns	35	25-Aug-03*	10-Oct-03
Pour Cellar Floor	100	01-Sep-03*	16-Jan-04
Form/Pour/Strip Cellar Walls	37	13-Oct-03*	02-Dec-03
Install Structural Steel 1st Floor	60	31-Oct-03*	22-Jan-04
Install Metal Decking 2nd Floor	20	05-Jan-04*	30-Jan-04
Form/Pour/Strip Elevated Slabs	80	19-Jan-04*	07-May-04
Concrete Slab on Grade	30	19-Jan-04*	27-Feb-04
Install Structural Steel 2nd Floor	60	23-Jan-04*	15-Apr-04
Concrete Slab on Deck 2nd Floor	20	02-Feb-04*	27-Feb-04
Misc. Concrete	274	12-Nov-03	29-Nov-04
Concrete Retaining Wall	274	12-Nov-03*	29-Nov-04
Misc Concrete Pads Cellar	35	23-Feb-04*	09-Apr-04

🟦 Actual Work
🟩 Remaining Work
🟥 Critical Remaining Work
◆ Milestone
Summary

HGS - Large Scale Manufacturing Facility

Produced by: Aaron Trout

Page 1 of 4

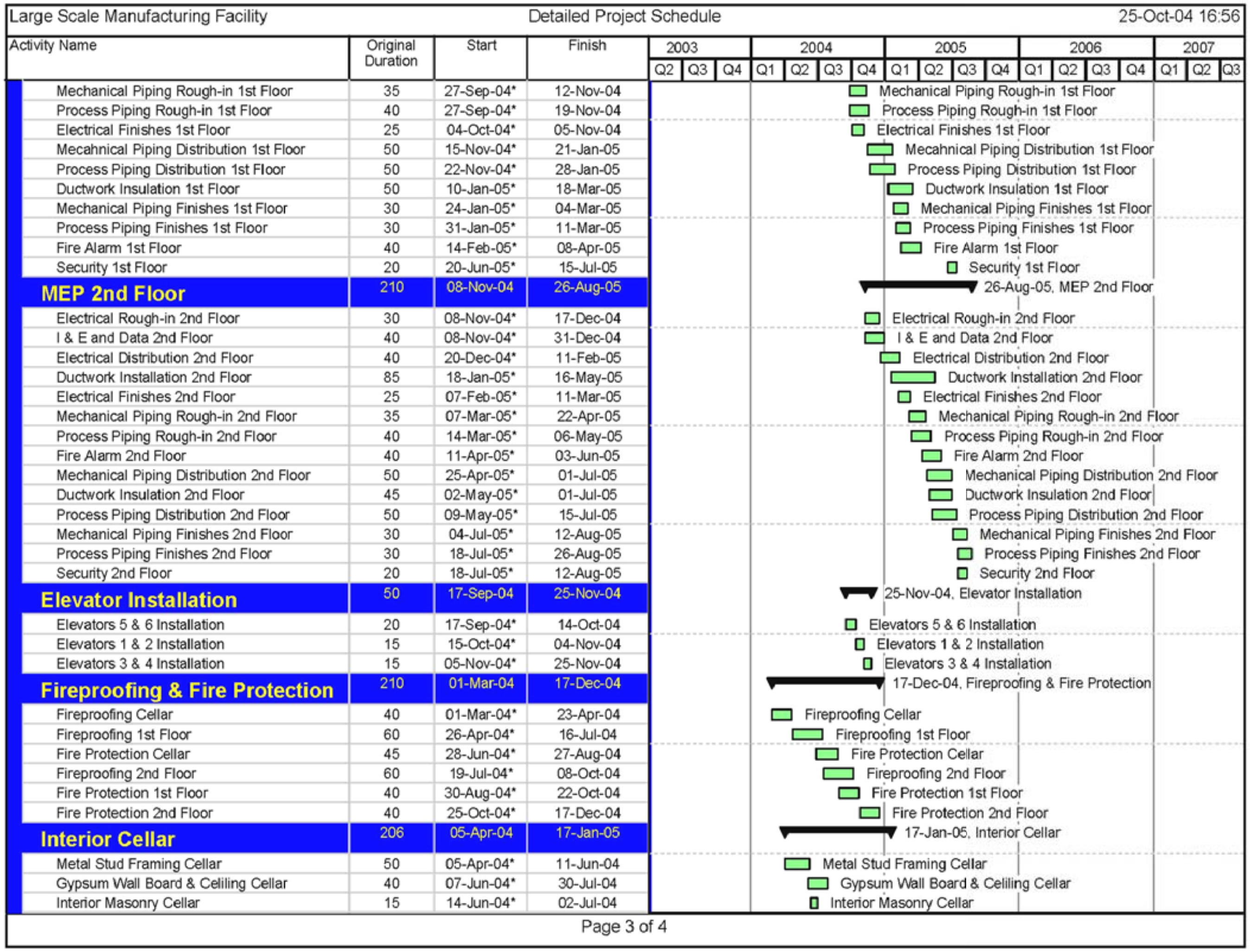


Large Scale Manufacturing Facility Detailed Project Schedule 25-Oct-04 16:56

Activity Name	Original Duration	Start	Finish
Misc Concrete Pads 1st Floor	30	12-Apr-04*	21-May-04
Misc Concrete Pads 2nd Floor	30	24-May-04*	02-Jul-04
Roofing & Exterior Skin	144	16-Feb-04	02-Sep-04
Install Purlins for Metal Siding	40	16-Feb-04*	09-Apr-04
Roofing Insulation	55	22-Mar-04*	04-Jun-04
Roofing Membrane	60	22-Mar-04*	11-Jun-04
Install Metal Decking Roof	20	29-Mar-04*	23-Apr-04
Install Sheathing for Siding	20	12-Apr-04*	07-May-04
Install Exterior Metal Wall Panels	60	10-May-04*	30-Jul-04
Exterior Masonry & Sound Enclosure	38	14-Jun-04*	04-Aug-04
Exterior Glazing	13	17-Aug-04*	02-Sep-04
Misc Metals	170	01-Mar-04	22-Oct-04
Pipe Rack Cellar & Misc Metals	70	01-Mar-04*	04-Jun-04
Pipe Rack 1st Floor & Misc Metals	50	07-Jun-04*	13-Aug-04
Pipe Rack 2nd Floor & Misc Metals	50	16-Aug-04*	22-Oct-04
Equipment Rigging	306	27-Feb-04	29-Apr-05
Equipment Rigging Cellar	140	27-Feb-04*	09-Sep-04
Equipment Rigging 1st Floor	120	12-Jul-04*	24-Dec-04
Equipment Rigging 2nd Floor	120	15-Nov-04*	29-Apr-05
MEP Cellar	350	16-Feb-04	17-Jun-05
Electrical Rough-in Cellar	30	16-Feb-04*	26-Mar-04
Mechanical Piping Rough-in Cellar	45	15-Mar-04*	14-May-04
Process Piping Rough-in Cellar	40	15-Mar-04*	07-May-04
Electrical Distribution Cellar	40	29-Mar-04*	21-May-04
Process Piping Distribution Cellar	70	10-May-04*	13-Aug-04
Mechanical Piping Distribution Cellar	60	17-May-04*	06-Aug-04
Electrical Finishes Cellar	25	24-May-04*	25-Jun-04
Ductwork Installation Cellar	70	25-May-04*	30-Aug-04
I & E and Data Cellar	30	02-Aug-04*	10-Sep-04
Mechanical Piping Finishes Cellar	35	09-Aug-04*	24-Sep-04
Process Piping Finishes Cellar	30	16-Aug-04*	24-Sep-04
Ductwork Insulation Cellar	30	16-Aug-04*	24-Sep-04
Fire Alarm Cellar	30	03-Jan-05*	11-Feb-05
Security Cellar	10	06-Jun-05*	17-Jun-05
MEP 1st Floor	275	28-Jun-04	15-Jul-05
Electrical Rough-in 1st Floor	30	28-Jun-04*	06-Aug-04
Electrical Distribution 1st Floor	40	09-Aug-04*	01-Oct-04
Ductwork Installation 1st Floor	100	31-Aug-04*	17-Jan-05
I & E and Data 1st Floor	40	13-Sep-04*	05-Nov-04

Page 2 of 4

Large Scale Manufacturing Facility Detailed Project Schedule 25-Oct-04 16:56



Activity Name	Original Duration	Start	Finish
Mechanical Piping Rough-in 1st Floor	35	27-Sep-04*	12-Nov-04
Process Piping Rough-in 1st Floor	40	27-Sep-04*	19-Nov-04
Electrical Finishes 1st Floor	25	04-Oct-04*	05-Nov-04
Mecahnical Piping Distribution 1st Floor	50	15-Nov-04*	21-Jan-05
Process Piping Distribution 1st Floor	50	22-Nov-04*	28-Jan-05
Ductwork Insulation 1st Floor	50	10-Jan-05*	18-Mar-05
Mechanical Piping Finishes 1st Floor	30	24-Jan-05*	04-Mar-05
Process Piping Finishes 1st Floor	30	31-Jan-05*	11-Mar-05
Fire Alarm 1st Floor	40	14-Feb-05*	08-Apr-05
Security 1st Floor	20	20-Jun-05*	15-Jul-05
MEP 2nd Floor	210	08-Nov-04	26-Aug-05
Electrical Rough-in 2nd Floor	30	08-Nov-04*	17-Dec-04
I & E and Data 2nd Floor	40	08-Nov-04*	31-Dec-04
Electrical Distribution 2nd Floor	40	20-Dec-04*	11-Feb-05
Ductwork Installation 2nd Floor	85	18-Jan-05*	16-May-05
Electrical Finishes 2nd Floor	25	07-Feb-05*	11-Mar-05
Mechanical Piping Rough-in 2nd Floor	35	07-Mar-05*	22-Apr-05
Process Piping Rough-in 2nd Floor	40	14-Mar-05*	06-May-05
Fire Alarm 2nd Floor	40	11-Apr-05*	03-Jun-05
Mechanical Piping Distribution 2nd Floor	50	25-Apr-05*	01-Jul-05
Ductwork Insulation 2nd Floor	45	02-May-05*	01-Jul-05
Process Piping Distribution 2nd Floor	50	09-May-05*	15-Jul-05
Mechanical Piping Finishes 2nd Floor	30	04-Jul-05*	12-Aug-05
Process Piping Finishes 2nd Floor	30	18-Jul-05*	26-Aug-05
Security 2nd Floor	20	18-Jul-05*	12-Aug-05
Elevator Installation	50	17-Sep-04	25-Nov-04
Elevators 5 & 6 Installation	20	17-Sep-04*	14-Oct-04
Elevators 1 & 2 Installation	15	15-Oct-04*	04-Nov-04
Elevators 3 & 4 Installation	15	05-Nov-04*	25-Nov-04
Fireproofing & Fire Protection	210	01-Mar-04	17-Dec-04
Fireproofing Cellar	40	01-Mar-04*	23-Apr-04
Fireproofing 1st Floor	60	26-Apr-04*	16-Jul-04
Fire Protection Cellar	45	28-Jun-04*	27-Aug-04
Fireproofing 2nd Floor	60	19-Jul-04*	08-Oct-04
Fire Protection 1st Floor	40	30-Aug-04*	22-Oct-04
Fire Protection 2nd Floor	40	25-Oct-04*	17-Dec-04
Interior Cellar	206	05-Apr-04	17-Jan-05
Metal Stud Framing Cellar	50	05-Apr-04*	11-Jun-04
Gypsum Wall Board & Celiling Cellar	40	07-Jun-04*	30-Jul-04
Interior Masonry Cellar	15	14-Jun-04*	02-Jul-04

Page 3 of 4

Large Scale Manufacturing Facility

Detailed Project Schedule

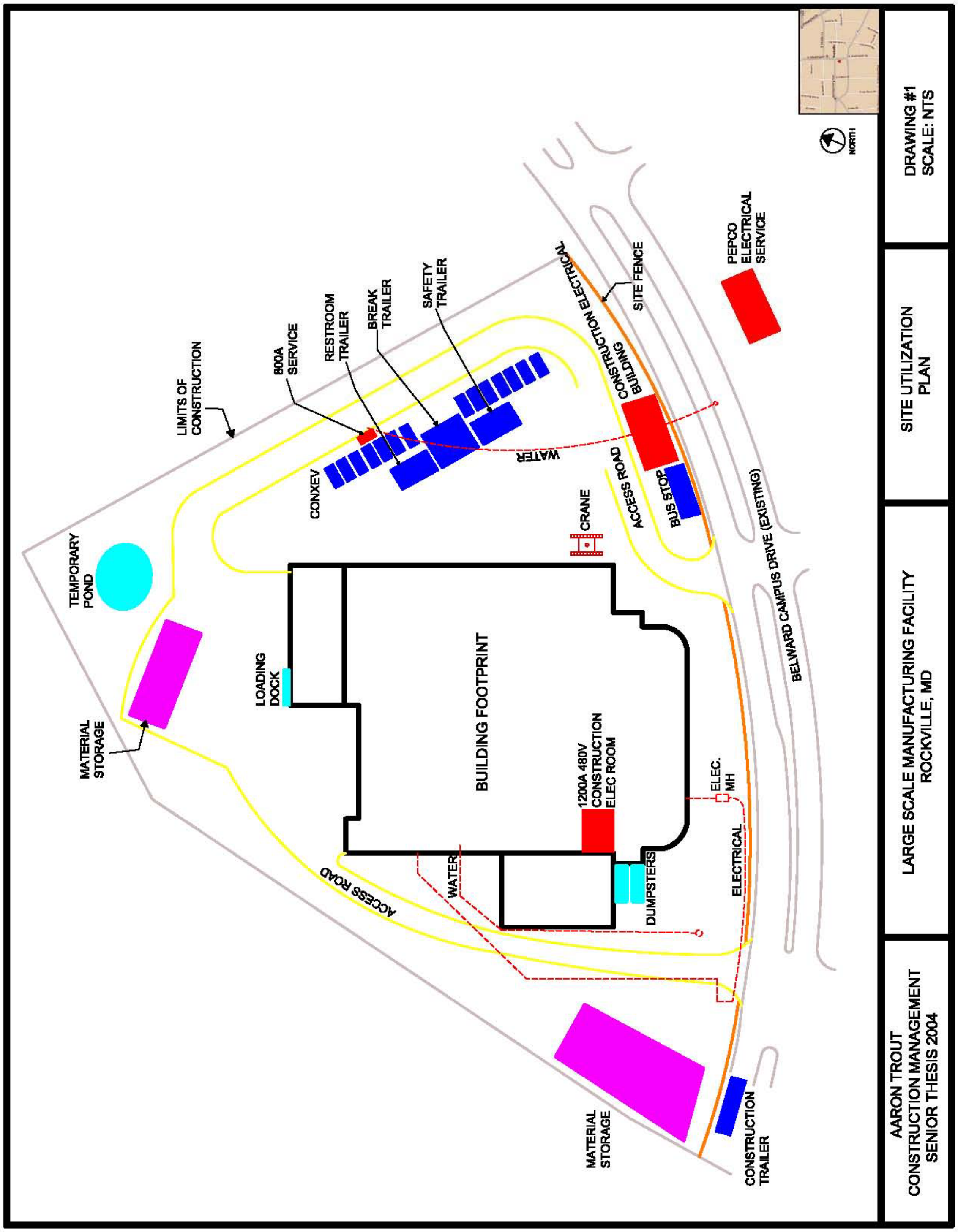
25-Oct-04 16:56

Activity Name	Original Duration	Start	Finish
Door Hardware & Interior Glass Cellar	25	02-Aug-04*	03-Sep-04
Painting Cellar	20	02-Aug-04*	27-Aug-04
Flooring Cellar	10	04-Jan-05*	17-Jan-05
Interior 1st Floor	195	01-Jun-04	28-Feb-05
Epoxy Flooring 1st Floor	120	01-Jun-04*	15-Nov-04
Metal Stud Framing 1st Floor	60	07-Jun-04*	27-Aug-04
Interior Masonry 1st Floor	7	05-Jul-04*	13-Jul-04
Gypsum Wall Board & Ceiling 1st Floor	50	02-Aug-04*	08-Oct-04
Door Hardware & Interior Glass 1st Floor	35	11-Oct-04*	26-Nov-04
Painting 1st Floor	30	11-Oct-04*	19-Nov-04
Flooring 1st Floor	30	18-Jan-05*	28-Feb-05
Interior 2nd Floor	209	14-Jul-04	02-May-05
Interior Masonry 2nd Floor	7	14-Jul-04*	22-Jul-04
Metal Stud Framing 2nd Floor	60	23-Aug-04*	12-Nov-04
Gypsum Wall Board & Ceiling 2nd Floor	50	11-Oct-04*	17-Dec-04
Epoxy Flooring 2nd Floor	120	16-Nov-04*	02-May-05
Door Hardware & Interior Glass 2nd Floor	35	20-Dec-04*	04-Feb-05
Painting 2nd Floor	30	20-Dec-04*	28-Jan-05
Flooring 2nd Floor	20	01-Mar-05*	28-Mar-05
Closeout Phase	105	11-Apr-05	02-Sep-05
Testing	25	11-Apr-05*	13-May-05
Balancing	40	16-May-05*	08-Jul-05
Closeout	40	11-Jul-05*	02-Sep-05

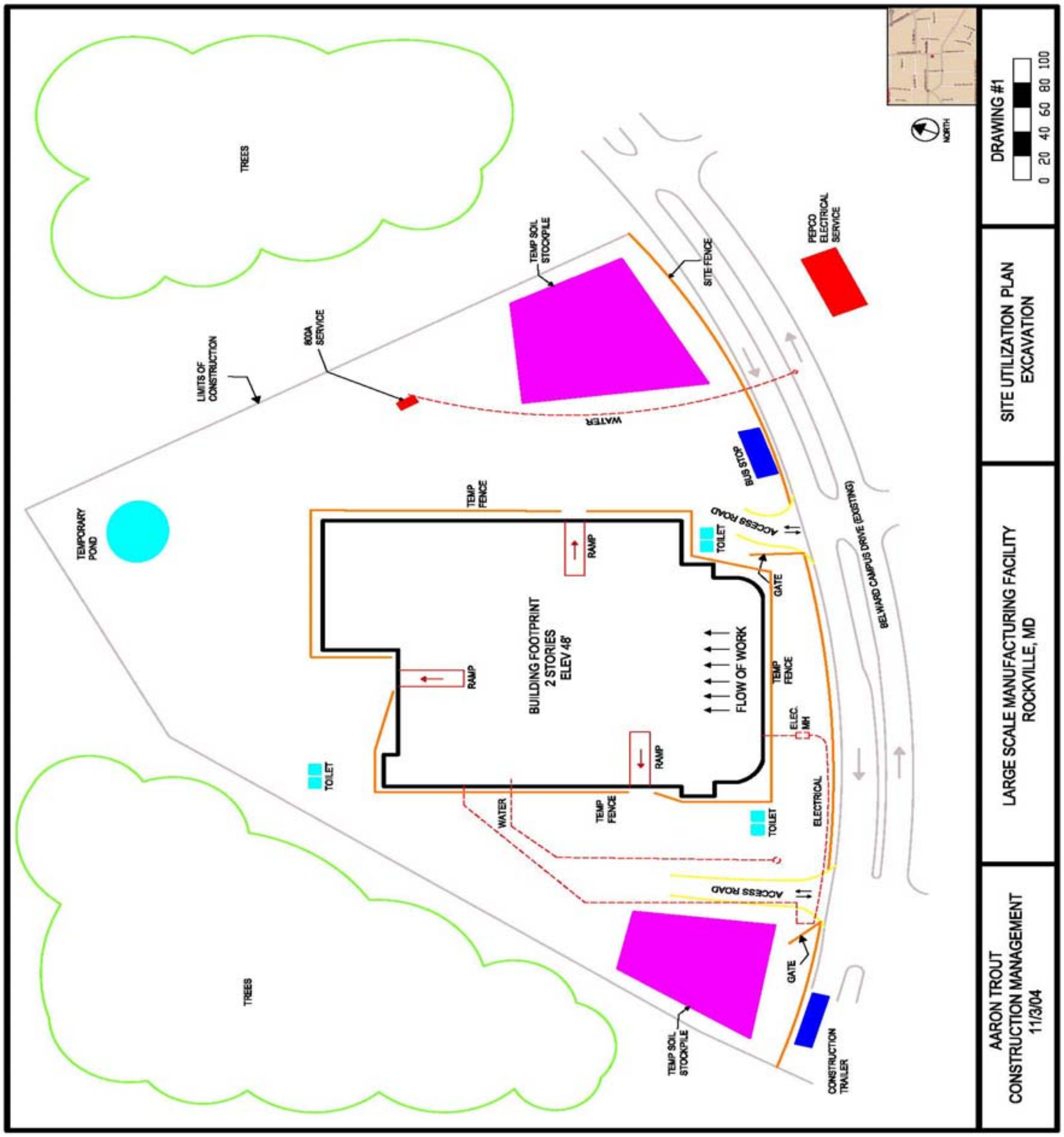
Page 4 of 4

Appendix B – Site Plans

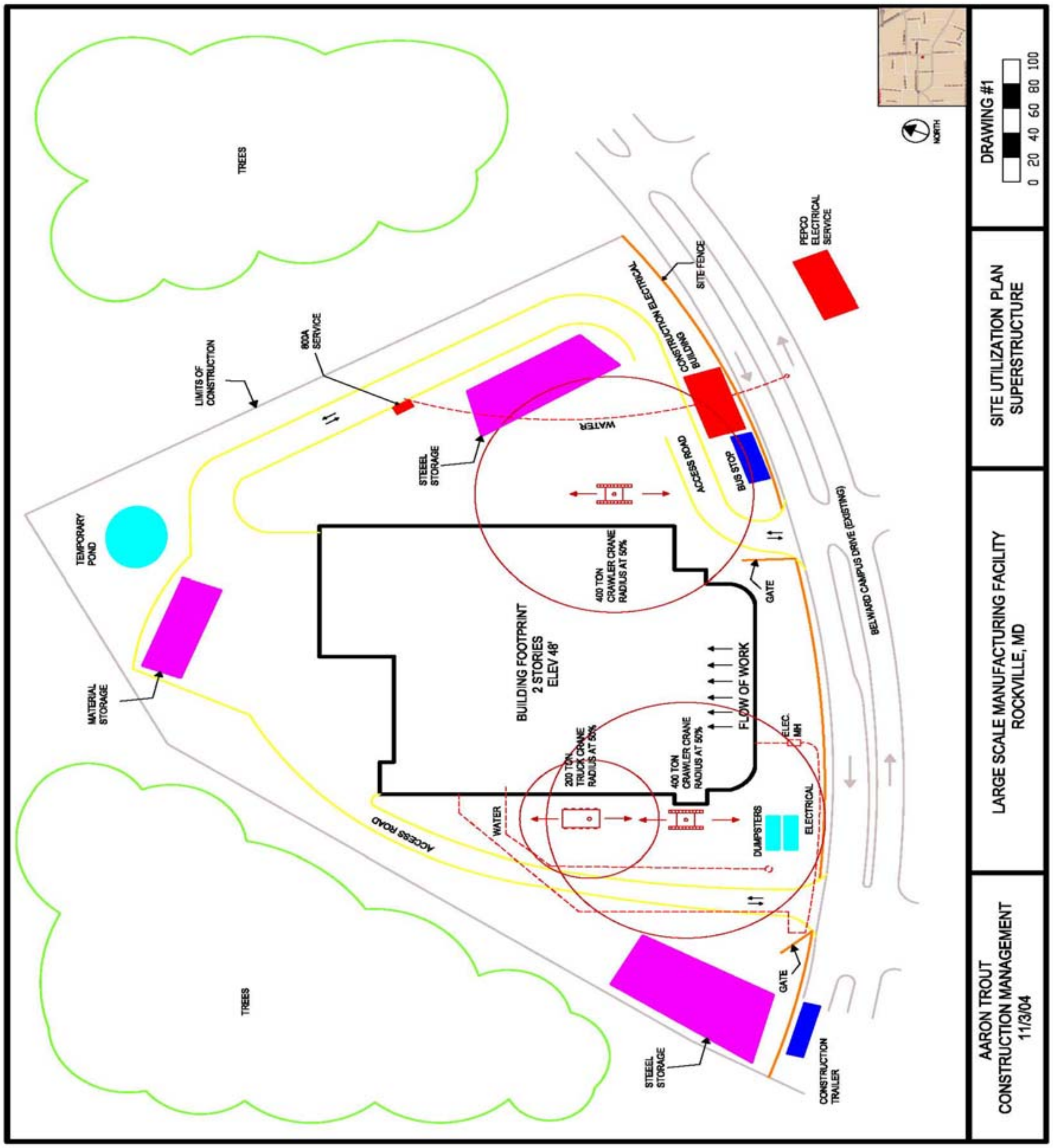
Site Plan of Existing Conditions



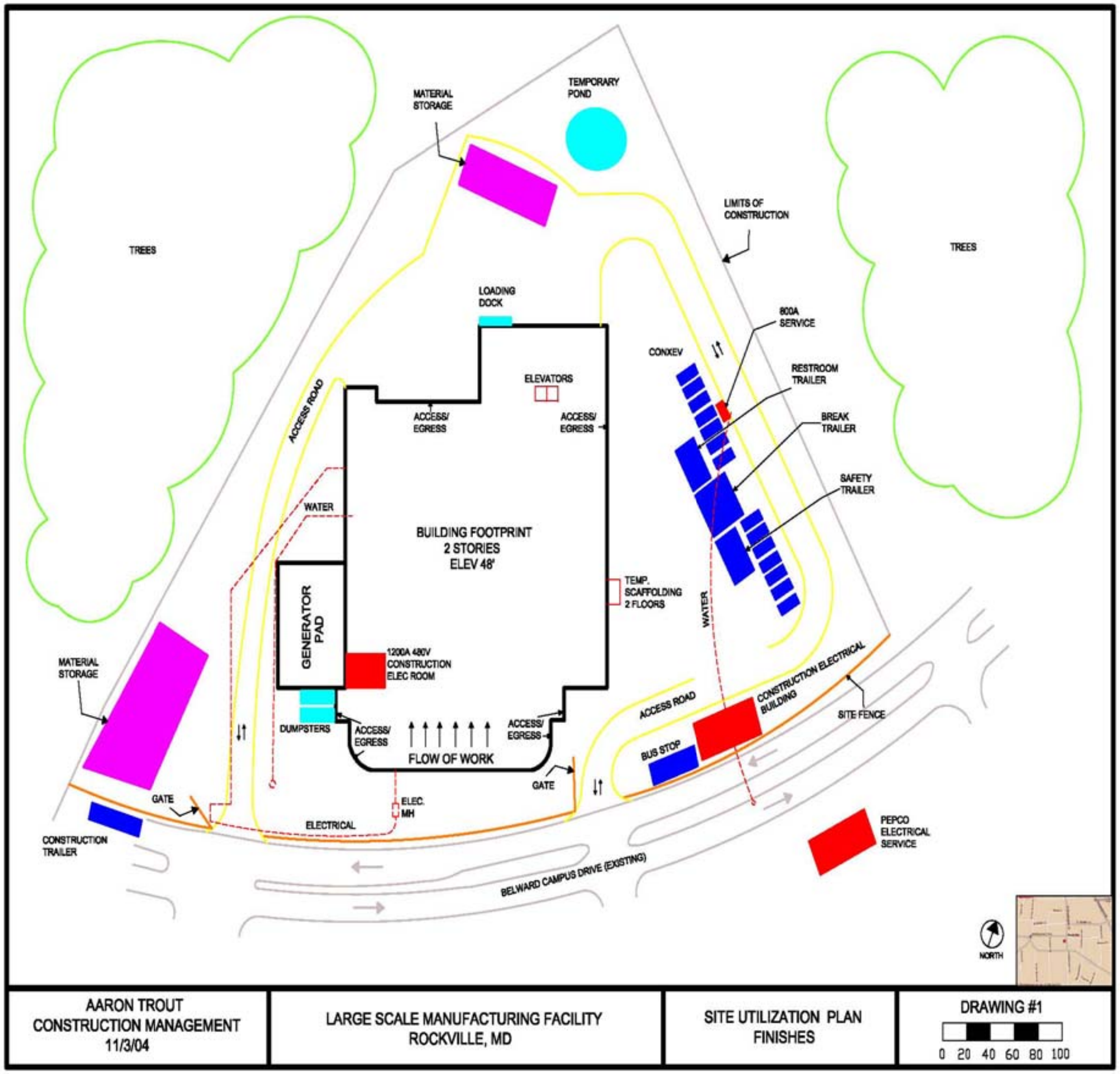
Excavation Plan



Superstructure



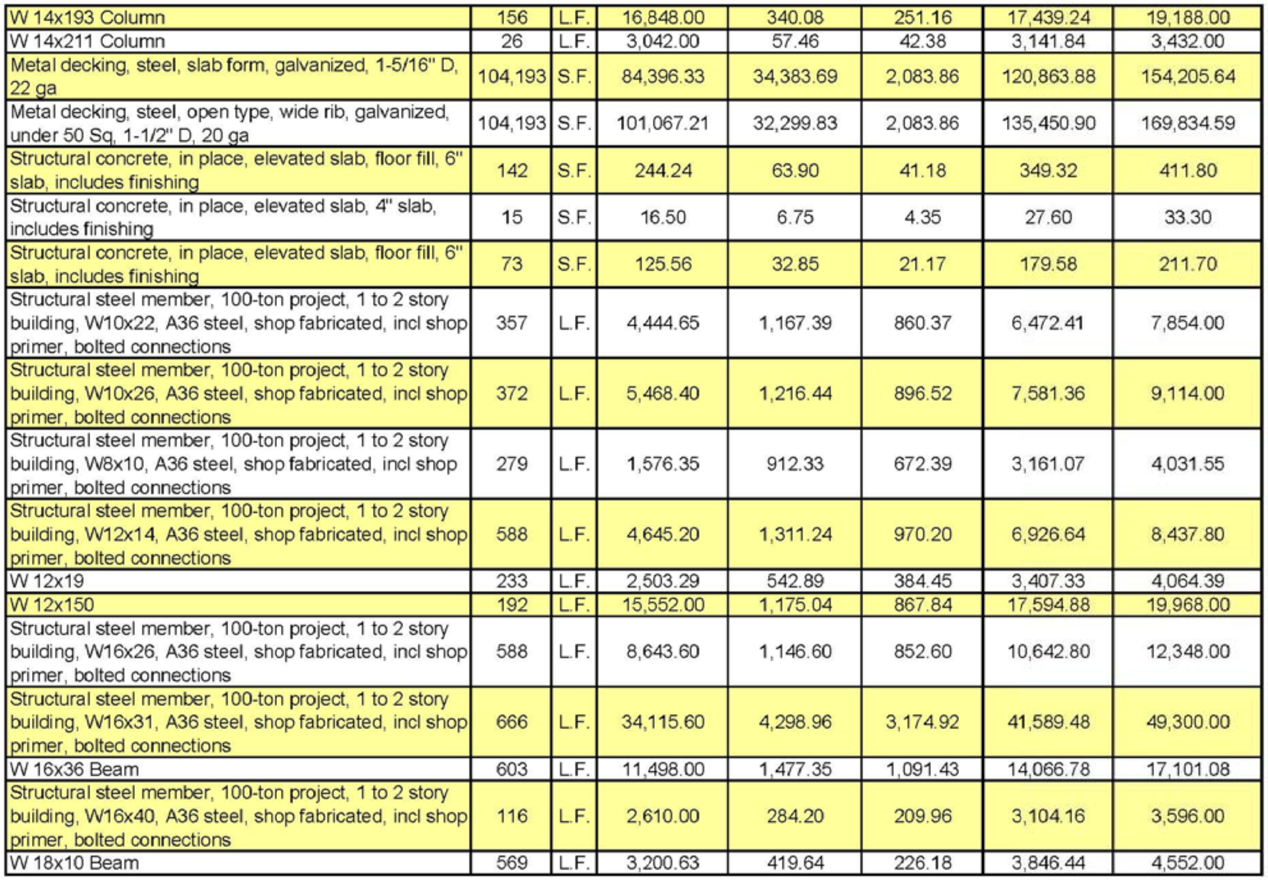
Finishes


TREES
MATERIAL STORAGE
TEMPORARY POND
LIMITS OF CONSTRUCTION
TREES
LOADING DOCK
800A SERVICE
CONXEV
RESTROOM TRAILER
ELEVATORS
BREAK TRAILER
ACCESS ROAD
ACCESS/ EGRESS
ACCESS/ EGRESS
SAFETY TRAILER
WATER
BUILDING FOOTPRINT
2 STORIES
ELEV 48'
TEMP. SCAFFOLDING 2 FLOORS
WATER
GENERATOR PAD
1200A 480V CONSTRUCTION ELEC ROOM
MATERIAL STORAGE
CONSTRUCTION ELECTRICAL BUILDING
ACCESS ROAD
SITE FENCE
DUMPSTERS
ACCESS/ EGRESS
ACCESS/ EGRESS
FLOW OF WORK
BUS STOP
GATE
GATE
ELEC. MH
ELECTRICAL
PEPCO ELECTRICAL SERVICE
CONSTRUCTION TRAILER
BELWARD CAMPUS DRIVE (EXISTING)
NORTH
AARON TROUT
CONSTRUCTION MANAGEMENT
11/3/04
LARGE SCALE MANUFACTURING FACILITY
ROCKVILLE, MD
SITE UTILIZATION PLAN
FINISHES
DRAWING #1
0 20 40 60 80 100

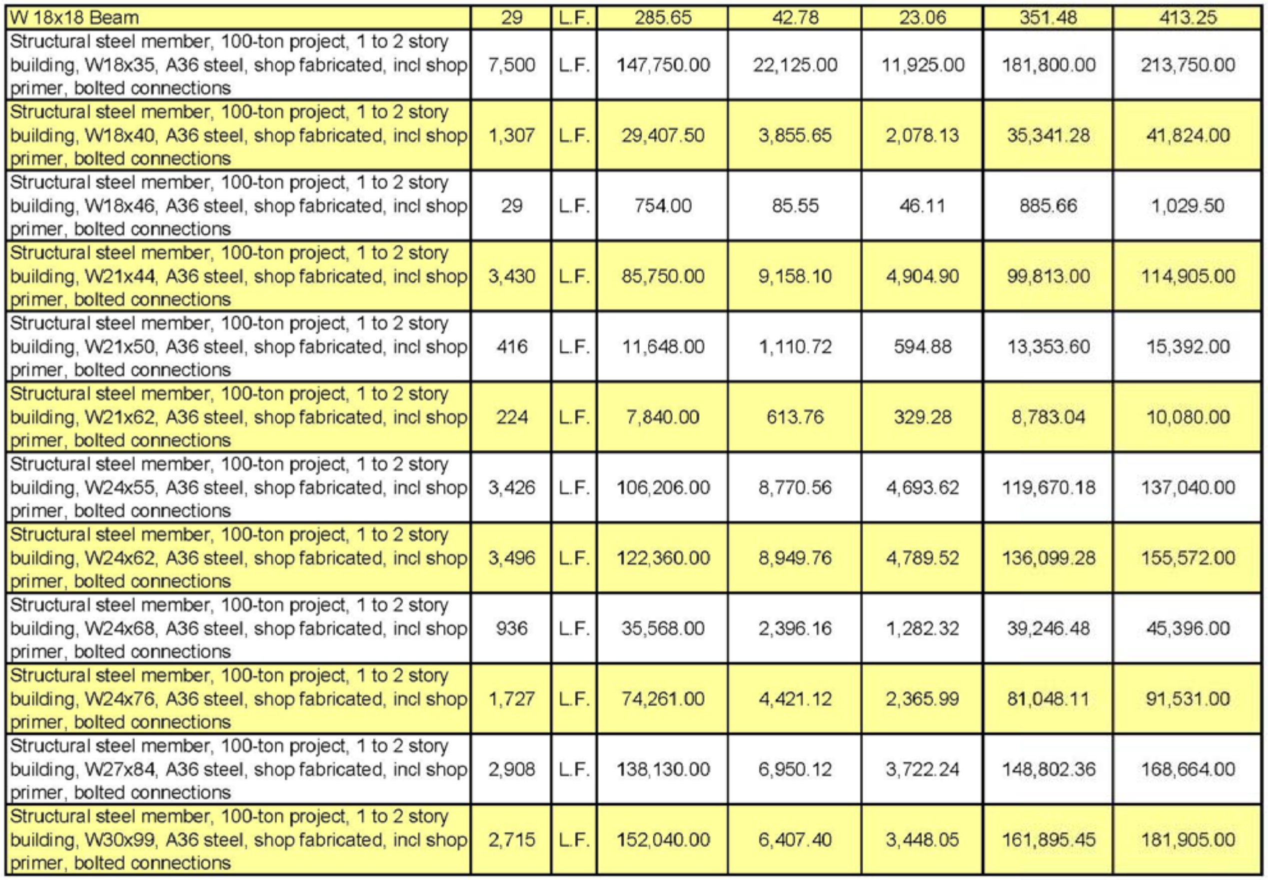
Appendix C – Detailed Estimate

Large Scale Manufacturing Facility Detailed Structural Estimate

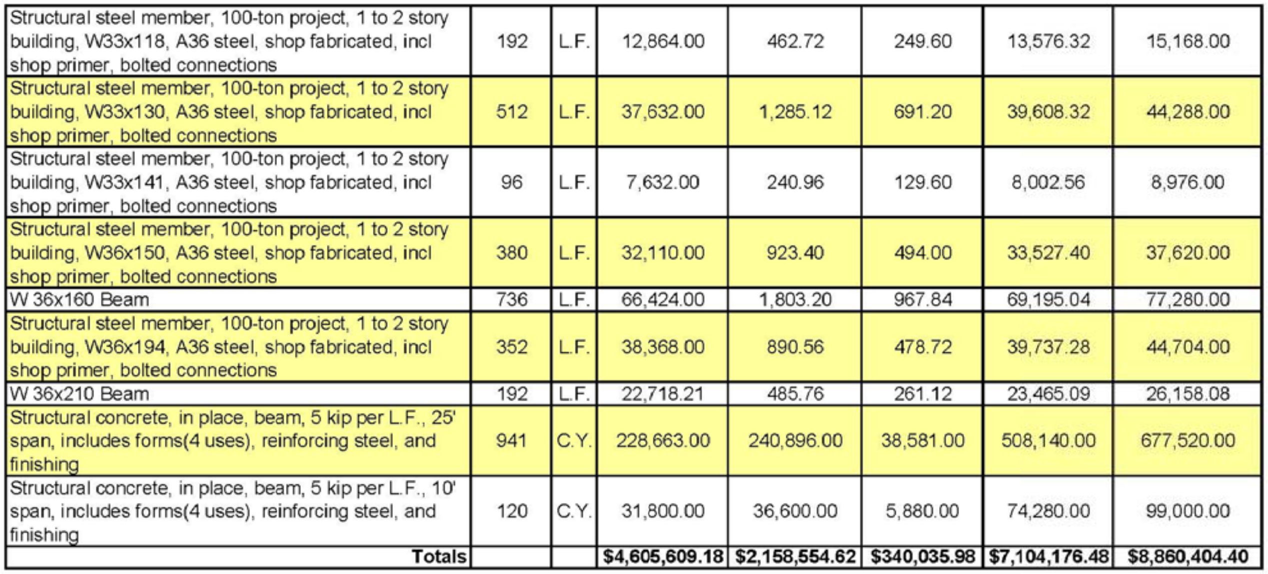
Description	Qty	Unit	Bare Mat.	Bare Labor	Bare Equip.	Total	Total Incl. O&P
Structural concrete, in place, spread footing, over 5 C.Y., includes forms(4 uses), reinforcing steel, and finishing	2,276	C.Y.	250,360.00	71,694.00	751.08	322,805.08	389,196.00
Structural concrete, in place, elevated slab, one way beam and slab, 125 psf superimposed load, 25' span, includes forms(4 uses), reinforcing steel, and finishing	6,433	C.Y.	1,125,775.00	894,187.00	138,309.50	2,158,271.50	2,798,355.00
Structural concrete, in place, elevated slab, one way beam and slab, 125 psf superimposed load, 25' span, includes forms(4 uses), reinforcing steel, and finishing	1,930	C.Y.	337,750.00	268,270.00	41,495.00	647,515.00	839,550.00
Structural concrete, in place, grade wall, 15" thick x 18' high, includes forms(4 uses), reinforcing steel, and finishing	1,602	C.Y.	222,678.00	154,593.00	24,991.20	402,262.20	512,640.00
Structural concrete, in place, slab on grade, 4" thick, includes forms(4 uses) and reinforcing steel	5,148	C.Y.	519,948.00	177,606.00	2,265.12	699,819.12	849,420.00
Structural concrete, in place, column, square, avg reinforcing, 36" x 36", includes forms(4 uses), reinforcing steel, and finishing	476	C.Y.	129,948.00	97,580.00	15,470.00	242,998.00	311,780.00
Structural concrete, in place, column, square, avg reinforcing, 24" x 24", includes forms(4 uses), reinforcing steel, and finishing	159	C.Y.	46,587.00	43,089.00	6,837.00	96,513.00	126,405.00
Structural concrete, in place, column, square, avg reinforcing, 16" x 16", includes forms(4 uses), reinforcing steel, and finishing	7	C.Y.	2,450.00	2,660.00	427.00	5,537.00	7,350.00
W 14x48 Column	144	L.F.	4,032.00	154.80	107.28	4,294.08	4,554.00
W 14x61 Column	592	L.F.	19,980.00	603.84	446.96	21,030.80	23,532.00
W 14x90 Column	2,464	L.F.	125,479.20	4,928.00	3,646.72	134,053.92	150,242.40
W 14x99 Column	234	L.F.	13,104.00	503.10	348.66	13,955.76	14,800.50
W 14x109 Column	182	L.F.	11,171.16	369.46	273.00	11,813.62	13,224.12
Column, structural, 2-tier, W14x120, A36 steel, incl shop primer, splice plates, bolts	234	L.F.	15,795.00	477.36	353.34	16,625.70	18,603.00
W 14x132 Column	130	L.F.	9,634.95	268.20	198.48	10,101.64	11,276.85
W 14x145 Column	514	L.F.	41,980.95	1,074.00	794.64	43,849.60	48,842.85
W 14x159 Column	260	L.F.	23,283.00	550.42	401.96	24,235.38	26,949.00
Column, structural, 2-tier, W14x176, A36 steel, incl shop primer, splice plates, bolts	156	L.F.	15,444.00	335.40	248.04	16,027.44	17,784.00



W 14x193 Column	156	L.F.	16,848.00	340.08	251.16	17,439.24	19,188.00
W 14x211 Column	26	L.F.	3,042.00	57.46	42.38	3,141.84	3,432.00
Metal decking, steel, slab form, galvanized, 1-5/16" D, 22 ga	104,193	S.F.	84,396.33	34,383.69	2,083.86	120,863.88	154,205.64
Metal decking, steel, open type, wide rib, galvanized, under 50 Sq, 1-1/2" D, 20 ga	104,193	S.F.	101,067.21	32,299.83	2,083.86	135,450.90	169,834.59
Structural concrete, in place, elevated slab, floor fill, 6" slab, includes finishing	142	S.F.	244.24	63.90	41.18	349.32	411.80
Structural concrete, in place, elevated slab, 4" slab, includes finishing	15	S.F.	16.50	6.75	4.35	27.60	33.30
Structural concrete, in place, elevated slab, floor fill, 6" slab, includes finishing	73	S.F.	125.56	32.85	21.17	179.58	211.70
Structural steel member, 100-ton project, 1 to 2 story building, W10x22, A36 steel, shop fabricated, incl shop primer, bolted connections	357	L.F.	4,444.65	1,167.39	860.37	6,472.41	7,854.00
Structural steel member, 100-ton project, 1 to 2 story building, W10x26, A36 steel, shop fabricated, incl shop primer, bolted connections	372	L.F.	5,468.40	1,216.44	896.52	7,581.36	9,114.00
Structural steel member, 100-ton project, 1 to 2 story building, W8x10, A36 steel, shop fabricated, incl shop primer, bolted connections	279	L.F.	1,576.35	912.33	672.39	3,161.07	4,031.55
Structural steel member, 100-ton project, 1 to 2 story building, W12x14, A36 steel, shop fabricated, incl shop primer, bolted connections	588	L.F.	4,645.20	1,311.24	970.20	6,926.64	8,437.80
W 12x19	233	L.F.	2,503.29	542.89	384.45	3,407.33	4,064.39
W 12x150	192	L.F.	15,552.00	1,175.04	867.84	17,594.88	19,968.00
Structural steel member, 100-ton project, 1 to 2 story building, W16x26, A36 steel, shop fabricated, incl shop primer, bolted connections	588	L.F.	8,643.60	1,146.60	852.60	10,642.80	12,348.00
Structural steel member, 100-ton project, 1 to 2 story building, W16x31, A36 steel, shop fabricated, incl shop primer, bolted connections	666	L.F.	34,115.60	4,298.96	3,174.92	41,589.48	49,300.00
W 16x36 Beam	603	L.F.	11,498.00	1,477.35	1,091.43	14,066.78	17,101.08
Structural steel member, 100-ton project, 1 to 2 story building, W16x40, A36 steel, shop fabricated, incl shop primer, bolted connections	116	L.F.	2,610.00	284.20	209.96	3,104.16	3,596.00
W 18x10 Beam	569	L.F.	3,200.63	419.64	226.18	3,846.44	4,552.00

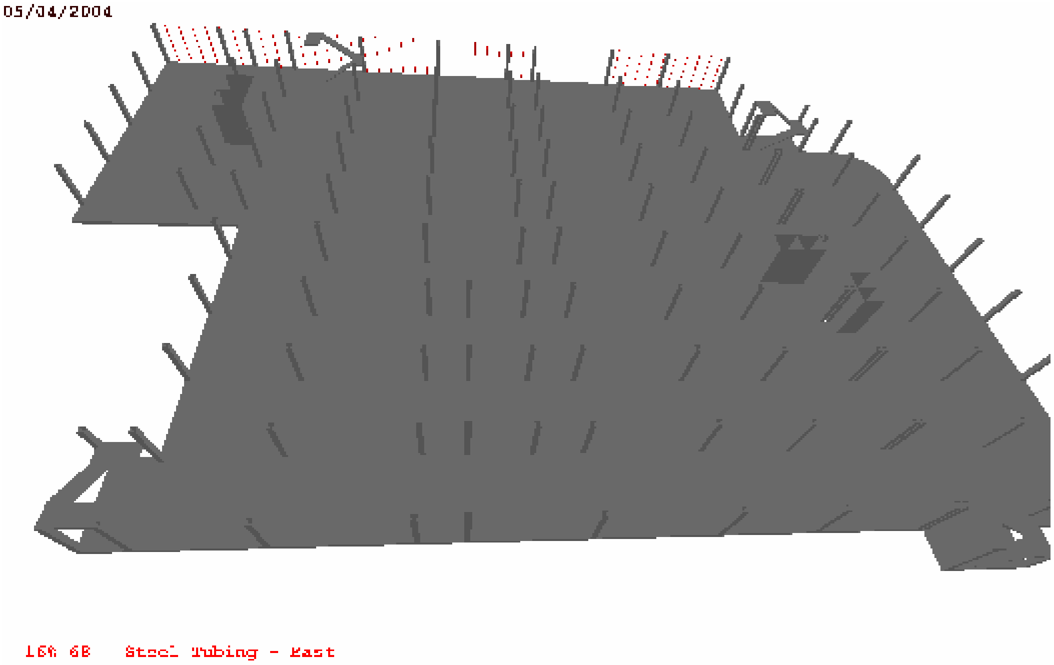


W 18x18 Beam	29	L.F.	285.65	42.78	23.06	351.48	413.25
Structural steel member, 100-ton project, 1 to 2 story building, W18x35, A36 steel, shop fabricated, incl shop primer, bolted connections	7,500	L.F.	147,750.00	22,125.00	11,925.00	181,800.00	213,750.00
Structural steel member, 100-ton project, 1 to 2 story building, W18x40, A36 steel, shop fabricated, incl shop primer, bolted connections	1,307	L.F.	29,407.50	3,855.65	2,078.13	35,341.28	41,824.00
Structural steel member, 100-ton project, 1 to 2 story building, W18x46, A36 steel, shop fabricated, incl shop primer, bolted connections	29	L.F.	754.00	85.55	46.11	885.66	1,029.50
Structural steel member, 100-ton project, 1 to 2 story building, W21x44, A36 steel, shop fabricated, incl shop primer, bolted connections	3,430	L.F.	85,750.00	9,158.10	4,904.90	99,813.00	114,905.00
Structural steel member, 100-ton project, 1 to 2 story building, W21x50, A36 steel, shop fabricated, incl shop primer, bolted connections	416	L.F.	11,648.00	1,110.72	594.88	13,353.60	15,392.00
Structural steel member, 100-ton project, 1 to 2 story building, W21x62, A36 steel, shop fabricated, incl shop primer, bolted connections	224	L.F.	7,840.00	613.76	329.28	8,783.04	10,080.00
Structural steel member, 100-ton project, 1 to 2 story building, W24x55, A36 steel, shop fabricated, incl shop primer, bolted connections	3,426	L.F.	106,206.00	8,770.56	4,693.62	119,670.18	137,040.00
Structural steel member, 100-ton project, 1 to 2 story building, W24x62, A36 steel, shop fabricated, incl shop primer, bolted connections	3,496	L.F.	122,360.00	8,949.76	4,789.52	136,099.28	155,572.00
Structural steel member, 100-ton project, 1 to 2 story building, W24x68, A36 steel, shop fabricated, incl shop primer, bolted connections	936	L.F.	35,568.00	2,396.16	1,282.32	39,246.48	45,396.00
Structural steel member, 100-ton project, 1 to 2 story building, W24x76, A36 steel, shop fabricated, incl shop primer, bolted connections	1,727	L.F.	74,261.00	4,421.12	2,365.99	81,048.11	91,531.00
Structural steel member, 100-ton project, 1 to 2 story building, W27x84, A36 steel, shop fabricated, incl shop primer, bolted connections	2,908	L.F.	138,130.00	6,950.12	3,722.24	148,802.36	168,664.00
Structural steel member, 100-ton project, 1 to 2 story building, W30x99, A36 steel, shop fabricated, incl shop primer, bolted connections	2,715	L.F.	152,040.00	6,407.40	3,448.05	161,895.45	181,905.00

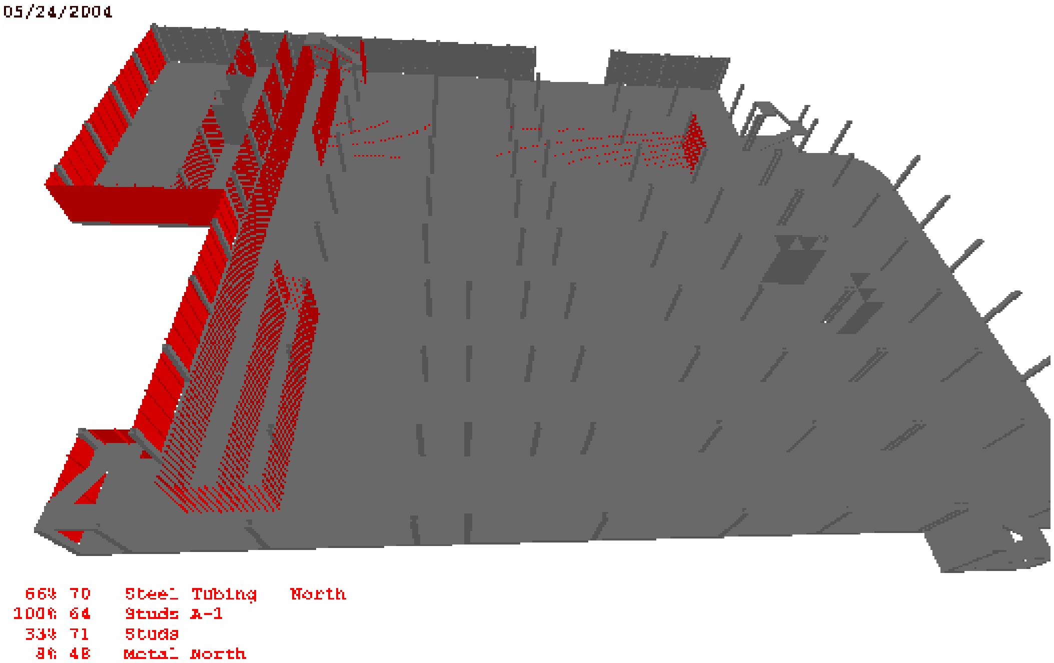


Structural steel member, 100-ton project, 1 to 2 story building, W33x118, A36 steel, shop fabricated, incl shop primer, bolted connections	192	L.F.	12,864.00	462.72	249.60	13,576.32	15,168.00
Structural steel member, 100-ton project, 1 to 2 story building, W33x130, A36 steel, shop fabricated, incl shop primer, bolted connections	512	L.F.	37,632.00	1,285.12	691.20	39,608.32	44,288.00
Structural steel member, 100-ton project, 1 to 2 story building, W33x141, A36 steel, shop fabricated, incl shop primer, bolted connections	96	L.F.	7,632.00	240.96	129.60	8,002.56	8,976.00
Structural steel member, 100-ton project, 1 to 2 story building, W36x150, A36 steel, shop fabricated, incl shop primer, bolted connections	380	L.F.	32,110.00	923.40	494.00	33,527.40	37,620.00
W 36x160 Beam	736	L.F.	66,424.00	1,803.20	967.84	69,195.04	77,280.00
Structural steel member, 100-ton project, 1 to 2 story building, W36x194, A36 steel, shop fabricated, incl shop primer, bolted connections	352	L.F.	38,368.00	890.56	478.72	39,737.28	44,704.00
W 36x210 Beam	192	L.F.	22,718.21	485.76	261.12	23,465.09	26,158.08
Structural concrete, in place, beam, 5 kip per L.F., 25' span, includes forms(4 uses), reinforcing steel, and finishing	941	C.Y.	228,663.00	240,896.00	38,581.00	508,140.00	677,520.00
Structural concrete, in place, beam, 5 kip per L.F., 10' span, includes forms(4 uses), reinforcing steel, and finishing	120	C.Y.	31,800.00	36,600.00	5,880.00	74,280.00	99,000.00
Totals			**$4,605,609.18**	**$2,158,554.62**	**$340,035.98**	**$7,104,176.48**	**$8,860,404.40**

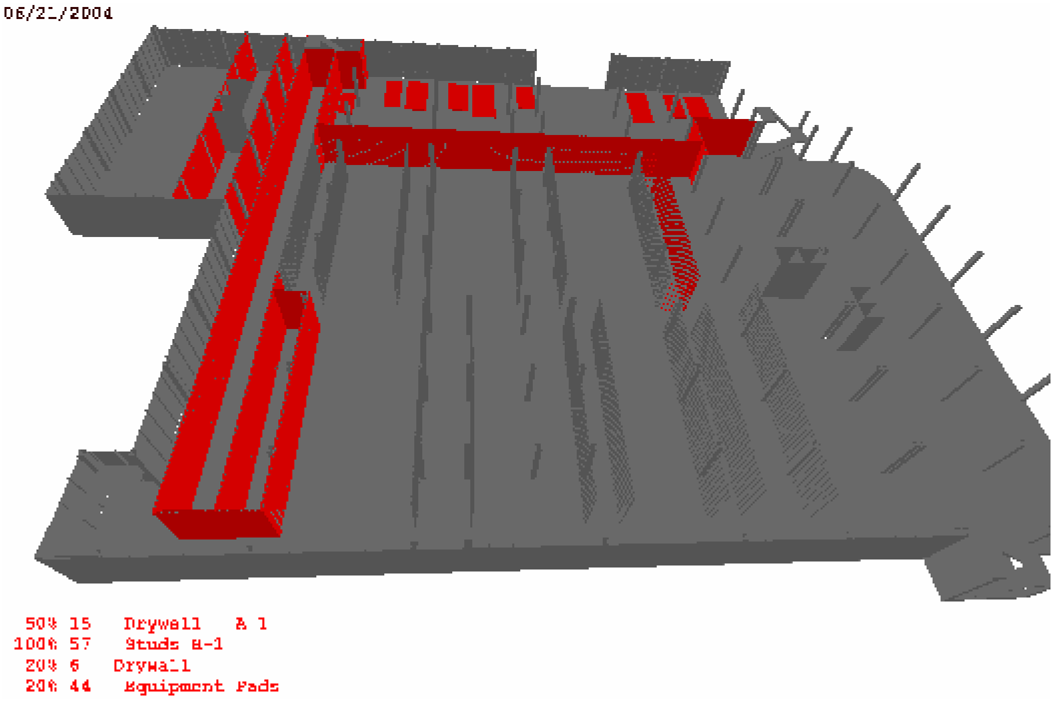
Appendix D – 4D Model Sequence Pictures



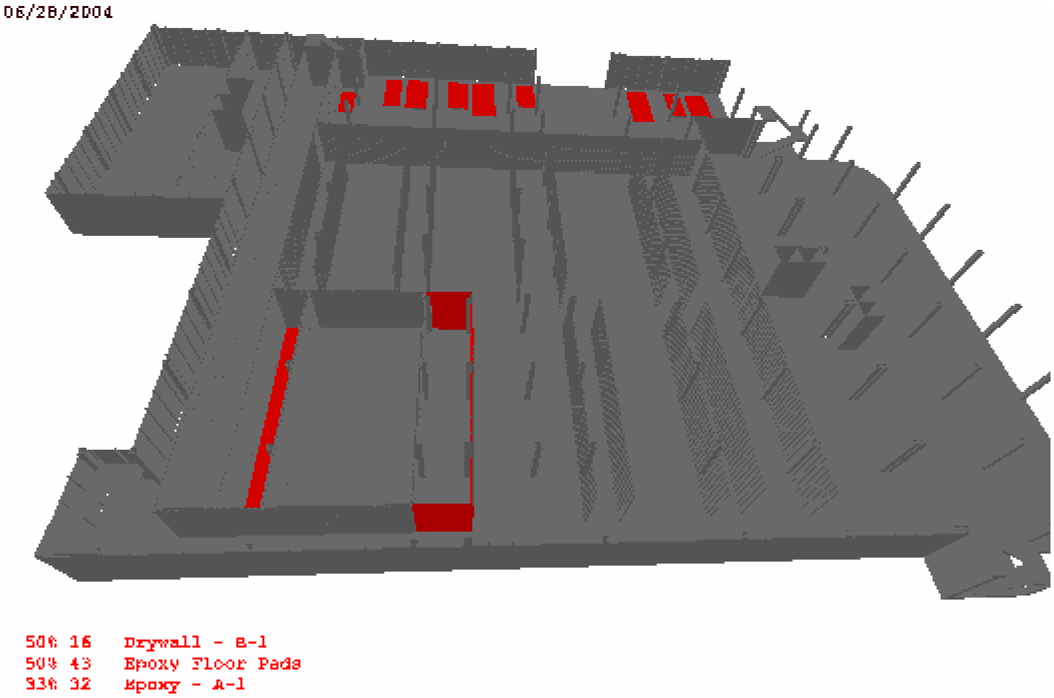
This is the initial phase: The first floor slab, stairs, elevator, and columns are already installed. Installation of steel tubing has begun on east façade.



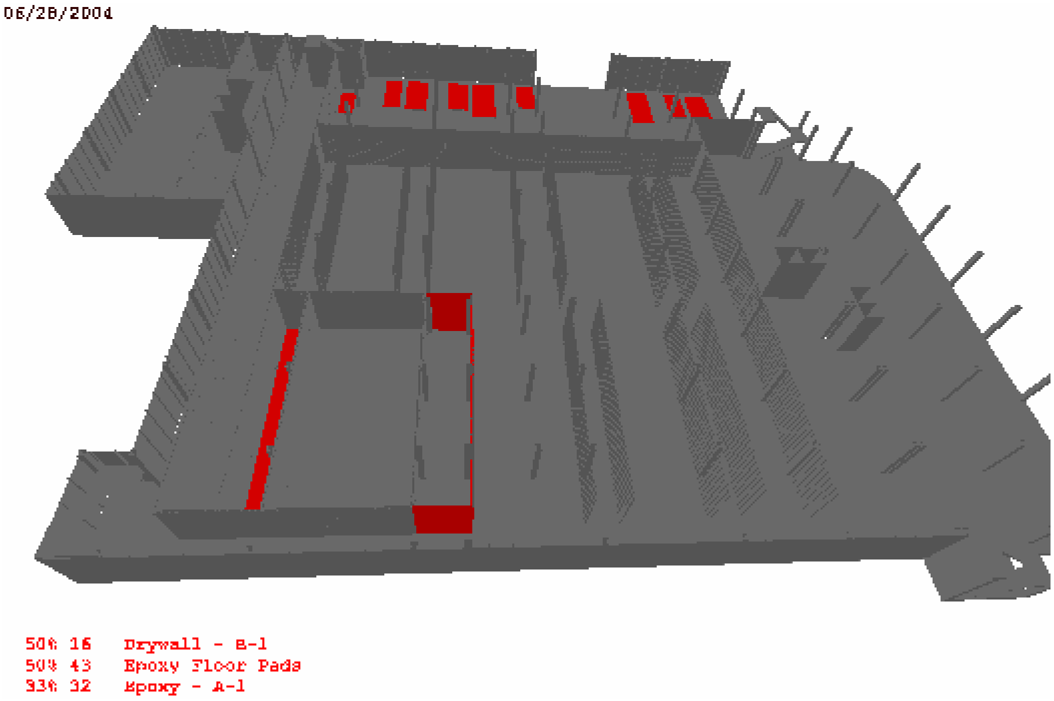
At this stage steel tubing is being installed on the north face as well as the metal wall panels. Also installation of the metal studs has begun on the northern side of the building.



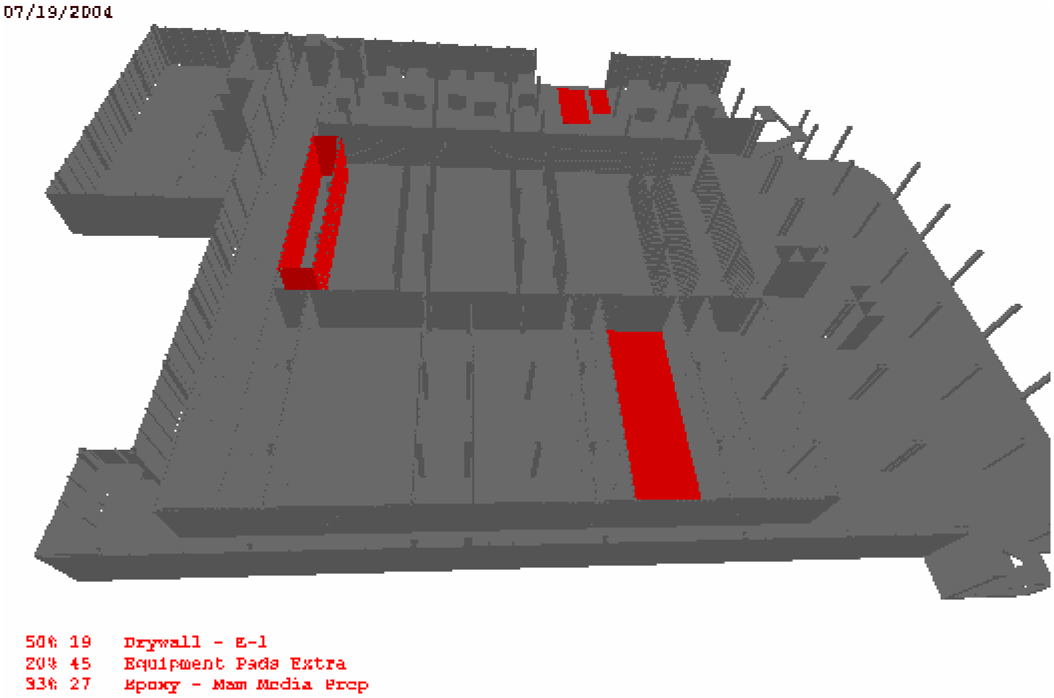
Once all of the metal siding has been installed, the equipment pads on the eastern side can be poured, and drywall installation can begin on the northern side of the building.



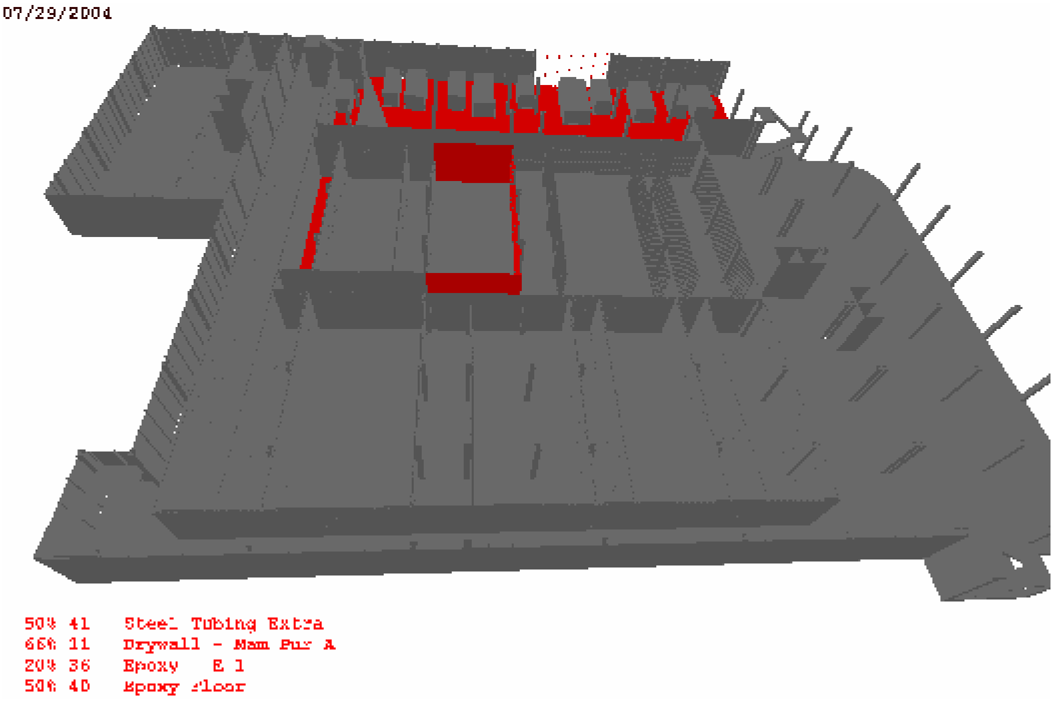
Once drywall has been installed in two rooms, the epoxy flooring can begin in the "clean rooms". Also, once the equipment pads have cured, the epoxy coating can be installed.



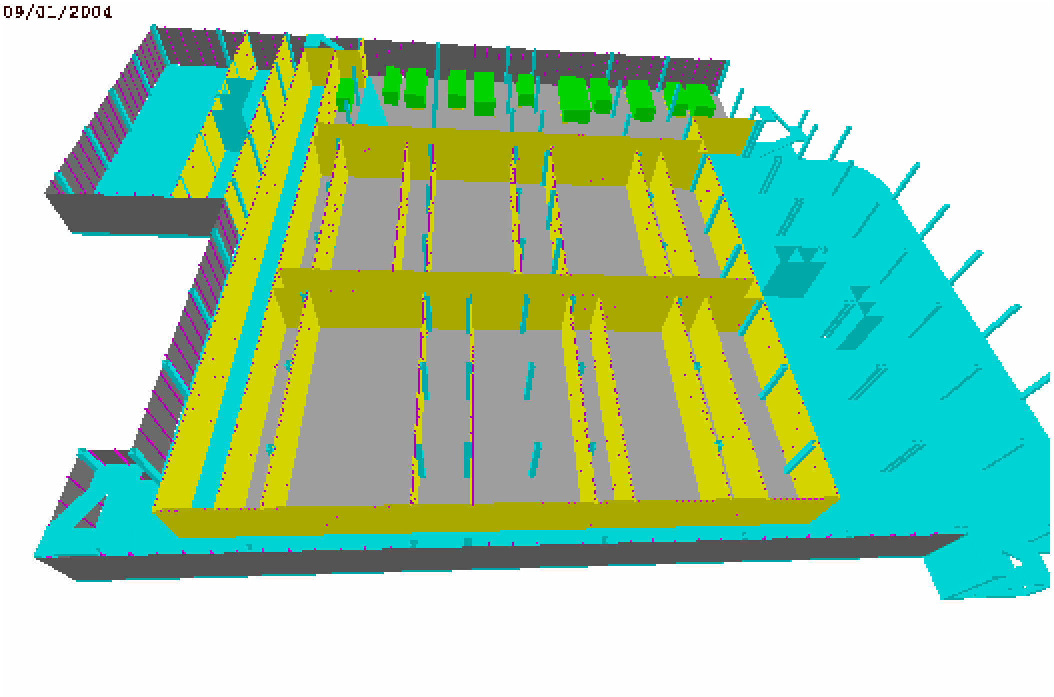
After the epoxy has cured on the equipment pads, the air handling units can be delivered to site and set on the pads.



Once the equipment has been delivered that is to be let into the building through the opening, the equipment pads for the remaining two air handling units can be poured.



After the remaining equipment pads have been delivered, the epoxy flooring can be installed in the MER room. Also the remaining steel tubing can be installed for the opening between column lines F.9 and H.



This is a snapshot of the model at the end of the final sequence; hence all actions have been completed.

Appendix E – Wall System Takeoff

Prefabricated Metal Wall Panels by "Centria"

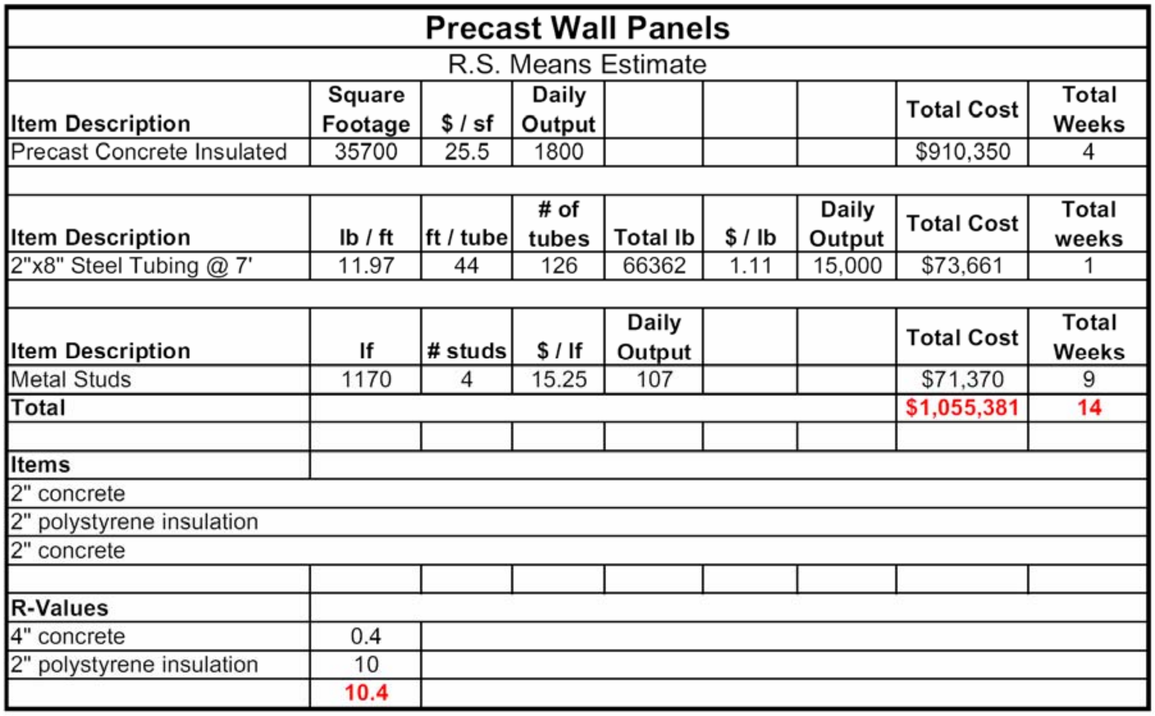
Actual Estimate from "Centria"

Item Description	Total sf	sf / day	$ / sf	Total Cost	Total Days	Total Weeks
Wall Panel	35700	600	25	$892,500	60	12
Steel Tube	35700	600	10	$357,000	60	12
Total				**$1,249,500**	**60**	**24**
R-Value						
Formwall Dimension Series		**14.5**				

Exterior Insulation and Finishes System

R.S. Means Estimate

Item Description	Square Footage	$ / sf	Daily Output	Total Cost	Total Weeks
EIFS System 4" EPS	35700	9.4	295	$335,580	24
Premium Finish	35700	1.83	1265	$65,331	6
Steel Tube	35700	10	600	$357,000	12
Total				**$757,911**	**42**
If the crew was doubled for installation of the EIFS system the values would be located below					
Item Description	**Square Footage**	**$ / sf**	**Daily Output**	**Total Cost**	**Total Weeks**
EIFS System 4" EPS	35700	13.42	590	$479,094	12
Premium Finish	35700	1.83	1265	$65,331	6
Steel Tube	35700	10	600	$357,000	12
Total				**$901,425**	**30**
Items					
Framing 2x4 studs 8' high 16"o.c					
Plywood sheathing on ext. stud wall, 5/8" thick					
Building paper, asphalt felt sheathing paper 15lb					
Stucco, 3 coats 7/8" thk, float finish, on frame construction					
Fiberglass insulation batts, paper or foil back, 4"					
Paint exterior stucco, brushwork, primer & 2 coats					
R-Values					
Plywood sheathing	0.77				
4" EPS insulation	16				
Felt paper	0.06				
	16.83				

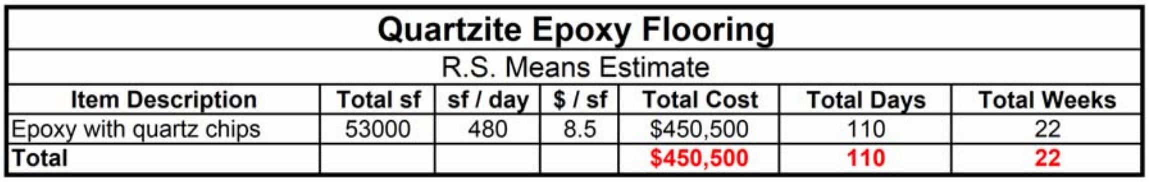


Precast Wall Panels

R.S. Means Estimate

Item Description	**Square Footage**	**$ / sf**	**Daily Output**				**Total Cost**	**Total Weeks**
Precast Concrete Insulated	35700	25.5	1800				$910,350	4
Item Description	**lb / ft**	**ft / tube**	**# of tubes**	**Total lb**	**$ / lb**	**Daily Output**	**Total Cost**	**Total weeks**
2"x8" Steel Tubing @ 7'	11.97	44	126	66362	1.11	15,000	$73,661	1
Item Description	**lf**	**# studs**	**$ / lf**	**Daily Output**			**Total Cost**	**Total Weeks**
Metal Studs	1170	4	15.25	107			$71,370	9
Total							**$1,055,381**	**14**
Items								
2" concrete								
2" polystyrene insulation								
2" concrete								
R-Values								
4" concrete	0.4							
2" polystyrene insulation	10							
	10.4							

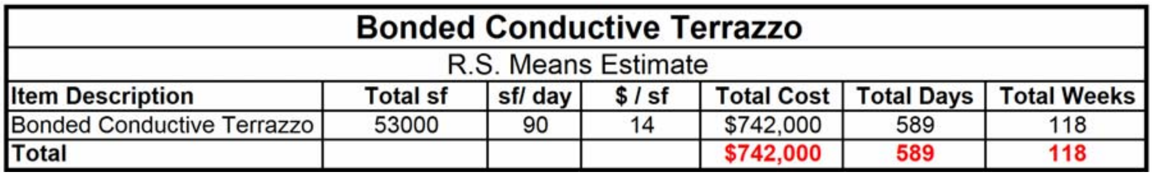
Appendix F – Floor Covering Takeoff



Quartzite Epoxy Flooring

R.S. Means Estimate

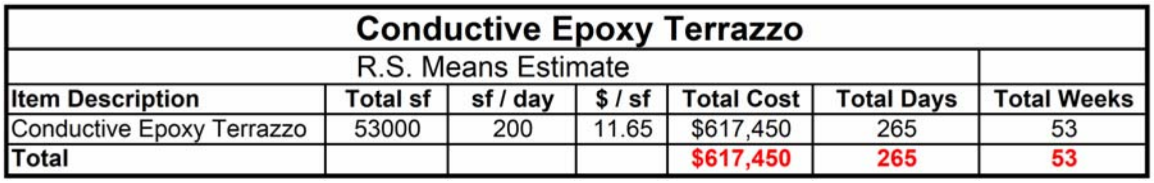
Item Description	Total sf	sf / day	$ / sf	Total Cost	Total Days	Total Weeks
Epoxy with quartz chips	53000	480	8.5	$450,500	110	22
Total				**$450,500**	**110**	**22**



Bonded Conductive Terrazzo

R.S. Means Estimate

Item Description	Total sf	sf/ day	$ / sf	Total Cost	Total Days	Total Weeks
Bonded Conductive Terrazzo	53000	90	14	$742,000	589	118
Total				**$742,000**	**589**	**118**



Conductive Epoxy Terrazzo

R.S. Means Estimate

Item Description	Total sf	sf / day	$ / sf	Total Cost	Total Days	Total Weeks
Conductive Epoxy Terrazzo	53000	200	11.65	$617,450	265	53
Total				**$617,450**	**265**	**53**