The Pennsylvania State University
5th Year Senior Thesis

Final Report

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Construction Management
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Unknown Data Center
Somewhere, USA
April 7, 2011

Unknown Data Center

Somewhere, USA

Building Information

PROJECT TEAM

Construction Manager: **Turner Construction INC.**

Architect: **Sigma 7 Design Group**

MEP: **Sigma 7 Design Group**

Structural: **GoldStein Associates**

Civil: **Birdsall Service Group**

BUILDING DATA

Occupancy/Type: **Business—Data Center**

Size: **17,445 SF**

\# of Stories: **1**

Dates of Construction: **12/2008—08/2010**

Building Cost: **$27.5 Million**

Project Delivery Method: **Design-Bid-Build**

Architecture

The Data Center is one story expansion/renovation project consisting of roughly 20,000 square feet of a new addition to an existing 114,500 square feet. This building is the second of three expansions. The project is designed for another a third expansion allowing for an additional 30,000 square feet. The addition will include more computer, electrical and mechanical rooms. As well as more storage and advanced data network distribution.

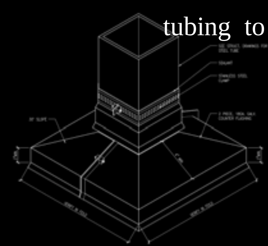
Construction Logistics

The construction of the Data Center includes three main phases.

- The first phase requires mass excavation as well as demolition to the existing building.
- The second phase includes crane placement/ setting of the structural components of the Data Center.
- The final phase includes intense MEP fit-out for the unique mechanical/electrical systems of the Data Center.

Structural

- **Foundation:** 6" slab on grade on top of normal weight concrete footers and concrete spread footers along the perimeter of the building.
- **Frame:** Braced steel frame system comprising with 40'X 25' column bays.
- **Enclosure:** Architectural precast concrete designed to withstand hurricane and tornado forces up to 200 mph.
- **Roof:** Lightweight concrete on metal deck topped with EPMD. Roofing Includes structural tubing to support mechanical systems.



Mechanical

- 350 Ton Chilled water systems
- 190 Ton Dry coolers for free cooling
- 1st Floor……2 air handling units
- Roof……….3 chilled water systems, 5 dry coolers, 3 radiators, 2 air handling units.

*All Mechanical equipment is constructed on vibration isolation pads and are seismically restrained. *

Electrical/Lighting

- 2N electrical infrastructure with concurrent maintenance.
- (3) 2MW Generators
- (1) Existing mass distribution panel: 480V, 3 Phase, 3 Wire, 600A
- (3) New mass distribution panels: 480V, 3 Phase, 3 Wire, 1200A

Daniel Suter | Construction MGMT Option | http://www.engr.psu.edu/ae/thesis/portfolios/2011/djs5162

Acknowledgements:

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Tom Atrens at Turner Construction

Brian Brunett – AE Student

My family and Friends

Executive Summary

Senior Thesis Final Report:
This report is intended to discuss the findings and conclusions of the four analyses performed on the Unknown Data Center on. This project includes a 17,500 SF new addition. The topics are centered on a theme of improving efficiency in the construction industry: project procurement efficiency, construction efficiency (schedule and cost), and energy efficiency.

Analysis #1 – Alternate Roof Type:
Based on the information in this analysis, a PV array design is recommended to the owner. The design should be based on the one in this analysis. This system's upfront cost is roughly $160 thousand and has a potential buyback of 17-18 years which is pretty reasonable.

The green roof is not recommended because the Data Center has a mass amount of mechanical equipment therefore making it virtually impossible to create an adequate design. The design that is given in this analysis was based on open space on the roof. This design could potentially work, but not in the Data Center's case. If the owner would want to pursue a green roof system, an extensive, modular green roof would be recommended.

Analysis #2 – Risk Management (Long Lead Items):
After performing the cash flow analysis, it concludes that the construction management firm takes on a lot of risk and must be very organized and detailed when taking on this method. The risk increases when the construction management firm has to borrow money to pay the upfront cost of the long lead mechanical and electrical equipment.

In addition to this analysis, it is recommended to all construction management firms to look into procuring long lead mechanical and electrical items with the method explained in this analysis. It is highly recommended for firm with excellent in house engineers and is financially large as a company to use this method because the company will take on less risk.

Analysis #3 – Façade Redesign (Implement Tit-up):
Based on the information in this analysis, Utilizing tilt-up as the primary method for erecting the façade is highly recommended. The cost of savings is very substantial, $326,480. In addition, the speed at which the concrete trade is beneficial, 33 panels in a 9 hour work day.

As for the redesigning the façade, the owner definitely look into it. The savings of 184,000 of reducing the parapet wall could go into paying for the PV array system from analysis one. In addition, the current design is losing opportunity to utilize the sun for energy. One drawback to note is the walls of the penthouse can be seen from a distance, therefore, Architectural analysis will need to be done.

Analysis #4 – Implement Tablet PC's (Commissioning):
After conducting the research, tablet PCs bring a lot of benefits to the construction industry. It is recommended for all construction management firms to learn the product and integrate it into the construction process. From a commissioning standpoint, it is highly recommended to use tablet PCs on projects that have a vast amount of complex MEP systems. Most projects like data centers, hospitals, and power plants would benefit greatly by using tablet PCs for the commissioning process.

Table of Contents:

Project Team Overview:

Client Information:

Due to the nature of this project, this report will not release any client information. For a general idea, the Data Center Expansion is the second of three expansions. The owner is building to expand their business.

Project Delivery System:

The project delivery system selected by the owner to use for the Data Center is a Design-Bid-Build. In the figure below, Figure 1, is a detailed breakdown of the project team organization chart.

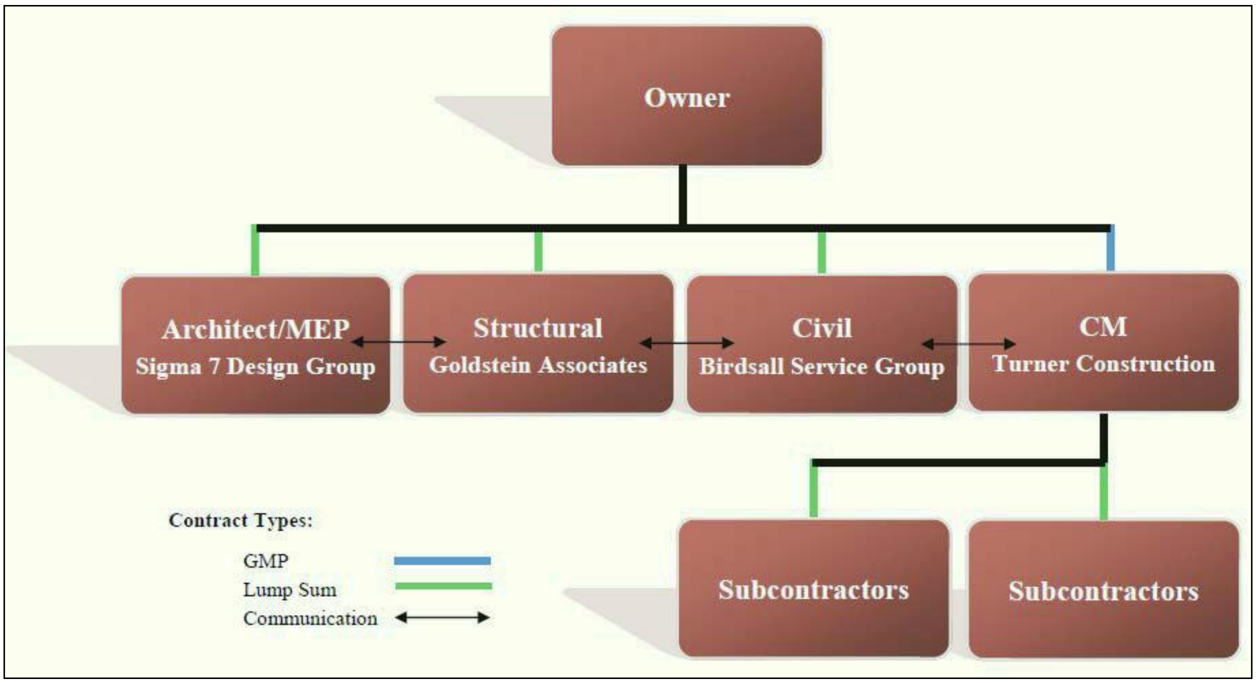


Figure 1- Project Organizational Chart

The owner holds a contract with Sigma 7 design group. Sigma 7 is a very odd company in which they service architecture as well as engineering design. The contract type is lump sum. Moving along the chart, the owner has lump sum contracts with Goldstein Associates, who serviced the structural components of the Data Center, and Birdsall Service Group, who serviced the civil part of the Data Center. Lastly, the owner holds a guaranteed maximum price (GMP) contract with Turner Construction Co. Turner holds lump sum contracts with several subcontractors.

The major subcontractors are as follows:

- **Nordic Contracting –** Concrete/Foundation
- **Universal Concrete –** Precast
- **Lynchburg Steel -** Steel Erection

For this particular project, it was critical for communication between all trades involved in this project, especially Turner and Sigma 7. Coordination meetings for all MEP systems were vital to keeping the project on schedule. For more information, refer to section A and Appendix A of this report.

Staffing Plan:

Turner Construction staffed this project a little different due to the Data Center being a specialized construction project. Below in Figure 2 show a detailed chart of the staffing plan used for the Data Center.

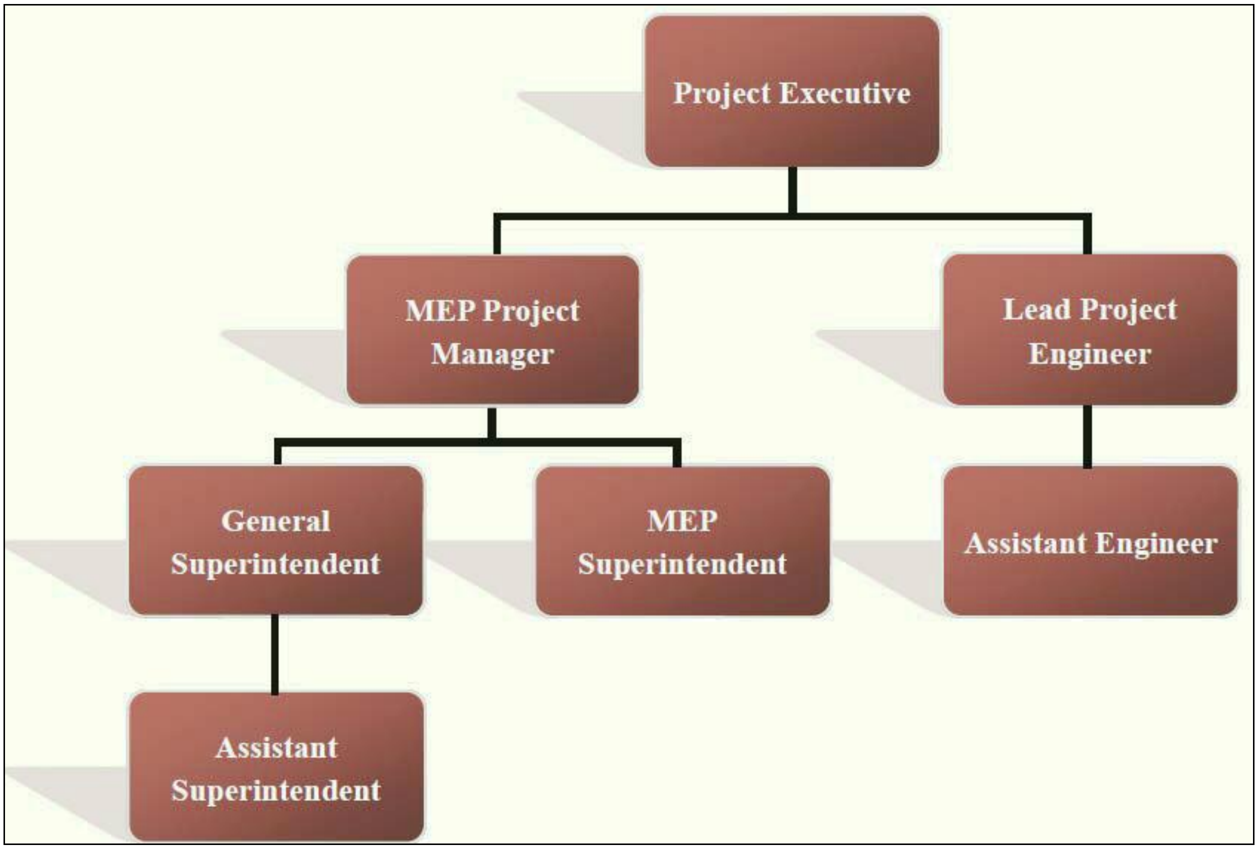


Figure 2 - Project Management and Supervision Staff Organizational Chart

Because the mechanical, electrical, and plumbing systems of this project were critical, it was necessary for Turner to have a MEP project manager look over the general superintendent and MEP superintendent.

Existing Conditions Report:

Design Overview:

Architecture:

The Data Center is one story expansion/renovation project consisting of roughly 17,500 square feet of a new addition to roughly an existing 114,500 square feet. This building is the second of three expansions. The project is designed for another a third expansion allowing for an additional 30,000 square feet. The addition will include more computer, electrical and mechanical rooms. As well as more storage and advanced data network distribution.

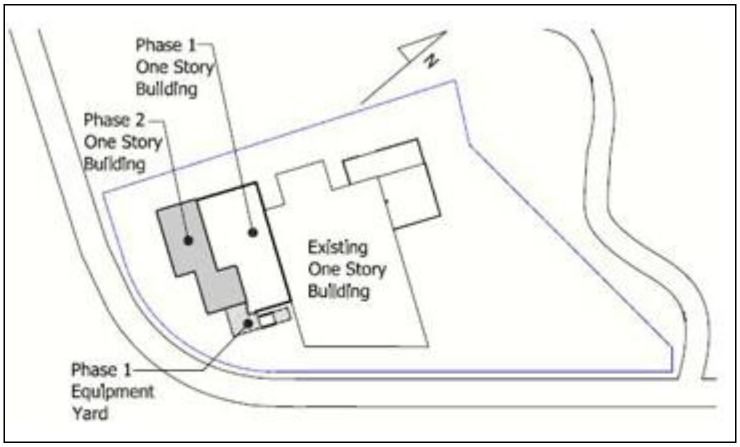


Figure 3 – Basic Layout

The building is a steel frame structure comprising of 40 feet by 25 feet columns bays. Due to heavy mechanical load and the slope of the roof, the structural engineer designed hollow structural tube (dunnage) to support the heavy mechanical equipment on the roof. These tubes are also used to support any mechanical rooms and/or penthouses located on the roof.

The data center is also designed for vibration isolation and seismic restraints for HVAC. All equipment, piping, ductwork and conduit must be seismically braced.

Major National Model Codes:

IBC Building Code Edition 2006

Zoning:

Max Height – 55 Feet/75 feet (Sprinklers included)
Max Building Area – Unlimited
Min # of exits – 3

Building Enclosure:

Building Façade:

The Data Center's shell is primarily made up of architectural precast concrete and is designed to withstand wind up to 200 miles per hour. A liquid membrane is used between the precast and flashing for maximum water protection. The precast is erected to bearing surfaces that must bear 2 ½ inches on steel and/or 3 inches on concrete block or masonry brick. Shims or jacks are used to align and level the precast panel.

The mechanical rooms and penthouse is enclosed with EIFS with 3 inch insulation with intake louvers on some areas of the rooms. The rooms are also equipped with acoustical silencer and dampers on a stand to account for any undesirable sound.

Roofing:

As stated above. The roof is equipped with hollow structural tubing to support any mechanical systems as well as penthouses. There are two types of these supporting tubes. One is an HSS 6X6 and the other a 4x4. There are hundreds of these supports located on the roof.

The roof is primarily constructed with EPMD fully adhered to concrete slab on deck. On top of the EPMD is interlocking insulation board covered with UV protection fabric and is topped off with interlocking concrete pavers.

Building System Summary:

Yes	No	Work Scope
	X	Demolition Required?
X		Structural Steel Frame
X		Cast in Place Concrete
X		Precast Concrete
X		Mechanical System
X		Electrical System
	X	Masonry
	X	Curtain Wall
	X	Support of Excavation

Table 1 – Building System Summary

Structural Steel Frame:

This project consists of a one story addition with a braced steel frame structure. A typical bay size is roughly 25’ X 40’. The design of the beams is very unique due to the heavy mechanical load on the roof. Therefore, the beam’s size and weight sporadically changes throughout the building. A typical size girder and beam where there is no mechanical equipment above is a W24X76 and a W24X68, respectively. Where mechanical systems lie on roof top, the girders and beams are typically a W30X90 and a W30X108, respectively. There are beams on this project that get up to W40’sX250’s. The steel was erected with a 250 ton All Terrain Crane. The crane was located on the south side of the building. More detail on the location of the crane will be presented in later reports

In addition to this unique steel frame design, the structural engineer had to design a dunnage type system to support the mechanical systems on the roof. This dunnage is made of 6”X6” hollow tube structural steel (See building statistics 2 for more detail).

The flooring of the Data Center consists of a composite slab structure. The total slab depth is 5" lightweight concrete. The metal deck used is 1 ½" 16 gauge composite metal deck and spans east-to-west along the building. The concrete slab is reinforced with 4X4 - W4.0XW4.0 welded wire fabric.

Cast in Place Concrete:
This project consisted of very little cast in place concrete. Cast in place concrete consisted of slab on grade, slab on deck, equipment pads, and the foundation footings and spread footings. The concrete used for the footers and slabs was 4000 psi normal weight concrete and 3000 psi lightweight concrete, respectively. The design of the formwork was the contractor's decision. The material of the formwork that was used on this project consisted of chamfer strips. These chamfer strips was one of the following material sporadically used onsite: wood, metal, PVC or rubber. The placement method used to place the concrete was by truck.

Precast Concrete:
The Data Center's expansion envelope was all done by precast concrete. Since the new expansion only included new mechanical, computer, and electrical rooms, no windows were needed. Due to the sensitivity of the project, the pre-casting location will remain unknown. The precast panels had at least a 20 work day lead time for contractor erection and review of calculations. The precast panels are designed to withstand wind forces up to 200 mph. The panels are connected by use of bearing pads. There are four different type of bearing pads used to connect the panels. The bearing pads include: Elastomeric, laminated fabric-rubber, frictionless and tempered hardboard pads. The panels will be temporarily braced by the contractor until ready to be placed permanently. Jacks, shims or bolts were used to align and level the precast depending on the type of bearing pad. The type of connection used is to fill with grout, bolt or weld depending on what is specified in the shop drawings. The minimum bearing on steel, concrete, and masonry (existing), shall be 2 ½", 3", and 3" respectively. To ensure quality, if any precast panel falls under any tolerances, the panels must be replaced to the cost of the contractor. As stated in the structural steel section. The crane used to erect the precast panels was a 250 ton All Terrain Crane.

Mechanical System(s):
The primary mechanical room is located on the first floor on the west side of the building. This project also includes a generator room, pump room, substation room, and a mechanical yard also located on the first floor. On the roof includes chillers, dry coolers, and radiators. The Data Center consists of many different types of mechanical systems. They include: Chilled water systems, glygol water systems. The chilled water system is 350 ton and the GPM ranges from 1,100 – 1,300. The dry cooling is a 190 ton system. The glygol water system is located on the roof and pumps out 110,040 CFM.

The fire-suppression systems include a combination of sprinkler piping, jockey pumps, fire pumps, control panels, service water supply piping, water tanks, fire dampers, smoke exhaust systems, and fire alarm panels.

Electrical System(s):
The design of the Data Center's electrical system includes a 2N electrical infrastructure with concurrent maintenance. The building includes an existing 600A, 480Y/277V mass distribution systems. The expansion includes three new mass distribution systems that consists of 1200A, 480Y/277V. First mass distribution panel distributes to a 600A, 480Y/277V system. This services the new lighting and receptacles, as well as some mechanical systems. The second mass distribution panel distributes to a 600A, 480Y/277V system that services mechanical equipment and is reserved for the future use (third expansion). The final mass distribution panel distributes to a 600A, 480Y/277V system that services more lighting and receptacles, as well as more mechanical systems. An important issue to note, the contractors had to bring in a 300 Ton Crane to set the generators on the roof.

Local Conditions:

Due to the sensitivity of the project, the location of the project will not be released in this section. The zoning type integrated in this project is type 2 zoning. The allowable height is restricted to 55 feet. Due to the use of sprinklers, the allowable height became 75 feet which was plenty for the 43 foot one story expansion.

The type of soil surrounding the area was a mix between sand, silt, clay, shale, siltstone, and sandstone. Because the Data Center is a one story expansion, excavation was not a complex issue on this project.

Site Plan of Existing Conditions:

Due to location restrictions on this project, the location will not be given in this report. Refer to Appendix A for a satellite view of the site. Based on the observation with the vicinity map, the site is fairly remote, thus, vehicular and pedestrian traffic was not a top concern. The attached site plan shows a basic north plan layout of Phase 2 of the Data Center's expansion as well as the Phase 1 and the existing building with the height related to the building. The attached site plan also shows traffic patterns, storm drainage and existing water layouts. The temporary facilities such as electric, sanitary and gas is not shown in the site plan. The reasoning is all temporary facilities used for this project came from the existing building, including phase 1. Refer to Appendix D.2 for more details.

Site Layout Planning:

When producing a site layout plan, the following key elements were established. The Data Center's site is located on privately owned land and is not surrounded by neighboring buildings. Turner used this element to their advantage to maximize the efficiency of the construction process. The project is an expansion on an existing structure. The owner granted Turner Construction permission to use valuable parking area. Turner used existing parking area for trailer area, storage of materials, temporary toilet, foreman parking, and dumpster area so that the congestion of the site was at a minimum.

To see details of the site layout plan, refer to Appendix B.

Superstructure Site Layout

The site plan represents the superstructure phases of construction associated with the Data Center. During this phase of the project, the site is congested the most out of any other phases of construction. The phases include: site excavation/foundation, steel erection, and precast panel enclosure. The crane represented on the site layout plan is a 250 ton all terrain crane that has a swing radius of roughly 200 feet. The crane is first positioned on the south side of the building and moves east to finish construction. The crane's swing radius can cover most of the building, therefore, the crane needed to move very little to complete the superstructure phase of this project. Deliveries including steel, precast panels and mechanical equipment can be picked up with this crane right at the construction delivery zone represent on the site layout plan. The second crane that is presented in the site layout plan is a 300 ton all terrain crane. The second crane is necessary to set the heavy loaded electrical backup generators that are located on the roof. The second crane does not mobilize onsite until all skeletal and shell construction is finished. This crane finishes all of the mechanical and electrical equipment that is located on the roof.

MEP/Interior Finishes Phase

The MEP/Interior finishes phase is represented with black arrows on the site layout plan. This phase runs west to east of the building. Whenever the superstructure of the building gets far enough ahead, the MEP/interior finish trades can proceed to work once the steel/concrete trades signoffs the building to the contractor. During this phase of construction, the majority of the materials are stored inside the building for less congestion within the site. Being that the Data Center was only a one story expansion, getting material into the building could be down with little effort or time.

Contractor Layout Critique

When analyzing Turner's site, a few discrepancies presented. The site layout plan provided by Turner shows only one way to gain access into the site. In Appendix B of this report, the access is the construction delivery zone. With all of the truck loads coming to this point to deliver materials, it may cause congestion which in turn may increase time and money as well as confusion between trades. Another criticism is that the contractor only created one site plan for all phases of construction. If another site plans were made specifying other phases of construction, it may better organize the different trades onsite.

Project Logistics Details:

Detailed Project Schedule:

To get more familiar with the Data Center's schedule and construction process, the Schedule is broken up into three main phases: Preconstruction/Procurement, Construction, and Closeout. Table A.1 represents milestones that were important to the Data Center's successful schedule. Note that some milestones are not present in the detailed project schedule.

Milestones	Date
Conceptual Documents	03 AUG 09
Soils Report	03 AUG 09
Temp. Weather Tight	10 MAR 10
All Equip. Set on 1st Floor	09 APR 10
All Roof Top Equip. Set	24 MAR 10
Substantial Completion	23 AUG 10

*For Detailed Project Schedule see Appendix C.

The conceptual documents for Data Center were released by Sigma 7 in the beginning of August 2009. Due to the sensitivity of this project, the time frame in which it took to release these documents will be stated unknown. Due to the complex MEP systems on this project, review of all mechanical and electrical equipment also began immediately. Turner Construction quickly began the submittal/fabrication process early September for primary trades for the project. The trades included: concrete, structural steel and precast panel. The schedule for the Data Center is very tight; therefore coordination was a primary concern for this project. After Turner awarded the primary trades, September 15, 2009, mobilization for these trades took about a week and construction of the second Data Center Expansion was underway.

Construction began on September 21, 2009. To further understand the construction process, this phase is broken up into five sequences: existing building, structure, MEP coordination, MEP and finishes. Furthermore, the structure, MEP, and finishes were broken up into sub-sequences. These sub-sequences include site, upper/lower slab on grade and roof. This was done to provide simplicity to whoever is viewing the schedule. MEP sequence includes both rough-in and fit-out in the detailed schedule.

The structure sequence was not a primary concern for Turner. The only feature that makes the structure of the data center unique is the one story and 42 feet in height. A main concern for the structure could have been keeping the steel columns plumb, as well as keeping the steel erectors safe.

The MEP/MEP coordination was split up to show how complicated the mechanical, electrical, and plumbing components are in this building. The schedule shows that the MEP portion was the main focal point of this project.

Each sequence flow runs from west to east. Figure 4 represents the flow of construction for each phase.

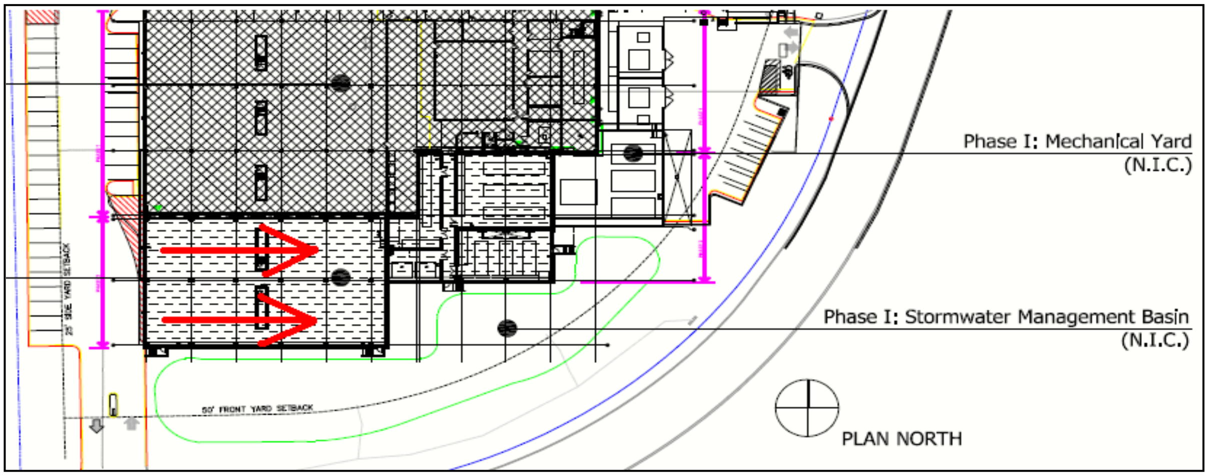


Figure 4 - Work Flow of construction

The closeout phase included all commissioning of the project. The entire Data Center construction was substantially completed on August 23, 2010. Finial C of O inspection was the next and last task to finish out the project. The project came to final completion on August 30, 2010.

Project Estimate Summary:

Due to Turner's contract agreement with the owner, the building system cost breakdown will not be included in this report. Below in Table 2 shows the different cost associated with the Data Center:

	Cost	Cost/SF
Construction:	$21 Million	$1,200.00
Total Project:	$33 Million	$1,890.00
Building System:	$12 Million	$688.00

Table 2 - Project Cost Summary

D4Cost was used for the Data Center. D4Cost does this by referencing historical data on past projects with similar size, type, and number of stories. D4Cost was used to generate an estimated construction cost of roughly $2.2 million with a square foot cost of $110.00. Also a total project cost of roughly $5.6 million and a square foot cost of roughly $321.00. To see a more detailed breakdown, refer to Appendix D. There are several reasons why these numbers differ from the actual project numbers. First, D4Cost did not have any data on a past project that consisted with a Data Center that used an Architectural precast envelope which will increase the cost sporadically. Additionally, the Unknown Data Center has multiple mechanical systems as well as an advanced electrical system that include three 2MW generators. Lastly, D4Cost did not include any cost for structural steel frame. The historical data only included a Data Center

that structure is cast in place concrete. The Unknown Data Center has a structural steel frame and composite slab on deck, as well as, cast in place concrete for the foundation spread footers and concrete footers.

RS Means Costworks was also used to produce a square foot estimate for this project. Like the D4Cost, RS Means Costworks uses historical data with similar size, building height, type, and number of stories. RS Means Costworks generated and estimated construction cost of $5.6 Million and a square foot costs of $320.00. The value that the RS Means Costworks generates closer to Turners values, given above. However, the values still falls short from Turners given cost information explained in the beginning of this section. The same reasoning for the differences in price from the D4Cost analysis applies to this scenario as well.

Detailed Structural Estimate:

A detailed structural estimate was performed to become more familiar with the Data Center. The takeoffs and estimate can be found in Appendix E of this report. The detailed estimate includes the structural steel and structural concrete with all accessories included. The Data Center was not designed with typical bays, therefore, each beam, column, footing, slab, etc. was counted and arranged orderly in a excel sheet. Note: No waste factors were used for the detailed structural estimate.

The detailed structural estimate is broken into concrete which includes formwork, reinforcing and cast in place concrete. Structural steel that includes: columns, beams, metal decking and shear studs. Table 3 summarizes the cost and quantities for each CSI Masterformat divisions.

CSI Masterformat				
Component	**Unit Cost**	**Unit**	**Quantity:**	**Cost**
031100 - Concrete Formwork	$ 10.90	SFCA	292	$ 3,182.80
032100 - Concrete Reinforcing	$ 1,862.50	TON	8	$ 14,900.00
033050 Cast in Place Concrete	$ 157.86	CY	873.11	$137,829.54
032205 - Uncoated WWF	$ 66.72	C.S.F	398	$ 26,553.68
051223 - Steel Columns	$ 84.34	LF	1463	$123,384.55
051223 - Steel Beams	$ 114.54	LF	5426	$621,513.05
053113 - Decking	$ 2.24	SF	17,895	$ 40,078.35
05050 - Shear Studs	$ 2.19	EA	4,040	$ 8,847.60
			Total:	$976,289.57

Table 3 Estimate Summary

To help visually see these costs, below in figure 5 represents a percentage breakdown of the structural system costs.

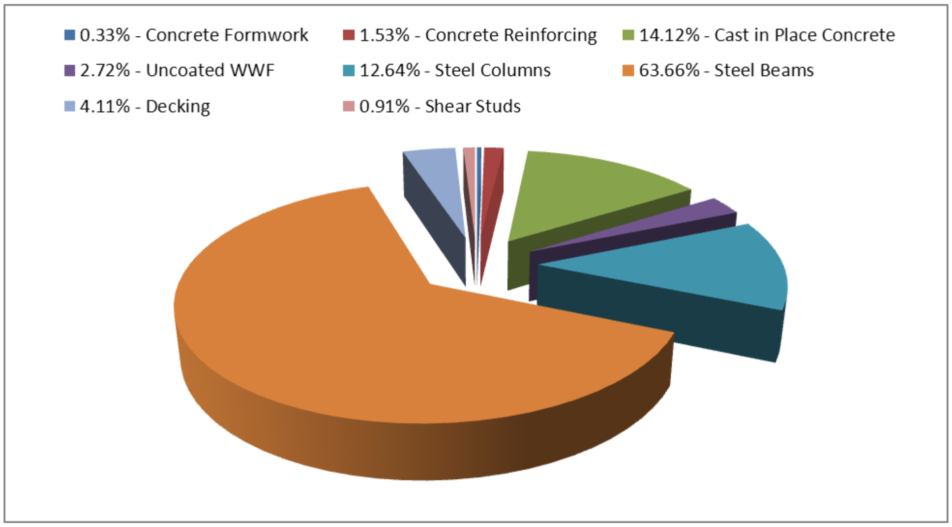


Figure 5 Structural System Component Percentages

All of the cost data was located in RS Means Costworks online. These costs included material, labor, equipment and total overhead and profit. Any members that are idealized in the detailed structural steel estimate pricing chart indicates that RS Means did not have that member. To compensate for these missing members, it was necessary to use to next size up.
As stated before in technical assignment one, table 4 shows the project cost summary to show cost comparisons from the detailed estimates and the total project, construction and building systems cost.

	Cost	Cost/SF
Construction:	$21 Million	$1,200.00
Total Project:	$33 Million	$1,890.00
Building System:	$12 Million	$688.00

Table 4 Project Cost Summary

Due to the sensitivity of this project, the actual prices for the structure of this building will remain unknown. However, RS Means provides a national average for the structure of any type of buildings. The structural system is roughly 14% of the construction cost. Using this data, RS Means gives a value of $2,940,000 for the structural systems. Table 5 shows the actual (according to RS Means) versus the estimated cost.

	Total Cost	Cost/SF
Actual:	$2,940,000	$168.53
Estimated:	$976,289.57	$55.96

Table 5 Actual vs. Estimated Structural Cost

The actual value versus the estimated value results in a 66.8% error.

There are many issues that brought about this error. As mentioned earlier, the actual prices of the building could not be released. Not having this information left out many values for the estimate. For example, there is roughly 100 rectangular structural steel supports to hold up mechanical and electrical systems on the roof. RS Means Costworks does not include any specialty prices in this nature. Having this information would have drove the estimate up. Below in Figure 6 represents the supports.

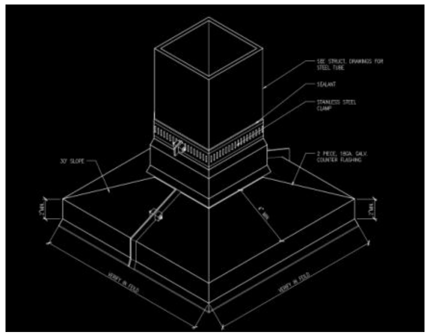


Figure 6 Dunnage roof support

General Conditions Estimate:

A general conditions estimate was calculated for the Data Center's site. Due to the sensitivity of this project, the actual general conditions cost was not released and will remain unknown. Detail for this estimate is available in Appendix F at the end of this report. The estimate is summarized in Table 6. This table presents the cost for each line item associated with the Data Center.

General Condition Summary		
Item	**Cost ($)**	
Supervision and Personnel	603,330	
Construction Facilities and Equipment	38,450	
Temporary Utilities	153,100	
Miscellaneous Costs	27,640	
Insurance and Bonds	841,500	
	Total:	**$1,671,720**

Table 6 General Condition Estimate Summary

The estimate was broken down into five main categories: Supervision and Personnel, Construction Facilities and Equipment, Temporary Utilities, Miscellaneous Cost and Insurance/Bonds. All prices that were used to calculate the general conditions estimate was obtained using RS Means Costworks.

The Supervision and Personnel category include the entire management staff and support teams for the project. For example, project executive, project managers, superintendents, and general labor. The Construction Facilities and Equipment category includes items that were needed onsite for construction. For example, office/storage trailers, survey, gang box, etc… The Temporary utilities include installation and consumption costs of power, water, and telecommunication services for the duration of the project. The Miscellaneous Cost category accounts for the site clean-up expenses as well as misc. field expenses associated with construction. The Insurance and Bonds category includes the bonds, permits, and insurance needed for the Data Center.

Show below in figure 7 is a percentage breakdown to help visually see the general condition cost associated for the Data Center.

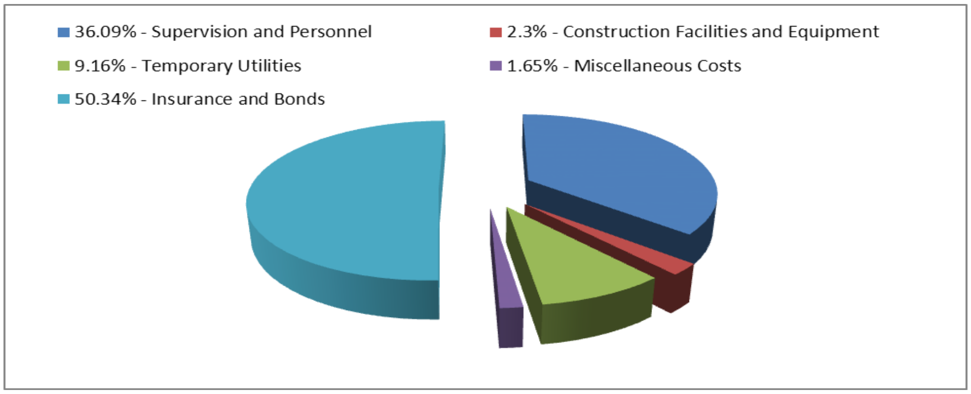


Figure 7 – Percentage Breakdown of General Conditions

Similar to the detailed structure estimate, the general conditions estimate is inaccurate. Figure D.2 shows the Supervision and Personnel category only accounting for roughly 37% of the total general condition cost. It should be noted that the Supervision and Personnel does not include the cost of the estimator to complete a detailed estimate. In the same respect, without the cost breakdown of the actual general condition estimate from Turner, the duration of personnel is hard to determine. Any change orders may also effect the duration of key personnel as well. If these factors were known, it may drive up the calculated general conditions estimate to a more reasonable value.

The overall general conditions estimate was calculated at a value of $1,671,720. This value is a little under 8% of the total construction cost. It is stated that the general conditions cost should ultimately be around 15% of the construction cost which is approximately $3.15 million. This results in a percent error of 47%. This error can be rectified with reasons stated above.

Analysis #1 – Alternate Roof Systems (Green, Solar):

Problem Statement:

The Data Center's roof construction primarily constructed with EPDM fully adhered to concrete slab on deck. On top of the EPDM is interlocking insulation board covered with UV protection fabric and is topped off with interlocking concrete pavers. This type of roof was selected for sound isolation purposes. The primary problem is that the owner is not utilizing the opportunity to implement green/solar roofing systems to increase to performance of his/hers building. In addition, the current roof constructed includes various amounts of materials and two different trades to construct this roof type.

Proposed Solution:

The proposed solution to this problem will be to explore two different types of roof systems, a green roof and a PV panel roof. Additionally, research will be conducted for the energy benefits of each roofing system. A financial feasibility study will be performed to indicate whether the proposed roofing system is best for the owner. In addition, an energy analysis will be conducted to determine the benefits and drawbacks of each type of roofing system, these calculations will fulfill an electrical breadth which will be explained later in this report.

Benefits:

- Green Roofing System:
  - Economic Benefits:
    - If constructed correctly, this type of roofing system may last longer than the original design resulting in savings on replacement/maintenance costs.
    - Potential savings on heating and cooling costs.
    - Reduces storm water runoff.
  - Sound Isolation Benefits:
    - Soil and plants can insulate sounds from the mechanical systems located on the roof.
    - Green roofing systems with a substrate layer up to 20 cm can reduce sound by 46-50 decibels.
  - Financial Benefits:
    - Increases the buildings value.
- PV Roofing System:
  - Reduce cost energy for the building.
  - Government benefits (Financial)

Disadvantages:

- More costs up front
- Depending on the type of green roof, a maintenance cost may occur.
- The weight increase may affect the structure of the building.

Research:

The research components of the analysis will include designs of the two types of roofing systems and determine the impacts on the cost and schedule of the project. Also, a life cycle cost analysis will be conducted to determine how much time it would take to pay for the new structure.

Additionally, a financial feasibility study will be performed to determine any additional cost savings using a green roof and/or PV roof in an effort to make this analysis more appealing.

Methodology:

- Develop conceptual designs of both roofing systems.
- Consult with professionals on the proposed designs.
- Evaluate the constructability issues associated with this proposed solution.
- Develop a feasibility study on both roofing systems.
- Calculate the cost and schedule impacts to the proposed solution.
- Calculate any energy savings (electrical breadth) cost that may appeal to the owner.
- Summarize findings.

Academic Tools Used:

- Industry Professionals
- AE Faculty – Acoustical
- Turner Construction
- Sigma 7 – Architect
- Microsoft Excel
- Project owner

Expected Outcomes:

The expected outcomes from this analysis will conclude that a PV panel roofing system will be more beneficial to the owner because of the type of building it is. The effects on duration and cost will be affected in a negative way, but the life cost cycle will make up for the longer duration and cost to the owner. To successfully complete this analysis, client research cannot be taken likely.

Detailed Description of Current Roof Structure:

The roof is primarily constructed with EPMD fully adhered to concrete slab on deck. On top of the EPMD is interlocking insulation board covered with UV protection fabric and is topped off with interlocking concrete pavers. Figure 8 is a cross section of the Data Center's primary roof system.

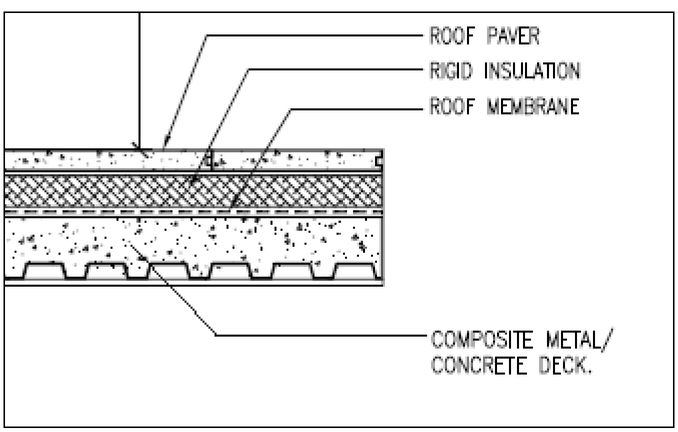


Figure 8 – Cross Section of Roof

It was necessary for the roof to be this thick due to the amount of mechanical and electrical systems on the roof.

There are two penthouses that are present on the roof. The structure of the penthouse roofs are different then the primary. The penthouses utilize concrete slab over metal roof deck but is topped off with a standing seam metal roof. The penthouses will be critical when designing the Photovoltaic panel roof system. Figure 9 shows a floor plane with the location of the two penthouses.

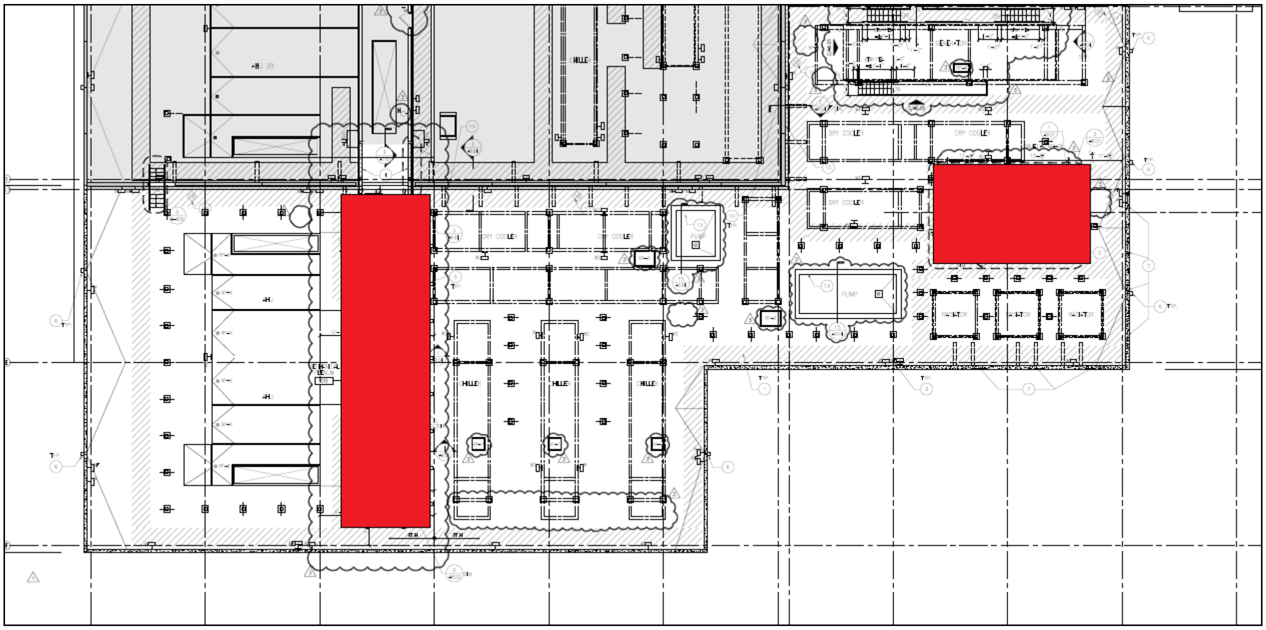


Figure 9 – Penthouse Location

Alternate Design (Green Roof System):

Types of Green Roofs:

Green roofs are divided into two main categories, intensive and extensive. Intensive green roofs require daily maintenance and need easy accesses to maintain the roof. Extensive green roofs require much less maintenance and are designed to be virtually self-sustaining. Extensive green roofs may be designed on very thin layer of soil so the load is not as problematic. Below depicts an image of basic green roofs properties.

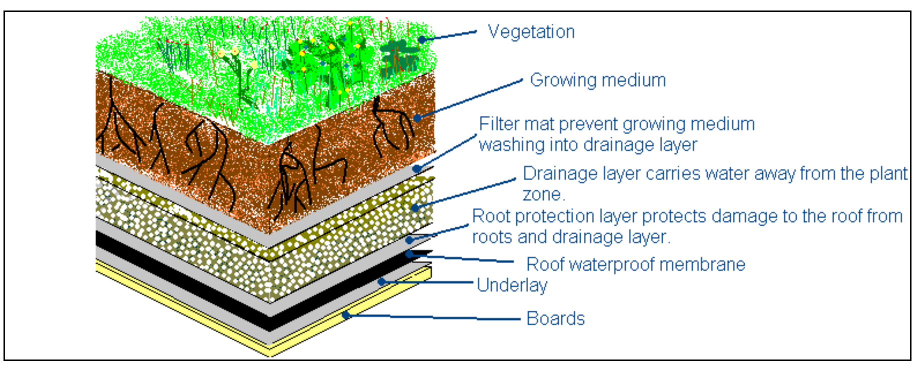


Figure 10 - Basic Green Roof Properties

Due to the nature of this project (i.e. type of building – Business), an extensive green roof type would be more acceptable. The reasons for the choice are maintenance and access. The Data Center is a place for business and the owner most likely has a maintenance crew on payroll. The need for more maintenance for a green roof would look unappealing for trying to sell to the owner, but having an extensive type green roof, yearly maintenance is one viable option. With intensive type green roofs, wide access is needed for maintenance. Since the Data Center has a vast amount of mechanical and electrical equipment on the roof, choosing an intensive type green roof poses a problem in future maintenance.

Advantages/Disadvantages:

One general advantages associated with green roofs are the potential to obtain LEED points for LEED certification. There are five to twenty-one potential LEED points that an owner can obtain be integrating a green roof into his/her building.

Another key advantage is the energy savings through thermal insulation of the building. During summer conditions, green roofs can reduce the indoor temperatures thus reducing the amount of electricity to cool the building. In addition, green roofs may improve stormwater management. Depending on the design, green roofs possibly could retain between 60 – 100 percent of stormwater. Green roofs also increase the life of the roof membrane by absorbing ultraviolet radiation from the sun, thus, protecting the roof's membrane. This portion of the report will focus on the energy savings by means of thermal insulation and stormwater management.

The main disadvantages include cost, increased schedule, and required maintenance. For an extensive type green roof, research suggests that the cost per square foot would be $15.33 this includes overhead and profit

Design Layout:

As stated above, the types of green roof chosen is extensive due to ease of construction and are designed lighter than intensive green roofs. Some design factors that must be taken account include: Climate, Structure, Size/Slope of the roof, and type of water proofing, Drains, and most importantly cost and schedule impact.

As stated in the beginning of this report, the Data Center's structural steel frame consists of strong beams to take the load of all of the mechanical and electrical systems located on the roof. The Data Center is located in climate closely related to that of Pennsylvania; the anticipation of the green roof going through four seasons will be assed. The main factors that this analysis will take account are the cost and impacted schedule. Another primary factor to note is the open space on the roof. The final design decision is an extensive green roof utilizing a modular system. This was chosen because it is lightweight and the ease of construction. The figure below depicts a section of a sample of the green roof.

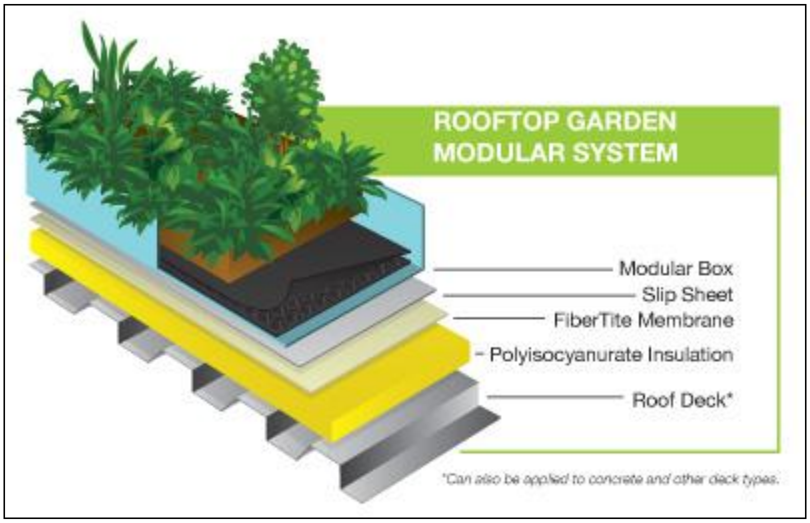


Figure 11 – Section of Modular Style (FiberLite Roofing Solutions)

Below in figure 12 is a roof plan of the Data Center. The green areas represent the area of interest for the alternate roof design. This design is intended for as much green roof area to be over the computer lab space. This design is expected to increase energy savings by reducing the cooling loads during summer climate conditions. The red rectangle indicates where the computer lab is with reference to the building. Unfortunately, the amount of mechanical and electrical systems kept the design from taking over the whole roof. In addition the majority of the roof is on the exterior of the building next to the parapet wall which will create problems for the sun to reach the green roof.

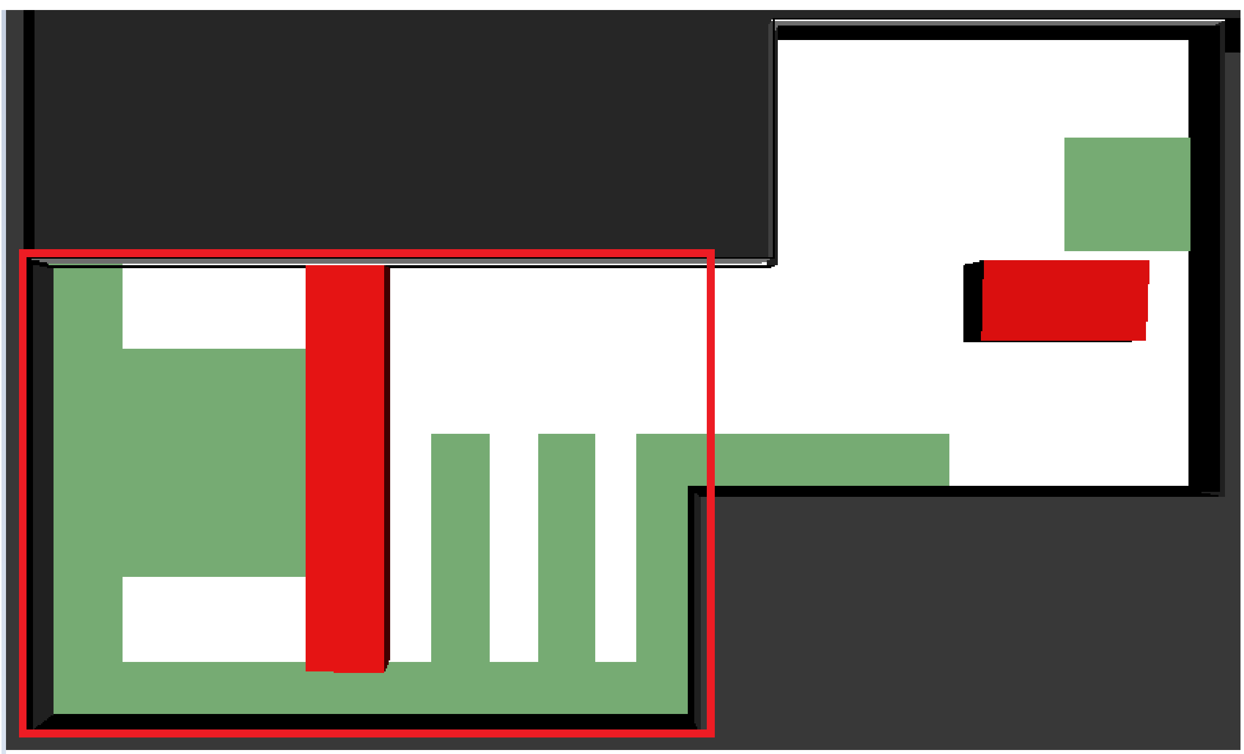


Figure 12 Roof Plan of Proposed Green Roof

Cost Analysis:

After contacting a Fiberlite Roofing Solutions representative, it was determines that the cost of the modular green roof to be approximately $15.00 per square foot. This cost includes the substrate, and Fiberlite's membrane. In addition, the labor cost associated with the installation was determined to be roughly $3 per square foot, making the overall price of the system to be $18 per square foot. To make this price more accurate, the labor and material costs for the concrete and metal deck needs to be accounted for. After researching RS Means prices, the cost of the green roof increase to $21 per square foot. Below in Table 8 shows the price comparisons of the proposed green roof system to the current roofing system, EPDM.

Cost Comparisons					
Roof Type	**Cost Per SF**	**Area**	**Cost**	**Life Expectancy**	**Possible Payback**
EPDM	11	5210	57,310	12	NO
Green Roof	21	5210	109,410	50	YES

Table 8 – Roof Cost Comparison

Schedule Impact:

As previous mentioned, aside from the mechanical benefits the green roofs bring, a modular green roof may bring relatively short time it takes to install this system. The Fiberlite representative claimed contractors can install 3,000 – 5000 square feet of their type of modular green roof system. With this value, the proposed green roof system would only take a day or two to install. In term of the critical path of the project, the green roof would have no effect because the green roof contractors could easily construct the green roof during a weekend therefore not affecting the critical path of the schedule.

Alternate Design (PV Panel Roof System):

Photovoltaic Basic Information:

This section of the report provides research information on how this technology works, different types of photovoltaic panels, basic costs, and how to integrate them into commercial buildings.

In short, photovoltaic's convert energy from the sun into usable electrical energy to cut down consumption cost in buildings. It is a simple concept to understand, but the process is fairly complex. PV systems can be compared to other electrical power generating systems, the main difference is the equipment used to produce the energy. The energy source (Sun) strikes the PV panel, which is when the energy conversion takes place. That energy is essentially transported to a DC-AC power inverter, energy storage battery, or both, depending on the design. The energy will be stored at this location until it is needed for building usage. When the building "calls" for the energy, the energy stored will be transferred to the buildings energy distribution system and distribute the natural energy throughout the building. Below in figure 13 shows a conceptual process of a PV system.

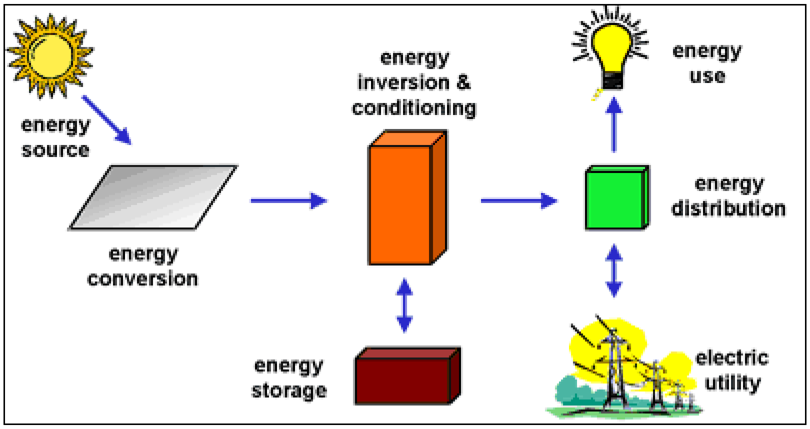


Figure 13 – Conceptual Process of a PV system

There are three types of Photovoltaic panels: Monocrystalline, Polycrystalline, and Amorphous. Research suggest that Monocrystalline is the most efficient types of PV panels, the efficiency ranges from 14%-19%. However, this type of panel is the most expensive. The costs are set up dollar per watt. Research suggests that Monocrystalline, Polycrystalline, and Amorphous panel cost $2/watt, $1.50/watt, and $1/watt, respectively. These costs are referenced from the book Green Building: Project Planning &Cost Estimating. The cost for analyzing the system will be referenced from actual PV distributers.

Photovoltaic's can be means of Building-Integrated Photovoltaics (BIPV). This method is a result where photovoltaic materials replace a conventional part of the building. The parts of

materials that can be replaced include: shingles, standing seam metal roofing, spandrel glass, and overhead skylight glass.

All of these concepts listed will be taken in account for the design.

Advantages/Disadvantages:

The main advantage is the energy that can be obtained by the sun. PV technology can be looked at an investment. It cost more up front, but if the system is designed correctly, there is an often a fair amount of savings in fuel and operations over time. Another advantage is incentives from the federal government and/or state of which the building is located. The federal government and state may provide tax credit for use of integrating photovoltaics in newly built projects.

The main disadvantages of photovoltaic systems are the space requirements and costs. PV systems require a large surface area to generate any significant amount of power. Current PV technology can only convert roughly ten percent of the solar power to electricity. The cost is very expensive due to the high-technology manufacturing process. Another disadvantage to note is the energy source (Sun). Solar power is a variable energy source and is hard to anticipate the lack of solar energy collection.

Design Layout:

The first aspect of PV system design is the orientation and shading of the Data Center. The orientation of the Data Center is optimal for a PV roofing system because the new expansion is oriented south. 3D models were created to show the shading throughout critical times of the year. Below in Figures 14-19 are 3D models created in AutoCAD 3D Studio Max that shows the summer solstice, spring equinox, and winter solstice. The times are indicated in the captions of the figures.

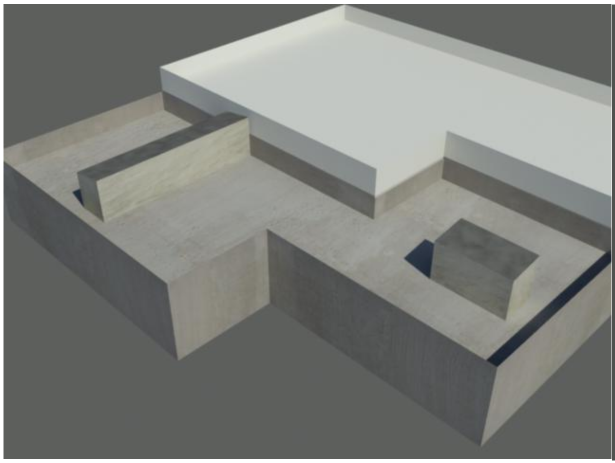


Figure 14– June, 9 am

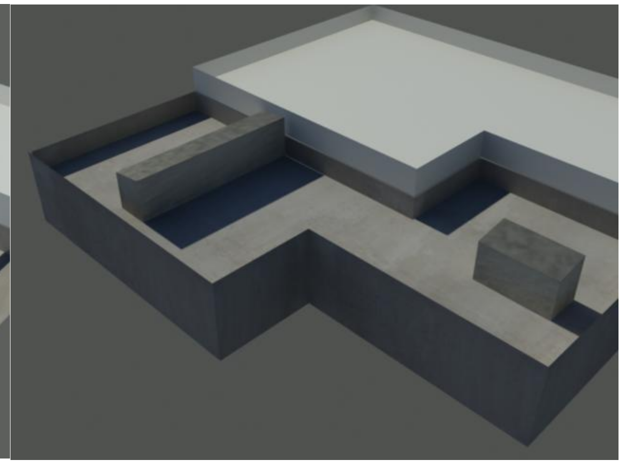


Figure 15 – June, 4 pm

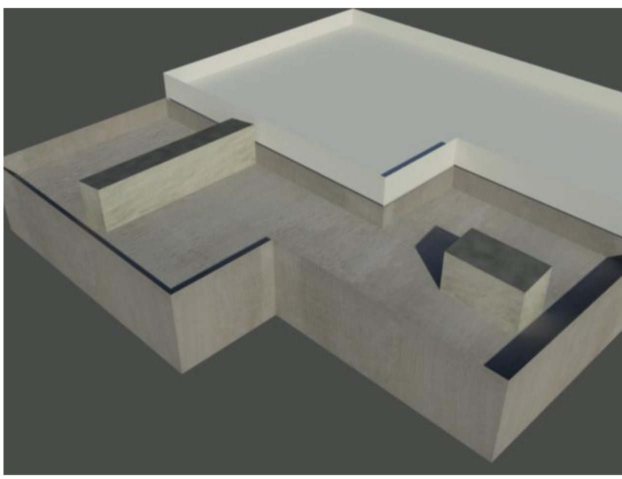


Figure 16 – March, 4 pm

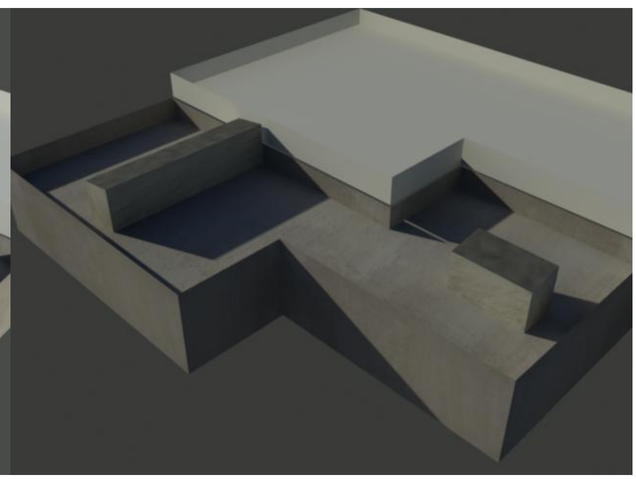
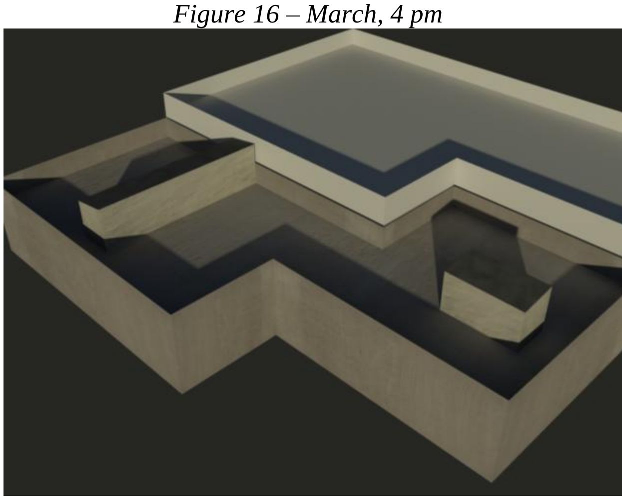


Figure 17 – March, 4 pm



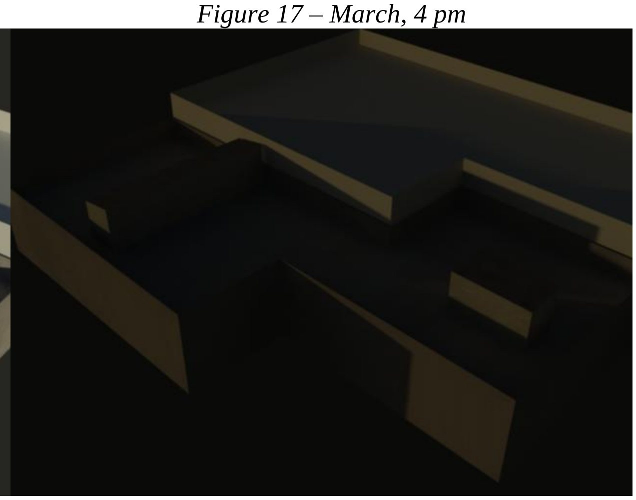


Figure 18 – December, 9 am *Figure 19 – December, 4 pm*

The 3D models suggest that to optimize the PV system, the penthouses will need to be utilized. In addition, the proposed panels will need to stay away from the parapet walls. With combining Analysis 3 to this analysis, it will be more advantageous to maximize the energy consumption using the proposed PV systems.

The next aspect of the design is to answer the question, "How much energy (watts) do you want the system to produce?" Before this question, we must determine the average amount of sun hours the Data Center obtains per day. Research suggests that the Data Center receives roughly 4.21 sun hours per day. Because the Data Center's roof is surrounded with mechanical and electrical equipment, to power the whole building using photovoltaics is not feasible. This design will focus primarily on the lighting fixtures in the computer room. The computer room utilizes 53 eight foot fluorescent lighting fixture. Below in Table 9 shows the energy in watts these light fixtures produce in a day.

Energy Loads – Computer Room Lighting Fixtures				
Component	**Quantity**	**Watts**	**Hrs/Day**	**kWH**
8' 277V Fluorescent	76	60	12	54.72
4' 277 Fluorescent	16	32	12	6.144
Total	**92**			**65**

Table 9 – Energy Load Calculations

The next aspect of the design to explore is what kind of photovoltaic panels to use for the Data Center. The type of panel will need to be a reasonably efficient PV panel. Researching different type of panels from manufactures (Sanyo Electric, Kyocera Solar, SPI, etc…), it was determined to rate each panel by their PTC Rating (rating given under realistic test condition). The PV panel that was chosen is a Sanyo Electric, HIP-200BA19/20. The spec sheet for this panel may be viewed in Appendix G of this report.

The energy load calculations are estimates of the electrical loads that the Data Center's lighting fixtures will produce. The hours per day was assumed to be twelve due to regular work hours plus to compensate for any off hour working. The total kWh was rounded up to 65000 to compensate for any inefficiencies in the lamp fixtures. Below in Table 10 shows how to determine the required amount of panels to produce the energy for the lighting fixtures.

Sizing Calculations	
Sun Hours Per Day	4.21
Watt-Hours Per Day	65000
Watts Per Hour of Sunlight	15439
Actual Power Produced Per Panel	123.5
Number of Panels Required	125

Table 10 – Solar Array Calculations

The calculations above suggest that the design should consist of 125 PV panels. The layout that will be used will consist of 129 panels. As mentioned earlier, all of the panels will be mounted on the penthouses for optimal performance and prevent shading from the parapet wall. The penthouse that is located on the west side of the building has the majority of the panels. There are twenty-one rows of five panels, 105 panels. There is a space of two feet in between each row for access for maintenance. The penthouse holds 24 panels with a similar layout. Below represents a floor plan showing the layout of the PV system.

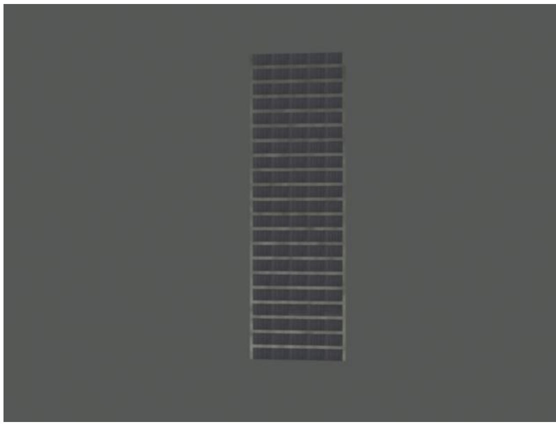


Figure 20 – West Penthouse Panel Layout

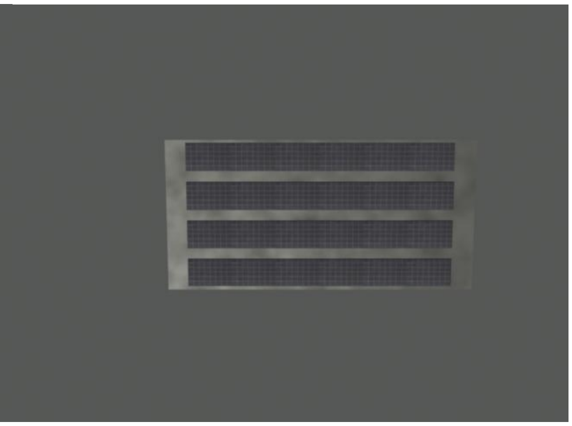


Figure 21 – East Penthouse Panel Layout

The next aspect of the design is to determine the tilt of the panels for optimal performance. The Data Center has Latitude at roughly 40 degrees. To optimize the performance of the building the tilt of the panel will be set to the mean of angles from the different seasons. Below in Table 11 summarizes this process for better understanding.

Tilt Calculations		
		Latitude 40 +/- 15
	Penthouse 1 (No Slope)	**Penthouse 2 (9° Slope)**
Summer	25°	19°
Fall/Spring	40°	31°
Winter	55°	46°
Mean	**40°**	**32°**

Table 11 – Tilt Calculations

The data above suggest to tilt the PV panels on penthouse 1 forty degrees and thirty-two degrees on penthouse 2 to achieve optimal performance. Below is a 3D model that shows the tilts of the panels as well as shadows.

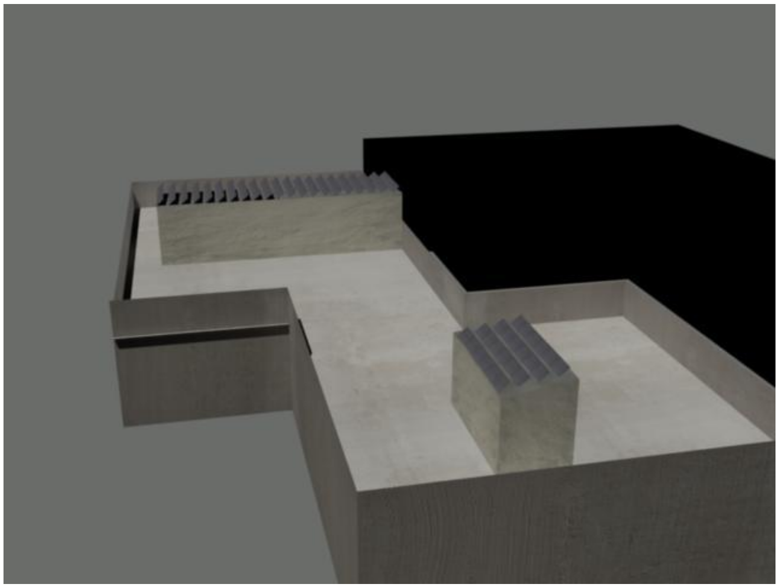


Figure 22 – 3D Model of PV Array System

Electrical Breadth:

Energy Production:

To become more familiar to the performance of the PV system design, the yearly AC energy was calculated based on parameters on the array design and local conditions. PVWatts calculator at pvwatts.org will perform the calculations given the PV array design parameters. Since this project must stay unknown, the local parameters will not be listed. The PV systems parameters are listed in Table 12 below. Table 13 shows the yearly results of the proposed PV system.

PV Array Parameters	
DC Rating:	25.8 kW
DC to AC Derate Factor	0.77
AC Rating:	19.9 kW
Array Type:	Fixed Tilt
Array Tilt:	40.5°
Array Azimuth:	180°
Energy Parameters	
Cost of Electricity	12.6 c/kWh

Month/Year Results			
Month	Solar Radiation (kWh/m^2/day)	AC Energy (kWh)	Energy Value ($)
1	3.08	1958	246.43
2	3.88	2212	278.40
3	4.93	2981	375.19
4	5.04	2847	358.32
5	5.35	3062	385.38
6	5.54	2981	375.19
7	5.21	2840	357.44
8	5.14	2822	355.18
9	4.98	2718	342.09
10	4.48	2624	330.26
11	3.25	1884	237.12
12	2.90	1805	227.18
Year	**4.48**	**30734**	**3868.18**

As shown to the right, PVWatts calculated the yearly AC energy that the solar panels can potential produce to be 30734 kWh. In addition, an energy savings value was calculated to be roughly $3,868. These values will be very useful for calculating the life cycle cost of the system as well as performing a financial study of the proposed system.

Energy Distribution:

The next aspect of the breadth is to determine the most effective way to distribute the calculated energy savings. The first step is to choose an economical inverter for the system. Research suggests that the Sunny Tower ST 36 was most efficient for this application. This inverter has a PV power rating of 36 kW. This size inverter was chosen because the tower may be mounted outdoors and includes all of the required DC/AC connects and disconnects, thus insuring easy installation. In addition, the DC rating for the selected inverter exceeds the DC ratings of the PV system, thus, the inverter can handle the electrical load demand. The dimensions for this particular inverter are 70.5” high, 43.3” wide, and 39” deep. The inverter will be located by the eastern side of the building beside the penthouse. This location was chosen because the mechanical room is located directly below. See Appendix F for complete product data for the selected inverter tower. Below is a schematic of how the energy will be distributed throughout the building.

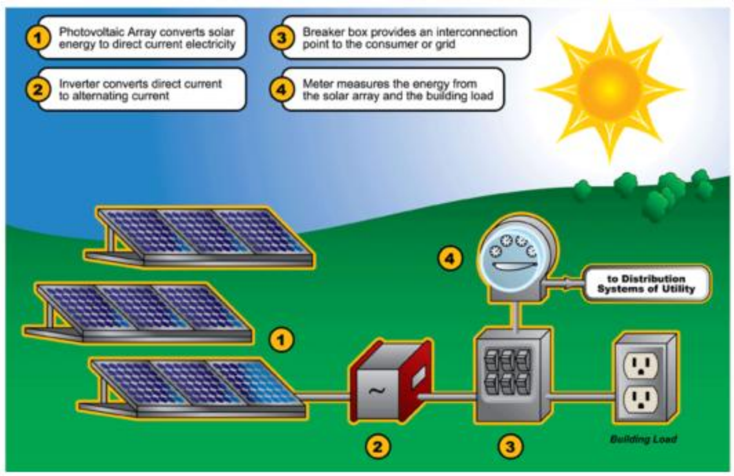


Figure 23 – Schematic Model of Energy Distribution

Below is an aerial view of the DC wire running from the solar panels to the inverter; and the AC wires running from the inverter to the grid. The blue box beside the west penthouse indicates the location of the inverter.

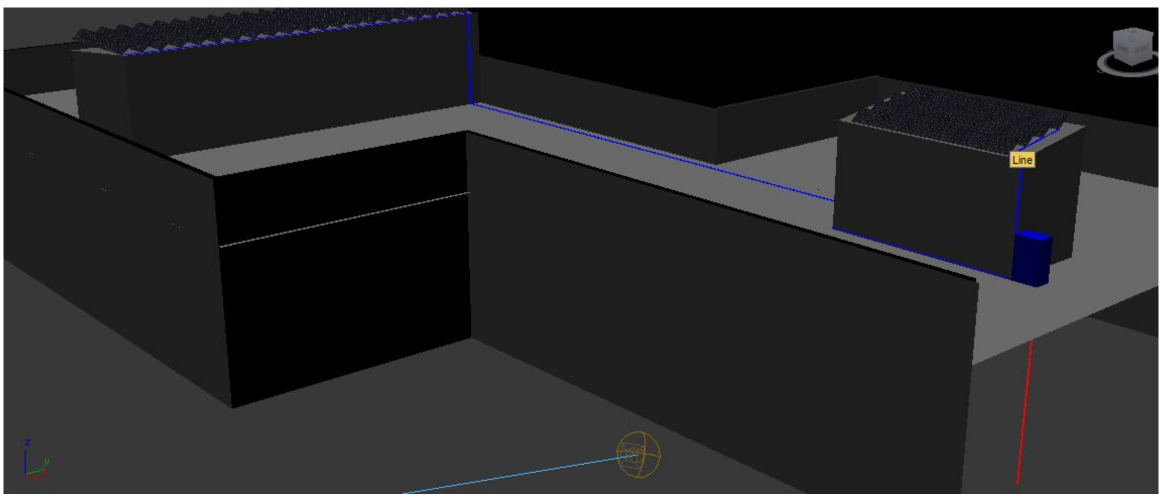


Figure 24 – DC/AC Wire Layout

The models suggest that the DC wire from the east penthouse will need to run roughly 150 feet to reach the inverter box. Therefore, a voltage drop will need to be calculated to determine the size of the DC wire. The calculations concluded that the size of the wire required (NEC standard) will need to be a #8 AWG. Appendix I shows detailed calculations to determine the DC wire size. The model suggest that a voltage drop for the AC wire run will not be needed because the wire is only 40 feet in length, therefore, the voltage drop will be minimal.

Cost Analysis:

A detailed estimate of this system will need to be calculated to determine how much more this proposed system will add to the Data Center's costs.

The costs include:

- Prices of panels, mounting systems, DC/AC wire, Inverter, and conduit/supports.
- Installation of panels, mounting systems, DC/AC wire, Inverter, and conduit/supports.
- Overhead and Profit. (Assumed to be 35%)

Below in Table 14 shows a cost breakdown of each component of the proposed system.

Detailed Cost Breakdown of Proposed System						
Item	Quantity	Unit	Material	Installation	O&P	Total
HIP – 200 BA19	129	EA	957	70	1,387	178,923
Mounting	129	EA	200	19	296	38,184
Inverter	1	EA	21,569	840	30,252	30,252
AC Wire	.26	C.L.F.	168	203	372	97
DC Wire	1.71	C.L.F.	188	203	391	669
Ground Wire	1.97	C.L.F.	75	86	209	412
Conduit/Supports	151	LF	2.02	4.88	9.315	1,407
					Total:	249,944

Table 14 – Cost Breakdown

Rebate and Incentives:

Using a PV system in buildings can qualify for federal and state rebates on the upfront cost of the system. Below is the list for federal and state incentives.

- Federal Tax Credit – 30% of gross installation cost
- State Energy Program – $15,000/kW system size up to 10kW
- State Alternative Energy Credit – $ 0.2/kWh produced

Applying the federal and state rebates/incentives, the upfront cost changes from $249,944 - $159,961.

Financial Study/Life Cost Cycle:

A financial study and life cost cycle will need to be calculated to determine the energy savings throughout the life of the PV system and the potential time (in years) that it takes for the system. This section of the report will determine the cost of the system through 25 years of the system.

The calculation will include the state energy tax credit, energy savings, and yearly maintenance cost. In addition, an assumed 1% increase per year on energy cost will be taken in account. Below in table 15 shows the Life Cost of the system.

Life Cycle Cost						
Year	Energy Cost ($/kWh)	Tax Credit ($/kWh)	Energy Savings (kWh)	Total Saving ($)	Yearly Maintenance Cost ($/kWh)	Total ($)
1	.126	0	30734	3872	0.02	3257.804
2	.127	.2	30734	10050	0.02	9435.338
3	.129	.2	30734	10111	0.02	9496.806
4	.130	.2	30734	10142	0.02	9527.54
5	.131	.2	30734	10173	0.02	9558.274
6	.132	.2	30734	10204	0.02	9589.008
7	.134	.2	30734	10265	0.02	9650.476
8	.135	.2	30734	10296	0.02	9681.21
9	.136	.2	30734	10327	0.02	9711.944
10	.138	.2	30734	10388	0.02	9773.412
11	.139	.2	30734	10419	0.02	9804.146
12	.141	.2	30734	10480	0.02	9865.614
13	.142	.2	30734	10511	0.02	9896.348
14	.143	.2	30734	10542	0.02	9927.082
15	.145	.2	30734	10603	0.02	9988.55
16	.146	.2	30734	10634	0.02	10019.28
17	.148	.2	30734	10695	0.02	10080.75
18	.149	.2	30734	10726	0.02	10111.49
19	.151	.2	30734	10788	0.02	10172.95
20	.152	.2	30734	10818	0.02	10203.69
21	.154	.2	30734	10880	0.02	10265.16
22	.155	.2	30734	10911	0.02	10295.89
23	.157	.2	30734	10972	0.02	10357.36
24	.158	.2	30734	11003	0.02	10388.09
25	.160	.2	30734	11064	0.02	10449.56
					Total:	**241507.77**

Table 15 – Life Cycle Cost/Buy Back

The life cycle cost calculations determined throughout 25 year the PV will save $241,508. The line indicates the buy back of the upfront cost (years 17-18). With that being stated, the owner could potentially save $81,547 in energy throughout the life span of the system.

Schedule Analysis:

Since the main driver of the Data Center is the schedule, the determination of how the panels affect the schedule will need to be accounted. Similar to the green roof design, the PV system will not affect the critical schedule of the project. The panels weigh 33 per panel. The only concern will be usage of the crane. The PV contractors may need to use the crane to get the bulk of the panels and mounting to the roof, but can easily set the panels by hand.

Conclusion/Recommendation:

Based on the information in this analysis, a PV array design is recommended to the owner. The design should be based on the one in this analysis. This system's upfront cost is roughly $160 thousand and has a potential buyback of 17-18 years which is pretty reasonable.

The green roof is not recommended because the Data Center has a mass amount of mechanical equipment therefore making it virtually impossible to create an adequate design. The design that is given in this analysis was based on open space on the roof. This design could potentially work, but not in the Data Center's case. If the owner would want to pursue a green roof system, an extensive, modular green roof would be recommended.

Analysis #2 – Risk Management – Long Lead Items:

Problem Statement:

The Data Center's procurement/fabrication process for major long lead items could have been implemented with risk management. Turner could possibly increase their profit by buying out the major, complex long lead items and taking care of the fabrication/procurement process themselves, other than the alternative (subcontractors).

Proposed Solution:

The solution for this situation is to investigate a Risk Management analysis for all the long lead items of the Data Center. This analysis will explore the hypothetical idea of Turner being in control of the buying/fabricating of all the mechanical/electrical long lead items and to determine the benefits and risks using this management method. Cash flow diagrams are appropriate for this analysis to compare the cash flow of the construction manager vs. the subcontractor's responsibilities of the long lead items. The schedule and costs of the Data Center will need to be adjusted for this analysis.

Benefits:

- Accelerate the Data Center's fabrication/procurement process.
- Increase in return for the construction manager.

Disadvantages:

- The construction manager takes on a greater risk using this management technique.

Research:

The research for this analysis will involve collaboration with Turner to get a list and a rough price on the mechanical/electrical long lead items. This analysis will need consultations with industry professionals that may have used this management technique. Costs analysis will be assessed to determine the effect on the cash flow of the project for both the construction manager and the subcontractors.

Methodology:

- Interview Turner contact and receive information on all the mechanical/electrical long lead items.
- Consult with the mechanical and electrical subcontractors.
- Develop a schedule integrating this management technique.
- Develop cash flow diagrams for both management situations (Construction management, Subcontractor.)
- Develop a risk analysis assessment.
- Summarize results.

Academic Tools Used:

- Industry Leaders
- PACE seminar contacts
- AE faculty – Construction
- Colleagues
- Equipment Manufactures
- Turner Construction

- o Subcontractors

Expected Outcomes:

The expectation of this analysis is to have a positive effect on the fabrication/procurement process. In addition, this analysis will increase the return for the Turner construction. To conclude this analysis, recommendation/conclusions will be analyzed to determine the feasibility of this management technique.

Overview:

The first step of this analysis is to identify all the major long lead items. The majority of the long lead items were located on the roof of the Data Center. The long lead items that were identified include:

- (3) AHU's
- (3) Chillers
- (1) 2MW Generators

The next step is to give a rough price on all the long lead items. The air handling units will roughly cost $300,000, the chillers $210,000, and the generator $300,000. This gives a total of $810,000 that Turner will need to borrow from a lender.

Schedule Impact:

Since the conceptual documents were complete in August of 2009, the construction manager could buy the long lead equipment right away and start the fabrication process. The difference in the schedule from the construction manager buying the equipment instead of contracting it out is roughly three months. Therefore, the fabrication, required on job dates, and setting the equipment will be waiting for transportation way before the detail schedule proposes.

Risk Analysis:

There is a high risk associated for the construction manager if he executes this method. One, if the construction manager initially buys the equipment right away, he is in charge of making sure that the design is perfect for the Data Center. If for some reason the design was flawed, the owner could potentially make the construction management firm pay to alter the design which might be pricy. Another risk that the construction manager takes on potentially has to borrow money from a lender to execute this management technique. If Turner does not have enough revenue to buy the entire long lead item, they will need to temporarily borrow money from a bank/lender to fit the upfront cost. The construction management firm would have to pay the lender back throughout the procurement process where they get money from the owner. If any payments from the owner are delayed, there might be a penalty fee the construction manager has to pay out of their pocket.

Benefits on Return:

While taking all the risk by implementing this method, there are also great benefits that the construction manager receives. Since the construction manager kept the long lead items in their contract. That firm gets most or all of the return for fabricating the equipment to the specs of the design. A rule of thumb that was followed was that the return/profit the construction manager makes is roughly 10-15%. With that being stated, the construction management firm can possibly profit $81,000 - $121,000 by implementing this risk management method.

Conclusion and Recommendations:

After performing the cash flow analysis, it concludes that the construction management firm takes on a lot of risk and must be very organized and detailed when taking on this method. The risk increases when the construction management firm has to borrow money to pay the upfront cost of the long lead mechanical and electrical equipment.

In addition to this analysis, it is recommended to all construction management firms to look into procuring long lead mechanical and electrical items with the method explained in this analysis. It is highly recommended for firm with excellent in house engineers and is financially large as a company to use this method because the company will take on less risk.

Analysis #3 – Façade Redesign (Implement Tilt-up Construction):

Problem Statement:

The architectural precast poses a problem due to the twenty foot parapet wall that extends past the roof, in turn, there is over use of materials and labor for this parapet wall.

Proposed Solution:

The proposed solution to redesign the parapet wall with conducting interviews with the architect about what he wanted to accomplish with the parapet walls. A structural analysis will need to be conducted to determine if any changes in beam/column sizes. The changes in the sizes of the beams and columns may decrease the cost of material for the Data Center. This will apply for a structural breadth. More information on this specific breadth can be viewed in Appendix A of this report. In addition to this redesign, incorporation of tilt-up construction will be assessed to essentially accelerate the Data Center's schedule.

Benefits:

- Decrease the labor and material costs.
- Accelerate the schedule.
- Decrease truck deliveries.

Disadvantages:

- Increase site congestion.
- Depending on design, possibly make the Data Center unappealing.
- Risky for the CM if the tilt-up method is not executed correctly.

Research:

An interview with the architect will need to the conducted with regards to the high parapet walls. Cost research will need to be conducted for the materials and labor savings. A construction analysis will need to be conducted to determine the effect of the schedule for integrating tilt-up construction.

Methodology:

- Interview Architect/Industry professionals.
- Develop a new façade design.
- Consult with industry professionals about façade design.
- Determine the effect on the schedule using tilt-up construction method.
- Run a structural analysis, determining the effect of the column/beam sizes.
- Determine the effect on the material and labor cost.
- Summarize results.

Academic Tools Used:

- AE faculty – Structural/Architectural
- Sigma 7 – Architect
- Revit
- Client
- Colleagues

Expected Outcomes:

The expected outcomes from this analysis would include having positive effects on the cost of materials and labor, as well as, accelerate the schedule for the Data Center. The redesign will minimize the size of the Data Center's exterior columns and possibly exterior beams. In turn, minimizing the cost of structural steel. Shortening up the precast panels will result in a decrease cost for the façade. Additionally, integrating tilt-up construction method will accelerate the schedule.

Description of Current Façade:

As stated before, the Data Center's shell is primarily made up of architectural precast concrete and is designed to withstand wind up to 200 miles per hour. A liquid membrane is used between the precast and flashing for maximum water protection. The precast is erected to bearing surfaces that must bear 2 ½ inches on steel and/or 3 inches on concrete block or masonry brick. Shims or jacks are used to align and level the precast panel.

The Architectural precast sequence runs from west to east of the building. The total amount of precast panels is thirty-three, taking the erecting crew roughly 10 days to erect, making the production roughly three panels per day. Below is a floor plan showing the basic sequencing of the Architectural precast panels.

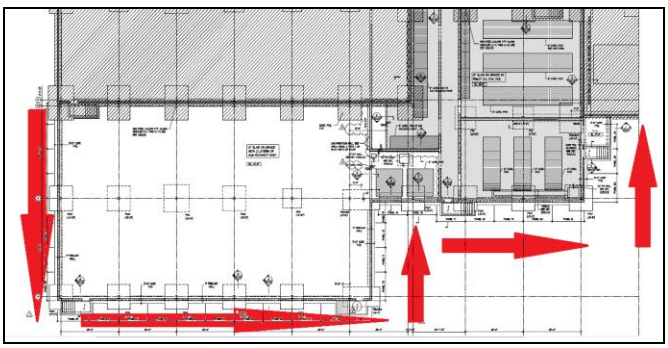


Figure 25 – Sequencing of Precast Panels

Description of Tilt-up Construction/Sequencing:

The method of tilt-up concrete panels has been around 1980's. The process is similar to the precast method, but the pouring takes place onsite. The panels are poured like floor slabs then are tilted in place be a crane. The tilting is done be an outrigger crane with a capacity of at least 1-1/2 times the weight of the panel at the required reach.

Advantages and Disadvantages:

Some advantages of tilt up construction include: low cost, essentially accelerate the schedule, and does not have a limit with respect to panel size. Tilt-up construction is cheaper than precast due to the travel time it takes for precast to arrive onsite. In many cases, Architectural precast fabricators are not locally available; therefore the cost of transporting the panels can be pricy. In addition, tilt-up concrete panels do not have a limit to how large in square-footage the panels must be. RS Means give a suggested 300-500 square foot per panel for optimum production. Precast panels have height restrictions due to highway state laws. Using tilt-up concrete panels may accelerate the schedule; RS Means claims that a four-man setting crew and a crane operator has the ability to set four panels per hour. With precast, there is a consistent lead time for the arrivals of the panels and most likely some delay will occur (i.e. Traffic).

The main disadvantages of tilt-up include the danger associated with the process. The panels weight many tones and is lifted by the crane. Therefore, quality control and safety must be very strict during this process. Another disadvantage to note is the increase of more site congestion. There will be more crews from the concrete trades for the preparation and pouring of the tilt-up concrete panels.

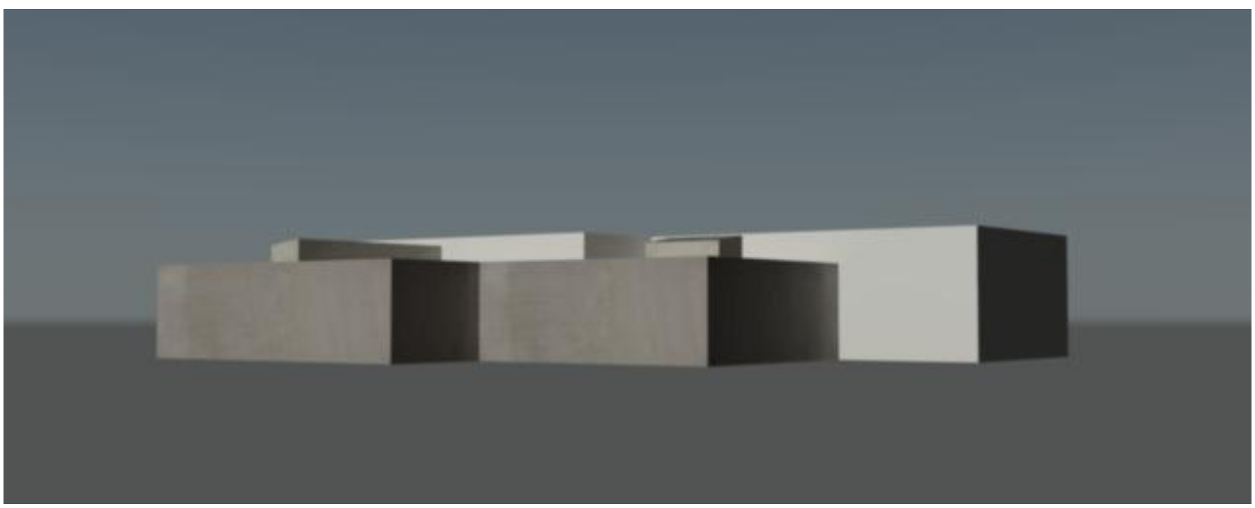
Process/Sequencing:

Tilt-up concrete panels is essentially a three step process. One, preparation of concrete panel forms. Two, pouring/finish the concrete panels. Three, standing the concrete panels into place and brace. The first two steps can be completed early on and stacked on top each other until the panels are ready to be set.

The sequence of tilt-up concrete will be very similar to how Turner's sequenced the precast. The panels are going to be formed and poured on the south side of the site. If the concrete contractors run out of room forming/pouring the panels, they can start forming/pouring on top of other panels.

Façade Redesign (Conceptual):

The Data Center's façade includes a parapet wall that extends up roughly seventeen feet above the roof's elevation. Research suggests that this was done for the sole purpose of hiding the penthouse, generators, and mechanical/electrical equipment located on the roof. The alternate designed includes a deduction of ten feet off the parapet wall. Thus, the parapet wall will only extend seven feet above the roof's elevation. In order to make this design acceptable, the walls of the penthouses must essentially match the exterior concrete panels. In addition, 3D models were created to show camera views of the Data Center from a person's perspective. Below are 3D models from a person's perspective.



3D model – South-East side of the Data Center

The 3D model shows the penthouses are visible. Therefore, a design change will need to be assessed to coordinate similar wall finishes for the tilt-up concrete panels and the penthouse walls from an Architectural standpoint.

Structural Breadth:

In an attempt to redesign the current architectural precast panels, a structural analysis will be performed to determine any size differences. There will be two different types of calculations. One will focus on the columns that are affected by the façade change and the other will focus on the exterior girders.

The calculations are in Appendix K of this report.

To better understand the process of the structural calculations, below is a floor plan of the column/girder numbers that correlate with the structural analysis from Appendix K.

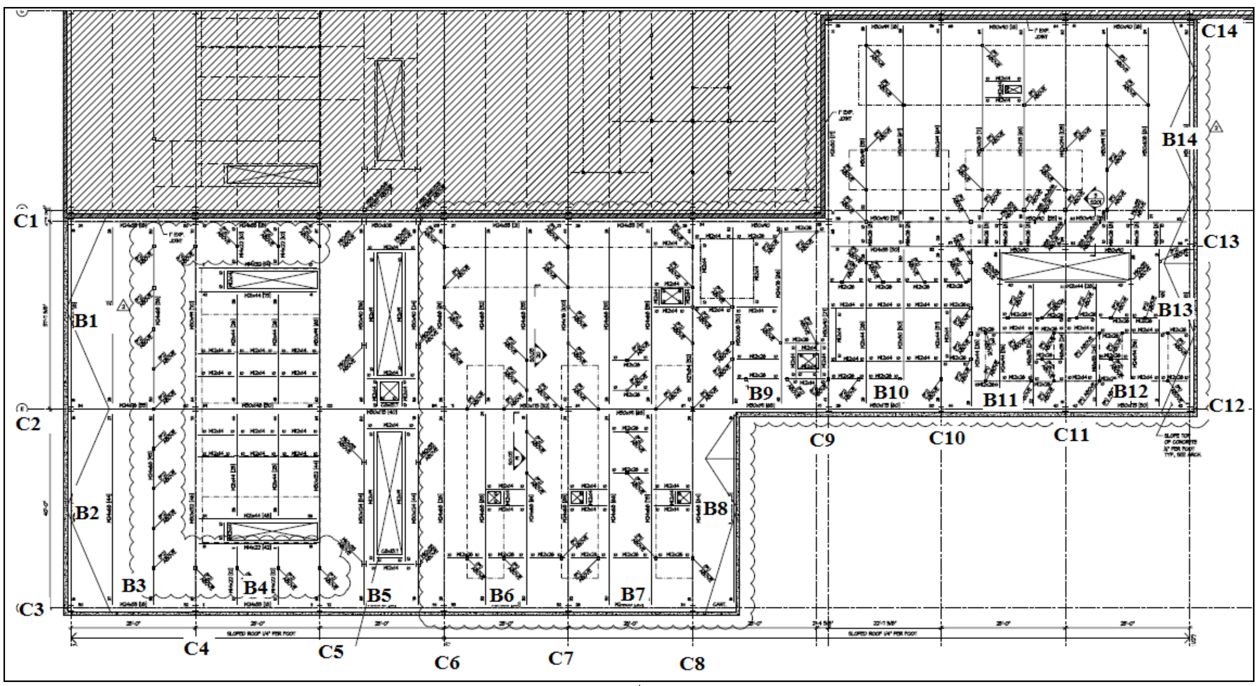


Figure 26– 1st Floor Plan

Without the professional engineer's loads, the calculation for each similar column used assumed loads. The process of this analysis is to determine the column size with the 42 foot parapet wall with the assumed loads, then resizing the column taking 10 feet in height off the parapet wall.

Assumptions:

- Snow Load = 30 psf
- Dead Loads:
  - Concrete Slab = 150 psf
  - Façade = 150 pcf
  - Superimposed Dead Load = 11 psf
  - Beam/Girder Weight = 8 psf
- Live Load = 20 psf*

*This live load was found in the 2006 International Building Code, Section 1602.1

Previous studies suggest that beam/girder weight and superimposed dead load are calculated to be 5 psf and 8 psf. However, for this application is was necessary to increase the value due to the mechanical equipment located on the roof.

Conclusion:

The calculations that were performed determine little change for the exterior columns, beams and girders. Of the fourteen potential columns, only four of them could be changed for a lighter, cheaper column. The weight reduction for the columns was calculated to be 1,196 pounds.

Revised Site Layout Plan:

Since the method to construct the Data Center's façade, it was appropriate to revise the current site plan. The revised site plan will be similar to the current plan. The difference is going to be in the layout spaces of the building. The current site plan is in Appendix B of this report. The revised site plan is in Appendix L.

A few aspects of this site were examined when revising the site. One major aspect was space. Tilt-up panels need an adequate amount of space to form and pour each panel. A great advantage to tilt-up is that the concrete contractor can stake panels on top one another and pick the panels from the stack when need be.

Cost Analysis:

The cost of utilizing tilt up was substantially different. Using tilt-up was estimated to be roughly around $15 per square foot. Precast was estimated to be roughly around $41.5 per square foot. In addition, the redesigning of the façade will be need to be taken in account for shaving 10' off the exterior perimeter of the Data Center. Below in Table 16 is a price comparison of both the systems.

Cost Comparisons					
Method Type	**Cost Per SF**	**Area before Design**	**Cost**	**Area after Redesign**	**Cost**
Precast	41.5	16,197	671,055	12,320	511,280
Tilt-Up	15	16,170	242,550	12,320	184,800

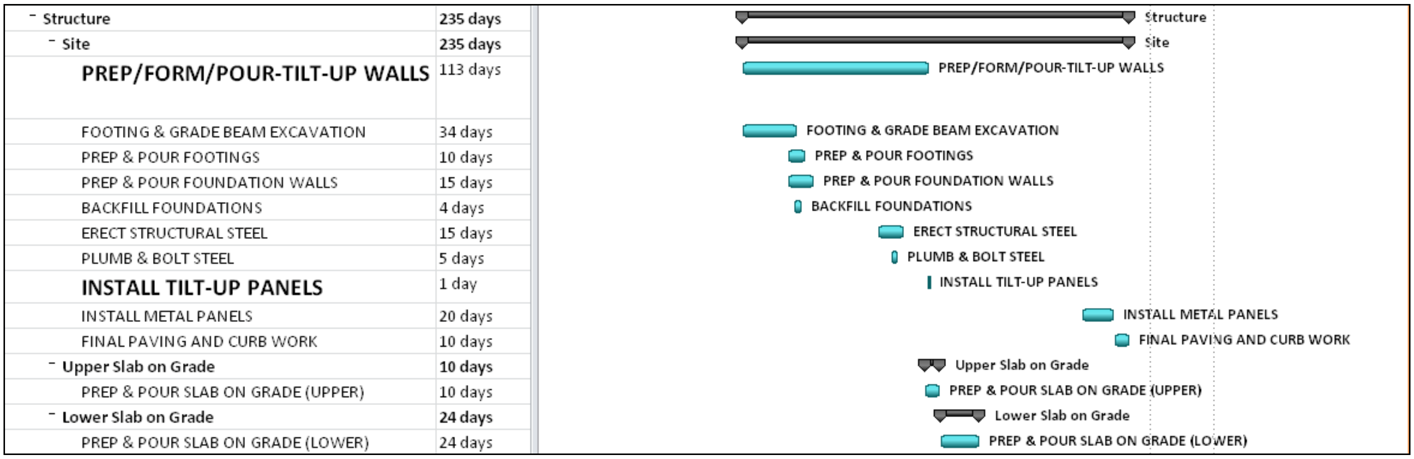
Table 16 – Cost Comparison of the Method

As shown in the table above, utilizing tilt-up concrete panels gave a total savings of $326,480 which is a substantial savings. The total savings of the redesign is roughly $58 thousand.

Schedule Impact:

After reviewing the current detailed schedule, the production of installing precast panels was determined to be 3.3 panels/day. Research suggests by using the tilt-up method, a four-man setting crew can set 4 panels every hour. There are a total of 33 panels. With that being stated, ideally using tilt-up, it would only take roughly a nine hour work day to install all the panels.

Since the concrete trade are first to mobilize to the site, they can start forming and pouring the tilt-up panels. Below shows an adjusted schedule calling out the structural potion.



Structure	235 days
Site	235 days
PREP/FORM/POUR-TILT-UP WALLS	113 days
FOOTING & GRADE BEAM EXCAVATION	34 days
PREP & POUR FOOTINGS	10 days
PREP & POUR FOUNDATION WALLS	15 days
BACKFILL FOUNDATIONS	4 days
ERECT STRUCTURAL STEEL	15 days
PLUMB & BOLT STEEL	5 days
INSTALL TILT-UP PANELS	1 day
INSTALL METAL PANELS	20 days
FINAL PAVING AND CURB WORK	10 days
Upper Slab on Grade	10 days
PREP & POUR SLAB ON GRADE (UPPER)	10 days
Lower Slab on Grade	24 days
PREP & POUR SLAB ON GRADE (LOWER)	24 days

Figure 27 – Adjusted Schedule

The schedule allows for 113 days for preparation of the tilt-up panels which is plenty of time to produce 33 panels.

Conclusions and Recommendations:

Based on the information in this analysis, Utilizing tilt-up as the primary method for erecting the façade is highly recommended. The cost of savings is very substantial, $326,480. In addition, the speed at which the concrete trade is beneficial, 33 panels in a 9 hour work day.

As for the redesigning the façade, the owner definitely look into it. The savings of 184,000 of reducing the parapet wall could go into paying for the PV array system from analysis one. In addition, the current design is losing opportunity to utilize the sun for energy. One drawback to note is the walls of the penthouse can be seen from a distance, therefore, Architectural analysis will need to be done.

Analysis #4 – *Critical Industry Analysis* - Implement Tablet PC's (Commissioning):

Problem Statement:

As mentioned in previous technical reports, the mechanical and electrical systems in the Data Center are highly complex. The owner(s) is a leader in current technology (cannot specify) and should take advantage of the current technology in the construction industry. The commissioning process for the data center is substantial given the size of the expansion.

Proposed Solution:

The proposed solution for this problem is to research the Latista technology during the construction process. The main focus of this analysis is to look into Latista's commissioning benefits. Latista is also a great tool for organization of materials onsite and procurement. This technology was discussed during the 2010 PACE roundtable. More information can be viewed in technical assignment two.

Benefits:

- Benefits of the Tablet PC onsite:
  - Decrease site congestion.
  - Increase efficiency.
  - Benefit the preconstruction/procurement of the project.
  - Material organization onsite.
  - Save costs on drawing documentation.
  - Track down material deliveries for all trades.
- Table PC commissioning benefits:
  - Accelerates the commissioning process.
  - PDF and paper forms can be recreated in LATISTA easily and are easier to manage, organize, and communicate than hardcopies.*
  - Record issues and performance for later reference (including facilities management) and risk management*
  - Improved collaboration between owner representatives and contractors in process and reporting*

Disadvantages:

- Increase in cost upfront
- May be a lack of knowledge from all the trades.
- Current technology may still be working out the defects/"bugs".

Research:

A research study on the knowledge/experience of this tool would need to be conducted to figure out if preliminary classes would need to be held for the project team to learn this tool. Additionally, the upfront costs for the equipment will need to be determined. Collaboration/Interviews with a variety of industry leaders will be conducted to develop a substantial case study of the technology.

Methodology:

- Research Latista – Benefits, Cost, Complexity of technology, etc…
- Determine the upfront cost from manufacture.
- Interview Turner and subcontractors on experience with Latista, develop survey on the knowledge/experience with tablet PC's for commissioning.
- Conduct a case study from other industry leaders that have used Latista for commissioning.
- Summarize whether Latista is a good tool to use for the Data Center and other construction projects.

Academic Tools Used:

- Industry Leaders
- PACE seminar contacts
- AE faculty – Construction
- Colleagues
- Equipment Manufactures
- Turner Construction
- Subcontractors

Expected Outcomes:

The expected outcome from this analysis is to show from the case studies/interviews that Latista is an adequate tool to use for commissioning on highly complex mechanical and electrical systems on a variety of projects. The results will include recommendations/conclusions for the use of this technology for the commissioning process for construction.

Introduction of Tablet PC's (Latista):

Tablet PC's are basically a small portable computer that can run multiple programs on it. The computer runs Microsoft Windows 7, Vista, or XP professional for the operating systems.

The programs that tablet pc's are able to run include:

- Microsoft Office
- QuickBooks
- AutoCAD
- Other scheduling programs

With programs like AutoCAD and Revit that can be run on tablet PC's, this aspect can essentially take over the paper trail in the construction industry and all management tasks on construction sites will be 100 percent technology.

Different types:

There are many different manufactures that produce Tablet PC's. Some to call out include:

- Latista
- Vela
- IBM
- Toshiba
- ACER
- HP

All of these companies produce Tablet PC's but what really sets them apart is that type of model a contractor will use in the field. The three types of models include:

1. Convertible: This type of tablet pc comes with a keyboard attachment and the appearance is that of a laptop. However the screen rotates 180 degrees and lies over the keyboard. Research suggests that using this model type for construction application is not recommended.
2. Slate: This type is very thin and requires no keyboard attachment. This type utilizes a pen for performing anything on the tablet pc. This type is not recommended for the construction application because the tablet is not durable.
3. Rugged: This model is recommended for military and construction uses. This type of tablet is equipped with a tough shock-mounted hard drive. If the tablet is accidently dropped or bumped, the tablet will not be affected.

Uses:

Tablet PC can have many uses in the construction industry. Some applications to note include:

- Quality Control
- Punch list Management
- Production Tracking
- Materials Management
- Safety
- Commissioning
- BIM in the Field
- Visual Reporting

Focus:

The focus of this analysis will be using the Latista PC for the commissioning phase of construction. To see the specifications of the product, refer to Appendix M

Using Latista for the Commissioning Process:

Traditional Method of Commissioning:

The National Institute of Building Sciences explains an efficient plan for performing commissioning on their website. The step-by-step plan includes:

1. Establish Goals for Quality, Efficiency, and Functionality
2. Establish a Commissioning Approach and Scope.
3. **Establish Commissioning Budgets**
4. **Establish Commissioning Plans**
5. **Establish Commissioning Schedules**
6. **Establish Testing and Inspection Plans**
7. **Develop Commissioning Specifications**
8. **Determine Special Testing Needs**

All of these steps are critical during the commissioning phase of any construction project. This process can be overwhelming on projects that have a more intense mechanical/electrical system.

Using Tablet PC for Commissioning:

The process that is stated above still need to be completed by a CM or a third party that specializes in commissioning. The steps that are in bold are an indicator of where using Latista can help the commission process. The next section will provide more detail.

Cost/Schedule Benefits/Savings:

The rough price of a rugged Latista tablet pc is $3,000. The price of the equipment is expensive but with the benefits that the technology brings makes it well worth it.

Latista can bring a vast amount of benefits to the construction process. For commissioning, Latista can bring benefits to the steps that were bolded in the last section. Latista can store pdf and paper forms of the budget, schedule, and specs of the commissioning process. From a managerial standpoint, the pdf and paper form are easier to organize and manage while onsite. Latista has the ability to record the performance of the mechanical system being commissioned. In addition, Latista can record any issues during the commissioning process. With that data being recorded and stored, any future project a construction manager is on can reference his data from previous projects when budgeting, making schedules, etc…

Research was conducted to find an actual value of savings; however, there was no finite price that could be used to calculate the savings. The savings essentially is determined how you use technology. The main focus on savings is to make the commissioning process easier to manage and organized, therefore potential savings will occur through a full collaborative commissioning team.

Challenges:

Many challenges can arise using Tablets in the construction industry. On a physical standpoint, the tablets are exposed to many hazards on the construction jobsites. In addition, extreme weather may affect the life of the tablet. On the commissioning side, this industry is basically founded by the craftsman. The older generation of this industry may not want to utilize this technology because of their alpha male attitude ("my method works best").

Case Study (Maryland General Hospital):

This section provides information on a short case study of Maryland General Hospital. Barton Malow was the acting CM on this project.

Basic Information:

This project is located in Baltimore Maryland. This building is known for being a highly respected teaching hospital. The project is a 57 million dollar, five story expansion to the central core of the building.

Integrating Tablet PC's

Barton Malow uses tablet pc on a majority of MEP related phases. However, this case study is only looking into the commissioning aspect. The renovation includes an array of indoor AHU

650-ton electric chillers/cooling towers. The way Barton Malow used tablet PCs was first taking their 3D MEP model to the field. This helped with determining locations of the MEP systems in the building when commissioning. What really sets this project apart is Barton Mallow utilized the Tablet PCs to be connected to the 3D models and the collected data and documents as one integrated unit. This in turn made a more productive commissioning process and essentially eliminated data re-entry. This managing process makes the commissioning and their BIM model totally in synched with one another. Once the commissioning was complete, Barton Malow handed their tablet PC they used to the facilities management staff to access the database from commissioning.

Recommendations/Conclusions:

After conducting the research, tablet PCs bring a lot of benefits to the construction industry. It is recommended for all construction management firms to learn the product and integrate it into the construction process. From a commissioning standpoint, it is highly recommended to use tablet PCs on projects that have a vast amount of complex MEP systems. Most projects like data centers, hospitals, and power plants would benefit greatly by using tablet PCs for the commissioning process.

References:

Analysis #1:

- FiberLite Roofing Solutions
- RS Means Costworks 2011
- Sanyo Electric
- Sunny Tower
- WBDG – wbdg.org
- NEC – National Electric Code 2009
- Green Building: Project Planning &Cost Estimating

Analysis #2:

- RS Means Electrial Costworks
- RS Means Mechanical Costworks

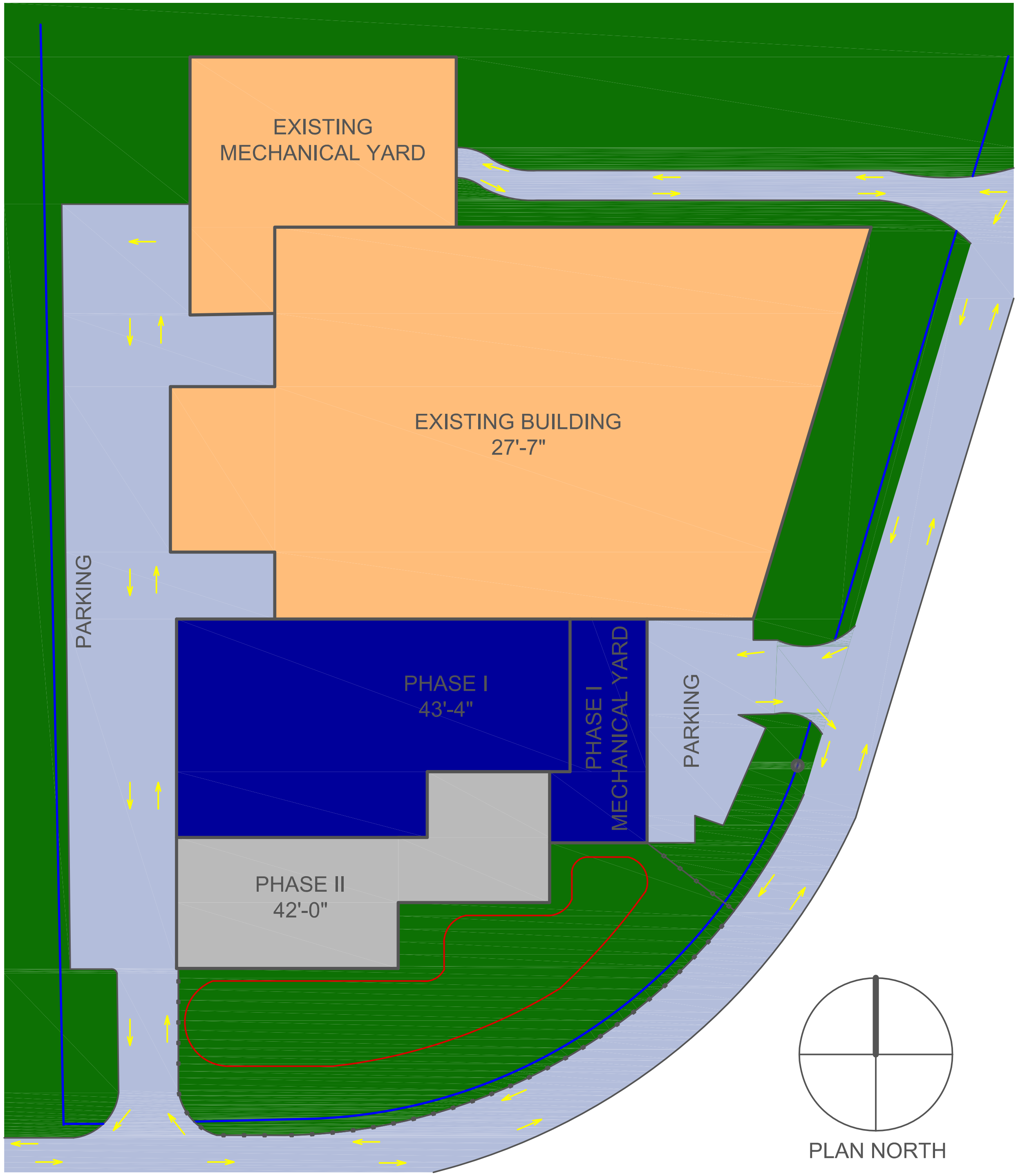
Analysis #3:

- Brian Brunett – AE Student
- RS Means Costworks
- American Institute of Steel Construction Inc.
- Vulcraft Catalog
- International Code Council 2006 - ICC

Analysis #4:

- Latista Technologies
- Vela Technologies
- Tekla.com

Appendix A – Site Plan of Existing Conditions



LEGEND:

EXISTING UTILITIES:

WATER ---------------------------------- EXISTING
GAS ------------------------------------ EXISTING
STORM ---------------------------------- EXISTING
SANITARY-------------------------------- EXISTING
ELECTRIC ------------------------------- EXISTING

SYMBOLS:

FIRE HYDRANT--------------------------
VEHICULAR TRAFFIC---------------------
CONSTRUCTION FENCE--------------------

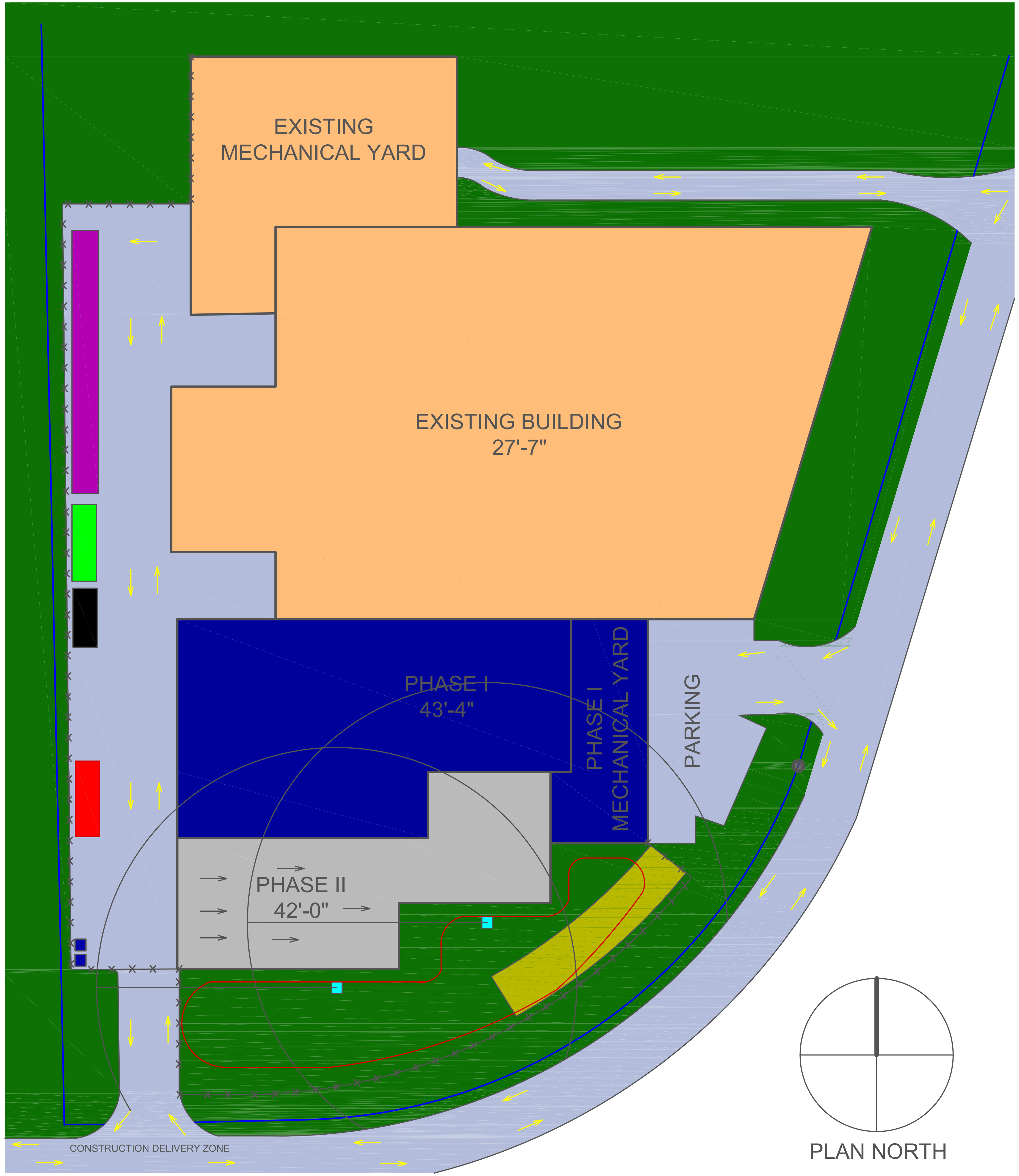
UNKNOWN DATA CENTER

EXISTING CONDITIONS SITE PLAN

OCTOBER 5, 2010

DANIEL SUTER - CM

Appendix B – Site Layout Plan



PLAN NORTH

LEGEND:

SYMBOLS:

- FIRE HYDRANT
- CONSTRUCTION TRAFFIC
- CONSTRUCTION FENCE
- WATER
- GAS — EXISTING
- STORM
- SANITARY — EXISTING
- ELECTRIC — EXISTING
- DUMPSTER AREA
- LAYDOWN AREA
- TRAILER AREA
- TEMP. TOILETS
- CRANE
- STORAGE SHED
- FOREMAN PARKING

UNKNOWN DATA CENTER

SUPERSTRUCTURE PHASE PLAN

OCTOBER 5, 2010

DANIEL SUTER - CM

Appendix C – Detailed Schedule

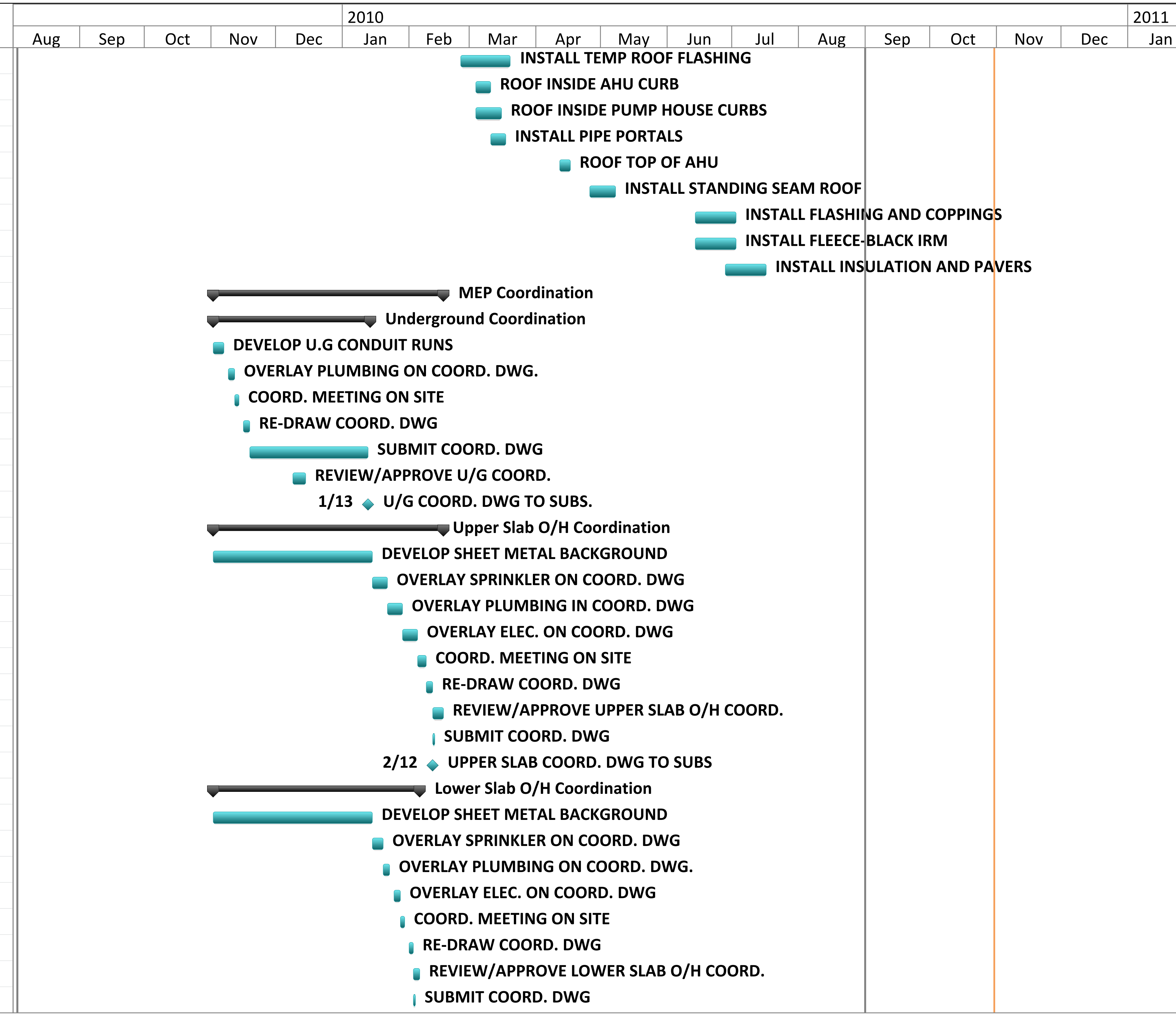
Daniel Suter
Unknown Data Center
Somewhere, USA

ID	Task Name	Duration	Start	Finish
1	CONCEPTUAL DOCUMENTS	0 days	Mon 8/3/09	Mon 8/3/09
2	**Preconstruction/Procurement**	**153 days**	**Wed 9/9/09**	**Fri 4/9/10**
3	BID DOCUMENTS RELEASED	0 days	Tue 9/22/09	Tue 9/22/09
4	REVIEW OF MECH EQUIP	153 days	Wed 9/9/09	Fri 4/9/10
5	AWARD PRIMARY TRADES	2 days	Mon 9/14/09	Tue 9/15/09
6	SUBMITTALS	48 days	Thu 10/1/09	Mon 12/7/09
7	AWARD LATER TRADES	98 days	Fri 10/30/09	Tue 3/16/10
8	FABRICATION	105 days	Mon 11/2/09	Fri 3/26/10
9	**Construction**	**247 days**	**Mon 9/21/09**	**Tue 8/31/10**
10	**Existing Building**	**105 days**	**Mon 12/14/09**	**Fri 5/7/10**
11	SAW CUT SLABS/OPENINGS	25 days	Mon 12/14/09	Fri 1/15/10
12	INSTALL U/G PLBG IN EXISTING BLDG	15 days	Mon 1/25/10	Fri 2/12/10
13	INSTALL U/G IN EXISTING BLDG	15 days	Mon 2/22/10	Fri 3/12/10
14	SHIP AND RECEIVE NEW SWITCH SW-3	22 days	Thu 3/18/10	Fri 4/16/10
15	INSTALL CERAMIC TILE	15 days	Mon 3/22/10	Fri 4/9/10
16	SET FIXTURES IN BATH	10 days	Mon 4/12/10	Fri 4/23/10
17	SET NEW SWITCH IN EXISTING BLDG	5 days	Mon 4/19/10	Fri 4/23/10
18	PULL AND TEREMINATE INTO SWITCH	10 days	Mon 4/26/10	Fri 5/7/10
19	**Structure**	**235 days**	**Mon 9/21/09**	**Fri 8/13/10**
20	**Site**	**235 days**	**Mon 9/21/09**	**Fri 8/13/10**
21	FOOTING & GRADE BEAM EXCAVATION	34 days	Mon 9/21/09	Thu 11/5/09
22	PREP & POUR FOOTINGS	10 days	Fri 10/30/09	Thu 11/12/09
23	PREP & POUR FOUNDATION WALLS	15 days	Fri 10/30/09	Thu 11/19/09
24	BACKFILL FOUNDATIONS	4 days	Wed 11/4/09	Mon 11/9/09
25	ERECT STRUCTURAL STEEL	15 days	Thu 1/14/10	Wed 2/3/10
26	PLUMB & BOLT STEEL	5 days	Mon 1/25/10	Fri 1/29/10
27	INSTALL PRECAST PANELS	10 days	Thu 2/25/10	Wed 3/10/10
28	INSTALL METAL PANELS	20 days	Mon 7/5/10	Fri 7/30/10
29	FINAL PAVING AND CURB WORK	10 days	Mon 8/2/10	Fri 8/13/10
30	**Upper Slab on Grade**	**10 days**	**Mon 2/22/10**	**Fri 3/5/10**
31	PREP & POUR SLAB ON GRADE (UPPER)	10 days	Mon 2/22/10	Fri 3/5/10
32	**Lower Slab on Grade**	**24 days**	**Mon 3/8/10**	**Thu 4/8/10**
33	PREP & POUR SLAB ON GRADE (LOWER)	24 days	Mon 3/8/10	Thu 4/8/10
34	**Roof**	**122 days**	**Thu 1/28/10**	**Fri 7/16/10**
35	LAY METAL DECK & INSTALL STUDS	5 days	Thu 1/28/10	Wed 2/3/10
36	STEEL AND DECK COMPLETE	0 days	Thu 2/4/10	Thu 2/4/10
37	PREP & POUR SLAB	5 days	Thu 2/18/10	Wed 2/24/10

Project: Detailed project schedule
Date: Sun 10/31/10

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

ID	Task Name	Duration	Start	Finish
38	INSTALL TEMP ROOF FLASHING	17 days	Thu 2/25/10	Fri 3/19/10
39	ROOF INSIDE AHU CURB	5 days	Thu 3/4/10	Wed 3/10/10
40	ROOF INSIDE PUMP HOUSE CURBS	8 days	Thu 3/4/10	Mon 3/15/10
41	INSTALL PIPE PORTALS	5 days	Thu 3/11/10	Wed 3/17/10
42	ROOF TOP OF AHU	5 days	Mon 4/12/10	Fri 4/16/10
43	INSTALL STANDING SEAM ROOF	10 days	Mon 4/26/10	Fri 5/7/10
44	INSTALL FLASHING AND COPPINGS	15 days	Mon 6/14/10	Fri 7/2/10
45	INSTALL FLEECE-BLACK IRM	15 days	Mon 6/14/10	Fri 7/2/10
46	INSTALL INSULATION AND PAVERS	15 days	Mon 6/28/10	Fri 7/16/10
47	**MEP Coordination**	**77 days**	**Mon 11/2/09**	**Tue 2/16/10**
48	**Underground Coordination**	**53 days**	**Mon 11/2/09**	**Wed 1/13/10**
49	DEVELOP U.G CONDUIT RUNS	5 days	Mon 11/2/09	Fri 11/6/09
50	OVERLAY PLUMBING ON COORD. DWG.	3 days	Mon 11/9/09	Wed 11/11/09
51	COORD. MEETING ON SITE	2 days	Thu 11/12/09	Fri 11/13/09
52	RE-DRAW COORD. DWG	3 days	Mon 11/16/09	Wed 11/18/09
53	SUBMIT COORD. DWG	39 days	Thu 11/19/09	Tue 1/12/10
54	REVIEW/APPROVE U/G COORD.	4 days	Wed 12/9/09	Mon 12/14/09
55	U/G COORD. DWG TO SUBS.	0 days	Wed 1/13/10	Wed 1/13/10
56	**Upper Slab O/H Coordination**	**77 days**	**Mon 11/2/09**	**Tue 2/16/10**
57	DEVELOP SHEET METAL BACKGROUND	54 days	Mon 11/2/09	Thu 1/14/10
58	OVERLAY SPRINKLER ON COORD. DWG	5 days	Fri 1/15/10	Thu 1/21/10
59	OVERLAY PLUMBING IN COORD. DWG	5 days	Fri 1/22/10	Thu 1/28/10
60	OVERLAY ELEC. ON COORD. DWG	5 days	Fri 1/29/10	Thu 2/4/10
61	COORD. MEETING ON SITE	2 days	Fri 2/5/10	Mon 2/8/10
62	RE-DRAW COORD. DWG	3 days	Tue 2/9/10	Thu 2/11/10
63	REVIEW/APPROVE UPPER SLAB O/H COORD.	3 days	Fri 2/12/10	Tue 2/16/10
64	SUBMIT COORD. DWG	1 day	Fri 2/12/10	Fri 2/12/10
65	UPPER SLAB COORD. DWG TO SUBS	0 days	Fri 2/12/10	Fri 2/12/10
66	**Lower Slab O/H Coordination**	**70 days**	**Mon 11/2/09**	**Fri 2/5/10**
67	DEVELOP SHEET METAL BACKGROUND	54 days	Mon 11/2/09	Thu 1/14/10
68	OVERLAY SPRINKLER ON COORD. DWG	3 days	Fri 1/15/10	Tue 1/19/10
69	OVERLAY PLUMBING ON COORD. DWG.	3 days	Wed 1/20/10	Fri 1/22/10
70	OVERLAY ELEC. ON COORD. DWG	3 days	Mon 1/25/10	Wed 1/27/10
71	COORD. MEETING ON SITE	2 days	Thu 1/28/10	Fri 1/29/10
72	RE-DRAW COORD. DWG	2 days	Mon 2/1/10	Tue 2/2/10
73	REVIEW/APPROVE LOWER SLAB O/H COORD.	3 days	Wed 2/3/10	Fri 2/5/10
74	SUBMIT COORD. DWG	1 day	Wed 2/3/10	Wed 2/3/10



Project: Detailed project schedule
Date: Sun 10/31/10

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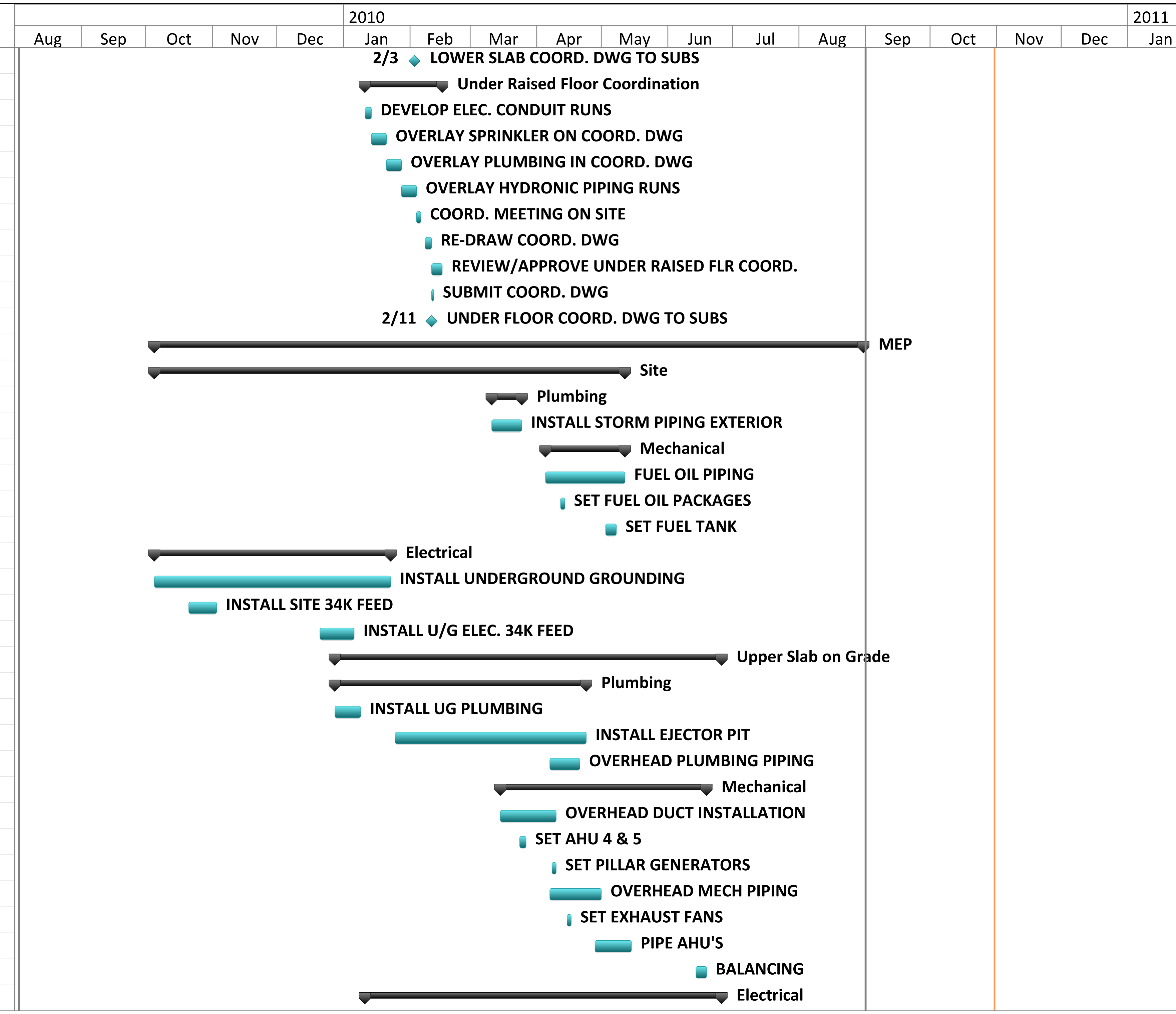
ID	Task Name	Duration	Start	Finish
75	LOWER SLAB COORD. DWG TO SUBS	0 days	Wed 2/3/10	Wed 2/3/10
76	**Under Raised Floor Coordination**	**26 days**	**Mon 1/11/10**	**Mon 2/15/10**
77	DEVELOP ELEC. CONDUIT RUNS	3 days	Mon 1/11/10	Wed 1/13/10
78	OVERLAY SPRINKLER ON COORD. DWG	5 days	Thu 1/14/10	Wed 1/20/10
79	OVERLAY PLUMBING IN COORD. DWG	5 days	Thu 1/21/10	Wed 1/27/10
80	OVERLAY HYDRONIC PIPING RUNS	5 days	Thu 1/28/10	Wed 2/3/10
81	COORD. MEETING ON SITE	2 days	Thu 2/4/10	Fri 2/5/10
82	RE-DRAW COORD. DWG	3 days	Mon 2/8/10	Wed 2/10/10
83	REVIEW/APPROVE UNDER RAISED FLR COORD.	3 days	Thu 2/11/10	Mon 2/15/10
84	SUBMIT COORD. DWG	1 day	Thu 2/11/10	Thu 2/11/10
85	UNDER FLOOR COORD. DWG TO SUBS	0 days	Thu 2/11/10	Thu 2/11/10
86	**MEP**	**236 days**	**Mon 10/5/09**	**Mon 8/30/10**
87	**Site**	**157 days**	**Mon 10/5/09**	**Tue 5/11/10**
88	**Plumbing**	**10 days**	**Thu 3/11/10**	**Wed 3/24/10**
89	INSTALL STORM PIPING EXTERIOR	10 days	Thu 3/11/10	Wed 3/24/10
90	**Mechanical**	**27 days**	**Mon 4/5/10**	**Tue 5/11/10**
91	FUEL OIL PIPING	27 days	Mon 4/5/10	Tue 5/11/10
92	SET FUEL OIL PACKAGES	2 days	Mon 4/12/10	Tue 4/13/10
93	SET FUEL TANK	5 days	Mon 5/3/10	Fri 5/7/10
94	**Electrical**	**80 days**	**Mon 10/5/09**	**Fri 1/22/10**
95	INSTALL UNDERGROUND GROUNDING	80 days	Mon 10/5/09	Fri 1/22/10
96	INSTALL SITE 34K FEED	9 days	Wed 10/21/09	Mon 11/2/09
97	INSTALL U/G ELEC. 34K FEED	12 days	Mon 12/21/09	Tue 1/5/10
98	**Upper Slab on Grade**	**130 days**	**Mon 12/28/09**	**Fri 6/25/10**
99	**Plumbing**	**85 days**	**Mon 12/28/09**	**Fri 4/23/10**
100	INSTALL UG PLUMBING	10 days	Mon 12/28/09	Fri 1/8/10
101	INSTALL EJECTOR PIT	65 days	Mon 1/25/10	Fri 4/23/10
102	OVERHEAD PLUMBING PIPING	10 days	Wed 4/7/10	Tue 4/20/10
103	**Mechanical**	**70 days**	**Mon 3/15/10**	**Fri 6/18/10**
104	OVERHEAD DUCT INSTALLATION	20 days	Mon 3/15/10	Fri 4/9/10
105	SET AHU 4 & 5	3 days	Wed 3/24/10	Fri 3/26/10
106	SET PILLAR GENERATORS	2 days	Thu 4/8/10	Fri 4/9/10
107	OVERHEAD MECH PIPING	18 days	Wed 4/7/10	Fri 4/30/10
108	SET EXHAUST FANS	2 days	Thu 4/15/10	Fri 4/16/10
109	PIPE AHU'S	13 days	Wed 4/28/10	Fri 5/14/10
110	BALANCING	5 days	Mon 6/14/10	Fri 6/18/10
111	**Electrical**	**120 days**	**Mon 1/11/10**	**Fri 6/25/10**



Project: Detailed project schedule
Date: Sun 10/31/10

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

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ID	Task Name	Duration	Start	Finish
112	INSTALL ELEC U/G IN UPPER SOG	25 days	Mon 1/11/10	Fri 2/12/10
113	SET SUBSTATIONS	6 days	Mon 3/8/10	Mon 3/15/10
114	SET UPS SWITCH BOARD	5 days	Mon 3/15/10	Fri 3/19/10
115	INSTALL O/H @ UPPER SLAB	45 days	Mon 3/15/10	Fri 5/14/10
116	SET MATER LOAD CABINETS	5 days	Thu 3/25/10	Wed 3/31/10
117	PULL U/G CABLE	25 days	Mon 3/29/10	Fri 4/30/10
118	SET PILLAR UPS	4 days	Thu 4/1/10	Tue 4/6/10
119	SET PDU (C1, C2, D1, D2)	3 days	Mon 4/12/10	Wed 4/14/10
120	SET PDU (E1, E2)	1 day	Thu 4/15/10	Thu 4/15/10
121	IN WALL ELEC/TELE/SECURITY RGH-IN	15 days	Mon 4/12/10	Fri 4/30/10
122	TERMINATIONS OF ALL U/G CABLE	26 days	Mon 5/3/10	Mon 6/7/10
123	PULL CABLES IN O/H @ UPPER SLAB	20 days	Mon 5/10/10	Fri 6/4/10
124	INSTALL INTERIOR LIGHTING	15 days	Mon 5/17/10	Fri 6/4/10
125	TERMINATIONS AT ELEC EQUIP	10 days	Mon 5/31/10	Fri 6/11/10
126	ENERGIZE MAIN ELEC. GEAR	0 days	Fri 6/11/10	Fri 6/11/10
127	SET ELEC PANELS	10 days	Mon 6/14/10	Fri 6/25/10
128	**Lower Slab on Grade**	**120 days**	**Tue 3/16/10**	**Mon 8/30/10**
129	**Plumbing**	**49 days**	**Tue 3/16/10**	**Fri 5/21/10**
130	INSTALL UNDER RAISED FLOOR PIPING	24 days	Tue 3/16/10	Fri 4/16/10
131	OVERHEAD PLUMBING PIPING @ LOWER SLAB	45 days	Mon 3/22/10	Fri 5/21/10
132	**Mechanical**	**96 days**	**Mon 4/19/10**	**Mon 8/30/10**
133	INSTALL HIGH DENSITY COOLING PIPE	15 days	Mon 4/19/10	Fri 5/7/10
134	O/H DUCTWORK	20 days	Thu 5/20/10	Wed 6/16/10
135	SET HUMIDIFIERS	5 days	Tue 7/6/10	Mon 7/12/10
136	SET /PIPE HUMIDIFIERS	15 days	Tue 7/13/10	Mon 8/2/10
137	BALANCING	5 days	Tue 8/24/10	Mon 8/30/10
138	**Electrical**	**97 days**	**Fri 4/9/10**	**Mon 8/23/10**
139	INSTALL O/H CONDUITS	16 days	Fri 4/9/10	Fri 4/30/10
140	INSTALL UNDERFLOOR CONDUITS TO RPP'S	20 days	Mon 4/12/10	Fri 5/7/10
141	PULL CABLES TO RPP'S	15 days	Mon 5/10/10	Fri 5/28/10
142	INSTALL UNISTRUT GRID	2 days	Thu 5/27/10	Fri 5/28/10
143	SET RPP'S	15 days	Tue 7/6/10	Mon 7/26/10
144	INSTALL INTERIOR LIGHTING	20 days	Tue 7/27/10	Mon 8/23/10
145	TERMINATE RPP'S	10 days	Tue 7/27/10	Mon 8/9/10
146	LOAD BANK RPP'S	10 days	Fri 8/6/10	Thu 8/19/10
147	**Roof**	**97 days**	**Thu 2/4/10**	**Fri 6/18/10**
148	**Plumbing**	**48 days**	**Thu 2/4/10**	**Mon 4/12/10**

Project: Detailed project schedule
Date: Sun 10/31/10

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

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ID	Task Name	Duration	Start	Finish
149	SET ROOF DRAINS W/ PIPING	48 days	Thu 2/4/10	Mon 4/12/10
150	**Mechanical**	**82 days**	**Thu 2/25/10**	**Fri 6/18/10**
151	SET PIPE SUPPORT STANDS	6 days	Thu 2/25/10	Thu 3/4/10
152	SET ROOF CURBS FOR AHU	5 days	Thu 2/25/10	Wed 3/3/10
153	INSTALL ROOF TOP PIPING TO EQUIP	51 days	Fri 3/5/10	Fri 5/14/10
154	SET CHILLERS	2 days	Thu 3/11/10	Fri 3/12/10
155	SET AHU 3A & 3B	3 days	Thu 3/11/10	Mon 3/15/10
156	SET DRY COOLERS 7 & 8	2 days	Fri 3/19/10	Mon 3/22/10
157	SET DRY COOLERS 4, 5 & 6	2 days	Fri 3/19/10	Mon 3/22/10
158	SET PUMP PACKAGE #3	1 day	Wed 3/24/10	Wed 3/24/10
159	SET PUMP PACKAGE #2	1 day	Wed 3/24/10	Wed 3/24/10
160	SET PILLAR RADIATORS	2 days	Tue 3/23/10	Wed 3/24/10
161	INSTALL FUEL PIPING	10 days	Mon 4/12/10	Fri 4/23/10
162	TEST FUEL PIPING	2 days	Wed 5/12/10	Thu 5/13/10
163	START UP ROOF TOP EQUIP	5 days	Mon 6/14/10	Fri 6/18/10
164	**Electrical**	**97 days**	**Thu 2/4/10**	**Fri 6/18/10**
165	FIRE ALARM ROUGH IN SOG	10 days	Thu 2/4/10	Wed 2/17/10
166	INSTALL CONDUIT @ ROOF	41 days	Fri 3/5/10	Fri 4/30/10
167	SET ROOF TOP GENERATOR	2 days	Mon 3/8/10	Tue 3/9/10
168	PULL ROOF CABLES	15 days	Mon 5/3/10	Fri 5/21/10
169	TERMINATIONS AT ROOF HVAC EQUIP	10 days	Mon 5/24/10	Fri 6/4/10
170	INSTALL ROOF TOP LIGHTING	20 days	Mon 5/24/10	Fri 6/18/10
171	**Finishes**	**140 days**	**Tue 2/16/10**	**Mon 8/30/10**
172	**Site**	**75 days**	**Mon 3/29/10**	**Sat 7/10/10**
173	PAINT EXTERIOR	60 days	Mon 3/29/10	Fri 6/18/10
174	INSTALL PUNCH WINDOWS	10 days	Mon 4/5/10	Fri 4/16/10
175	INSTALL LOUVERS	3 days	Mon 5/3/10	Wed 5/5/10
176	SET HURICANE DOORS	16 days	Mon 6/21/10	Sat 7/10/10
177	**Upper Slab on Grade**	**95 days**	**Mon 3/15/10**	**Fri 7/23/10**
178	OVERHEAD SPRINKLER PIPING	21 days	Mon 3/15/10	Mon 4/12/10
179	SET HOLLOW METAL FRAMES	11 days	Fri 4/9/10	Fri 4/23/10
180	INSTALL SPRINKLER DROPS	8 days	Mon 4/12/10	Wed 4/21/10
181	INSTALL OVERHEAD DOOR	3 days	Mon 4/19/10	Wed 4/21/10
182	TIE SPRINKLERS INTO EXISTING	3 days	Thu 4/22/10	Mon 4/26/10
183	INSTALL SPRINKLER TRIMS	5 days	Thu 4/22/10	Wed 4/28/10
184	INSTALL EPOXY FLOORING	5 days	Tue 6/1/10	Mon 6/7/10
185	INSTALL RESILIENT FLOORING	3 days	Mon 6/7/10	Wed 6/9/10

Project: Detailed project schedule
Date: Sun 10/31/10

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

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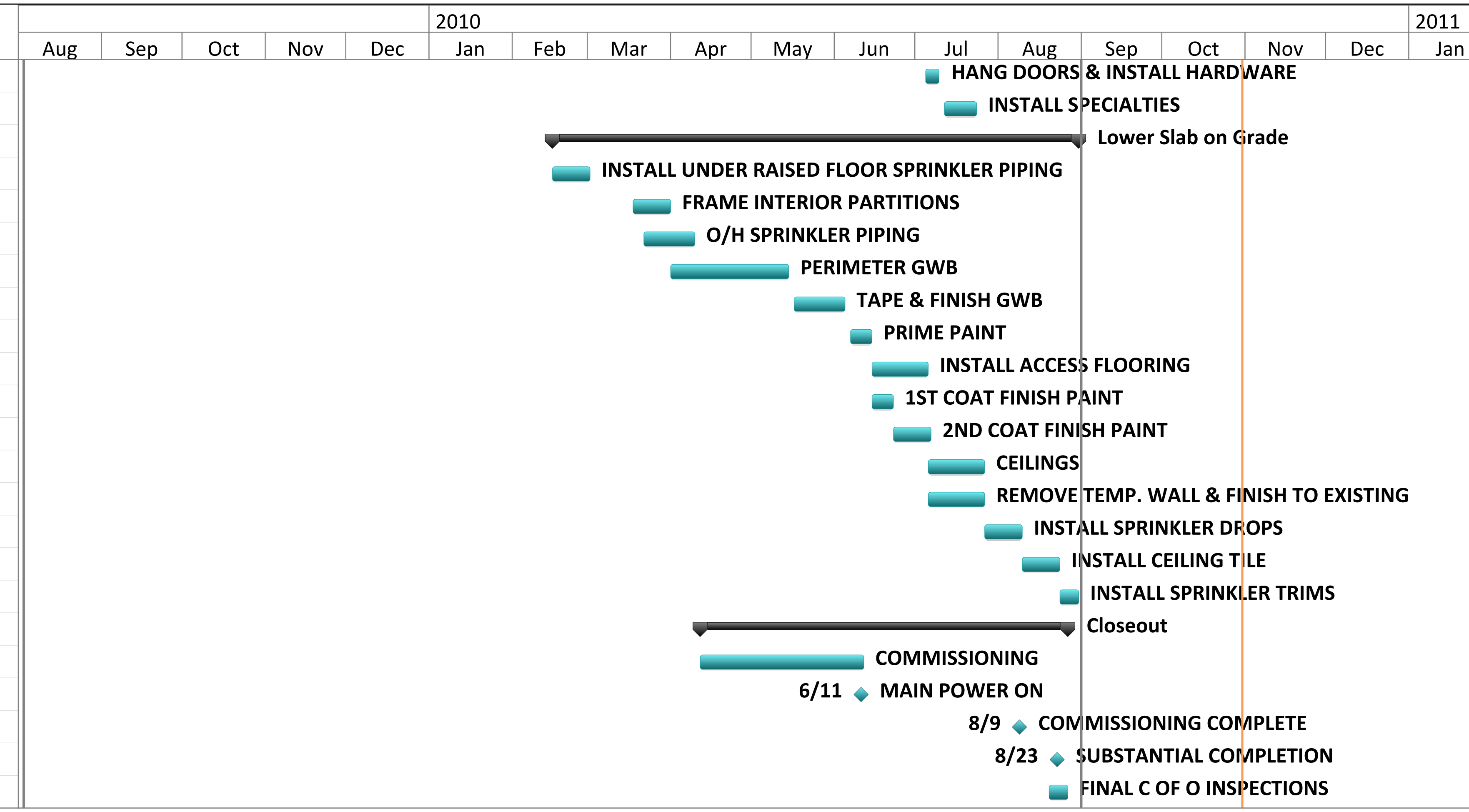
ID	Task Name	Duration	Start	Finish
186	HANG DOORS & INSTALL HARDWARE	5 days	Mon 7/5/10	Fri 7/9/10
187	INSTALL SPECIALTIES	10 days	Mon 7/12/10	Fri 7/23/10
188	**Lower Slab on Grade**	**140 days**	**Tue 2/16/10**	**Mon 8/30/10**
189	INSTALL UNDER RAISED FLOOR SPRINKLER PIPING	10 days	Tue 2/16/10	Mon 3/1/10
190	FRAME INTERIOR PARTITIONS	10 days	Thu 3/18/10	Wed 3/31/10
191	O/H SPRINKLER PIPING	15 days	Mon 3/22/10	Fri 4/9/10
192	PERIMETER GWB	32 days	Thu 4/1/10	Fri 5/14/10
193	TAPE & FINISH GWB	15 days	Mon 5/17/10	Fri 6/4/10
194	PRIME PAINT	6 days	Mon 6/7/10	Mon 6/14/10
195	INSTALL ACCESS FLOORING	15 days	Tue 6/15/10	Mon 7/5/10
196	1ST COAT FINISH PAINT	6 days	Tue 6/15/10	Tue 6/22/10
197	2ND COAT FINISH PAINT	10 days	Wed 6/23/10	Tue 7/6/10
198	CEILINGS	15 days	Tue 7/6/10	Mon 7/26/10
199	REMOVE TEMP. WALL & FINISH TO EXISTING	15 days	Tue 7/6/10	Mon 7/26/10
200	INSTALL SPRINKLER DROPS	10 days	Tue 7/27/10	Mon 8/9/10
201	INSTALL CEILING TILE	10 days	Tue 8/10/10	Mon 8/23/10
202	INSTALL SPRINKLER TRIMS	5 days	Tue 8/24/10	Mon 8/30/10
203	**Closeout**	**99 days**	**Mon 4/12/10**	**Thu 8/26/10**
204	COMMISSIONING	45 days	Mon 4/12/10	Fri 6/11/10
205	MAIN POWER ON	0 days	Fri 6/11/10	Fri 6/11/10
206	COMMISSIONING COMPLETE	0 days	Mon 8/9/10	Mon 8/9/10
207	SUBSTANTIAL COMPLETION	0 days	Mon 8/23/10	Mon 8/23/10
208	FINAL C OF O INSPECTIONS	5 days	Fri 8/20/10	Thu 8/26/10



Project: Detailed project schedule
Date: Sun 10/31/10

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

Appendix D – D4 Project Cost Estimate

Appendix C.1 – D4 Cost Summary:

Div.#	Division/Subdivision	Base Cost	%	Sq. Cost	Projected
00	Procurement and Contracting Require	63,379	4.99	5.47	109,358
01	General Requirements	165,036	12.98	14.24	284,765
03	Concrete	310,448	24.43	26.78	535,667
04	Masonry	13,611	1.07	1.17	23,485
05	Metals	65,400	5.15	5.64	112,845
06	Wood, Plastics, and Composites	5,950	0.47	0.51	10,266
07	Thermal and Moisture Protection	30,402	2.39	2.62	52,457
08	Openings	62,684	4.93	5.41	108,158
09	Finishes	50,476	3.97	4.35	87,095
10	Specialties	1,611	0.13	0.14	2,780
11	Equipment	52	0.00	0.00	89
12	Furnishings	36,676	2.89	3.16	63,284
14	Conveying Systems	24,028	1.89	2.07	41,459
21	Fire Suppression	9,640	0.76	0.83	16,633
22	Plumbing	34,535	2.72	2.98	59,590
23	HVAC	166,263	13.08	14.34	286,882
26	Electrical	230,834	18.16	19.91	398,295
	Total Building Cost	1,271,024	100.00	109.66	2,193,108
	Total Project Cost	3,231,352			5,575,588

Appendix E – Detailed Structural Esimate

Structural Steel Estimate Take-off Chart

Beams:

ID	Type:	Unit:	Quantity:	Length (LF):
Roof	W24X55	LF	10	223
Roof	W30X108	LF	6	204
Roof	W30X90	LF	13	361.5
Roof	W21X50	LF	5	177
Roof	W30X99	LF	6	199
Roof	W30X173	LF	6	157
Roof	W30X191	LF	2	52.5
Roof	W14X22	LF	6	98
Roof	W21X44	LF	12	273
Roof	W12X14	LF	53	424
Roof	W30X148	LF	1	25
Roof	W12X26	LF	41	292
Roof	W24X68	LF	16	616
Roof	W30X132	LF	2	80
Roof	W40X249	LF	2	68
Roof	W16X26	LF	8	32
Roof	W18X40	LF	1	37
Roof	W18X35	LF	3	97
Roof	W12X19	LF	6	96
Roof	W30X124	LF	2	80
Roof	W24X76	LF	3	99
Roof	W27X84	LF	2	74
MEP	W8X18	LF	4	20
MEP	W24X55	LF	12	270
MEP	W12X14	LF	42	360
MEP	W12X26	LF	19	297
MEP	W14X38	LF	8	142
MEP	W14X43	LF	6	36
MEP	W18X50	LF	2	56
MEP	W18X86	LF	1	21
MEP	W18X130	LF	1	29
MEP	W24X76	LF	8	164
MEP	W12X16	LF	23	266
		Total:	332	

Columns:

ID	Type:	Unit:	Quantity:	Length (LF):
Roof	W12X50	LF	23	989
Roof	W12X87	LF	8	344
MEP	W10X45	LF	13	130
MEP	HSS 8"X4"	EA	3	

		Total:	47	

Metal Deck:

ID	Type:	Unit:	Area (SF):	Total:
Roof	1-1/2" 16 GA	SF	17,445	17,895
MEP	1-1/2" 16 GA	SF	450	

Shear Studs:

ID	Type:	Unit:	Quantity:	Total:
Roof	4" Shear Studs	EA	3,896	4,040
MEP	4" Shear Studs	EA	144	

Cast in Place Concrete Estimate Take-off Chart

Slab on Grade

Type:	Area (SF):	Thickness (ft)	Concrete (CY):	Rebar Type	Rebar Quantity	Rebar Total Weight (Lbs)
6" NW	10,800	0.500	200	(2) WWF*	21,600 SF	N/A
8" NW	6,645	0.670	164.80	#5	90@ 71' **	6709.5
		Totals:	365	216 - Total C.S.F		6709.5

Slab on Deck

Type:	Area (SF):	Thickness (ft)	Concrete (CY):	Rebar Type	C.S.F	TOTAL C.S.F:
6" LW	17,445	0.5	324	WWF***	174.45	178.95
5" LW	450	0.4	324	WWF***	4.5	

Footings

Length (FT)	Width (FT)	Depth (FT)	Quantity	Rebar Type	Rebar Quantity	Rebar Weight (Ib/FT)	Concrete (CY)	Rebar Total Weight (Lbs)
8	8	1.83	1	#6	18	1.5	4.34	216
9	9	2.08	1	#6	22	1.5	6.24	297
10	10	2.17	12	#8	192	2.67	96.44	5126.4
11	11	2.42	1	#8	20	2.67	10.85	587.4
12	10	2.33	1	#8	21	2.67	10.36	608.8
16	8	2.5	2	#8/#5	8.0/8.0	2.67/1.05	23.7	683.52/134.4
						Totals #4-#7:	151.93	647.4
						Totals #8-#18:	N/A	6322.6

Isolation Pads

Length (FT)	Width (FT)	Height (FT)	Quantity	Rebar Type	Rebar Quantity	Concrete (CY)	Total C.S.F
33	6	0.5	3	N/A	N/A	11	N/A
18	6	0.5	3	N/A	N/A	6	N/A
10	9	0.5	2	N/A	N/A	3.33	N/A
18	4	0.5	1	WWF***	72 SF	1.33	0.72
38	5	0.5	1	WWF***	190 SF	3.52	1.9
					Totals:	25.18	2.62

Isolation Pads - Formwork Take-off

Length (FT)	Width (FT)	Height (FT)	Quantity	Units	Total
33	6	0.5	3	SFCA	117
18	6	0.5	3	SFCA	72
10	9	0.5	2	SFCA	38
18	4	0.5	1	SFCA	22
38	5	0.5	1	SFCA	43
				Total:	292

Detailed Stuctural Steel Estimate Pricing

Description	Quanitity	Unit	Bare Material	Bare Labor	Bare Equipment	Bare Total	Total O & P	Total Cost
Columns								
Roof - W12X50	989	LF	$ 60.50	$ 2.27	1.52	$ 64.29	$ 72.09	$ 71,297.01
Roof - W12X87	344	LF	$ 105.00	$ 2.38	1.59	$ 108.97	$ 121.86	$ 41,919.84
MEP - W10X45	130	LF	$ 54.50	$ 2.27	1.52	$ 58.29	$ 65.59	$ 8,526.70
MEP - HSS 8"X4" - 14'	3	EA	$ 400.00	$ 43.50	29.00	$ 472.00	$ 547.00	$ 1,641.00
							TOTAL:	$ 123,384.55
Beams								
Roof - W24X55	223	LF	$ 66.50	$ 3.33	$ 1.58	$ 71.41	$ 80.44	$ 17,938.12
Roof - W30X108	204	LF	$ 131.00	$ 3.08	$ 1.46	$ 135.54	$ 150.86	$ 30,775.44
Roof - W30X90	361.5	LF	$ 120.00	$ 3.08	$ 1.46	$ 124.54	$ 138.86	$ 50,197.89
Roof - W21X50	177	LF	$ 60.50	$ 3.47	$ 1.65	$ 65.62	$ 74.26	$ 13,144.02
Roof - W30X99	199	LF	$ 120.00	$ 3.08	$ 1.46	$ 124.54	$ 138.86	$ 27,633.14
Roof - W30X173	157	LF	$ 209.00	$ 3.30	$ 1.57	$ 213.87	$ 237.37	$ 37,267.09
Roof - W30X191	52.5	LF	$ 231.00	$ 3.30	$ 1.57	$ 235.87	$ 261.37	$ 13,721.93
Roof - W14X22	98	LF	$ 43.00	$ 2.46	$ 1.76	$ 47.22	$ 53.14	$ 5,207.72
Roof - W21X44	273	LF	$ 53.00	$ 3.47	$ 1.65	$ 58.12	$ 66.26	$ 18,088.98
Roof - W12X14	424	LF	$ 43.00	$ 2.77	$ 1.98	$ 47.75	$ 53.92	$ 22,862.08
Roof - W30X148	25	LF	$ 179.00	$ 3.19	$ 1.51	$ 183.70	$ 204.11	$ 5,102.75
Roof - W12X26	292	LF	$ 31.50	$ 2.90	$ 1.83	$ 36.23	$ 41.42	$ 12,094.64
Roof - W24X68	616	LF	$ 82.50	$ 3.33	$ 1.58	$ 87.41	$ 97.94	$ 60,331.04
Roof - W30X132	80	LF	$ 160.00	$ 3.19	$ 1.51	$ 164.70	$ 183.11	$ 14,648.80
Roof - W40X249	68	LF	$ 365.00	$ 3.57	$ 1.69	$ 370.26	$ 407.96	$ 27,741.28
Roof - W16X26	32	LF	$ 31.50	$ 2.55	$ 1.61	$ 35.66	$ 40.59	$ 1,298.88
Roof - W18X40	37	LF	$ 48.50	$ 3.85	$ 1.83	$ 54.18	$ 61.61	$ 2,279.57
Roof - W18X35	97	LF	$ 42.53	$ 3.85	$ 1.83	$ 48.18	$ 55.11	$ 5,345.67
Roof - W12X19	96	LF	$ 31.50	$ 2.90	$ 1.83	$ 36.23	$ 41.42	$ 3,976.32
Roof - W30X124	80	LF	$ 160.00	$ 3.19	$ 1.51	$ 164.70	$ 183.11	$ 14,648.80
Roof - W24X76	99	LF	$ 92.00	$ 3.33	$ 1.58	$ 96.91	$ 108.44	$ 10,735.56
Roof - W27X84	74	LF	$ 102.00	$ 3.11	$ 1.47	$ 106.58	$ 118.92	$ 8,800.08
MEP -W8X18	20	LF	$ 25.50	$ 3.91	$ 2.61	$ 32.02	$ 37.62	$ 752.40
MEP -W24X55	270	LF	$ 66.50	$ 3.06	$ 1.53	$ 71.09	$ 80.03	$ 21,608.10
MEP -W12X14	360	LF	$ 16.95	$ 2.66	$ 1.78	$ 21.39	$ 25.21	$ 9,075.60
MEP -W12X26	297	LF	$ 31.50	$ 2.66	$ 1.78	$ 35.94	$ 41.06	$ 12,194.82
MEP -W14X38	142	LF	$ 52.00	$ 2.89	$ 1.93	$ 56.82	$ 64.13	$ 9,106.46
MEP -W14X43	36	LF	$ 52.00	$ 2.89	$ 1.93	$ 56.82	$ 64.13	$ 2,308.68

MEP -W18X50	56	LF	$ 60.50	$ 3.72	$ 1.86	$ 66.08	$ 75.05	$ 4,202.80
MEP -W18X86	21	LF	$ 104.00	$ 3.77	$ 1.89	$ 109.66	$ 122.68	$ 2,576.28
MEP -W18X130	29	LF	$ 128.00	$ 3.77	$ 1.89	$ 133.66	$ 149.68	$ 4,340.72
MEP -W24X76	164	LF	$ 92.00	$ 3.06	$ 1.53	$ 96.59	$ 108.03	$ 17,716.92
MEP -W12X16	266	LF	$ 26.50	$ 3.91	$ 2.61	$ 33.02	$ 39.12	$ 10,405.92
							TOTAL:	$ 621,513.05
Metal Deck								
Roof - 1 1/2" 16 GA	17,445	SF	$ 1.41	$ 0.35	0.03	$ 1.79	$ 2.21	$ 38,553.45
MEP - 1 1/2" 16 GA	690	SF	$ 1.41	$ 0.35	0.03	$ 1.79	$ 2.21	$ 1,524.90
							TOTAL:	$ 40,078.35
Shear Studs								
Roof - 4" Shear Studs	3,896	EA	$ 0.70	$ 0.81	0.39	$ 1.90	$ 2.19	$ 8,532.24
MEP - 4" Shear Studs	144	EA	$ 0.70	$ 0.81	0.39	$ 1.90	$ 2.19	$ 315.36
							TOTAL:	$ 8,847.60
							TOTAL ESTIMATE:	$ 793,823.55

Cast in Place Concrete Estimate Pricing Chart								
Description	**Quanitity**	**Unit**	**Bare Material**	**Bare Labor**	**Bare Equipment**	**Bare Total**	**Total O & P**	**Total Cost**
Rebar								
Footings - #4 - #7	1	Tons	$ 890.00	$ 655.00	-	$ 1,545.00	$ 2,050.00	$ 2,050.00
Footings - #8 - #18	3	Tons	$ 840.00	$ 380.00	-	$ 1,220.00	$ 1,550.00	$ 4,650.00
Slab on Grade	4	Tons	$ 890.00	$ 655.00	-	$ 1,545.00	$ 2,050.00	$ 8,200.00
Slab on Grade - WWF	216	C.S.F	$ 20.00	$ 23.50	-	$ 43.50	$ 61.00	$ 13,176.00
Isolation Pads	2.62	C.S.F	$ 29.00	$ 25.50	-	$ 54.50	$ 74.00	$ 193.88
Roof - Slab on Deck	174	C.S.F	$ 29.00	$ 25.50	-	$ 54.50	$ 74.00	$ 12,909.30
MEP - Slab on Deck	5	C.S.F	$ 20.00	$ 23.50	-	$ 43.50	$ 61.00	$ 274.50
							TOTAL:	$ 41,453.68
Concrete								
Footings	151.93	CY	$ 109.00	$ 13.00	$ 4.86	$ 17.86	$ 145.35	$ 22,083.03
Slab on Grade	365	CY	$ 109.00	$ 13.00	$ 4.86	$ 17.86	$ 145.35	$ 53,052.75
Isolation Pads	25.18	CY	$ 109.00	$ 13.00	$ 4.86	$ 17.86	$ 145.35	$ 3,659.91
Roof - Slab on Deck	324	CY	$ 153.00	$ 13.00	$ 4.86	$ 17.86	$ 178.35	$ 57,785.40
MEP - Slab on Deck	7	CY	$ 153.00	$ 13.00	$ 4.86	$ 17.86	$ 178.35	$ 1,248.45
							TOTAL:	$ 137,829.54
Formwork								
Isolation Pads	292	SFCA	$ 2.32	$ 5.40	-	$ 7.72	$ 10.90	$ 3,182.80
							TOTAL:	$ 3,182.80
							TOTAL ESTIMATE:	$ 182,466.02

Appendix F – General Condition Estimate

General Conditions Estimate

Supervision and Personnel

Item	Unit Rate	Unit	Quantity:	Cost
Project Executive	$ 1,600.00	Week	42	$ 67,200.00
MEP Project Manager	$ 2,100.00	Week	42	$ 88,200.00
Lead Project Manager	$ 2,100.00	Week	42	$ 88,200.00
MEP Superintendent	$ 1,950.00	Week	42	$ 81,900.00
General Superintendent	$ 1,950.00	Week	42	$ 81,900.00
Assistant Superintendent	$ 1,550.00	Week	42	$ 65,100.00
Assistant Engineer	$ 1,550.00	Week	42	$ 65,100.00
General Laborer	$ 1,200.00	Week	42	$ 50,400.00
Secretary	$ 365.00	Week	42	$ 15,330.00
			Sub-Total:	$ 603,330.00

Construction Facilities and Equipment

Field Office Trailer Set-up	$ 2,000.00	EA	1	$ 2,000.00
Field Office Trailer Rental	$ 1,000.00	Months	11	$ 11,000.00
Field Office Trailer Removal	$ 2,500.00	EA	1	$ 2,500.00
Construction Site Fence	$ 600.00	Months	11	$ 6,600.00
Storage Trailer	$ 150.00	Months	11	$ 1,650.00
Survey/Layout Equipment	$ 200.00	Months	2	$ 400.00
Gang Box	$ 55.00	Months	11	$ 605.00
Tools/Equipment	$ 650.00	Months	9	$ 5,850.00
Fire Extinguishers	$ 75.00	EA	10	$ 750.00
Computer/LAN Equipment	$ 2,500.00	Months	11	$ 27,500.00
Mobile Phones	$ 100.00	Months	11	$ 1,100.00
PPE	$ 100.00	Months	10	$ 1,000.00
Signage	$ 10.00	EA	50	$ 500.00
Dumpsters	$ 175.00	Months	10	$ 1,750.00
			Sub-Total:	$ 38,450.00

Temporary Utilities

Field Telephone Service	$ 100.00	Months	11	$ 1,100.00
Temp. Power Consumption	$ 12,000.00	Months	10	$ 120,000.00
Temp. Water Hook Up	$ 1,000.00	EA	1	$ 1,000.00
Temp. Water	$ 2,100.00	Months	10	$ 21,000.00
Temp. Lighting	$ 1,000.00	Months	10	$ 10,000.00
Portable Toilts	$ 350.00	Months	11	$ 3,850.00
			Sub-Total:	$ 153,100.00

Miscellaneous Costs

Clean-up Expenses	$ 490.00	Week	36	$ 17,640.00
Misc. Field Expenses	$ 1,000.00	Months	10	$ 10,000.00
			Sub-Total:	$ 27,640.00

Insurance and Bonds

Item	% of Contract	Building Cost	Cost
Bonds	1.00%	$ 33,000,000.00	$ 330,000.00
Permits	1.00%	$ 33,000,000.00	$ 330,000.00
Insurance	0.55%	$ 33,000,000.00	$ 181,500.00
		Sub-Total:	$ 841,500.00
		Total:	$ 1,671,720.00

Appendix G – PV Panel Specifications

Think GAIA
For Life and the Earth

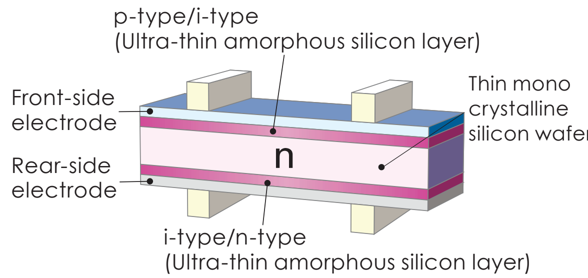
SANYO

HIT Photovoltaic Module

HIT Power 200
Photovoltaic Module

Module Efficiency: 17.2%
Cell Efficiency: 19.7%
Power Output: 200 Watts

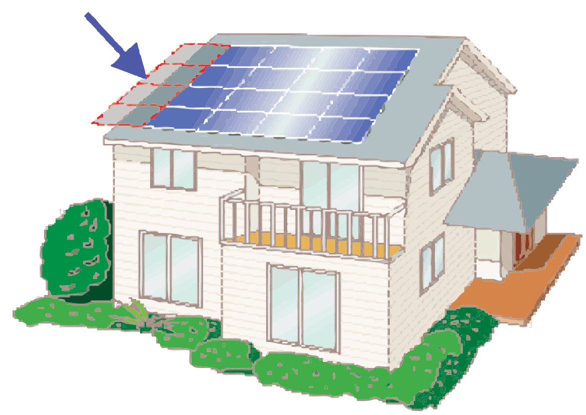
SANYO HIT® Solar Cell Structure



High Efficiency

HIT® Power solar panels are leaders in sunlight conversion efficiency. Obtain maximum power within a fixed amount of space. Save money using fewer system attachments and racking materials, and reduce costs by spending less time installing per watt.

Unnecessary Section When Using SANYO



Power Guarantee

SANYO's power ratings for HIT Power panels guarantee customers receive 100% of the nameplate rated power (or more) at the time of purchase, enabling owners to generate more kWh per rated watt, quicken investment returns, and help realize complete customer satisfaction.

Temperature Performance

As temperatures rise, HIT Power solar panels produce 10% or more electricity (kWh) than conventional crystalline silicon solar panels at the same temperature.

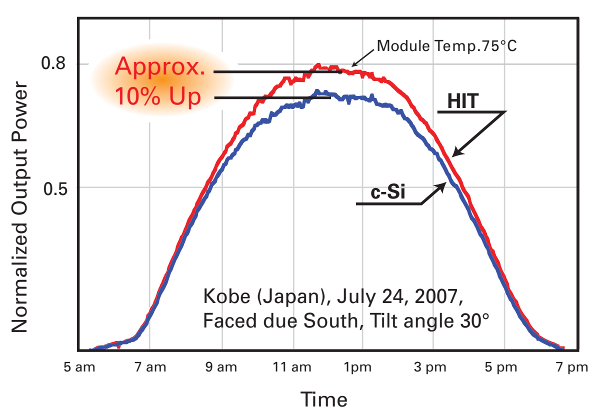
Proprietary Technology

HIT solar cells are hybrids of single crystalline silicon surrounded by ultra-thin amorphous silicon layers, and are available solely from SANYO. HIT Power models are ideal for grid-connected solar systems, areas with performance based incentives, and renewable energy credits.

Structural Strength

HIT Power panels have a double-wall black anodized aluminum frame for extra strength, and are tested to 60PSF. The panels come pre-equipped with a touch-safe junction box, USE-2 outdoor rated cables, MC4™ locking connectors, and are UL 1703 safety rated for wind, hail, and fire.

Increased Performance with SANYO



Valuable Features

HIT Power solar panels operate silently, have no moving parts and are among the lightest per watt in the industry. Unique eco-packaging minimizes cardboard waste at the job site. The packing density of the panels reduces transportation, fuel, and storage costs per installed watt.

Quality Products

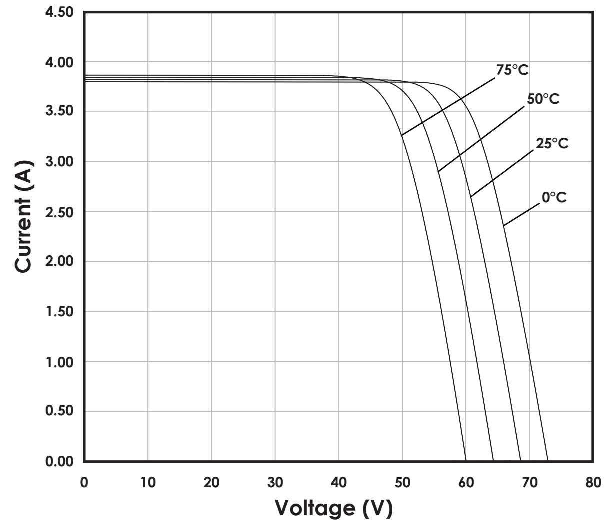
SANYO silicon wafers located inside HIT solar panels are made in California USA, and the panels are assembled in an ISO 9001 (quality), 14001 (environment), and 18001 (safety) certified factory. The panels have a Limited 20-Year Power Output and 5-Year Product Workmanship Warranty.

HIT Power 200
Photovoltaic Module

Electrical Specifications

Model	HIT Power 200 or HIP-200BA19
Rated Power (Pmax)[1]	200 W
Maximum Power Voltage (Vpm)	55.8 V
Maximum Power Current (Ipm)	3.59 A
Open Circuit Voltage (Voc)	68.7 V
Short Circuit Current (Isc)	3.83 A
Temperature Coefficient (Pmax)	-0.348 % / °C
Temperature Coefficient (Voc)	-0.190 V / °C
Temperature Coefficient (Isc)	2.01 mA / °C
CEC PTC Rating	185.9 W
Cell Efficiency	19.7%
Module Efficiency	17.2%
Watts per Ft.^{2}	16.0 W
Maximum System Voltage	600 V
Series Fuse Rating	15 A
Warranted Tolerance (-/+)	-0% / +10%

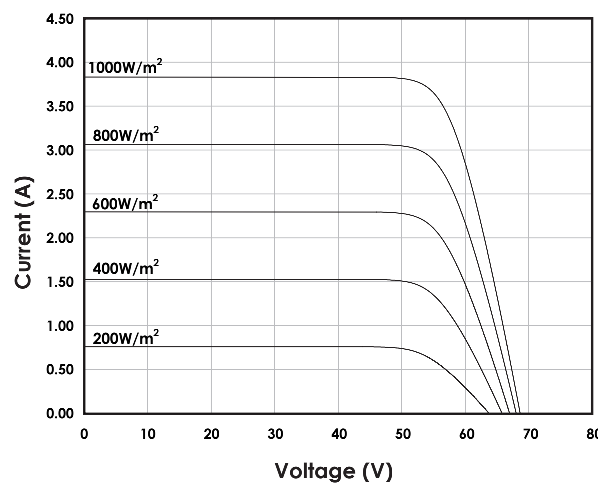
Dependence on Temperature[1]



Mechanical Specifications

Internal Bypass Diodes	4 Bypass Diodes
Module Area	12.49 Ft.^{2} (1.16m^2)
Weight	33.07 Lbs. (15kg)
Dimensions LxWxH	51.9x34.6x1.8 in. (1319x880x46mm)
Cable Length -Male/+Female	30.7/24.8 in. (780/630mm)
Cable Size / Connector Type	No.12 AWG / MC4™ Locking Connectors
Static Wind / Snow Load	60PSF (2880Pa) / 39PSF (1867Pa)
Pallet Dimensions LxWxH	53x35x77 in. (1346x897x1952mm)
Quantity per Pallet / Pallet Weight	34 pcs. / 1166 Lbs. (530kg)
Quantity per 20', 40', and 53' Container	340 pcs., 714 pcs., 918 pcs.

Dependence on Irradiance[1]

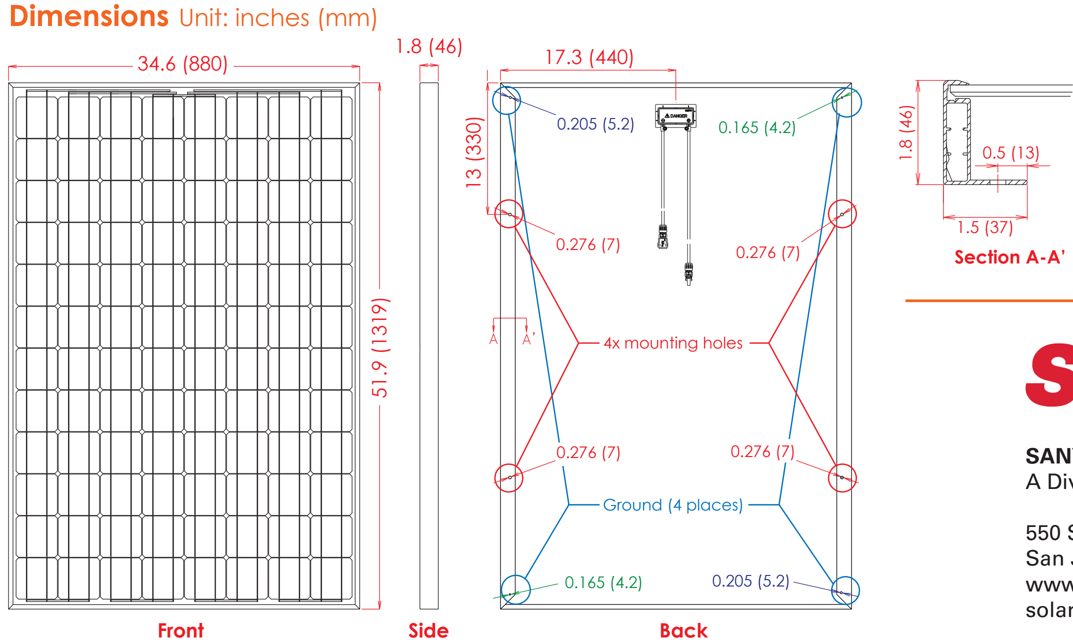


Operating Conditions & Safety Ratings

Ambient Operating Temperature	-4°F to 115°F (-20°C to 46°C)[2]
NOCT	113°F (45°C)
Hail Safety Impact Velocity	1" hailstone (25mm) at 52 mph (23m/s)
Fire Safety Classification	Class C
Safety & Rating Certifications	UL 1703, cUL, CEC
Limited Warranty	5 Years Workmanship, 20 Years Power Output

[1]STC: Cell Temp. 25°C, AM1.5, 1000W/m^2 [2]Monthly average low and high of the installation site.
Note: Specifications and information above may change without notice.

Dimensions Unit: inches (mm)



⚠ **CAUTION!** Read the operating instructions carefully before use of these products

SANYO

SANYO Energy (U.S.A.) Corp.
A Division of SANYO North America Corporation

550 S. Winchester Blvd., Suite 510
San Jose, CA 95128, U.S.A.
www.sanyo.com/solar
solar@sec.sanyo.com

Appendix H – Inverter Specifications

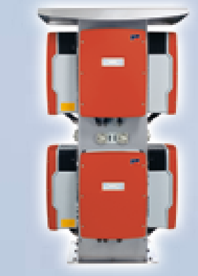
INVERTER GUIDE

Please also refer to the SMA design tool, Sunny Design, which can be downloaded free-of-charge at www.SMA-America.com.










	SUNNY BOY 700U			SUNNY BOY 3000US		SUNNY BOY 4000US	
(Input Voltge) Output Voltage	(150 Vdc)	(200 Vdc)	(250 Vdc)	208 V	240 V	208 V	240 V
DC Input Values							
Recommended Max. PV Power (Module STC)	575 W	750 W	875 W	3750 W		4375 W	5000 W
DC Max. Voltage	150 V	200 V	250 V	500 V		600 V	600 V
Peak Power Tracking Voltage	77–120 V	100–160 V	125–200 V	175–400 V	200-400 V	220–480 V	250–480 V
DC Minimum Start Voltage	95 V	125 V	150 V	228 V		285 V	
DC Max. Input Current	7 A			17 A		18 A	
Number of Fused String Inputs	2			2 (Inverter) 4 x 15 A (DC Disconnect)		2 (Inverter) 4 x 15 A (DC Disconnect)	
AC Output Values							
AC Nominal Power	460 W	600 W	700 W	3000 W		3500 W	4000 W
AC Max. Output Power	460 W	600 W	700 W	3000 W		3500 W	4000 W
AC Max. Output Current	4.4 A	5.7 A	6.6 A	15 A	13 A	17 A	17 A
AC Output Voltage Range	106–132 V			183–229 V	211–264 V	183–229 V	211–264 V
AC Nominal Voltage/Field Configurable	120 V/NA			208 V/YES	240 V/YES	208 V/YES	240 V/YES
Total Harmonic Distortion	< 3%			< 4%		< 4%	
AC Frequency: Nominal/Range	60 Hz/59.3–60.5 Hz			60 Hz/59.3–60.5 Hz		60 Hz/59.3–60.5 Hz	
Power Factor	0.99 @ Nominal Power			0.99 @ Nominal Power		0.99 @ Nominal Power	
Efficiency							
Max. Efficiency	93.6 %			96.5%		96.8%	
CEC Efficiency	91.5 %			95.0%	95.5%	95.5%	96.0%
Safety & Regulatory Compliance							
EMC	FCC, Part 15, Class A & B			FCC, Part 15, Class A & B		FCC, Part 15, Class A & B	
Certification	UL1741, UL1998 IEEE 1547			UL1741, UL1998 IEEE 1547		UL1741, UL1998 IEEE 1547	
Reverse Polarity Protection	Short Circuit Diode			Short Circuit Diode		Short Circuit Diode	
Short-Circuit Protection	Current Controlled			Current Controlled		Current Controlled	
General Information							
Size (HxWxD) (in) Size DC Disconnect (HxWxD) (in)	12.6 x 12.7 x 7.1 in			13.8 x 17.8 x 9.3 in 11 x 7.3 x 7.6 in		13.8 x 17.8 x 9.3 in 11 x 7.3 x 7.6 in	
Shipping Size (in) Shipping Size DC Disconnect (in)	9 x 15 x 15 in			19 x 15 x 23 in 22.8 x 16 x 11 in		19 x 15 x 23 in 22.8 x 16 x 11 in	
Weight (lbs) Weight DC Disconnect (lbs)	51 lbs			84 lbs 8 lbs		84 lbs 8 lbs	
Shipping Weight (lbs) Shipping Weight DC Disconnect (lbs)	57 lbs			97 lbs 9 lbs		97 lbs 9 lbs	
Ambient Temperature Range	-13 to + 113 °F -25 to + 45 °C			-13 to + 113 °F -25 to + 45 °C		-13° to + 113 °F -25° to + 45° C	
Power Consumption: standby/nighttime	<4 W/0.1 W			< 7 W/0.1 W		< 7 W/0.1 W	
Topology	Low frequency transformer True sinewave			Low frequency transformer True sinewave		Low frequency transformer True sinewave	
Cooling Concept	Convection			OptiCool Forced Active Cooling		OptiCool Forced Active Cooling	
Mounting Location: Indoor/Outdoor (NEMA 3R)	●/● (NEMA 3X)			●/●		●/●	
Features							
Display: LCD	●			●		●	
Additional Communication Boards: RS485/Wireless	○/○			○/○		○/○	
Lid Color: aluminum/red/blue/yellow	-/●/○/○			●/○/○/○		●/○/○/○	
Warranties	10 year			10 year		10 year	

	SUNNY BOY 5000US			SUNNY BOY 6000US			SUNNY BOY 7000US		
(Input Voltge) Output Voltage	208 V	240 V	277 V	208 V	240 V	277 V	208 V	240 V	277 V
DC Input Values									
Recommended Max. PV Power (Module STC)	6250 W			7500 W			8750 W		
DC Max. Voltage	600 V			600 V			600 V		
Peak Power Tracking Voltage	250–480 V			250–480 V			250–480 V		
DC Minimum Start Voltage	300 V			300 V			300 V		
DC Max. Input Current	21 A			25 A			30 A		
Number of Fused String Inputs	3 (Inverter) 4 x 15 A (DC Disconnect)			3 (Inverter) 4 x 15 A (DC Disconnect)			3 (Inverter) 4 x 15 A (DC Disconnect)		
AC Output Values									
AC Nominal Power	5000 W			6000 W			7000 W		
AC Max. Output Power	5000 W			6000 W			7000 W		
AC Max. Output Current	24 A	21 A	18 A	29 A	25 A	22 A	34 A	29 A	25 A
AC Output Voltage Range	183–229 V	211–264 V	244–305 V	183–229 V	211–264 V	244–305 V	183–229 V	211–264 V	244–305 V
AC Nominal Voltage/Field Configurable	208 V/YES	240 V/YES	277 V/YES	208 V/YES	240 V/YES	277 V/YES	208 V/YES	240 V/YES	277 V/YES
Total Harmonic Distortion	< 4%			< 4%			< 4%		
AC Frequency: Nominal/Range	60 Hz/59.3–60.5 Hz			60 Hz/59.3–60.5 Hz			60 Hz/59.3–60.5 Hz		
Power Factor	0.99 @ Nominal Power			0.99 @ Nominal Power			0.99 @ Nominal Power		
Efficiency									
Max. Efficiency	96.8%			97.0%			97.1%		
CEC Efficiency	95.5 %			95.5 %	95.5 %	96.0 %	95.5 %	96.0 %	96.0 %
Safety & Regulatory Compliance									
EMC	FCC, Part 15, Class A & B			FCC, Part 15, Class A & B			FCC, Part 15, Class A & B		
Certification	UL1741, UL1998 IEEE 1547			UL1741, UL1998 IEEE 1547			UL1741, UL1998 IEEE 1547		
Reverse Polarity Protection	Short Circuit Diode			Short Circuit Diode			Short Circuit Diode		
Short-Circuit Protection	Current Controlled			Current Controlled			Current Controlled		
General Information									
Size (HxWxD) (in) Size DC Disconnect (HxWxD) (in)	24.1 x 18.4 x 9.5 in 11 x 7.3 x 7.6 in			24.1 x 18.4 x 9.5 in 11 x 7.3 x 7.6 in			24.1 x 18.4 x 9.5 in 11 x 7.3 x 7.6 in		
Shipping Size (in) Shipping Size DC Disconnect (in)	31 x 15 x 23 in 22.8 x 16 x 11 in			31 x 15 x 23 in 22.8 x 16 x 11 in			31 x 15 x 23 in 22.8 x 16 x 11 in		
Weight (lbs) Weight DC Disconnect (lbs)	141 lbs 8 lbs			141 lbs 8 lbs			141 lbs 8 lbs		
Shipping Weight (lbs) Shipping Weight DC Disconnect (lbs)	148 lbs 9 lbs			148 lbs 9 lbs			148 lbs 9 lbs		
Ambient Temperature Range	-13 to + 113 °F -25 to + 45 °C			-13 to + 113 °F -25 to + 45 °C			-13 to + 113 °F -25 to + 45 °C		
Power Consumption: standby/nighttime	<7 W/0.1 W			<7 W/0.1 W			<7 W/0.1 W		
Topology	Low frequency transformer True sinewave			Low frequency transformer True sinewave			Low frequency transformer True sinewave		
Cooling Concept	OptiCool Forced Active Cooling			OptiCool Forced Active Cooling			OptiCool Forced Active Cooling		
Mounting Location: Indoor/Outdoor (NEMA 3R)	●/●			●/●			●/●		
Features									
Display: LCD	●			●			●		
Additional Communication Boards: RS485/Wireless	○/○			○/○			○/○		
Lid Color: aluminum/red/blue/yellow	●/○/○/○			●/○/○/○			●/○/○/○		
Warranties	10 year			10 year			10 year		

	SUNNY TOWER 36			SUNNY TOWER 42			SUNNY CENTRAL 250U	SUNNY CENTRAL 500U PRELIMINARY
(Input Voltge) Output Voltage	208 V	240 V	277 V	208 V	240 V	277 V	NA	NA
DC Input Values								
Recommended Max. PV Power (Module STC)	45 kW			52.5 kW			295 kW	580 kW
DC Max. Voltage	600 V			600 V			600 V	600 V
Peak Power Tracking Voltage	250–480 V			250–480 V			300 V–600 V	300 V–600 V
DC Minimum Start Voltage	300 V			300 V			400 V	400 V
DC Max. Input Current	150 A			180 A			800 A	1600 A
Number of Fused String Inputs	24 x 15A AC/DC Disconnect			24 x 15A AC/DC Disconnect			6	9
AC Output Values								
AC Nominal Power	36.0 kW			42.0 kW			250 kW	500 kW
AC Max. Output Power	36.0 kW			42.0 kW			250 kW	500 kW
AC Max. Output Current	100 A	87 A	44 A	117 A	101 A	51 A	300 A (@ 480 V)	600 A (@ 480 V)
AC Output Voltage Range	183–229 V	211–264 V	244–305 V	183–229 V	211–264 V	244–305 V	422–528 V	422–528 V
AC Nominal Voltage/Field Configurable	208 V/YES	240 V/YES	277 V/YES	208 V/YES	240 V/YES	277 V/YES	480 V/NA	480 V/NA
Total Harmonic Distortion	< 4%			< 4%			< 5%	< 5%
AC Frequency: Nominal/Range	60 Hz/59.3–60.5 Hz			60 Hz/59.3–60.5 Hz			60 Hz/59.3–60.5 Hz	60 Hz/59.3–60.5 Hz
Power Factor	0.99 @ Nominal Power			0.99 @ Nominal Power			0.99 @ Nominal Power	0.99 @ Nominal Power
Efficiency								
Max. Efficiency	97.0%			97.1%			97.5%	97.5%
CEC Efficiency	95.5%	95.5%	96%	95.5 %	96.0 %	96.0 %	97%	97%
Safety & Regulatory Compliance								
EMC	FCC, Part 15, Class A & B			FCC, Part 15, Class A & B			FCC, Part 15, Class A & B	FCC, Part 15, Class A & B
Certification	UL1741, UL1998 IEEE 1547			UL1741, UL1998 IEEE 1547			UL1741, UL1998 IEEE 1547	UL1741, UL1998 IEEE 1547
Reverse Polarity Protection	Short Circuit Diode			Short Circuit Diode			Software Controlled	Software Controlled
Short-Circuit Protection	Current Controlled			Current Controlled			Current Controlled	Current Controlled
General Information								
Size (HxWxD) (in) Size DC Disconnect (HxWxD) (in)	70.5 x 43.3 x 39 in			70.5 x 43.3 x 39 in			80 x 110 x 33	80 x 134 x 33
Shipping Size (in) Shipping Size DC Disconnect (in)	41 x 45 x 79 in Call for Info			41 x 45 x 79 in Call for Info			88 x 74 x 40 and 88 x 48 x 40	88 x 96 x 40 and 88 x 59.5 x 40
Weight (lbs) Weight DC Disconnect (lbs)	330 lbs/ 1176 lbs with 6 inverters			330 lbs/ 1176 lbs with 6 inverters			4200 lbs	6725 lbs
Shipping Weight (lbs) Shipping Weight DC Disconnect (lbs)	500 lbs/ 1388 lbs with 6 inverters Call for Info			500 lbs/ 1388 lbs with 6 inverters Call for Info			1863 lbs and 3186 lbs	2737 lbs and 4846 lbs
Ambient Temperature Range	-13 to + 113 °F -25 to + 45 °C			-13 to + 113 °F -25 to + 45 °C			–13 to 123 °F full power output up to 122 °F at reduced power	–13 to 123 °F full power output up to 122 °F at reduced power
Power Consumption: standby/nighttime	<42 W/0.6 W			<42 W/0.6 W			69 W Standby, <1000 W with fans	69 W Standby, <1500 W with fans
Topology	Low frequency transformer True sinewave			Low frequency transformer True sinewave			Low frequency transformer, True sinewave with galvanic insulation	Low frequency transformer, True sinew-ave with galvanic insulation
Cooling Concept	OptiCool Forced Active Cooling			OptiCool Forced Active Cooling			Variable speed forced air	Variable speed forced air
Mounting Location: Indoor/Outdoor (NEMA 3R)	●/●			●/●			●/●	●/●
Features								
Display: LCD	●			●			●	●
Additional Communication Boards: RS485/Wireless	○/○			○/○			○/○	○/○
Lid Color: aluminum/red/blue/yellow	●/○/○/○			●/○/○/○			NA	NA
Warranties	10 year			10 year			5 year	5 year

Legend: ● Standard ○ Optional Data under nominal conditions.
Last modified: October 2008 · Technical specifications subject to change without notice.

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SMA America, Inc.
www.SMA-America.com

Appendix I – Electrical Breadth (Voltage Drop)

Sizing DC wire

Try a #12'

L = 171'

V = (55.8 V)

I = 3.59

- Assumptions
  - $\frac{3}{4}$ PVC Conduit

- References
  - NEC Table 9 pg 662

- Formula:

$$VD = \frac{2LRI}{1000 ft} \Rightarrow$$

L = 151'

R = 2 → From NEC Table 9

I =

$$= \frac{2(171)(2)(3.58)}{1000 ft}$$

$$VD = 2.449 V$$

$$\%VD = \frac{2.449}{55.8} \times 100$$

$$= 4.4\% > 3\% \;\times$$

∴ #12 will not work

Try #8

$$VD = \frac{2(171)(.78)(3.58)}{1000 ft}$$

$$VD = .955 V$$

$$\%VD = \frac{.955 v}{55.8 v} \times 100$$

$$= 1.71 > 3\% \;✓$$

∴ **use #8 wire**

Appendix K – Structural Analysis

Loads: DL: - Beams/Girders
- Concrete Slab
- Facade - Acts as a Point load
- Snow Load
- Live Load

Formulas Used:

$$\phi P_n = 1.2(DL) + 1.6(LL) + 0.5(SL)$$

- $LL = LL_0\left[0.25 + \frac{15}{\sqrt{K_{LL} A_T}}\right]$
- $LL \geq .50 L_0$

Assumptions: *

SL = 30psf

Superimposed DL = 11psf

Concrete slab = 150pcf

Facade = 150pcf

LL_0 = 30psf

Beam/Girder weight = 8psf

Determine Acting loads

- Find Tributary Area

Column 1/14(2)

$$A_T = \left(\frac{37.5'}{2}\right)\left(\frac{25'}{2}\right) = 234.375 \text{ sf}$$

$K_{LL} = 2$

DL)

$[150pcf(\frac{5}{12})]$ psf
+ 8psf
+ 11psf

Total → 81.5psf

Facade:
- $150pcf(42')(\frac{37.5'}{2})(.58')$
- 68,512.5 lbs

LL)

Reduction:

$$LL = 30psf\left[.25 + \frac{15}{\sqrt{(2)234.375}}\right]$$

LL = 28.28

$$\boxed{LL = 28.28psf} \geq \underbrace{.5(30)}_{15psf} \checkmark$$

Sizing Column:

$$P_n = 1.2(81.5psf) + 1.6(28.28) + .5(30)$$

$$= 158.048psf\left(\frac{234.375 ft^2}{1000}\right) + 1.2(68.513)$$

P_n = 119.26 kips

P_n = 107.334

KL = 26'

Use $\boxed{W12x45}$

$\phi_c P_n = 116k > 107.3k$ ✓

* Assumptions clarified in Report pg.

- Resizing Column 1/14

: Facade - 10' off height

$= 150\,pcf\,(32')\left(\frac{37.5'}{2}\right)(.58')$

$= 52.2$ Kips

$P_n = 158.048\left(\frac{234.375}{1000}\right) + 1.2(52.2\text{ Kips})$

$= 99.68$ Kps, KL, 26' $= 89.71$

Use **W 10X35**

$\phi P_n = 98.3\,K > 89.71\,K$ ✓

Total weight reduction (WR)

$W_R = [(26')(45) - 26(35)]2$

$W_R =$ **520 lbs**

Column 2/B 38.75

$A_T = \left[\left(\frac{37.5}{2}\right) + \left(\frac{40}{2}\right)\right]\left(\frac{25}{2}\right)$

$= 484.375$ sf

DL)

- 81.5 psf

Facade:

$= 150\,pcf(42')(38.75)(.58)$

$= 141.6$ Kips

LL) - Reduction

$LL = 30\left[.25 + \frac{15}{\sqrt{(2)\,484.375}}\right]$

$= 21.96$ psf

$LL =$ **21.96 psf** > 15 psf ✓

Sizing Column:

$P_n = 1.2(81.5) + 1.6(21.96) + (.5)(30)$

$= 147.936\left[\frac{484.375}{1000}\right] + 1.2(141.6)$

$P_n = 241.58$ Kips @ KL = 26'

$= 217.422$

Use **W12X53**

$\phi_c P_n = 222 > 217.4$ K ✓

Resizing Column 2/13

Facade - 10' off Height

$= 150psf(32)(38.75)(.58)$

$= 107.88 Kips$

$P_n = 147.936\left[\frac{464.375}{1000}\right] + 1.2(107.88)$

$= 201.11$ Kips @ KL = 26' = 180 Kips

use **W10x48**

$\phi_c P_n = 216K > 181 K$ ✓

Total WR

$WR = [(26)(53) - (26)(48)]2$

WR = 260.16

Column 3/12 (2)

$A_T = (20)\left(\frac{25}{2}\right)$

$= 250 sf$

DL:

$= 81.5 psf$

Facade:

$= 150(42)(20+\frac{25}{2})(.58)$

$= 118.78$ Kips

LL-Reduction

$LL = 30\left[.25 + \frac{15}{\sqrt{2(250)}}\right]$

$LL =$ **27.62 psf** > 15 psf ✓

Sizing Column:

$P_n = 1.2(81.5) + 1.6(27.62) + (.5)(30)$

$= 156.992\left[\frac{250}{1000}\right] + 1.2(118.78)$

$= 181.784$ Kips @ KL = 26'

$= 163.6$ Kips

use **W10x48**

$\phi_c P_n = 216^K > 163.6$ Kip ✓

Resizing Column 3/12

Facade -10' off H

$= 150(32)(20 + \frac{35}{2})(.58)$

$= 90.48$ kips

$P_n = 156992\left[\frac{250}{1000}\right] + 1.2(90.48)$

$= 147.824$ kips $= 133$ kips

use W 8x40

$\phi_c P_n = 142K > 133K$ ✓

* No WR

64.L

Column 4-7 (4)

$A_T = (25)20$

$= 500sf$

DL:

$= 81.5psf$

Facade:

$= 150(42)(25)(.58)$

$= 91.35$ kips

LL -Reduction

$LL = 30\left[.25 + \frac{15}{\sqrt{(2)(500)}}\right]$

$LL = 21.73 > .5(30)$ ✓

Sizing Column:

$P_n = 1.2(81.5) + 1.6(21.73) + .5(30)$

$= 147.568\left[\frac{500}{1000}\right] + 1.2(91.35K)$

$= 183.404K$ @ $KL = 26' = 165K$

Use W10x48

$\phi_c P_n = 216K > 165K$ ✓

Resizing Columns 4-7(4)

Facade - 10' off 1+

= 150(32)(25)(.58)

= 69.6 kips

$P_n = 147.568\left[\frac{500}{1000}\right] + 1.2(69.6)$

= 157.304 kips. @ KL = 26' = 142 K

use [8x48]

$\phi_c P_n = 142 k \geq 142 k$ ✓

* NO WR

Column 9,-11 (3)

$A_T = (25)(20)$
= 500 sf

DL:
150pcf (5/12)
+ (8)(2)
+ (11)(2)
100.5

Facade:
= 150(42)(25)(.58)
= 91.35 kips

LL-Reduction

LL = 21.72 > 15 ✓

Sizing Column:

$P_n = [1.2(100.5) + 1.6(21.72) + .5(30)]\left[\frac{500}{1000}\right] + 1.2(91.35)$

= 194.8 kips @ KL = 26'

use [W10x48]

$\phi_c P_n = 216 K > 194.8 K$ ✓

Resize Column 10-11 (2)

Facade - 10' off H

$= 150(32)(25)(.58)$

$= 69.6$ kips

$P_n = 1.2(100.5) + 1.6(21.72) + .5(30)\left[\frac{500}{1000}\right] + 1.2(69.6)$

$P_n = 168.7$ kips @ 26'

Use W10x48

$\phi_c P_n = 216\text{ K} > 168.7\text{ K}$ ✓

* No WR

Column 12

$A_T = 250$ sf   DL = 100.5   Facade = 118.78 kips

LL Reduction

LL = 27.62 psf

Sizing:

$P_n = 1.2(100.5) + 1.6(27.62) + .5(30)\left[\frac{250}{1000}\right] + 1.2(118.78)$

$= 187.5$ kips @ KL = 26'

Use W10x48

$\phi_c P_n = 216\text{K} > 187.5$ kips ✓

Resize Column 12

Facade - 10' off H

$= 150(32)(20 + \frac{35}{2})(.58)$

$= 90.48$ kips

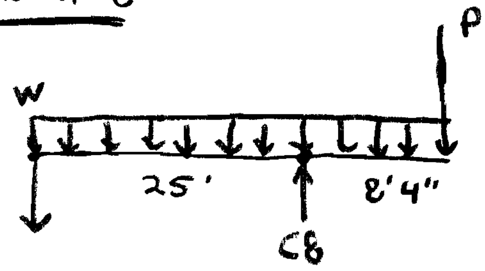
$P_n = 1.2(100.5) + 1.6(27.62) + .5(30)\left[\frac{250}{1000}\right] + 1.2(90.48)$

$P_n = 153.524$ kips @ KL = 26'

Use W 10x48

$\phi_c P_n\ 216\text{ K} > 153.524\text{ K}$ ✓

Column 8



P = 150(20)(.58)(42)
= 73,080 lb
ω = 158.05 psf (20') = 3161 plf

ω)

C8 = $\frac{3161}{2(25)}(25+8.33)^2$

= 70,230 lbs

P)

C8 = $\frac{73\,080}{25}(25+8.33)$

= 97430.3 lb

Total Load on C8 (P_n)

P_n = (70,230 + 97430.3)/1000
= 167.7 kips @ K_L = 26'
ϕP_n = 150.9 kips

use W10×48

$\phi_c P_n$ = 216 k > 150.9 k ✓

Resize Column 8

ω = 70,230 lbs

P = $\frac{150(20)(.58)(32')}{25}(25+8.33)$

= 74 232.6

P_n = 144.5 k @ K_L = 26'
ϕP_n = 130 kips

use W8×48

$\phi_c P_n$ = 142 k > 130 k ✓

No W_R

Assumptions:

- Same Assumptions from Column Analysis
- B1, B2, B8, B13, B14 act as Beams (5 Beams)
- B3 - B7, B9 - B12 act as Girders (9 Girders)

Beam Analysis:

- SL = 30psf
- LL = 30psf
- DL: - SDL = 11psf
  - Precast = 150pcf ⇒ Act as pt load in center of Beam.
  - Metal Deck w/ LW Concrete = 40psf

Total = 51 psf + Precast

B1/B13 (2)

LL Reduction:

$LL = \overset{30}{L_o}\left(.25 + \frac{15}{\sqrt{(2)313.79}}\right)$

$= 25.5\,psf > 15$ ✓

$A_T = (8.33')(37.67)$

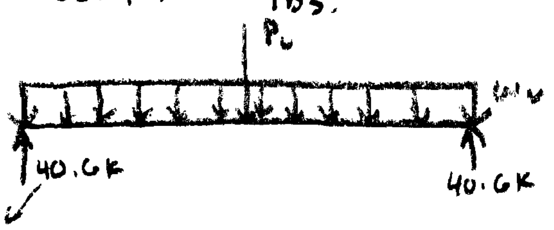
$= 313.79\ sf$

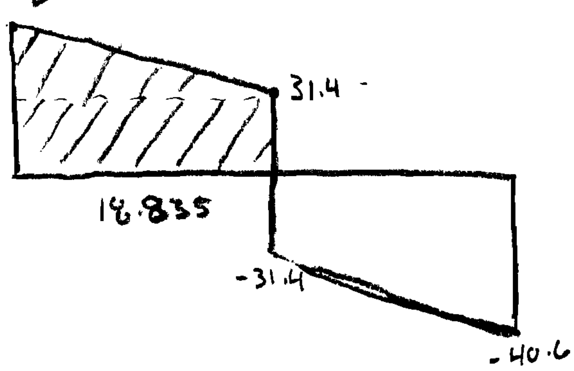
$\omega_u = [1.2(51) + 1.6(25.5) + .5(30)]\left[\frac{8.33}{2}\right]$

$= 487.3\ plf$

$P = [150(.58)(16)(37.67)]1.2$

$= 62.9\ k$ lbs.





$M_u = (18.835)(31.4) + [(.5)(18.835)(9.1)]$

$M_u = 677.1 \times .9$

$\phi_b M_u = 609.4\ k\cdot ft$

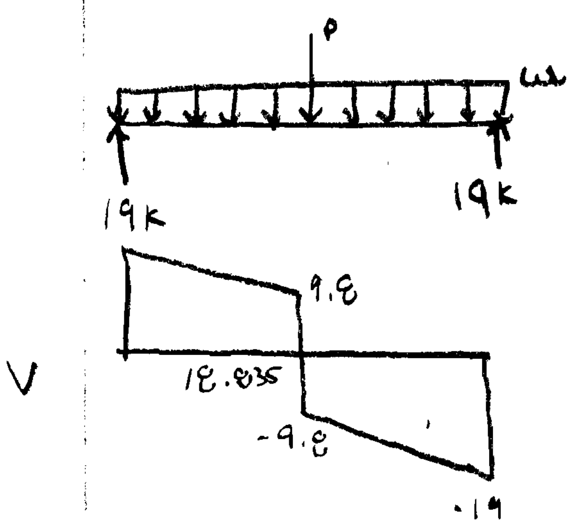
Use **W24x68**

$\phi_b M_{px} = 664 > 609.4\,k\cdot ft$ ✓

Resizing B1/B13 (2)

$P = [150(.58)(6)(37.67)]1.2$

$= 19.7\ K$



$M_u = (18.835)(9.8) + [.5(18.835)(9.2)]$

$= 271.224$

$\phi_b M_u = 244\ k\cdot ft$

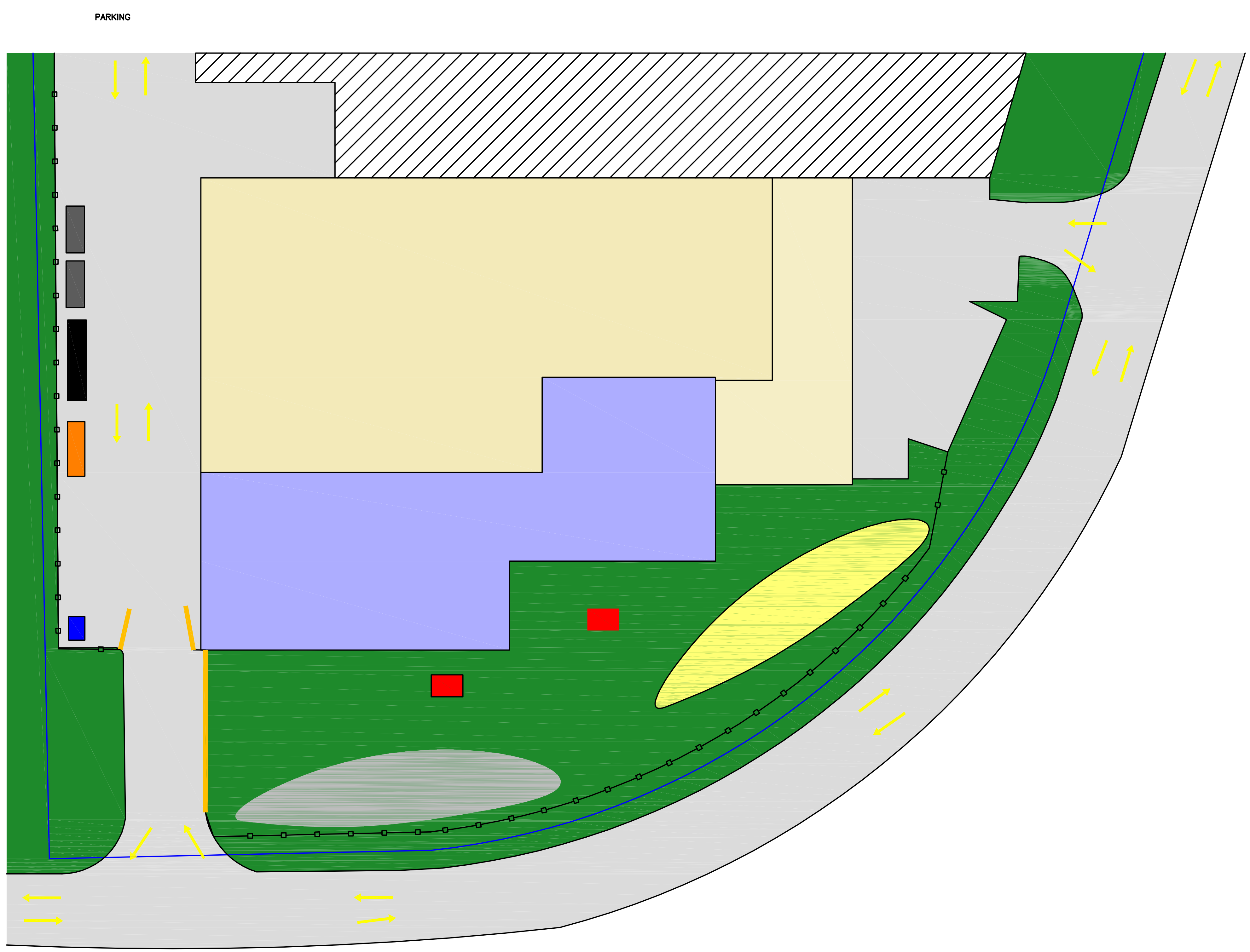
Use **W18x35**

$\phi_b M_{px} = 249 > 244\ k\cdot ft$ ✓

$W_R = 2[37.67(66) - 37.67(35)]$

$W_R = 2,486.2\ lbs$

Appendix L – Revised Site Plan



General Notes

CONSTRUCTION TRAFFIC

CRANE LOCATION

CONSTRUCTION FENCE

TEMP TOILETS

TRAILER AREA

STORAGE AREA

DUMPSTER AREA

STEEL LAYOUT

TILT-UP CONCRETE LAYOUT

No.	SITE PLAN REVISED	04/11

DANIEL SUTER – CM

DATA CENTER

Project

Date

Scale

Sheet

Appendix M – Specification of Tablet PC (Latista)

Motion® J3500

PRODUCT SPECIFICATIONS

Processor / Cache
- Intel® Core™ i7-640UM vPro™ Processor 1.2 GHz with Intel® Smart Cache (4MB of L3 cache, 2 Cores/4 Threads)

or
- Intel® Core™ i5-520UM vPro™ Processor 1.06 GHz with Intel® Smart Cache (3MB of L3 cache, 2 Cores/4 Threads)

Operating System
- Genuine Windows® 7 Professional (32-bit)

Durability Features
- Meets MIL-STD-810G
- IP52 rated
  - Water, dust and splash resistant
- Shock-mounted display and hard drive
- Durable Gorilla™ glass (non-touch configurations only)
- Rubberized coated bottom housing for shock dampening
- Magnesium-alloy internal frame

System Software
- Motion Dashboard control panel
- Motion QuickNav
- Motion/Softex OmniPass™ Security software
- Infineon Security Platform Tools
- Adobe® Acrobat® Reader
- Windows Journal
- Sticky Notes
- Pen enabled BIOS setup

Chipset
- Intel® QM57

Displays
- 12.1" AFFS+ LED backlight digitizer wide screen (WXGA) display with dual touch
- 12.1" TN LED backlight digitizer wide screen (WXGA) display with dual touch
- 12.1" AFFS+ LED backlight digitizer wide screen View Anywhere® (WXGA) display with Gorilla™ glass

Graphics
- Intel® HD Graphics with dynamic frequency
- Screen Rotation: 0°, 90°

Video RAM
- Maximum 256MB total with Intel Dynamic Video Memory Technology (DVMT)

HD Audio Controller
- Realtek ALC272 High Definition Codec

System Memory
- Two DIMM slots; upgradeable to 4GB max total memory (2GB x 2).
- DDR3 memory operating at 800MHz

System Storage
- 1.8" Hard Disk Drive (HDD) with 160GB capacity
- SATA 2.0 - 3.0Gb/s
- 5400 RPM
- Optional 64GB or 128GB Solid State Drive (SSD)

Integrated Communications
- Optional Integrated Mobile Broadband (Gobi™ 2000) with GPS capabilities
  - 1 SIM slot
- WiFi® 802.11 a/b/g/n
- 10/100/1000 Ethernet
- Integrated Bluetooth® 2.1+EDR Module

Audio
- Motion Speak Anywhere® noise cancellation technology
  - Multi-directional array microphone design intelligently switches between two of the three microphones based on screen orientation
- Two integrated speakers

I/O Ports
- Microphone-in
- Headphone-out
- Two USB 2.0 ports
- Keyboard connector
- External VGA port
- RJ-45 connector (Gigabit LAN)
- Docking connector
- DC power in

Expansion Card Slots
- One Smart Card slot
- One Express Card 34 slot

Security
- Integrated AuthenTec AES2550 Fingerprint Reader
- TCG Trusted Platform Module (TPM) 1.2
- Universal lock slot
- Computrace® Complete (optional)

Dimensions
- 12.7" x 9.09" x 0.90" (323mm x 231mm x 23mm)

Weight
- 3.6 lbs. with one battery[1]
- 4.0 lbs. with two batteries[1]

Batteries
- Lithium-ion battery with 30WHr capacity
  - One battery capacity: ~3.3 hours[2]
  - Two battery capacity: ~7 hours[2]
- Maximum 60WHr

Battery Charging
- 1.5 hours for each system battery (Tablet PC on/off)[3]

System Status Indicators
- Power on/off/sleep
- Battery status

Control Buttons
- 5-way directional for navigation
- Three multi-functional programmable
- Camera
- Secure Attention Sequence (SAS)

For more information and localized websites, please visit www.MotionComputing.com

1-866-682-2538

Motion® J3500

PRODUCT SPECIFICATIONS

Built-in Camera (optional)
- Autofocus
- Up to 3 megapixel image resolution
- JPG photo format with a resolution up to 2048 x 1536 pixels
- Illumination light

AC Adapter
- 65W universal, 3-pin jack
- 100-240V ~1.5A, 50-60Hz

Environmental
- Temperature
  - Operation:
    - AC Power: +5°C to +40°C (+41°F to +104°F)
    - Battery Power: +5°C to +45°C (+41°F to +113°F)
  - Storage: -20°C to +60°C (-4°F to 140°)
- Humidity
  - Operating humidity: 8% to 80% without condensation
  - Storage humidity: 8% to 90% without condensation
- Altitude
  - Operation: sea level 0 to 10K ft; sea level to 15K ft. when configured with SSD storage
  - Storage: sea level 0 to 15K ft.

Warranty
- Standard 1-year field-ready warranty
- Multi-year options available

Standards
- ACPI 3.0b compliant

Safety
- AS/NZS 3260:1997
- AS/NZS 60950-1 (1st & 2nd Edition)
- FCC/ANSI C63.41
- UL, CUL, CE (IEC/EN60950-1 A11/2009)
- IEC/EN 60950-1 2nd Edition (2005)
- CAN/CSA RSS-102
- FCC OET65 Supplement C
- ETSI EN 50392
- LVD (73/23/EEC)
- EU Directive 2002/95/EC
- EU Directive 2002/96/EC
- EU Directive 2006/66/EC and its amendments
- California Proposition 65
- Technical Instructions for Safe Transport of Dangerous Goods by Air (ICAO Doc #9284)
- Emergency Response Guidance for Aircraft incidents involving Dangerous Goods (ICAO Doc #9481)

Regulatory
- AS/NZS 3548:1995 Class B
- AS/NZS 4771
- AS/NZS 4268
- AS/ACIF S042.1 (WCDMA/HSDPA)
- AS/ACIF S042.3 (WCDMA/HSDPA)
- AS/ACIF S042.1 (GSM/EDGE)
- AS/ACIF S042.3 (GSM/EDGE)
- CAN/CSA ICES-003 Class B
- CAN/CSA RSS-210 Issue 7
- CAN/CSA RSS-132 (1xRTT/EVDO0/EVDOA)
- CAN/CSA RSS-133 (1xRTT/EVDO0/EVDOA)
- CENELEC EN 55011 (CISPR11)
- CENELEC EN 55022 Class B (CISPR22)
- CENELEC EN 55024 (CISPR24)
- CENELEC EN 61000-3-2
- CENELEC EN 61000-3-3
- ETSI EN 301-893
- ETSI EN 300-328
- ETSI EN 301-489-1
- ETSI EN 301-489-3
- ETSI EN 301-489-7
- ETSI EN 301-489-17
- ETSI EN 301-489-24
- ETSI EN 300-330
- ETSI EN 301-511
- ETSI EN 301-908
- FCC Part 15 Subpart B Class B
- FCC Part 15 Subpart C (2.4Ghz)
- FCC Part 15 Subpart E (5Ghz)
- FCC Part 22 H (1xRTT/EVDO0/EVDOA)
- FCC Part 24 E (1xRTT/EVD00/EVDOA)
- R&TTE (89/336/EEC) & R&TTE (99/5/EC)

For more information and localized websites, please visit www.MotionComputing.com

1-866-682-2538

[1]Weight represents approximate system weight. Actual system weight may vary depending on component and manufacturing variability.

[2]Battery life varies by configuration, applications in use, utilized features and operating conditions. Maximum battery capacity decreases with time and use. Motion battery life estimates based on MobileMark® 2007 performance testing.

[3]Approximate charging time. Validated charging from 0% to 90% with system on or system off.