JetBlue Training Facility

Orlando International Airport

Final Report

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Architectural Engineering Thesis
Construction Management
2005

JetBlue Training Facility
Orlando International Airport
Orlando, FL

Project Overview
- 100,000 square feet
- $15 million total building cost
- Will house 8 full flight simulators, 2 cabin trainers, cabin crew training equipment, classrooms, and administrative offices
- Serve to continuously train JetBlue pilots and crew

Project Team

General Contractor:	Suitt Construction Company
Architect/Engineer:	BRPH Architects – Engineers, Inc.
Owner:	JetBlue Airways
Owner's Representative:	Tishman Construction Corporation
Owner's Architect:	Rubin & Rotman Associates

Architecture
- Composite Aluminum panels with architectural pre-cast concrete
- Aluminum curtain walls with spandrel glass
- Palm court and large steel and glass monumental stairway

Structural
- Cast-in-place spread footings with slab on grade
- (8) - 2 feet thick reinforced concrete pads for simulators
- Concrete elevated slab on composite metal deck
- Light-Gauge Steel Framing
- Galvanized Type B Steel Roof Deck

Mechanical
- VAV with Electric Reheat
- 12 Rooftop Units varying from 9,000 – 26,000 CFM
- 6 AHU dedicated to the Simulator Bays ranging in size between 800 & 10,725 CFM
- 10 Humidifier Units varying from 3,000-12,000 CFM

Electrical
- 480/277 V, 3 phase, 4 wire Primary
- 208/120 V, 3 phase, 4 wire Secondary
- 2000 kVA & 2500 kVA, 3 phase Y Main Transformers
- Copper Lightning Protection System
- Neon jetBlue Corporate exterior signs

Sarah Lippai

Construction Management Option

http://www.arche.psu.edu/thesis/2005/sal223

SUITT
A BE&K COMPANY

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Executive Summary

The following Architectural Engineering thesis focuses on the methods and design of the JetBlue Training Facility at the Orlando International Airport in Orlando, Florida. The analysis consists of 4 main topics; the first details the project information, project team information, and the execution of the project. The next three sections focus on specific designs of the project; a 4D CAD model for constructability, an exterior skin redesign, and a humidification redesign.

The first analysis examines the constructability and sequencing of the JetBlue Training Facility through a 4D CAD model. A clearer understanding of the construction sequence and schedule will be obtained using this model, providing a visual representation for the project team members. A survey was created to gain some insight into the industry’s view of the use of 4D CAD modeling during the bidding process of a project.

The second analysis looks at redesigning the exterior skin using tilt-up concrete panels instead of the precast concrete and metal panels. The tilt-up system was chosen because it is a frequently used method in the central Florida area. A comparison between the constructability of the two systems in regards to cost, schedule, and site conditions will be completed.

The final analysis will focus on the humidification system proposed by the flight simulator specifications. The training facility’s Florida location and climate along with the number of people that will be using the facility each day will be the driving force in decreasing the system. A psychometric chart along with the required specifications and average weather conditions on an hourly basis for the Orlando area will support the decrease in the humidification equipment.

Proposal

Analysis I – 4D CAD Model Analysis

Aim:

The objective of this analysis is to provide a 3D visual of the construction of the JetBlue Training Facility linked with the construction schedule. With this production of a 4D model, research will investigate the use of 4D models during the bidding process and how it may affect the award of a project.

Purpose:

During the beginning of this project, issues were arising concerning the schedule and how it showed the construction of the building. Through a 4D analysis, a better understanding of the construction sequence and methodology will be met. Owners often do not understand the construction sequence and have concerns about how their building is going to be built. Since JetBlue is so involved with the design and construction of the project, a visual of the sequence and construction will be very helpful to build their confidence.

Method:

I started by researching the usefulness of 4D CAD models for constructability, sequencing, and scheduling. I will also create a survey to distribute to industry members for their views on 4D CAD implementation during the bidding process. With these results, I would like to get a better understanding of how the industry views these models compared to how researchers view them. A 3D CAD model will be constructed and linked with the project schedule in Commonpoint.

Expected Results:

Producing a 3D & 4D model will uncover any discrepancies in the construction schedule.

Through a survey of the industry on the effectiveness of the models will show that they are found very helpful. However, owners are not always willing to accept the cost and time elements that accompany the production of the model. With most construction issues, cost and time are very important elements that are usually the underlying factors in project decisions.

Analysis II– Redesign of Exterior Skin

Aim:

The intent of this analysis is to redesign the exterior skin system of the simulator bay areas of the JetBlue Training Facility while investigating the reasons why it was chosen. The existing exterior skin consists of steel corrugated panels on metal studs, aluminum composite panels, and concrete precast panels. With this redesign, I would like to change this current system to a concrete tilt-up system, keeping a similar design of the building.

Purpose:

After speaking with Paul Wood, the project manager for JetBlue Airways, I decided on this change because it was an option given to bidders in the RFP documents. Bidders were permitted to bid on a tilt-up system. In addition, concrete tilt-up systems are frequently used throughout the Florida area. By examining these two systems, I would like a better understanding of why the steel corrugated, and precast panel system was chosen.

Method:

In order to perform analysis, I must research tilt-up panel construction and be able to design panels to provide an equal level of protection and durability. I must also consider the site conditions and schedule that have been established for the project. I will also research why the current system was chosen in lieu of a tilt-up concrete panel system.

Expected Results:

Through this investigation of the cost, schedule, and constructability of the metal panel and precast system versus the concrete tilt-up system, a better understanding of the design choices will be met. The analysis should reflect the reasoning of the architect and general contractor choosing the existing system.

Analysis III– Redesign of the Humidification System

Aim:

The intent of this investigation into the humidification system is to design a more appropriate system for the central Florida location and climate. Through this examination, the humidification system can be reduced to better suit the needs of the facility.

Purpose:

The RFP documents for the JetBlue Training Facility called for the standard humidification system for CAE, the simulator manufacturer, which was based on a temperate climate. The Simulator Bays and cabin trainer rooms need to be climatically controlled to reduce static forces generated by the equipment. Through this modification of the humidification system, there is a potential to save costs and schedule time on the project.

Method:

I will begin this analysis by researching the requirements for the temperature that must be maintained throughout the facility, and the humidification that is needed to reach this temperature. I will investigate the average temperature range for the central Florida area throughout the year to see how that relates to the humidification levels.

Expected Results:

Through these investigations the humidification system proposed will not be required for the Florida location. The calculations will prove that the humidification system would be too intense for the already moist climate in Florida. Conclusions should find that the climate will provide enough moisture in the air.

Project Introduction

Occupant: JetBlue Airways Corporation

Function: Training Facility for JetBlue Airways – Eight full flight simulators, two cabin trainers, classrooms, administration offices, training pool, & fire-fighting training station

Size: 105,475 sq.ft.

Primary Project Team:

General Contractor – Suitt Construction Company
Owner's Representatives – Tishman Construction Corp.
Rubin & Rotman Associates
Architect/Engineer – BRPH Architects – Engineers, Inc.
Mechanical & Plumbing Engineer – *Shappley Design*
Mechanical & Plumbing Contractor – *J&A Mechanical*
*E**lectrical Contractor*** – *Tri-City Electrical*

Dates of Construction: February 2004 – June 2005

Cost Information:

Total Building Cost: $15 million
Simulator & Equipment Cost: $50 million

Project Delivery Method: Design –Build

Project History and Design

JetBlue Airways is building this training facility to house approximately 200 permanent daytime employees and up to 300 students on any given day. The facility will be used for initial and continuous training of all JetBlue pilots and in-flight crew, as well as support training for its technical operations and customer service crew. One of JetBlue Airways main company focuses is an inviting image with innovative technologies. The building design brings a strong, contemporary design element that projects a bright and inviting image for the students and crew.

Architecture

The exterior of the building will consist of composite aluminum panels in JetBlue corporate blue and grey along with architectural pre-cast concrete panels with exposed aggregate. Aluminum curtain walls and spandrel glass will encompass areas along the west façade which will function as the main entrance.

The interior will bring the strong, contemporary design elements that will project a bright and inviting image for students and crew. The main reception and areas of congregation will have porcelain or vinyl tile in shades of white, grey, and blue. Classrooms and administrative offices will be carpeted with colors and styles complimenting the tile areas. The main reception area and palm court will house multiple interior palm trees and a large steel and glass monumental stairway.

Major National Codes:	BOCA The Florida Energy Efficiency Code for Building Construction South Florida Building Code, Miami-Dade & Broward Edition
Zoning Requirements:	Greater Orlando Aviation Authority

Structural

Cast-in-place spread and strip footings with a slab on grade will support the structural steel system. Eight 2' thick slabs will be poured to provide extra support below grade for the Simulators. Elevated slabs will be 3" insulating concrete on rigid insulation board on 1-1/2" metal deck. Building will be framed with light gauge steel framing with galvanized metal studs. Galvanized Type B steel roof deck with 3" insulating concrete and a bituminous membrane will provide support and protection on the roof.

Mechanical

The JetBlue Training Facility has a 311-ton air-cooled chiller providing chilled water for 6 air handling units serving the Simulator Bays. Twelve packaged roof top air handling units provide cooling for the remaining office and classroom spaces. Heat is provided by electric coils in the VAV system. A 3-ton split system will service the separate security building adjacent to the entrance gate.

Electrical

The electrical system for the JetBlue Training Facility is typical for normal power conditions. The system consists of a main distribution panel 3 phase, 4 wire 480/270 V Primary System and a 208/120 V 4 wire, 3 phase, 4 wire Secondary System. It also contains 2000kVA and 2500kVA, 3 phase Y main transformers. Conduit will be run under the slab and in the walls. Electrical will be run from the OUC electrical pull box across Hangar Blvd.

Lighting

Different forms of fluorescent lighting will be used throughout the JetBlue Training Facility. Offices and classrooms are dominated by 2'x4" recessed parabolic and grid - troffer lighting on all floors. Recessed compact fluorescent downlights are used throughout the auditorium, break room, lounge and main entrance stairwell. The Simulator Bays and mezzanine areas are illuminated with fluorescent dome wrap and wrap around surface mount fixtures around the perimeter of the bays. In grade ground

fixtures illuminate the Palm Court area, while decorative surface mount lighting illuminates the terrace on the third floor.

Fire Protection

The Training Facility involves 3 wet-pipe fire sprinkler systems, two single interlock pre-action systems and a class 11 manual wet standpipe system without hose racks. The Simulator Bay, computer rooms, and cabin trainers will be protected by the pre-action system, and all other areas protected by the wet-pipe system. An electric solenoid valve for the simulator bay and computer room’s pre-action system will be released by the fire alarm detection system. Pre-action system supervisory air pressure switches shall also be monitored by the fire alarm system. Valve tamper switches are being provided and shall be controlled by the fire alarm detection system.

Project Delivery System

While this project is being delivered in a design-build manner, it also has taken on a fast-track approach. Design criteria and a set of requirements were developed by the owner's architect to present to the pre-qualified Design/Build firms for proposal. These firms were to develop a firm lump sum proposal that complied with or exceeded the requirements of the design criteria. Design on the majority of the building continued after the job was awarded and will continue while JetBlue makes final decisions on their needs.

Since JetBlue Airways is managing many projects and has little experience with the construction industry, they hired Tishman Construction Corporation to act as the owner's representative on site for both their training facility and a hangar that is being built simultaneously on the other end of Hangar Road. During the initial design phase of the building, JetBlue also hired Rubin & Rotman Associates to function as the architect that would express their needs. JetBlue holds lump sum contracts with both Rubin and Rotman and Tishman Construction.

Suitt Construction Company was awarded the general contractor position on the project in January 2004 after receiving the Request for Proposal two months earlier. During the proposal design phase, Suitt Construction hired BRPH Architects-Engineers, Inc. to function as the architect and engineers on this project. BRPH Architects-Engineers will provide electrical and structural engineering with Shappely Design Consultants providing the mechanical and plumbing engineering and Global Fire Engineering providing the fire protection engineering. Suitt Construction has a standard lump sum contract with JetBlue Airways, and will hold multiple lump sum contracts with all subcontractors.

Project Cost

Actual Building Construction Costs:	Total: Unit Cost:	$15,000,000 $150/SF
Total Project Costs: *(Excluding the cost of simulators and cabin trainers)*	Total: Unit Cost:	$16, 200,000 $162/SF
Approximate Electrical Costs:	Total:	$1,614,000
Approximate Mechanical Costs:	Total:	$292,000
Approximate Plumbing Costs:	Total:	$3,237,800
Approximate Fire Protection Costs:	Total:	$177,226
Approximate Structural System Costs:	Total:	$727,709
Design Costs:	Approx.	$455,000

**Note: These are only approximate values and should not be used beyond this project.*

Local Market Conditions

Since Suitt Construction self-performs their concrete work, there is a need to hire skilled, experienced laborers. Having multiple jobs in different stages of construction in the Florida area, allows Suitt to move experienced workers from one job to another keeping them almost continuously employed and a constant supply of experienced laborers available. With the growing population in the Florida area, there is an endless supply of laborers.

This 13-acre site allows for plenty of parking and staging areas for construction materials. The lack of congestion on site allows for easier scheduling of material delivery and parking.

Existing Conditions

Subsurface and Soil Conditions

The JetBlue Training Facility is located on the Orlando International Airport. This 13-acre site allows for plenty of parking and staging areas for construction materials. The lack of congestion on site allows for easier scheduling of material delivery and parking. The site is bordered on the north by the Beeline Expressway and by an undeveloped, vacant lot with moderate to heavy growth on the south. A newly constructed Goldenrod Road parallels the site on the east with a drainage ditch between, while the west is bordered by Hangar Boulevard and a similar drainage ditch.

The site is located on generally flat terrain with Smyrna sand as the predominant soil type. The region in which the site is located is underlain mostly by marine limestone, dolomite, shale, sand, and anhydride to a depth of approximately 6,500 feet. Groundwater levels observed in the open boreholes indicate that levels range from 1.3 to 6 feet below grade, but will fluctuate with the amount of rainfall. Local ground water drains to the existing retention pond on the south side of the site through drainage ditches on the east and west sides.

The site was used for cattle grazing until the late 1980s, and no existing structures were discovered on the site. There is a buried, high voltage, electrical utility that crosses the northeastern portion of the site. No indications of denatured or distressed vegetation, aboveground or underground storage tanks, electric transformers, water wells, septic tanks, hazardous material use or storage, or stained soils were observed at this site.

Site Layout Planning

As seen on the project's site plans available in Appendix A, site Trailers were located far enough away from the site as to not interfere with daily activities, but with an available view of the entire site. The owner, JetBlue Airways, and his representatives, Tishman Construction, were located in a trailer, while the general contractor, Suitt Construction, and the MEP subcontractors were located closer to the site. Temporary parking was located for staff and visitors adjacent to the owner trailer and laborer parking was located adjacent to the general contractor trailer. Access to the site was via the entrance at the end of Hangar Road and continued through the site to eliminate turnaround areas.

Excavation Phase

With the Florida location and relatively level ground, deep excavation was not necessary. Support for excavation and large excavation stockpiles were not necessary because of this lack of excavation. Small excavation equipment will be used around the site. JetBlue Airways requested that Suitt Construction keep Hangar Blvd clean of mud and debris. Storage and materials staging areas were set up on the north side of the site, close to the construction trailers and parking areas.

Superstructure

With the concrete being poured and the structural steel being erected, a third entrance/exit to the site was opened for easy movement around the site. Staging areas were laid out over the site to allow movement of the mobile crane. Dumpster locations were moved to accommodate the laborers better.

Finishes

Areas were allowed within the building for the staging of finish materials near their locations of installation. Metal for inside the simulator bays was laid out within the simulator areas. Final locations for these materials have not been decided since the building is still weeks away from these stages.

Excavation and beginning superstructure phases were laid out based on experience and pictures from the site during the summer. Later superstructure and finish plans were based on conversations with the superintendent.

Project Team

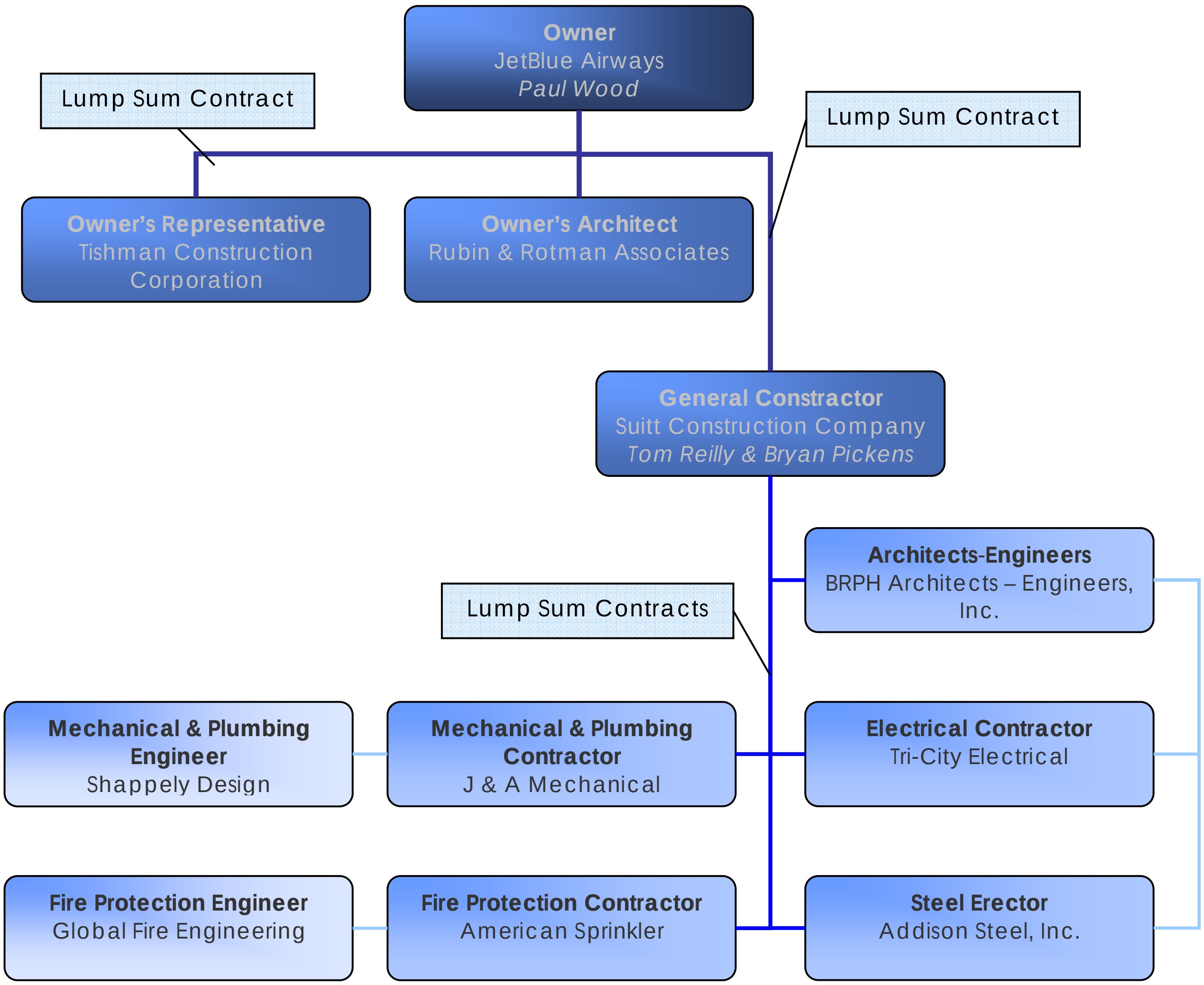
Client Information

JetBlue Airways is building this training facility to house approximately 200 permanent daytime employees and up to 300 students on any given day. The facility will be used for initial and continuous training of all JetBlue pilots and in-flight crew, as well as support training for its technical operations and customer service crew. JetBlue has grown immensely in the past few years, requiring the training of many new employees in order to keep their ideals of superb customer service.

Although the building is privately funded by JetBlue, cost is a concern. JetBlue strives to keep ticket prices low, while maintaining a high level of customer satisfaction. Therefore, an expensive building increases costs for the public. More importantly, the schedule of the project is a primary concern. With more than $50 million invested in the six simulators, two cabin trainers, and accessories arriving in February, the facility must be ready for their installation. A delay in the construction would require JetBlue to find a location to store this equipment and further increase costs of the project. Safety is a high priority with Suitt Construction, and also JetBlue, requiring a full time safety manager on site. Quality is a concern with JetBlue, requiring the interior and exterior finishes to match the corporate custom colors of the company.

The owner and owner's representatives are very involved with the project, keeping a full time construction project manager and on site to monitor daily progress and quality. The owner's representatives are very involved with reviewing each of the submittals and keeping the project on schedule. Changes to the project are discussed in the weekly owner-architect-subcontractor meeting and formally issued to JetBlue for approval. The key to completing this project to JetBlue's expectations would be to meet the substantial completion of the simulator halls for equipment installation, and meeting the final completion date.

Team Organizational Chart



Contracts

JetBlue Airways, the owner, contracted Tishman Construction to act as the Owner's Representative to basically act as an extension of the JetBlue staff. Tishman's responsibility is to look out for the best interest of JetBlue Airways and to help out in any possible way on site. JetBlue Airways and Tishman Construction hold a standard lump sum contract with the only thing not covered is expenses. JetBlue has worked with Rubin and Rotman from the beginning to develop the concept design for the RFP documents. Since Rubin and Rotman have had experience building SIM centers, they have acted as an additional owner's representative as well as the design architects. Rubin and Rotman hold a lump sum contract with JetBlue throughout the construction of the project. During the building process, they make sure that Suitt's developed design adheres to the original RFP documents.

Suitt Construction was selected as a part of the prequalified list of bidders for this project and was presented the RFP documents for bid. Through meetings and negotiations with the bidders, JetBlue selected a general contractor. Ultimately, the negotiated bids dictated which general contractor was selected for the training facility as the Design-Builder.

JetBlue and Suitt hold a standard DBIA lump sum contract with slight modifications. The Design-Builder must take steps necessary to ensure that the Owner is in compliance with all Greater Orlando Aviation Authority (GOAA) and City of Orlando requirements regarding design and construction. With the simulators arriving on site in February, Suitt must have attained substantial completion of the Simulator Hall and coordinate the installation process. Suitt holds standard lump sum contracts drawn and modified for each subcontractor with all subcontractors and the architect-engineer.

JetBlue Airways requires Suitt Construction to provide payment and performance bonds issued by a surety licensed in the State of Florida to cover the full contract amount. Suitt requires all subcontractors with a contract value over a few hundred thousand

dollars, and all subcontractors that have to do with the building envelope, such as caulker, roofer, and window installer to provide bonds. If a subcontractor has a low financial rating, they will also be required to carry a bond.

Worker's compensation, automobile liability, general liability, umbrella policy and errors and omissions insurance are required by all subcontractors as required by the State of Florida. JetBlue Airways carries a builder's risk policy to cover damages to installed items during the construction process.

These contract agreements are standard given the inexperience of the owner with the general contractor in a design-build process. Since Suitt holds a fairly standard design-build mentality, standard contracts, bonds and insurance are required by the subcontracts.

Project Execution

General Conditions Estimate

General conditions vary from project to project and company to company. Below is an estimate of the General Conditions with data compiles from the JetBlue Estimate and R.S. Means. This estimate does not reflect the final cost of the project General Conditions.

The project personnel units were taken from the Staffing Plan shown below. The cost has not been modified for location and insurance and bonds are not included. Senior staff, such as the Project Executive, and Senior Estimators were not added into General Conditions, but carried in Home Office Overhead. Costs for the summer intern were taken from the intern budget and did not affect the project.

Total General Conditions: $891,473

Project Schedule

Before any site work or mobilization on site could occur, the site and foundation drawings had to be developed and approved by both the Greater Orlando Aviation Authority (GOAA) and the City of Orlando. Once the Site & Foundation drawings were permitted, mobilization of the site and clearing of the site could commence. During this time, the 60% Building Design drawings were also being developed. After the 60% drawings were reviewed and the 90% drawings were being developed, the project manager began the process of bringing on the major subcontractors.

The site subcontractors started by bringing the site to grade, and excavating the areas where the (6) 24" slabs for the simulators and elevator slab would be located. Once these areas were excavated, they were formed up and able to receive concrete. At the same time, footings around the perimeter of the building and spread footings were being dug.

Before any vertical construction could occur onsite, the 100% Building Design drawings had to be approved by GOAA and the City of Orlando. Once these drawings were approved, steel erection could start onsite, in conjunction with the metal decking. Once steel erection is complete, the slab on grade is poured and the concrete masonry unit stairway is built. The 24" simulator pad slabs are now at the same height as the slab on grade, providing an even surface for the interior floor. The interior stud framing will be installed simultaneously with the rough-in of the MEP components. The installation of the aluminum composite panels, curtain wall and glazing, and precast panels will be slightly offset from the framing, but will complete approximately a week apart. The electrical, plumbing, HVAC, and fire sprinkler systems will be installed simultaneously while interior finishes are being installed and finished.

Substantial completion of the simulator halls must be completed by the beginning of February, so the installation of the simulators can begin and have to be installed and tested before substantial completion of the remaining building. Substantial completion

of the building must be complete before June 2005 (full project schedule available in Appendix A).

Analysis I: 4D CAD Analysis

Background

Combining 3D CAD elements with the schedule of the project produces an image that aids in visualizing the schedule, determining any inconsistencies in the schedule sequence, and discovering potential time and accessibility conflicts. The use of a 4D model during the beginning of the project can build the confidence of the owner in the general contractor's ability to construct the project. This would have been especially useful during the beginning of construction of the JetBlue Training Facility.

During the beginning of the project, issues arose concerning the schedule and the sequence of construction of the building elements. The owner and their representatives found it difficult to visualize the construction of the Training Facility with the schedule that was given to them. Many of the activities were very broad and did not explain the sequence of construction properly.

Having never worked with Suitt Construction, JetBlue Airways and Tishman Construction did not have complete confidence in the schedule that was established. Although this is not an extremely complex building and Suitt has many years of experience, the owner's confidence was still not high.

Through many owner-architect-contractor meetings, Suitt tried to help the owner's visualize what was going to occur and when; and to build their confidence in the schedule and the knowledge of the superintendent. Also, being a design-build project, JetBlue was very involved with Suitt Construction and the architects and engineers as the design of the building progressed. A 4D CAD model would be a great tool to aid the general contractor, owner, and owner's representatives during the start of this project.

Proposed Solution: 4D CAD Model

As explained above, the main issue was a lack of visual aid presented to the owner and their representatives causing a lack of confidence in the schedule established. With owners and general contractors who have worked together previously this is not a problem, but can pose trust issues between a new team especially at the beginning of the project. This is where the development of a 4D CAD model would help tremendously.

A 4D model is a combination of a 3D model and time, or the schedule. A 3D model was created and linked with the CPM schedule using 4D CAD software (Commonpoint). The resulting model is a simulation of the building construction and the dates attached to it. This model will allow the owner to visualize the activity as it will be built.

The development of the 3D model must be done according to the erection sequence. The CPM schedule is compared to the model to make sure each activity appears on both the model and the schedule. Many items on the schedule for the JetBlue Training Facility were very broad and had to be broken down into smaller activities to correspond to the erection groups in the 3D model. Both the elements of the 3D CAD model and the schedule had to be imported and linked together. This is why organization of the schedule and the 3D model layers is essential. The erection process should be planned before the modeling begins to simply this process. The 4D model gives a great perspective to the construction sequence of the JetBlue Training Facility.

In addition to the model, a survey was conducted to obtain the industry's view on the use of a 4D model during the bidding process. The survey will focus on how a 4D model can establish confidence in the schedule early in the project, with the possibility of awarding the job to a non-low bidder, and last for the extent of the project.

Survey Methodology

In order to study the usefulness of 4D CAD models during the bidding process, data must be obtained from industry members on its use in the industry. Along with its usefulness, a conclusion will be drawn based on the benefits of 4D CAD models compared to the cost, time, and familiarity of industry members with this technology

Sources of information were first derived from journal articles about the constructability and effectiveness of 4D CAD. This information was used to create an online survey form which can be viewed in Appendix C. A series of rated response and open-ended questions were developed to get a variety of useful information. Online surveys were distributed to the project team of the JetBlue Training Facility, PACE members, Centex Construction, and Turner Construction.

Once results are obtained from the surveys, trends in the responses will be discovered and graphed accordingly. From the open-ended questions, a clearer and more useful conclusion will be made about its usefulness.

Analysis: 4D CAD Model

Reference Appendix B for a copy of the 4D CAD Simulation as well as the simulation schedule.

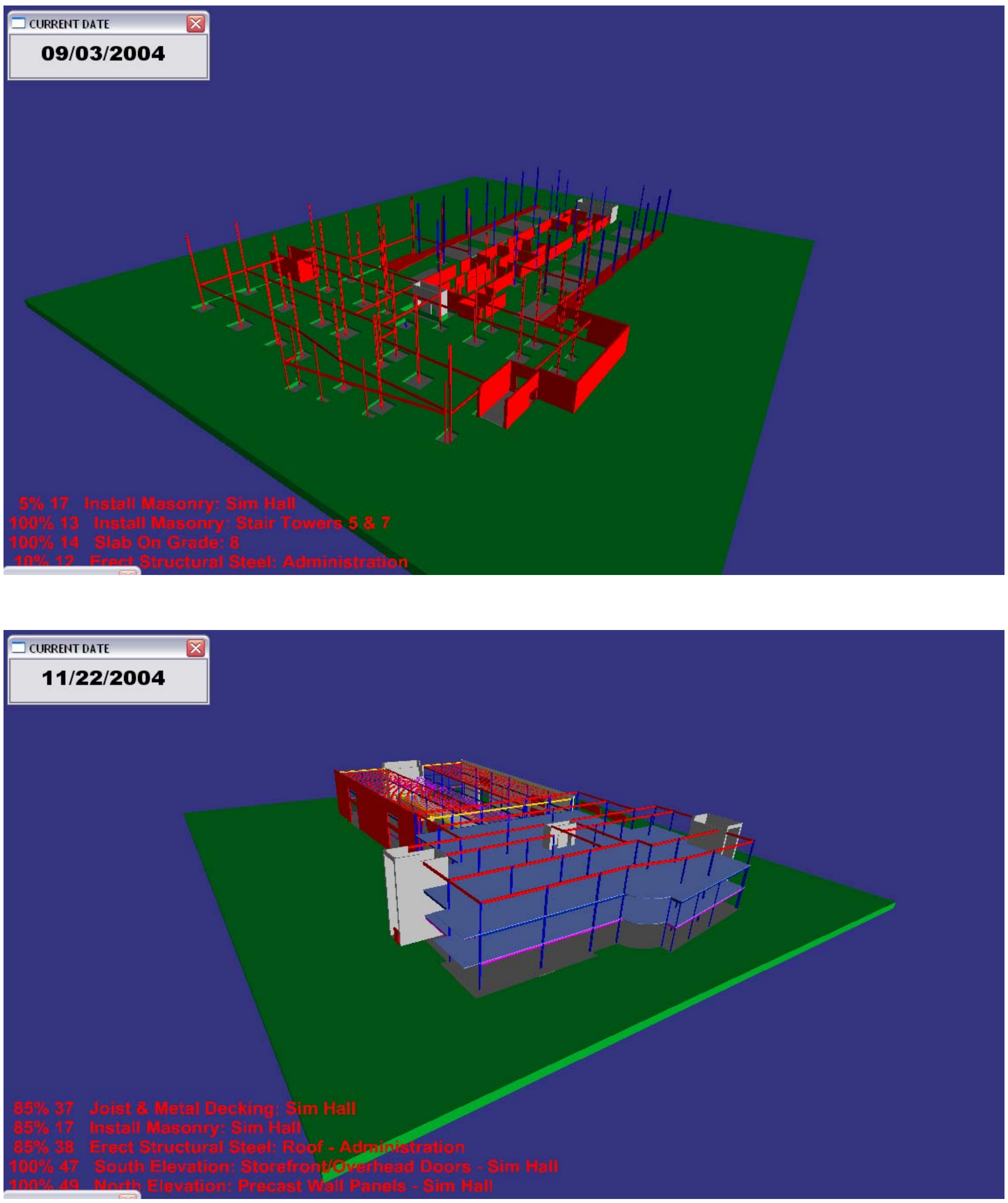


Figure 1: Snapshots of 4D CAD Model produced using Commonpoint

Feasibility of 4D CAD Modeling

As seen in Figure 1, the 4D CAD model gives an enhanced perspective of the construction process and provides a compelling visual aid to the owner. A 4D model provides a means of understanding the construction process in a form that is easier to comprehend than a standard CPM schedule and set of 2D drawings. Producing this 4D model uncovered some construction sequence issues within the construction schedule, which were easily adjusted to reflect how the training facility is being constructed.

Through my survey conducted of industry members and personal experience with learning and adjusting the schedule and 4D model, some conclusions have been drawn reflecting its use during the bidding process.

Use in the Industry

As seen in Figure 2, 4D CAD modeling has been seen by 2/3 of industry members, and was found useful by the majority. However in most cases, these industry members did not have the opportunity to actually use the model, but rather were part of a presentation where a model was used. The majority of 4D model users were project engineers relatively fresh out of school, many of these being Penn State graduates.

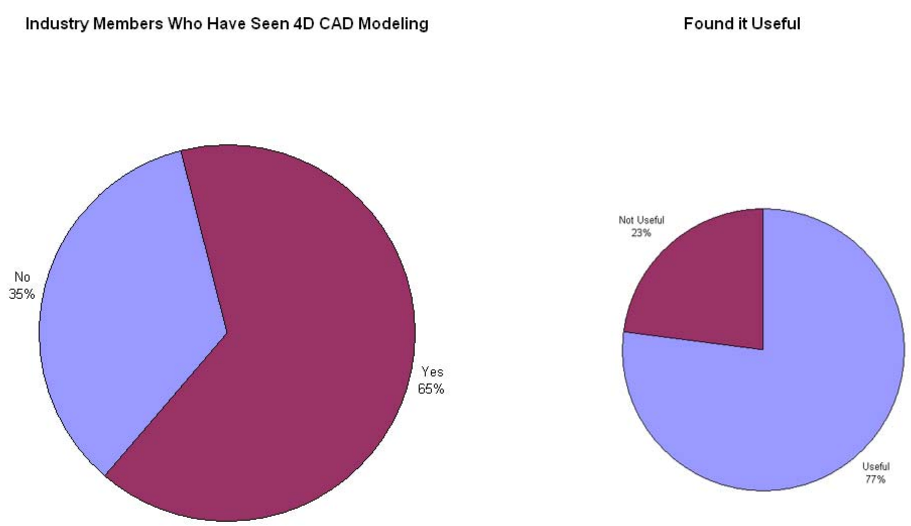


Figure 2: 4D CAD Modeling Use in the Industry

Application in the Industry

There are several applications for using 4D CAD modeling in the industry. The confidence of the owner is enhanced with the use of 4D modeling, providing them with a visualization tool that is easier for them to understand than a set of drawings and schedule separately. The owner also has more confidence that the general contractor understands the project and is providing to them a well thought-out plan for construction by building the project on the computer. The most beneficial use of 4D modeling is presenting to the owner a detailed schedule, especially when the owner and their team do not have a good handle on how the building will come together. The 3D graphics merged with the schedule communicate the overall picture of the project faster without having to page through drawings and details.

Schedule Confidence and Aiding Visualization

As seen in Figure 3, the majority of industry members agree that a 4D model would increase their confidence in the schedule. The added visualization of the 4D model (Figure 4) shows how the different building systems will interact with each other, resolving conflicts within the schedule. However, it does not show the level detail where certain connections might be improperly sequenced. A 4D model cannot show the level of detail that certain project schedules entail, and would be more useful for a broader schedule. This is where the hesitation of industry members of how useful the 4D can portray the actual detailed construction schedule of the project is shown.

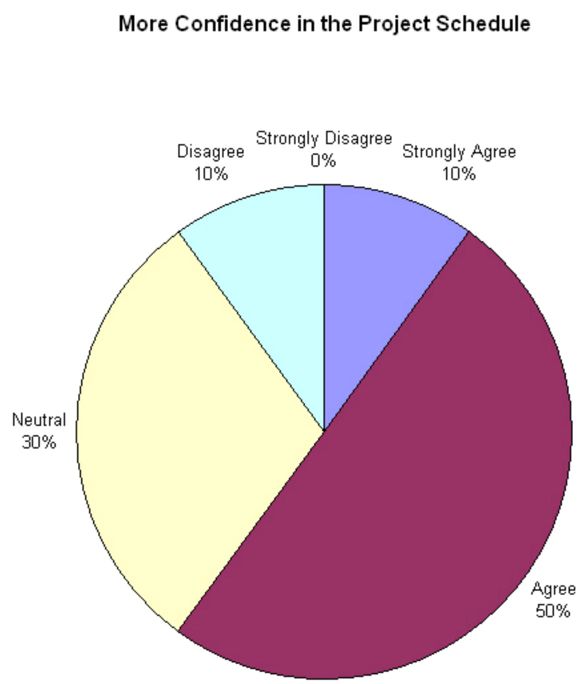


Figure 3: Schedule Confidence

A 4D Model is very useful during the sales pitch of the project during the proposal process. It is shown that owners are more likely to pick a general contractor that has prepared a model that depicts the schedule and sequence of the construction process. This is especially true for an inexperienced owner. This model shows the owner that the process has been thought out and can reduce conflicts in the construction sequence that would cause large cost issues later in the project. Overall, it provides a helpful visualization tool to the owner that can increase their confidence of the general contractor to build the project according to the schedule.

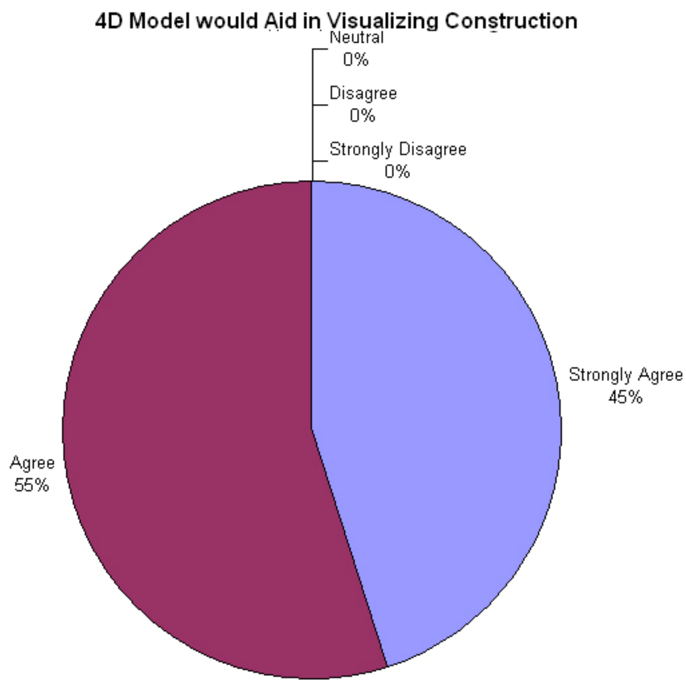


Figure 4: Visualizing Construction

Drawbacks of 4D CAD Modeling

Since 4D CAD modeling is relatively new in the construction industry, it has many drawbacks that are preventing it from spreading quickly through the industry. To produce a 4D CAD model, a person needs to have computer and scheduling skills, along with knowing construction means and methods. With its relatively new development, there are not many individuals that have all of these qualities. Many field personnel are not familiar with the functions of CAD, and are not interested in learning this technology. Another drawback to 4D modeling is the level of detail that is achieved with the model. Many times a 4D model does not provide the level of detail that a 2D drawing does, because it would take too long to develop. This is can be exemplified in the connections of systems. Very rarely is a detailed schedule that could be used for construction available during the bidding and proposal stage of the project. Making the

schedule used and model developed a rough estimate how the building will actually be constructed.

Two of the largest concerns of the construction industry are cost and time. Implementing 4D CAD Modeling can be very expensive and the process of developing the model takes a great deal of time. If no one in-house is able to develop the model, the work must be subcontracted out. If there is the ability in-house, the software and the time taken to develop the model are very costly. An important issue with the cost is determining who will absorb the cost of the model. Few owners would be willing to absorb these costs for the proposal presentation or during the duration of the project. Absorbing these costs may not be an immense task for larger general contractors, but for smaller companies it is almost impossible. This is also the case for the size of the project. Larger and more complex projects would benefit and absorb the cost of the 4D model more readily than smaller projects.

Conclusions

Overall, 4D CAD modeling is a useful tool in presenting a visual to the owner during the bidding process, but can be extremely time and cost ineffective. From my experience using 4D CAD, it takes countless hours to develop the model from 2D drawings even with having previously Autocad knowledge. The model was developed to show the interaction of different building systems, but was not created down to the last detail. For someone who has no experience with 4D modeling, using and changing elements of a 4D model can be very time consuming and difficult. Since most of field personnel do not have much experience with Autocad, and do not wish to learn new technologies, 4D CAD modeling is almost useless other than providing a fancy movie of how the building is going to look once constructed. Most field personnel are accustomed to looking at 2D drawings, and can build the project from experience without having a detailed schedule.

However, if the resources are available and there are qualified personnel that have experience with 4D CAD modeling, it can be a very useful resource. Having the ability to detect scheduling and sequencing conflicts early in the project can save projects costs and time. The benefits of the saved cost and time from problems can fully account for the cost of the software and time invested in the model.

4D CAD Model can be viewed at:

http://www.arche.psu.edu/thesis/2005/sal223/sal223FinalReport.htm

Analysis II: Redesign of the Exterior Skin to a Tilt-up System

Background

The RFP documents for the JetBlue Training Facility gave several options to the bidders of the project. One of these options, the precast panels with aluminum composite and metal corrugated panels was chosen for the façade of the facility. The owner's representative and the original architect decided that the precast panels would be able to provide a higher level of detail and quality for the façade. However, there was another viable option available in concrete tilt-up panels. Concrete tilt-up is a popular construction technique in Florida due to the amounts of concrete available, strength to resist weather, and relatively flat terrain. An exposed aggregate finish, as shown in Figure 5, is identified for all concrete panels in the specifications, and is easily done immediately after the tilt-up panel has been erected. Sand-blasting the surface to expose the aggregate also helps with eliminating the uneven surface appearance that often occurs from contact with the slab below.

Photo Courtesy SiteCast Construction Corp.

Figure 5: Exposed Aggregate Finish

Considering the recent developments of weather in Florida, and the amount of rain that occurs each year in that area, a total concrete system would benefit the facility. Concrete is a more durable building element to withstand wind and precipitation forces caused by the Florida weather conditions. Aluminum composite panels and corrugated metal panels tend to detach from the building structure causing detrimental effects during hurricanes. An exclusively concrete facade would have lower maintenance costs and would prove to be cost effective during hurricanes in that area.

Existing Design

The existing façade was chosen to portray an inviting presence and allow for large amounts of light to flood the classroom and administration areas. The simulator bay areas were designed to keep the noise levels produced by the simulators and their equipment to a minimum outside the facility. The curtain wall and storefront systems installed on the main entrance to the facility were designed to allow plenty of light through, while structurally and architecturally flowing into the simulator areas.

The precast panels in the simulator bay area were designed to be 42'-6" high and 11'-7" wide (Figure 6). These 11" insulated wall panels were designed to rest on the strip footings and connect to the structural steel frame. The east elevation of the facility was designed to have two large corrugated metal panels that correspond to the locations of the simulators.

Figure 6: Concrete Tilt-Up Panels – Simulator Bay

The three stair towers and the elevator shaft are constructed from 8" CMU block. Two of the stair towers have 4" precast concrete panels on the exterior to match the architectural features of the rest of the building, while the remaining tower on the north façade has aluminum composite panels. The stair towers on the north and south facades have an integrated curtain wall system to allow light to permeate the stairs.

The north and south facades in the administration region of the building are constructed of various sized 8" thick concrete precast panels integrated with a storefront system. The west façade is constructed partly of 8" thick concrete precast panels with a storefront system ,and aluminum composite panels with an incorporated curtain wall system. The building entrance is constructed of a curved curtain wall and aluminum composite panel system.

The structural steel system is supported by cast-in-place spread and strip footings with a slab on grade. The building will be framed with typical structural I –beams and light gauge steel framing with lateral bracing in the simulator bays. The structural steel will support the façade as well as the joists and elevated slabs. (Figure 7)

Figure 7: Structural Steel Erection

Proposed Design – Concrete Tilt-Up

Since concrete tilt-up panels were an option in the RFP documents, the structural steel system was designed so it could support whichever façade design was chosen. For this reason, some elements of either system are very similar.

Panel Size

Since the panels are being cast-on-site, the panels can be designed to be much larger, combining many of the precast panel layouts. Combining panel sizes does not affect the crane, since the crane can pick a large piece of concrete just as easy as a small piece. The increase in panel size is shown in Figure 8 for the south elevation, combining two of the precast panels to make one tilt-up panel, as in Panel #2. The

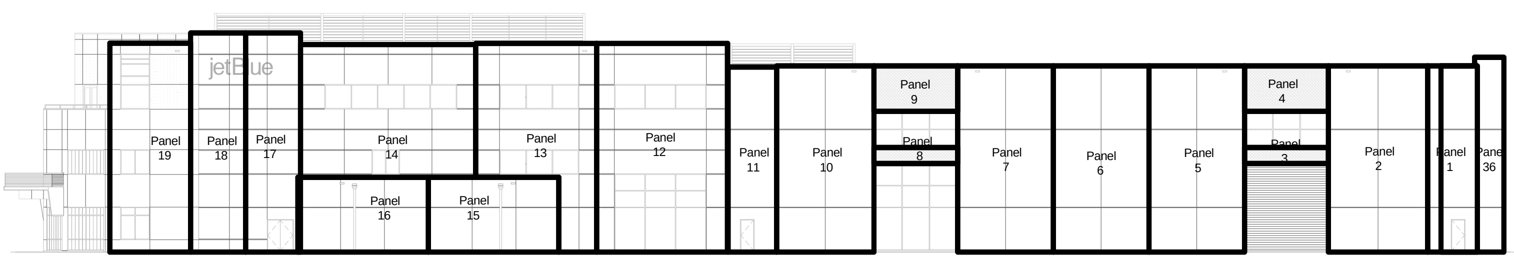


Figure 8: South Elevation Tilt-Up Panel Layout Design

combination of precast panels to one tilt-up panel can be shown in Panel #12 on the south elevation in Figure 8. On the west elevation, the window design had to be changed slightly to accommodate the formation of tilt-up panel design. This only eliminated one window between Panels 57 and 58 as seen in Figure 9. Panel design layouts for the remaining elevations along with a complete listing of panel sizes can be found in Appendix D.

Figure 9: West Elevation Tilt-up Panel Design – Window Elimination

Panel Laydown Locations

The training facility has a relatively open floor plan and the site location on the Orlando International Airport has a relatively flat terrain. These features work in conjunction with the forming and laydown areas for the tilt-up panels. Tilt-up panels require 70 – 80% of the floor area which is 52,000 sq. ft. for the JetBlue Training Facility. The majority of the panels are located within the footprint of the building, but some are located outside the perimeter a shown in Figure 10. The panels in the simulator bay areas are erected first, with the administration areas to follow. The panels located on the exterior of the floor area are the last panels to be installed and will be placed by the "walking" method. These panels are for the most part smaller and lighter, and need to be integrated with the storefront and curtain wall systems. A larger view of the tilt-up laydown areas is available in Appendix D.

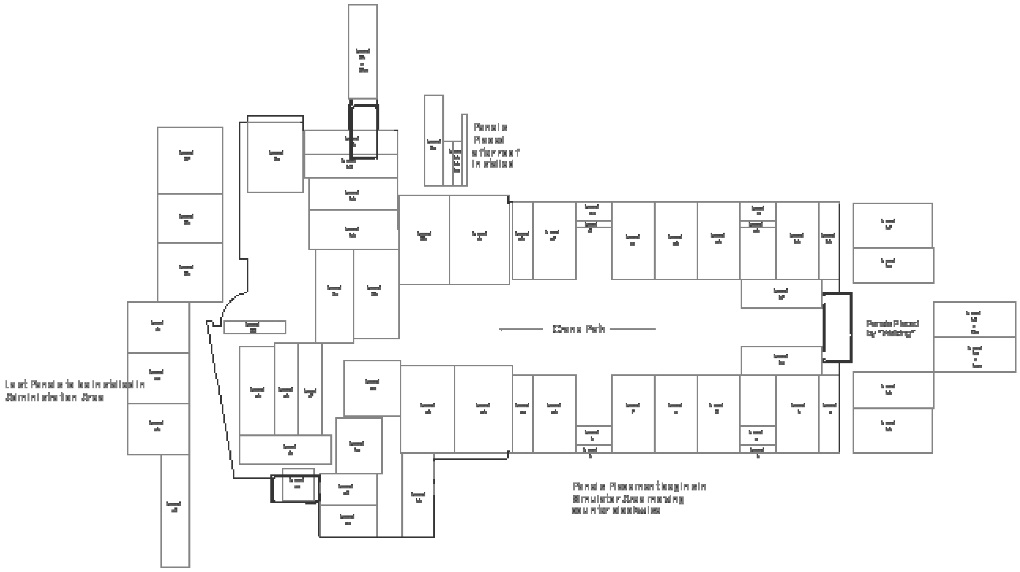


Figure 10: Laydown Areas for Tilt-Up Panels

Panel Thickness

Panel thicknesses were chosen based on their precast counterparts. An 11" insulated non-composite panel was chosen for the simulator bay areas to resemble the 11" precast panels that were scheduled for that area (Figure 11). The panels consist of a 6" interior structural concrete layer with a 2" insulation layer and a 2" exterior concrete architectural layer. An 8" solid tilt-up panel was designed for the administration areas, with the exception of the 5" spandrel panels on the west façade. These spandrel panels serve an

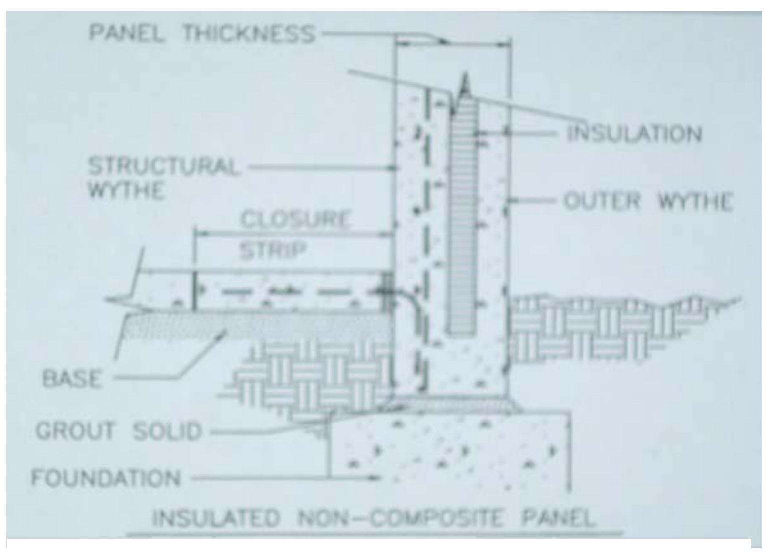


Photo Courtesy of Tilt-Up Design and Construction Manual

Figure 11: Insulated Non-Composite Tilt-Up Panel

architectural purpose and are supported by the structural steel and their surrounding panels. Individual panel thicknesses are shown in Appendix D along with the panel sizes.

Panel Erection

After the panels were sized and the thicknesses chosen, the weight of the panels was calculated. The full listing of panel weights is available in Appendix D. A carbon steel P-52 SL Foot Anchor was chosen to be embedded in the slab to support the panel during lifting (Appendix E). This anchor has a lifting capacity of 10 tons, so calculations were made to support each panel individually. Panel anchor configurations were in multiples of 2, 4, and 8 to coordinate with the rigging capabilities of the crane crew.

With the opportunity to double the size of the panels in the simulator area, this decreases the number of lifts throughout the building, and will help the rigging crew

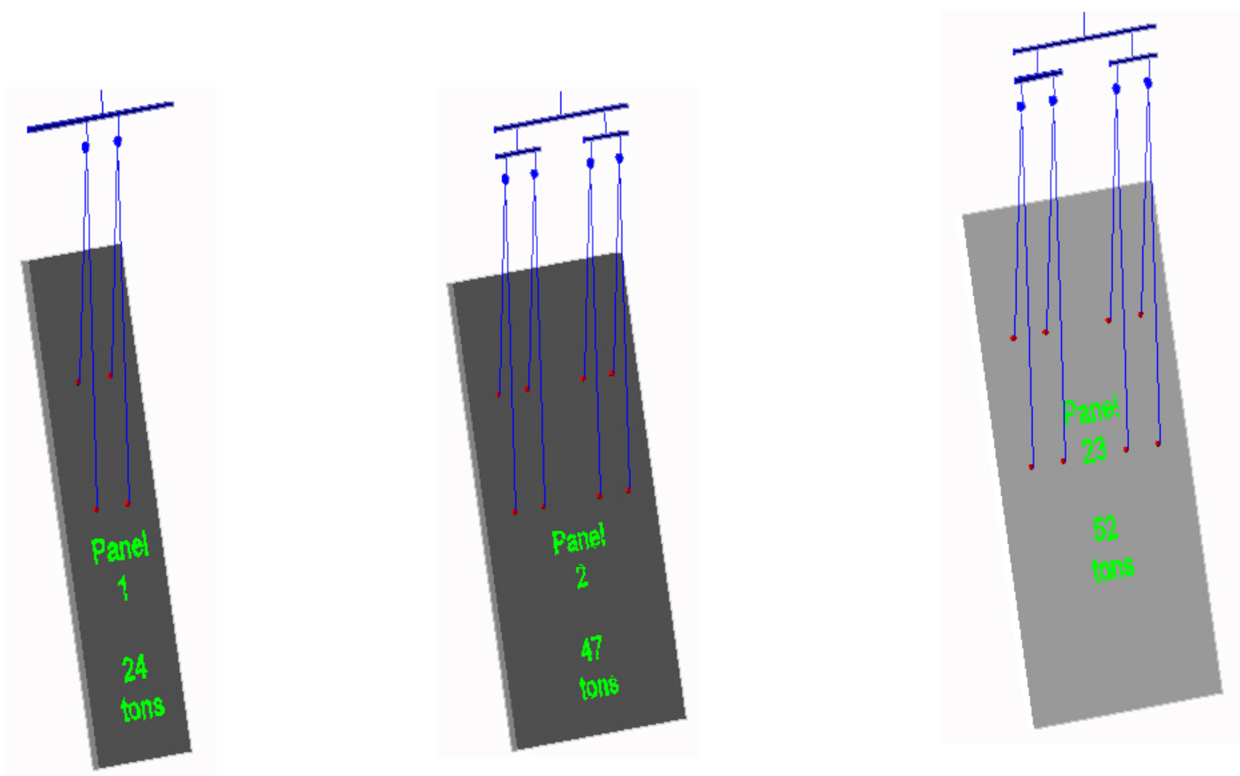


Figure 12: (a) 4-point lifting (b) 8 Point lifting (c) 8 Point lifting Maximum Weight

keep a consistent lifting configuration. Shown in Figure 12 are the lifting configurations for (a) a panel if it is not doubled in size, (b) panel that is double in size, and (c) the heaviest panel that must be lifted by the cranes. The 4-point and 8-point rigging are overly designed for proper rigging capacity, since the configurations have to be 2, 4, or 8 point.

The precast panels required a 100-ton Manitowoc crane, but the recommended crane capacity for lifting tilt panels is twice the size of the largest panel. Panel 23 and 26 are 52 tons each, so a larger crane must be specified. A 120-ton Manitowoc crane is specified to support the weights of the tilt-up panels.

Cost and Schedule

	Tilt – Up Concrete	**Existing System**
Cost		
Material	• Concrete affordable in Florida area • Equal in cost to Precast material	• Masonry for stair towers and elevator shaft is very expensive
Transportation	• Cast-on-site • No transportation costs	• Transportation from plant to site • Precast Plant not near site • Toll roads in Florida
Crane and Labor	• On-site less time	• On-site longer
Schedule		
Lead Time	• Cast-on-site • No lead time	• Long lead time • Fast-track project
Erection Time	• Number of panels decreased • Less erection time • Crane on-site less	• Number of panels decreased • Less erection time

Conclusions

After review of the tilt-up concrete system in comparison to the precast panel with aluminum composite and metal corrugated panels, a tilt-up system is a feasible replacement. The complete concrete structure will be more durable against the weather elements in Florida, while requiring less maintenance. The exposed aggregate architectural finish can be achieved, but with slightly less quality than plant precast concrete panels. The thicknesses of the panels would not change drastically, keeping the same structural integrity of the building. Overall, there is no structural difference in the façade, so the structural steel and reinforcing in the panels would not change. The difference between the two systems lies in where the panels are formed.

Casting the tilt-up panels on-site allows the size of the panels to be increased, speeding up the erection time for the façade. Only a slightly larger crane would be required on site to support the larger panels. The increase in cost for this crane would be negligible and may even decrease depending on local availability. Having a relatively open floor plan and flat site, the laydown area for tilt-up panels is not an issue.

The materials used to construct both the tilt-up and precast concrete systems are relatively similar, making the difference in material costs between the systems negligible. The main difference in cost between the two systems is in the transportation costs to the jobsite for the precast system.

In conclusion, the choice to choose the precast system in the original bid documents was based on the quality and level of detail that could be achieved in a precast concrete plant. However, a tilt-up system could have been an equally viable system.

Analysis III: Redesign of the Humidification System

Background

The humidification system for the JetBlue Training Facility was specified in the RFP documents as the standard humidification system designed by CAE for their simulators. This humidification system was designed for a temperate climate. The manufacturer states that a humidification level should be reached to reduce the static forces produced by the operation of the simulators. Since the initial design architect was from Canada, consideration for the Florida location and climate was not part of the RFP documents.

After considering the Orlando, Florida climate and the 500 students, faculty, and maintenance crew that would be using the facility on a daily basis, I decided to propose that the humidification system be reduced or eliminated. Since the shear number of people frequenting the facility would provide an increased amount of humidity in the air, this consideration should be taken into effect. Also considering the dry-bulb and wet-bulb temperatures for Orlando, Florida are so similar to each other, the relative humidity is well over the required humidity to operate the simulators. The average dry-bulb temperature is 72 degrees F and wet-bulb is 65 degrees F, producing a relative humidity of 73% (as shown in Figure 13). This will provide enough relative humidity in conjunction with the occupancy load to supply the 35 – 55% relative humidity required for the building.

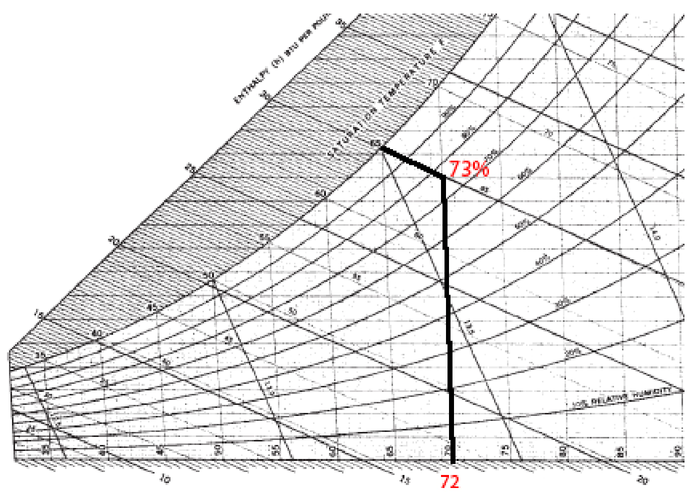


Figure 13: Average Temperatures & Relative Humidity

Existing System Issues

The JetBlue Training Facility must be maintained between 70 – 75 degrees Fahrenheit with a relative humidity between 35 – 55%. The current system has 12 roof top air handling units supplying outdoor air to all parts of the building. There are 10 Armstrong EHU704 Humidifiers used to supply humidification to the building. These humidifiers produce 59.9 – 229.5 lbs. of water/hour each to the building.

Based on occupancy of 500 students, faculty, and maintenance workers throughout the building and the minimum outdoor air supply of the rooftop units, the relative humidity was calculated using Engineering Equation Solver (EES). The relative humidity within the building must be maintained between 35 – 55 %. As shown in Figure 14, the minimum and maximum relative humidity produced by each roof top unit stays above

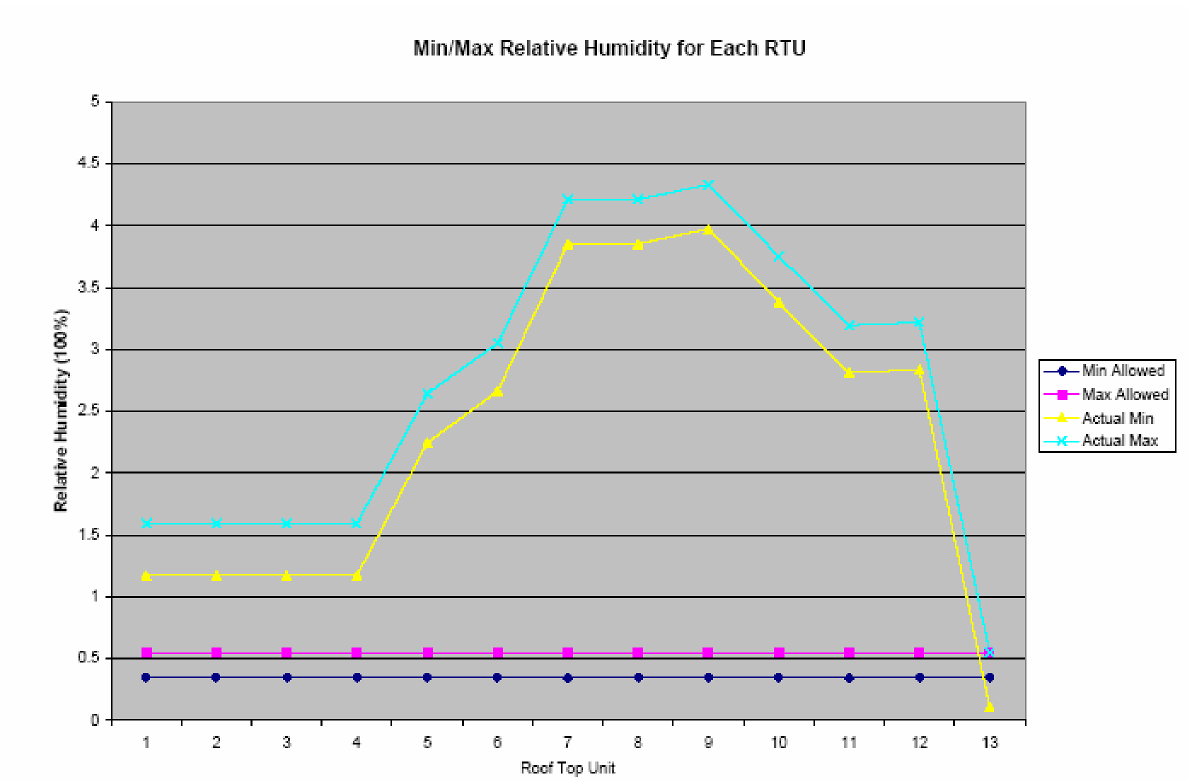


Figure 14: Min/Max Relative Humidity for Each RTU

the minimum blue line and is even above the pink maximum line. The only time that the relative humidity drops below the minimum amount, is at #13, which represents the unoccupied building. However, this can be easily remedied by shutting down the roof top units during the unoccupied times. With these systems being shut down, the humidity that has accumulated throughout the day will be re-circulated throughout those times.

Throughout the year, Florida experiences some minor temperature changes which can affect the relative humidity within the building. Figure 15 shows the minimum relative humidity level for every month of the year. The minimum level of humidity produced by each rooftop unit remains well above the 35 – 55% range throughout the year, and is even over the 400% mark in some places. Figure 16 shows the maximum relative

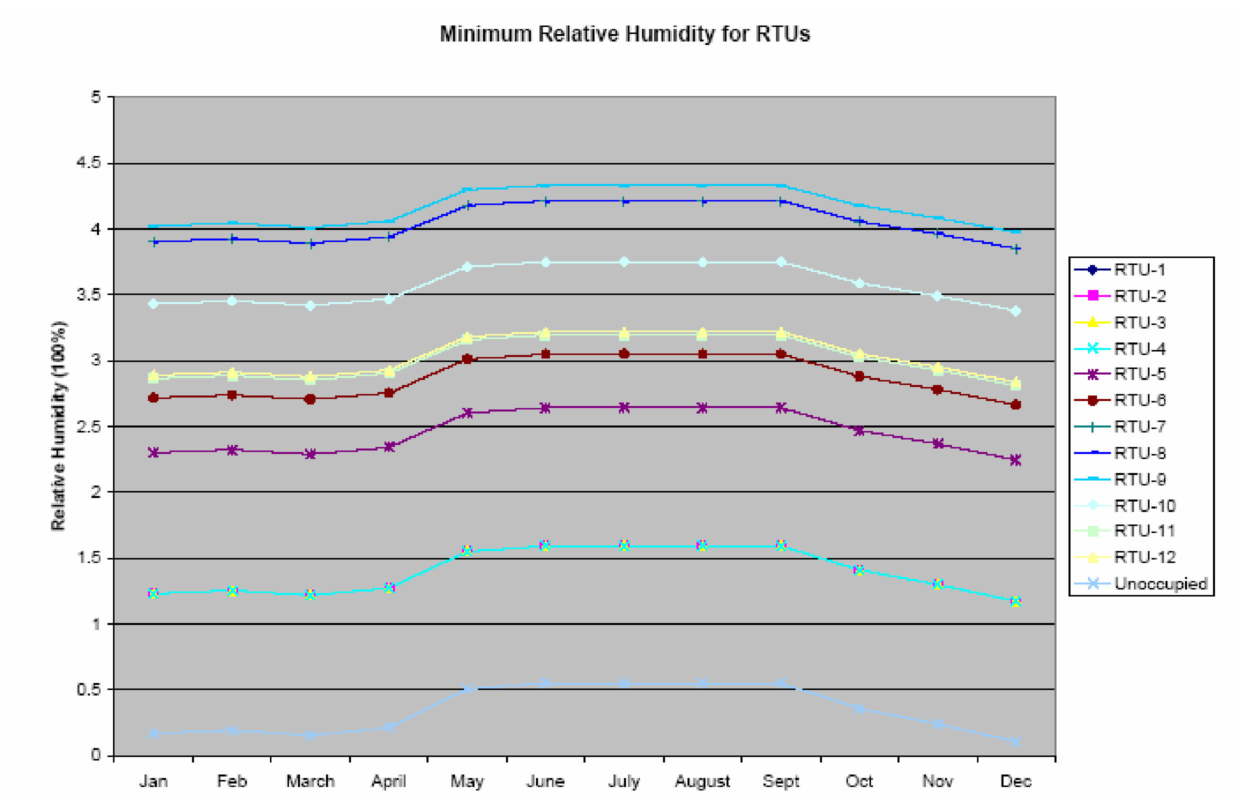


Figure 15: Minimum Relative Humidity for Each RTU throughout the Year

humidity produced by each rooftop unit throughout the year, which is also well above the 35 - 55 % range.

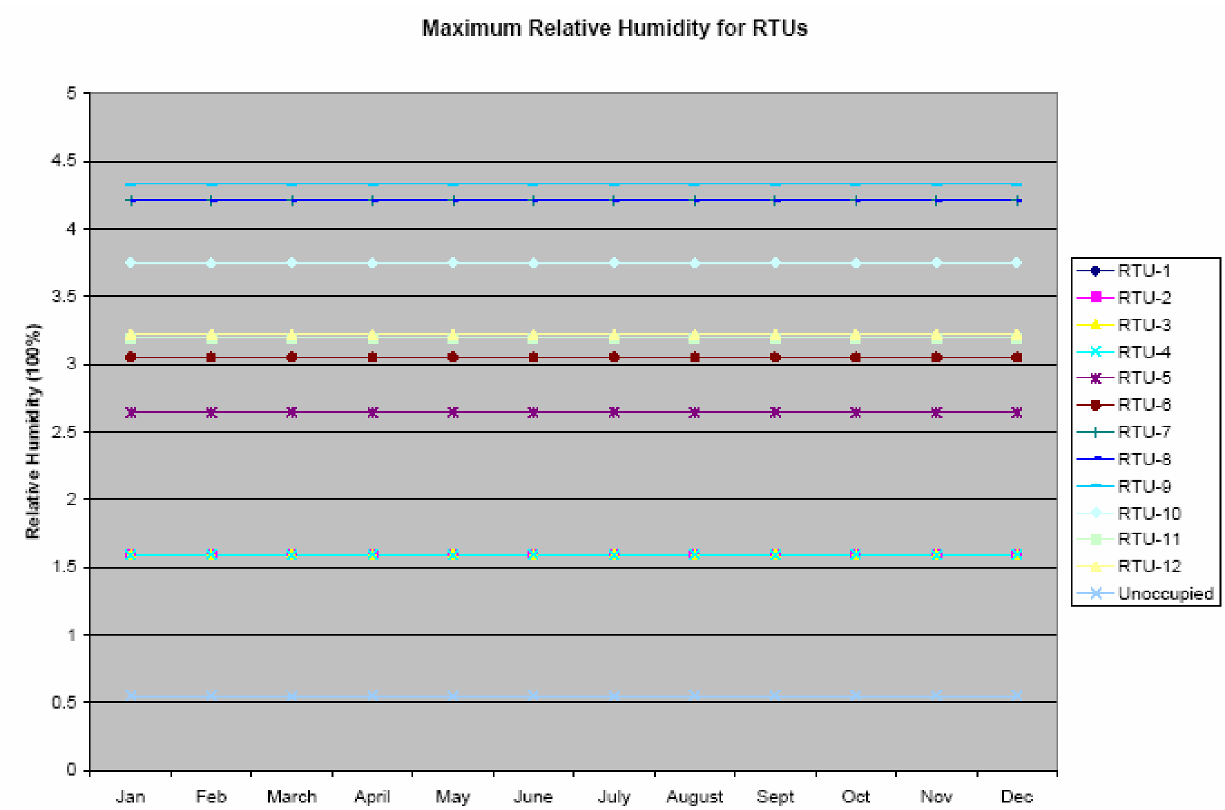


Figure 16: Maximum Relative Humidity for Each RTU throughout the Year

The exact values for these charts are available in Appendix F.

Proposed Redesign of Humidification System

After reviewing the extremely large relative humidity levels produced by the roof top units and the occupancy loads, the complete humidification system can be eliminated. The simulator and their equipment will absorb some of this extra humidity, but all of it to maintain the 35-55% range. Since the humidity levels are so great, a dehumidification or enthalpy wheel system should be put into place.

Calculations within Engineering Equation Solver (EES) found that each rooftop unit system should have water removed from the area that it is supplying air to. The average amounts are shown in Figure 17.

Humidity to be Removed by Each Rooftop Unit (lbs of water/hr.)											
1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*
1.288	1.288	1.288	1.288	3.145	3.133	6.227	6.227	19.29	19.76	20.86	20.44

Figure 17: Humidity Levels to be removed for each RTU

Cost and Schedule Impact

Eliminating the humidification system has multiple cost impacts for the project. Removing this system results in cheaper material, testing, and labor costs along with increasing space within the building's mechanical areas. Below is a list of some of the savings:

Project Costs:

- Material cost for 12 Armstrong Dehumidifier Units
- Material cost for humidity controls and supply piping
- Labor to install units and piping
- Lower training and maintenance costs

Schedule:

- No lead time on equipment
- Mechanical system installation time decrease
- Elimination of testing of equipment

Training and Commissioning

- Humidification system is difficult to maintain – eliminates training
- No testing of system
- No calibration

Conclusions

After viewing the yearly temperature ranges for the Florida location, in conjunction with the occupancy loads and the rooftop unit loads, the humidification system should be elminated. However, with the relative humidity levels reaching 100 – 400% at some times, a dehumidification or enthalpy wheel system should be installed to replace the 1 – 20 lbs of water/hr extra in the air. Further calculations concerning the humidity that the simulators absorb, can be done in cooperation with the simulators manufacturer.

Summary & Conclusions

A 4D CAD Model can be a very useful tool during the bidding process by providing the owner a visual aid that expresses the schedule and construction sequence. The 4D format expresses the building and schedule in an easier to understand format than 2D drawings and a typical schedule. However, creating this model can be extremely time and cost ineffective. With my experience using Autocad, creating the 3D model from the 2D drawings still took countless hours. For an inexperienced CAD user, creating the 3D model can be very frustrating and very time consuming. Organizing the CAD elements for easy importing into the 4D modeling program is key. Meshing the schedule elements and CAD components depends on the organization of both of these.

The industry's view of 4D CAD is rather universal. Most industry members agree that a 4D CAD model provides a nice visual aid to understand the construction sequence. Nonetheless, cost and time are the major drawbacks to its implementation into the industry. Another major concern with 4D implementation is the "old school" mentality of many field personnel. For these reasons, it is going to be some time before 4D modeling is implemented in the industry as a standard feature of any project.

The tilt-up concrete system is a feasible replacement for the precast panel with aluminum composite and metal corrugated panel system. The architectural and functional elements that JetBlue identified for this facility would still be reached with a tilt-up design. Had the design architect been more familiar with the Florida building options, tilt-up concrete may have been chosen. Tilt-up concrete has the potential to lower construction costs, increase durability, and complete the project faster.

The elimination of the humidification system will eliminate costs and scheduling issues within this project. Again, since the design architect was not familiar with the Florida area, they did not consider the outdoor air humidity levels that would be circulated into the facility. Eliminating the humidification system reduces the possibilities for mold and moisture problems in the future. With the calculated levels of humidity in the air, a dehumidification system to eliminate these levels should be installed.

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  - Randy Winger
  - Bryan Pickens
  - Tom Reilly
- Tishman Construction Company:
  - Carrie Macsuga
- BRPH Architects – Engineers:
  - Jon Scott
  - Charlene Gainey
- Turner Construction
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  - Dad, Mom, Luke, & Alex
- Friends
  - Shawn Sambol
  - Jason Jones
  - Jesse Fisher
  - Michelle Siano

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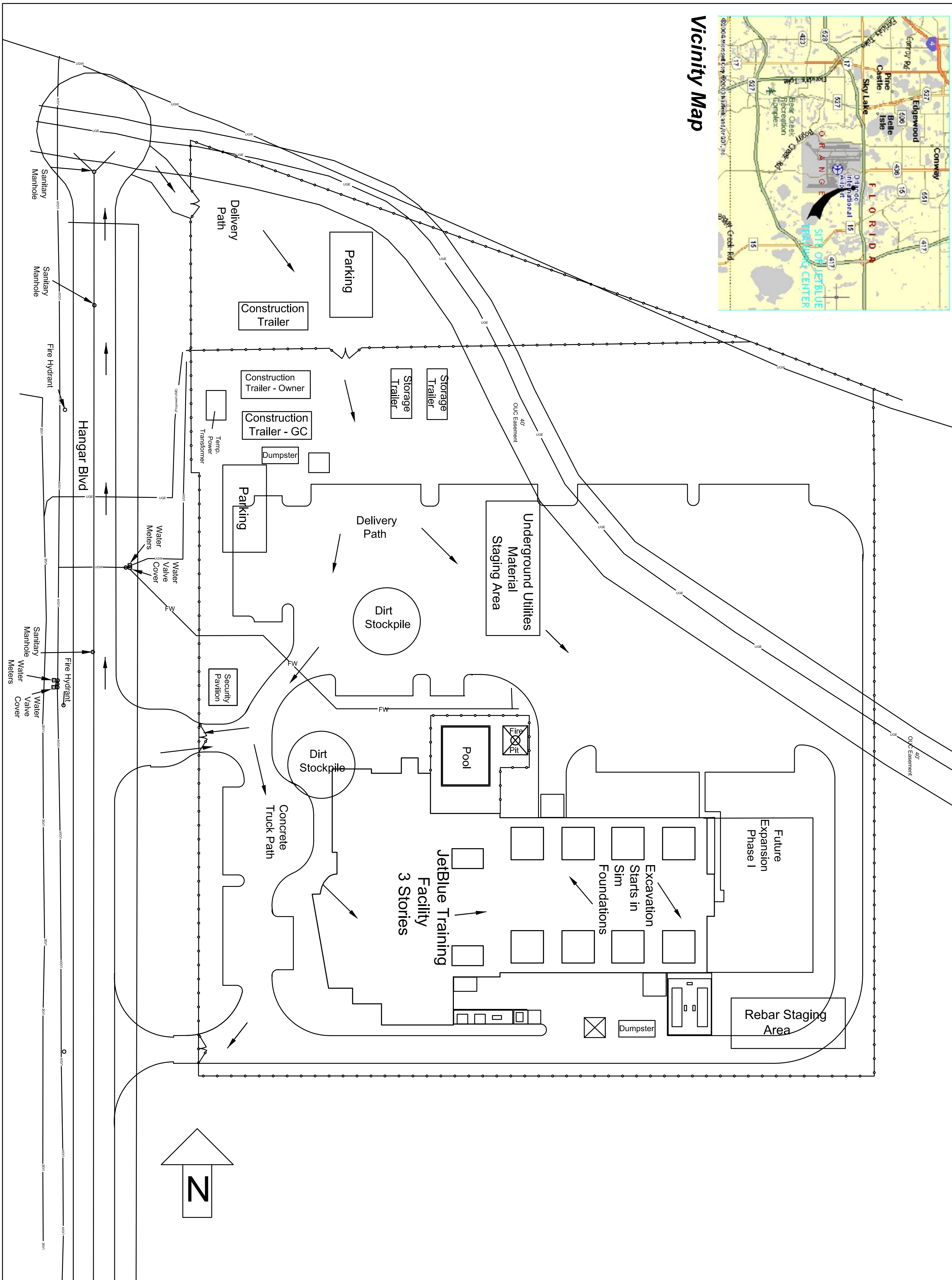
Appendix A

Site Plans

Project Schedule



Excavation Site Plan

JetBlue Training Facility

Thesis 2004-2005

Orlando International Airport

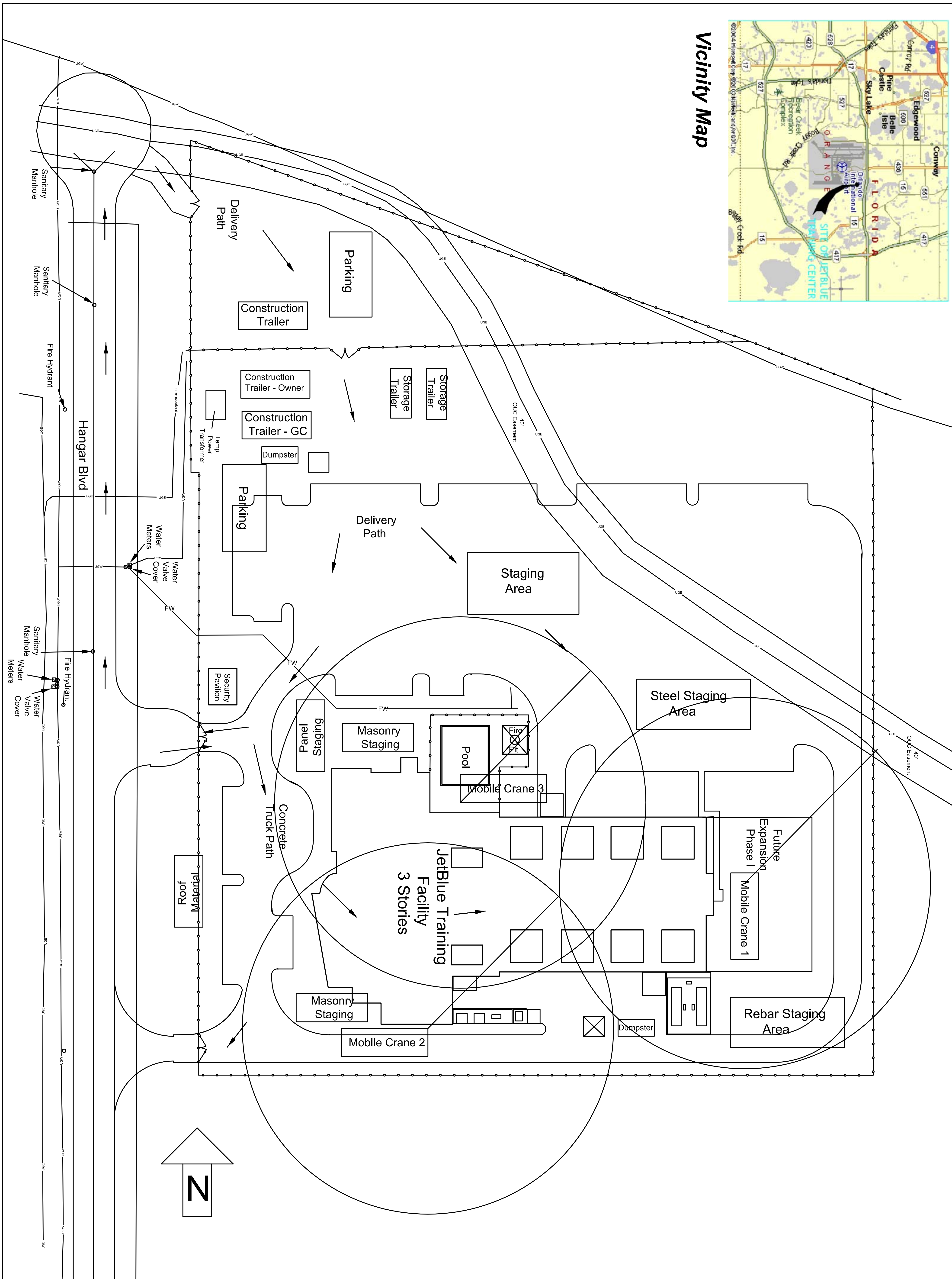
8465 Hangar Blvd, Orlando, FL 32827

Drawn by: Sarah Lippai

Date: 11.3.04

Sheet C-02

Revision	
#	Date



Superstructure Site Plan

JetBlue Training Facility

Thesis 2004-2005

Orlando International Airport

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Date: 11.3.04

Sheet C-03

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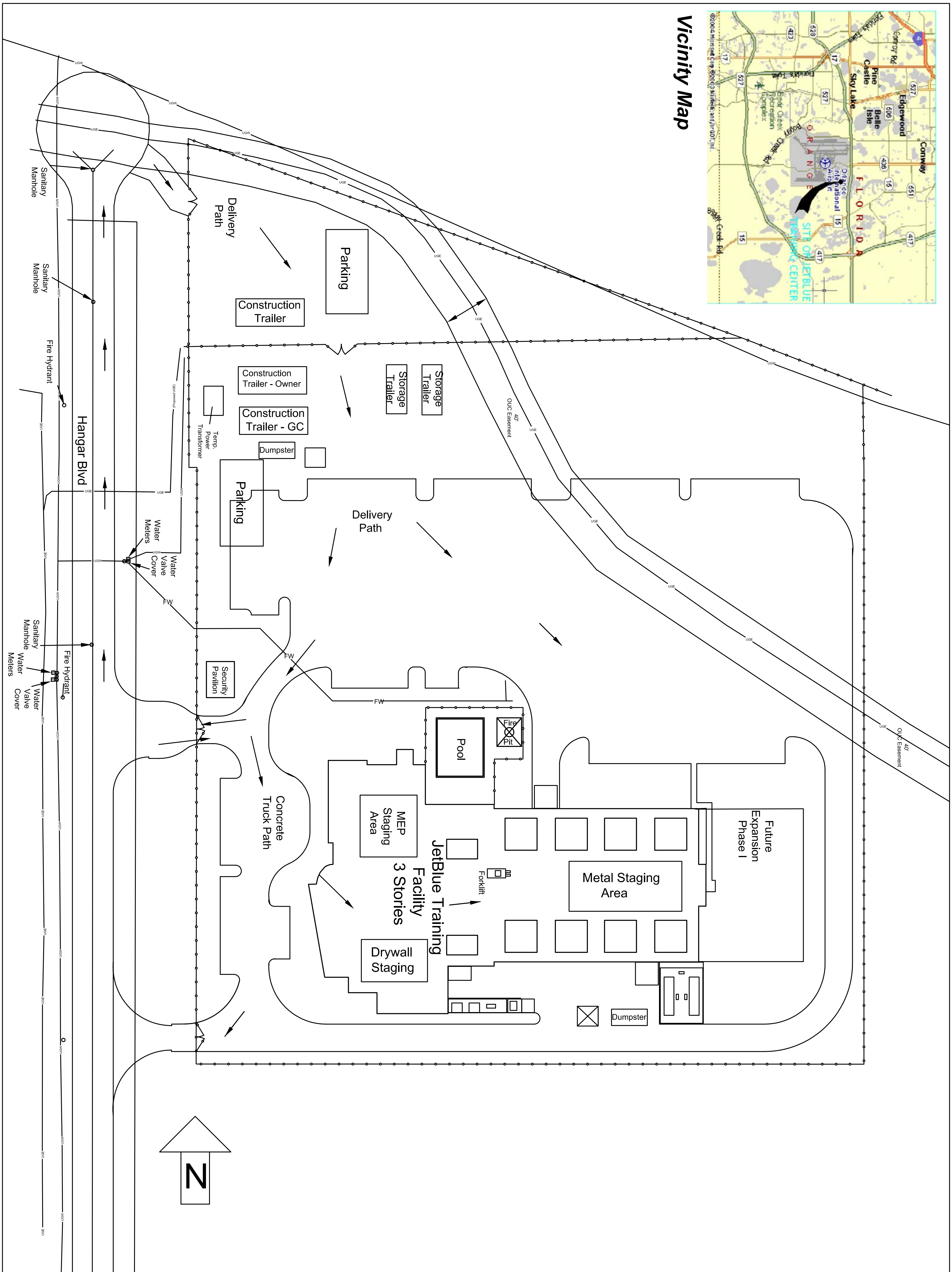


Finishes Site Plan

JetBlue Training Facility

Thesis 2004-2005

Orlando International Airport

8465 Hangar Blvd, Orlando, FL 32827

Drawn by: Sarah Lippai

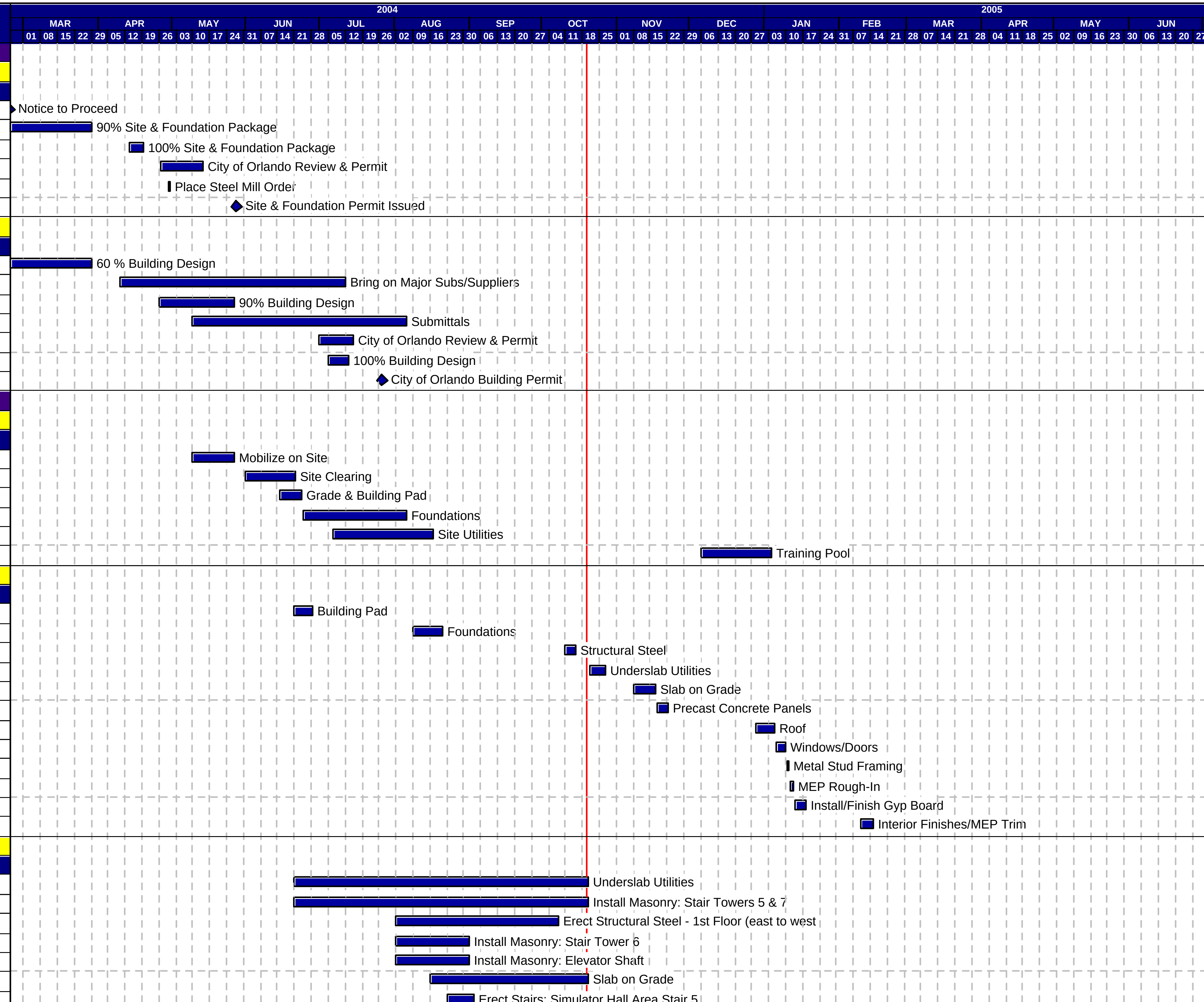
Date: 11.3.04

Sheet C-04

Revision

#	Date

Activity ID	Description	Original Duration	Early Start	Early Finish
Preconstruction				
Site & Foundations				
B190	Notice to Proceed	0	02/24/04	
B200	90% Site & Foundation Package	25	02/24/04	03/29/04
B210	100% Site & Foundation Package	4	04/14/04	04/19/04
B230	City of Orlando Review & Permit	47	04/27/04	05/14/04
B220	Place Steel Mill Order	0	04/30/04	04/30/04
B240	Site & Foundation Permit Issued	0		05/27/04
Building Structure & Envelope				
B140	60 % Building Design	25	02/24/04	03/29/04
B150	Bring on Major Subs/Suppliers	0	04/10/04	07/12/04
B160	90% Building Design	48	04/26/04	05/27/04
B130	Submittals	188	05/10/04	08/06/04
B180	City of Orlando Review & Permit	10	07/01/04	07/15/04
B170	100% Building Design	7	07/05/04	07/13/04
B250	City of Orlando Building Permit	0		07/26/04
Building Construction				
Sitework & Foundations				
ST100	Mobilize on Site	14	05/10/04	05/27/04
0016	Site Clearing	15	06/01/04	06/21/04
0017	Grade & Building Pad	15	06/15/04	06/24/04
0018	Foundations	30	06/25/04	08/06/04
0019	Site Utilities	30	07/07/04	08/17/04
0020	Training Pool	20	12/06/04	01/04/05
Guard Shack				
0090	Building Pad	5	06/21/04	06/28/04
0110	Foundations	10	08/09/04	08/21/04
0100	Structural Steel	5	10/11/04	10/15/04
0130	Underslab Utilities	5	10/21/04	10/27/04
0120	Slab on Grade	8	11/08/04	11/17/04
0140	Precast Concrete Panels	3	11/18/04	11/22/04
0150	Roof	5	12/29/04	01/05/05
0160	Windows/Doors	3	01/06/05	01/10/05
0170	Metal Stud Framing	1	01/11/05	01/11/05
0180	MEP Rough-In	2	01/12/05	01/13/05
0190	Install/Finish Gyp Board	3	01/14/05	01/18/05
0200	Interior Finishes/MEP Trim	4	02/10/05	02/15/05
Building Structure & Envelope				
1st Floor				
0022	Underslab Utilities	86	06/21/04	10/20/04
0023	Install Masonry: Stair Towers 5 & 7	25	06/21/04	10/20/04
0024	Erect Structural Steel - 1st Floor (east to west	49	08/02/04	10/08/04
0025	Install Masonry: Stair Tower 6	23	08/02/04	09/01/04
0026	Install Masonry: Elevator Shaft	23	08/02/04	09/01/04
0027	Slab on Grade	59	08/16/04	10/20/04
0028	Erect Stairs: Simulator Hall Area Stair 5	10	08/23/04	09/03/04



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Must finish date	06/01/05 9:59PM
Target finish date	
Run date	04/07/05 9:00AM
Page number	1A

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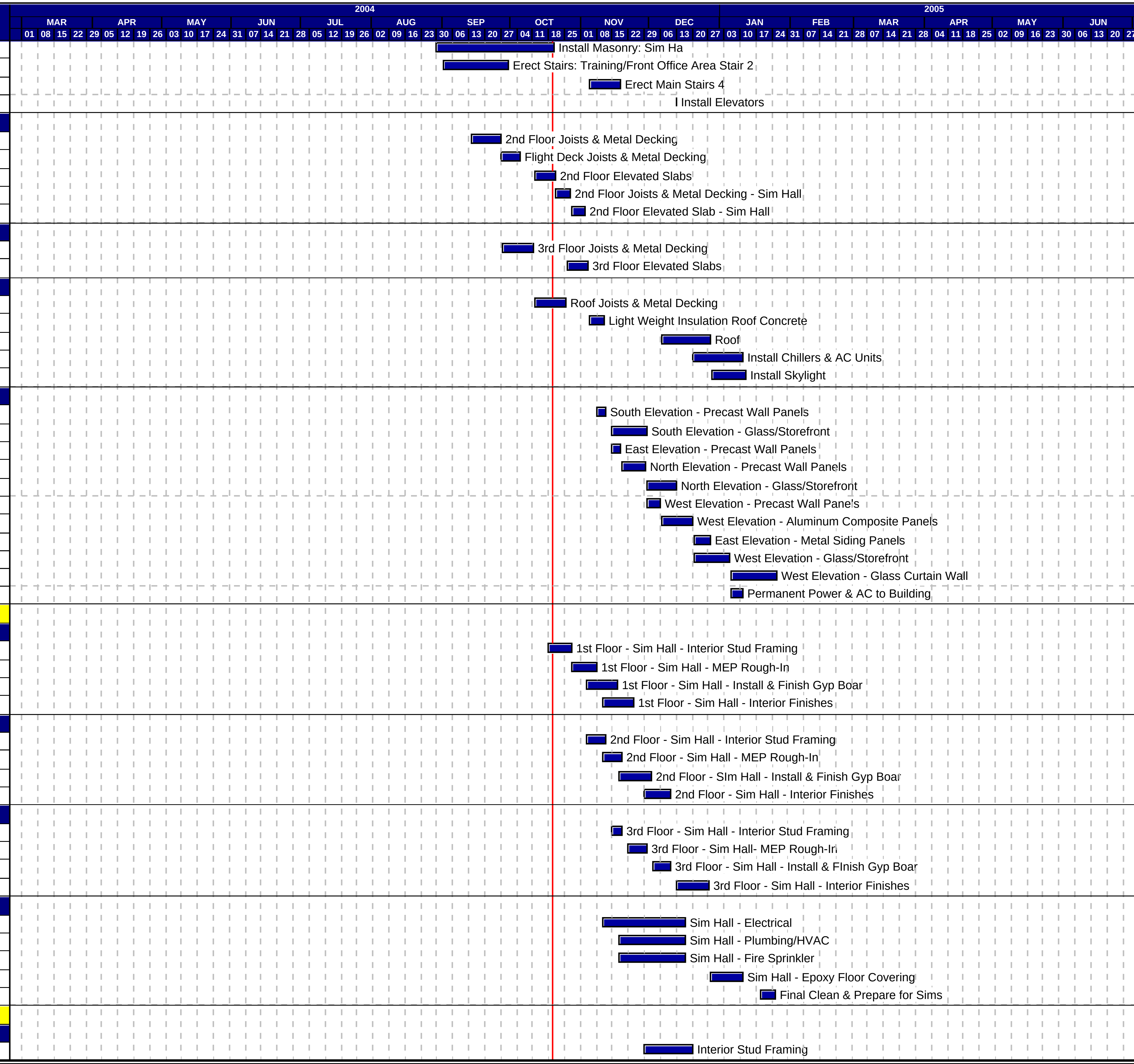
Sarah Lippai
Construction Management Option
Dr. Michael J. Horman

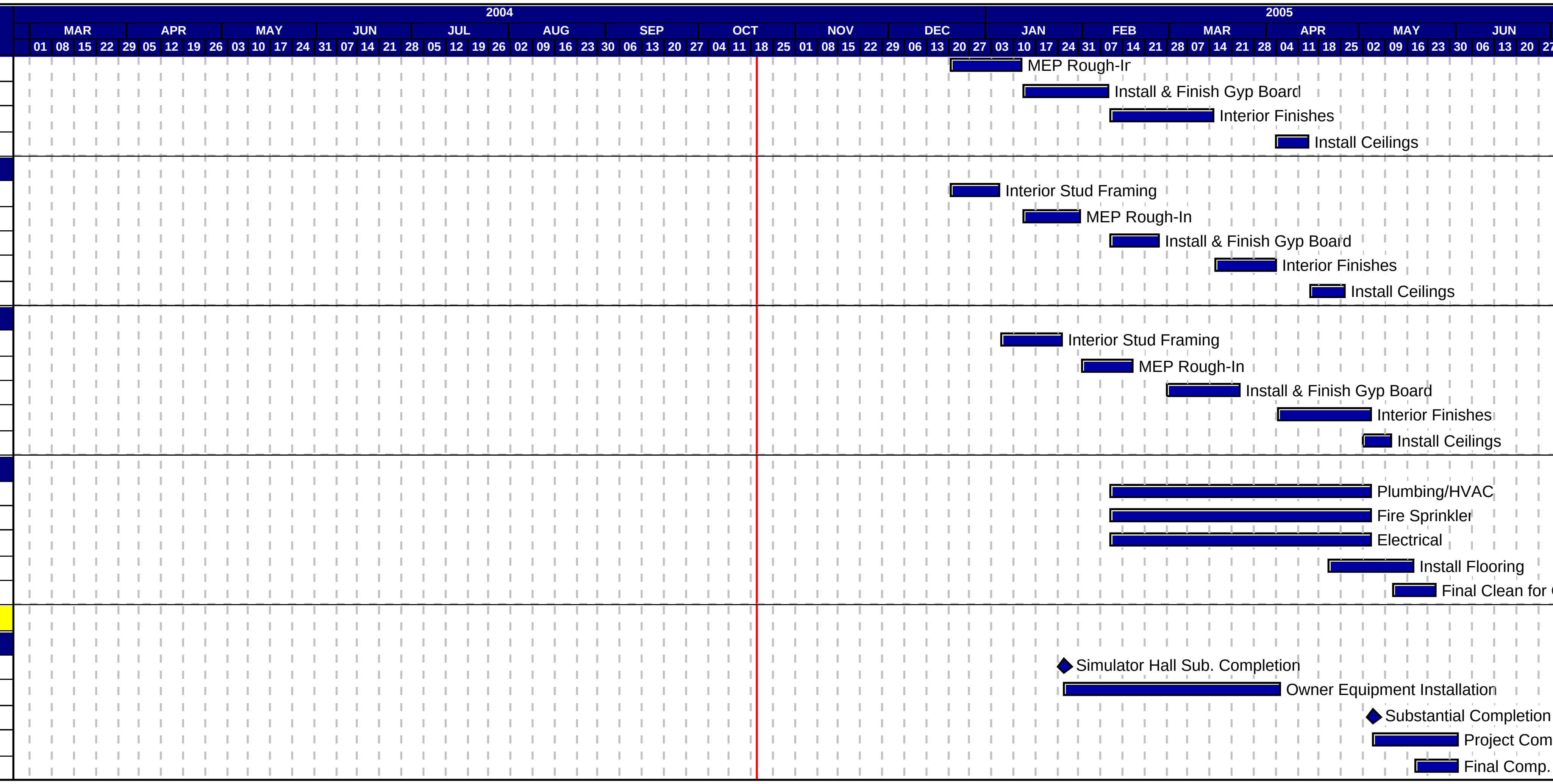
jetBlue Training Facility
Orlando International Airport
Project Schedule

Early bar
Progress bar
Critical bar
Summary bar
Progress point
Critical point
Summary point
Start milestone point
Finish milestone point

Activity ID	Description	Original Duration	Early Start	Early Finish
0029	Install Masonry: Sim Hall	72	08/30/04	10/20/04
0030	Erect Stairs: Training/Front Office Area Stair 2	20	09/02/04	09/30/04
0031	Erect Main Stairs 4	10	11/05/04	11/18/04
0032	Install Elevators	40	12/13/04	12/13/04
2nd Floor				
0033	2nd Floor Joists & Metal Decking	10	09/14/04	09/27/04
0034	Flight Deck Joists & Metal Decking	7	09/27/04	10/05/04
0035	2nd Floor Elevated Slabs	8	10/12/04	10/21/04
0036	2nd Floor Joists & Metal Decking - Sim Hall	5	10/21/04	10/27/04
0037	2nd Floor Elevated Slab - Sim Hall	5	10/28/04	11/03/04
3rd Floor				
0038	3rd Floor Joists & Metal Decking	10	09/28/04	10/11/04
0039	3rd Floor Elevated Slabs	8	10/26/04	11/04/04
Roof				
0040	Roof Joists & Metal Decking	10	10/12/04	10/25/04
0041	Light Weight Insulation Roof Concrete	5	11/05/04	11/11/04
0042	Roof	15	12/07/04	12/28/04
0043	Install Chillers & AC Units	15	12/20/04	01/11/05
0044	Install Skylight	10	12/29/04	01/12/05
Exterior Finish				
0045	South Elevation - Precast Wall Panels	5	11/08/04	11/12/04
0046	South Elevation - Glass/Storefront	10	11/15/04	11/30/04
0047	East Elevation - Precast Wall Panels	4	11/15/04	11/18/04
0048	North Elevation - Precast Wall Panels	5	11/19/04	11/29/04
0049	North Elevation - Glass/Storefront	10	11/30/04	12/13/04
0050	West Elevation - Precast Wall Panels	5	11/30/04	12/06/04
0051	West Elevation - Aluminum Composite Panels	10	12/07/04	12/20/04
0052	East Elevation - Metal Siding Panels	5	12/21/04	12/28/04
0053	West Elevation - Glass/Storefront	10	12/21/04	01/05/05
0054	West Elevation - Glass Curtain Wall	15	01/06/05	01/26/05
0055	Permanent Power & AC to Building	4	01/06/05	01/11/05
Simulator Hall				
1st Floor				
0056	1st Floor - Sim Hall - Interior Stud Framing	9	10/18/04	10/28/04
0057	1st Floor - Sim Hall - MEP Rough-In	8	10/28/04	11/08/04
0058	1st Floor - Sim Hall - Install & Finish Gyp Boar	10	11/04/04	11/17/04
0059	1st Floor - Sim Hall - Interior Finishes	10	11/11/04	11/24/04
2nd Floor				
0060	2nd Floor - Sim Hall - Interior Stud Framing	7	11/04/04	11/12/04
0061	2nd Floor - Sim Hall - MEP Rough-In	7	11/11/04	11/19/04
0062	2nd Floor - SIm Hall - Install & Finish Gyp Boar	9	11/18/04	12/02/04
0063	2nd Floor - Sim Hall - Interior Finishes	10	11/29/04	12/10/04
3rd Floor				
0064	3rd Floor - Sim Hall - Interior Stud Framing	5	11/15/04	11/19/04
0065	3rd Floor - Sim Hall- MEP Rough-In	5	11/22/04	11/30/04
0066	3rd Floor - Sim Hall - Install & FInish Gyp Boar	6	12/03/04	12/10/04
0067	3rd Floor - Sim Hall - Interior Finishes	10	12/13/04	12/27/04
0068	Sim Hall - Electrical	25	11/11/04	12/17/04
0069	Sim Hall - Plumbing/HVAC	20	11/18/04	12/17/04
0070	Sim Hall - Fire Sprinkler	20	11/18/04	12/17/04
0071	Sim Hall - Epoxy Floor Covering	10	12/28/04	01/11/05
0072	Final Clean & Prepare for Sims	5	01/19/05	01/25/05
Training & Front Office				
1st Floor				
0073	Interior Stud Framing	16	11/29/04	12/20/04



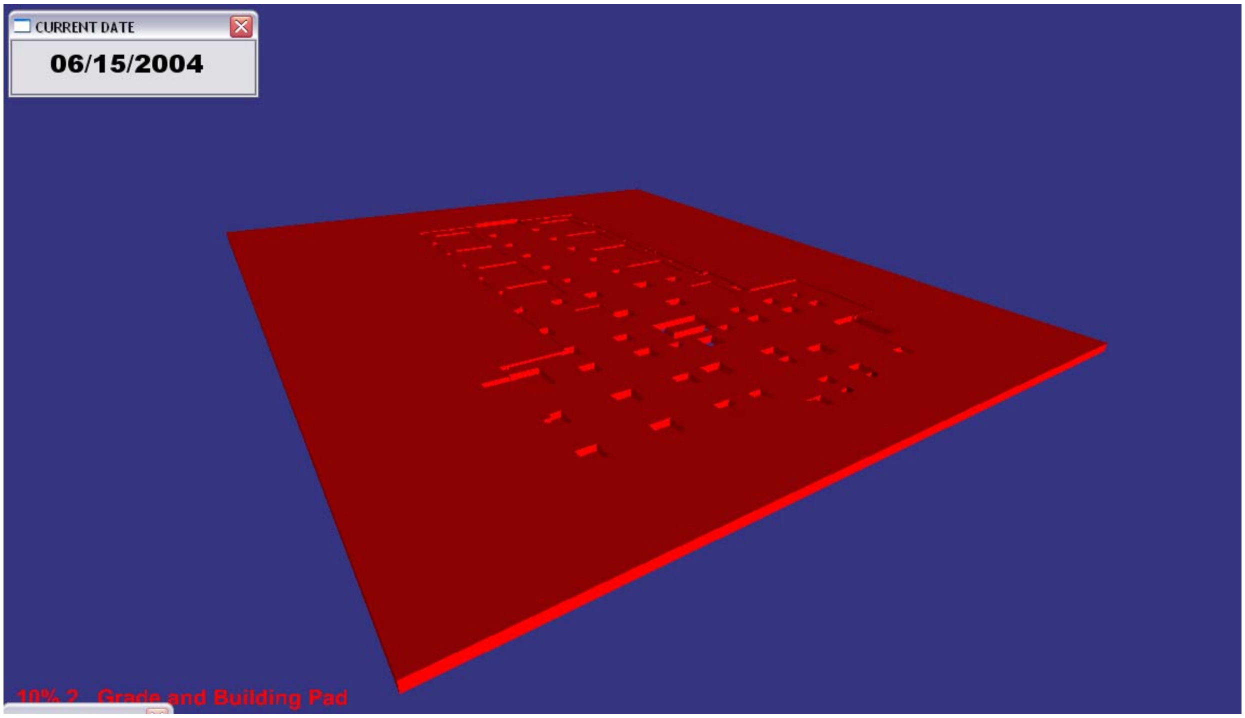
Activity ID	Description	Original Duration	Early Start	Early Finish
0083	MEP Rough-In	15	12/21/04	01/12/05
0093	Install & Finish Gyp Board	20	01/13/05	02/09/05
0103	Interior Finishes	24	02/10/05	03/15/05
0113	Install Ceilings	9	04/04/05	04/14/05
2nd Floor				
0123	Interior Stud Framing	10	12/21/04	01/05/05
0133	MEP Rough-In	13	01/13/05	01/31/05
0143	Install & Finish Gyp Board	12	02/10/05	02/25/05
0153	Interior Finishes	14	03/16/05	04/04/05
0163	Install Ceilings	8	04/15/05	04/26/05
3rd Floor				
0173	Interior Stud Framing	14	01/06/05	01/25/05
0183	MEP Rough-In	13	02/01/05	02/17/05
0193	Install & Finish Gyp Board	18	02/28/05	03/23/05
0203	Interior Finishes	22	04/05/05	05/04/05
0213	Install Ceilings	8	05/02/05	05/11/05
0233	Plumbing/HVAC	60	02/10/05	05/04/05
0243	Fire Sprinkler	60	02/10/05	05/04/05
0253	Electrical	60	02/10/05	05/04/05
0263	Install Flooring	20	04/21/05	05/18/05
0273	Final Clean for C.O.	10	05/12/05	05/25/05
Project Completion & Commissioning				
0293	Simulator Hall Sub. Completion	0		01/25/05
0283	Owner Equipment Installation	50	01/26/05	04/05/05
0303	Substantial Completion	0		05/04/05
0313	Project Commissioning	19	05/05/05	06/01/05
0323	Final Comp. & Certificate of Occupancy	9	05/19/05	06/01/05

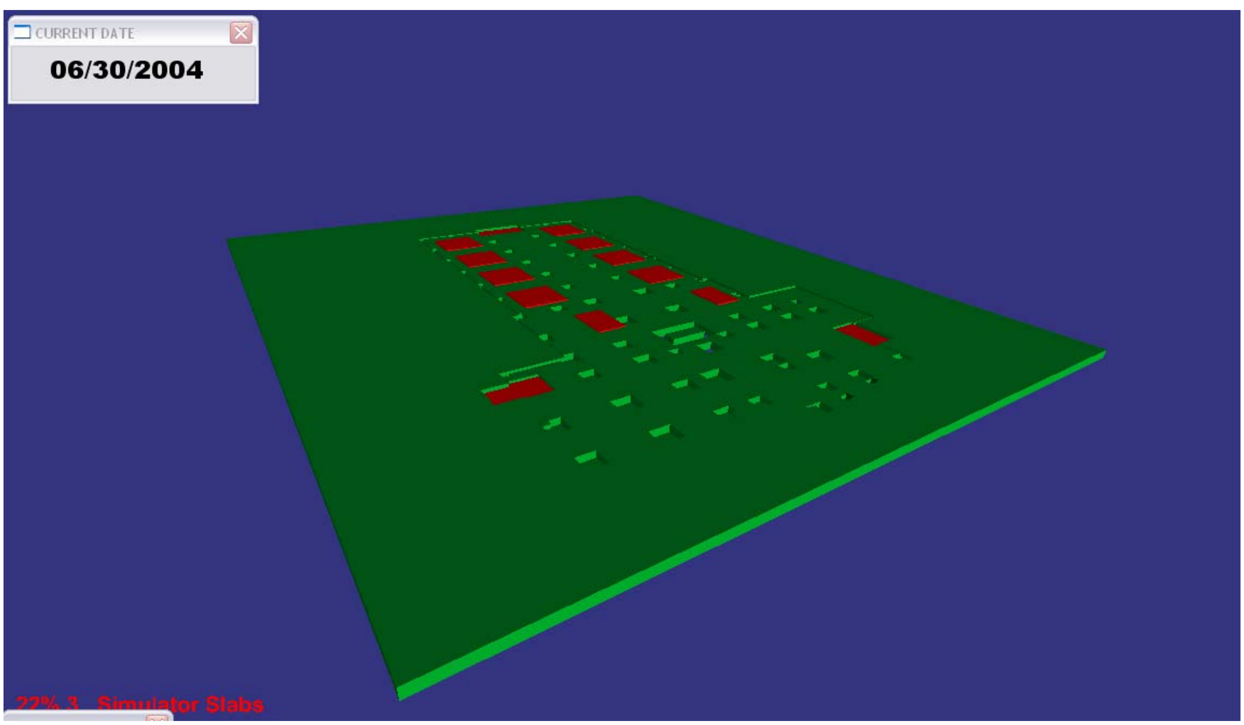


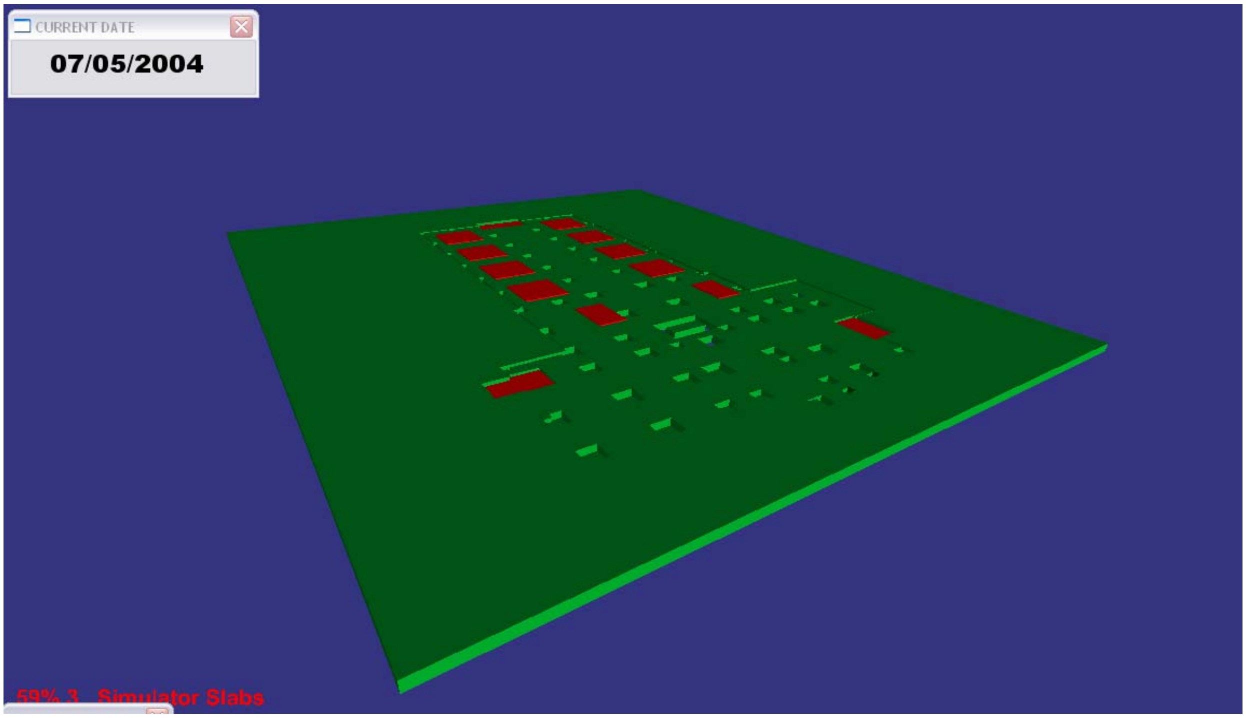
Appendix B

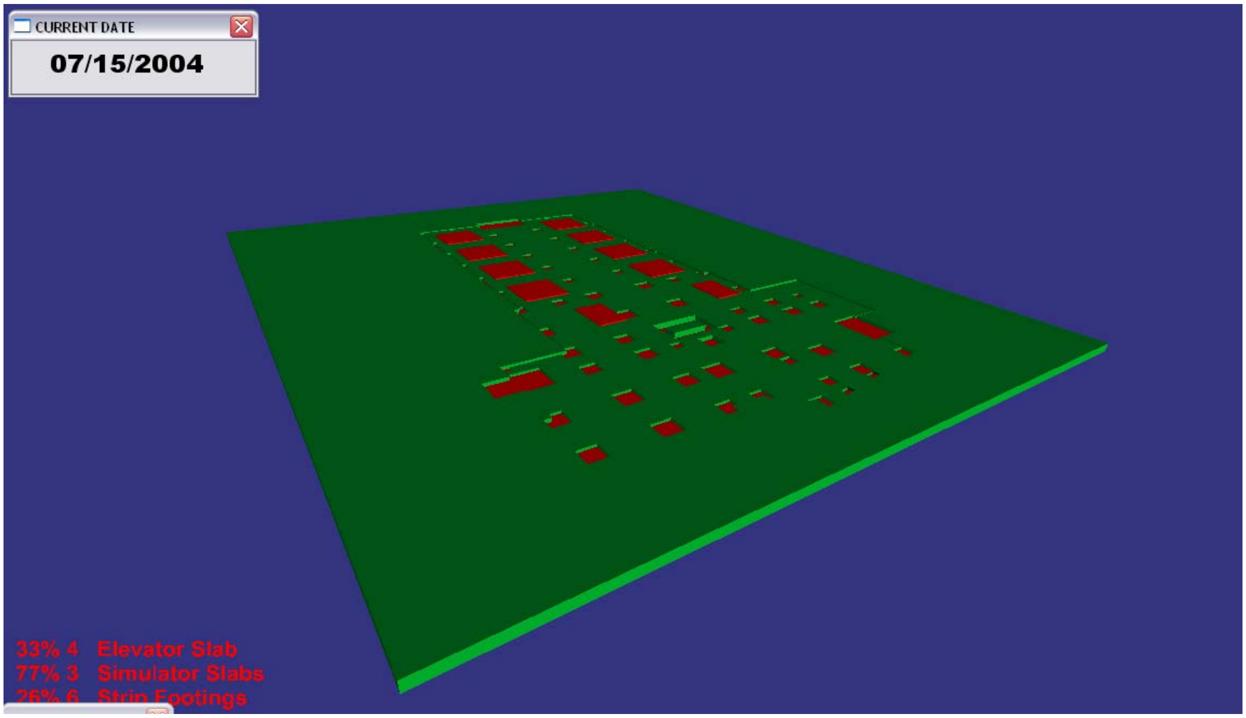
4D CAD Simulation

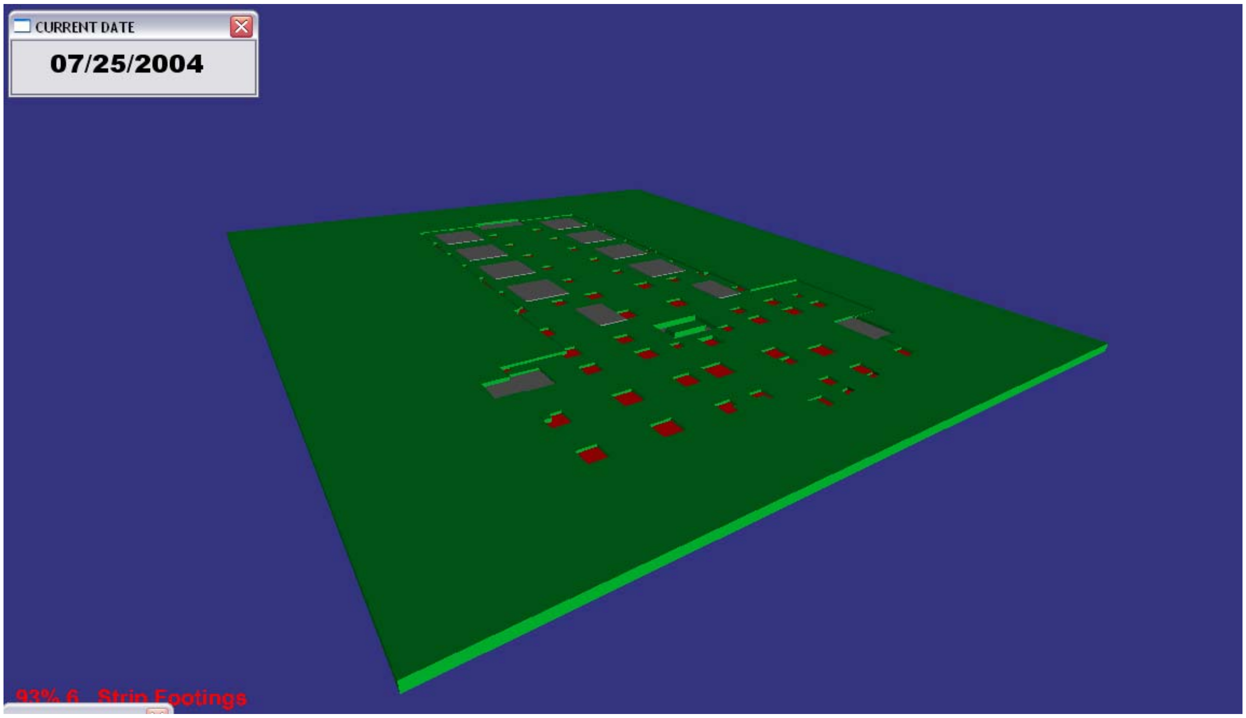
Simulation Schedule

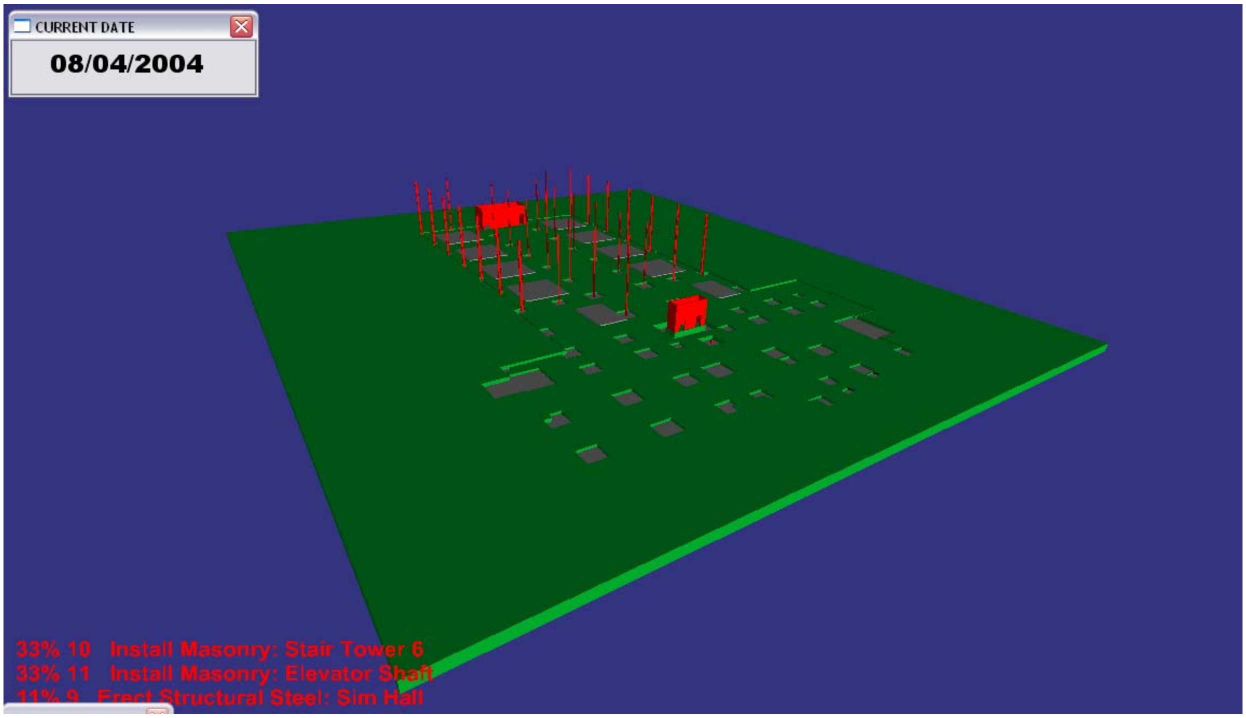

CURRENT DATE
06/15/2004
10% 2 Grade and Building Pad

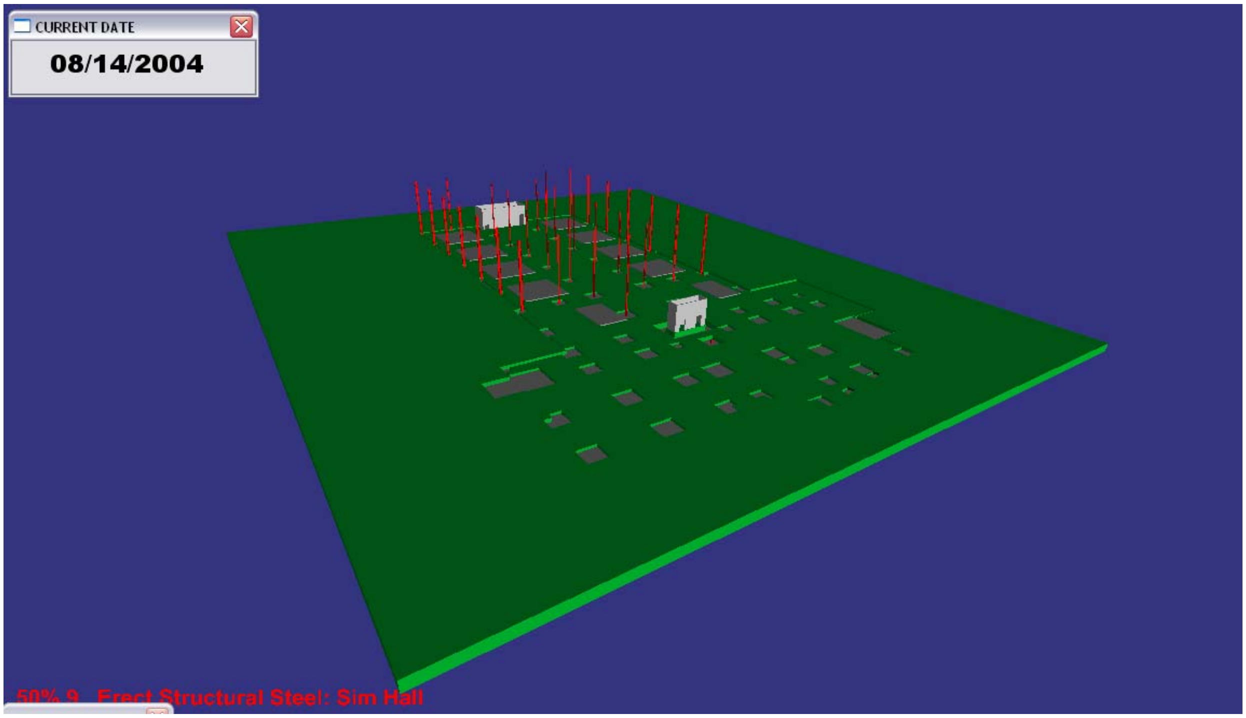

CURRENT DATE
06/30/2004
22% 3 Simulator Slabs

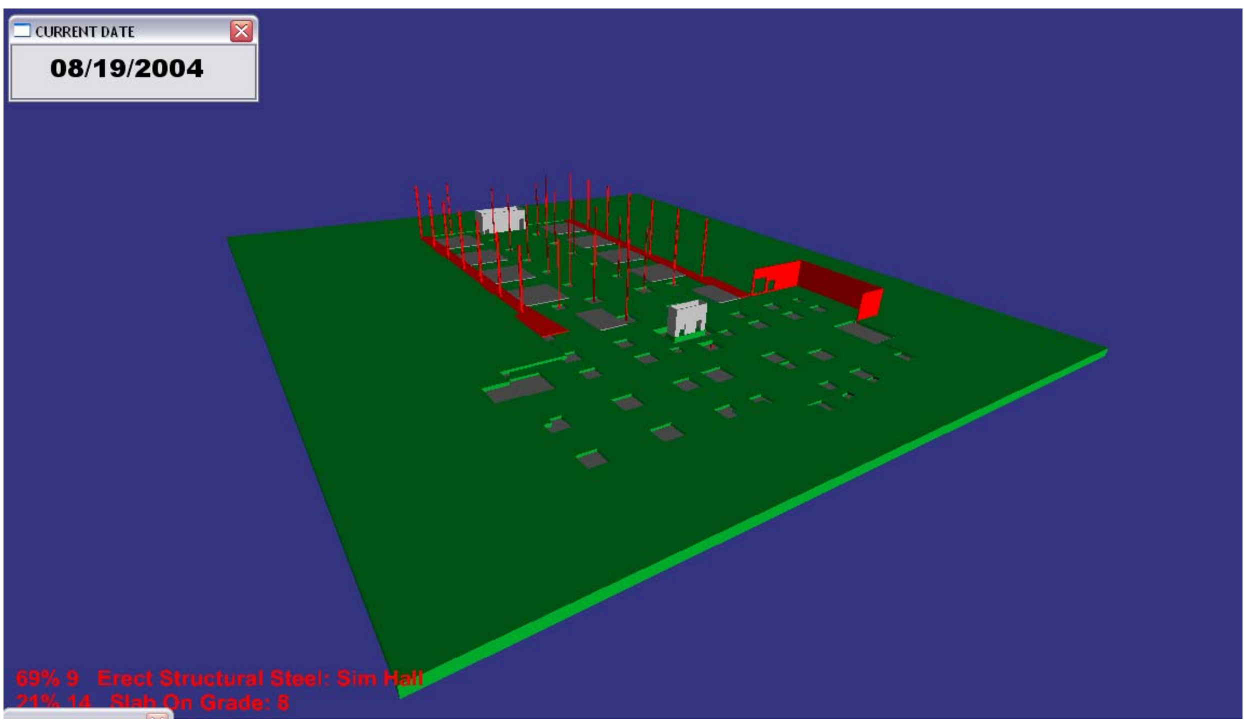

CURRENT DATE
07/05/2004
59% 3 Simulator Slabs

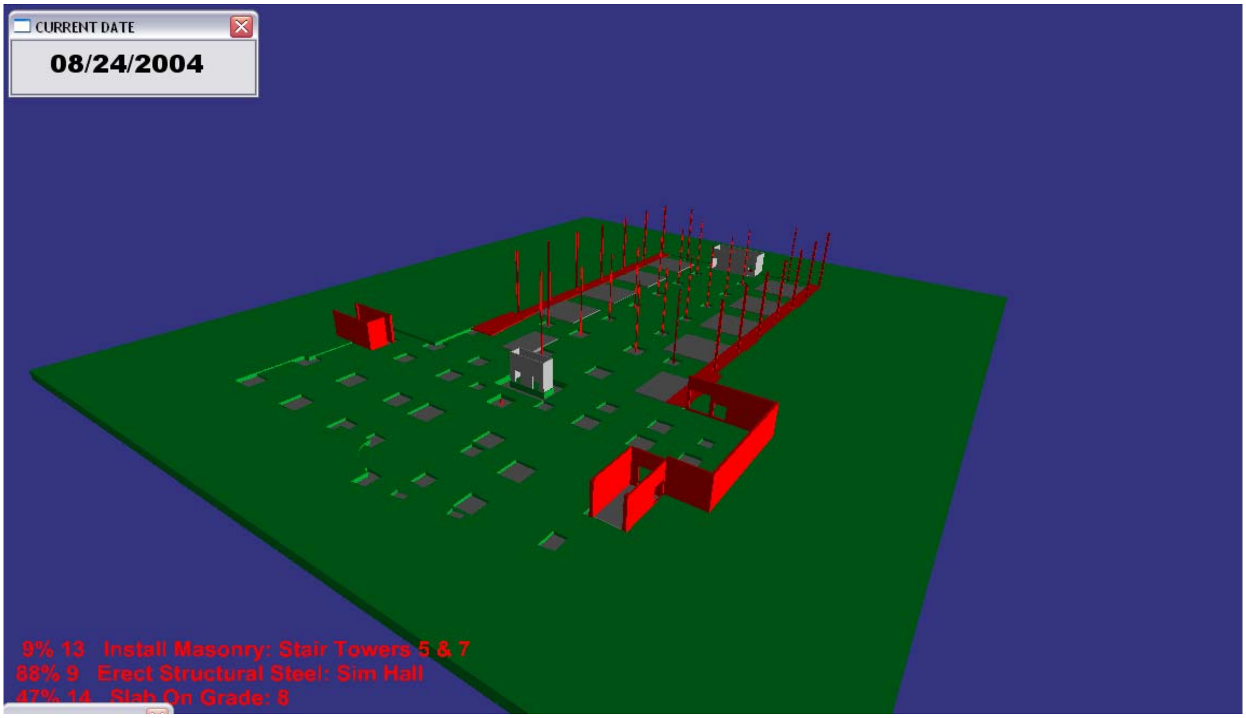

CURRENT DATE
07/15/2004
33% 4 Elevator Slab
77% 3 Simulator Slabs
26% 6 Strip Footings

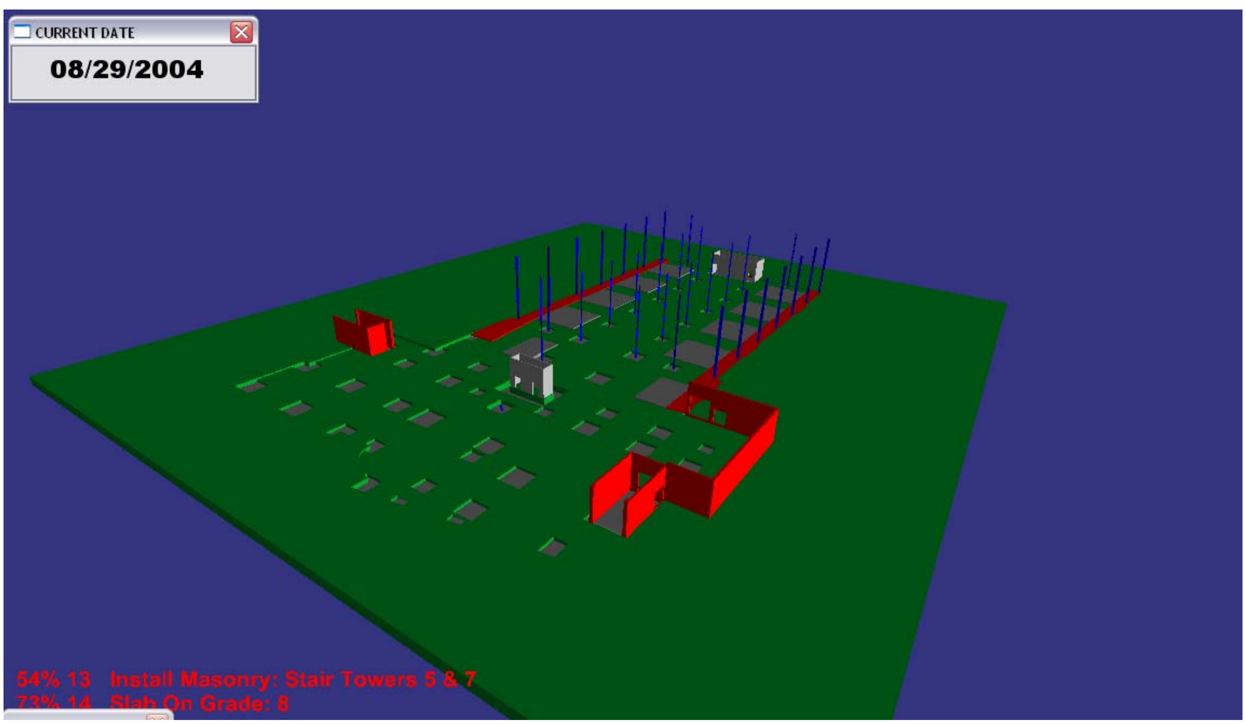

CURRENT DATE
07/25/2004
93% 6 Strip Footings

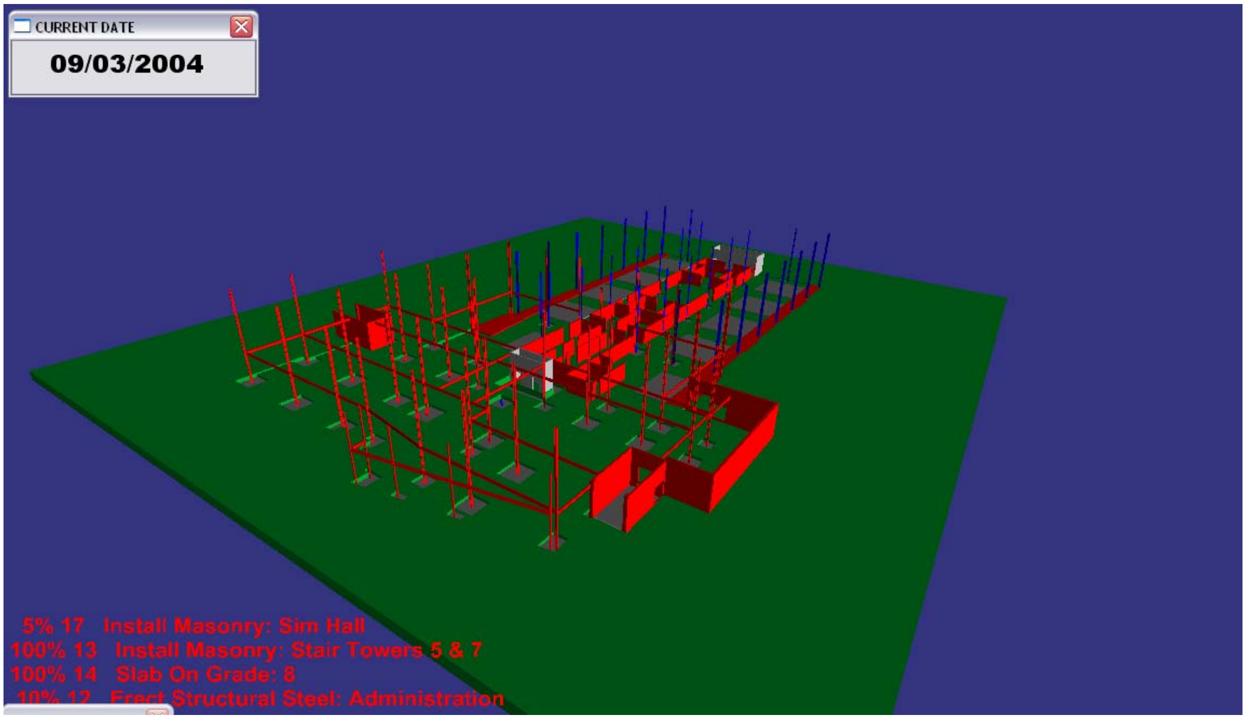

CURRENT DATE
08/04/2004
33% 10 Install Masonry: Stair Tower 6
33% 11 Install Masonry: Elevator Shaft
11% 9 Erect Structural Steel: Sim Hall

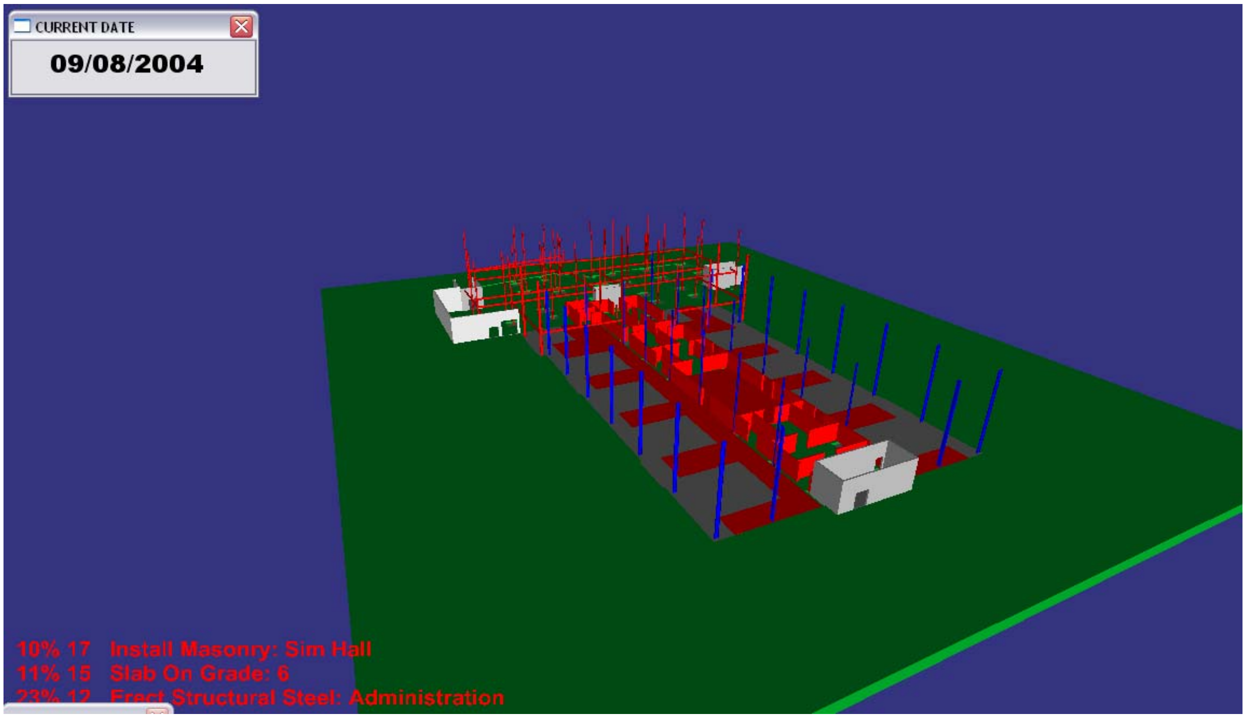

CURRENT DATE
08/14/2004
50% 9 Erect Structural Steel: Sim Hall

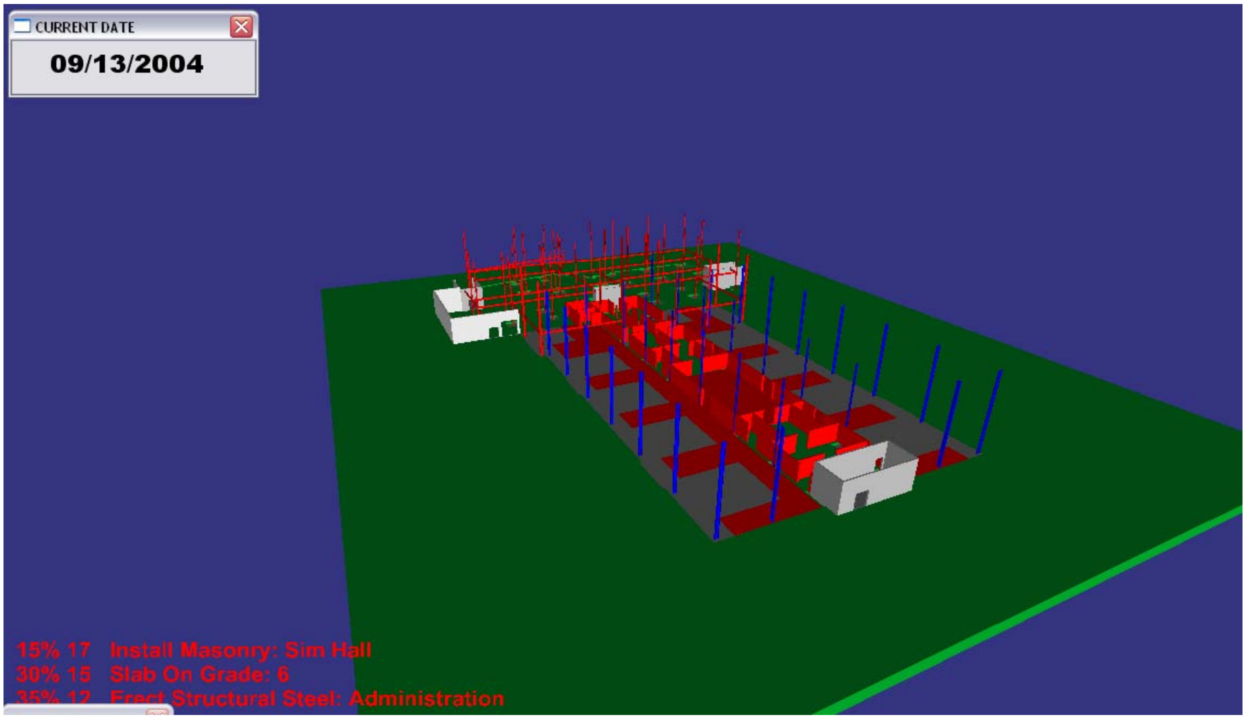

CURRENT DATE
08/19/2004
69% 9 Erect Structural Steel: Sim Hall
21% 14 Slab On Grade: 8

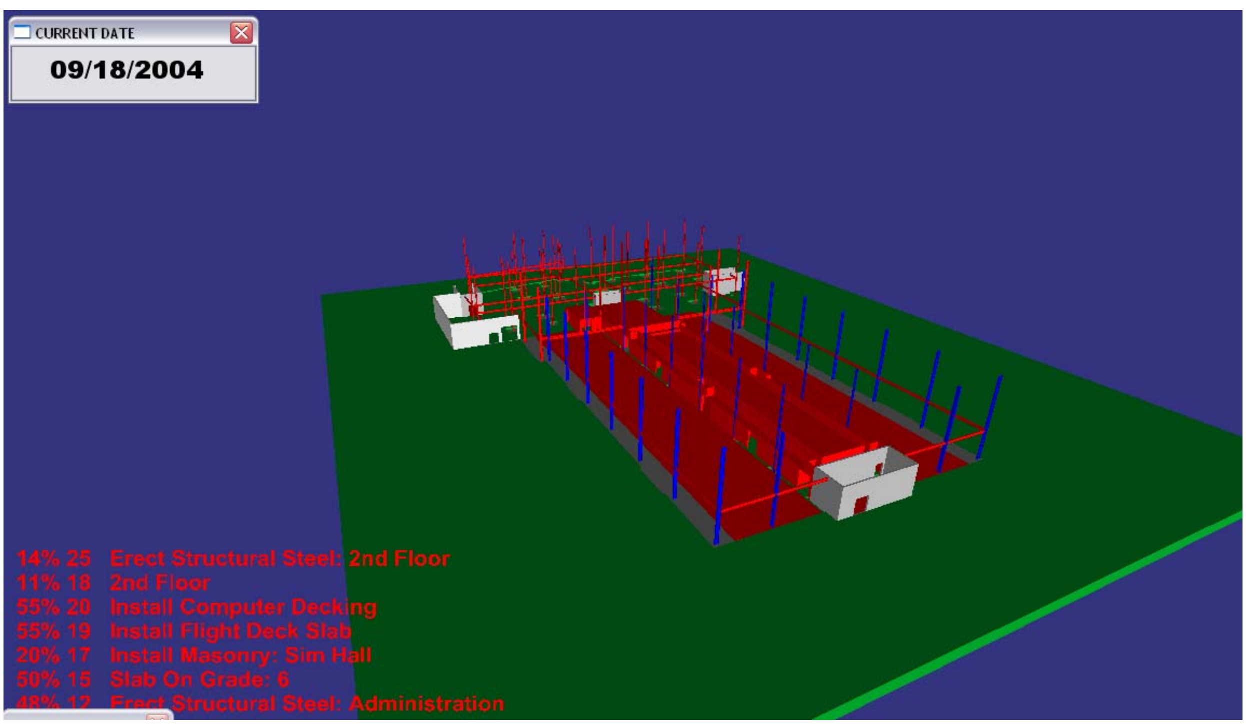

CURRENT DATE
08/24/2004
9% 13 Install Masonry: Stair Towers 5 & 7
88% 9 Erect Structural Steel: Sim Hall
47% 14 Slab On Grade: 8

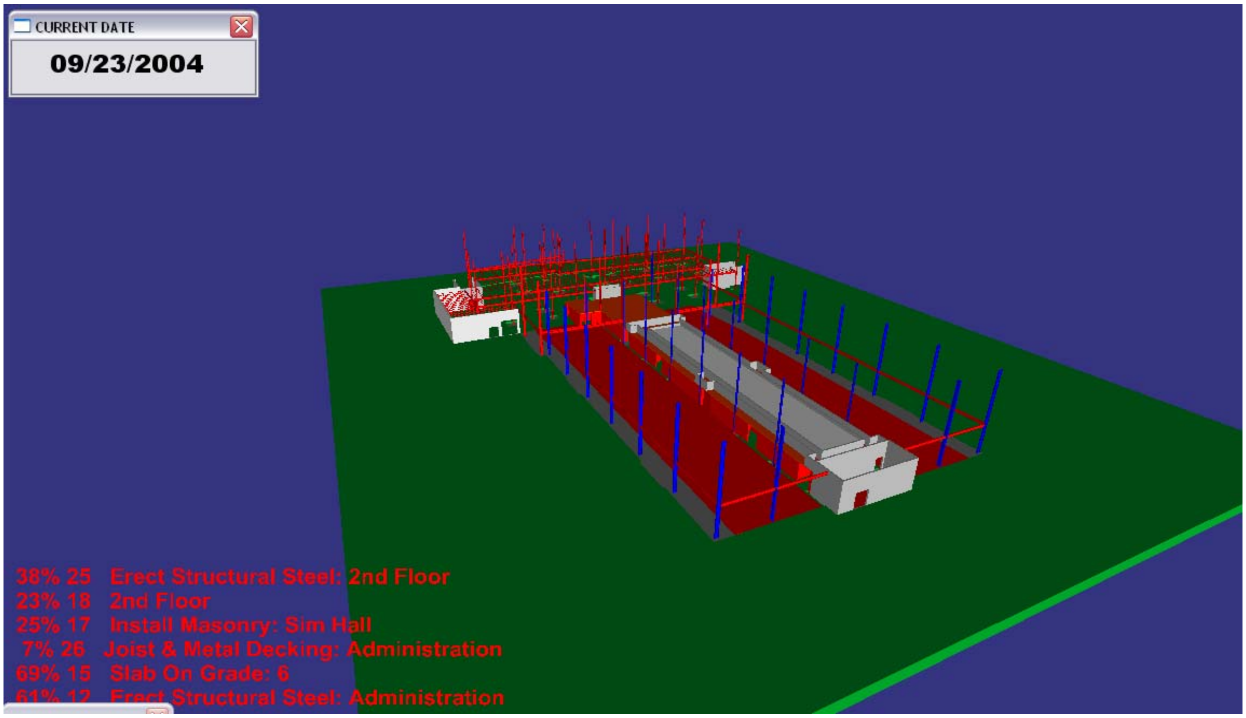

CURRENT DATE
08/29/2004
54% 13 Install Masonry: Stair Towers 5 & 7
73% 14 Slab On Grade: 8

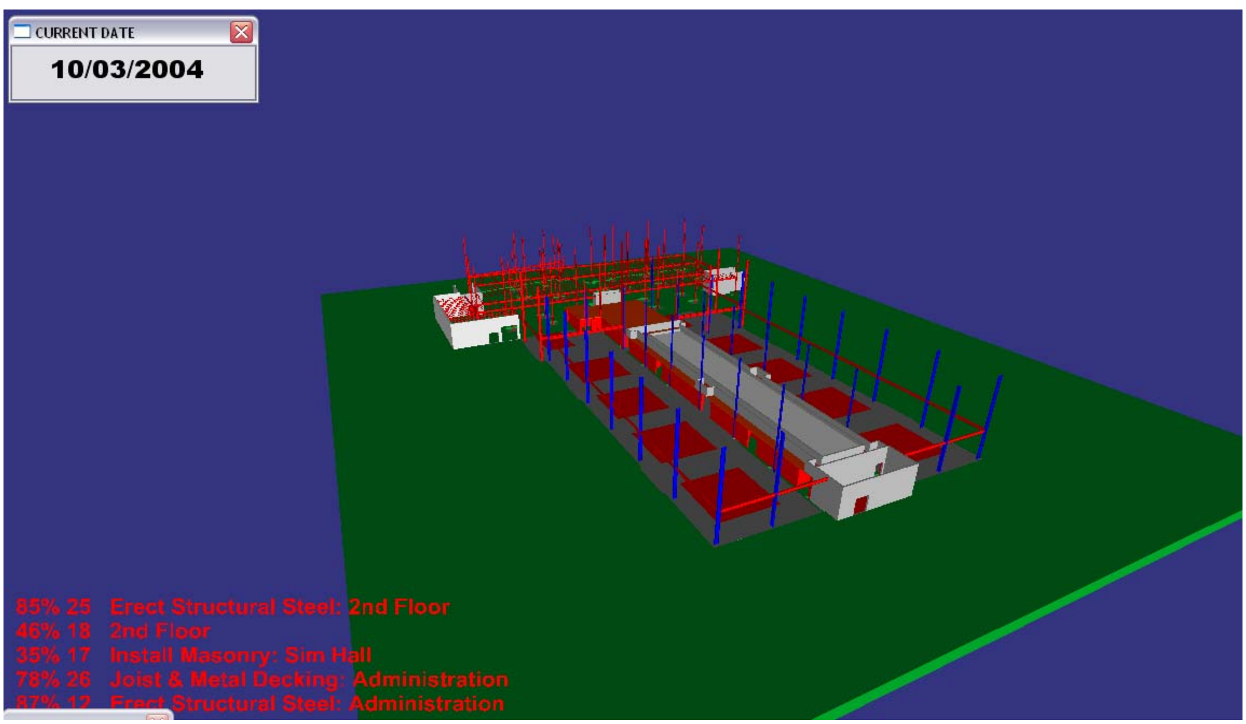

CURRENT DATE
09/03/2004
5% 17 Install Masonry: Sim Hall
100% 13 Install Masonry: Stair Towers 5 & 7
100% 14 Slab On Grade: 8
10% 12 Erect Structural Steel: Administration

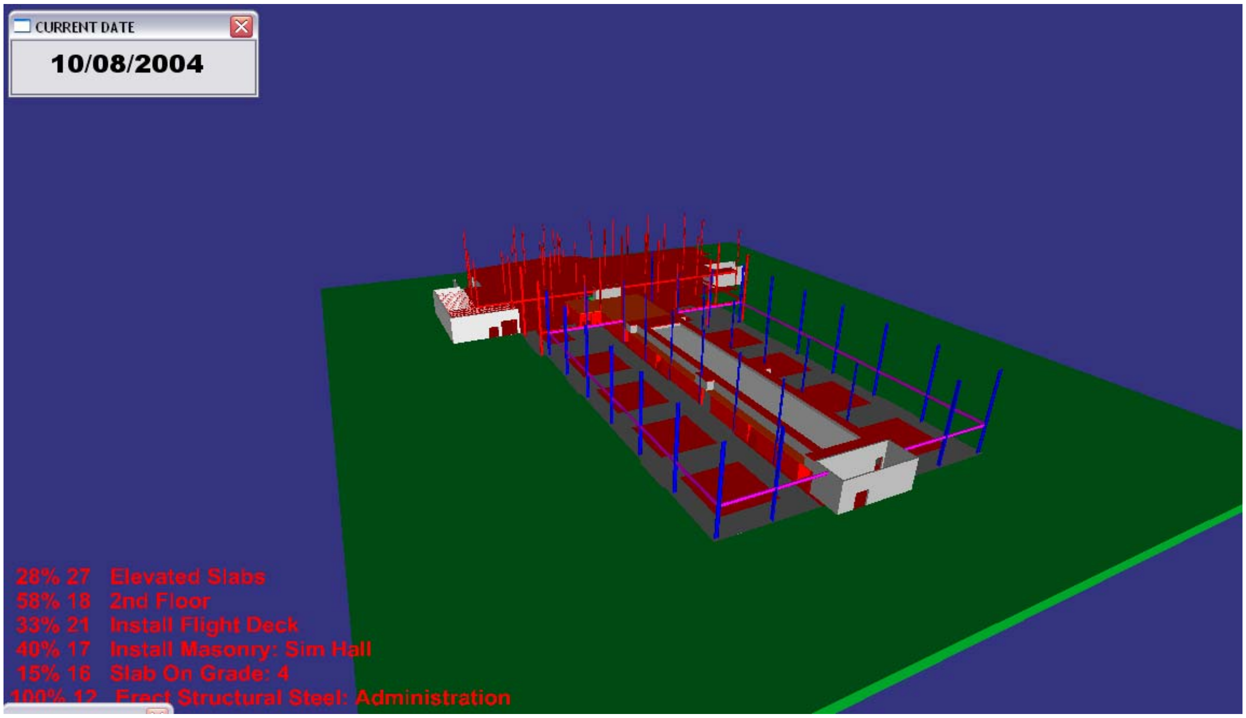

CURRENT DATE
09/08/2004
10% 17 Install Masonry: Sim Hall
11% 15 Slab On Grade: 6
23% 12 Erect Structural Steel: Administration

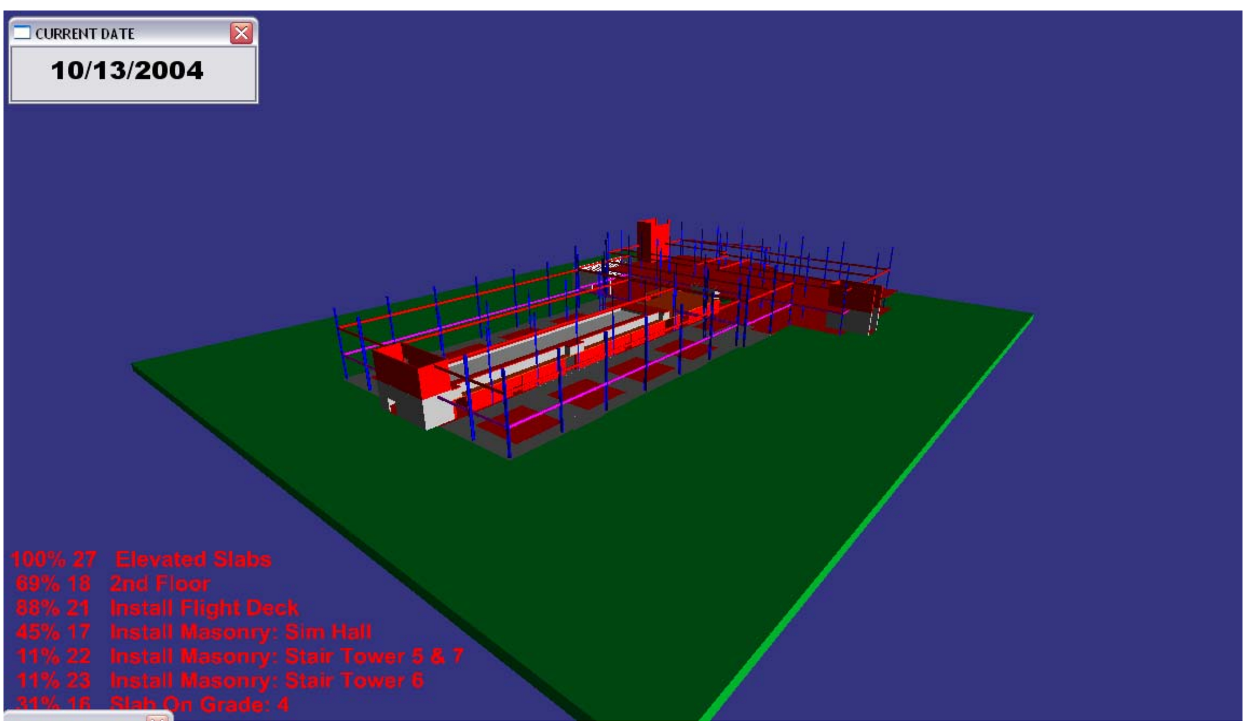

CURRENT DATE
09/13/2004
15% 17 Install Masonry: Sim Hall
30% 15 Slab On Grade: 6
Erect Structural Steel: Administration

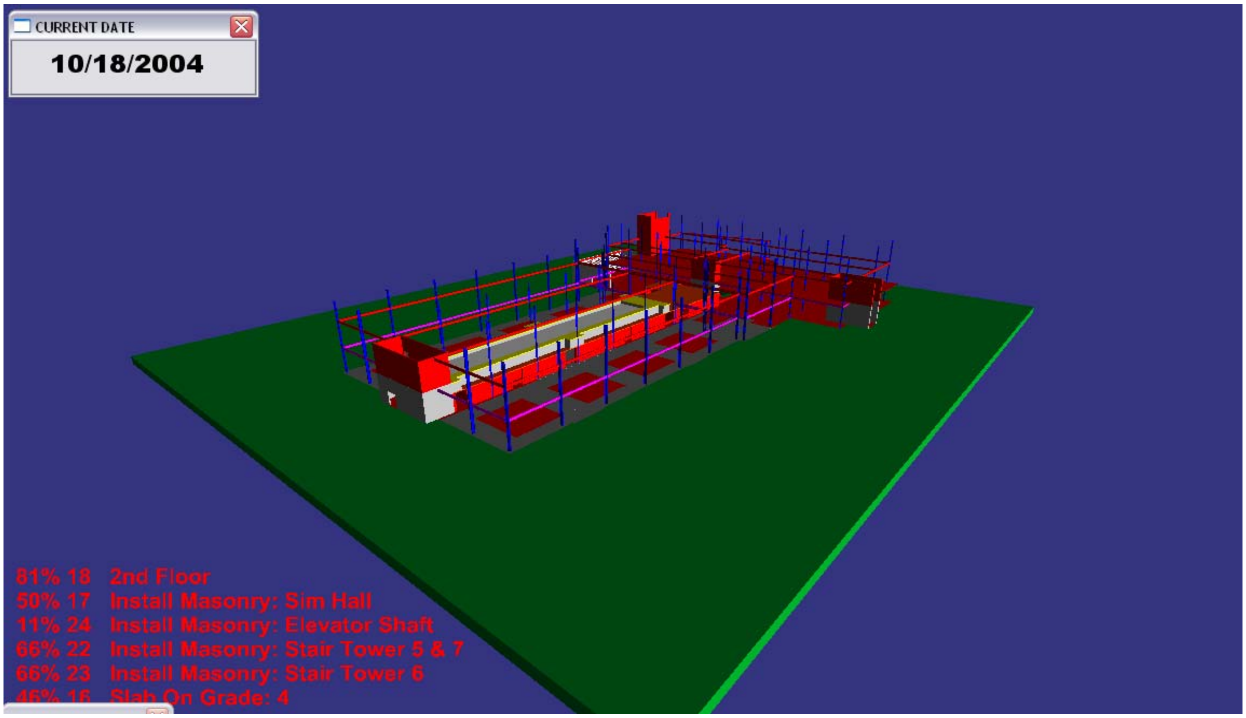

CURRENT DATE
09/18/2004
14% 25 Erect Structural Steel: 2nd Floor
11% 18 2nd Floor
55% 20 Install Computer Decking
55% 19 Install Flight Deck Slab
20% 17 Install Masonry: Sim Hall
50% 15 Slab On Grade: 6
Erect Structural Steel: Administration

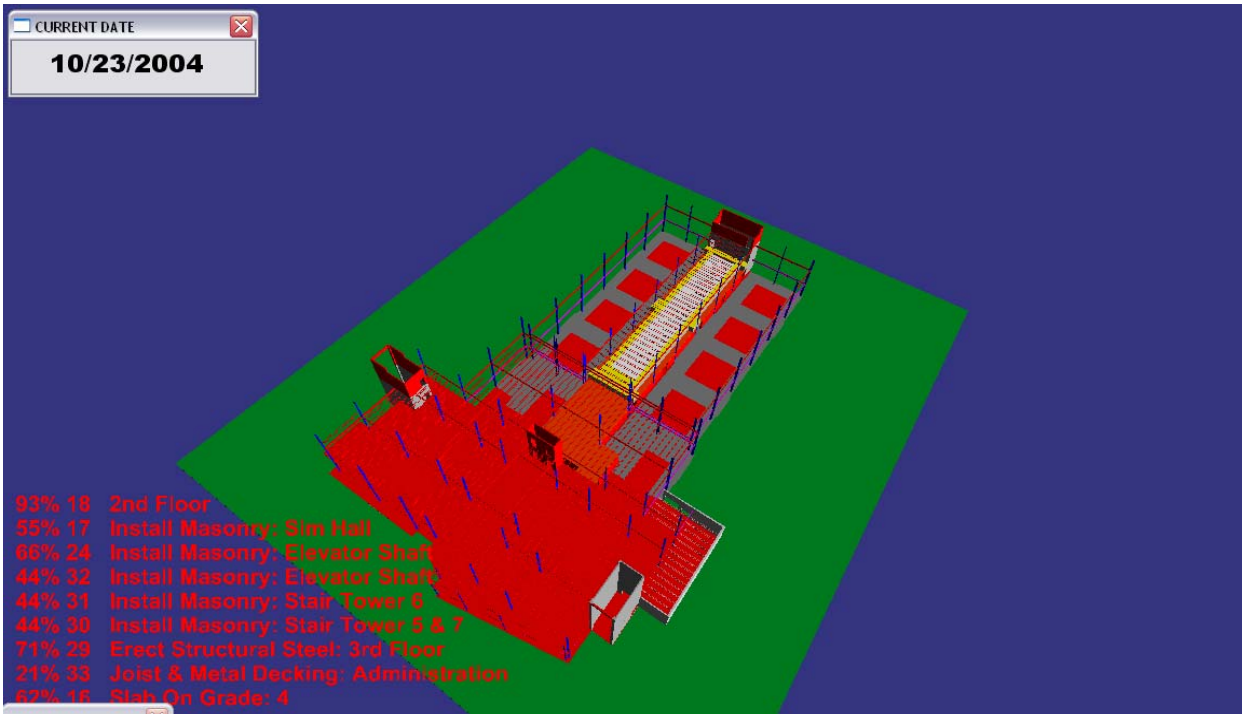

CURRENT DATE
09/23/2004
38% 25 Erect Structural Steel: 2nd Floor
23% 18 2nd Floor
25% 17 Install Masonry: Sim Hall
7% 26 Joist & Metal Decking: Administration
69% 15 Slab On Grade: 6
Erect Structural Steel: Administration

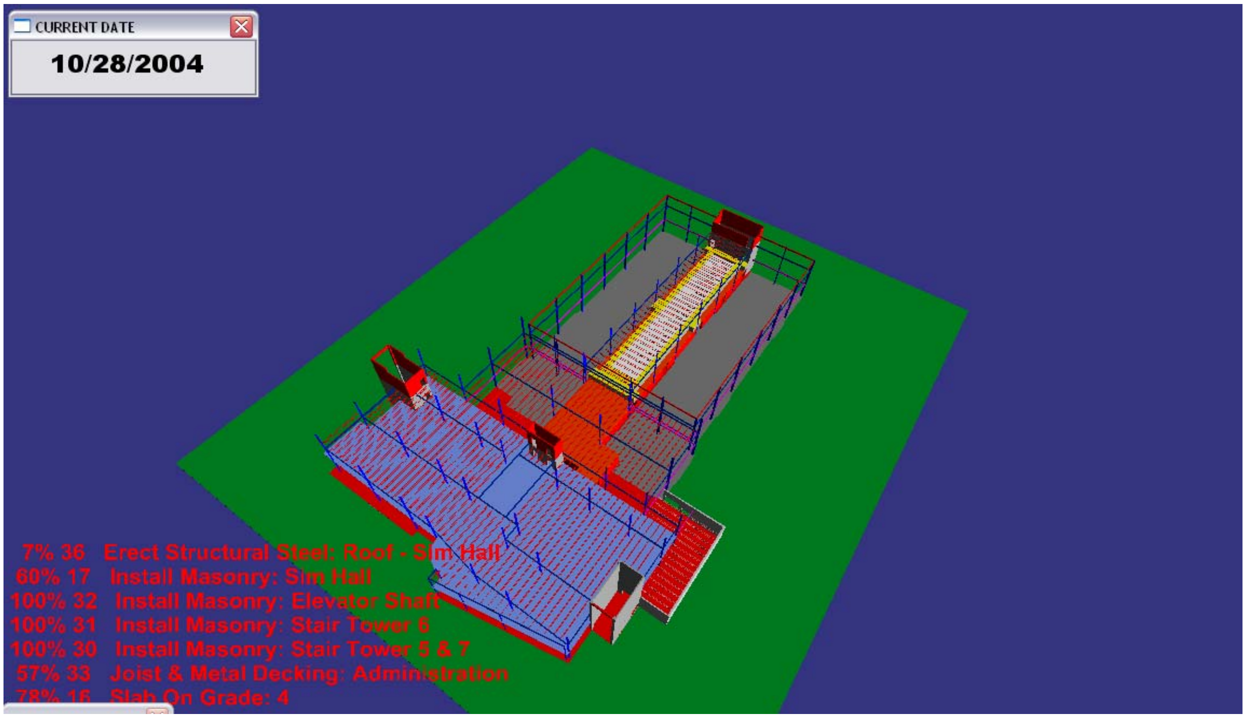

CURRENT DATE
10/03/2004
85% 25 Erect Structural Steel: 2nd Floor
46% 18 2nd Floor
35% 17 Install Masonry: Sim Hall
78% 26 Joist & Metal Decking: Administration
Erect Structural Steel: Administration

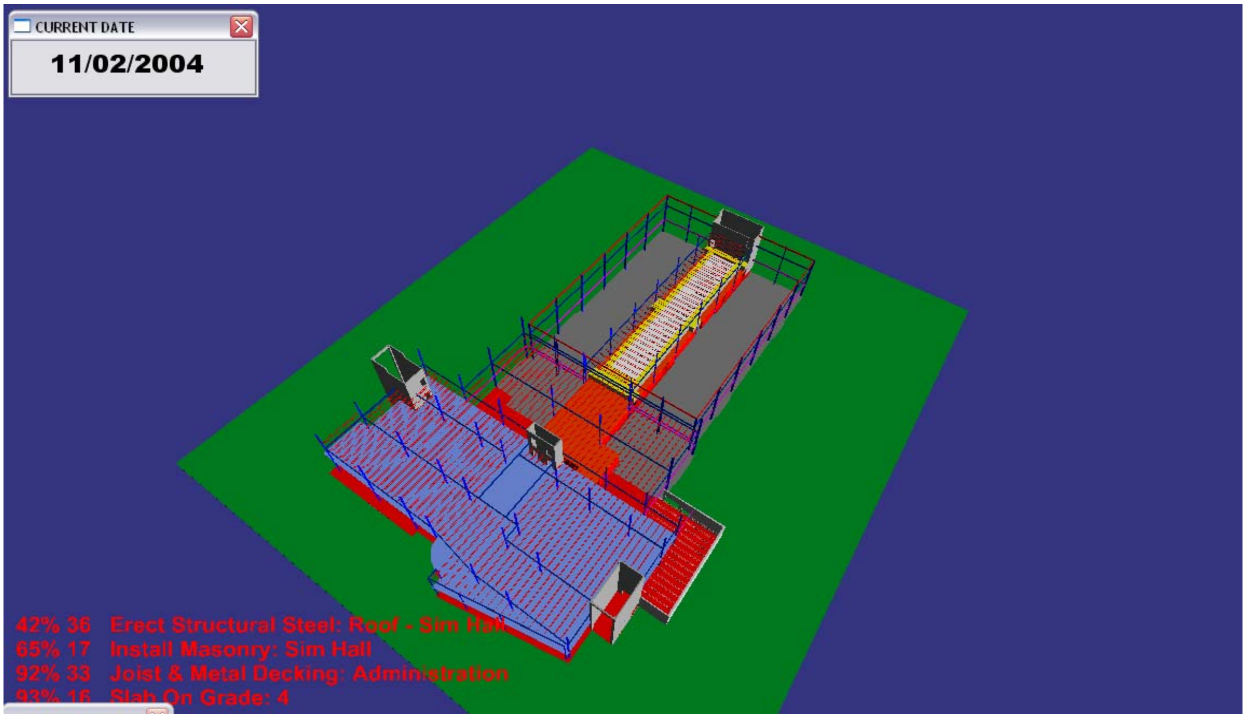

CURRENT DATE
10/08/2004
28% 27 Elevated Slabs
58% 18 2nd Floor
33% 21 Install Flight Deck
40% 17 Install Masonry: Sim Hall
15% 16 Slab On Grade: 4
100% 12 Erect Structural Steel: Administration

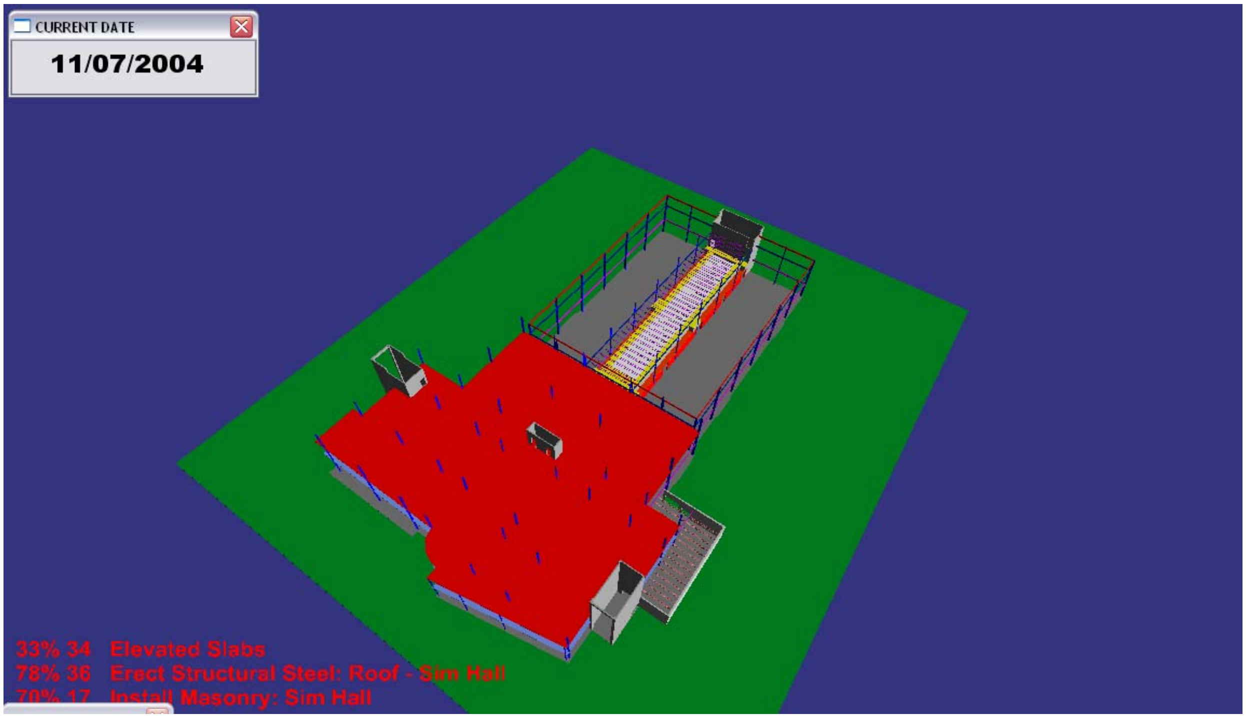

CURRENT DATE
10/13/2004
100% 27 Elevated Slabs
69% 18 2nd Floor
88% 21 Install Flight Deck
45% 17 Install Masonry: Sim Hall
11% 22 Install Masonry: Stair Tower 5 & 7
11% 23 Install Masonry: Stair Tower 6
31% 16 Slab On Grade: 4

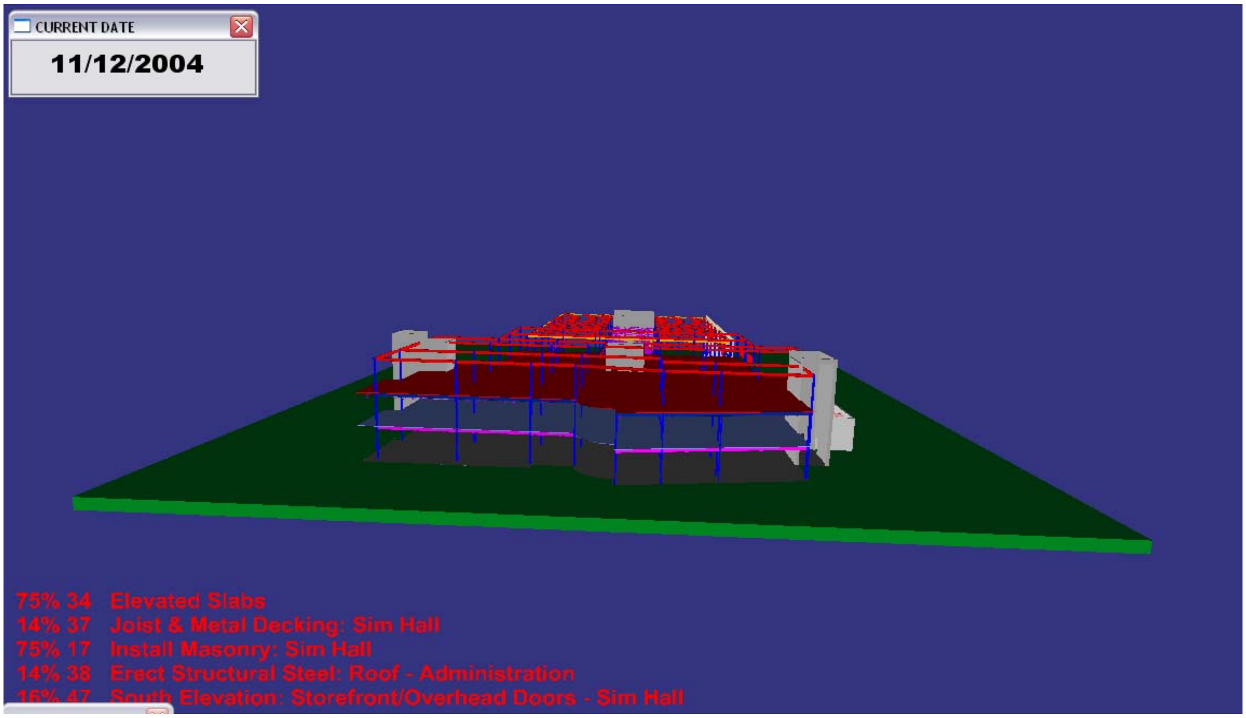

CURRENT DATE
10/18/2004
81% 18 2nd Floor
50% 17 Install Masonry: Sim Hall
11% 24 Install Masonry: Elevator Shaft
66% 22 Install Masonry: Stair Tower 5 & 7
66% 23 Install Masonry: Stair Tower 6
Slab On Grade: 4

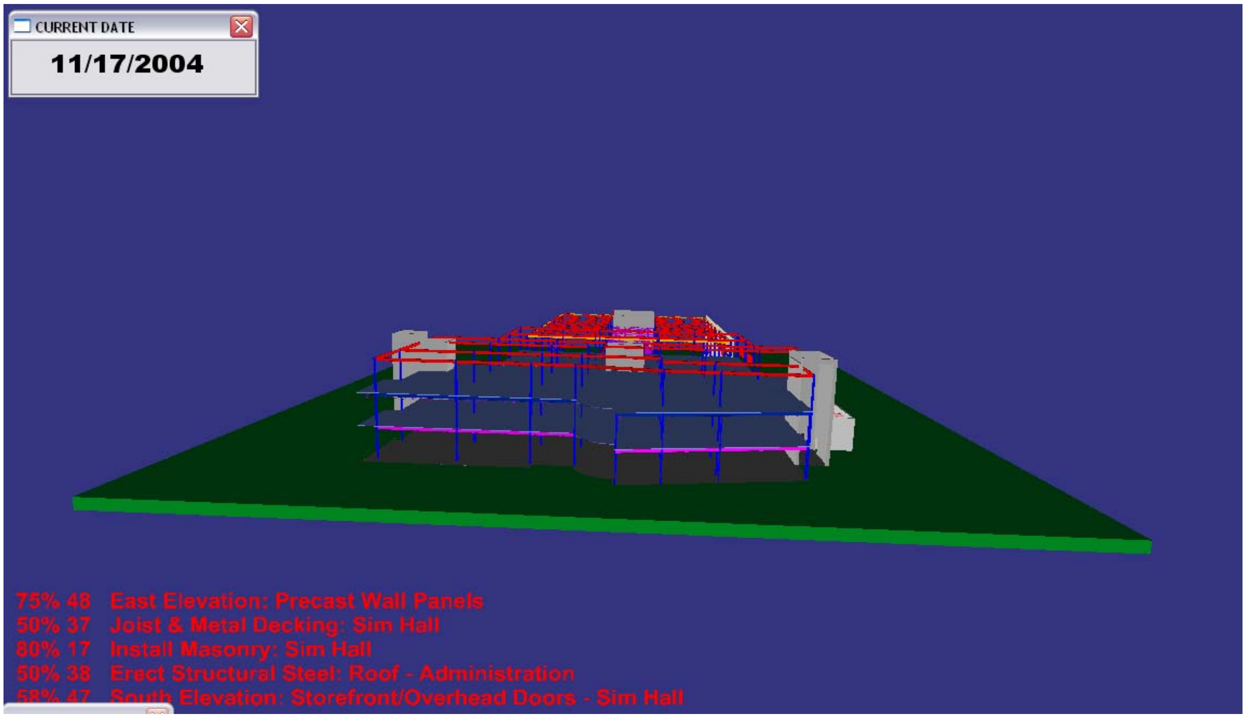

CURRENT DATE
10/23/2004
93% 18 2nd Floor
55% 17 Install Masonry: Sim Hall
66% 24 Install Masonry: Elevator Shaft
44% 32 Install Masonry: Elevator Shaft
44% 31 Install Masonry: Stair Tower 6
44% 30 Install Masonry: Stair Tower 5 & 7
71% 29 Erect Structural Steel: 3rd Floor
21% 33 Joist & Metal Decking: Administration
Slab On Grade: 4

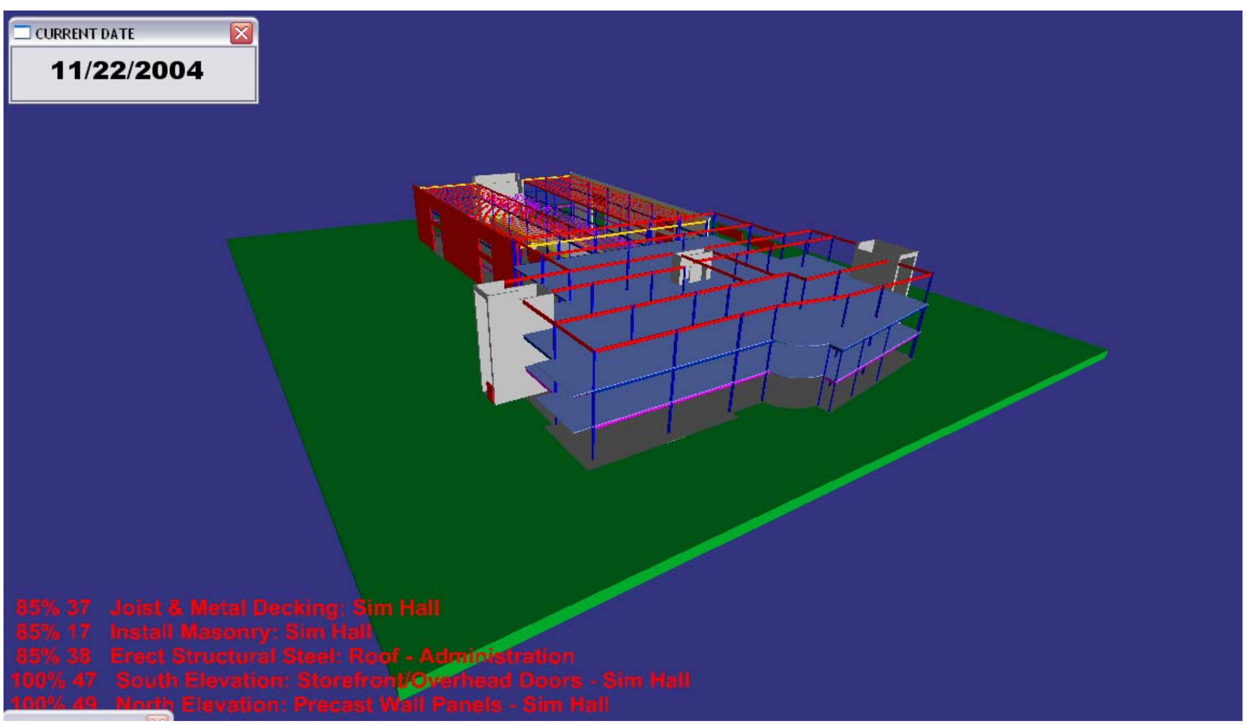

CURRENT DATE
10/28/2004
7% 36 Erect Structural Steel: Roof - Sim Hall
60% 17 Install Masonry: Sim Hall
100% 32 Install Masonry: Elevator Shaft
100% 31 Install Masonry: Stair Tower 6
100% 30 Install Masonry: Stair Tower 5 & 7
57% 33 Joist & Metal Decking: Administration
78% 16 Slab On Grade: 4

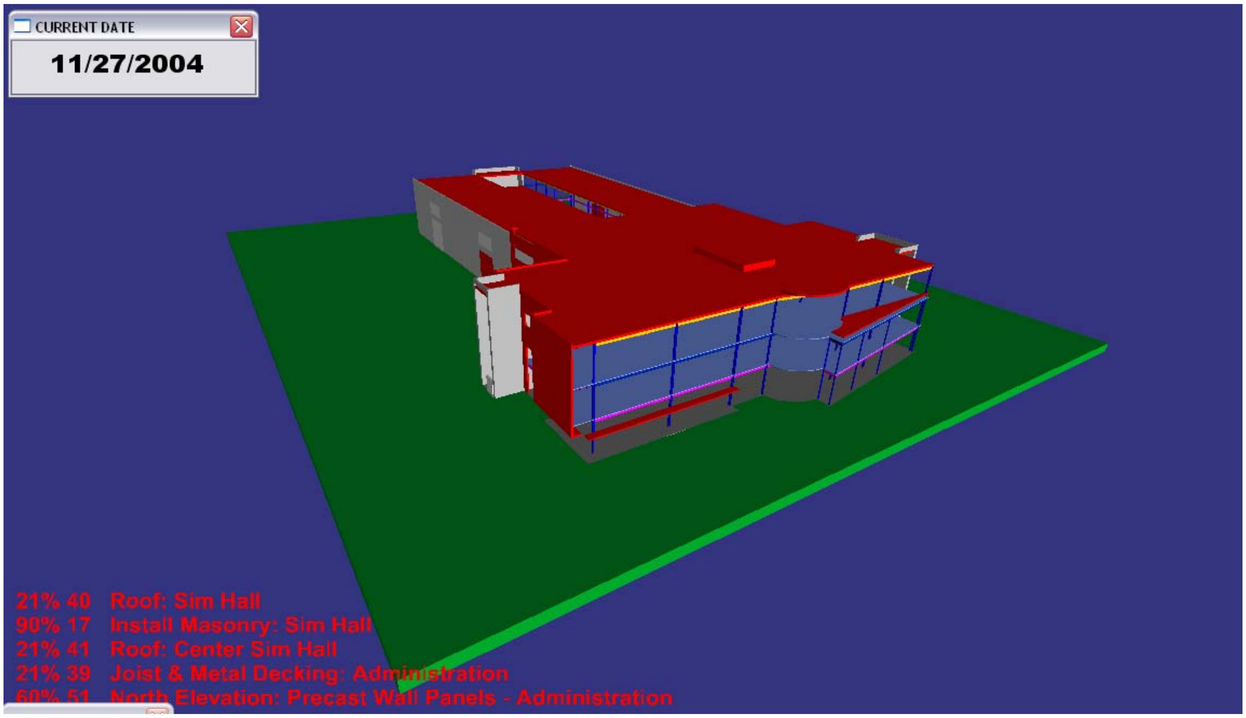

CURRENT DATE
11/02/2004
42% 36 Erect Structural Steel: Roof - Sim Hall
65% 17 Install Masonry: Sim Hall
92% 33 Joist & Metal Decking: Administration
93% 16 Slab On Grade: 4

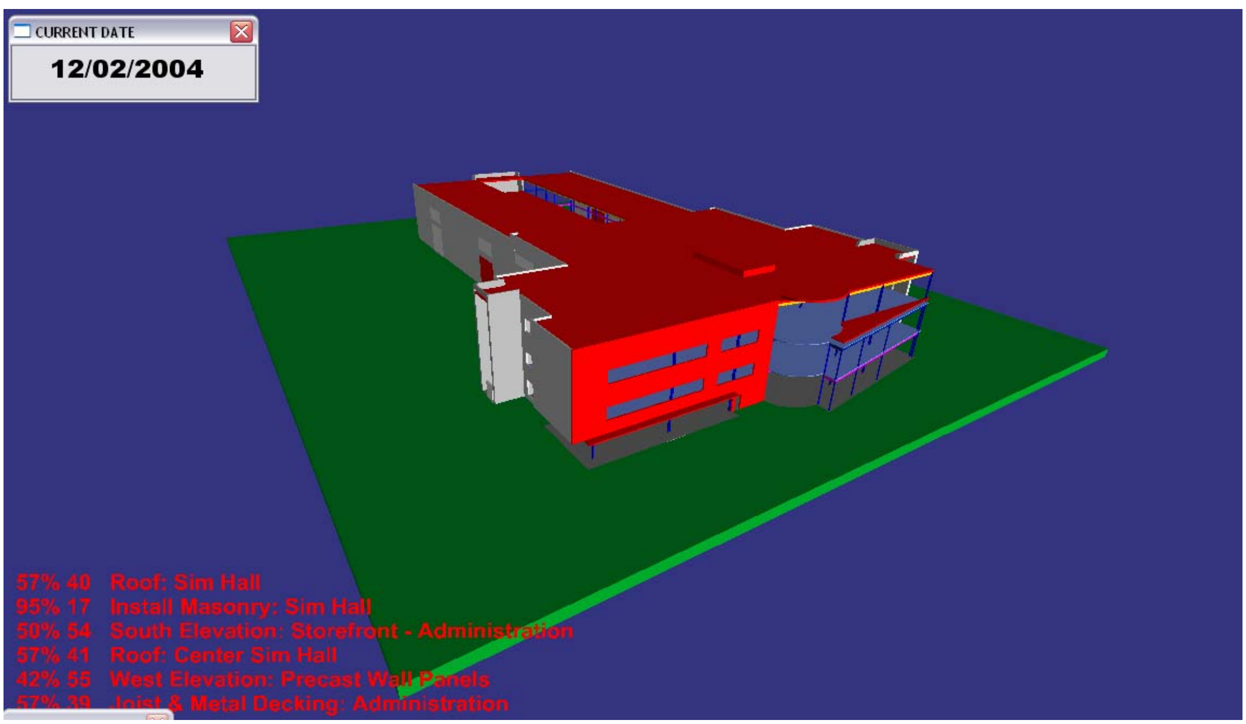

CURRENT DATE
11/07/2004
33% 34 Elevated Slabs
78% 36 Erect Structural Steel: Roof - Sim Hall
70% 17 Install Masonry: Sim Hall

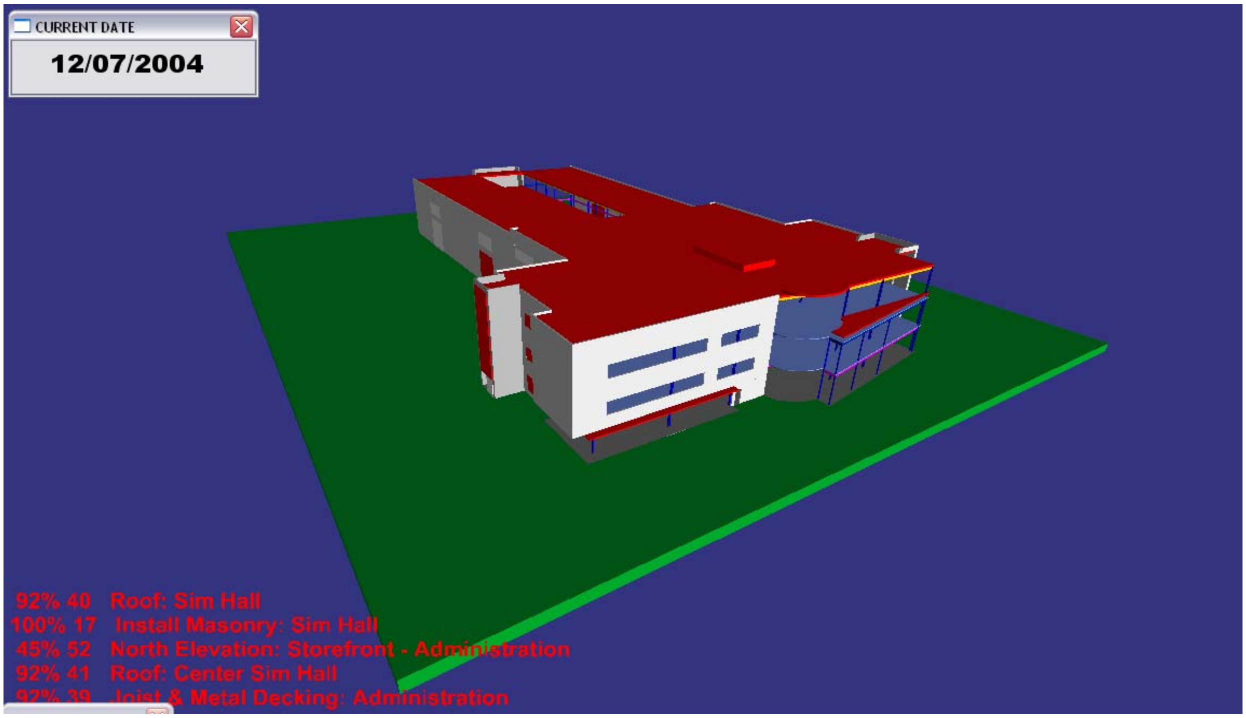

CURRENT DATE
11/12/2004
75% 34 Elevated Slabs
14% 37 Joist & Metal Decking: Sim Hall
75% 17 Install Masonry: Sim Hall
14% 38 Erect Structural Steel: Roof - Administration
16% 47 South Elevation: Storefront/Overhead Doors - Sim Hall

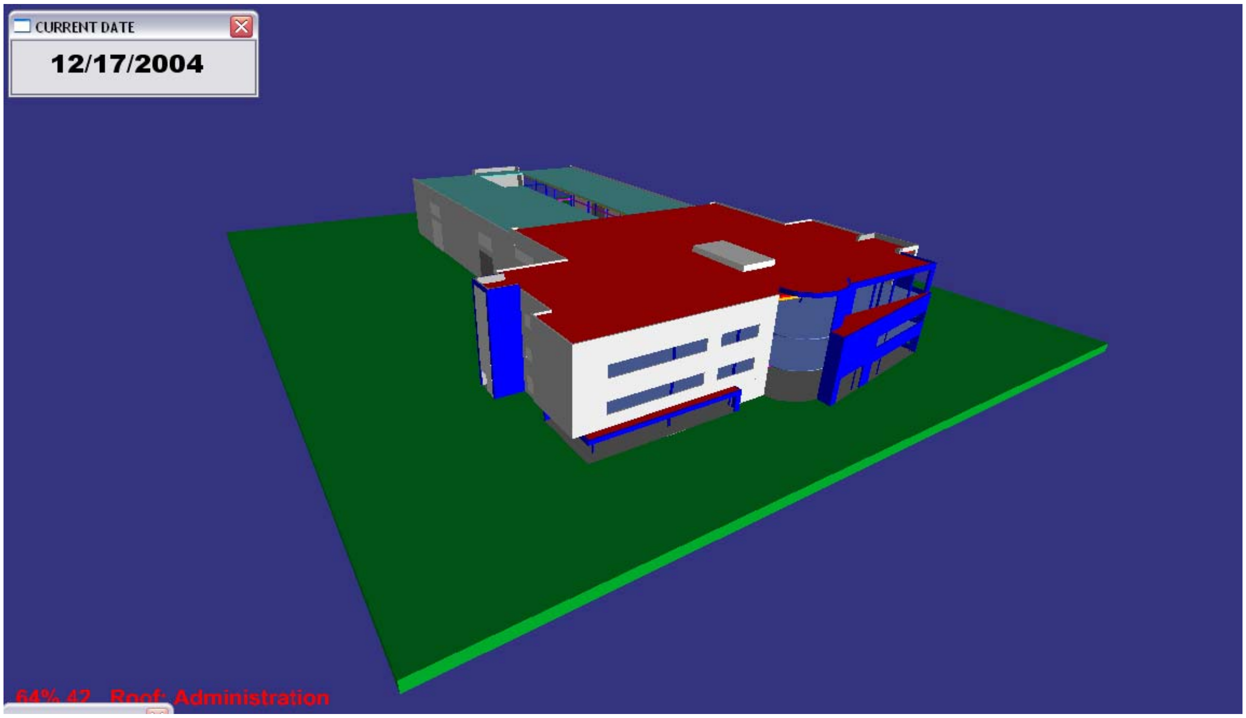

CURRENT DATE
11/17/2004
75% 48 East Elevation: Precast Wall Panels
50% 37 Joist & Metal Decking: Sim Hall
80% 17 Install Masonry: Sim Hall
50% 38 Erect Structural Steel: Roof - Administration
58% 47 South Elevation: Storefront/Overhead Doors - Sim Hall

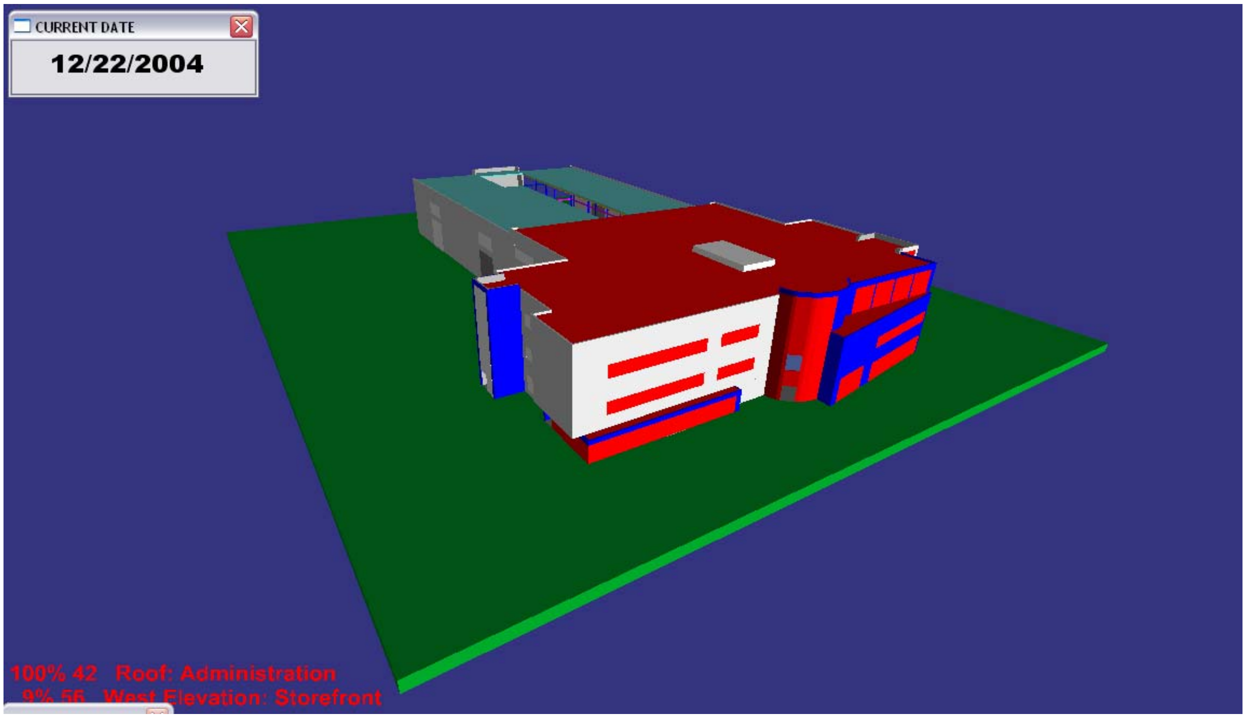

CURRENT DATE
11/22/2004
85% 37 Joist & Metal Decking: Sim Hall
85% 17 Install Masonry: Sim Hall
85% 38 Erect Structural Steel: Roof - Administration
100% 47 South Elevation: Storefront/Overhead Doors - Sim Hall
100% 49 North Elevation: Precast Wall Panels - Sim Hall

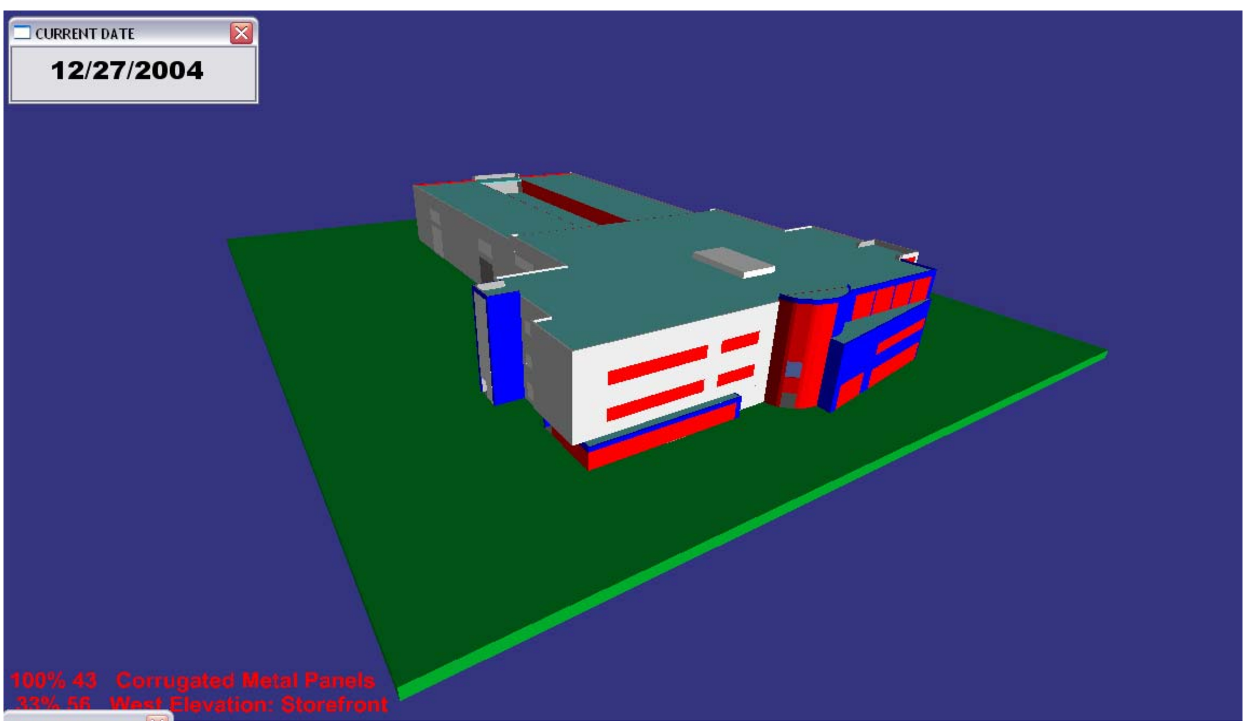

CURRENT DATE
11/27/2004
21% 40 Roof: Sim Hall
90% 17 Install Masonry: Sim Hall
21% 41 Roof: Center Sim Hall
21% 39 Joist & Metal Decking: Administration
60% 51 North Elevation: Precast Wall Panels - Administration

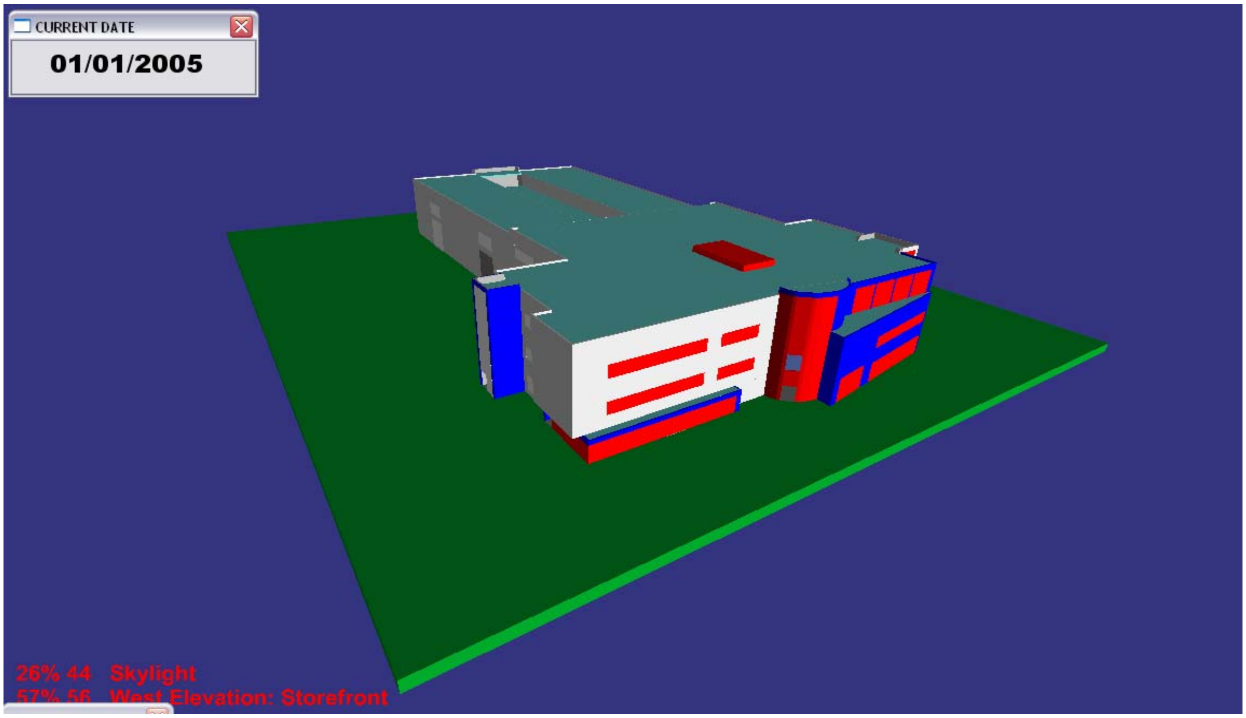

CURRENT DATE
12/02/2004
57% 40 Roof: Sim Hall
95% 17 Install Masonry: Sim Hall
50% 54 South Elevation: Storefront - Administration
57% 41 Roof: Center Sim Hall
42% 55 West Elevation: Precast Wall Panels
57% 39 Joist & Metal Decking: Administration

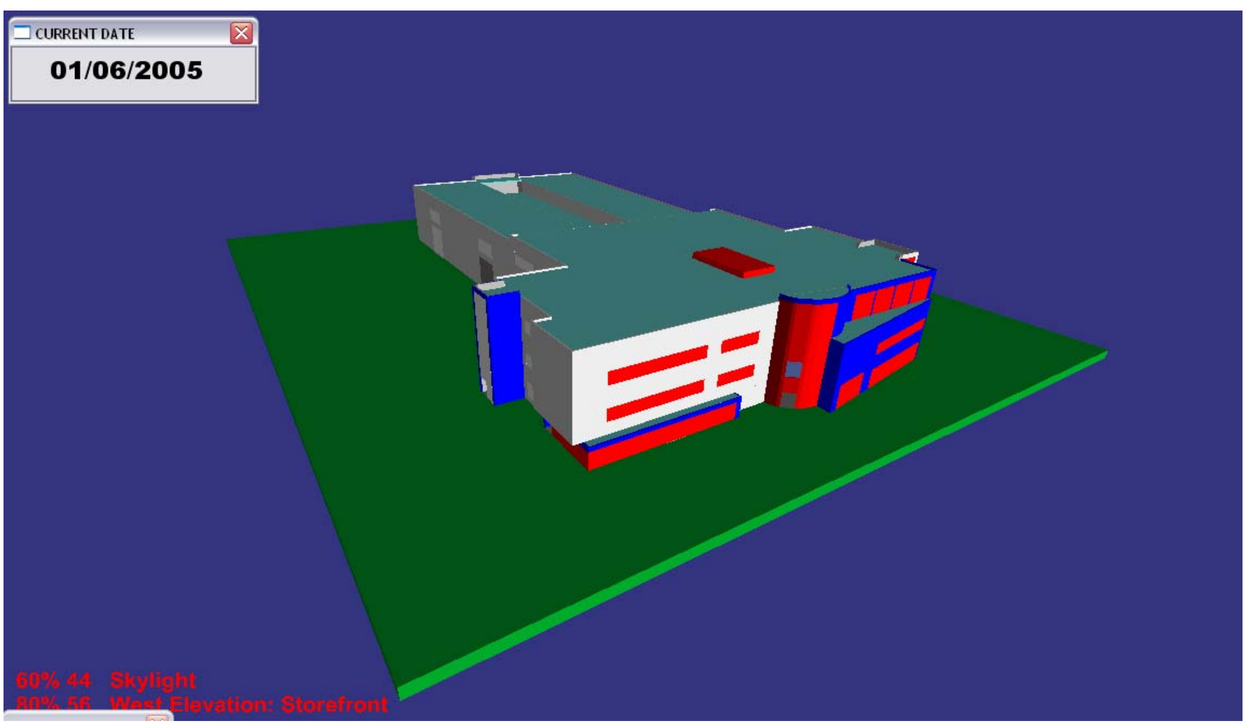

CURRENT DATE
12/07/2004
92% 40 Roof: Sim Hall
100% 17 Install Masonry: Sim Hall
45% 52 North Elevation: Storefront - Administration
92% 41 Roof: Center Sim Hall
92% 39 Joist & Metal Decking: Administration

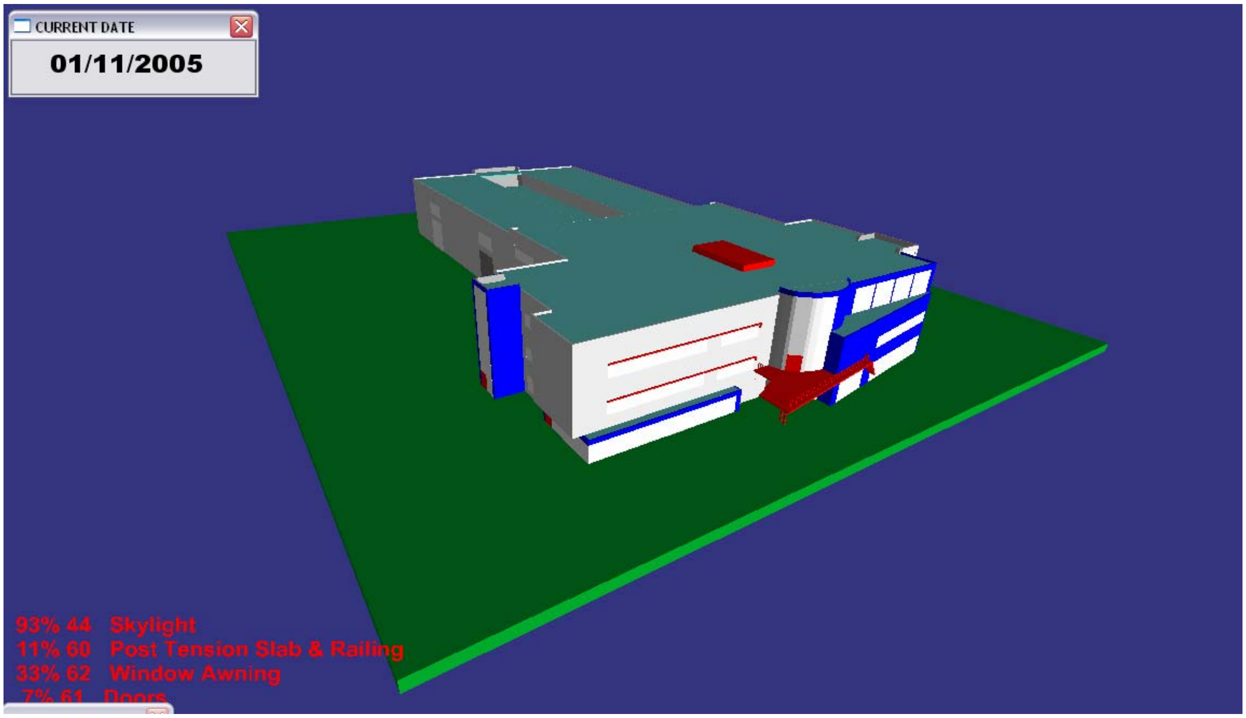

CURRENT DATE
12/17/2004
64% 42 Roof: Administration

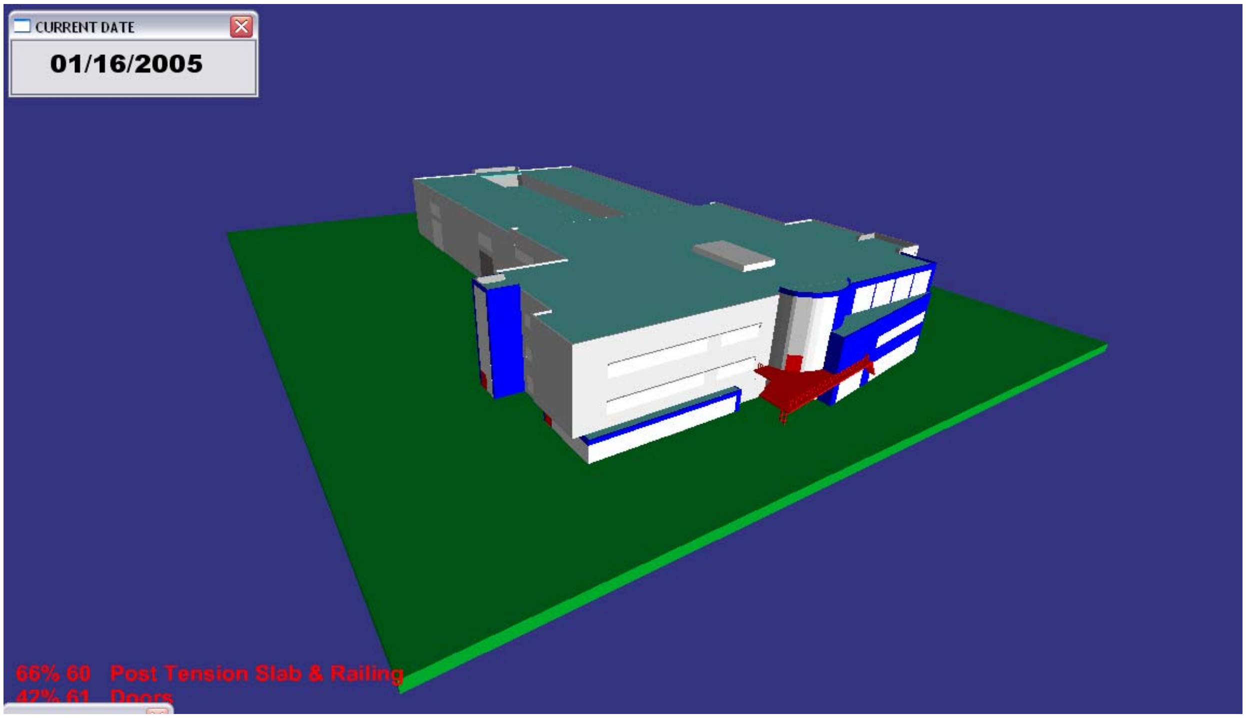

CURRENT DATE
12/22/2004
100% 42 Roof: Administration
9% 56 West Elevation: Storefront

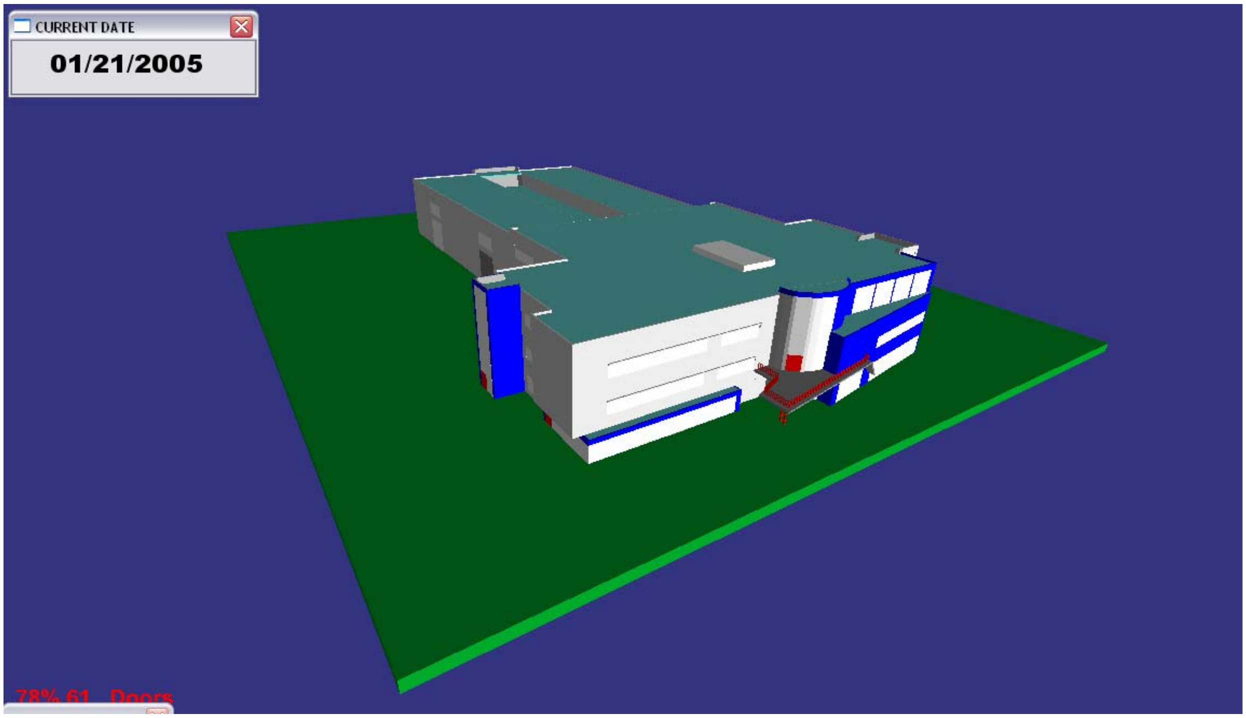

CURRENT DATE
12/27/2004
100% 43 Corrugated Metal Panels
33% 56 West Elevation: Storefront

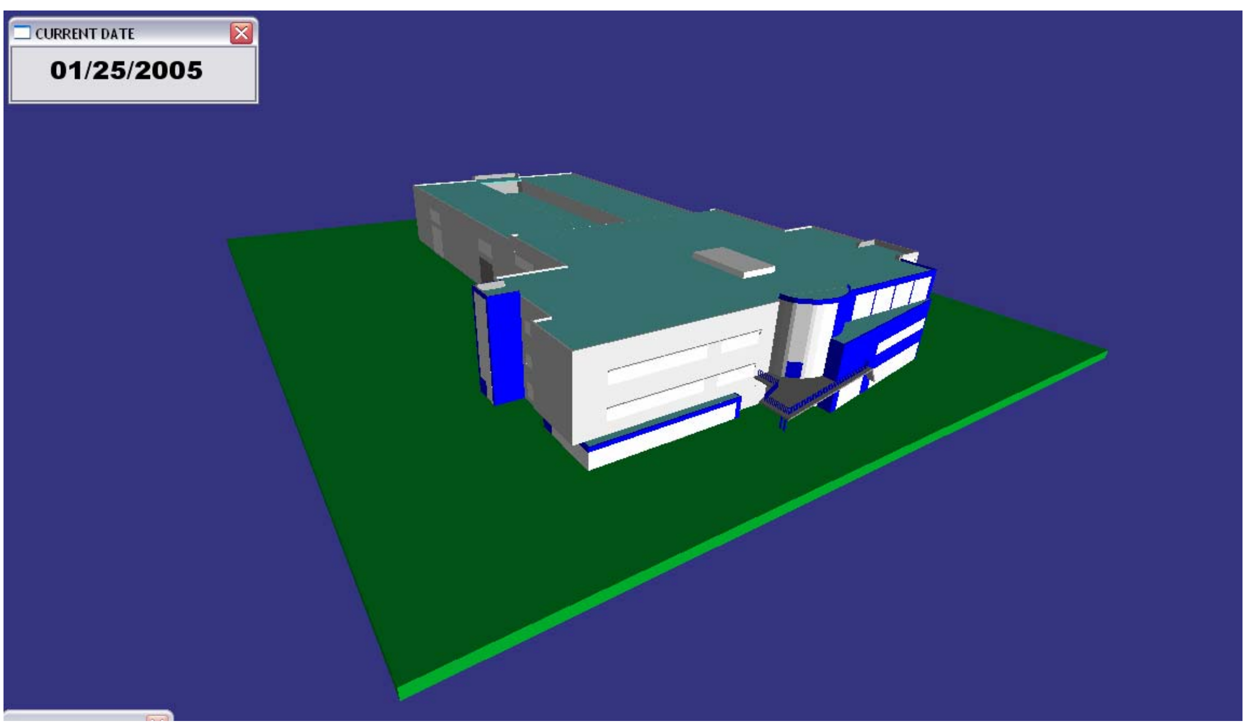

CURRENT DATE
01/01/2005
26% 44 Skylight
57% 56 West Elevation: Storefront


CURRENT DATE
01/06/2005
60% 44 Skylight
80% 56 West Elevation: Storefront

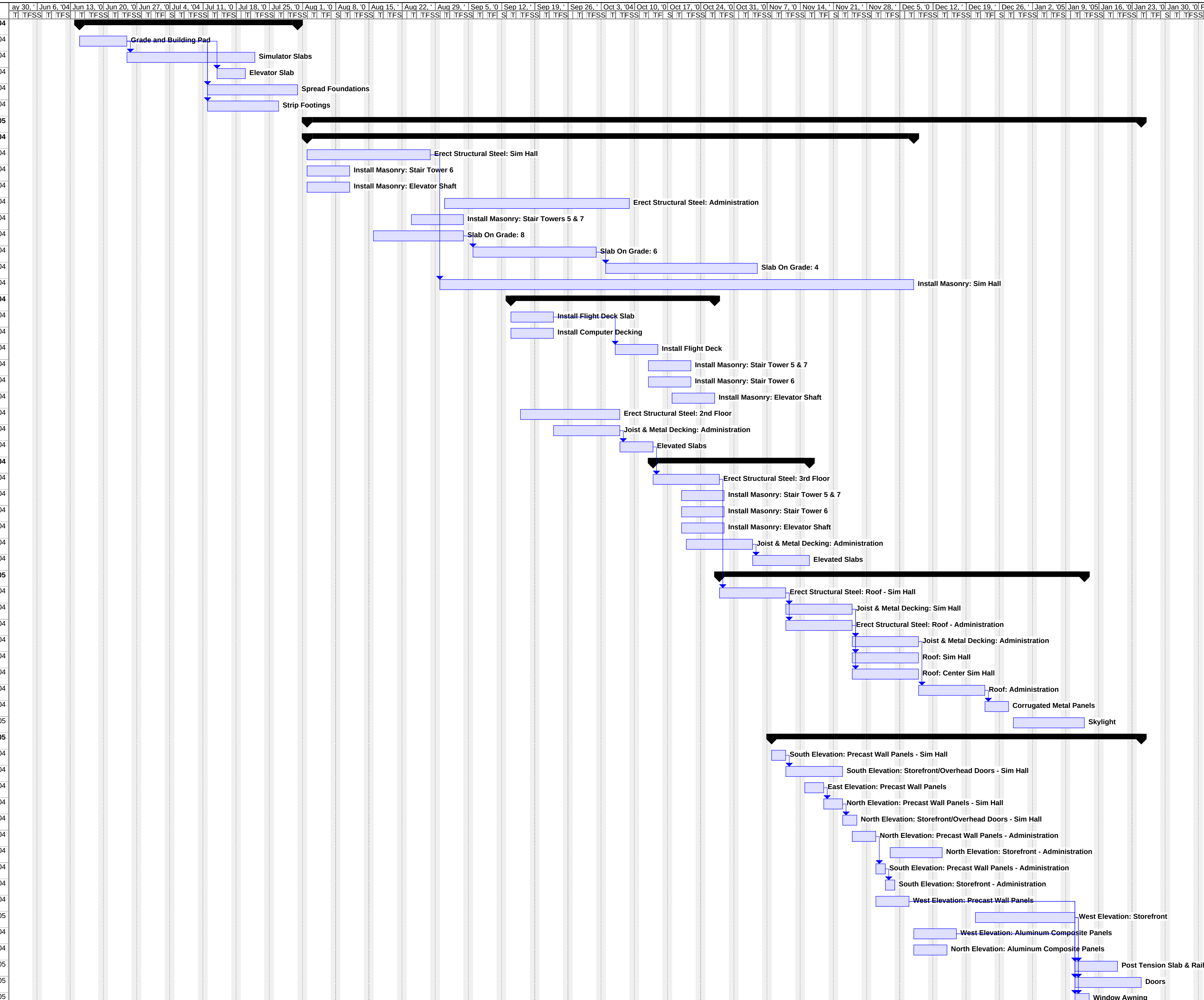

CURRENT DATE
01/11/2005
93% 44 Skylight
11% 60 Post Tension Slab & Railing
33% 62 Window Awning
7% 61 Doors


CURRENT DATE
01/16/2005
66% 60 Post Tension Slab & Railing
42% 61 Doors


CURRENT DATE
01/21/2005


CURRENT DATE
01/25/2005

ID	Task Name	Duration	Start	Finish
1	**Sitework & Foundation**	**34 days?**	**6/15/04**	**7/30/04**
2	Grade and Building Pad	8 days?	6/15/04	6/24/04
3	Simulator Slabs	19 days?	6/25/04	7/21/04
4	Elevator Slab	4 days?	7/14/04	7/19/04
5	Spread Foundations	15 days?	7/12/04	7/30/04
6	Strip Footings	11 days?	7/12/04	7/26/04
7	**Building Structure & Envelope**	**126 days?**	**8/2/04**	**1/24/05**
8	***1st Floor***	**92 days**	**8/2/04**	**12/7/04**
9	Erect Structural Steel: Sim Hall	20 days	8/2/04	8/27/04
10	Install Masonry: Stair Tower 6	7 days	8/2/04	8/10/04
11	Install Masonry: Elevator Shaft	7 days	8/2/04	8/10/04
12	Erect Structural Steel: Administration	29 days	8/31/04	10/8/04
13	Install Masonry: Stair Towers 5 & 7	9 days	8/24/04	9/3/04
14	Slab On Grade: 8	15 days	8/16/04	9/3/04
15	Slab On Grade: 6	20 days	9/6/04	10/1/04
16	Slab On Grade: 4	24 days	10/4/04	11/4/04
17	Install Masonry: Sim Hall	72 days	8/30/04	12/7/04
18	***2nd Floor***	**31 days**	**9/14/04**	**10/26/04**
19	Install Flight Deck Slab	7 days	9/14/04	9/22/04
20	Install Computer Decking	7 days	9/14/04	9/22/04
21	Install Flight Deck	7 days	10/6/04	10/14/04
22	Install Masonry: Stair Tower 5 & 7	7 days	10/13/04	10/21/04
23	Install Masonry: Stair Tower 6	7 days	10/13/04	10/21/04
24	Install Masonry: Elevator Shaft	7 days	10/18/04	10/26/04
25	Erect Structural Steel: 2nd Floor	15 days	9/16/04	10/6/04
26	Joist & Metal Decking: Administration	10 days	9/23/04	10/6/04
27	Elevated Slabs	5 days	10/7/04	10/13/04
28	***3rd Floor***	**23 days?**	**10/14/04**	**11/15/04**
29	Erect Structural Steel: 3rd Floor	10 days	10/14/04	10/27/04
30	Install Masonry: Stair Tower 5 & 7	7 days	10/20/04	10/28/04
31	Install Masonry: Stair Tower 6	7 days	10/20/04	10/28/04
32	Install Masonry: Elevator Shaft	7 days	10/20/04	10/28/04
33	Joist & Metal Decking: Administration	10 days?	10/21/04	11/3/04
34	Elevated Slabs	8 days?	11/4/04	11/15/04
35	***Roof***	**55 days?**	**10/28/04**	**1/12/05**
36	Erect Structural Steel: Roof - Sim Hall	10 days	10/28/04	11/10/04
37	Joist & Metal Decking: Sim Hall	10 days	11/11/04	11/24/04
38	Erect Structural Steel: Roof - Administration	10 days	11/11/04	11/24/04
39	Joist & Metal Decking: Administration	10 days	11/25/04	12/8/04
40	Roof: Sim Hall	10 days	11/25/04	12/8/04
41	Roof: Center Sim Hall	10 days	11/25/04	12/8/04
42	Roof: Administration	10 days	12/9/04	12/22/04
43	Corrugated Metal Panels	3 days	12/23/04	12/27/04
44	Skylight	11 days?	12/29/04	1/12/05
45	***Exterior Finish***	**56 days**	**11/8/04**	**1/24/05**
46	South Elevation: Precast Wall Panels - Sim Hall	3 days	11/8/04	11/10/04
47	South Elevation: Storefront/Overhead Doors - Sim Hall	8 days	11/11/04	11/22/04
48	East Elevation: Precast Wall Panels	4 days	11/15/04	11/18/04
49	North Elevation: Precast Wall Panels - Sim Hall	2 days	11/19/04	11/22/04
50	North Elevation: Storefront/Overhead Doors - Sim Hall	3 days	11/23/04	11/25/04
51	North Elevation: Precast Wall Panels - Administration	3 days	11/25/04	11/29/04
52	North Elevation: Storefront - Administration	7 days	12/3/04	12/13/04
53	South Elevation: Precast Wall Panels - Administration	2 days	11/30/04	12/1/04
54	South Elevation: Storefront - Administration	2 days	12/2/04	12/3/04
55	West Elevation: Precast Wall Panels	5 days	11/30/04	12/6/04
56	West Elevation: Storefront	15 days	12/21/04	1/10/05
57	West Elevation: Aluminum Composite Panels	7 days	12/8/04	12/16/04
58	North Elevation: Aluminum Composite Panels	5 days	12/8/04	12/14/04
59	Post Tension Slab & Railing	7 days	1/11/05	1/19/05
60	Doors	10 days	1/11/05	1/24/05
61	Window Awning	3 days	1/11/05	1/13/05



Task | Split | Progress | Milestone | Summary | Project Summary | External Tasks | External Milestone | Deadline

Appendix C

Online Survey Questions

4D CAD Model Analysis Survey

Sarah Lippai
Construction Management
Capstone Project e-Portfolio
The Pennsylvania State University

Description

As part of my Senior Thesis, I am researching the use of 4D CAD Model during the proposal process. Through this 4D CAD Model Survey, a better understanding of the views of industry members on its use in the bidding proposal will be analyzed. All results will be used for the sole purpose of my senior thesis.

A 4D Model is a combination of a 3D Model and Time, as in the Schedule.

Respondent Information

Name | **Company** | **Location**

Type of Experience in the Industry (PM, superintendent, owner, etc.) | **Years of Experience**

Have you used/seen 4D CAD on a project? If so, which application, and was it valuable?

General Questions

I would have more confidence in the schedule if I see a 4D model of the project.

- ☐ Strongly Disagree
- ☐ Disagree
- ☐ Neutral
- ☐ Agree
- ☐ Strongly Agree

A 4D model would aid in visualizing how the project will be constructed.

- ☐ Strongly Disagree
- ☐ Disagree
- ☐ Neutral

- Agree
- Strongly Agree

A 4D model would be useful during owner-contractor-architect meetings.

- Strongly Disagree
- Disagree
- Neutral
- Agree
- Strongly Agree

The type of project would heavily influence the decision as to how useful a 4D model is.

- Strongly Disagree
- Disagree
- Neutral
- Agree
- Strongly Agree

A 4D model could be used to provide information on a construction project website.

- Strongly Disagree
- Disagree
- Neutral
- Agree
- Strongly Agree

The research community tends to believe that the best application of this technology is in communication of the design information among project participants. Do you agree or disagree with this perspective? Why?

Can you identify reasons why this technology is not rapidly adopted in the industry?

What do you feel would be the benefits of implementing this technology in the bidding proposal process?

Owner Questions

If a general contractor/construction manager were to present a 4D model with the proposal, would it influence the decision to award the job? Why or why not?

Would you have more confidence in the proposed schedule if you saw a 4D model of the project?

Would providing a 4D model with a proposal have any influence on picking a general contractor even if they are not the lowest bidder? Why or why not?

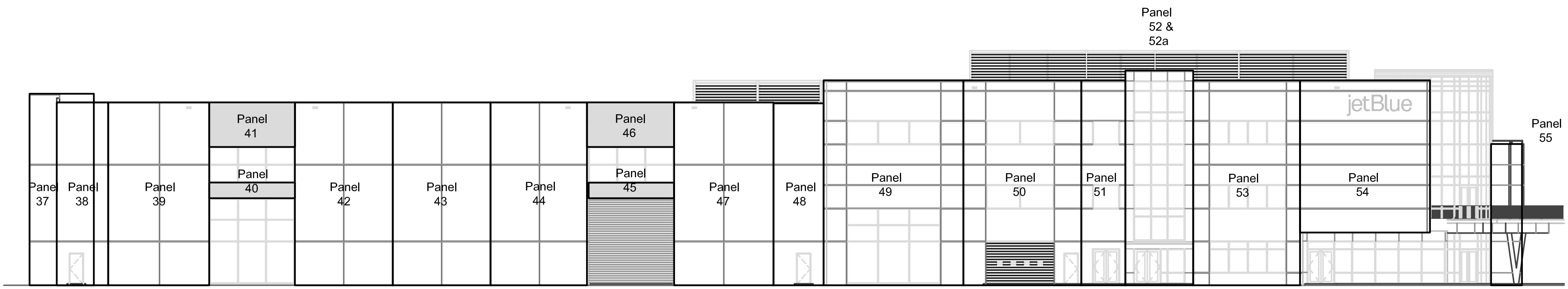
Would you be willing to pay to have a 4D model produced for a project?

Would having a 4D model provided by the general contractor increase your confidence in their ability to construct the building?

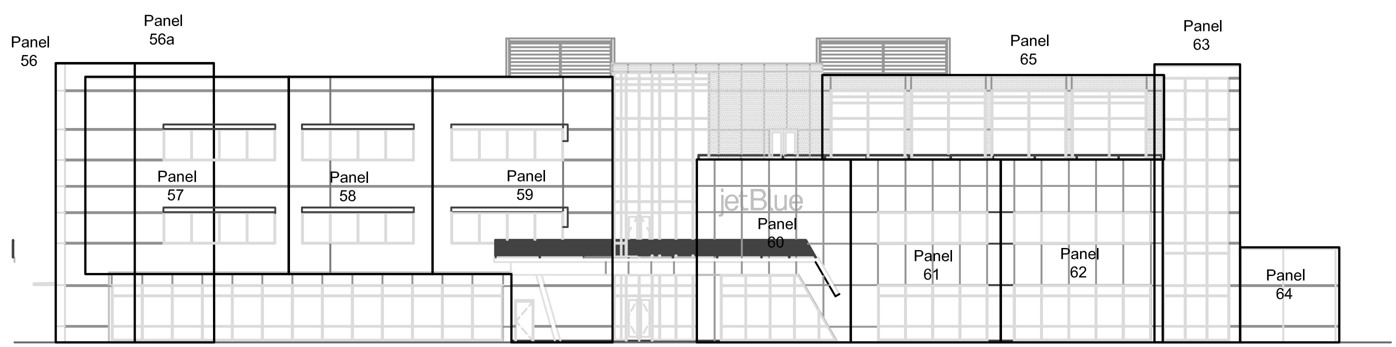
If a 4D model was provided, would you in turn provide fewer checks on the general contractor?

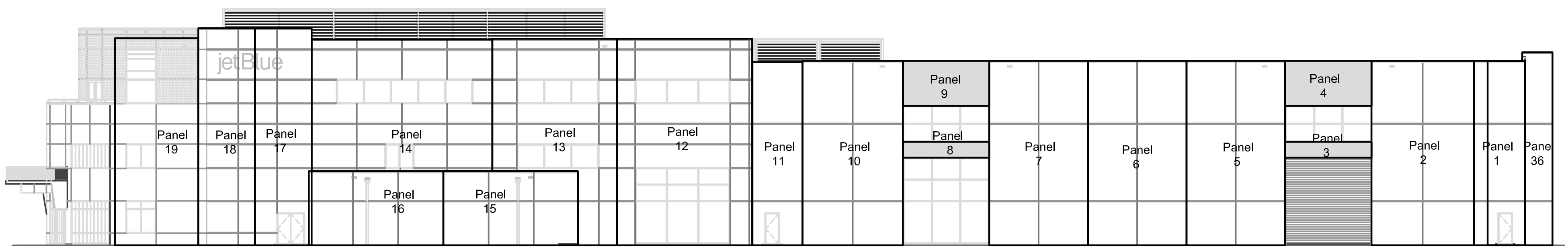
Appendix D

Tilt-up Panel Elevation Layout
Tilt-up Panel Size & Weight Table
Tilt-up Panel Laydown Areas

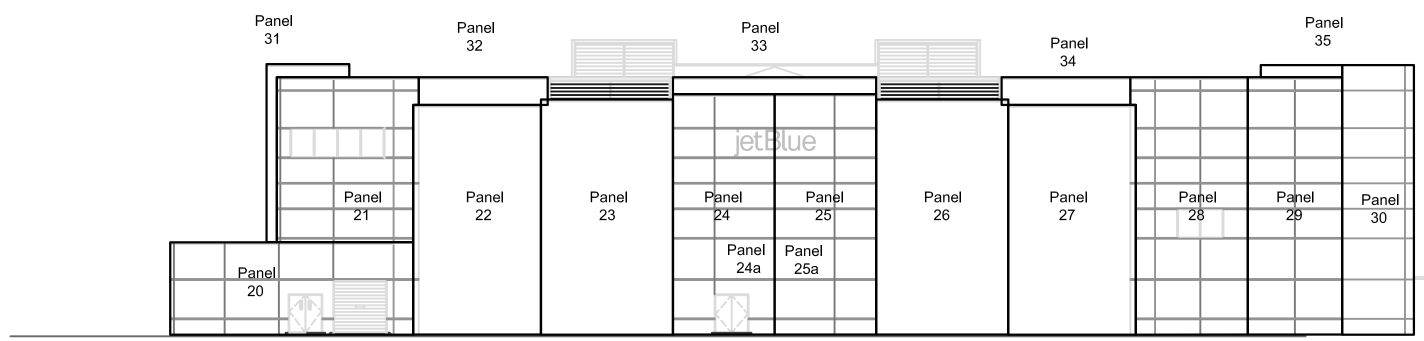


NORTH ELEVATION





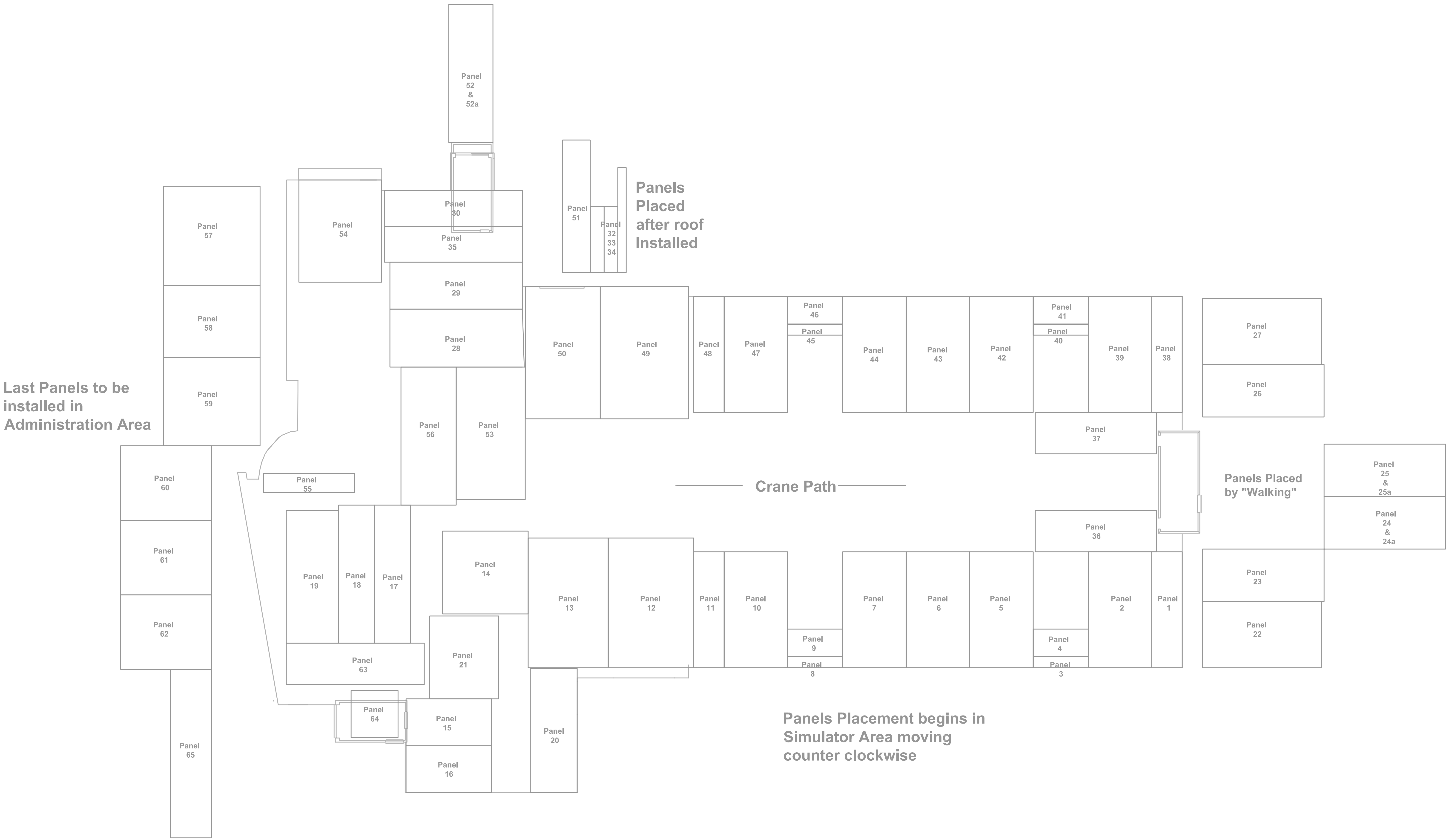
SOUTH ELEVATION



EAST ELEVATION

Concrete Tilt-Up Panels

Elevation	Panel	Panel Dimensions				Panel Area (SF)	Panel Concrete Thickness (in)	Blockouts (SF)	Panel Weight (lbs)	Panel Weight (tons)
		Height		Width						
		ft.	in.	ft.	in.					
South	1	42	9	11	7	495	8		47,538	24
	2	42	9	23	2	990	8		95,076	48
	3	3	8	20	0	73	8		7,040	4
	4	10	2	20	0	203	8		19,520	10
	5	42	9	23	2	990	8		95,076	48
	6	42	9	23	2	990	8		95,076	48
	7	42	9	23	2	990	8		95,076	48
	8	10	2	20	0	203	8		19,520	10
	9	3	8	20	0	73	8		7,040	4
	10	42	9	23	2	990	8		95,076	48
	11	42	9	11	7	495	8		47,538	24
	12	47	8	31	3	1490	8	528	92,312	46
	13	47	8	28	10	1374	8	568	77,413	39
	14	30	6	31	10	971	8	228	71,320	36
	15	17	0	31	2	530	8		50,864	25
	16	17	0	31	2	530	8		50,864	25
	17	50	4	13	1	659	8	49	58,515	29
	18	50	4	13	1	659	8		63,219	32
	19	48	0	19	3	924	8		88,704	44
	36	44	9	15	0	671	8		64,440	32
East	20	17	2	45	3	777	8	42	70,540	35
	21	30	9	25	5	782	8	108	64,662	32
	22	42	9	23	9	1015	8		97,470	49
	23	43	9	24	7	1076	8		103,250	52
	24	44	9	19	0	850	8		81,624	41
	24a	44	9	19	0	850	8		81,624	41
	25	44	9	19	0	850	8		81,624	41
	25a	44	9	19	0	850	8		81,624	41
	26	43	9	24	7	1076	8		103,250	52
	27	42	9	23	9	1015	8		97,470	49
	28	47	11	21	9	1042	8	42	96,018	48
	29	47	11	17	7	843	8		80,883	40
	30	50	2	13	6	677	8		65,016	33
	31	33	2	15	5	511	8		49,087	25
	32	5	2	24	0	124	8		11,904	6
	33	3	2	37	10	120	8		11,501	6
	34	5	2	24	0	124	8		11,904	6
	35	50	2	13	6	677	8		65,016	33
North	37	44	9	15	0	671	8		64,440	32
	38	42	9	11	7	495	8		47,538	24
	39	42	9	23	2	990	8		95,076	48
	40	3	8	20	0	73	8		7,040	4
	41	10	2	20	0	203	8		19,520	10
	42	42	9	23	2	990	8		95,076	48
	43	42	9	23	2	990	8		95,076	48
	44	42	9	23	2	990	8		95,076	48
	45	10	2	20	0	203	8		19,520	10
	46	3	8	20	0	73	8		7,040	4
	47	42	9	23	2	990	8		95,076	48
	48	42	9	11	7	495	8		47,538	24
	49	47	11	32	7	1561	8	528	99,195	50
	50	47	11	27	6	1318	8	352	92,708	46
	51	47	11	10	3	491	8	120	35,630	18
	52	50	2	15	10	794	8	570	21,533	11
	52a	50	2	15	10	794	8		76,253	38
	53	47	11	24	11	1194	8	349	81,113	41
	54	35	7	30	4	1079	5		64,762	32
	55	33	0	7	2	237	5		14,190	7
West	56	50	4	14	3	717	8		68,856	34
	56a	50	4	14	3	717	8		68,856	34
	57	35	4	36	8	1296	5	220	64,533	32
	58	35	4	25	11	916	5	220	41,743	21
	59	35	4	32	5	1145	5	4	68,510	34
	60	33	0	27	9	916	5	252	39,825	20
	61	33	0	27	0	891	5	320	34,260	17
	62	33	0	27	8	913	5	413	30,030	15
	63	50	2	15	5	773	8	576	18,951	9
	64	17	2	17	11	308	8		29,527	15
	65	15	3	61	4	935	5	675	15,620	8


Last Panels to be installed in Administration Area
Panels Placed after roof Installed
Crane Path
Panels Placed by "Walking"
Panels Placement begins in Simulator Area moving counter clockwise
Panel 52 & 52a
Panel 30
Panel 35
Panel 51
Panel 32 33 34
Panel 57
Panel 54
Panel 29
Panel 28
Panel 58
Panel 59
Panel 50
Panel 49
Panel 48
Panel 47
Panel 46
Panel 45
Panel 44
Panel 43
Panel 42
Panel 41
Panel 40
Panel 39
Panel 38
Panel 27
Panel 26
Panel 56
Panel 53
Panel 37
Panel 60
Panel 55
Panel 25 & 25a
Panel 24 & 24a
Panel 36
Panel 61
Panel 19
Panel 18
Panel 17
Panel 14
Panel 13
Panel 12
Panel 11
Panel 10
Panel 9
Panel 8
Panel 7
Panel 6
Panel 5
Panel 4
Panel 3
Panel 2
Panel 1
Panel 23
Panel 22
Panel 62
Panel 63
Panel 21
Panel 64
Panel 15
Panel 20
Panel 16
Panel 65

Appendix E

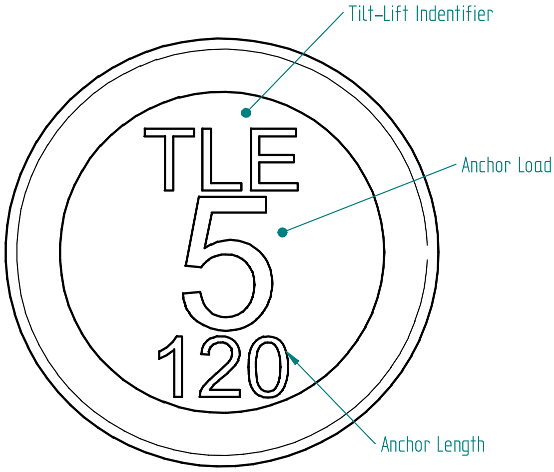
Tilt-up Panel Anchors

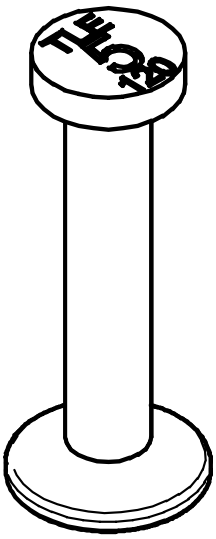
P-52 SL Foot Anchor

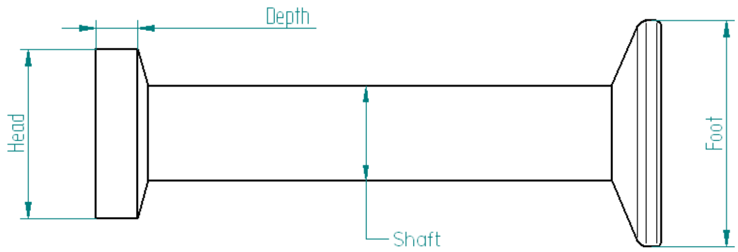
The P-52 SL Foot Anchor is forged from carbon steel that obtains the minimum 2.5 factor of safety as set out in AS3850. Both ends of the anchor are hot forged, the head designed to suit the P-50 SL lifting Eye, while the disc shaped foot creates a large shear cone in the concrete while under load. The anchor also meets the V–notch charpy test minimum 27 joule requirements for L15 steels as set out in AS 3850. The anchors are hot dipped galvanised for corrosion protection and are available to come in grade 316 stainless steel upon request.

Tilt-Lift Equipment anchors can be identified through the unique marking that is on top of the Foot Anchor. The diagram opposite shows the typical head of a standard foot anchor. The initial “TLE” identify this as one of our foot anchors. Also marked on the head of the foot anchor is the load group of the anchors, as well as the over length of the anchor.

Please note that the load group represents the strength of the steel of the anchor and not necessarily the concrete failure of the anchor.

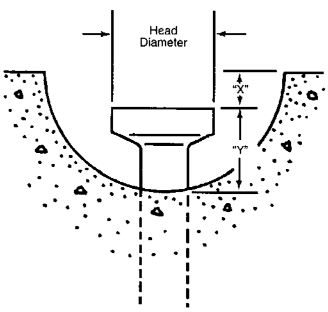


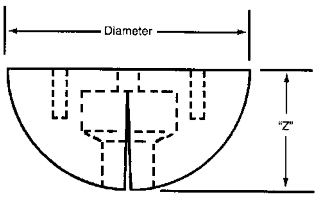




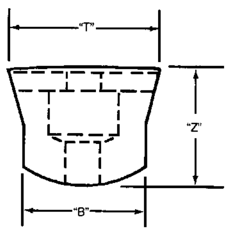
Anchor Rated Load	Head Diameter	Shaft Diameter	Foot Diameter	Head Depth	Avalaible Lengths
1.3 t	19	10	24	5	35, 45, 55, 65, 85, 120, 240
2.5 t	26	14	34	7	55, 75, 85, 120, 170, 280
5 t	36	20	49	9	75, 95, 120, 140, 170, 240
10 t	47	28	70	11	150, 340
20 t	70	39	98	15	340, 500, 1000

Anchors length are standard stock sizes, other sizes are avaliable on request.
Stock anchors are hot dipped galavanised - Stainless Steel Avaliable on request





SL Round Recess Plug



SL Narrow Recess Plug

Tilt–Lift Equipment P/L
Concrete Accessories

P-52 SL Foot Anchor

Anchor Size	Diameter of Recess Plug	"Z" Dimesion	"T" Dimension	"B" Dimension	"X" Dimension	"Y" Dimension
1.3	60	30	42	34	10	20
2.5	76	37	52	44	11	26
5	95	46	70	58	15	31
10	120	60	85	78	15	45
20	162	79	125	116	15	64

Working Load Limits

The Table below lists the working load of the P-52 SL Foot Anchor for various lengths and concrete strengths. When the P-52 SL anchors is properly embedded in normal weight concrete, the tabulated working loads are applicable for any direction of loading. This applies even if the direction of load is parrallell to the axis of the anchor, perpendicular or any other direction.

Working Load Limit (Tonnes)

P-52 Foot Anchor

Anchor Size	Anchor Length	Concrete Strength (mPa) @ Lift			
		15	20	25	30
1.3	35	0.47	0.55	0.61	0.67
1.3	45	0.93	1.08	1.20	*1.30*
1.3	55	1.21	*1.30*	*1.30*	*1.30*
1.3	65	*1.30*	*1.30*	*1.30*	*1.30*
1.3	85	*1.30*	*1.30*	*1.30*	*1.30*
1.3	120	*1.30*	*1.30*	*1.30*	*1.30*
2.5	55	1.08	1.30	1.40	1.52
2.5	75	1.70	1.98	2.20	2.40
2.5	85	2.15	2.40	*2.50*	*2.50*
2.5	120	*2.50*	*2.50*	*2.50*	*2.50*
2.5	170	*2.50*	*2.50*	*2.50*	*2.50*
2.5	280	*2.50*	*2.50*	*2.50*	*2.50*
5	75	2.13	2.46	2.75	3.01
5	95	2.92	3.37	3.77	4.13
5	120	4.03	4.65	5.00	*5.00*
5	140	5.00	5.00	5.00	*5.00*
5	170	*5.00*	*5.00*	*5.00*	*5.00*
5	240	*5.00*	*5.00*	*5.00*	*5.00*
10	150	4.95	5.72	6.40	7.01

The above table assumes the following:
1. Minimum edge distance is 3 x anchor length.
2. Minimum anchor spacing is 6 x anchor length

Do not attempt to use the foot anchor in concrete that is less then 15 mPa.
Factor of Safety: 2.5 to 1
Italics represents those condition that are limilted by steel and clutch strength

Appendix F

Temperature Values

Minimum and Maximum Relative Humidity for each Rooftop Unit throughout the Year														
Month		**RTU - 1**	**RTU - 2**	**RTU - 3**	**RTU - 4**	**RTU - 5**	**RTU - 6**	**RTU - 7**	**RTU - 8**	**RTU - 9**	**RTU - 10**	**RTU - 11**	**RTU - 12**	**Unoccupied**
Jan	Min	1.231	1.231	1.231	1.231	2.302	2.717	3.904	3.904	4.025	3.432	2.865	2.891	0.1669
Jan	Max	1.593	1.593	1.593	1.593	2.644	3.051	4.215	4.215	4.334	3.752	3.196	3.221	0.5507
Feb	Min	1.255	1.255	1.255	1.255	2.325	2.74	3.925	3.925	4.046	3.454	2.888	2.913	0.1927
Feb	Max	1.593	1.593	1.593	1.593	2.644	3.051	4.215	4.215	4.334	3.752	3.196	3.221	0.5507
March	Min	1.218	1.218	1.218	1.218	2.29	2.706	3.893	3.893	4.014	3.421	2.854	2.879	0.1534
March	Max	1.593	1.593	1.593	1.593	2.644	3.051	4.215	4.215	4.334	3.752	3.196	3.221	0.5507
April	Min	1.273	1.273	1.273	1.273	2.342	2.756	3.94	3.94	4.061	3.469	2.904	2.929	0.2114
April	Max	1.593	1.593	1.593	1.593	2.644	3.051	4.215	4.215	4.334	3.752	3.196	3.221	0.5507
May	Min	1.551	1.551	1.551	1.551	2.604	3.012	4.179	4.179	4.299	3.715	3.158	3.182	0.5061
May	Max	1.593	1.593	1.593	1.593	2.644	3.051	4.215	4.215	4.334	3.752	3.196	3.221	0.5507
June	Min	1.593	1.593	1.593	1.593	2.644	3.051	4.215	4.215	4.334	3.752	3.196	3.221	0.5507
June	Max	1.593	1.593	1.593	1.593	2.644	3.051	4.215	4.215	4.334	3.752	3.196	3.221	0.5507
July	Min	1.593	1.593	1.593	1.593	2.644	3.051	4.215	4.215	4.334	3.752	3.196	3.221	0.5507
July	Max	1.593	1.593	1.593	1.593	2.644	3.051	4.215	4.215	4.334	3.752	3.196	3.221	0.5507
August	Min	1.593	1.593	1.593	1.593	2.644	3.051	4.215	4.215	4.334	3.752	3.196	3.221	0.5507
August	Max	1.593	1.593	1.593	1.593	2.644	3.051	4.215	4.215	4.334	3.752	3.196	3.221	0.5507
Sept	Min	1.593	1.593	1.593	1.593	2.644	3.051	4.215	4.215	4.334	3.752	3.196	3.221	0.5507
Sept	Max	1.593	1.593	1.593	1.593	2.644	3.051	4.215	4.215	4.334	3.752	3.196	3.221	0.5507
Oct	Min	1.41	1.41	1.41	1.41	2.471	2.883	4.058	4.058	4.179	3.591	3.029	3.054	0.3573
Oct	Max	1.593	1.593	1.593	1.593	2.644	3.051	4.215	4.215	4.334	3.752	3.196	3.221	0.5507
Nov	Min	1.3	1.3	1.3	1.3	2.368	2.781	3.964	3.964	4.085	3.493	2.929	2.954	0.2406
Nov	Max	1.593	1.593	1.593	1.593	2.644	3.051	4.215	4.215	4.334	3.752	3.196	3.221	0.5507
Dec	Min	1.173	1.173	1.173	1.173	2.247	2.664	3.854	3.854	3.976	3.381	2.812	2.838	0.1055
Dec	Max	1.593	1.593	1.593	1.593	2.644	3.051	4.215	4.215	4.334	3.752	3.196	3.221	0.5507

Appendix G

Dehumidification/Humidification Calculations

Calculations from Engineering Equation Solver

"RTU OA Flow"
OA_1 = 910
OA_2 = 910
OA_3 = 910
OA_4 = 910
OA_5 = 1100
OA_6 = 910
OA_7 = 1200
OA_8 = 1200
OA_9 = 3590
OA_10 = 4410
OA_11 = 5710
OA_12 = 5540

"Occupancy"
OC_1 = 6
OC_2 = 6
OC_3 = 6
OC_4 = 6
OC_5 = 15
OC_6 = 15
OC_7 = 30
OC_8 = 30
OC_9 = 93
OC_10 = 95
OC_11 = 100
OC_12 =98

"Outdoor Conditions"
W_OA = HUMRAT(AirH2O, t=DBT, b=WBT,p=Po#)
R_OA = RELHUM(AirH2O, t=DBT, b=WBT,p=Po#)
W_55 = HUMRAT(AirH2O, t=55, r=1,p=Po#)
W_SA = MIN(W_55,W_OA)
W_72 = HUMRAT(AirH2O, t= 72,r=.5,p=Po#)

"Space Humity Ratios"
W_1 = MIN(W_55,W_OA) + ((OC_1 * .205)/(OA_1/13.5))
W_2 =MIN(W_55,W_OA) + ((OC_2 * .205)/(OA_2/13.5))
W_3 = MIN(W_55,W_OA) + ((OC_3 * .205)/(OA_3/13.5))
W_4 = MIN(W_55,W_OA)+ ((OC_4 * .205)/(OA_4/13.5))
W_5 =MIN(W_55,W_OA) + ((OC_5 * .205)/(OA_5/13.5))
W_6 = MIN(W_55,W_OA) + ((OC_6 * .205)/(OA_6/13.5))
W_7 = MIN(W_55,W_OA) + ((OC_7 * .205)/(OA_7/13.5))
W_8 = MIN(W_55,W_OA) + ((OC_8 * .205)/(OA_8/13.5))
W_9 = MIN(W_55,W_OA) + ((OC_9 * .205)/(OA_9/13.5))
W_10 = MIN(W_55,W_OA) + ((OC_10 * .205)/(OA_10/13.5))
W_11 = MIN(W_55,W_OA) + ((OC_11 * .205)/(OA_11/13.5))
W_12 = MIN(W_55,W_OA) + ((OC_12 * .205)/(OA_12/13.5))

```
"Space Relative Humidity"
RH_1 = RELHUM(AirH2O, t=72,w=W_1,p=Po#)
RH_2 = RELHUM(AirH2O, t=72,w=W_2,p=Po#)
RH_3 = RELHUM(AirH2O, t=72,w=W_3,p=Po#)
RH_4 = RELHUM(AirH2O, t=72,w=W_4,p=Po#)
RH_5 = RELHUM(AirH2O, t=72,w=W_5,p=Po#)
RH_6 = RELHUM(AirH2O, t=72,w=W_6,p=Po#)
RH_7 = RELHUM(AirH2O, t=72,w=W_7,p=Po#)
RH_8 = RELHUM(AirH2O, t=72,w=W_8,p=Po#)
RH_9 = RELHUM(AirH2O, t=72,w=W_9,p=Po#)
RH_10 = RELHUM(AirH2O, t=72,w=W_10,p=Po#)
RH_11 = RELHUM(AirH2O, t=72,w=W_11,p=Po#)
RH_12 = RELHUM(AirH2O, t=72,w=W_12,p=Po#)
RH_UC = RELHUM(AirH2O, t=72,w=W_SA,p=Po#)

"lb/hr of dehumidification"
m_dot_1 = MAX(0,(W_1 - W_72)) * (OA_1 / 13.5)
m_dot_2 = MAX(0,(W_2 - W_72)) * (OA_2 / 13.5)
m_dot_3 = MAX(0,(W_3 - W_72)) * (OA_3 / 13.5)
m_dot_4 = MAX(0,(W_4 - W_72)) * (OA_4 / 13.5)
m_dot_5 = MAX(0,(W_5 - W_72)) * (OA_5 / 13.5)
m_dot_6 = MAX(0,(W_6 - W_72)) * (OA_6 / 13.5)
m_dot_7 = MAX(0,(W_7 - W_72)) * (OA_7 / 13.5)
m_dot_8 = MAX(0,(W_8 - W_72)) * (OA_8 / 13.5)
m_dot_9 = MAX(0,(W_9 - W_72)) * (OA_9 / 13.5)
m_dot_10 = MAX(0,(W_10 - W_72)) * (OA_10 / 13.5)
m_dot_11 = MAX(0,(W_11 - W_72)) * (OA_11 / 13.5)
                                m_dot_12 = MAX(0,(W_12 - W_72)) * (OA_12/ 13.5)
```