Adam G. Weis

Construction Management Option

Wilkes-Barre/Scranton International Airport

Avoca, Pennsylvania

Spring 2006

Dr. John Messner

Wilkes-Barre/Scranton International Airport

Location: Avoca, Pennsylvania

Size: 127,000 Square Feet

Project Cost: $30,000,000.00

Completion Date: December 31, 2005

Owner: Bi-County Board of Commissioners
(Luzern/Lackawanna Counties)

Contract Type: CM Agency

Architect: HNTB

Construction Manager: Turner Construction

Major National Codes – FAA, BOCA 96
PA Code Title 34 of 1998,1990 ADA

Architecture:

-Splitface to polished surface transitional sand stone wall
-Meditation Room for nervous passengers
-Terrazzo Flooring
-Wood Ceilings
-Wood Clad cable Trusses
-Exposed Steel Beams

Structural:

-Spread footings With Steel Columns (W14s & W12s)
-Tube Steel Columns
-Heavy Duty Lintels To Support Sandstone Wall Overheads

Electrical:

2 1500KVA Transformers-
2 2000A 277/480V 3-Phase Busses-
Fully Loaded 480V Diesel Generator-

Mechanical:

-12 Roof Top Air Conditioners
-9 Variable Air Volume Boxes with hotwater reheat coils
-2 11130 Gallon Gas/Oil Boilers
-2 Air Cooled condensers

Fire Protection:

-Wet Pipe System for interior
-Dry Pipe system for breezeways and commuter gates
-FM-200 Clean Agent Extinguishing System for the Building Computer Server

Conveyance:

3 One Story Esclators, 3 Two Story Esclators-
3 Elevators, 1 Freight Elevator-
2 Baggage Claim Belts, 1 Baggage Check Belt-

Adam Weis - Construction Management
CPEP Senior Thesis Website - http://www.arche.psu.edu/thesis/eportfolio/current/portfolios/agw118/

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Executive Summary

The following is the culmination of a student driven research of building analysis as well as an up coming technology in the construction industry. This report will show the students ability to critically analyze issues in and out of their own field. There will be a main focus on construction with a breadth in the structural and mechanical side of their major.

The main focus will be on 4D modeling and its use in the construction community and industry today. This will detail how it's used in preconstruction, why it is or is not being used in construction and the community's response to this technology. 4D modeling will also be applied to the Wilkes-Barre/Scranton International Airport to analyze the steel erection sequence. A comparison to the developed schedule and a SIPS schedule will be reviewed and the SIPS schedule will be applied to the building via 4D model.

For the breadths, structural and mechanical elements of the building have been evaluated and studied. The structural analysis will consist of beam analysis and the affect of punches through the web and the mechanical analysis will cover the transfer of partial loads from one rooftop to another and it's affect on the overall system.

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Introduction

Wilkes-Barre and Scranton are in the beginning stages of bringing life back to the Lackawanna Valley in Northeastern Pennsylvania. The Wilkes-Barre/Scranton International Airport was designed to make a means of transportation for larger business to travel in and out of the valley. The site that they are building on couldn't be any better. It's secluded, and there is plenty of space for parking. Construction parking is located just north of the site, and a section of airport apron has been fenced off for construction use. In this area the contractors' trailers can be found, along with supply and material storage as well as a spacious parking lot.

The conditions of the Wilkes-Barre/Scranton International Airport are quite favorable. The site is located at the top of the Lackawanna valley. Much of the soil is quite porous and drains very well down through the valley. Coal was found in some parts of the excavation of the building as well. Being in northeastern Pennsylvania doesn't make for good construction either do to their harsh winters. Completing the building enclosure is important to favorable working conditions.

Owner Information

The Wilkes-Barre/Scranton International Airport is owned by the Bi-County Board of Trustees. This board is composed of Luzerne and Lackawanna counties, found in the northeastern part of Pennsylvania. This part of the state is very well known for mining and has had a very strong economy in the past due to the coal industry. But as


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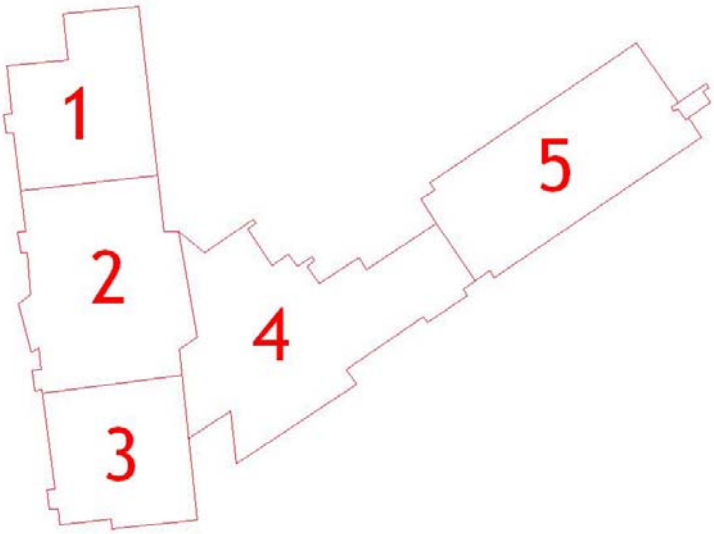
time went on, coal mining became more and more dangerous and declined in popularity, so the area started to decline with it. Today the mayor of Wilkes-Barre has a plan to rejuvenate what is commonly known as the Lackawanna Valley. Part of this plan is to make Wilkes-Barre and Scranton more alluring to big business; unfortunately, the airport this valley has used for more than 30 years was far past its prime. It had two gates, and people were very displeased with the service of this airport located at the top of the valley in Avoca, PA. The best way to bring business back to the valley would be to make it easier for businessmen and women to get into the valley — hence the brand new airport construction.

The Bi-County board wanted an entirely new airport, since it would be pointless to renovate the old airport; clearly, a new airport had to be built. The airport could not be as big as the Bi-County Board wanted it to be, because there would be a small market for flight. The airport would be just starting out, and the need for a huge airport would not be critical, but the possibility for expansion is important. The old airport would eventually be torn down after the new airport is put into commission. There were two key players that helped out on the job progress and referred back to the Board.



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Money was not a critical issue with the board either. A large amount of the money that went into this airport came from the FAA. The quality of this building is very impressive: large architectural trusses clad in wood, a stone wall running the entire length of the building, large open spaces found throughout the building, and the airport being part of a four-phase contract definitely shows the seriousness put into the project. There were some delays that came up during the project over various items, but nothing entirely critical that would hold up the overall completion of the project. This brings up the schedule of this project. The schedule is mildly important; there was a large delay in construction during the erection of the steel that set the project off-schedule for many months. Many vocal change orders were made that confused many of the workers, and the schedule had to be reworked many times to keep the final completion date. The standard of safety throughout the job site was based on what the GC and CM would consider safe, assuming that the GC and CM would reinforce the safety issues.

The sequencing of the building was very difficult. Phase A of the project was to make a new parking deck; this parking deck would have a walkway below grade that connects to the new building. A tunnel entrance was designed to accompany the passengers coming from the garage and entering the airport. What makes this difficult is that there will be a road that runs along side the front of the building to drop off and pick up people; the tunnel entrance would have to go under the road. Another major issue in sequencing is aligning the construction of the building with the construction of the new apron surrounding the terminal of the building.

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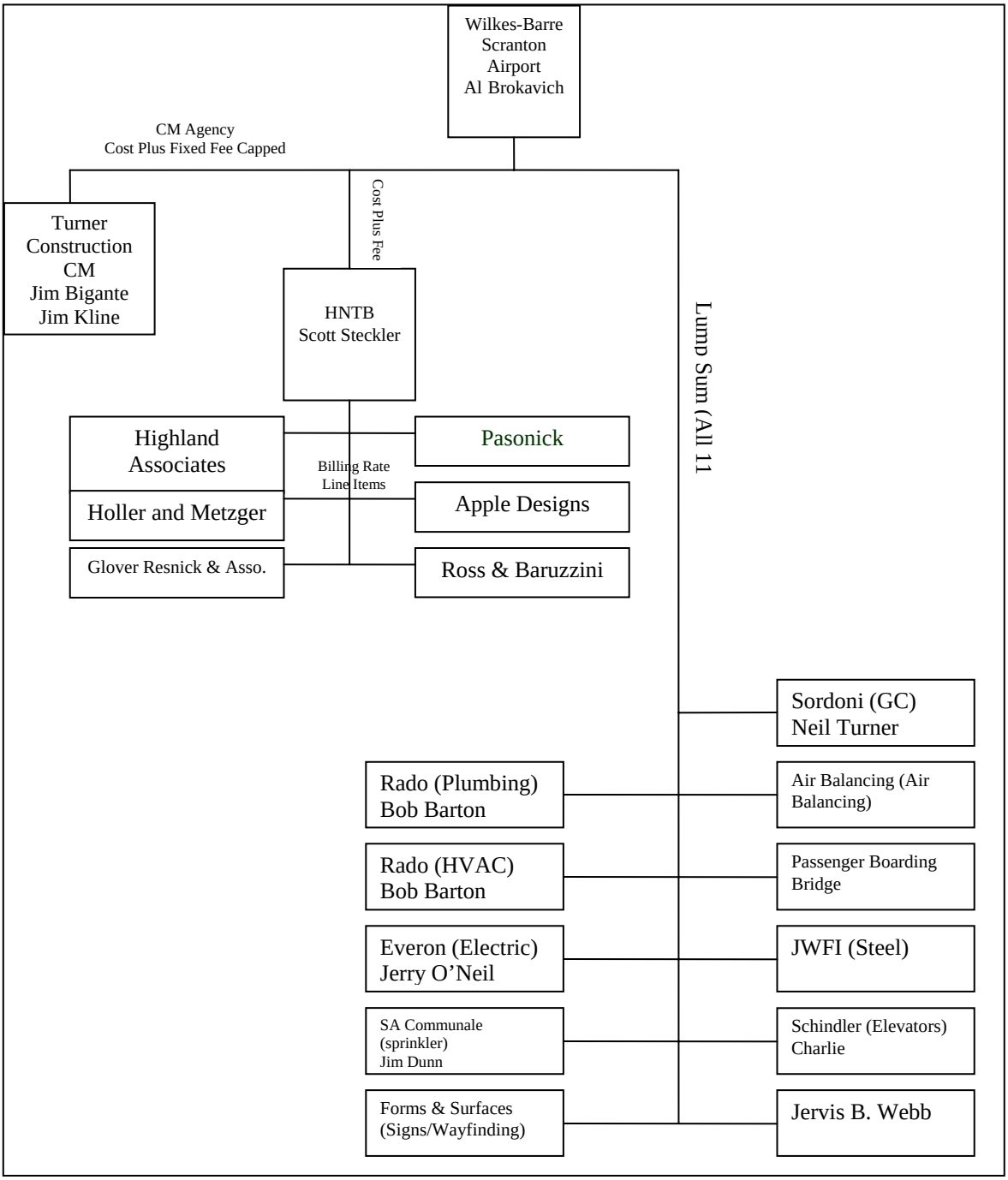
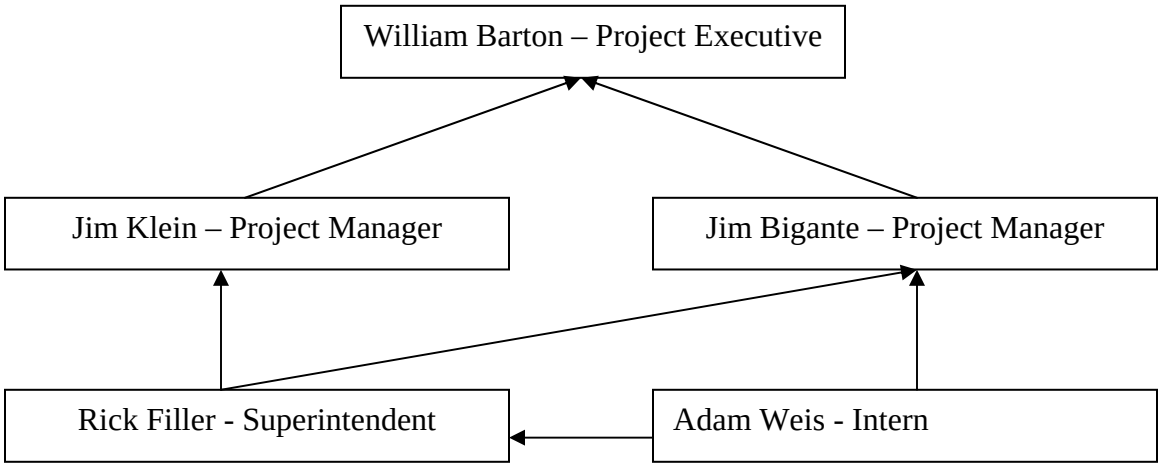
Project Delivery System

The Wilkes-Barre/Scranton International Airport was a CM Agency contract. This delivery method was chosen because it saved the airport money and many of the members of the board were quite knowledgeable about construction. Turner was hired as a consultant, because the airport did not know enough about construction to make this a multiple prime job.


Wilkes-Barre Scranton Airport Al Brokavich
CM Agency
Cost Plus Fixed Fee Capped
Cost Plus Fee
Turner Construction CM Jim Bigante Jim Kline
HNTB Scott Steckler
Lump Sum (All 11
Highland Associates
Holler and Metzger
Glover Resnick & Asso.
Billing Rate Line Items
Pasonick
Apple Designs
Ross & Baruzzini
Sordoni (GC) Neil Turner
Rado (Plumbing) Bob Barton
Rado (HVAC) Bob Barton
Everon (Electric) Jerry O'Neil
SA Communale (sprinkler) Jim Dunn
Forms & Surfaces (Signs/Wayfinding)
Air Balancing (Air Balancing)
Passenger Boarding Bridge
JWFI (Steel)
Schindler (Elevators) Charlie
Jervis B. Webb

Staffing Plan for Turner Construction



The staffing for Turner Construction at the Wilkes-Barre/Scranton International Airport is quite small compared to many other jobs. This is mainly because the contract held between the airport and Turner is for that of a CM agency. However, the need for extra personnel on this job was clearly evident. A secretary was needed, as well an extra superintendent or field engineer — both of which would have proven useful.

Jim Klein was in charge of the long-term issues of the project, as in what would happen in the following two months and how it would happen. Jim Bigante was more of a day-to-day manager, processing RFIs and DCs. Rick Filler was called in late spring to help with some of the critical phases of the building, dealing with interiors as well as his expertise on the fourth phase of the project, the airport apron. Rick Filler was in the field and dealt with issues on the spot and was more in touch with the workers. Adam Weis

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was hired for the summer as an intern and was put to work on writing smaller RFIs and evaluating DCs for the ten weeks he was there.


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Credits and Acknowledgements

I would like to thank Al Brokavich and the Bi-Country Board of the Wilkes-Barre/ Scranton International Airport. Thank you for allowing me to analyze the building and use it for my thesis topics. I truly could not have done it with out you.

I would like to thank Turner Construction for being incredibly helpful in supplying me with a phenomenal amount of information. I think I was the only one that had the most drawings in the thesis lab. Their continued help with answering any of my technical questions also will not go unnoticed. I would like to thank Jim Bigante of Turner Construction for being my go to guy for many of my questions and making the time to help me as well.

I would also like to thank all the members of the construction industry with supplying me with hard facts about their relationship with 4D modeling in the real world. With their input my research would not have been as fruitful as it has been. I would like to extend my thank you to Matt Bruchey of BE&K, Jake Hawes of Clark Construction, Mark McGaughan of Facchin-McGaughan, Seth Glinsky of Forrester, David Epps of Holder Construction, Jim McAllister of ISEC, Mera Faddoul of Jacobs and Charlie Yetter of Trammel Crowe. Thank you for making my real world research helpful and very informative. I could not have done any of this with out any of you all. Thank you very much.

I would also like to thank Dr. Messner for his continued support and feedback to guiding me in the right direction. Dr. Hanagan as well for her input on my structural breadth.


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Thesis Proposal

Industry Issue Research

Analysis 1: 4 Dimensional CAD in Preconstruction

This is an interesting topic and needs to be researched further in how it is applied and where it can be best applied in the industry. Many companies and firms want to use the software but are too afraid of the risk involved. 4D CAD and modeling are important tools which can be used in construction but, due to the reluctance of the construction industry to try new things, have gone unrefined. Proving the effectiveness of 4D CAD would be most helpful to bring the development and application of this technology further into the construction industry. The proposed thesis research topic is an in-depth look at how 4D CAD can be used in the pre-construction process — and even during construction — to solve conflicts between trades.

Research foci will include the kind of jobs that would best be outfitted for this kind of program and a look into whether there is a most effective company or firm to use it, such as an architectural firm or design-build firm. By looking at each kind of pre-construction company or firm and how it operates, a “best fit” will be determined as to where 4D CAD will best operate. Research will include many views from different industry members. Design firms, construction managers, and architectural firms will need to be interviewed to determine their opinions and applications of 4D CAD.

The best way to gather information is to talk to the people who are actively using 4D CAD and taking the risks involved with using it. Trammel Crow will be the first


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company to research; they have actively used 4D CAD in one of their Virginia projects. Research will also include looking into peer reviewed journal articles that have been published on the topic

A survey will also help gather information. The survey will be set up by targeting different positions in the industry and their involvement in 4D; there also may be a pre-survey to determine how the survey should be modified according to each particular party. The survey will provide clues of what is holding back or pushing 4D CAD in the industry, and from that, a conclusion will be drawn.

Research Methodology

- Review any current or related material dealing with the effectiveness of 4D CAD modeling
- Design a survey for industry members who use 4D CAD
- Analyze surveys and interpret them for informational value
- Determine what is keeping the industry from advancing its use of 4D CAD
- Determine where 4D CAD is best applied in terms of contract format or company usage

Analysis 2: Steel Erection Phasing

The steel erection on this job was a critical issue with the overall timing and phasing of this project. Due to the steel erectors' preference, they erected the steel out of the sequence that was originally planned for financial reasons. This set back the overall project by approximately three months and caused further complications by pushing typical seasonal construction phases into different times of the year. Analysis of this issue

will determine the time that would have been saved if the schedule was followed, along with a new phasing of steel. The scheduling of this new phasing will include the foundation work as well as the steel erection because many of the steer erection activities are ultimately determined by the concrete schedule. A SIPS schedule will be developed and applied to the building through a 4D model this issue will cover all three core investigations, with the most focus on schedule reduction.

Analysis 2 Planned Research Solution

- Review the As Planned phasing/erection of the steel for feasibility
- Review the As Built drawings for the error of sequence
- Re-sequence the phasing/erection
    - Plan which phases can/cannot be erected simultaneously
    - Review cash flow impact on the project and sub contractors
    - Design feasibility for sequencing/layout/delivery for two cranes
    - Review schedule and cost impacts
    - Use 4-D Modeling of the new sequencing of the erection process.
    - Select most appropriate method based on project goals

Analysis 3: Beam Analysis for structural integrity of punches

The main focus of the structural breadth will be on beam design. There is a section of the building where a lintel had to be lowered due to two HVAC ducts. An analysis of the beam will be calculated to see if the ducts can punch though the web of the beam. If not another analysis will be determined if one larger duct can go through the mid span of the beam and have the ducts branch of that.

Analysis 3 Planned Research Solution

- Analyze beam for structural integrity in both cases.
- Determine which system will not fail.
- Plan re-route for duct if both systems fail.

Analysis 4: Coordination of the HVAC system

An investigation of the HVAC system will be necessary to review the conflict with lintel height. The area in conflict is the location of a lintel for the sandstone wall, an area where the duct was bent around a superstructure beam. The ducts involved will require a rerouting path, as well as resizing of the ducts themselves if needed. The effects on the air loads/pressure will be reviewed when making any changes to the ducts.

Analysis 4 Planned Research Solution

- Review above ceiling plan and coordination
- Review As-Built plans and compare
- Review possible routes new duct work could take around obstacles or restrictions
- Calculate effects of new ducts on the HVAC system loads

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Building Summary

Demolition

A surprisingly small amount of demolition was needed to build this project. A small three-room concourse loading dock and its accessories on the end of the existing airport had to be removed. A large amount of concrete apron and bituminous runway/taxiway had to be removed from the site. The rest of old airport will be demolished after the completion of the new airport.

Structural Steel Frame

Steel columns are held in place by concrete footers. Tube steel was used in the meditation room because of its intricate shape and design. All beams are moment connected to columns. The beams are moment connected to the columns by bolts. All supported floor slabs are composite slabs. The building is only two stories tall, the structure of the building is basic and not very complex. The most complex areas will be the columns and beams that have been sized up to support a massive interior sand stone wall which runs the entire length of the building. There are also expansive architectural cable trusses that are found in the ticketing and baggage circulation of the building. These trusses are composed of metal plate with glu-lam cladding and the cable runs along a series of posts running along the metal plate at typical points of load.

Cast-In-Place Concrete

The concrete on this job will mainly be placed by truck and chute. For the areas that are below grade ramps will be used to bring the trucks in and out of the construction area. After the sub grade foundations have been poured the rest of the concrete will continue by truck and chute as well as by pump. All the grade sections of the buildings have a footing grade beam layout. The slab on grade will be in place before any steel erection will occur. Elevated slabs will be composite slabs.

Precast Concrete

A majority of the precast concrete is found along the front of the building. Columns supporting the cable trusses are encased in large concrete shells. The knee wall that runs along the front of the building is also precast concrete, supporting the storefront windows. This concrete was supplied by Sun Precast.

Mechanical System

The mechanical system for the airport is composed of twelve rooftop air conditioners; nine types of variable air volume boxes with hot water reheat coils, two dual-burner 11130 water boilers and two air-cooled condensers. All of the mechanical elements are found on the roof or in the basement of the building. There are three forms of fire protection: wet for interiors, dry for exteriors and an FM-200 rated Clean Agent Extinguishing System found in the server room.

Electrical System

The electrical system within in this building is composed of two 1500KVA Transformers. These transformers convert the electricity coming from 12.5 KVA down to 480/277V. The power is then distributed by two 2000A 277/480V 3 phase Busses. The back-up generator, a 1500KVA Diesel-powered generator, was installed in an earlier phase of the construction project. This generator is wired to the building so that, in case of a power outage at the airport, the building can support all function on its own. This is a fully loaded generator and can support the entire building in-case of power failure.

Masonry

A majority of the masonry work in this building is interior. CMU walls are found throughout the building and will act as the support for an enormous sandstone block wall that runs through the entire length of the building. There are architectural CMUs found along the lower level of the building and have a finished face for the exterior. The sandstone wall has a split face at the tunnel entrance and phases to a polished face at the end of the terminal. The blocks are approximately 150 pounds each. The wall is held in place by steel angles bolted to the wall. To keep in alignment, holes are drilled into the top and bottom of the block, and steel pins are inserted for added stability. The finish of the sandstone wall will be caulked and sealed along the joints of where the blocks meet.

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Curtain Wall

The curtain wall that encases the building is composed of metal panels and large storefront windows. The metal panels are non-insulated and require fiberglass batting to be installed before the exterior walls are constructed. The panels are attached directly to the frame of the building. The windows are double-glazed and UV-rated. A majority of the southern-facing windows have thin lines painted on them at the factory to prevent any more of the sun's heat from entering the building. General installation of the windows was set in place by workers with suction cup grips. For larger panes weighing over 250 pounds, a crane was used to set them in their frames.

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Analysis I: 4D Modeling in Preconstruction

Introduction

The construction industry is moving at an incredible rate and the technology that goes with construction can't seem to keep up. Within the past century of construction there have been many advances in how a building is designed, planned and even built. Building these buildings has become big business, many companies trying to out bid one another in within the last hours a bid is due. People trying to prove the best way to compose their estimates, prove their schedule is the most efficient and produce a building that will be used for years to come.

With all of this competition in the market there is something bound to come of it. It is well known that competition breeds innovation, and the construction industry is starting to switch its gears to produce better ways to manage and construct what they do best. The construction industry has become too complex to do things the old fashioned way. The complication of higher standards, LEED design, pre-fabrication, and more efficient systems are all factors leading to this cause. This is causing too much confusion on all fronts with the laborers, owners and even some of the construction managers themselves. With the competition, there is the complexity of this industry, both being the major drivers to make their jobs easier and to even give others an edge in making their own projects that much better than the other guy.

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4D modeling is one of the hot topics that is abuzz the construction industry. Last year in October a PACE (Partnership for Achieving Construction Excellence) seminar was held in Penn State. At least 60 members of the construction industry came to hear and discuss major issues in construction. Issues covered at the PACE seminar were LEED construction, prefabrication, safety and technology. The technology discussion focused on 4D modeling and animation and how it is and is not being used in construction. 4D modeling seemed to be the biggest taboo in construction as well.

4D modeling is one of the most discussed taboos in construction. 4D modeling is not some futuristic tool; it is a lot less complex than is sounds. Construction companies commonly use CPM schedules to design how a building will go together. These schedules can be hard to read due to the fact they only show the activity and the duration of that activity. Only people that have been in the business can effectively read these schedules and pick out areas of the project that will eventually have issues. Though this is even hard to see from the most experienced of schedulers. The schedules never actually show the complexities of the project as a whole. Interpreting the schedule with only 2D prints gives the reader a very broad aspect of what is actually going on. It's tough enough as it is to visualize how to put something together without being able to actually see how it should look overall. Reviewing the hundreds of activities of a schedule can also be a drain on anyone trying to find mistakes or logical explanations of how the building should be built. (Koo, Fischer) The use of Gantt charts are another method of visually understanding what activities are going on within a building. With those charts one can at


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least see what activities are occurring at the same time as well as what actives precede them.

"The combination of the graphic potential of 3D CAD with the construction project schedule is known as 4D CAD"(Webb, Smallwood, Haupt). With construction companies always needing to make deadlines and make quick decisions and keep that all with in the standards of construction, there has to be a more efficient way to review the schedule. With the advances in computer technology and programming there is an efficient way to review building schedules and that is through these models. Being able to view what activities are going on in a building at any given time will easy the frustrations of the entire construction community, an issue that has been a thorn in the side of many for years.

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How To Make A 4D Model

Making a 4D model work is a very simple process. A 3 dimensional model is developed depending on the level of detail that will need to be used or will be presented. It's pointless to completely design a building in 3 dimensions when only the skin of the building will be analyzed. Granted having a complete model would be preferred to any owner that is having a building built for them, it is not always necessary. The model can be designed in a variety of programs most of which are AutoDesk applications. AutoCAD is one of the most popular programs out on the market for design and drafting. Other programs such as Autodesk VIZ and RevIT are 3 dimensional drawing programs. This cuts out the annoying process of extruding 2D plans into a 3D model in AutoCAD. RevIT can draw in 2 dimensions and have it automatically extrude to the heights that are needed based upon what the user inputs. What makes modeling in RevIT or VIZ so incredibly useful is the ability to name 3 dimensional objects individually or in groups. When a 3D model is made in AutoCAD there are no features outside of color of objects within the model. The other programs allow the option of naming and grouping of objects. This can prove useful when naming mass quantities of similar objects, like footings or light fixtures. The reason this is so helpful is when the 4D model has the schedule applied to it, finding the pieces of the building that the schedule is referring to is incredibly easy and efficient.

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Name	Add into existing CAD package	Stand-alone package	Manual linking of product process	Formalized PBS-WBS linking	Type of CAD data required	IFC compliant	Planning software supported	Visualization medium	Web enabled	Real time updates of task 3D model	3D product object grouping	Real time navigation of 3D environment
Bentley Schedule Simulator	No	Yes	Yes	No	Microstation	No	Primavera	Internal Bentley 3D Format	No	No	Manual	No
Common Point 4D	No	Yes	Yes	No	AutoCAD, VRML	Yes	MS Project Primavera	VRML, 3D Studio, Macromedia Shockwave, AutoCAD dwg format	No	Yes	Manual	Yes
SmartPlant Review	No	Yes	Yes	No	VR 3D objects (VRML)	No	MS Project Primavera	Internal 3D Format	No	Yes	Manual	No
Project Navigator	No - Add in to Web Browser	Yes	Yes	No	3D VR Objects (VRML)	No	None	VRML	Yes	No	Manual	Yes
FourDviz	No	Yes	Yes	No	3D CAD data (DXF)	No	None	Internal 3D Format	No	Yes	Manual	Yes
Visual Project Scheduler	No	Yes	Yes	No	DXF	No	None	OpenGL	No	No	Manual	Yes

[1] Now the building model has been designed, and all the objects have been named, the next step of the process is importing the tagged building model into a 4D modeling program. There are many 4D modeling programs on the market and each one can do their job effectively. The table above describes some of the programs and their data input methods and resources. Some of the major programs that are on the market today and are being used actively are Graphisoft's Constructor and NavisWorks' JetStream[2]. The model is imported into the 4D modeling program and there the user can review the model with an assortment of tools varying to fly through, walking and orbital review. The schedule is then imported from generally a Microsoft Project file. After the schedule has been imported the program will have to build a list of all the tasks that stem from the schedule, this is where the 3D objects will be assigned to the schedule tasks.

Assigning building objects to schedule tasks is as simple as three clicks of the mouse. The first step here is selecting the 3D object or objects, then go to the task on the schedule that the objects correspond to. Select that task and right click on it and select the

[1] The graph is used from Heesom and Mahdjoubi Trends of 4D CAD Applications
[2] Navisworks Jet Stream is used as the basis of the "how to."


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"assign selected objects" option in the drop down menu and, viola, the first task has been assigned. Continue this process for all the objects in the building and be sure to match up the objects to the proper part of the schedule, otherwise the 4D model will not make any sense. There are also specific functions the schedule can assign depending on the type of work and how the objects appear in the 4D model.

Upon completion of assigning all the tasks in the schedule to the building, the user can see the fruits of their effort in the animation of the model. Click on the play button and view how the building is put together, after that the user can return to the schedule in NavisWorks and critique how and when objects appear. The user can specify how the object appear or disappear throughout the construction schedule. Objects can start out as invisible, appear in a transparent form while under construction, and appear as a solid when construction is complete. This can also work in reverse if demolition is required in building. Where the objects and show up as solid and then fade away over the duration of the demolition. Colors can be assigned to show from task to task, such as finishes, a room can be built, then have a color code define what stage the room is in. The possibilities are endless with how to display what the 4D model will look like and how it will perform.

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Real World Application

With the application of today's modern technology, jobs can become easier; that is bearing in mind that technology is properly used. With the rise of 4D modeling in the construction industry it is inevitable that change will come, and it will come fast. David Epps said, "There's a wave coming, and it's gonna be sink or swim." Mr. Epps is part of Holder Construction and is a BIM Specialist there. Holder construction have made many 4D models, this comes to no surprise since Holder's specialty is constructing data centers. The centers have an incredible amount of coordination with their mechanical system with keeping the server rooms at a cool temperature as well as keeping the air quality in those rooms very clean.

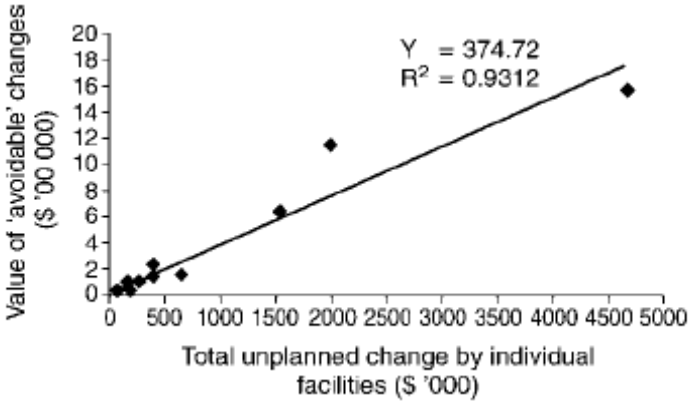
Currently the majority of 4D modeling applications are used as an explanative and communication tool (Heesom ,Mahdjoubi). The explanation can be used functionally as well as marketing tool. 4D models are used mainly in weekly foramen's meetings to describe where work is in process and where they should continue to work. Fifty percent of the time is spent in this manner. With the marketing also a large part of this, 4D modeling can provide a "medium" between all the parties involved in the project. The owner can visualize how the building layout will work best; contractors can see how complex a job will be as well as construction managers. Jim McAllister has the same idea about 4D modeling. Jim sees 4D modeling as a tool for CMs or architects to help their clients make the decision of why to select them over anyone else. The 4D simulations help the visual aspect of construction. "Each party receives project information including a project schedule, 2D drawings and 3D product model and from this builds a mental 4D

model of how the building will be built. It is often these are not the same, which leads to communication difficulties," (Heesom, Mahdjoubi). This brings up a very good point of why the construction industry is only using this as a tool for visualization. As of right now, the industry is at a turning point, many of the members are people that have worked their way up through the ranks. Many of these members aren't to computer savvy and keeping this technology to a visual aid is very helpful and can improve the effectiveness of the work.

With all this focus on providing 4D modeling as strictly a visual aid there is so much more potential than just that. The potential to using 4D models for in-depth analysis and even prediction of what will happen on a job site is a huge eye opener. The best example of using 4D modeling for deep analysis is with Charlie Yetter of Trammel Crowe Company. Charlie was working on the Shirlington Condos and encountered a major set back in their schedule. While 20 percent of the way through their overall construction Charlie found the project to be lagging by 6 weeks. A schedule was developed to bring the activities up to speed, but the complexity of this schedule left many scratching their heads. This is where the visualization is important; transferring that schedule to a 3D model of the condos explained what tasks had to be done where and when. Now this visualization was conducted after construction had begun. This makes the case of analysis of the current building construction and what was holding the schedule back. After that the visualizations were used in the meeting to push what areas had to have the most attention and focus on construction. When this schedule was implemented the project regained the six weeks that was lagging the job and set them

back on track. This is where 4D modeling can be used to asses the logic of the schedules and feasibility of overlapping tasks.

Mera has a similar situation with the use of 4D modeling on some of Jacob's projects. As soon as the modeling was completed and implement on the job, she noticed an immediate change in the rate of construction that took place. The schedule got back on track and even was ahead of itself in some areas. Using 4D modeling a tool to analyze the logic of a schedule is where the real application can be applied. While schedules are made by good old fashioned logic, sometimes that is not enough. With the thousands upon thousands of activities that occur within a schedule, it is 100 percent likely that something will go wrong during construction and will set the schedule back. This is inevitable on any job. Nothing is perfect, but with the use of 4D in the preconstruction stage to analyze the schedule for validity before anything is even built can save thousands upon thousands of dollars as well as weeks in lost work.



"The graph[3] above illustrates the value of unplanned changes using 4D modeling. The cost incurred to a project through unplanned changes is reduced dramatically," (Heesom, Mahdjoubi). That graph shows the amount of money that would have been

[3] The graph was used from (Heesom, Mahdjoubi) 4D CAD trends article.

spent in RFIs, DCs and other changes in the construction documents and schedule that could be avoided if 4D modeling was used.

Application	Attributes			
	Level of interactivity with 4D simulation	Level of graphical representation	Level of interactivity with 4D simulation	Level of dynamic capability of simulation
Product modelling and visualization	Low	High	Low	Low
Process modelling and analysis	High	Low	High	High
Collaboration and communication	High	Low	High	High/Low

[4]The chart above depicts what tasks best fit fro 4D modeling. 4D modeling has had many other real world uses in complex projects. One of the most well noted projects being Frank Gehry's Disney concert Hall in Los Angeles. This concert hall would have tested the limits of the contractors as well as the CMs involved. With the help of 4D modeling the building went up a lot easier than expected. Mera Faddoul of Jacobs is currently using 4D modeling to reduce the need of making mock-ups. Jacobs has composed a detailed 3D model of a court room in a courthouse that is being built in Virginia. The model will be used in an immersive environment and presented to judges and other judicial members of the court. This eases the mid construction change orders of the owner by determining the faults right up front. This will also save thousands of dollars and time in the overall scheme of things. While this may not apply to 4D, the overall building can be modeled in the same manner of detail. The technology to make models of this scale is there, but is it that necessary? Jake Hawes of Clark construction asked the same question. Using 4D modeling as a visual aid will defiantly be a selling point to some, but to convey a basic concept it is not necessary to have that level of

[4] The chart is referenced from (Heesom, Mahdjoubi) 4D CAD trends.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detail. Depending on what the model will be used for will ultimately determine the level of detail. The used of a highly detailed model can still be used to analyze schedules as a basic model, it never hurts to have the detail around just incase.

Neglect of Use

Old habits die hard, many people know that phrase and it couldn't be farther from the truth. With that mindset, the technology that is being developed for construction isn't catching on as quickly as expected. The issues that are the driving the lack of development stem from a variety of reasons such as the generation difference and money.

Through some of the interview made to gather details of 4D in the real world, the interviewees had a variety of reasons for using and not using 4D modeling. One of the most prominent reasons was due to the transition of people in the construction industry. A generation of young adults is graduating from college with a lifetime of computer usage under their belts. Working with computers comes as second nature, and the computers that they grew up with advanced a lot faster then the generation before that. These young professionals find it easy to grasp the technology and the logic behind using the technology. Granted many do not have the real world experience to realize that the simulations of a computer can not generally take into account typical errors of being a human involves. The generations before now have worked through the ranks and have seen and experienced a life time of knowledge of how the construction industry works. It has worked that way for their entire lives. The use of 4D modeling seems like a bad idea by many of the older construction workers. Its difficult gain the trust of something you know very little about let along a program that produced the logic for the schedule.

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Convincing these workers is one of the biggest reasons that 4D isn't as popular as it is today. Slowly 4D is pushing its way into how the job gets done. Seth Glinsky of Forrester construction mentioned how Forrester is introducing new ideas and technology little by little in weekly update meetings. These meetings inform the staff of Forrester how this technology is used and educating them on how to use it. This is used in all fields and not just 4D.

That is where a lot of this boils down to, is educating the industry the full capabilities of what 4D modeling can do. The laborers may be open to viewing the model if it has been created by a CM or GC but to model one for them selves is not very common. A rising trend is a lot of larger contractors are taking this issue into their own hands and making 4D models for themselves, but mainly from the new hires that know how to use the software or are open to learning the software. Making these 4D models can be very labor intensive which just adds to the reasons of why it's so expensive to have made for a company, and also hard to train people to use as well.

Another issue that was found as another reason to not use 4D modeling is the costs. The costs are most likely the number one reason that some companies aren't using 4D modeling. Mark McGaughan of Facchina-McGaughan is adamant about their usage of 4D modeling. The first reason being that modeling is not required by owners. Many owners are still looking for the best deal, and if you have an $80,000 model as part of your bid package, and another company doesn't, that other company is $80,000 lower than you, and you lose the job. As soon as 4D is quantified then we might rethink our situation. The costs of modeling a building through a 3rd party company are also

ludicrous. Jake Hawes of Clark mentioned that they are using Graphisoft software for their models. Graphisoft can actually sub them selves out and be a modeler, but their focus is on the software. Jake is head of estimating for Clark and also pushing the start up of a stand alone department within Clark for 4D modeling. Clark was dependent on Graphisoft at first, but were trained to use the software so Clark could become self sufficient in making their own models. Over time Clark would need less and less support from Graphisoft and eventually be fully functional in their modeling. His main complaint is there needs to be more functional training of the program instead of just how to use the program verbatim.

To make 4D modeling more mainstream many professionals comment that the software needs to be better designed. This design can swing in both directions of making it more or less sophisticated. Mera Faddoul mentioned that while designing some of their models she mentioned that NavisWorks was far too easy to operate. While being so easy that it actually caused some major frustrations throughout their process. Working in the 3D environment of only being able to visualize and not edit caused a few headaches. A simple fix of moving a wall required that the 3D model be opened up in whichever modeling program that was used to model the building, making the required fix or changes to the model and then importing that model back into NavisWorks. If there were more tools that could be used to edit the physical building that would make Mera and the rest of her team so much more at ease.

Charlie Yetter also thinks that these programs are still not being used to their full potential, he wants to see the dollar amount, or a "5th Dimension" introduced as part of

the programs. Jake Hawes would agree with Charlie on this topic. While 5D modeling is not to much different than 4D modeling, it takes on a whole new level of data and communication. There most definitely will be this technology in the near future. David Epps and Jakes Hawes biggest complaint about Graphisoft is the complexity of the program in it's self. The files that are used in Graphisoft are very large files and loading them takes a significant amount of time. Graphisoft consequently also produces large files that can take up an unnecessary amount of hard drive space.

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Conclusions

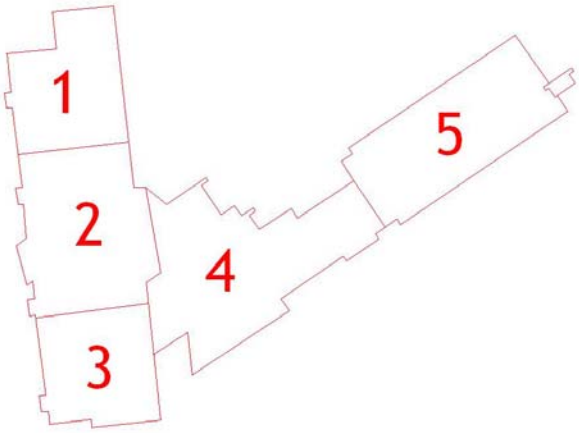
4D modeling is undoubtedly the wave of the future and will eventually be used by everyone in the construction industry. The catch is making the industry use it. Construction seems to be in the midst of a technological renaissance and needs to embrace the fact that the opportunities to advance and provide a better service and make their jobs easier are good things and worth the risk in investing into.

The focus needs to be educating the industry on its potential and not through seminars either demonstrating everything that has been said in this paper thus far. More interactive learning session's sponsored by the construction company or software company is an excellent option to start educating. This is hands on learning as well, sitting there taking notes will only influence people so much. Sitting people down and actually going through tutorials will show these people the ease that is involved in making basic models and fundamentals. With the fact that college graduates that know about this technology should be tapped into as well and used in companies effort to start their own modeling departments. With all the potential colleges and universities are putting out on the construction market, companies should take the initiative, invest in the technology and hire these grads to manage or create 4D models. The construction industry seems to stubborn to accept this technology and is waiting for the industry to change naturally and adapt to the new people that will eventually make it up. While some companies are taking the initiate and are using this technology on a daily basis, these are the ones that will be ahead of the game when 4D modeling becomes and industry standard. Other companies should follow suit and do the same.

Analysis II: Application of 4D modeling

Introduction

The use of 4D technology is pervasive in the college learning atmosphere. Where else can students be exposed to the newest trends in all forms of technology with no bias? Through out the Penn State curriculum students are exposed to these technologies and are shown how to use them on an introductory level. Through the PACE seminar that took place in October 2005 many ideas were discussed and 4D modeling was one of the topics discussed in depth. With the use in the construction industry as well as what has been learned in class, modeling is the trend of the future of construction.



The Wilkes-Barre/ Scranton International Airport is a prime candidate to use as a part of an in depth analysis of 4D modeling. The airport has been sectioned into 5 major sections and the building was supposed to be erected in the order of the sections that have been labeled. The scheduled activities have been lumped into broad categories, but overall the building is split into five sections. The building is in the shape of a T, and the top of the T is split into three sections, the base of the T in two.

The original plan was to work on building the top of the T first, and then continue along with the base. Section one of the building has a basement, so a great deal of

excavation had to be done as well as the sub grade areas found areas two and four. The sub-grade levels in area one are actually accessible via truck ramp which also doubles as a cargo transfer yard for freight. After the basement excavation of section one was completed, excavation for the rest of the grade-level structures would begin. The phasing of the sublevel with grade-level sections provides a good way to mark specific finishing points and milestones between each section of the building. But these outlines are all theoretical, and the job was completed in an entirely different manner, due to loading of the project and money issues.

The 3 dimensional model was created from the 2 dimensional floor plans of the airport. The model was originally created in AutoCAD, the model was drawn to scale and the floor plan was extruded from this plan. This is the typical method of making 3D models and is one of the most tedious of methods as well. The model depicts the structural elements of the building. The foundations as well as the structural steel are what have been modeled. This brings up the point of the detail of the models used in 4D modeling, since only the structural elements are under analysis a model that contains everything dealing with the building structure, thus making the model easier as well as simple to understand.

After the building was extruded and properly put together the 3D CAD model was imported to AutoDesk VIZ. To save time on modeling and representation of the model the floor and roof beams were represented by a single 4” plane. This plane would also represent other phases of construction including the metal floor decking as well as

pouring the slab on deck. Using this method saved time on modeling the building as well as representing stages of the model.

After the model was created the model was then imported to VIZ and the building objects were labeled appropriately. The building pieces were mainly grouped together as similar tasks such as grade beams or columns. Each group included parts of the building that corresponded to the schedule specifics. Area one has low and high foundation elements and is grouped together as such. The schedules used in this analysis are derived from the as-built schedule received from Turner Construction. Assigning the tasks of the building to the erection schedule was quite simple. With the building objects named in groups the same as the activities, matching the schedule to the model was easier than expected.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Schedule Review

The as-built schedule of the Wilkes-Barre/ Scranton International Airport is very unique in how the building was actually built. As planned the building was supposed to be build sections 1 through 5 in that order and not deviate from that pattern. Unfortunately the steel erector had a different plan in mind. With the way Turner had the schedule laid out; the steel erector would be dealing with a layout plan that had a low steady cash flow. The cash flow was apparently not sufficient enough for the erector and decided to erect the steel in a way that cash flow would be higher in the early stages of construction.

The plan that steel erector planned out erected the steel in order that follows: Section 1, Section 2, Section 5, Section 4, Section 3. Erecting the steel in this manner would give the contractor more work to do up front and that means more money up front as well. But due to the sequence that occurred a 3 month gap in steel erection occurred. The erector had to stop due to financial reasons of their own and stopped erecting steel. This caused some major headaches on the job and would eventually push the planned schedule back by two months. Due to this delay in erection the curtain wall of the building was placed in the winter months, which made for very unfavorable working conditions at the airport.

If the steel erector just followed the schedule and did their job, the building would have been on track and even the steel erector would not have run into the financial problems that pulled them off the job. But hind sight is always 20/20 which makes for an

excellent analysis of what could have been done instead. The schedule can be reviewed in the appendices under "As-Built Schedule"

SIPS Scheduling

SIPS is an industry acronym for Short Interval Production Schedule. These schedules are commonly used on high rise building with many repetitive activities. The key to making a sips schedule work efficiently is the coordination of the schedule to overlap activities. Typically with SIPS schedule there is a specific process to determine the best way to complete the schedule. Starting out with the building plans and dividing it into manageable areas of work is the first step. Identifying the activities that are contained within each section and the duration of each of those activities would be next to come. From there the development of the activity sequence occurs and is followed by planning the work involved and review with the project foremen and superintendents will tie the schedule together. After the schedule has been reviewed by the foremen communicating the plan is where people can be creative.

Sub contractors or site superintendents would generally communicate the plan through the plans that are hand. Others would use maybe a power point focusing on the areas that need to be worked on. Why use these primitive forms of communication when there is 4D modeling to fully visualize the process. Applying a SIPS schedule to a 4D model is a double whammy, using advanced scheduling and applying that to advanced communication is the most effective way to get the job done. There would be no questions about what the schedule is trying to show.


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With the Wilkes-Barre/Scranton International airport a SIPS schedule will be developed and analyzed for the effectiveness of using it on the building. The building is already broken down into 5 sections of construction. The durations of each activity can be utilized from the original schedule and applied to the schedule. The activities of the building can be sorted into 10 different activities:

- Footings
- Grade Beams
- Slab On Grade
- Column erection
- Floor Beams
- Floor Decking
- Cable Trusses
- Roof Beams
- Roof Decking
- Slab On Deck

Each activity is basic and many of the activities such as curing, backfill and trim out have been either assimilated into the duration of the activity or would occur at the same time as another activity. Focusing on the steel erection is what is important to this analysis. The foundations of the building had to be taken into account because the columns wouldn't stand without the foundations and also the erection of the steel is ultimately determined by when the concrete is finished.

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The plan to build the building is working from the inside out. A major issue is that the old airport still stands next to the one that is under construction and the road that is used runs along areas 1, 2 and 3. The site limits are tight on two sides and working away from the current airport would be most logical. Starting with section 3 is the best way to start this process. To continue with trades, sections 2 and 4 would be next and then finish up with section 5 and 1. As soon as one activity in an area, that activity will move to the next section of the building. One drawback to this plan is that the mechanical room for the building is in the basement of area 1. Area 1 is the only area that has a basement and areas 2 and 4 have sub grade walls and foundations. This is a major issue when designing the schedule for the new erection sequence. One of the critical activities is making sure the mechanical equipment is in place and is covered from the elements. With that in mind, section one has to be started first. Instead of building the building by sections, the building will have to have the sub grade foundations constructed first, and then the rest of the building as planned. Constructing areas 1, 2 and 4 will set the building on the same plane and construction can take off from there. The use of an extra crane during the erection of the building will also contribute to the overall speed of the erection of the steel.

As the foundations are being completed the footings in area 3 will start and thus start the rest of the scheduled plan. The schedule will follow the activity sequence as detailed in the previous page. The detailed schedule can be viewed in the appendices under SIPS schedule.


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Comparing Schedules

After completing the SIPS schedule, it was immediately applied to the 4D model created for the as-build schedule. Upon review of the schedule, the plan looked good on paper and in logic but didn't work out the way it was expected to run. The schedule saved a month over all with overlapping of trades and some activity compression by adding more crews. The key that made the building work well is the use of two cranes on the project working simultaneously. The major problem with the model was no matter how the activities were sequenced or added extra crews, area 4 could not finish as planned. Granted the schedule saved a month of time, but the sequencing of the project just didn't look like it would be easy to work on. As a student, viewing the model it was easy to spot simple mistakes that were made during the assigning of tasks. On top of all of that it really made the logic used to plan out the building look like a joke. The building jumped from area to area so much that the crane operators would go crazy through the erection. The use of an extra crane on the SIPS schedule is what mainly pushed the envelope of construction. Trying to keep the building crews and durations to what was originally planned made coordination difficult of the SIPS schedule, but in the long run two months was saved. The costs of having an extra crane would make an additional cost of $132,000. This is according to RSMeans, but the actual costs of having the crane on site wouldn't cost a penny since the GC (Sordoni) owned the crane. The only costs would be paying the crane operator and that would be around $81,000. The duration of the activities did not change dramatically nor did the amount of workers, so the additional

costs would actually only be $81,000. Not bad for cutting 2 months of work out of the schedule.

Conclusion

Scheduling is most definitely an art form in itself. There's lots of art out there, but that doesn't mean its good. The logistics behind developing a schedule for the steel erection sequencing takes phenomenal amounts coordination and long term thinking. This is a skill that is acquired over years of experience and learning.

Overall the SIPS schedule that was developed saved 6 weeks in construction time which by any standard is a considerable amount of time. Charlie Yetter was amazed at how the 4D model developed with the recovery schedule regained 6 weeks of work on his job, the 4D model for the airport advanced building by 6 weeks from the as-built schedule. Unfortunately the flow of work did not go as planned. Working from the inside moving outward as described in the schedule is a very logical idea. This is not always how it works. When making the schedule everything was falling into place and two months were removed from the schedule in overall build time, but do to the duration of some of the activities, the actual sequence that occurred was not as smooth. Section 4 was the main reason behind this due to its size and volume. Areas 1 through 3 do not have a second floor that is the same size as it's first. Construction for the sections of the second floor took much less time than the first. With area 4 the area involved with the second floor and the erection of the beams took an awfully long time to erect. Area 5, though having a second floor of the same size as its first, wasn't as large as area 4 and thus it's completion before the rest of the building.


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When the SIPS schedule was first developed it looked like it would work, but as soon as it was applied to a 4D model, some of the flaws were much more pronounced than on paper. After viewing the animation changes in the sequence were made to make activities run more smoothly. Granted this did increase the amount of work done overall it still could not be arranged that the sections were to be built as planned. The only way to bring the schedule to up to the speed that was in theory was to add 2.5 more crews to the activities that were affecting the duration of area 4. Trying to keep costs down and workers not crowed in their workspace, this was not an option to consider.

What did make the difference in the two months less of construction time is the use of an extra crane. As mentioned before two fewer months of work for $81,000 is not a bad amount to pay at all.

Analysis III: Beam Analysis for Structural Integrity

Introduction

The Wilkes-Barre/Scranton is a very unique building with its architecture. The entire building is has a gigantic sandstone wall that spans the entire length of the building. This wall starts from the lower entrance from the parking garage and runs all the way to the end of the terminal. The stones that are used are about 150 pounds each, and the wall reached to well over 40 feet in height in some areas. Navigating through the airport would be quite difficult if there were not any openings along this wall. The wall can not just stop for when an opening is needed either. The wall will continue overtop of the openings and will be supported by lintels to continue the pattern of the wall.

The sandstone wall has an interior CMU wall for supporting the large stones. The stones are tied into the CMU for any lateral support to prevent tipping and relief angles are found in the taller sections of the walls where the lintels can not support the weight of the wall. All of the openings in the wall have a prefabricated lintel that sits on a CMU pier on either side of the lintel. This case is true for all but one opening in the wall. The opening found in section two of the building, next to the freight elevator, does not have a prefabricated lintel, or CMU piers to bear the load from the stone clad lintel.

The lintel that is found in this area uses the supported floor slab beam as its source of support for the stones to hang off of. The supports for the stones are welded on to the beam through a series of long steel angles for the face of the walls and W/WT beams to attach the stones to the underside as well as support the steel angles. The stones are set in

place through steel pins on the face of the wall and embedded bolts for the under side to leave a smooth unflawed surface on the sandstone.

The issue that arises from this particular lintel is that when the HVAC system was roughed in and ducts were hung, the duct had to wrap around the same beam that would be holding up the lintel in this area. When the duct was installed the lintel was lowered by 10 inches and this caused some distress with the design of the wall and concerned the architect as well. This brings up the point of how to solve this problem effectively and regain the 10 inches that was lost in the original plans. The most logical way to solve this problem is to analyze the beam for having the duct punch through the web of the beam and not wrap around.

Beam Analysis

The beam that will undergo structural analysis will mainly focus on shearing issues of the beam. The beam that is in contest is a W33 x 118 and is simply supported at each end. The beam is 44 feet in length and composed of A572-50 steel. There is a distributed load, which was found from the steel details, of 165 psf which equates to 990 pounds per foot. There is also a column that rests on this beam for supporting the roof and has a point load of 7.5 kips in the beam. The load that comes from the lintel takes into account of the steel that has been welded on to the beam as well as the stones that will later be mounted on to the lintel. The load from the steel and the stone comes to 313.3 pounds per foot. The distributed loads were calculated and converted into point loads on the beam for analysis of a determinate structure. Upon finding the shear values of the beam the where there was no shear actions working was almost in the middle of the beam in spite of the odd loading setup. The point where the shear is zero is 22'-4_11/16" from the left side of the beam in plan view. This is frustrating because to have a punch work most efficiently a punch would ideally go through the web of a beam where the shear is zero. But the location of where the shear is at it's lowest is 18 feet away from where the ducts would normally travel.

The ducts are 9" in diameter and are located 3'-3" and 7'-4" from the left end of the beam. The shear in this area of the beam is at 24.5 kips at the 3'-3" punch and 19.18 kips at the 7'-4" punch.

There is a great impossibility that the beam will be able to withstand this shearing effect. The next best step is to re route the duct further along the beam where the duct can

effectively punch through the beam with out risk of web shearing. Mentioned above the point where the beam's shear is equal to zero is at about 22'-5" from the left side of the beam. While the shear is zero no risks will be taken and only one hole will be punched through the web of the beam to allow access of the ducts or duct to pass through the beam.

After talking with the structural engineer of the building, he supplied the information on this issue. When the problem arose on the job site the engineer analyzed the beam for the punches in the far left of the beam. Upon analysis the engineer found that the beam failed when the holes were cut through the web of the beam for the ducts. The lack calculations proving this point came down to a few issues. First of all not having a building model to use for personal analysis and load analysis made determining the loads of the building much more difficult than anticipated. Analyzing the calculations by hand with out the use of the model also proved to be very difficult for the lack of information and resources to provide empirical evidence. The engineer did not save the calculations of the hole punches because it was more for checking purpose and not an option to follow through and try to fix. The simple solution was to lower the lintel, end of story.

Conclusion

The holes punched in the beam will actually cause more problems than anticipated. The failure of the beam where the two ducts originally were designated to punch through would in fact fail the beam from what Highland Associates, the structural engineer on the project, determined. The holes that would be there did in fact have to high of a shear force that would cause failure of the beam. Making the hole in the center of the beam where the shear is equal to zero is a far better plan to locate any punch through the duct.

Placing the punch at the center of the beam will be able to withstand the shear forces found with in the beam. The shear forces in the left end of the beam were above 19kips at one hole and 24kips at the other hole. The beams redistribution of the shear forces acting through that hole would fail the beam. The forces that would be affecting the hole at the center of the beam are less than 1000 pounds acting through that area. The shear forces that would be redistributed around the punch are around 500 pounds, that's 2 percent of what was being redistributed in the other planned holes. The beam can withstand this force and will not fail if a hole is cut there.

The analysis of the cost effectiveness of re routing the duct an additional twenty feet to punch through that duct will be covered in the HVAC analysis.

Analysis IV: HVAC Re-routing due to Structural Instability

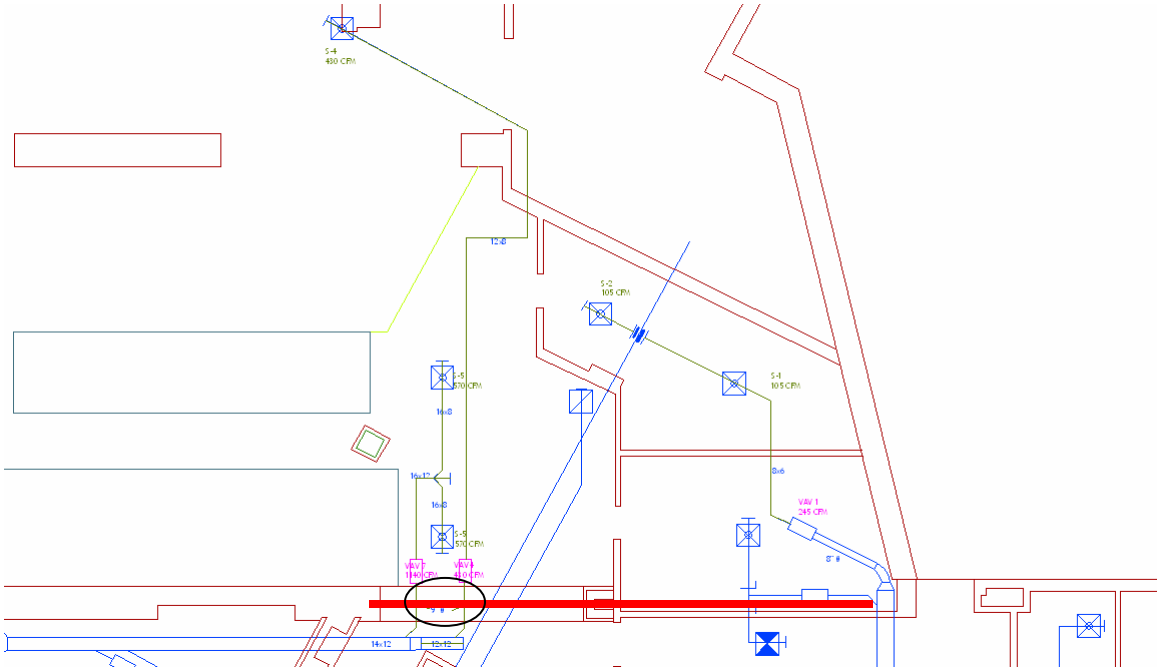
Introduction

After calculating the possibilities of the points where ducts could punch through there is more to analyze on top of all of that. Will making the duct go through the proposed section of the beam be cost effective? Or will it add to other complications from the other trades in the above ceiling plan?

There are three main diffusers that will need to be taken into account when analyzing the issue at stake. These diffusers are in open areas and will be supplying conditioned air to circulation areas and open areas. The need to supply an appropriate amount of conditioned air is important, but not critical. The areas that are being conditioned are open circulation areas and a hallway. The one diffuser is supplying the edge of the baggage claim circulation area which is a vast open area. The other two diffusers are supplying a hallway underneath the escalators. This hallway leads mainly to the security section of the airport.

The main idea is to remove three of the diffusers off of one roof top unit to another roof top unit. The reason to move the branches is due to the beam that blocking the route of the ducts which ultimately lowered the opening of the lintel in the building.

Load Transfer Analysis

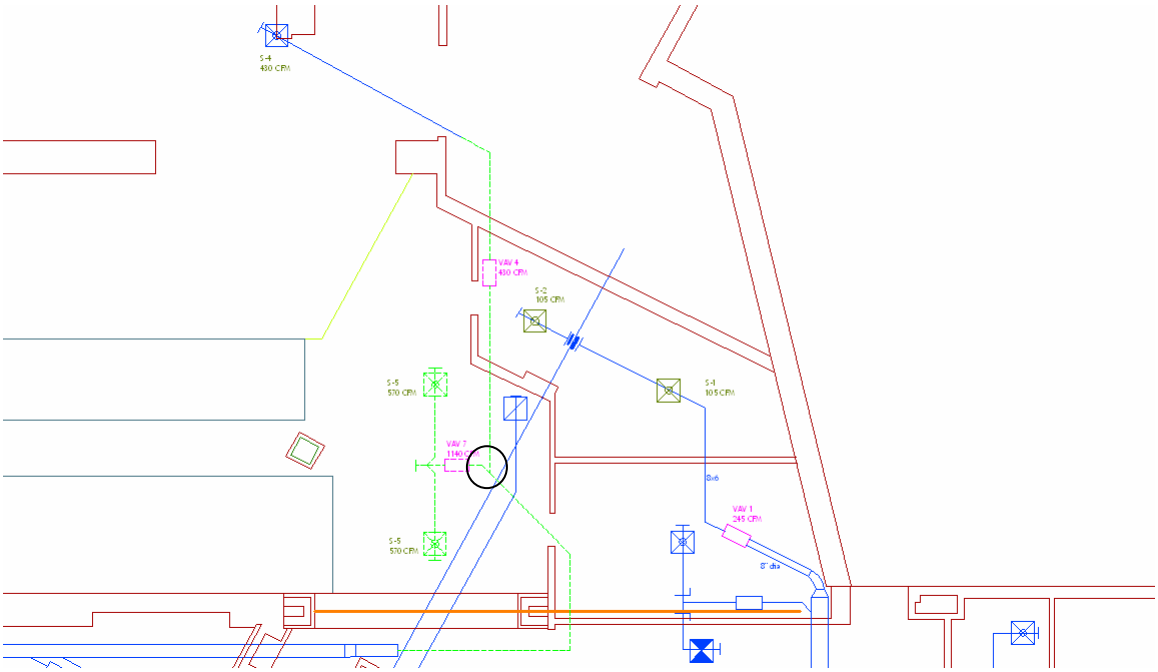


The mechanical plan above shows the area in which this analysis is taking place. The thick red line at the bottom of the plan is the W33x118 and on the left side of the beam is the two ducts that bend around the beam. The conflict is indicated by the oval. The two ducts that are in conflict are supplied by Roof Top Unit 5. This rooftop unit is a Trane SFHFC20 and has a total output of 6000 CFM being processed by this unit. There are 2 compressors inside that are rated at 10 tons per compressor. This is the tonnage for conditioning and not the actual weight. The duct main that supplies the two branches is the 14x12 duct that is in the lower left hand corner of the plan. Larger plans can be reviewed in the appendices.

There are three diffusers that will be affected by any change of the duct layout. These diffusers are diffusers S-4 and S-5. Each branch is regulated by a VAV box and these boxes are VAV 7 and VAV4. Each VAV box has been designed to regulate the flow of air to the areas by amount of CFM. VAV box 7 has been set to regulate 1140 CFMs. The two diffusers on the same line as VAV 7 will have 570 CFMs diffuse out of each. The far diffuser on the branch that has VAV 4 will put out 430 CFMs and that VAV box 4 will be set to have 430 CFMs flow through it. The static pressure found with in the duct pre VAV box must be less than 6000 CFMs but each VAV box has been rated to control the flow from the main. The total amount of CFMs that are being distributed equal up to 1570 CFMs.

After the beam analysis found that the section of the web where the shear was equal to 0 was found to be 22’-5” from the left end of the beam in plan view. The duct would have to continue from where it initially branched off and continue along the beam to the point where a punch can be cut through the center of the web. The plan is to cut a hole in the web that can let a 9” diameter duct pas through the web. The hold will have to be cut an extra 1.5” to allow for insulation as well as expansion and contraction of the duct as well as the beam to prevent any unnecessary forces that could damage the duct.

Duct Layout 1

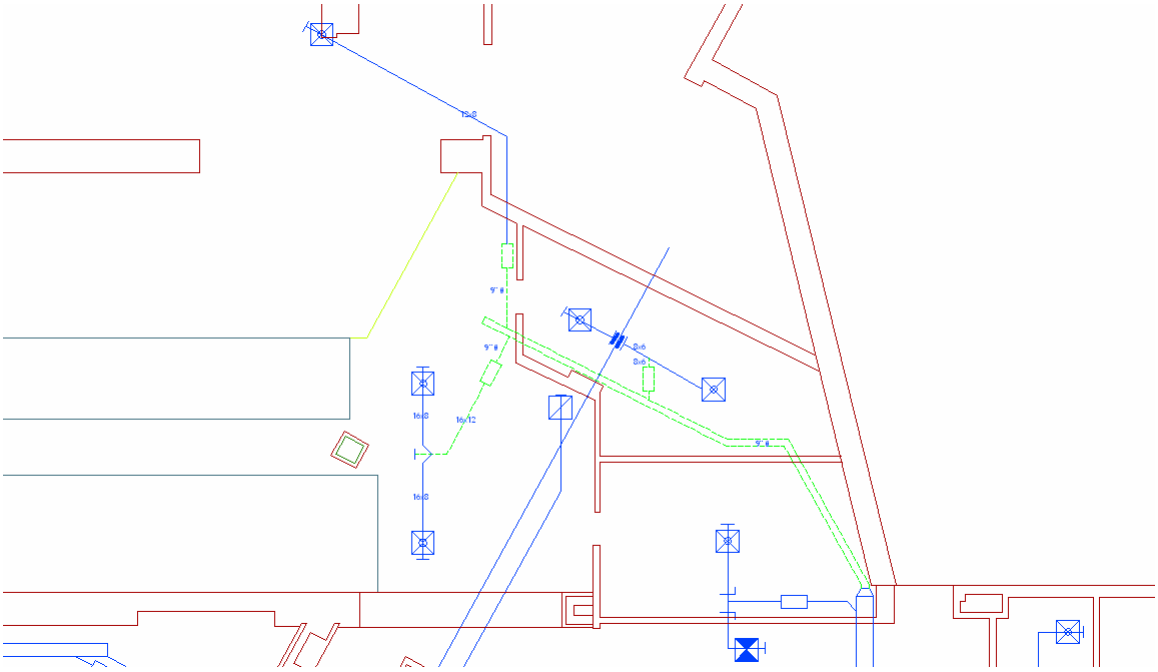


The plan above shows the new plan of the duct to punch through the beam at the point where the shear is zero. The reason the punch has to occur in a location where the beam is equal to zero is because of the redistribution the beam will have to do when a deduction in the structural support of the web is missing. From the beam analysis only a load of about 500 pounds will have to be redistributed around the hole in the web. This is much easier for the beam to do rather than the 25,000 pounds that would have to be redistributed around the two holes in the left end of the beam.

The new plan can be seen by the light green dotted line. All affect ducted paths are colored in this manner. The new plan has a 9" diameter duct run up to the beam where it can pass through, and continue up to a "Y" intersection indicated by a circle on

the plan. The VAV boxes will have the 9” duct connect to them and will switch to the original duct that was planned to connect to the diffusers.

Duct Layout 2



The second proposed duct layout actually moves the loads from Rooftop Unit 5 and adds onto the load of Rooftop Unit 7. The main that was in area two can be removed because it is no longer needed to run the length it did up to the original point. The duct that was originally in place was an 8” diameter duct that supplied two diffusers in a smoking lounge. The new duct will now have to supply 5 diffusers instead of the original two. The duct will increase in diameter as well as gauge to handle the additional pressure that will be within the duct. The two diffusers in the smoking lounge run off the same VAV box. The plan is to have the VAV boxes right off of the main line and have the original sized ducts used for after the VAV boxes. The above ceiling coordination shows

that there is plenty of space to place a duct along the proposed path. The path of the new duct is also shown in a green dotted line. The lines that are still blue indicate that there was no change in the duct layout and size.

The additional load that will be required from Rooftop unit 7 is an additional 17 percent more than what the rooftop is producing now. According to the specifications of rooftop unit 7 the maximum output load of this particular rooftop maxes out at 11700. This rooftop will suffice for the needed load to supply the additional load on to the branch the rooftop is 1130 CFM in excess what is needed. The choice to move the new branches onto Rooftop unit will work and save plenty of money.

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Conclusion

The practical application of each new duct layout will theoretically work best in each scenario. The issue that is driving the plans is the costs behind it. The major costs are that of cutting the hole in the web of the beam and the costs of the duct with the labor included.

As it turns out, the original duct layout would cost approximately $7,100. This is including the labor to install the duct. The value was found by summing the weight of the duct. Using a basic sum of two sides and gauge of duct a n approximate weight of the total duct being installed came to 1163 pounds of galvanized steel. The costs to have two holes cut into the beam would cost approximately $3.17 per linear foot for steel cut. The steel cut would be 5.76 feet. With the equipment feel of Oxygen-Acetylene torch, regulator, and goggles of $200 the total costs of cutting would be $218.25 (Getaquote.com) The over all costs would equal up to $7,315.

The costs of installing the duct to punch through the middle of the beam are actually more expensive than expected. With the beam will only have one hole punching through the center the costs of cutting that would be $209 for one 11” hole. The additional duct to stretch from the original point actually adds 95 pounds of galvanized steel to the total. That brings the total cost of duct up to $7,680, with the cutting fee its $7,889. This is an additional $500 on to the total, this is small change in the overall building costs.

The final option to re route the duct off of a new rooftop proves itself much more cost effective in terms of duct and labor. The amount of duct to install comes to 1055

pounds of galvanized steel. This comes to a total of $6,435.81. There is no need to cut any holes in a beam either which makes this a possible solution. Fortunately the rooftop unit that will be supplying the additional load is 1130 CFM over the required CFM to run efficiently with the added load. Moving the loads off of Rooftop 5 and onto rooftop 7 will save $880.


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Conclusions

This last year of the AE curriculum has required students into proving to their professors that they did pay attention in class and the past 5 years have not been in vein. The mere fact that the Architectural Engineering curriculum has an extra year than most majors is telling the public something.

Studying for a thesis topic is some heavy stuff and quite frankly scares most people. But the process was not as bad as it seemed. With the bulking up of information and the structured schedule of gathering that information made a strong foundation to build a thesis on top of. The CM opportunity to sit in on the discussions at the PACE seminar held this past October help a majority of the students within CM get a thesis topic way before the other options considered one. From there the technical reports were valuable resources for the second semester to find the answers that students need to prove their points.

4D modeling as the basis of this thesis proved to have a plethora of information from the taboo in the industry to the cases and research already written about what it is and how to use it. Talking with the industry professional was the biggest input to this thesis. Drawing on the opinions and facts from the people that know and use, or don't use, the technology every day could not have made the research any easier. Granted not as many people responded to take the survey, but that's the nature of the beast. There are enough cases out in the real world now that people should be more open minded about using new technologies in the construction industry. It's like trying to argues it's still

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winter outside when it's blatantly the end of spring. The evidence is there, just accept it and use it to one's advantage.

Also the requirement of using a building that is under construction is an interesting idea. Using a building that is still under construction helps the student find major issues with the building. Also the issues with the building mostly occur during construction and not after construction. The issues at stake are fresh in the minds of the people working on the building give the student something to consider for research or how the student feels they could have fixed the problem. The issues found in the airport may have been trivial, but upon further research became a bigger issue.

Solving problems is going to be a big part of every AE graduate and the ability to solve those problems will be invaluable. Developing a schedule for a quicker way of erecting the building proved to be quite the challenge and a big learning experience. Not all buildings can have SIPS schedules applied to them, but reviewing the SIPS schedule with the 4D modeler proved to be a great way to cross check the logic of the developed schedule. Overall using the 4D modeling proved the point made in this thesis that it is needed to review the logic of schedules as well a develop a better way to build a building.

Analyzing the beam for the structural integrity became a big deal because it would not have worked at the point that would have been easy, and extending the duct along the beam to punch through the beam at a more safe point proved to be more expensive. When looking for a better option the analysis of the HVAC system came into play and load analysis and efficiency issues came into play. Moving the loads from one


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roof top unit to another rooftop was a considerable solution and proved to be quite cost effective.

Overall the process of writing this thesis made the student draw upon topics and subjects that they learned from years back. Granted many students would prefer to avoid some of these topics, but that is not the real world. Analyzing topics outside of their degree are going to come up every day in their lives. This is why the Penn State degree is so higly regarded in the building industry. The graduates of this program know how to solve problems to some extent out of their own focus. This knowledge makes Penn Staters have that extra edge in the real world, and having that edge makes life all the better.

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Seth Glinsky

Forrester Construction No Experience 3/20/06

Q1. What is the main reason to why you are not using 4D modeling on your projects?
A1. 'The major reason we are not using 4D modeling on our jobs, is because the costs and the time involved with training employees will not be beneficial to the overall process. We use Fast Track construction, so the time that we would spend on planning and designing the model would only take away from the time we could actually be building. Speed and getting the job done is our priority

Q2. Would your employees be open to trying out/learning 4D modeling?
A2. Yes, they would be.

Q3. What jobs would you use 4D on if you used it?
A3. If we took on larger jobs, we would definitely focus the planning and modeling on larger projects, but since our target range of projects vary from $2-$20 million dollars. Anything larger than 20 million would definitely be considered for modeling

Q4. Would you like to see more opportunities for training or seminars in 4D modeling?
A4. 'As of now we have weekly training classes that we can introduce new techniques, technologies or what's new in the construction industry. A large percentage of the contractors that we work with have worked their way up through the ranks and are not very proficient with computers. This may cause some conflict between parties. Though it would be worth while if there were more seminars about 4D modeling.

Q5. Would you use a 4D modeling company or firm and have them model the building for you?
A5. 'We would if the price is right. If it came down to the owner requested a building model as part of the bid package, then yes defiantly we would make one. We would spend $1000 on a $1Million project.


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Mera Faddoul
Jacobs 6 Months Experience 3/6/06

Q1. How many buildings has your company modeled?
A1. 5 Buildings

Q2. What program did you use to model the building?
A2. Commonpoint – NavisWorks

Q3. Did the owner of any of your buildings influence your decision in using 4D Modeling?
A3. Definitely, we also approach owners and convince them to use 4D modeling on their buildings. Owners mainly find out about 4D modeling through word of mouth.

Q4. How long did it take to model the building?
A4. The model the courthouse, it took between 40 and 80 hours. The model was made from 2D to a 3D model through extrusion. But the model really depends on what you want to show in the model. If you are looking for something to show during a weekly meeting of areas of the building that need to be focused on, it doesn't have to be too complex. You model on the level to how much you want to benefit from the model

Q5. In what stage did you model the building?
A5. All buildings have been modeled Mid-Construction, and noticed results immediately.

Q6. Where do you feel 4D modeling is best suited?
A6. Contractor would benefit the most, and CMs. The general contractor is the key user.

Q7. What was the main risk your company had before you started?
A7. The main risk was, what 'ARE the benefits of modeling'. Time and money were the driving force otherwise, sinking time and money and not seeing any benefits immediately was the major concern. We started to model rooms only first and small issues on the job site. After we proved that modeling worked and actually helped out, we applied it to larger issues.

Q8. Are there any improvements you would like to see with the software you used?
A8. NavisWorks is too user friendly. There needs to be a lot more content, restraints and be a little more complicated. Work from 4D model to devise the schedule instead of adding a schedule into the 3D model. Add more real time editing tools

into the model space so one can do minor changes on the fly instead of re-importing the model from VIZ or other 3D programs.

Q9. Was there any training or seminars presented by the program developers?
A9. There was no training from CommonPoint – NavisWorks, but technical training would be more useful than how to use the program as is. Learning how to make models more useful and more informational rather than making them pretty. Better use of 4D modeling is what we're after.

Q10. Would you help other companies with 4D modeling?
A10. We definitely would advise others on how to use; the industry could not work otherwise if everyone helped their selves. We would help, but try to keep our competitive edge at the same time.

Q11. Do you feel that 4D modeling will 'take away' from the jobs of estimators and schedulers?
A11. This is more of a way to improve the scheduling/estimating department.


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David Epps **BIM Spc/Proj Eng**
Holder Construction **1 Year Experience** **3/10/06**

Q1. How many buildings has your company modeled?
A1. Right now we have one building fully modeled and 3 or 4 are in progress now.

Q2. What program did you use to model the building?
A2. GraphiSoft Constructor and NavisWorks

Q3. Did the owner of any of your buildings influence your decision in using 4D Modeling?
A4. We (Holder) presented to the owner the service for an extra cost, and were impressed and accepted the model.

Q5. How much did it cost to model the building?
A5. $80,000

Q6. In what stage did you model the building?
A6. After the construction documents on the Data Center, pre construction documents for all the other buildings.

Q7. Where do you feel 4D modeling is best suited?
A7. The Architect should make the model. 2D to 3D is most conventional, but making it 3D initially and making 2D plans from that would be best.

Q8. What was the main risk your company had before you started?
A8. There were not many risks at all. We were very excited to start using the programs. The company backed us all the way. Our only regret is not using it earlier.

Q8a.
A8a. It's hard to quantify the benefits of 4D modeling, and even harder to get tangible results. Need hard proof of effectiveness, there are too many programs out on the market to choose from, so there is no industry standard. Really looking forward to 5D modeling as the industry standard. The most forward thinking will benefit the best from this technology.

Q9. Are there any improvements you would like to see with the software you used?
A9. RevIT – Needs 5D capabilities
NavisWorks - Needs to try and program into it what people want, it's very user friendly and large files load quickly.
Graphisoft – Loading models takes a long time. Generates to many large files.

Q10. How did the subcontractors react to this software?
A10. The subs loved it, especially the younger guys. One of their own subs actually developed their own 4D MEP model.

Q11. Is there any piece of advice you would give other companies about 4D modeling?
A11. "There's a wave coming, and it's gonna be sink or swim" It's slow now, but it's going to climax really fast.

Q12. Do you feel that 4D modeling will 'take away' from the jobs of estimators and schedulers?
A12. The Precon guys will be affected directly, but this will more facilitate their work. But the old fashioned way will always be around, never fully switch over. Everyone will have their own par in modeling the building, and nothing will be replaced by it.

Charlie Yetter **Senior Vice President**
Trammel Crowe **One Time Application** **3/7/06**

Q1. How many buildings has your company modeled?
A1. 1 – Shirlington Condos

Q2. What Programs did you use to model the building?
A2. Penn State modeled the model and used NavisWorks

Q3. How did you come about 4D Modeling?
A3. I Visited PSU, and saw the power of 4D modeling through Dr. Messner. Had a recovery schedule developed but it was hard to visualize the schedule, so asked PSU to make the model and help visualize the schedule. The key is the fast the building is complete, the faster you can start gaining money. This was the most important factor and drove the process.

Q4. In what stage did you model the building?
A4. 55% the way through the concrete framing, and backfilling, 20% overall project

Q5. How much did the building cost?
A5. Less than $10,000, having PSU helped cut costs greatly.

Q6. How much money or time did you save?
A6. The cost to bring the project up to speed was pretty steep, but in the overall scheme of things, there wasn't much money lost. Money spent wasn't out of contingency, only to bring it back up on track.

Q7. Where do you feel 4D modeling is best suited?
A7. Modeling should be used on every project, as soon as it's designed by the architect make the model, even have the model made by the architect. But use the model to derive the schedule, and have the language to provide the model. Make 4D part of the bid package as well.

Q8. What was the main risk your company had before you started?
A8. Did not know it existed before Penn State. Don't really see 4D modeling as a risk, just a new tool to use and manage construction.

Q9. Are there any improvements you would like to see with the software you used?
A9. The Dollar amount!! Need to have the 5th dimension programmed. The program needs to estimate model materials.

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Q10. Is there any piece of advice you would give other companies about 4D modeling?
A10. You will be left behind if you don't get with the times. Trammel Crowe will be using the software via 3rd party company or firm.

Q11. Do you feel that 4D modeling will 'take away' from the jobs of estimators and schedulers?
A11. Jobs will be redesigned; contractors will still have to use their own schedules and developed their own schedules. Both subs and architect need to work on same level enhances schedules job.


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Jim McAllister Vice President
ISEC No Experience 3/21/06

Q1. What is your stand on 4D modeling?
A1. I haven't seen much of it; we're a subcontractor and see 4D modeling used more by Architect and CMs to help their client. Use 4D as a tool in presentation and, "why should the owner select you" tool. It separates you from the competition, and can show understanding of the owners needs.

How we are a part of the whole deal is we review the specs and keep updating the technology between the market and the architect or CM. Always updating the specs. Don't really see the need for 4D modeling.

Q2. Would you be open to using 4D modeling with a CM?
A2. Yes indeed. I feel it would be easier to talk about all aspects of a job w/o a 4D model.

Q3. Did you know that there are many more applications to 4D modeling than just presentations, such as regaining lost time on a schedule?
A3. Well then it's a lot more useful in that matter. I do not know much about this topic, but I'm definitely learning things now. I would like to see more opportunities to go to seminars about this topic now.

Q4. How would you react to working with a CM and 4D?
A4. This sounds like a very easy way to visualize complex jobs. We do a lot of work with finishes and you talking about the Jacobs courtroom visualization, 4D would really help out our cause. We are working on a hospital right now and renovating 4 rooms and being able to visualize the ¾" thick renovation schedule.

Q5. How much would you invest in education on 4D modeling?
A5. I wouldn't mind personally educating myself and taking the initiative to investigate the software and what's out there. I would start out small on any real application and learn from there. As far as the company goes, that's another issue.

Q6. Would you use a 4D modeling firm or company to make any models?
A6. We would like to keep our options open.


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Jake Hawes **Chief Estimator**
Clark Construction **Just Started** **3/7/06**

* Clark Construction just started to implement 4D modeling, very well read and working with operations now. Though much of this is still in the works.

Q1. How many buildings have you modeled?
A1. No complete buildings yes, mainly rooms and partials.

Q2. What programs did you use?
A2. Graphisoft Constructor. Used separate scheduling program. There is no major dependence on Graphisoft now either, we will start our own department in Clark, and will refer back to Graphisoft if any major issues come up.

Q3. Why did you wait so long to start using 4D Modeling?
A3. Fear of the unknown, the costs and training, contractual relationships and data sharing were many of the points that held us back. Using this program as a tool to address risks and problems, and trying to make the program risk free were what we would like to do. Also the company mentality was another hold back.

Q4. What are some improvements you would like see with 4D software?
A4. A lot more in terms of estimating, this is a powerful tool but need to be refined, and getting it out of the box and start using it, difficult to start using. *Is it really necessary to have an overly detailed model?*

Q5. Where do you feel 4D modeling is best suited?
A5. The GC would benefit the most from 4D, there is less risk dealing with the time scheduling side of the business. The CM could get the best out of 4D modeling in huge industrial planning, like chemical plants or oil refineries. Design/Build firms benefit from fast track construction, working with the client up front to find out how long it will take to build, then define budget from there, take out loans, have tenant move-in and show client the accuracy of an on the fly design. (Design build technically doesn't have time to model)

Q6. How will you present these models to your subcontractors?
A6. Weekly meetings like foreman's or GC meetings would work the best. This would be where the models would be most effective. There would be one-on-ones for exclusive training and model analysis.

Q7. Do you feel that 4D modeling will take away from the schedulers/estimating job?
A7. The schedulers and estimators job will be more redefined. There will be a capability to do more work, so how could anything be taken away? Design/Build

companies will take work form the GC on a small scale, but on large scale operations, DB will find it very helpful financially.

Q8. What piece of advice could you offer to non-users of 4D?
A8. Be open, research, is there a benefit for your company, proceed with caution, be gradual yet aggressive

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Matt Bruchey **Project Engineer**
BE&K **No Experience** **3/23/06**

Q1. What is the main concern behind not using 4D CAD/Modeling?
A1. Finding someone that knows how to use it or training the rest of the people to use the software. Great to have, but to have someone very proficient in it.

Q2. Do you feel that it would be beneficial to your company/job?
A2. Absolutely, form a broader point; it's easier to show someone visually how to build something or how to translate at schedule. Use visually aided schedule, not as in-depth as 4D with foremen.

Q3. Would your employees be open to trying it on certain jobs?
A3. Sure would. Some of the older guys, not so much.

Ind Ques Vis aided schedules: diagram of what's going on, for different processes of construction. Foremen can walk in and see where the work and what kind of work is going on in areas of the building. Everything to hand sketches to computer 'SureTrack', power point presentations.

Q4. Would you like to see opportunities for training in 4D CAD/Modeling?
A4. Seminars, defiantly would go to,
Go to day programs where you get to *use* the program instead of listen to the

Q5. -Would you like to see the development of a professional 4D Modeling Firm as a buffer between the Architect and CM/GC? Would you use such a firm on your projects or jobs?
A5. As long as it is cost prohibitive, more complex projects. Be dependent on them at first but slowly devise their own department to make their own 4D models. At first yes, over time no.


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Mark McGaughan **Vice President**
Facchina-McGaughan **No Experience** **3/23/06**

Q1. What is the main concern behind not using 4D CAD/Modeling?
A1. Not required by owners to much. GC will only include it if necessary. Money issue is pushing it. If you have 80K, with 4D, and other guy that does not, his bid is 80K cheaper. Extra expense. As soon as 4D is quantified and making this a requirement and actual value efficiency in saving and outlay of cash.
The operator, schedule in house as part of company, they know how to do it, if take on 4d then you need to hire people that know or hire a company to do so.

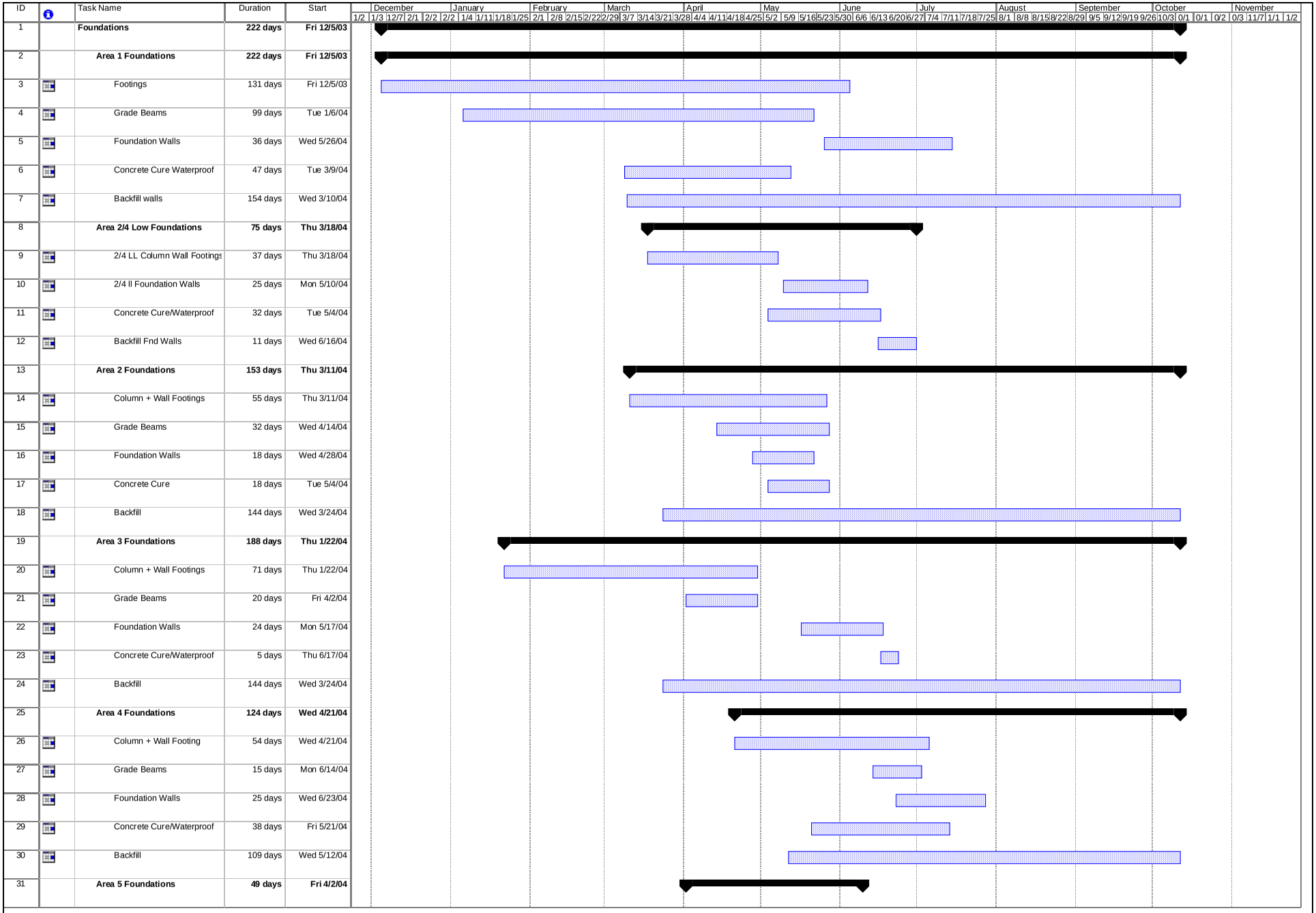
Q2. Do you feel that it would be beneficial to your company/job?
A2. I would love to for the benefits to the project, saves on screwing things up. But the work is prohibitive. As soon as the owners demand this you wait till then

Q3. Would your employees be open to trying it on certain jobs?
A3. Would be open but mainly cost driven.

Q4. To what kind of jobs would you most likely apply it?
A4 Any at all. 4D is universal. If you have the capability, then just straight up use it. Otherwise it's a waste.

Q5. Would you like to see opportunities for training in 4D CAD/Modeling?
A5. Only if it's part of the job costs.

Q6. Would you like to see the development of a professional 4D Modeling Firm as a buffer between the Architect and CM/GC? Would you use such a firm on your projects or jobs?
A6. Use in house not consultant rates. "Follow the money"


ID
Task Name
Duration
Start
December
January
February
March
April
May
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July
August
September
October
November
1 Foundations 222 days Fri 12/5/03
2 Area 1 Foundations 222 days Fri 12/5/03
3 Footings 131 days Fri 12/5/03
4 Grade Beams 99 days Tue 1/6/04
5 Foundation Walls 36 days Wed 5/26/04
6 Concrete Cure Waterproof 47 days Tue 3/9/04
7 Backfill walls 154 days Wed 3/10/04
8 Area 2/4 Low Foundations 75 days Thu 3/18/04
9 2/4 LL Column Wall Footings 37 days Thu 3/18/04
10 2/4 ll Foundation Walls 25 days Mon 5/10/04
11 Concrete Cure/Waterproof 32 days Tue 5/4/04
12 Backfill Fnd Walls 11 days Wed 6/16/04
13 Area 2 Foundations 153 days Thu 3/11/04
14 Column + Wall Footings 55 days Thu 3/11/04
15 Grade Beams 32 days Wed 4/14/04
16 Foundation Walls 18 days Wed 4/28/04
17 Concrete Cure 18 days Tue 5/4/04
18 Backfill 144 days Wed 3/24/04
19 Area 3 Foundations 188 days Thu 1/22/04
20 Column + Wall Footings 71 days Thu 1/22/04
21 Grade Beams 20 days Fri 4/2/04
22 Foundation Walls 24 days Mon 5/17/04
23 Concrete Cure/Waterproof 5 days Thu 6/17/04
24 Backfill 144 days Wed 3/24/04
25 Area 4 Foundations 124 days Wed 4/21/04
26 Column + Wall Footing 54 days Wed 4/21/04
27 Grade Beams 15 days Mon 6/14/04
28 Foundation Walls 25 days Wed 6/23/04
29 Concrete Cure/Waterproof 38 days Fri 5/21/04
30 Backfill 109 days Wed 5/12/04
31 Area 5 Foundations 49 days Fri 4/2/04
Project: Steel Erection Schedule
Date: Mon 4/3/06
Task
Split
Progress
Milestone
Summary
Project Summary
External Tasks
External Milestone
Deadline
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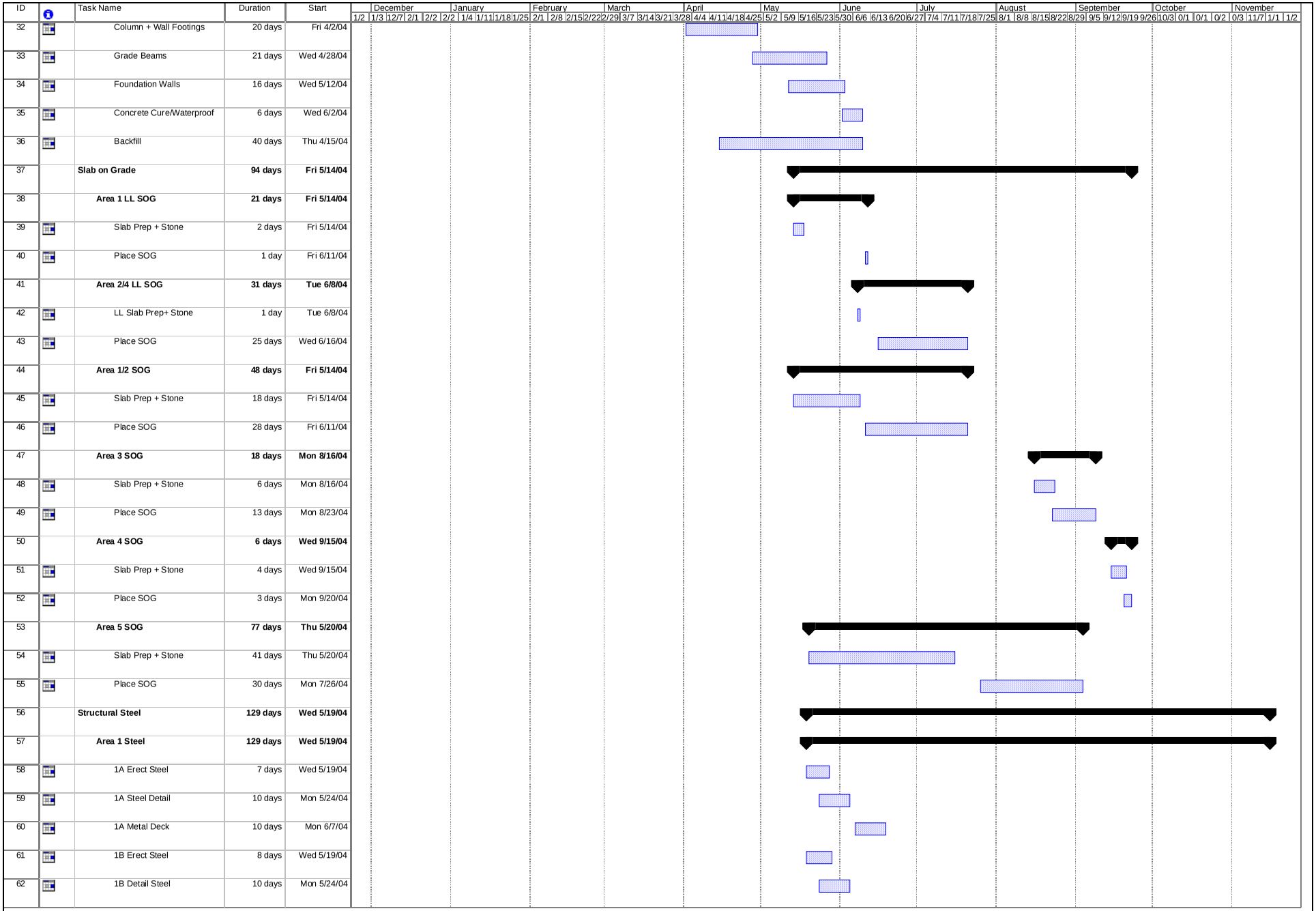

ID	Task Name	Duration	Start
32	Column + Wall Footings	20 days	Fri 4/2/04
33	Grade Beams	21 days	Wed 4/28/04
34	Foundation Walls	16 days	Wed 5/12/04
35	Concrete Cure/Waterproof	6 days	Wed 6/2/04
36	Backfill	40 days	Thu 4/15/04
37	**Slab on Grade**	**94 days**	**Fri 5/14/04**
38	**Area 1 LL SOG**	**21 days**	**Fri 5/14/04**
39	Slab Prep + Stone	2 days	Fri 5/14/04
40	Place SOG	1 day	Fri 6/11/04
41	**Area 2/4 LL SOG**	**31 days**	**Tue 6/8/04**
42	LL Slab Prep+ Stone	1 day	Tue 6/8/04
43	Place SOG	25 days	Wed 6/16/04
44	**Area 1/2 SOG**	**48 days**	**Fri 5/14/04**
45	Slab Prep + Stone	18 days	Fri 5/14/04
46	Place SOG	28 days	Fri 6/11/04
47	**Area 3 SOG**	**18 days**	**Mon 8/16/04**
48	Slab Prep + Stone	6 days	Mon 8/16/04
49	Place SOG	13 days	Mon 8/23/04
50	**Area 4 SOG**	**6 days**	**Wed 9/15/04**
51	Slab Prep + Stone	4 days	Wed 9/15/04
52	Place SOG	3 days	Mon 9/20/04
53	**Area 5 SOG**	**77 days**	**Thu 5/20/04**
54	Slab Prep + Stone	41 days	Thu 5/20/04
55	Place SOG	30 days	Mon 7/26/04
56	**Structural Steel**	**129 days**	**Wed 5/19/04**
57	**Area 1 Steel**	**129 days**	**Wed 5/19/04**
58	1A Erect Steel	7 days	Wed 5/19/04
59	1A Steel Detail	10 days	Mon 5/24/04
60	1A Metal Deck	10 days	Mon 6/7/04
61	1B Erect Steel	8 days	Wed 5/19/04
62	1B Detail Steel	10 days	Mon 5/24/04

Project: Steel Erection Schedule
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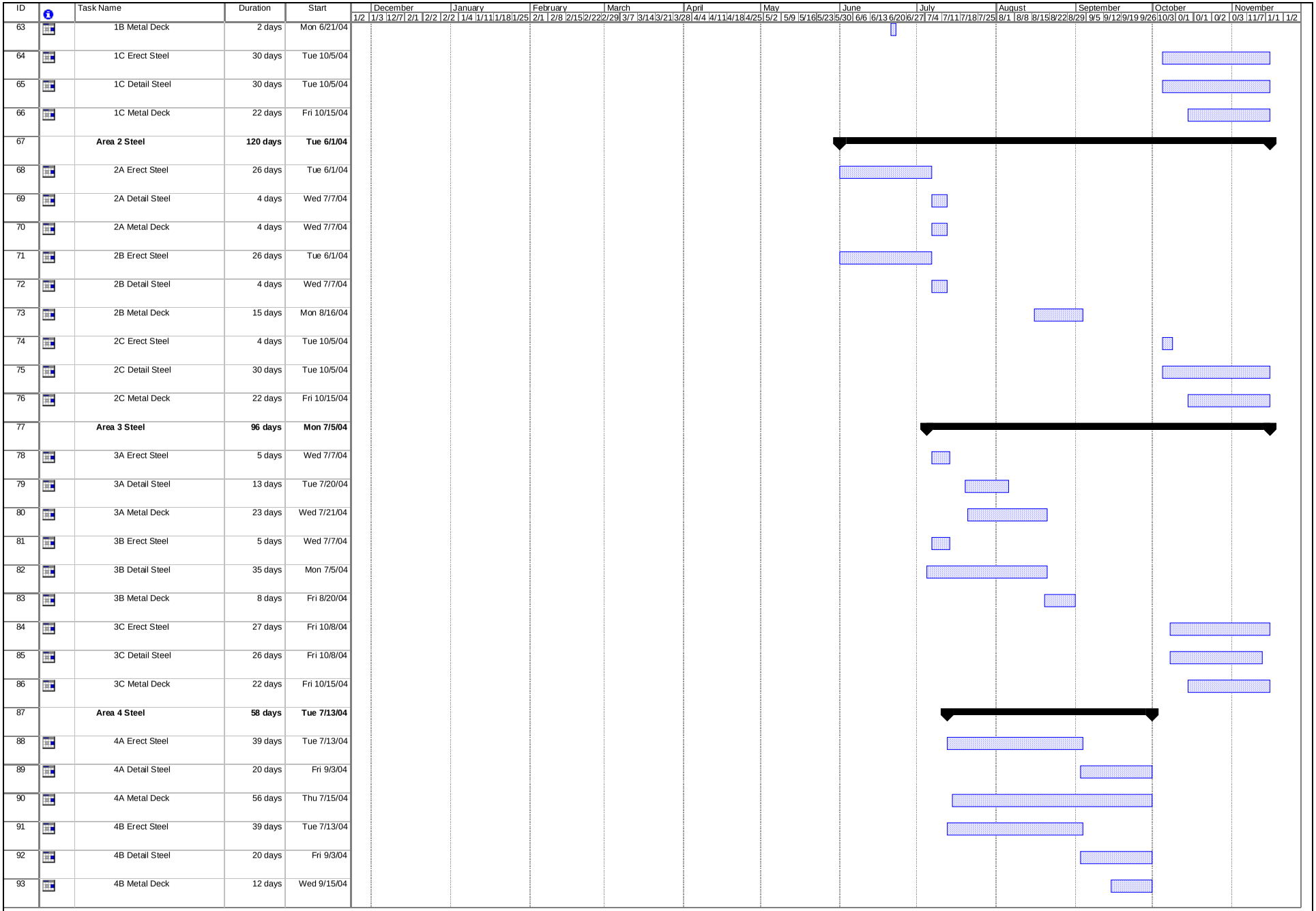

ID	Task Name	Duration	Start
63	1B Metal Deck	2 days	Mon 6/21/04
64	1C Erect Steel	30 days	Tue 10/5/04
65	1C Detail Steel	30 days	Tue 10/5/04
66	1C Metal Deck	22 days	Fri 10/15/04
67	**Area 2 Steel**	**120 days**	**Tue 6/1/04**
68	2A Erect Steel	26 days	Tue 6/1/04
69	2A Detail Steel	4 days	Wed 7/7/04
70	2A Metal Deck	4 days	Wed 7/7/04
71	2B Erect Steel	26 days	Tue 6/1/04
72	2B Detail Steel	4 days	Wed 7/7/04
73	2B Metal Deck	15 days	Mon 8/16/04
74	2C Erect Steel	4 days	Tue 10/5/04
75	2C Detail Steel	30 days	Tue 10/5/04
76	2C Metal Deck	22 days	Fri 10/15/04
77	**Area 3 Steel**	**96 days**	**Mon 7/5/04**
78	3A Erect Steel	5 days	Wed 7/7/04
79	3A Detail Steel	13 days	Tue 7/20/04
80	3A Metal Deck	23 days	Wed 7/21/04
81	3B Erect Steel	5 days	Wed 7/7/04
82	3B Detail Steel	35 days	Mon 7/5/04
83	3B Metal Deck	8 days	Fri 8/20/04
84	3C Erect Steel	27 days	Fri 10/8/04
85	3C Detail Steel	26 days	Fri 10/8/04
86	3C Metal Deck	22 days	Fri 10/15/04
87	**Area 4 Steel**	**58 days**	**Tue 7/13/04**
88	4A Erect Steel	39 days	Tue 7/13/04
89	4A Detail Steel	20 days	Fri 9/3/04
90	4A Metal Deck	56 days	Thu 7/15/04
91	4B Erect Steel	39 days	Tue 7/13/04
92	4B Detail Steel	20 days	Fri 9/3/04
93	4B Metal Deck	12 days	Wed 9/15/04

Project: Steel Erection Schedule
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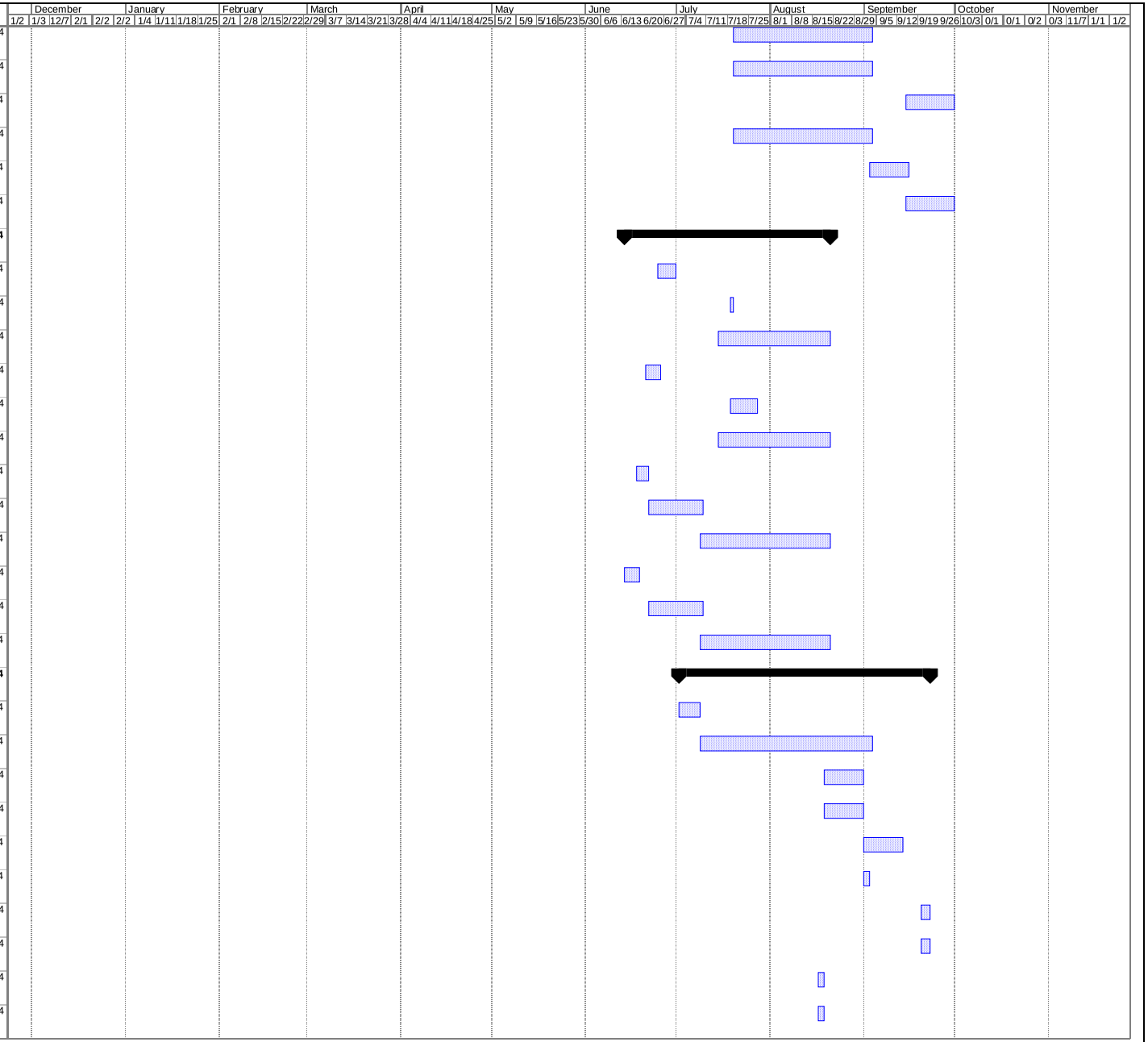
ID	Task Name	Duration	Start
94	4C Erect Steel	34 days	Tue 7/20/04
95	4C Detail Steel	34 days	Tue 7/20/04
96	4C Metal Deck	12 days	Wed 9/15/04
97	4D Erect Steel	34 days	Tue 7/20/04
98	4D Detail Steel	9 days	Fri 9/3/04
99	4D Metal Deck	12 days	Wed 9/15/04
100	**Area 5 Steel**	**50 days**	**Mon 6/14/04**
101	5A Erect Steel	4 days	Fri 6/25/04
102	5A Detail Steel	1 day	Mon 7/19/04
103	5A Metal Deck	27 days	Thu 7/15/04
104	5B Erect Steel	5 days	Mon 6/21/04
105	5B Detail Steel	7 days	Mon 7/19/04
106	5B Metal Deck	27 days	Thu 7/15/04
107	5C Erect Steel	2 days	Fri 6/18/04
108	5C Detail Steel	14 days	Tue 6/22/04
109	5C Metal Deck	31 days	Fri 7/9/04
110	5D Erect Steel	5 days	Mon 6/14/04
111	5D Detail Steel	14 days	Tue 6/22/04
112	5D Metal Deck	31 days	Fri 7/9/04
113	**Slab On Deck**	**59 days**	**Fri 7/2/04**
114	Area 1 SOD Prep	5 days	Fri 7/2/04
115	Area 1 Place SOD	41 days	Fri 7/9/04
116	Area 2 SOD Prep	9 days	Thu 8/19/04
117	Area 2 Place SOD	9 days	Thu 8/19/04
118	Area 3 SOD Prep	9 days	Wed 9/1/04
119	Area 3 Place SOD	2 days	Wed 9/1/04
120	Area 4 SOD Prep	3 days	Mon 9/20/04
121	Area 4 Place SOD	3 days	Mon 9/20/04
122	Area 5 SOD Prep	2 days	Tue 8/17/04
123	Area 5 Place SOD	2 days	Tue 8/17/04



Project: Steel Erection Schedule
Date: Mon 4/3/06

Task | Progress | Summary | External Tasks | Deadline
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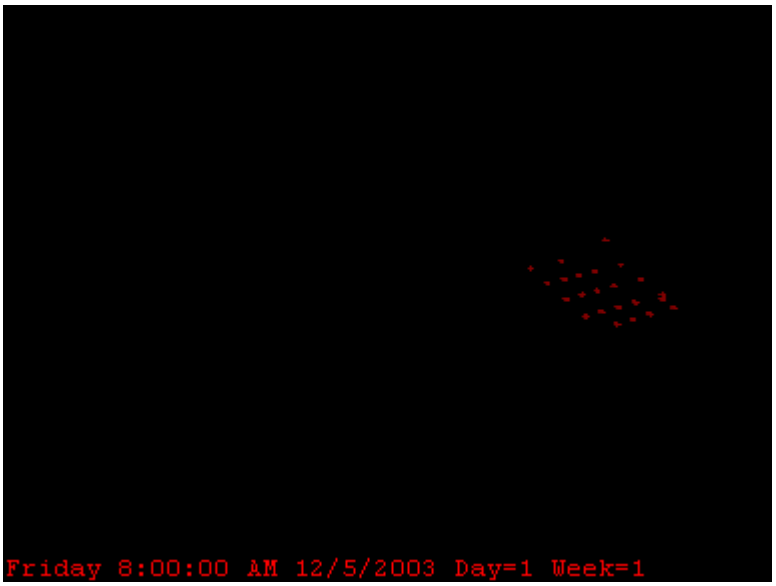
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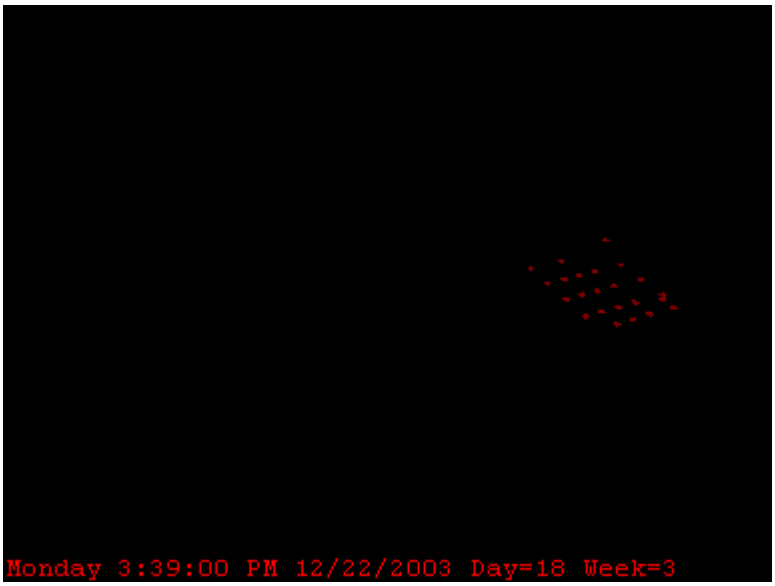
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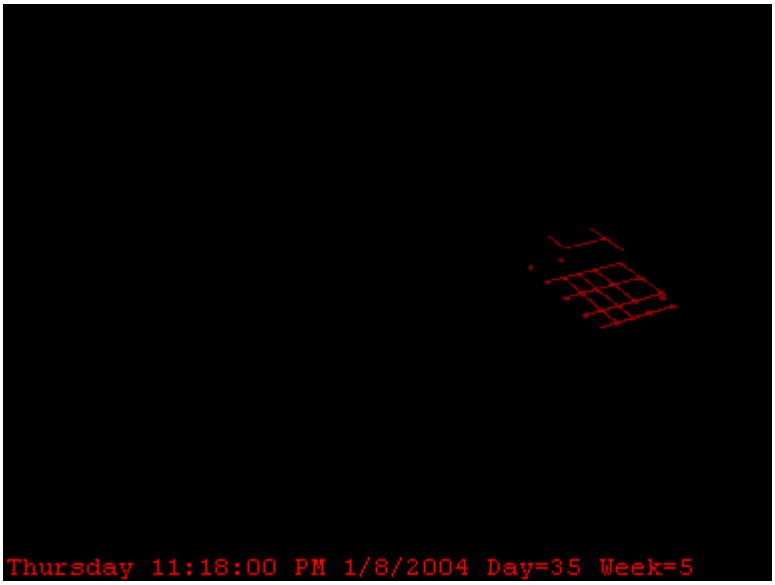
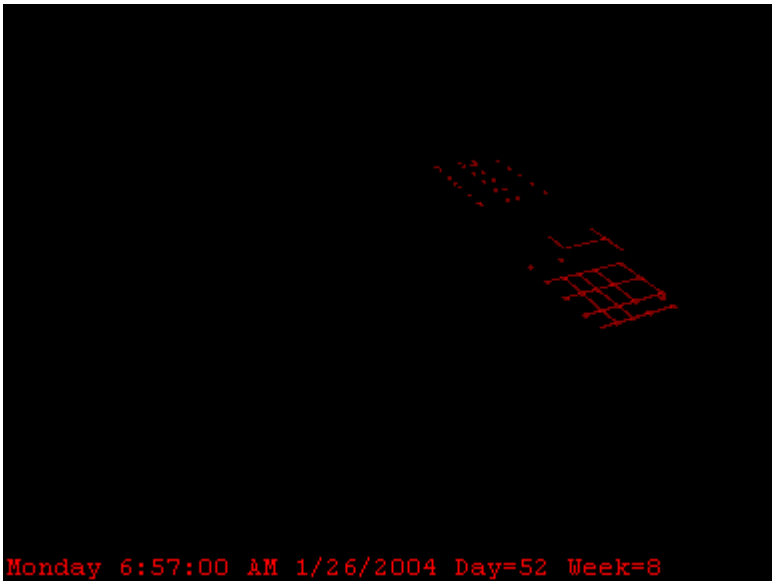
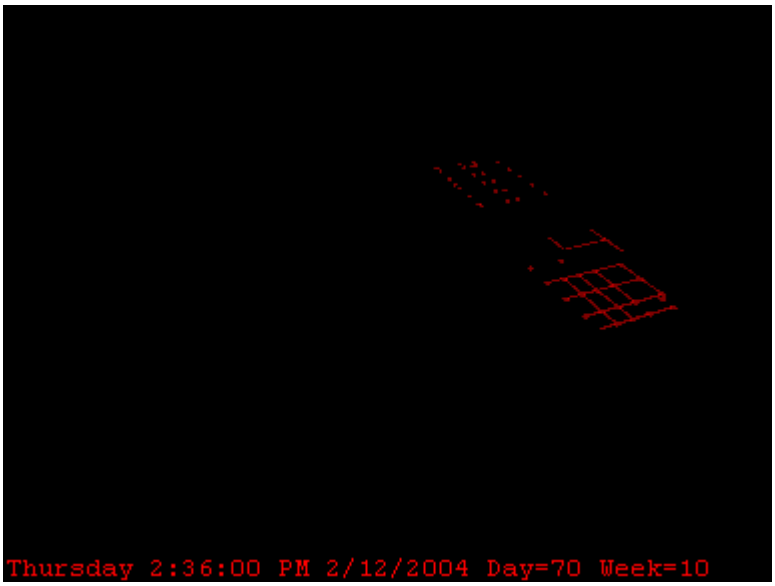
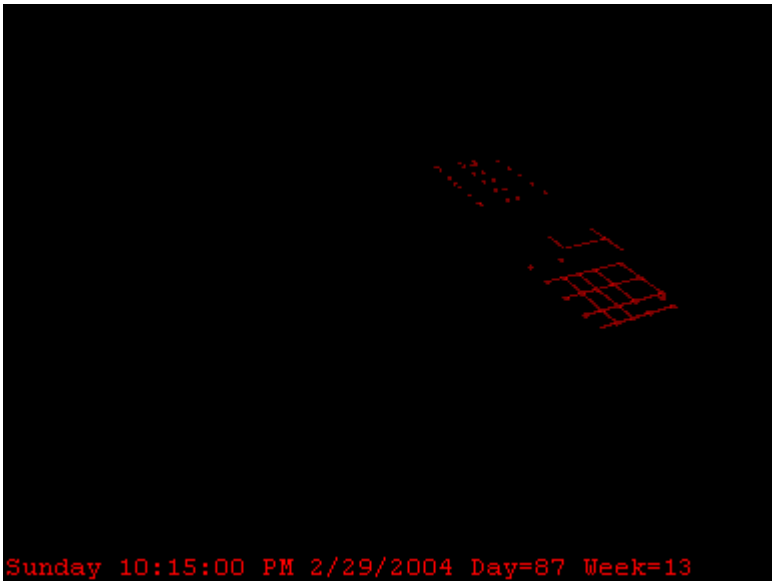
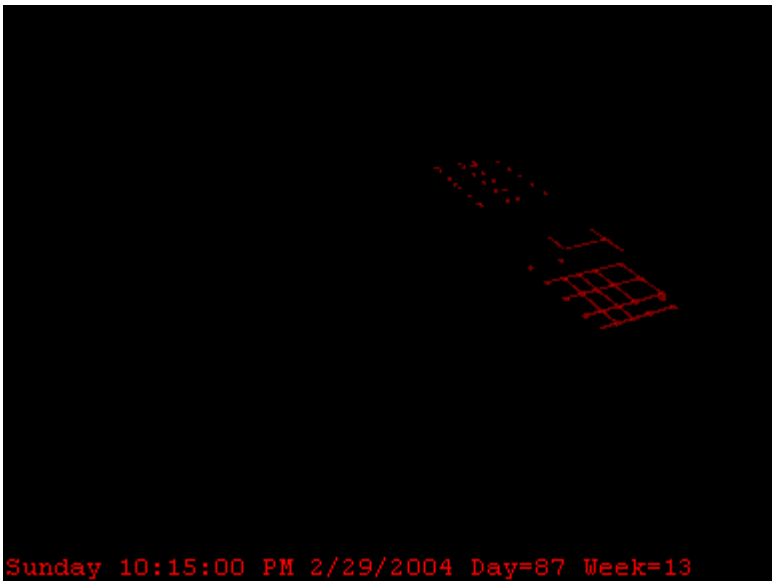
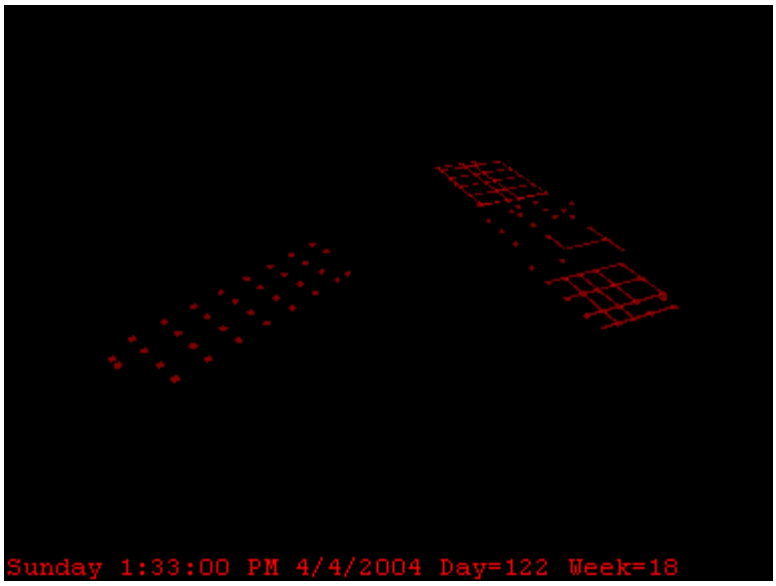

Thursday 11:18:00 PM 1/8/2004 Day=35 Week=5

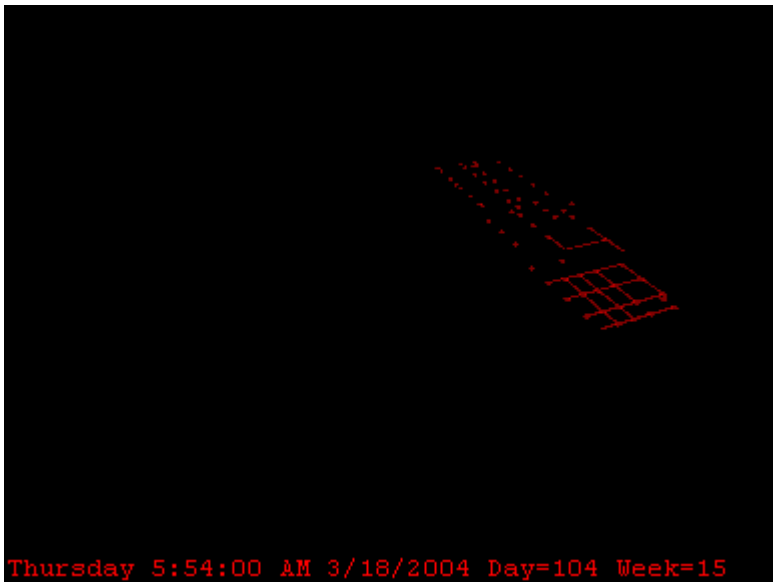

Monday 6:57:00 AM 1/26/2004 Day=52 Week=8


Thursday 2:36:00 PM 2/12/2004 Day=70 Week=10


Sunday 10:15:00 PM 2/29/2004 Day=87 Week=13


Sunday 10:15:00 PM 2/29/2004 Day=87 Week=13


Sunday 1:33:00 PM 4/4/2004 Day=122 Week=18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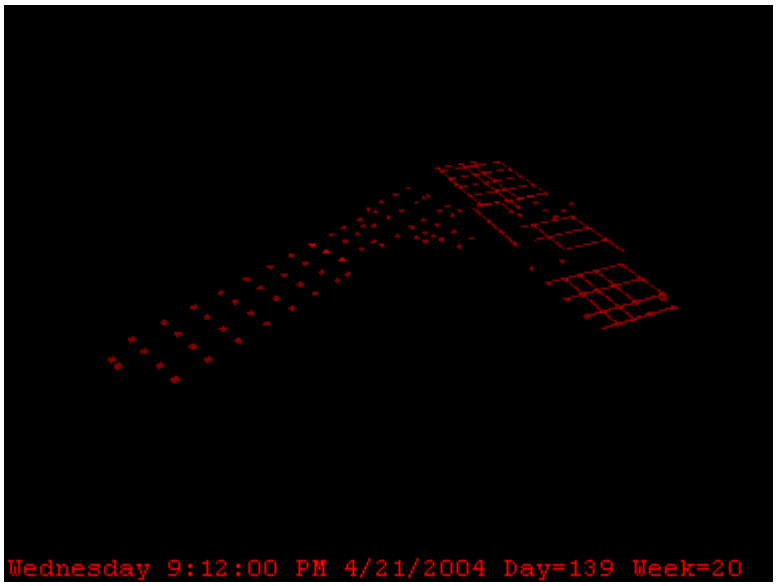
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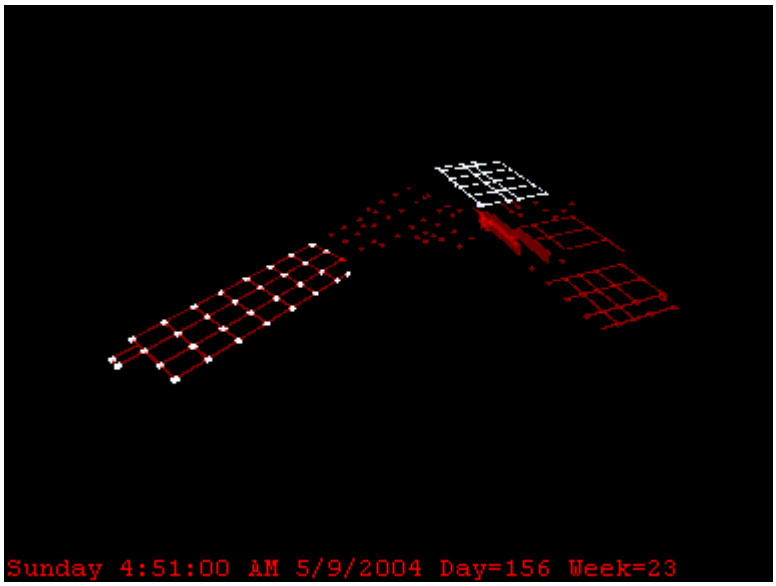
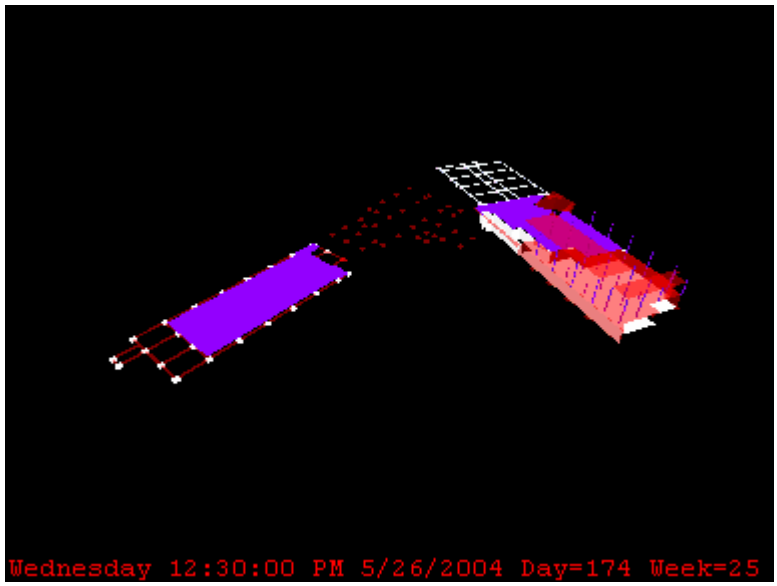
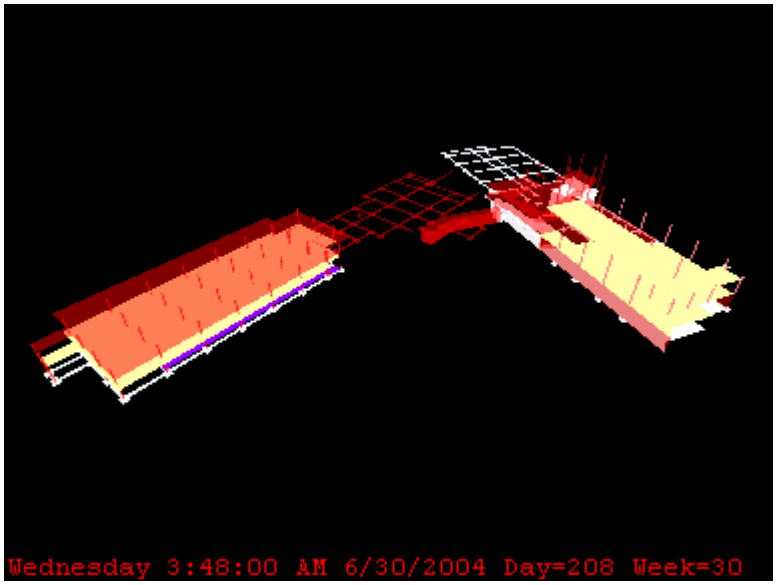
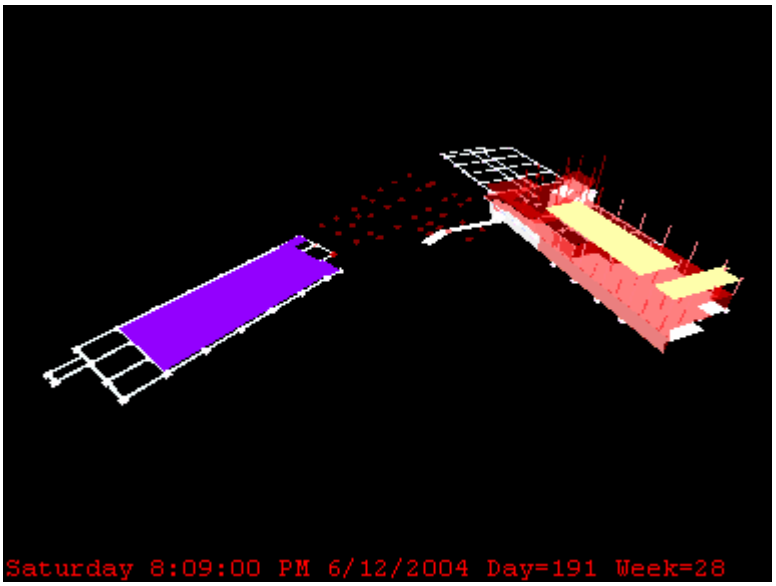
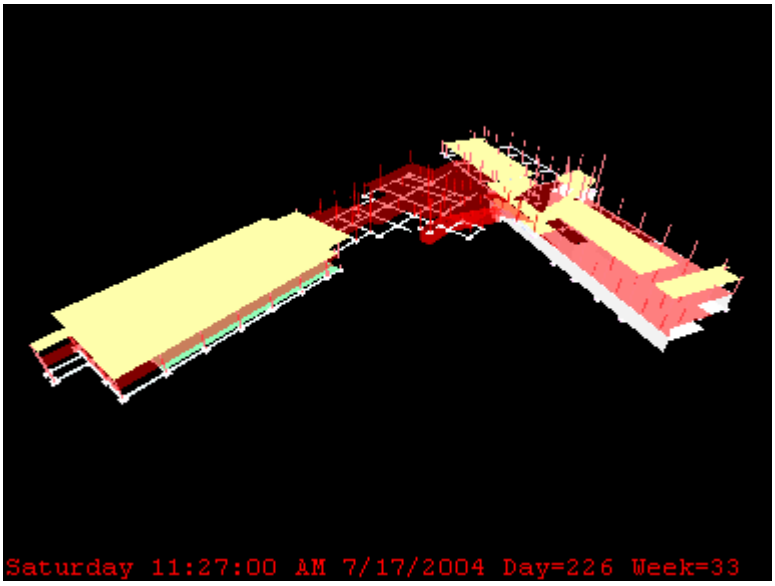

Sunday 4:51:00 AM 5/9/2004 Day=156 Week=23

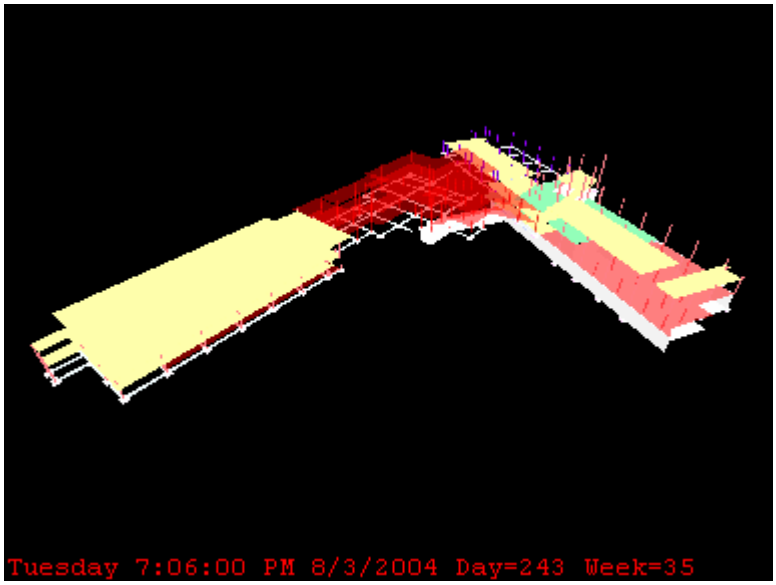

Wednesday 12:30:00 PM 5/26/2004 Day=174 Week=25

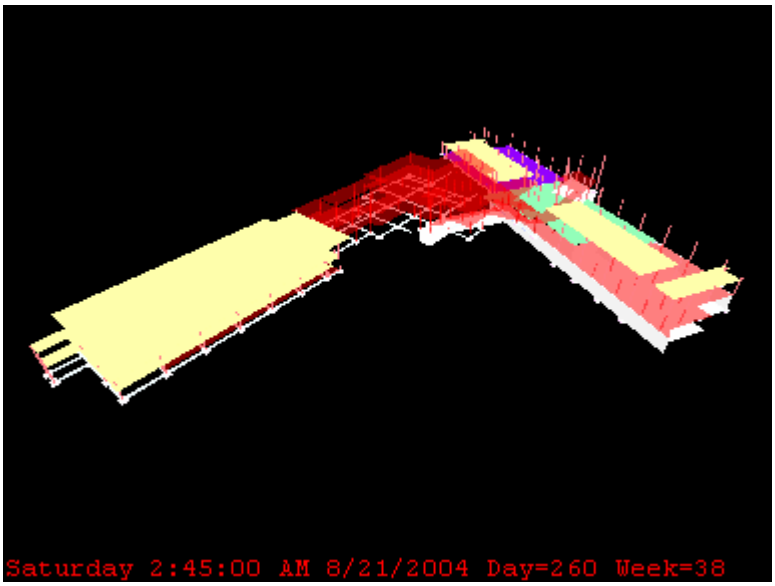
As-Built Graphical Analysis

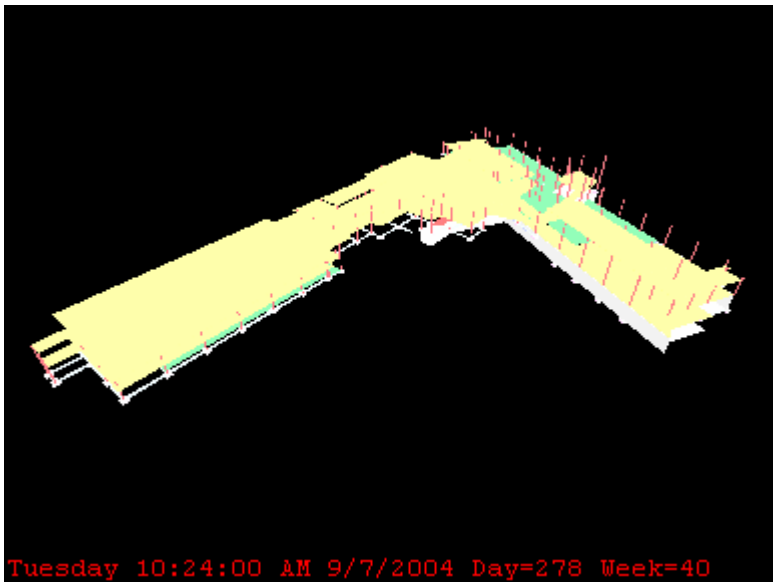




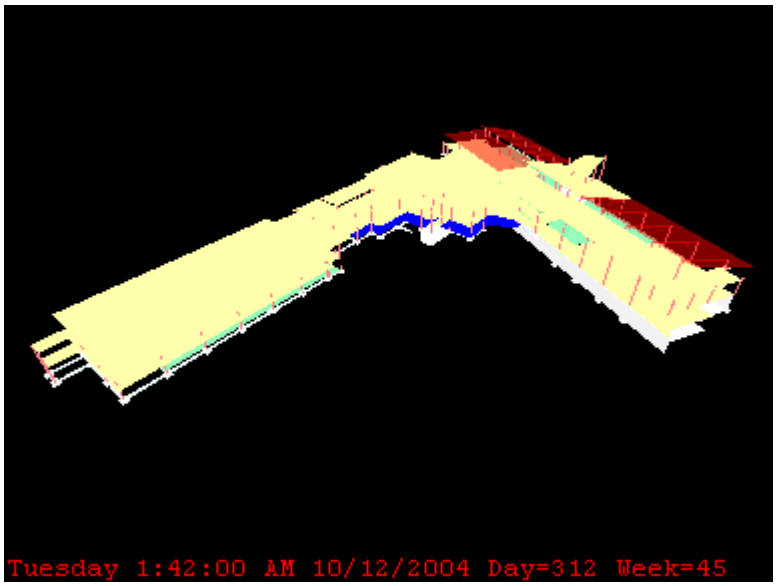


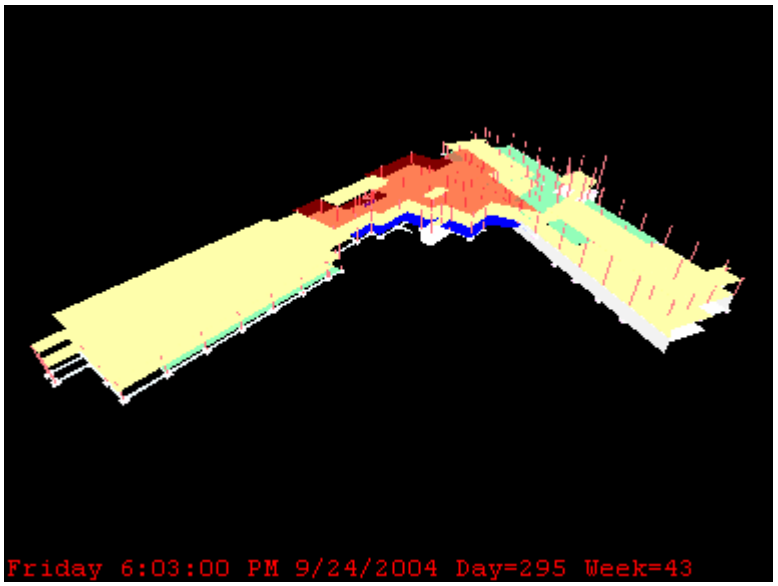


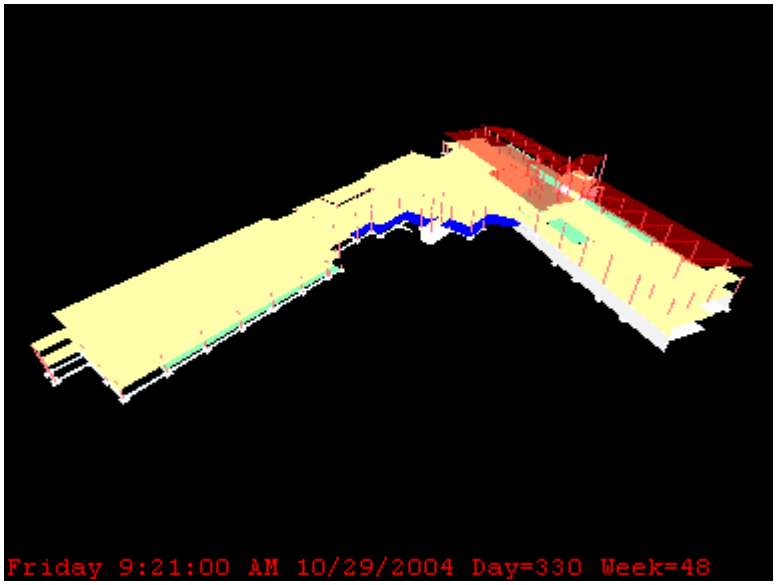


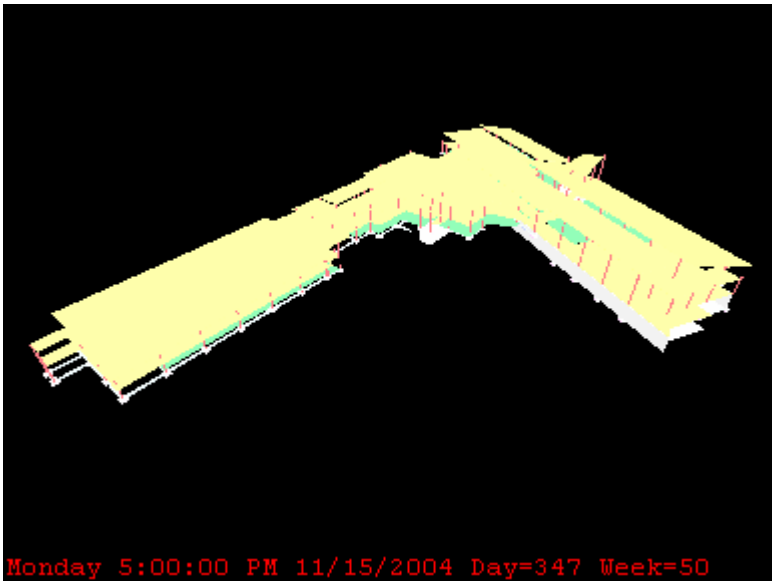


As-Built Graphical Analysis

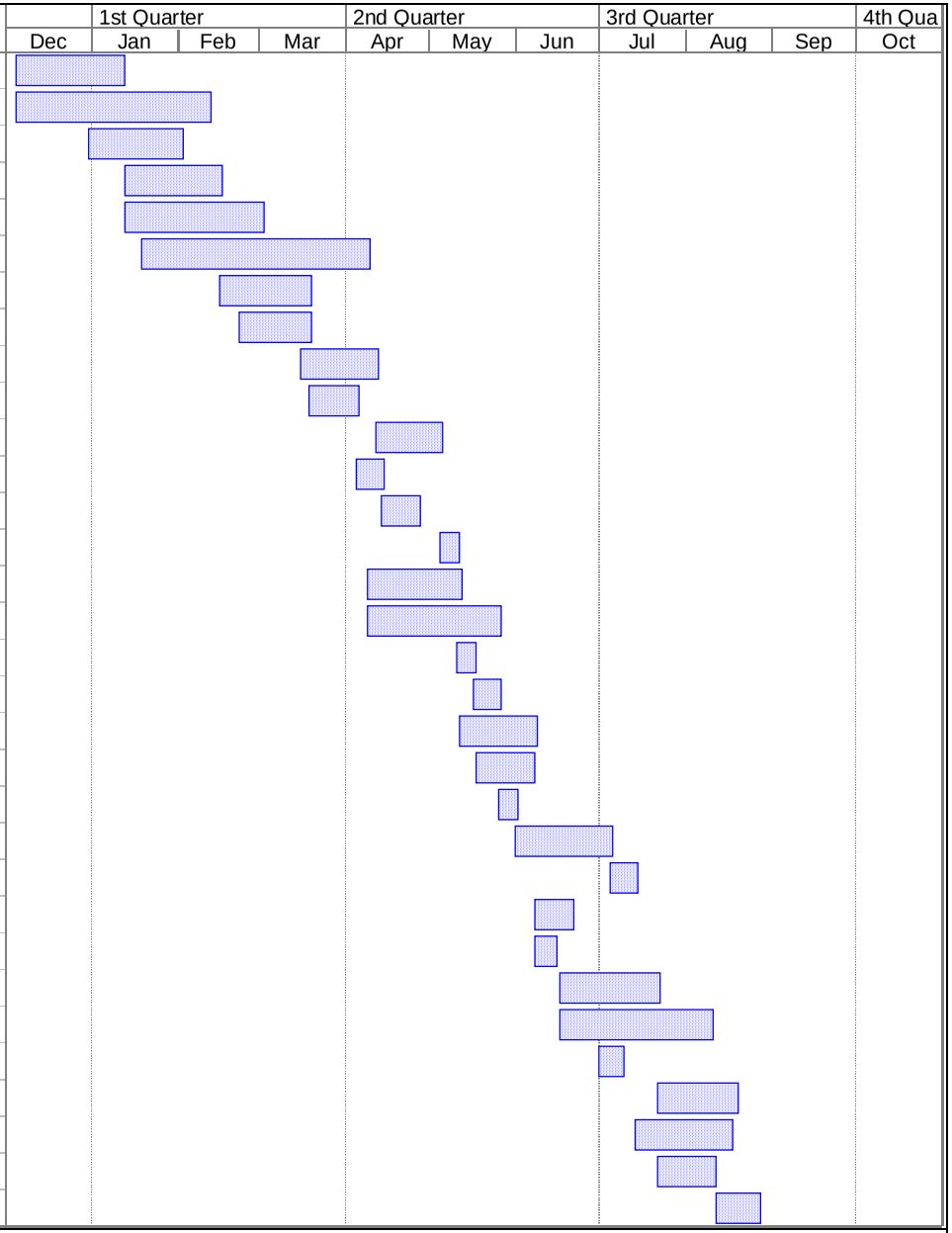








ID	Task Name	Duration	Start	Finish
1	Area 2/4 Low Footings	27 days	Fri 12/5/03	Mon 1/12/04
2	Area 1 Low Footings	50 days	Fri 12/5/03	Thu 2/12/04
3	Area 1 Low Grade Beams	24 days	Wed 12/31/03	Mon 2/2/04
4	Areas 2/4 Foundation Walls	25 days	Tue 1/13/04	Mon 2/16/04
5	Area 1 Foundation Walls	36 days	Tue 1/13/04	Tue 3/2/04
6	Area 3 Footings	60 days	Mon 1/19/04	Fri 4/9/04
7	Area 2/4 Slab On Grade	25 days	Mon 2/16/04	Fri 3/19/04
8	Area 1 Slab On Grade	20 days	Mon 2/23/04	Fri 3/19/04
9	Area 3 Grade Beams	20 days	Tue 3/16/04	Mon 4/12/04
10	Area 1 Erect Columns	12 days	Fri 3/19/04	Mon 4/5/04
11	Area 3 Slab on Grade	18 days	Mon 4/12/04	Wed 5/5/04
12	Area 1 Floor Beams & Deck	8 days	Mon 4/5/04	Wed 4/14/04
13	Area 1 Metal Deck	10 days	Wed 4/14/04	Tue 4/27/04
14	Area 3 Erect Columns	5 days	Wed 5/5/04	Tue 5/11/04
15	Area 2 High Footings	24 days	Fri 4/9/04	Wed 5/12/04
16	Area 4 Footings	34 days	Fri 4/9/04	Wed 5/26/04
17	Area 3 Floor Beams	5 days	Tue 5/11/04	Mon 5/17/04
18	Area 3 Metal Floor Deck	8 days	Mon 5/17/04	Wed 5/26/04
19	Area 2 Grade Beams	20 days	Wed 5/12/04	Tue 6/8/04
20	Area 4 Grade Beams	15 days	Tue 5/18/04	Mon 6/7/04
21	Area 3 Trusses	5 days	Wed 5/26/04	Tue 6/1/04
22	Area 3 Roof Beams	25 days	Tue 6/1/04	Mon 7/5/04
23	Area 3 Metal Deck	8 days	Mon 7/5/04	Wed 7/14/04
24	Area 2 Slab On Grade	10 days	Tue 6/8/04	Mon 6/21/04
25	Area 4 Slab on Grade	6 days	Tue 6/8/04	Tue 6/15/04
26	Area 2 Erect Columns	26 days	Thu 6/17/04	Thu 7/22/04
27	Area 4 Erect Columns	39 days	Thu 6/17/04	Tue 8/10/04
28	Area 3 Slab On Deck	7 days	Thu 7/1/04	Fri 7/9/04
29	Area 2 Floor Beams	21 days	Thu 7/22/04	Thu 8/19/04
30	Area 4 Floor Beams	25 days	Wed 7/14/04	Tue 8/17/04
31	Area 2 Metal Floor Deck	15 days	Thu 7/22/04	Wed 8/11/04
32	Area 4 Metal Floor Deck	12 days	Thu 8/12/04	Fri 8/27/04



Project: SIPS Erection Schedule
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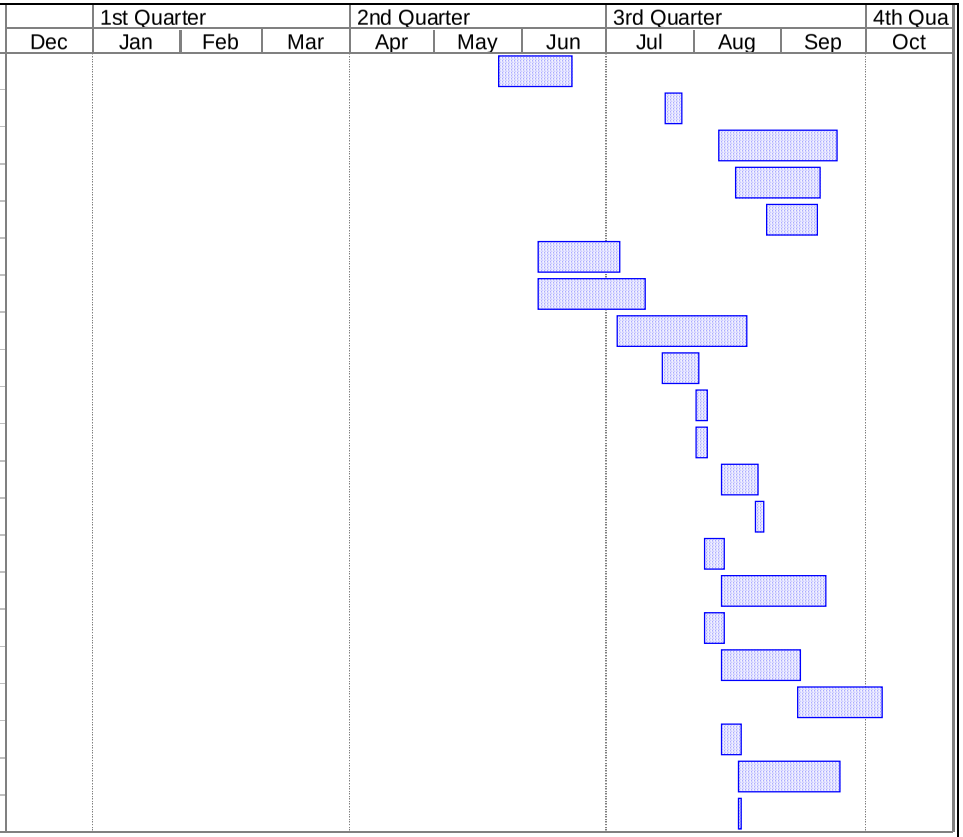
ID	Task Name	Duration	Start	Finish
33	Area 5 Footings	20 days	Mon 5/24/04	Fri 6/18/04
34	Area 2 Roof Beams	4 days	Thu 7/22/04	Tue 7/27/04
35	Area 4 Roof Beams	30 days	Tue 8/10/04	Mon 9/20/04
36	Area 2 Roof Deck	22 days	Mon 8/16/04	Tue 9/14/04
37	Area 4 Roof Deck	12 days	Fri 8/27/04	Mon 9/13/04
38	Area 5 Grade Beams	21 days	Mon 6/7/04	Mon 7/5/04
39	Area 1 Grade Beams	28 days	Mon 6/7/04	Wed 7/14/04
40	Area 5 Slab on Grade	34 days	Mon 7/5/04	Thu 8/19/04
41	Area 1 Slab on Grade	9 days	Wed 7/21/04	Mon 8/2/04
42	Area 5 Erect Columns	4 days	Mon 8/2/04	Thu 8/5/04
43	Area 1 Erect High Columns	4 days	Mon 8/2/04	Thu 8/5/04
44	Area 2 Slab on Deck	9 days	Wed 8/11/04	Mon 8/23/04
45	Area 4 Slab on Deck	3 days	Mon 8/23/04	Wed 8/25/04
46	Area 5 Floor Beams	5 days	Thu 8/5/04	Wed 8/11/04
47	Area 5 Metal Floor Deck	27 days	Wed 8/11/04	Thu 9/16/04
48	Area 1 Trusses	5 days	Thu 8/5/04	Wed 8/11/04
49	Area 1 Roof Beams	20 days	Wed 8/11/04	Tue 9/7/04
50	Area 1 Metal Deck	22 days	Tue 9/7/04	Wed 10/6/04
51	Area 5 Roof Beams	5 days	Wed 8/11/04	Tue 8/17/04
52	Area 5 Roof Deck	26 days	Tue 8/17/04	Tue 9/21/04
53	Area 5 Slab on Deck	1 day?	Tue 8/17/04	Tue 8/17/04



Project: SIPS Erection Schedule
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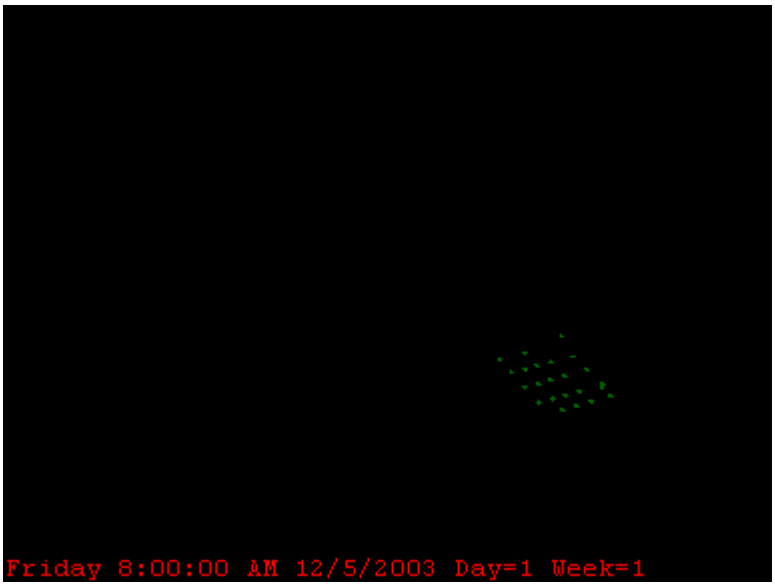
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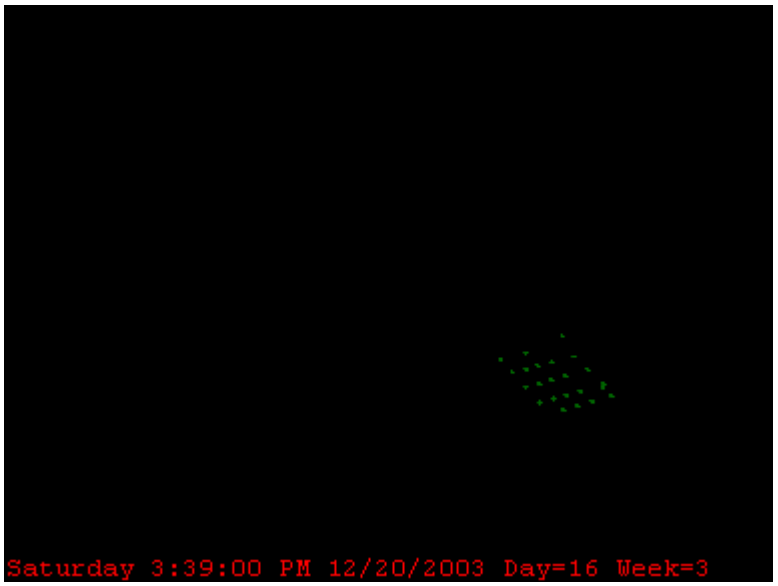
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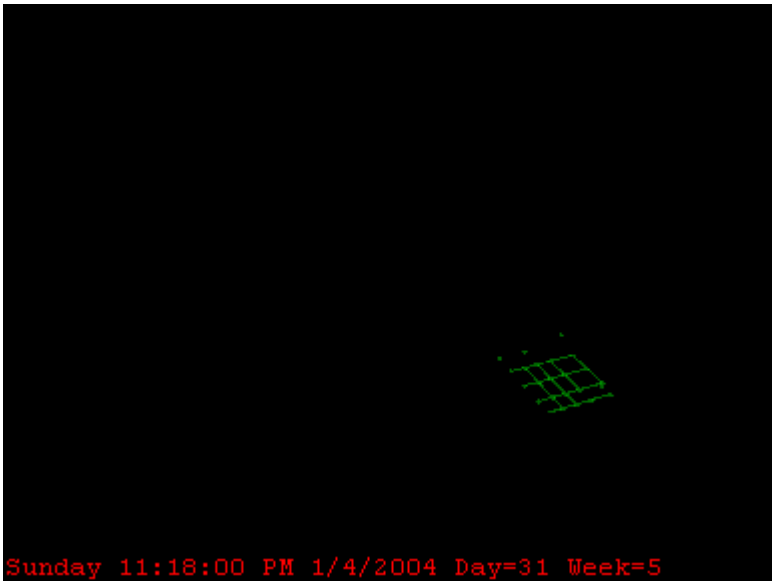
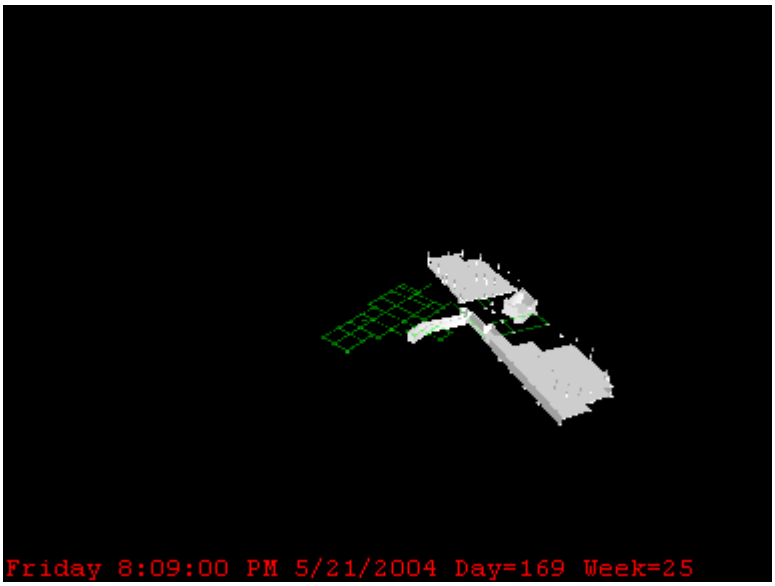

Sunday 11:18:00 PM 1/4/2004 Day=31 Week=5


Tuesday 6:57:00 AM 1/20/2004 Day=46 Week=7


Wednesday 2:36:00 PM 2/4/2004 Day=62 Week=9


Thursday 10:15:00 PM 2/19/2004 Day=77 Week=11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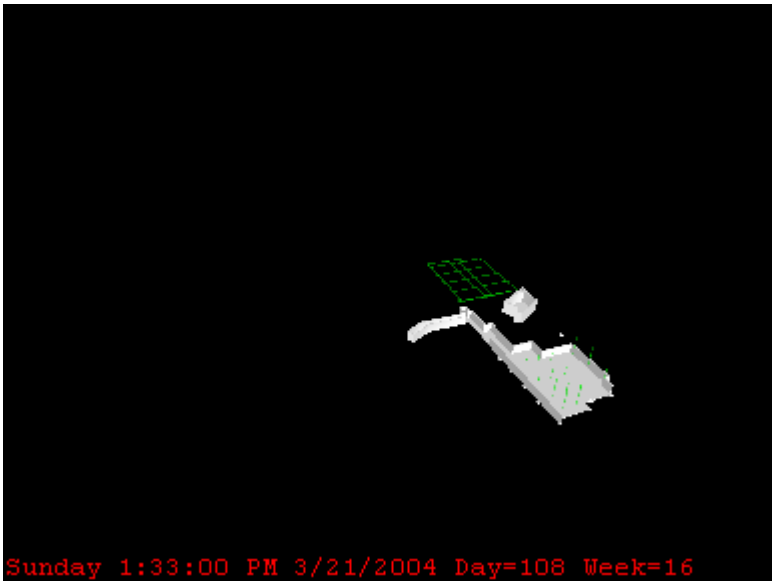
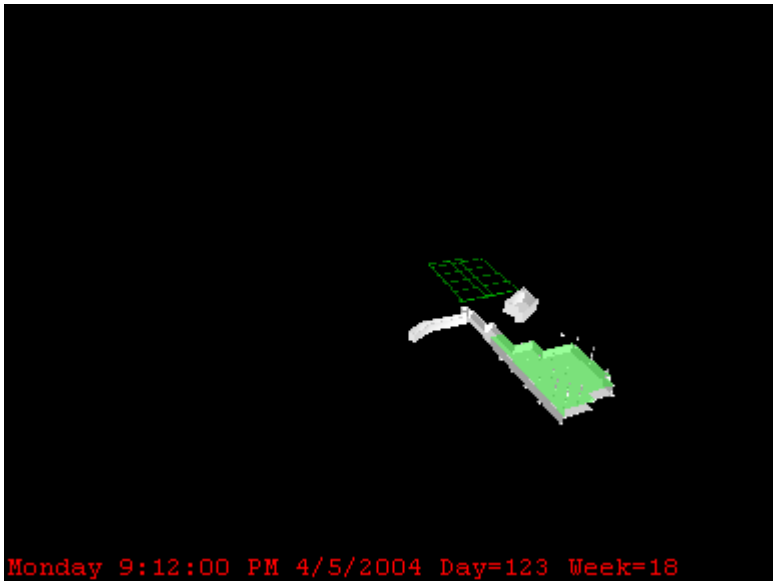
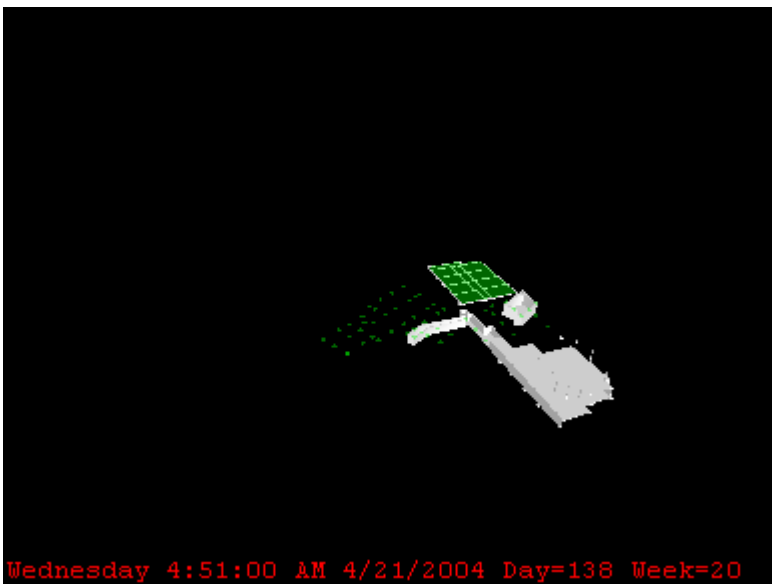
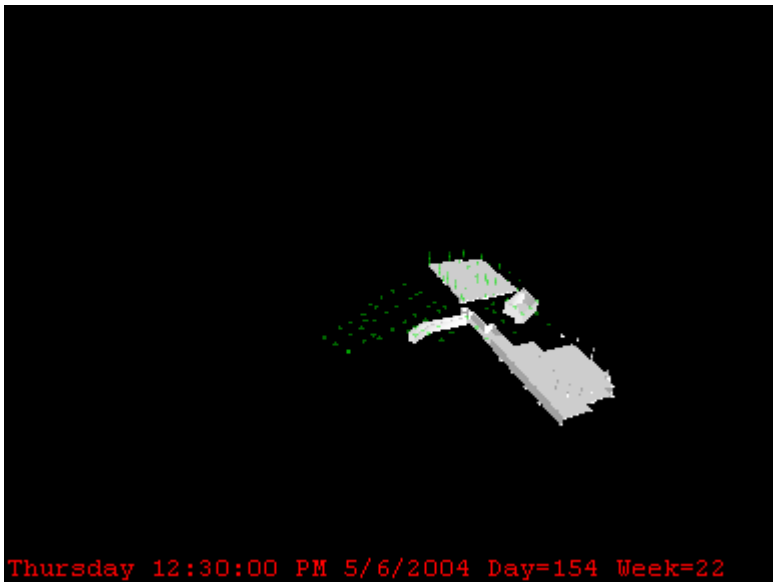
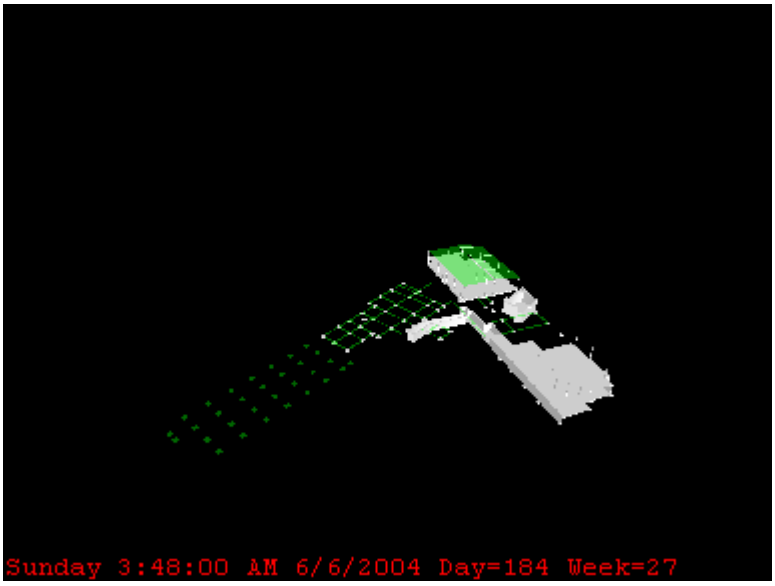
Saturday 5:54:00 AM 3/6/2004 Day=92 Week=14

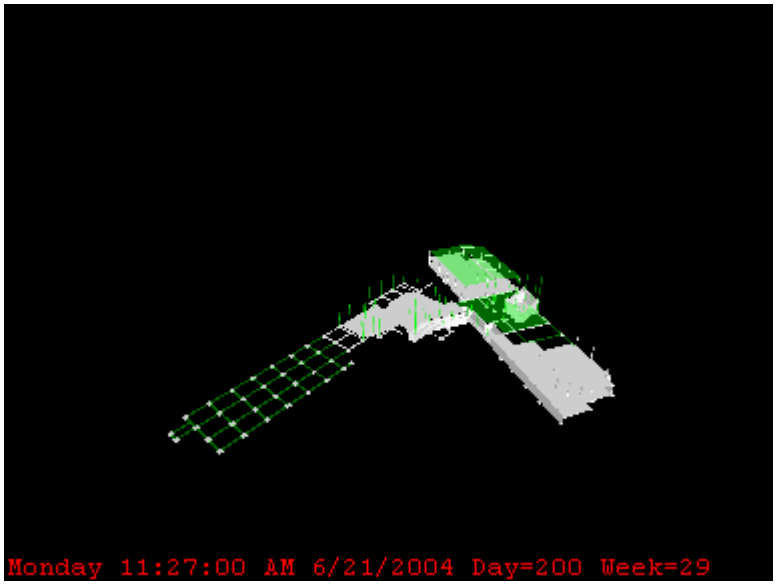

Sunday 1:33:00 PM 3/21/2004 Day=108 Week=16


Monday 9:12:00 PM 4/5/2004 Day=123 Week=18

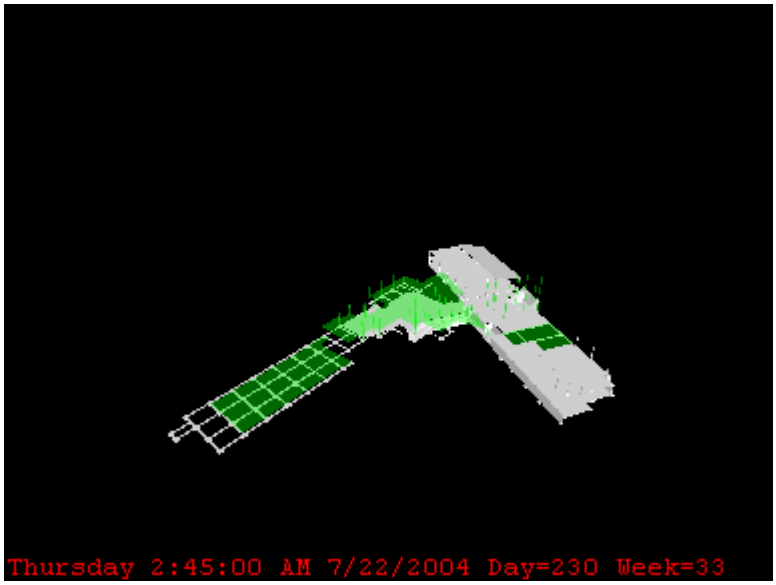

Wednesday 4:51:00 AM 4/21/2004 Day=138 Week=20

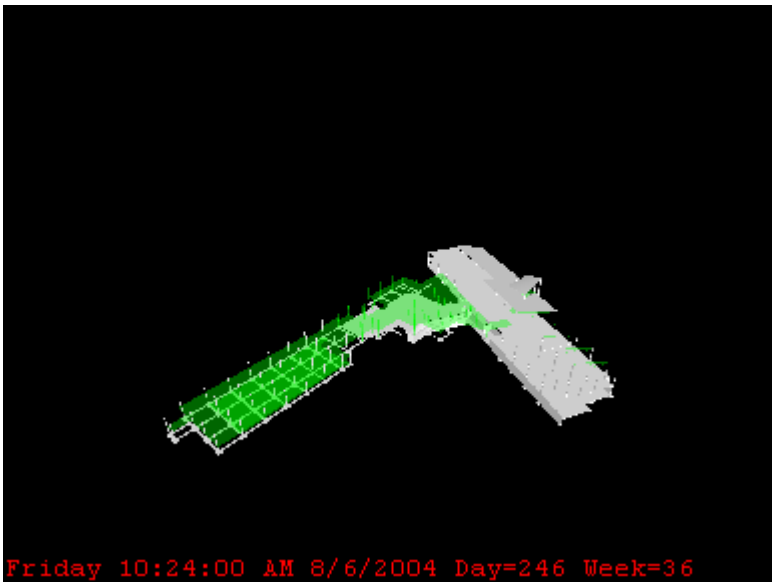

Thursday 12:30:00 PM 5/6/2004 Day=154 Week=22

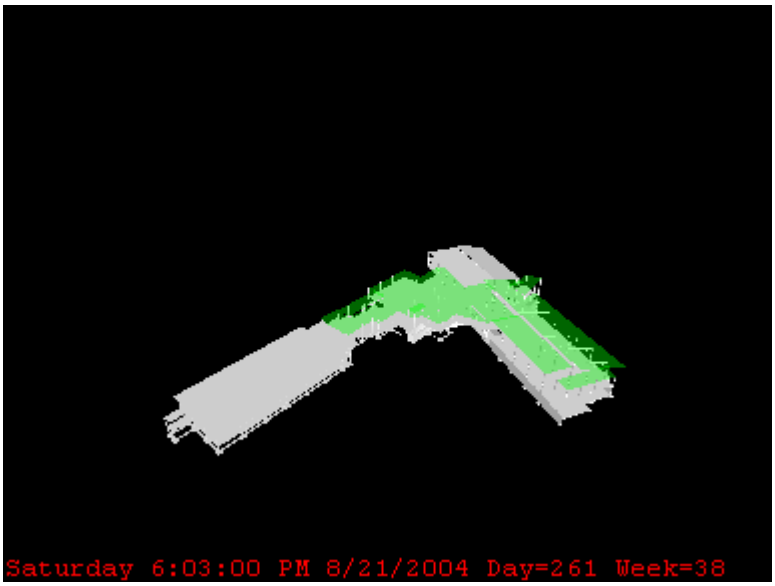

Sunday 3:48:00 AM 6/6/2004 Day=184 Week=27

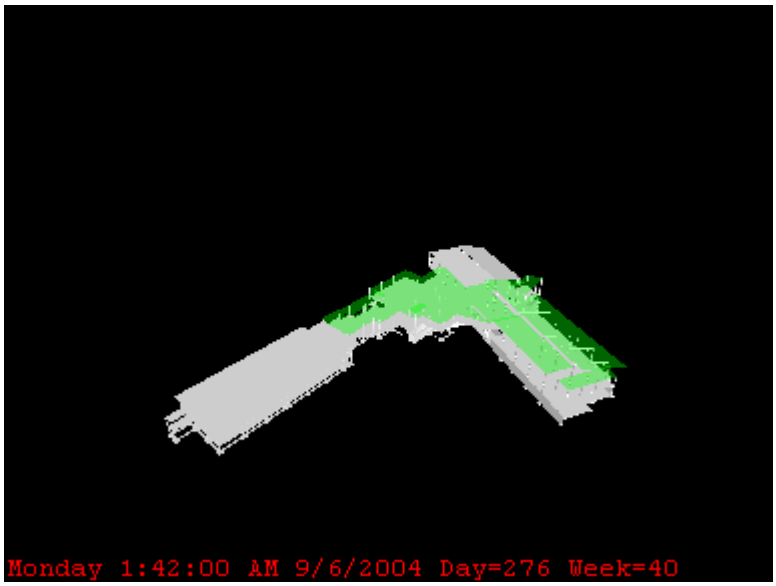

Monday 11:27:00 AM 6/21/2004 Day=200 Week=29

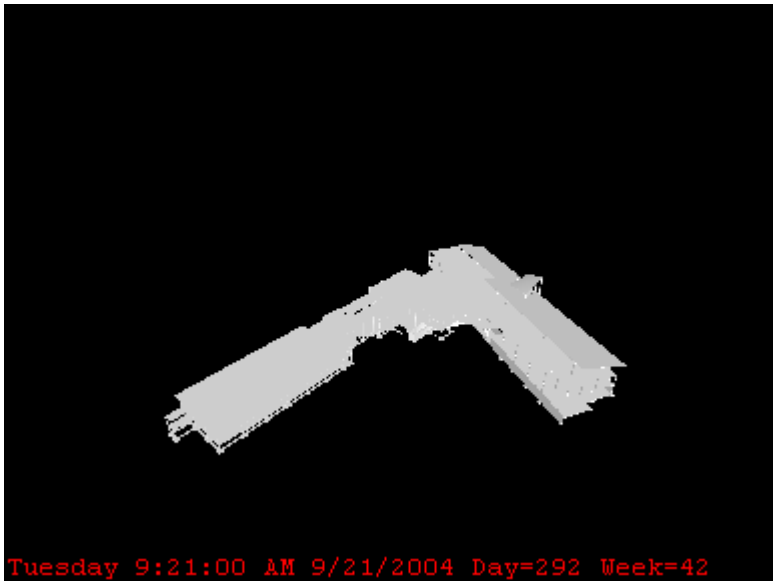

Tuesday 7:06:00 PM 7/6/2004 Day=215 Week=31

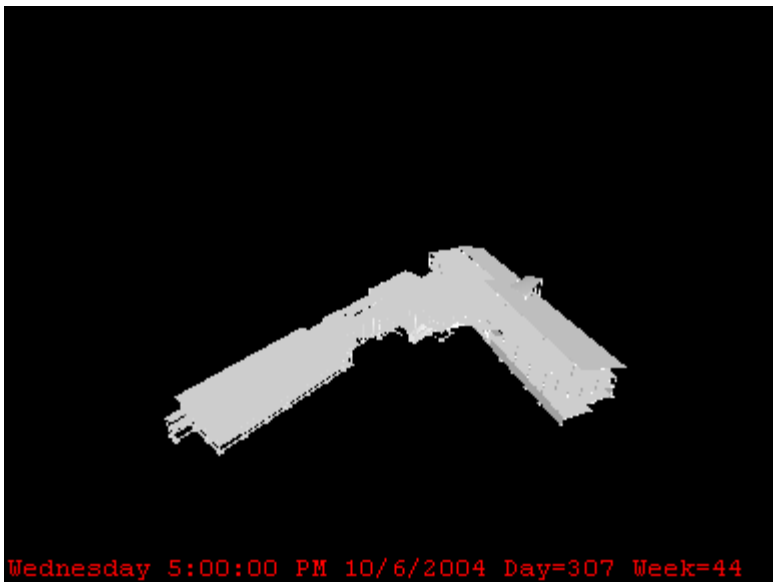

Thursday 2:45:00 AM 7/22/2004 Day=230 Week=33


Friday 10:24:00 AM 8/6/2004 Day=246 Week=36


Saturday 6:03:00 PM 8/21/2004 Day=261 Week=38


Monday 1:42:00 AM 9/6/2004 Day=276 Week=40


Tuesday 9:21:00 AM 9/21/2004 Day=292 Week=42


Wednesday 5:00:00 PM 10/6/2004 Day=307 Week=44

Section 2		
VAV Box	Diffuser	CFMs
VAV 4	S-4	430
VAV 7	S-5	570
VAV 7	S-5	570
	Total	1570

Section 4		
VAV Box	Diffuser	CFMs
VAV 1	S-1	105
VAV 1	S-2	140

Duct lengths

Original Plan	Feet	Gauge	Sum 2 Sides	lb/ft	Total Wt
8" Dia	7.8125	20	25	7.3	57.03125
9" Dia	10.083	20	28	8.1	81.6723
12x8	63	18	20	7.6	478.8
16x12	10	22	28	7	70
16x8	18	22	24	6	108
14x12	35.33	18	26	9.9	349.767
12x12	3.583	24	24	5.2	18.6316
				Total Weight	1163.90215
				Cost	$7,099.80

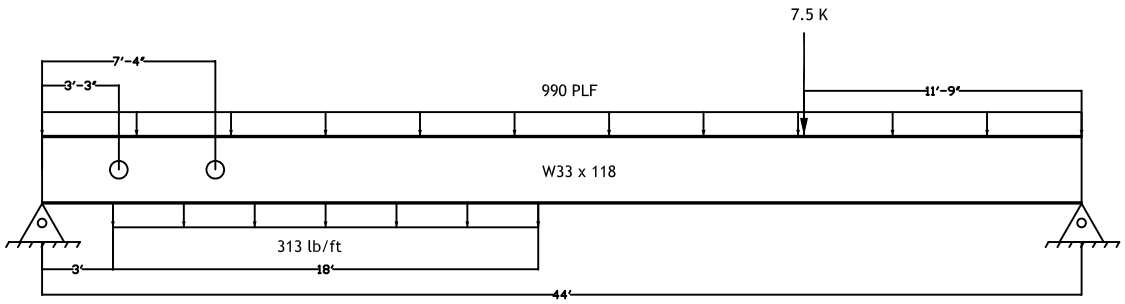
Punch Through	Feet	Gauge	Sum 2 Sides	lb/ft	Total Wt
8" Dia	N/A		25		
9" Dia	52.083	18	28	10.6	552.0798
12x8	32	18	20	5.2	166.4
16x12	2.5	22	28	7	17.5
16x8	17	18	24	9.1	154.7
14x12	35.33	18	26	9.9	349.767
12x12	3.583	24	24	5.2	18.6316
				Total Weight	1259.0784
				Cost	$7,680.38

Re Route	Feet	Gauge	Sum 2 Sides	lb/ft	Total Wt
8" Dia	0		25		0
9" Dia	53	18	28	10.6	561.8
12x8	30	18	20	7.6	228
16x12	10	18	28	10.6	106
16x8	17.5	18	24	9.1	159.25
14x12	0		26		0
12x12	0		24		0
				Total Weight	1055.05
				Cost	$6,435.81

VAV Boxes	CFM	Min CFM	Inlet Size	Min Inlet	Max ADP	Model #
VAV 1	0-250	25% PSG	5"	10"	0.28	VCWE03
VAV 4	401-600	25% PSG	8"	12"	0.28	VCWE11
VAV 7	1001-1200	25% PSG	12"	16"	0.28	VCWE24

Supply Diffusers	CFM	S.D. Max	Throw	NC	Size	Spread
S-1	50-120	0.03	5'-10'	20	24"x24"	2'-6'
S-2	121-210	0.01	4'-6'	20	12"x12"	3'-8'
S-4	326-470	0.01	11'-14'	21	24"x24"	5'-12'
S-5	471-735	0.01	10'-14'	22	12"x12"	6'-15'

Roof Top Units	Total CFM	O/A CFM	Compressors	Mfg #	Weight
RT-5	6000	1250	2 @ 10 Tons	Trane SFHFC20	5430 Tons
RT-7	9000	5900	2 @ 15 Tons	Trane SFHFC30	6270 Tons



990 x 44' / 1000 = 43.560 k 313 x 18' / 1000 = 5.634 k

Floor Loads

Live	100
Slab on Deck	45
Mech/Elec	10
Ceiling	5
Floor Finish	5 +
	=165psf
	=990plf

Stone Blocks

150 lbs/block
x30 blocks
4500 lbs
$\frac{4500}{18}$ = 250 lbs/ft

Lintels

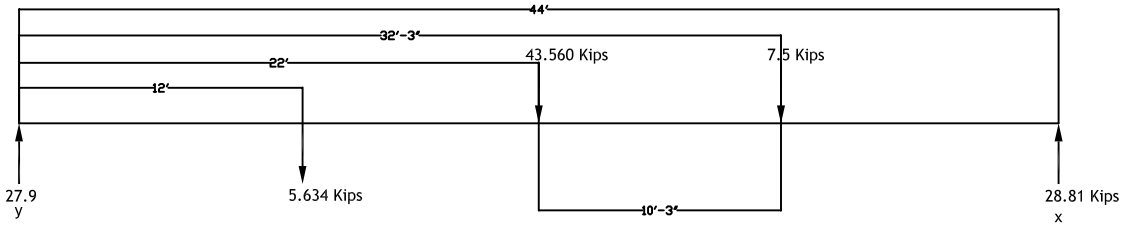
(4) L6x3 @ 22' = 264lbs
(12) W6x15 @ 1.5' = 270lbs
(10) WT10.5x22 @ 2.75' = 605lbs +
1139lbs
18'
= 63.3lbs/ft

Hanging Load

250 lbs/ft - Blocks
63.3 lbs/ft - Lintel
313.3lbs/ft

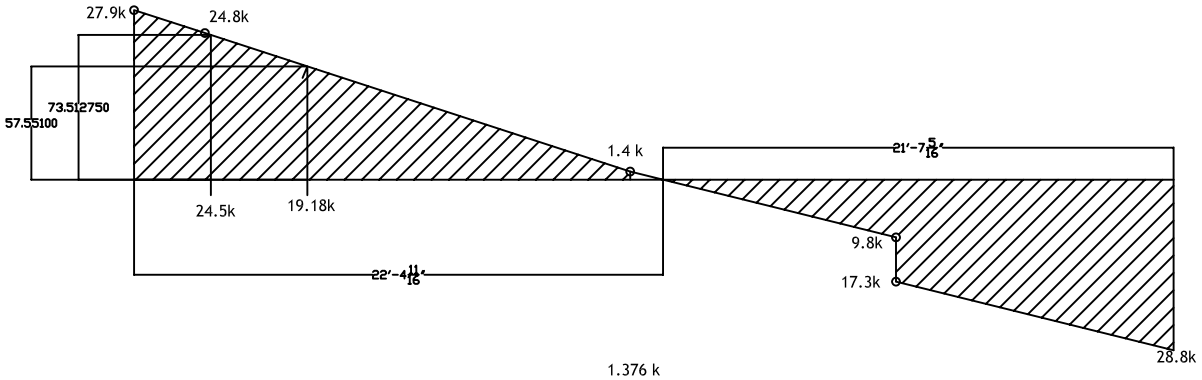
Point Load

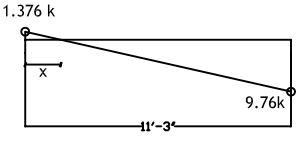
Tributary Length
32.25 /2 + 5.875 = 22'
Tributary Width = 6'
Tributary Area
22' x 6' = 132ft^2
Load
132 ft^2 x 57psf = 7.5k



SUM(M) = 43.56k(22') + 5.634(12') + 7.5k(32.25') - 44(x)
= 958.32 'k + 67.61 'k + 241.875 'k -44x 'k
= 1267.81 'k -44x 'k
x = 28.81 k

SUM(Fy) = y -5.634 - 43.56 - 7.5 + 28.81
y = 27.884





Moment Capacity
.75 x 12 = 9"
M=9" x 32" = 288
[.5 x 3] x $\frac{26}{3}$" = 6
2% Moment Capacity at
center of beam mid span

1.376/x = 9.76/(11.25-x)
15.48 - 1.376x = 9.76x
15.48 = x(9.76 + 1.376)
15.48 = 11.14x
x = 1.39'