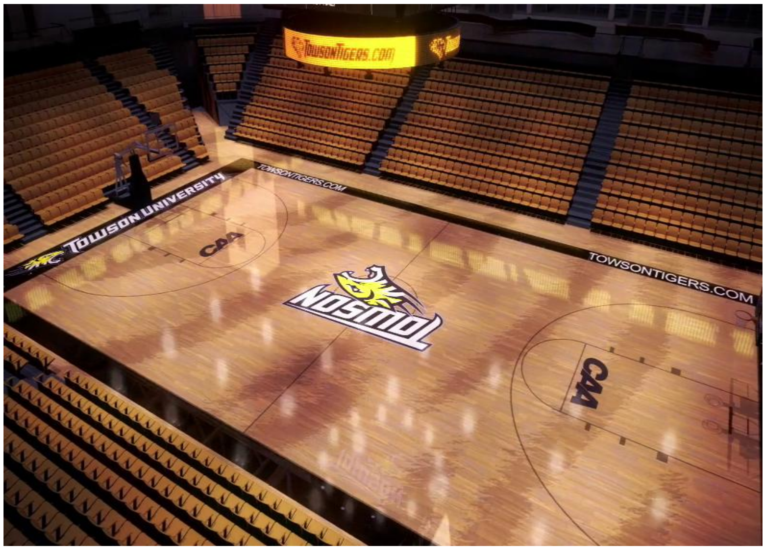


Towson Tiger Arena

Senior Thesis Final Report

Derek R. Stoecklein

Construction Management

Advisor: Ray Sowers

April 3, 2013

Towson Tiger Arena

Towson University, Towson, MD

Project Overview

Building Function	Sports Arena
Overall Project Cost	$56 Million
Size	120,000 S.F.
Number of Stories	4
Project Delivery Method	CM at Risk
Contract Type	GMP

Project Team

Owner	Towson University
Construction Manager	Gilbane Building Solutions
Architect	Hord Coplan Macht, Inc.
Civil Engineer	Site Resources, Inc.
Structural Engineer	Faisant, Inc.
M/E/P Engineer	James Posey Associates

Architecture

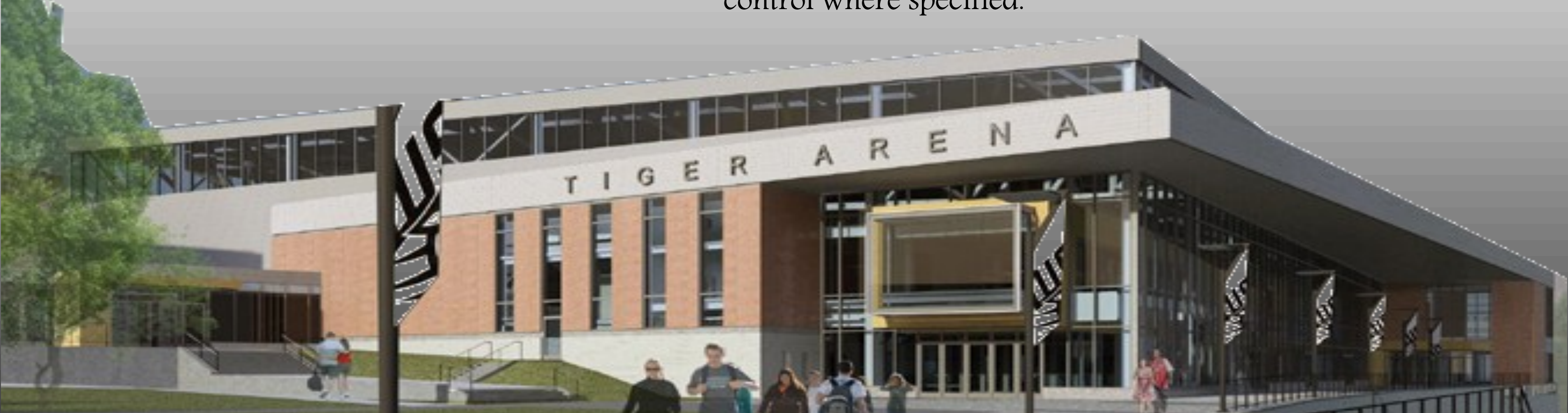
This arena, scheduled at 120,000 (GSF), will house approx. 5000 seats, several executive level suites and concession stands. Press boxes and audio/video equipment rooms will allow for broadcasting sporting events. The exterior of the new arena consists of Terra cotta, metal panels, 12" & 6" C channel, storefront glazing, curtain wall, a clear story, and split face CMU's.

Structure

Tiger Arena is built on foundation systems consisting of retaining walls, spread and continuous footings, and grade beams. CIP concrete walls, columns and beams, will be resting on theses foundations systems and support the above slabs and structural steel. Precast Concrete Seat riser sections will be support by steel risers and beams from below. To complete the structure is a Pratt truss system consisting of 11, three piece trusses.

M/E/P Systems

Heating for this building will be provided by two 400hp, four pass, fire tube boiler/burner set ups. Two centrifugal Chillers rated at 450 tons each will provide chilled water for the building and two cooling towers rated at 450 tons each will provide cooling water for the chillers, each cooling tower will be rated for 1125 GPM and 450 tons of cooling. Chilled and heating water will be circulated through the building to various air handlers for temperature and humidity control within the arena. Power to the existing center arena is supplied by 15kV underground feeders. Switch gear for these 15kV lines will be provided with the new construction and transformers will be used to step down to 480/277V 3 Phase. Three 150kW generators will be installed for emergency power and will be located near the boiler room outside the existing Towson Center. Air handling units, pumps, fans and other specialties will be furnished with variable frequency drives for motor control where specified.



Executive Summary

The following report is intended to provide a detailed overview of the analysis performed for Towson Tiger Arena. These analysis topics include a fabric duct system, pre-fabricated terra cotta panels, Production planning of the truss MEPF, and the integration of Cisco StadiumVision.

Analysis one includes a mechanical breadth and the implementation of a fabric duct system within the arena trusses. This is a very common system for sporting arena and large recreational centers due to its high level of efficiency and flexibility. Applying this system at Tiger Arena could greatly help improve the safety and quality of site logistics, as well as provide potential cost and schedule savings.

Analysis two looks at the potential benefits of prefabricating Terra Cotta wall panels. Utilizing prefabrication for a large part of the exterior of Tiger Arena will help greatly to increase site logistics and safety. The current system requires a lot of staging and storage room onsite for the terra cotta panels. With all the terra cotta being prefabricated offsite in a controlled environment, it will relieve this demand for space and help to increase flow and productivity around the site as well as increase the time it takes to close in the arena for interior work to begin.

Analysis three explores LEAN construction and the how production planning can improve or increase quality, schedule, and value to the customer. Production planning has many functions such as utilization of resources, steady flow of production, provide better work environment, ensure optimum inventory, and reduction in production costs. In particular, the Last Planner System will be analyzed to help improve the overall production of the MEPF systems within the trusses.

The final analysis includes an electrical breadth and involves the research of Cisco's new StadiumVision; an innovative application for sporting venues that helps promote fan engagement and growth. Cisco has been an industry leader with technology and innovative designs geared to provide a higher level of customer service and create a better business model. The integration of a system like this to the already advanced and cutting edge arena would set Towson University apart from the rest and continue to aid in the growth of the university and basketball program.

Acknowledgments

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Family and Friends

TABLE OF CONTENTS

Project Overview

Project Overview	
Building Name	Towson Tiger Arena
Location	Towson. Maryland
Occupant	Towson University
Occupancy	Sports, Performance
Arena Size	120,000 SF
Number of Stories	4 levels
Schedule	18 Months
Overall Cost	$56 Million
Delivery Method	Design-Bid-Build, CM at Risk
Contract Type	GMP

Table 1 Project Overview, created by Derek Stoecklein

Project Description

Towson Tiger Arena, scheduled at 120,000 (GSF), will house approx. 5,000 seats, several executive level suites and concession stands. The 5,000 seats will consist of bolted sections to precast and retractable floor seating. Press boxes and audio/video equipment rooms will allow for broadcasting sporting events. The exterior of Tiger Arena consists of Terra Cotta, Zinc metal panels, 12" & 6" C channel, storefront glazing, curtain wall, a clear story, and split face CMU's. The first floor contains two elevators, press room, chiller room, main electrical & tel/data room, three mechanical rooms, offical lockers, and two connection stairwells to the existing Tiger Center. The second floor is home to the main concourse level; with three concession stands, three men's bathrooms and four women's bathrooms, ticketing areas, hall of fame room, and a feature wall. The third level of the arena houses a presidents suite, a hospitality suite, donors suite, multipurpose room, as well as communications and electronics rooms for broadcasting. The fourth floor of the arena holds more precast seats, a camera platform for coverage of games and events, and the catwalk. This will all be under a structural steel braced frame structure sitting on a continues spread footing foundation, with a steel truss system supporting a built-up roof.

Tiger Arenas utilities will be serviced by new connections to the existing campus loops, entering into the arena through the first level. The new arena will have two chillers and a cooling tower to provide chilled water for humidity and climate control throughout the Arena and renovated areas of the building. Air will be supplied to the building via one of the 12 AHU's located throughout and exhausted through six fans located on the roof.

Client Information

"Towson University, founded in 1866, is known as one of the nation's best regional public Universities. TU offers more than 100 bachelors, masters, and doctoral degree programs in the liberal arts and science, and applied professional fields."

-Towson.edu/aboutme

TU has over 21,000 students and is among the largest universities in Maryland. Towson is located eight miles north of Baltimore and sits on 328-acres. TU has a strategic plan, *TU2016*, which evaluates the growth of the university and what they want to build on. Within *TU2016*, Towson has new 22 goals. Included in these goals is the addition of a new sports complex; *Tiger Arena.*

Figure 1 Towson Image- Courtesy of Bing

Tiger Arena provides a large opportunity for the university to expand their athletic programs, attract performers, and connect with the community. When looking at the value added by the new arena, we quickly see why this is built into *TU2016*. The construction of Tiger Arena will play a role in the future recruitment of students and excitement of current students.

Quality, schedule, and safety are very important to TU and the University of Baltimore, UMB. With the facility being built on an active college campuses and eventually being used by NCAA sports programs; quality, schedule and safety play are significantly important. The NCAA has very strict regulation for court sizing and slopes, lighting and broadcasting standards. In addition to this, the arena must be completed by the 2013 home opener. Safety of college students will be watched closely by TU and managed even closer by Gilbane to protect the university and the students from any unforeseen incidents.

**Campus Map in APPENDIX A*

Building System Summary

Architecture:

Figure 2 Rendering of TA, courtesy of hcm

This arena, scheduled at 120,000 (GSF), will house approx. 5,000 seats, several executive level suites and concession stands. The 5,000 seats will consist of bolted sections to the precast and retractable floor seating. Press boxes and audio/video equipment rooms will allow for broadcasting sporting events. The exterior of the new arena consists of Terra cotta, metal panels, 12" & 6" C channel; storefront glazing, curtain wall, a clear story, and split face CMU's. The first floor consist of two elevators, press room, chiller room, main electrical & tel/data room, three mechanical rooms, official lockers, and two connection stairwells to the existing center. On the second floor, there are three concession stands, three men's bathrooms and four women's bathrooms, ticketing areas, a hall of fame room, and a feature wall. The third level of the arena is home to a president's suite, a hospitality suite, donor's suite, and multipurpose room, as well as communications and electronics rooms for broadcasting. The fourth floor of the arena holds more seating, a camera platform for coverage of games and events, and the catwalk. This will all be housed under a structural steel frame sitting on a continuous spread footing foundation, with a steel truss system supporting a built-up roof and two custom 47,000CFM, air handling units.

Structural System:

Starting from the ground up, Tiger Arena is built on foundation systems consisting of retaining walls, spread and continuous footings, and grade beams. The retaining walls are located along the entire north and east exterior. This is due to the large change in elevation from the NW corner to the SE. Grade beams are found interior, between the exterior footings and interior footings for the bowl. The grade beams will support interior concrete columns and the one way slab above. CIP concrete walls, columns and beams, will be resting on theses foundations systems and support the above slabs and structural steel. All CIP concrete will be 4000psi normal weight concrete with grade 60 r-bar. A steel braced frame system will tie into the CIP concrete columns at the second floor. All building steel will be ASTM A992, grade 50, with bolted connections. Precast concrete seat riser sections will be support by steel risers and beams from below. To complete the structure is a Pratt truss system consisting of 11, three piece trusses.

Figure 3 Section of TA Structure, taken by Ryan Simmons

Mechanical Systems:

Heating for this building will be provided by two 400hp, four pass, fire tube boiler/burner set ups. These boilers will be set up to run parallel or independently from each other. Unlike the boilers they are replacing, these units are both natural gas and oil fired, because of this BGE will be required to run natural gas lines to the facility. Two centrifugal chillers rated at 450 tons each will provide chilled water for the building, and two cooling towers rated at 450 tons each will provide cooling water for the chillers. Each cooling tower will be rated for 1125 GPM and 450 tons of cooling. Chilled and heated water will be circulated through the building to various air handlers for temperature and humidity control within the arena. Two custom air handling units made by Air Enterprises, rated at 47,000 CFM each will be used in the main portions of the arena for climate control, and will be located on the roof. In addition to these custom units, eight smaller air handling units will supply conditioned air to offices and suites throughout the building. An ERU or energy recovery unit will be located on the roof of the arena to allow some of the air to be diverted through the building. This ERU will be rated for 11,000 CFM.

Figure 4 Custom AHU for TA, taken by Derek Stoecklein

Electrical Systems:

Power to the existing center arena is supplied by 15kV underground feeders; these lines run from the utility company to transformers located next to the arena, which have been moved for construction. The feeder is now run through a duct bank that supplies power to the construction trailers, and also the building via a different underground run. Moving this utility was required due to the new stadium location. Switch gear for these 15kV lines will be provided with the new construction and transformers will be used to step down to 480/277V 3 Phase. From there, the building electric is fed to transformers located in mechanical and electrical rooms to step the power down to 208/120V. Equipment and motors throughout the facility will use 480v or 277v electric unless otherwise noted in specs and drawings. Three 150kW generators will be installed for emergency power and will be located near the boiler room outside the existing Towson Center. Air handling units, pumps, fans and other specialties will be furnished with variable frequency drives for motor control where specified

Building Facade:

Towson Arena is made of several unique façade systems that are used to visually link the adjacent Unitas Stadium and the existing Tiger Center. These systems include Terracotta, Zinc panels (Standing Seam and Flat Lock), 12" and 6" C-Channel, Split Face CMU, Ground Face CMU, Curtain Wall, Glazing, and a Clear Story. The structure of the façade is made up of cast-in-place concrete and 6", 16 GA.

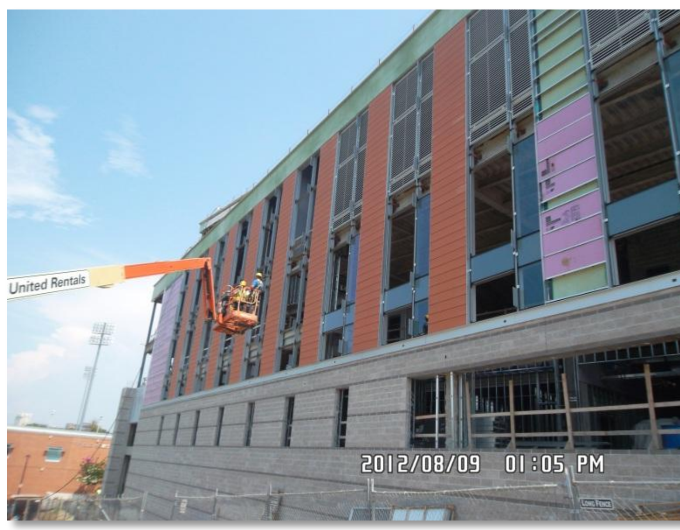


Figure 5 West Facade, taken by Derek Stoecklein

structural stud framing. Wrapping the structural studs is a 5/8" layer of moisture and mold resistive glasrock. A layer of liquid applied air barrier is sprayed over the glasrock and all exterior cast-in-place concrete. The North (Unitas facing) façade is a used to draw the spectators into the Arena with a long promenade walkway from Auburn drive and large span glazing to allow for a view into the beyond space. Covering the promenade is a canopy roof with zinc soffit that is returns from the façade above seamlessly. Also along this north façade is a large splitface and groundface wall, terracotta panels, and a clear story above the canopy that wraps the entire building.

Roofing:

The roofing system is a two-ply Styrene-butadiene-styrene (SBS); touch applied, white granular membrane with an aluminum roof edge set in multi-purpose MB flashing cement. Below the SBS cap sheet is a tapered, 4"min, ISO 95+ insulation, covered with ¼" Densdeck and sealed with a base sheet to create a water, vapor and air barrier. At the perimeter of the roof there is wood blocking to support a perlite cant strip, and several layers of flashing to allow for proper water from and drainage around the edges. To top the roof of, walk pads will be installed to allow for access to the air handling units and ERU's.

Protection

Moisture protection on the roof will be completed with SBS modified bituminous membrane. This membrane slopes north towards two sets of drains to provide adequate drainage. Moisture protection below grade in the addition section of the building will be bituminous damp proofing on foundation walls, self-adhering sheet waterproofing on foundation will be used on walls with proximity to an occupied space, and cold fluid applied plaza deck water proofing is to be applied under concourse pavers. In the elevator pits, modified cement waterproofing is to be completed. The exterior has a liquid applied waterproofing coving all glass rock.

Figure 6 West Air Vapor Barrier, taken by Derek Stoecklein

Sustainability Features:

Towson Tiger Arena's LEED Gold design encompasses many sustainable features including low VOC content for all interior products, all wood material meet FSC, and all waste will be recycled according. In addition to these features, Towson will utilized Energy Recovery units (ERU's) to capture energy from the exhausted air, as well as a large clear story around the entire truss level to introduce day lighting into the "bowl" of the arena. To improve the indoor air quality within the arena, two centrifugal chillers will be installed to supply chilled water to several Air Handling Units (AHU) throughout the building.

LEED Requirements

Figure 7 Towson GO Green Logo, Towson.edu

Tiger Arena was identified to obtain LEED Silver certification based on LEED-NC, Version 2.2. USGBC LEED-NC Version 2.2 consists of Sustainable Sites (SS), Water Efficiency (WE), Energy & Atmosphere (EA), Material & Resources (MR), Indoor Environmental Quality (IEQ), and Innovation & Design Process (ID). With a possible 69 points plus five ID bonus points, Tiger Arena is scheduled at a mandatory Silver certification between 33-38 points.

During the design and preconstruction phases, Gilbane and the architect (HCM) discussed with Towson University (TU) the importance of each credit and there goals as a University. After reviewing these credits with TU and completing the LEED NC, Version 2.2 checklist, a Gold certification was estimated. With 42 "yes" credits and six "maybe" credits, a much more sustainable building than originally planned could be obtained. Gilbane and HCM, upon owner's approval or given credits, organized each credit into Design and Construction Submittals for tracking purposes. Currently, the project is still striving for this new Gold certification. Gilbane and HCM are working closely with the owner on the "maybe" credits to evaluate the feasibility and cost to achieve each and the potential value to TU.

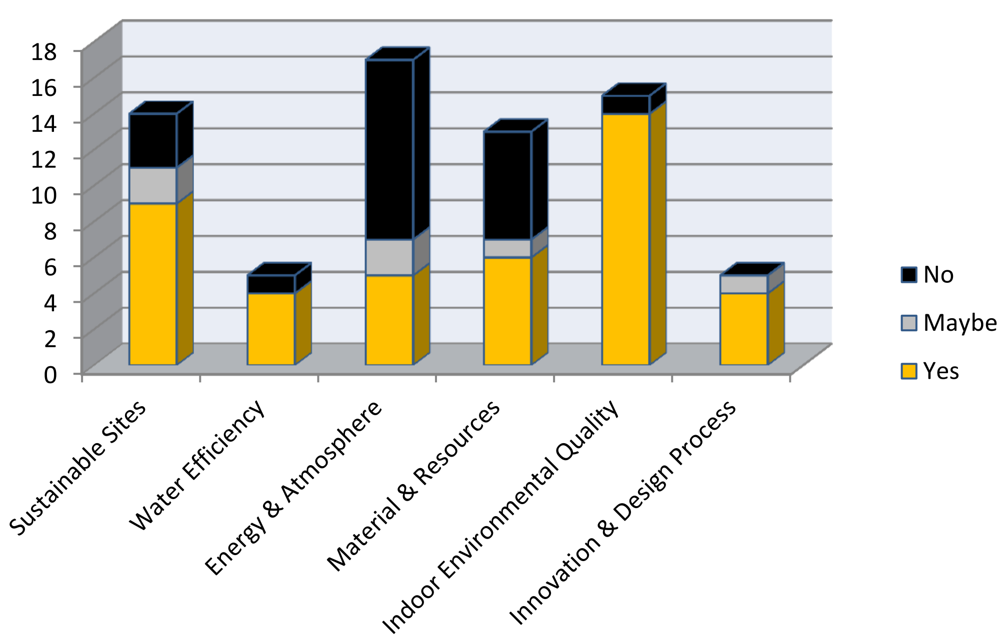


Table 2 Towson LEED Point Breakdown, created by Derek Stoecklein

LEED is more than a rating system used by the government to promote green thinking and techniques. LEED helps create high performance and efficient facilities for owners. This generates a building that promotes thinking and an environment that people want to be in and are comfortable. Additionally, this effort provides a return for the owner over the life of the building. Tiger Arena has spent a lot of its time during design to create innovative approaches for IEQ, WE, and EA.

Looking at Water Efficiency, a 49 percent modeled reduction of water compared to the 30 percent needed to achieve the credit. Additionally, a water efficient landscape has been designed. These approaches have allowed for a possible four out of five points in Water Efficiency.

Another huge effort put forth in design and enforced by Gilbane is Indoor Environmental Quality during and after construction. Gilbane has created a detailed IEQ plan that ensures all these measures are understood and met by each contractor prior to awarding their contracts. IEQ equates to over 20 percent of the total possible credits offered in Version 2.2 of LEED-NC. Of these 15 credits, 14 are listed as "yes" and some are mandatory according to TU. This large effort will help a great deal in establishing a high performance building for TU, and a user-friendly environment.

LEED Facts

for New Construction (v 2.2)

Gold	**48**
Sustainable Sites	11/14
Water Efficiency	4/5
Energy & Atmosphere	7/17
Material & Resources	7/13
Indoor Environmental Quality	14/15
Innovation & Design Process	5

Points possible = 69 points

Table 3 Towson LEED Facts, created by Derek Stoecklein

To further illustrate the attention to detail and innovation in design, four possible credits can be earned based on exemplary performance in Sustainable Sites, Water Efficiency, and Contractor Performance. Gilbane and HCM plan to follow the submittal process closely and aggressively to insure these credits are maintained, creating a building TU will be able to use as a benchmark for future high performance building around campus.

Project Delivery System

The project delivery used at Towson Tiger Arena was Design-Bid-Build. The major contracts were a GMP with Gilbane Building Company (Construction Manager) and Fixed Fee with hord | coplan | macht (Architect). Gilbane Building Company played a CM at Risk rule and managed all the Subcontracts for Towson University. Figure 8 shows a complete organizational chart of the TA project with all the contracts and lines of communication shown.

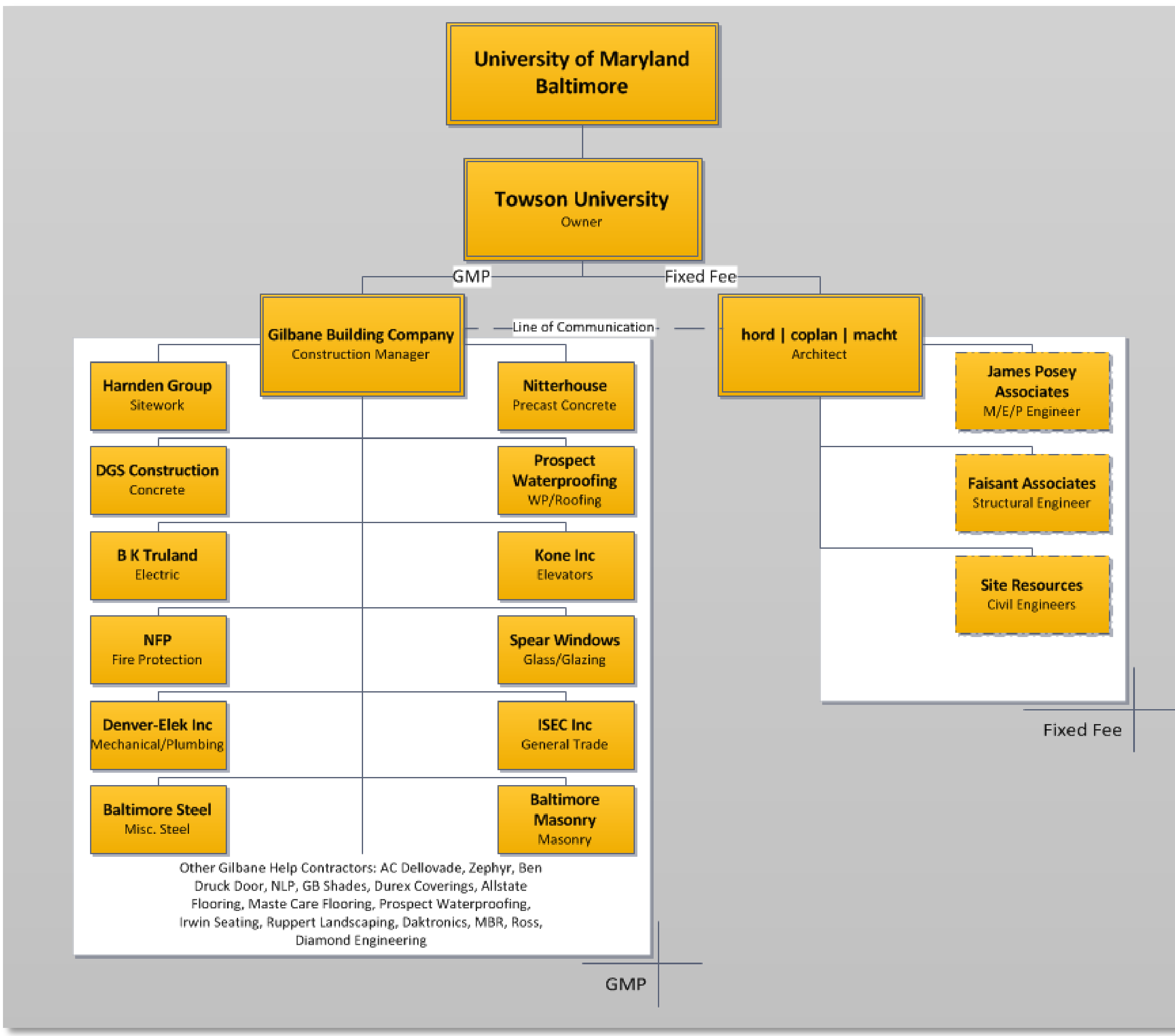


Figure 8 Tiger Arena Org Chart, created by Derek Stoecklein

Project Team Staffing Plan

Gilbane's project team consisted on five full time, on-site, personnel as well as an estimating executive, purchasing agent, and project executive. Of the on-site team, there were two superintendents, Steve Bond and Keith Beacom. Steve played the role of general super and over saw then entire project. Keith was responsible for the MEP trades only and coordination between them. The project manager on-site was Corey Sarver, and the two engineers were Ryan Becker and Matt Karle. Ryan and Matt split the engineering responsibilities by trades. Corey helped play the rule between the executive level and accounting responsibilities and the field management. The schedule and cost of the project was constantly monitored and updated by Corey and Steve. Figure 9 shows an organizational chart of the Gilbane project team.

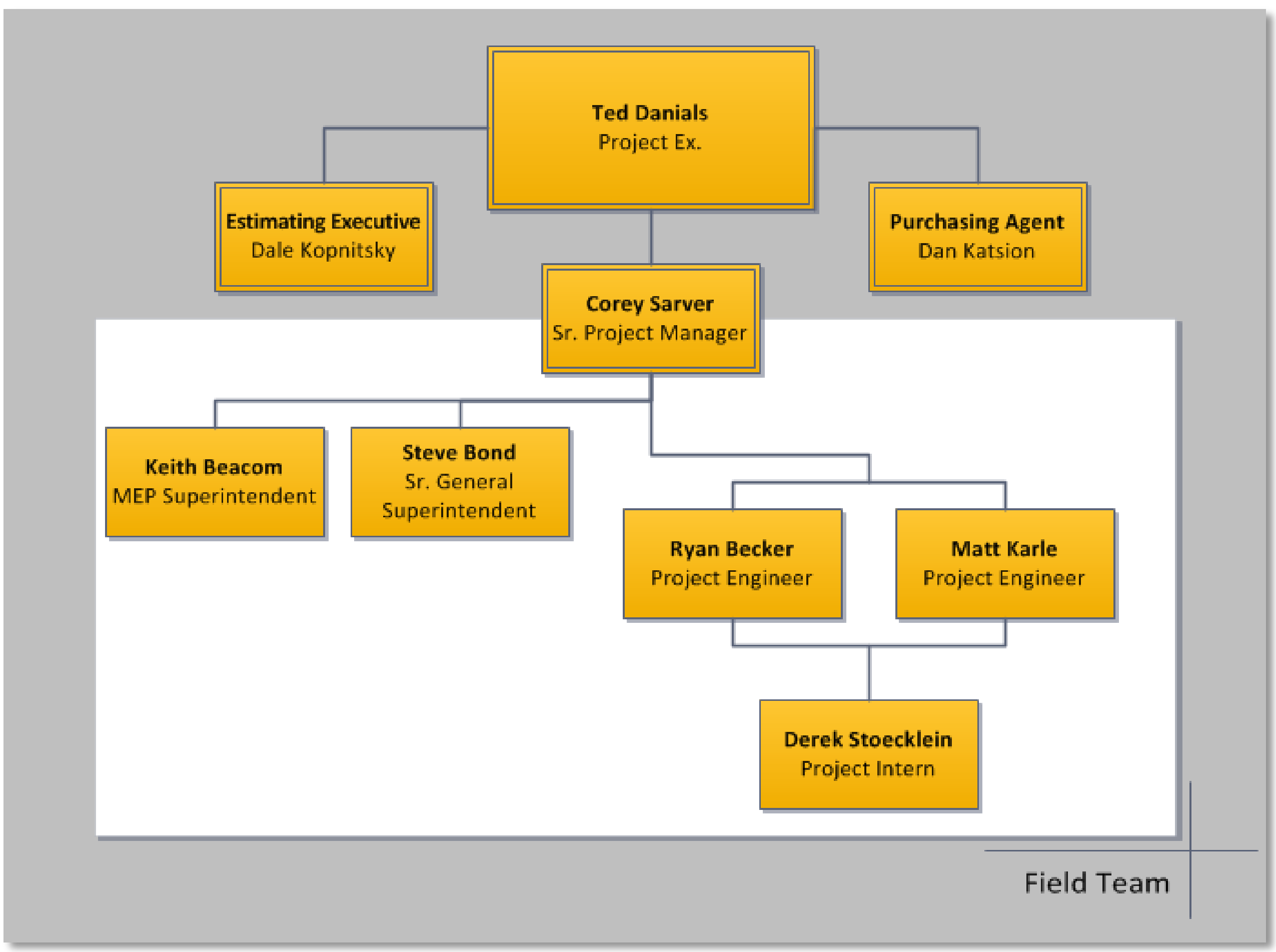


Figure 9 Gilbane Organization Chart, created by Derek Stoecklein

Construction Overview

Existing Conditions Site Plan Summary

Tiger Arena is built on an existing parking lot and grass field on the Far Southwest end of Towson University, adjacent to Tiger Center and Unitas Stadium, *Figure1.* With Tiger Arena being so close to the existing Unitas Stadium and Tiger Center, the utilities will be easily tied into. During phase one, Ross contracting will be redirecting all the building utilities from auburn drive to locations under the new arena. As seen in *figure 1,* the sanitary and storm drain line will extend from the main down Auburn drive to the North side of the building below grade. Electric will be run from the existing 15kV line at the South end of the Tiger Center. Also on the south side will be the new chilled water lines and domestic water. Gilbane has chosen to organize there site as shown below. The layout was design by the Sr. Superintendent to optimize the site as well as maintain proper pedestrian flow around Unitas, Tiger Center and the maintenance building located south the Gilbane trailer. Pedestrian flow will be impeded in one location due to the site restraints, this being on the building side of Auburn drive. The fence here will overtake the sidewalk which will be demoed at an early stage for excavation and utility purpose. Other things to note on the existing site plan are the use of temporary electric. The existing 15kV transformer for Towson Center is located on the south side, allowing the electrical contractor to run temporary electric to the trailer locations through a temporary ductbank.

Figure 11 – Proposed site, taken by Ryan Simmons

Figure 10 Corner of Auburn Drive and service road, taken by Ryan Simmons

Site Layout Planning

Phase One

- Site Utility
- Site Electric

This was done by two contractors; MBR, handling all site electrical and Ross, responsible for storm, water and sanitary lines. During phase one, site mobilization will also begin and temporary fencing will be installed.

Phase Two

- Site work
- Concrete
- Structural steel
- Misc. Steel
- Precast

Phase two started with the demolition of existing curd and cutters, sidewalks and asphalt were needed. Also in the early stage of phase two, the erosion and sediment plan began to eliminate run off during excavation and other site activities that will begin to start. Along Auburn drive are two storm drains that will have asphalt curbs installed to direct water to them and away from the site. Wheel wash stations are also installed at both gates to eliminate tracking mud onto the streets. Sitework is done in four phases, starting with the excavation of the loading dock from the existing Towson center and grading along the service road. This work is done first to allow to necessary flow of future work and current Towson employees. As mentioned before, the maintenance building is located behind the proposed site and the only access is a single lane service road. This road will be expanded to a two way road to allow for deliveries during construction. The next phase of sitework involves the installation of wheel wash stations and excavation of the building footprint. During the next phase, foundations will be excavated and installed followed by furnishing a crane pad inside the building footprint. Also done during phase three is the excavation of the North and East side of the building and installation of a temporary access road to the north side of the site, of Auburn drive. Lastly will be the excavation of the south side of the building.

Phase Three

- M/E/P rough-in and completion
- Exterior Framing
- Roofing
- Facade
- Interior Finishes (Framing, Drywall, Flooring, Painting)
- Masonry
- Site Grading

Phase three involves the most coordination and planning to allow for proper flow and use of the site. During this phase there will be an average of 200 workers on site, deliveries daily, and a large assortment of motorized equipment. Safety will also be critical when laying out the site plan for this phase due to the large increase in trades and equipment.

Phase Four

- Scoreboard
- Ribbon board
- Food Service Equipment
- Retractable Seating
- Casework
- Landscaping

The final phase of construction of Tiger Arena will consist of equipment install and commissioning of systems. This means the cranes and larger equipment will be off site and all final grading will be complete.

** Reference Site Plan, APPENDIX B*

Local Conditions

The community of Towson has had a large impact on the construction and location of Tiger Arena. From the very beginning the community has been supportive and informative of what they would like to get out of the arena and during construction. Work hours are regulated from 7:00 a.m. - 5:30 p.m., in order to respect the surrounding residences. In addition to these work regulations, parking will also be regulated. The site is very small and only allows enough space for foreman and Gilbane employee parking. This means that the contractors must park in LOT 14, located on the north side of Unitas Stadium. This has proven to be a problem due to the fact its pay-to-park and many employees disregard that and receive tickets. Parking permits are available to purchase and are prorated through a given period. If a permit is not purchased, daily passes can be bought at a kiosk in the lot.

Towson University is governed under University of Maryland, Baltimore (UMB). This means that all process from change orders to purchasing must be approved by TU and UMB prior to Gilbane receiving the go ahead. This creates some challenges and coordination requirements to maintain a good chain of communication up and down the parties.

Soils Classifications

The existing site is underlain by a thin surface layer of a man-made fill. The top of the residual soil was encountered directly below this fill, and these residual soils extend to the top of bedrock surface, which is located 6 to 38 feet below the ground surface. The lower portions of the residual soils are defined as disintegrated rock, and consist of very dense soils with rock-like properties,

**Information found in geotech report done by D. W. Kozera, INC.*

Project Schedule

Tiger Arena Schedule Summary			
Phase	**Duration**	**Start**	**Finish**
Design	653 Days	10/1/08	4/1/11
Preconstruction	458 Days	7/1/09	4/1/11
Owner NTP	0 Days	4/11/11	4/11/11
Construction	469 days	4/11/11	1/24/13
Sitework	357 Days	6/17/11	10/29/12
Structure	181 Days	9/19/11	5/28/12
Façade	168 Days	1/26/12	9/17/13
MEPF Systems	196 Days	2/16/12	11/15/12
Interior Finishes	236 Days	3/1/12	1/24/13
Closeout	103 Days	10/9/12	3/1/13
Substantial Completion	0 Days	3/1/13	

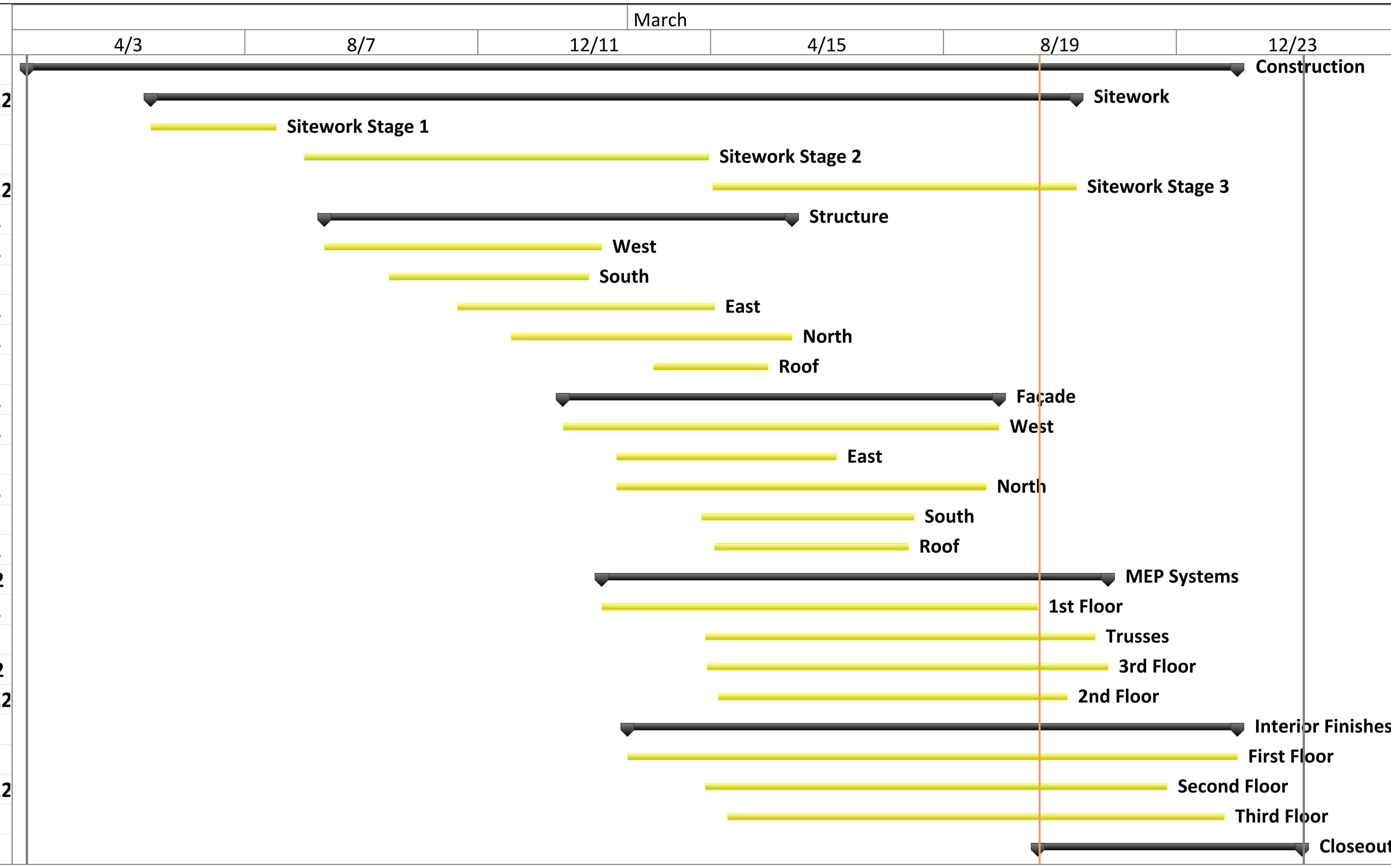
Figure 12 Summary Schedule Durations, created by Derek Stoecklein

Overview

The project was initiated by Towson University and was especially driven by planned events that the University requested the arena for, such as commencement services for the 2013 graduating class. Liquid damages were built into Gilbane's contract, charging $10,000 a day that they did not turn over the building. With this in mind, Gilbane knew they needed to create a well-designed and manageable schedule to insure the important deadlines were met. During preconstruction, all the subcontractors were brought in to perform a "card trick." Essentially, the "card trick" is a white board with all critical scheduled dates. Each contractor is assigned their own color sticky note that they will create their schedule with. Through much collaboration and discussion between Gilbane, Towson, and the contractors, the final schedule was created. This schedule had a construction start date of 06/07/2011 and a substantial completion on 03/01/2013, establishing overall construction duration of 469 days.

Towson Tiger Arena Summary Schedule
Created by Derek Stoecklein

ID	Task Name	Duration	Start	Finish
1	**Construction**	469 days	Mon 4/11/11	Thu 1/24/13
5	Sitework	357 days	Fri 6/17/11	Mon 10/29/12
6	Sitework Stage 1	48 days	Fri 6/17/11	Tue 8/23/11
10	Sitework Stage 2	157 days	Thu 9/8/11	Fri 4/13/12
23	Sitework Stage 3	141 days	Mon 4/16/12	Mon 10/29/12
35	Structure	181 days	Mon 9/19/11	Mon 5/28/12
36	West	108 days	Mon 9/19/11	Wed 2/15/12
55	South	78 days	Mon 10/24/11	Wed 2/8/12
70	East	99 days	Wed 11/30/11	Mon 4/16/12
82	North	108 days	Thu 12/29/11	Mon 5/28/12
100	Roof	44 days	Thu 3/15/12	Tue 5/15/12
107	Façade	168 days	Thu 1/26/12	Mon 9/17/12
108	West	168 days	Thu 1/26/12	Mon 9/17/12
121	East	85 days	Fri 2/24/12	Thu 6/21/12
132	North	142 days	Fri 2/24/12	Mon 9/10/12
143	South	83 days	Tue 4/10/12	Thu 8/2/12
152	Roof	75 days	Tue 4/17/12	Mon 7/30/12
158	MEP Systems	196 days	Thu 2/16/12	Thu 11/15/12
159	1st Floor	168 days	Thu 2/16/12	Mon 10/8/12
173	Trusses	151 days	Thu 4/12/12	Thu 11/8/12
180	3rd Floor	155 days	Fri 4/13/12	Thu 11/15/12
190	2nd Floor	135 days	Thu 4/19/12	Wed 10/24/12
200	Interior Finishes	236 days	Thu 3/1/12	Thu 1/24/13
201	First Floor	236 days	Thu 3/1/12	Thu 1/24/13
210	Second Floor	178 days	Thu 4/12/12	Mon 12/17/12
218	Third Floor	193 days	Tue 4/24/12	Thu 1/17/13
227	**Closeout**	103 days	Tue 10/9/12	Fri 3/1/13



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

Sequencing and Milestones

The Owner NTP on 04/11/2011 allowed Gilbane to mobilize the site and begin to locate and redirect existing utilities, as well as tie in temporary utilities. Construction started almost two months later with site clearing and E&R control. Following this was the excavation of the building foundation from west to east. The foundation and structure will begin to be constructed following the foundation excavation. The structure will be constructed from west-south-east-north-roof. This sequence was chosen due to the complexity and size of the CIP foundation walls along the north and south side. The building top of milestone is set for April18, 2012. The façade of the building begins as the north structure is underway, starting on the west again. The façade is sequenced slightly differently than the structure with the east following the west, then moving to the north and finishing on the south side. This sequence was driven by the façade material and location on the building. In order the avoid congestion on one side or another of the building, the contractors stared in different locations. The building Dry-in date is set for September 17, 2012.

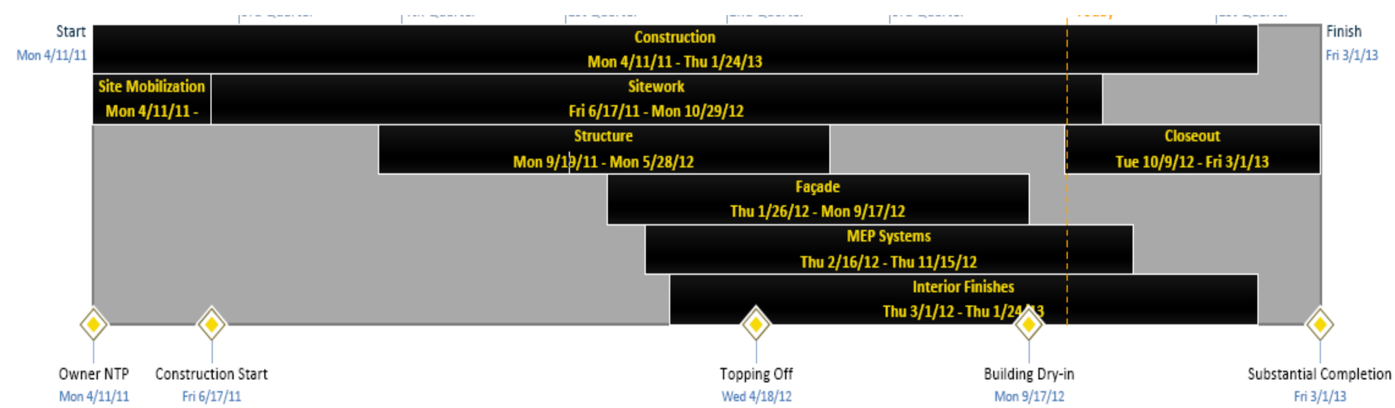


Figure 13 Timeline of TA, created by Derek Stoecklein

The buildings MEPF systems began on the first floor and moved to the truss level where they would finish from top down. This was do the large amount of rough-in and equipment that needed to be run through the trusses, prior to them getting painted and finished. Interior finishes were sequenced bottom-up, and followed along with the completion of MEPF rough-in work on each floor. Closeout will begin on October 9, 2012, with RCL/Punch list and system commissioning from October to the end of January 2013. The substantial project completion date is March 1, 2013.

Analysis 1: Application of DuctSox System

Problem Identification

The truss area of Towson Tiger Arena has presented many problems during installation of the building MEPF systems. Access to this area of the building is limited due to the 20' spacing truss to truss and the amount of usable floor space. This limitation makes it hard for large ductwork to be safely installed while other trade contractors are working in the same area. During duct install, the mechanical contractor would hang chain pullies and set the duct from man lifts, usually involving two or three lifts and four crew members. In addition to the issue of space in the trusses, the bowl is limited to staging capacity. Some pieces of duct work exceeded 10' in width and took up hundreds of square feet in staging on the bowl floor. Not only do these problems create a logistics nightmare but is a safety hazard to the other trades working in the bowl.

Figure 14 photo of duct work on the bowl floor, taken by Derek Stoecklein

Research Objectives

A clean and safe site is a large driver for productivity on a construction project. The current sheet metal duct system requires the staging and install of oversized and dangerous pieces, not only to the mechanical contractor but all trade contractors in the area. It is possible that the implementation of a fabric system will greatly decrease this issue of safety and congestion on site due to its compact size and flexibility. Not only will this help to improve the productivity of the team members within the bowl, it will greatly increase the productivity of the mechanical contractor's installation. Eliminating the oversized, awkward sheet metal pieces and installing very light fabric will require much less time to erect.

After analyzing a fabric duct alternative, it is expected that a large schedule savings will occur as well as a substantial increase in install productivity and decreased manufacturing cost.

Detailed analysis of site logistics will show a decrease in onsite congestion and the creation of a cleaner and safer site. Lastly, through examining the current mechanical system a potential decrease in the rooftop AHU's.

Methodology

The following approach was taken to analyze the supplementation of a fabric duct system:

- Evaluate the current system within Tiger Arena
- Calculate the required service loads of the court and spectator seating areas
- Research various fabric duct systems and compare the advantages and disadvantages of each type
- Contact several manufactures to receive design assist and added impute towards system selection
- Design a new fabric duct system
- Analyze the cost and schedule saving potential of the fabric system
- Provide conclusions and recommendations

Current System Overview

The court and spectator area of Tiger Arena is service from two custom AIR ENTERPRISES rooftop air handling units (AHUs). These units are designed as single-zone variable air volume with a CO2 reset, as seen in Figure 16. The two rooftop VAV units will supply over 2,635,720 CF of volume and 43,340 SF of floor space. This space consists of the main court, councourse level, and the upper deck seating. Air will be supplied to this space through large sheet metal ductwork suspended between the trusses. To meet the demand of this space, the AHUs are scheduled at 47,000 CFM (cubic feet per minute) each, with a total system load of 94,000 CFM.

Considering Tiger Arena is located in Towson, MD, the supply load for this system was designed to meet the cooling demand. Ventilation and heating loads were also calculated and incorporated into the design of the system but the largest demand of a venue in this climate comes from the cooling demands. To help with ventilation and air curculation within this larrge space, ten exhaust fans are placed on the roof to exhaust the preconditioned air. In addition, the rooftop unit uses large return fans to provide pre conditioned air into the AHU were it will be combined with outside air (OA), passed through a preheat coil (P/C), cooling coil (C/C) and finally through a reheat coil (R/C) before being supplied back into the space. Also in this process the air will pass through several filters and across mulitple sensor to deterime the humidity and CO2. All these sensor will determine weather the air is heated or cooled as well as how much OA to mix with the return air; Figure 16.

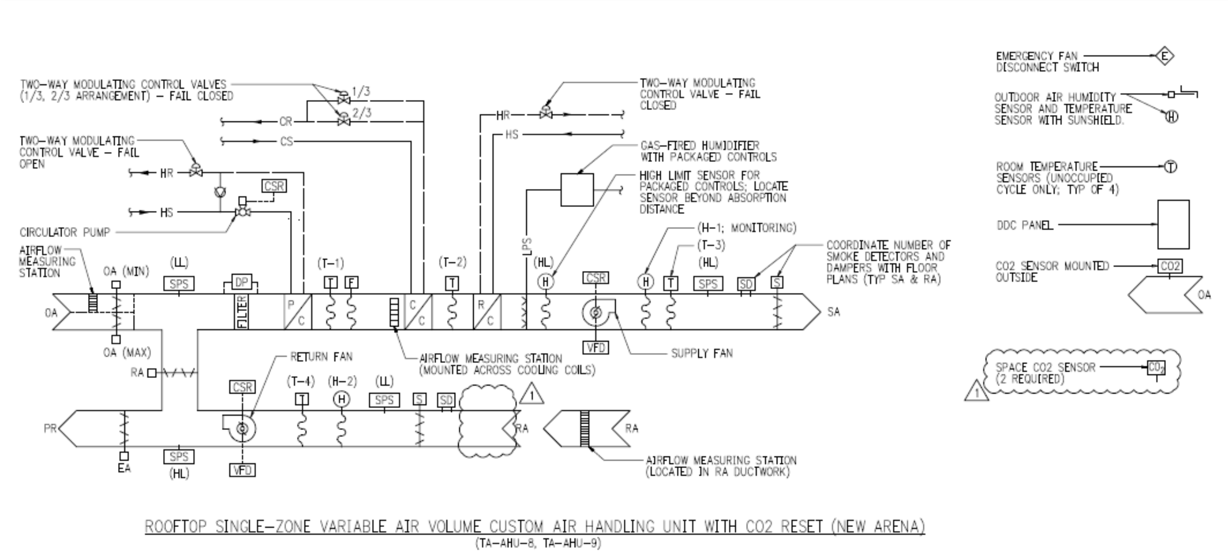


Figure 16 TA AHU Diagram, TA Contract Documents

Like stated before, the current system is sheetmetal duct suspended within the trusses. The duct ranges in size from 62" Diameter to 14" Diameter. The duct over the court area supplys air through 2-40"x12" Louvers, seen in Figure 15 . The duct above the seating areas uses large drum louvers to throw the air in a wide circular fashion versus the direct through of the court louvers.

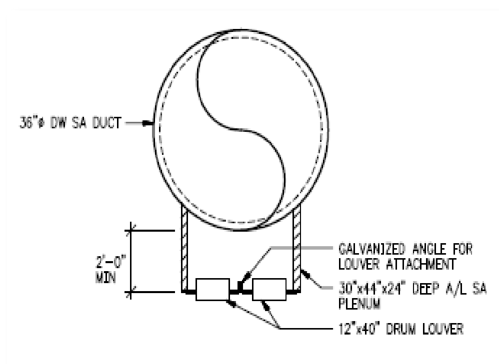


Figure 15 TA Duct Louver Detail, TA Contract Documents

Load Calculations of the Designed Space (Mechanical Beadth)

Before I began to explore a new system for Tiger Arena, I wanted to verify that the size of the custom rooftop units was accurate and necessary to supply this space with cooling, heating and ventilation. In doing this I believe I will discover that the units are oversized for engineering purposes such as energy consumption factors of running a unit at max output for extended periods of time. When calculation the necessary building loads for the given space I used ASHRAE and TRACE700 along with the contract documents. Below you will find in detail the calculations and procedures followed to complete these calculations.

Ventilation Load

Using the ASHRAE Standard 62.1-2010, I was able to calculate the minimum ventilation rates of the space.

Table 4 ASHRAE 62.1-2010 Sport & Entertainment, created by Derek Stoecklein

Occupancy Category	R_p	R_a
	CFM/Person	CFM/ft^2
Sports Arena	-	.30
Spectator Areas	7.5	.06

R_p (People Outdoor Air Rate, CFM/person) = 7.5 x 5000 people = 37,500 CFM

R_a (Area Outdoor Air Rate, CFM/SF) = .30 x 26040 = 7,812 CFM

Total Ventilation Load= 45,312 CFM

Cooling/Heating Load

Using TRACE700, I was able to calculate the PEAK Heating and Cooling loads of the space. The calculation of these loads consumed a lot more time and data to insure accuracy. The choice to use TRACE700 to help in this calculation was made due to the simplicity and relative accuracy of the program. TRACE700 works by taking the defined "space", location, and applying your created system to calculate the peak loads. The hardest challenge with this program is properly defining your space and identifying the system you wish to use for your load calculation.

When you open TRACE you will see the following navigator box, Figure 17 . From here you will be able to enter project information, select weather information, create templates, create rooms, create systems, assign rooms to systems, and several other features.

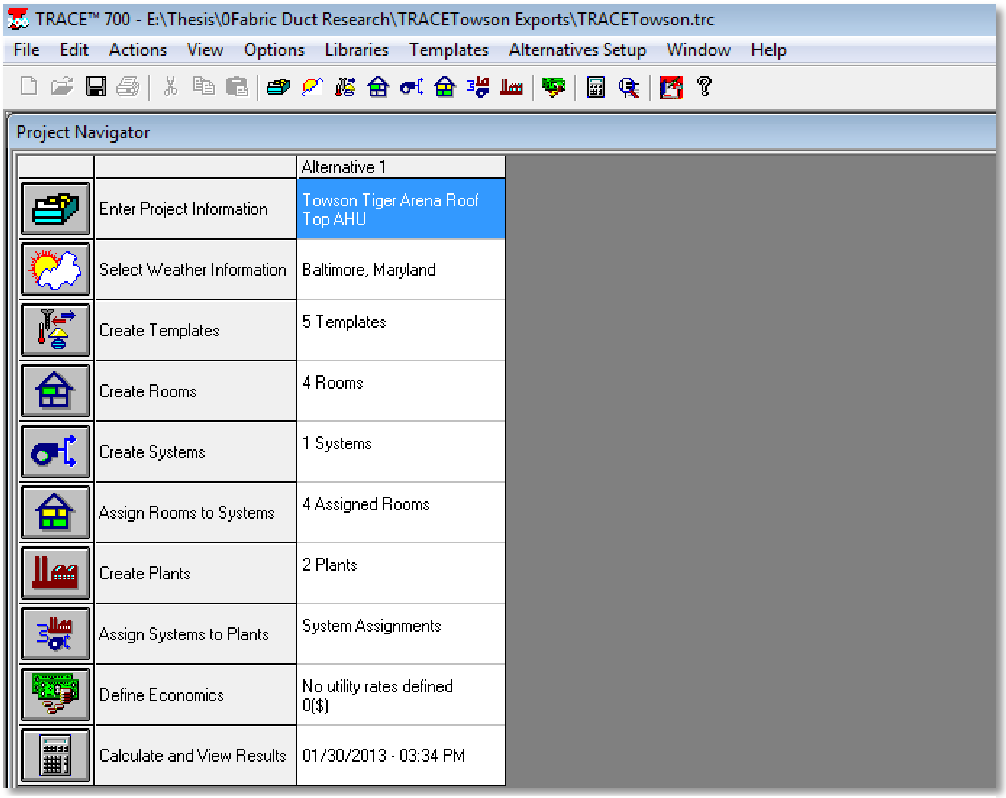


Figure 17 Trace Project Navigator

I began my TRACE analysis by selecting my weather information or location selection, Figure 18.

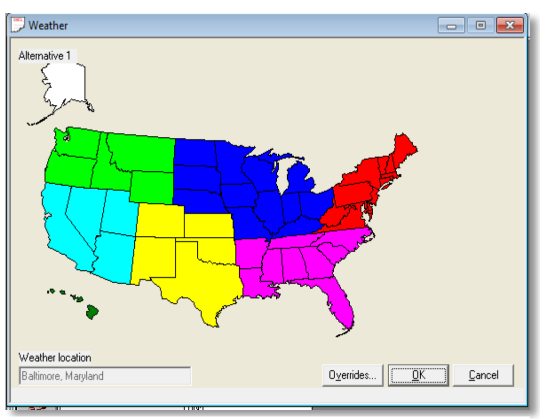


Figure 18 Weather Information, TRACE

Next, I began to create my "rooms". Since my space is not a typical box and has different elevations within it, I had to divide it up into separate rooms. The way TRACE recognizes a space is through room creation. When creating typical rooms you would also create floor to ceiling walls. This will change for my application, where I must create a 4 different room volumes and assign different floor to ceiling heights and base level constraints to trick the program into thinking I have created one single zone. I have created a SketchUp model to illustrate these "rooms" and how it will ultimately create a single zone within TRACE, Figure 19.

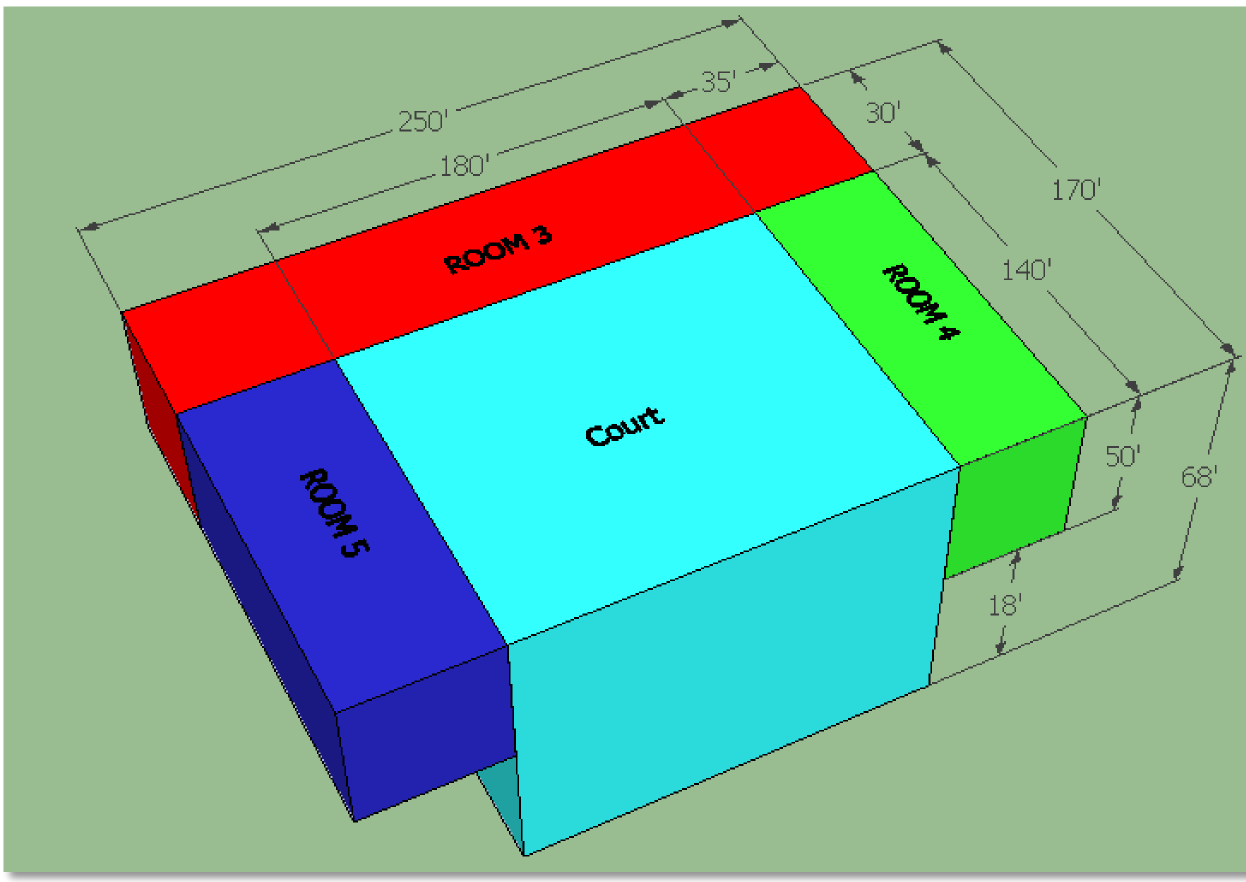


Figure 19 SketchUp "Room" Massing, Derek Stoecklein

In order to do this, I needed to design 4 rooms in TRACE as seen above. Next, I needed to assign all these dimensional parameters to each room within TRACE and create walls with building properties. For the Court room, I only have walls around the first 18' of the space. These are 8" thick reinforced concrete walls with a U-factor of .1244 Btu/hft^{2}F. These walls must be entered as partition in TRACE due to adjacent building construction on the other side, Figure 20 (1).

These adjacent spaces will be supplied by other AHU within TA but this must be recognized as a partition not a wall. If entered as wall construction, it will assume expositor to outside air of the other side which is not correct at this location.

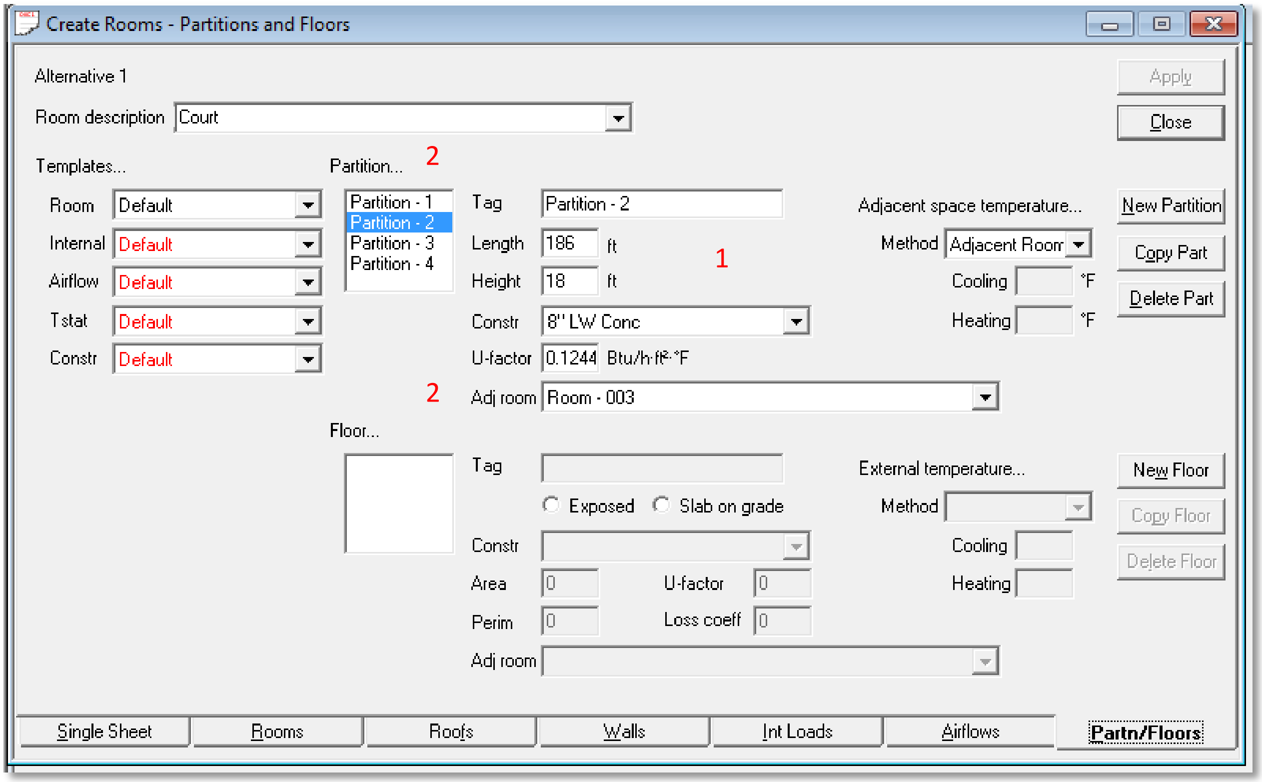


Figure 20 TRACE Partitions Screenshot

With these wall modeled at only 18" high, TRACE will recognize the remaining space as not having any walls. This will be import later when we assign the rooms to each other. After creating these partition walls, I have to assign the respective room to the respective partition. This allows the program to identify room 003 as the room attached to the west side of the court room, Figure 20 (2). Lastly, I must assign a floor to floor height, or in this case, floor to roof height or 68'.

Now that I have a template of my building within Trace, I could complete the same steps with the remaining rooms. Since I have assigned them to the partition around the court, the program identifies them at these locations and will generate a space like the one I have modeled above, Figure 19.

To complete the construction of the remaining three rooms, I need to complete their wall properties. The exterior wall construction for these rooms is a metal frame system with 2" Ins, and a U-factor of 0.13 Btu/hft^{2}F. In addition, these exterior walls have a clear store around the top. TRACE recognizes these windows as opening and an assigned U-factor. Using shop drawings submitted by the glazing contractor, I found the U-factor of these windows to be tested at 0.41 Btu/hft^{2}F. The length and height of each window opening must be entered into TRACE at each location, as seen in Figure 21.

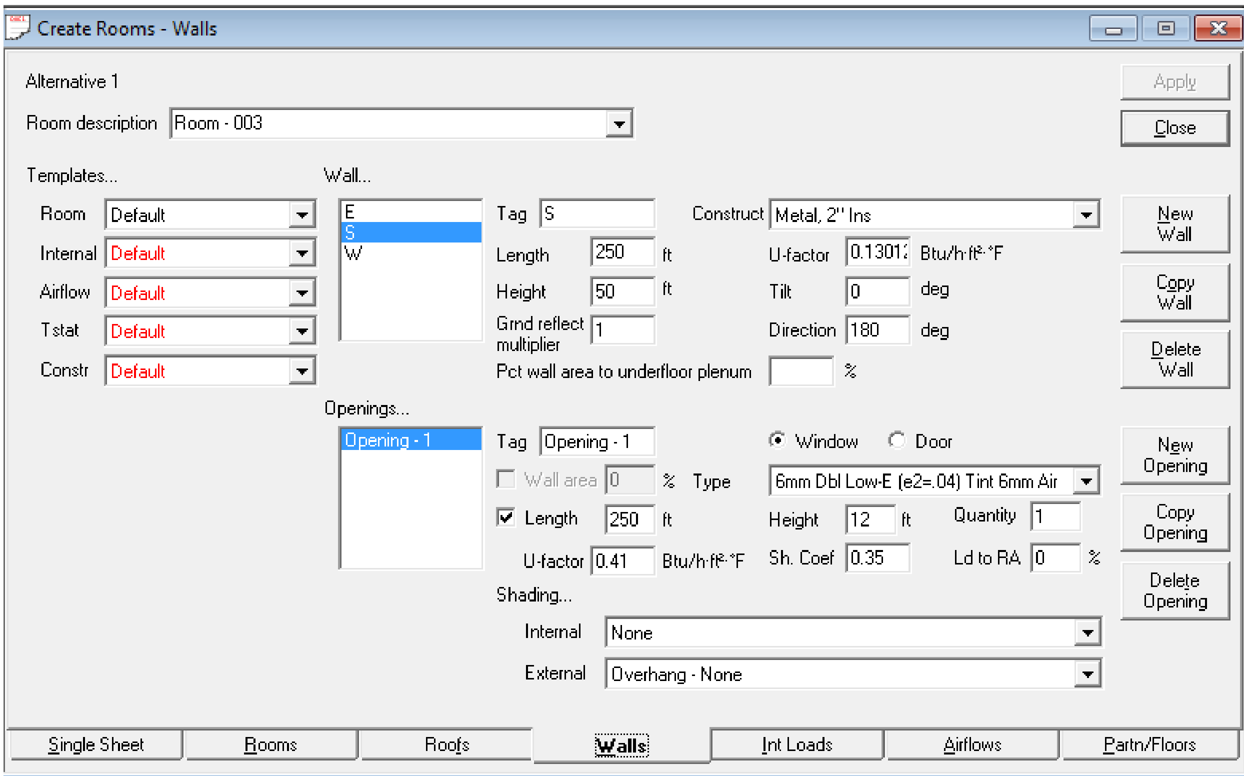


Figure 21 Wall Creation Window in TRACE

After entering the construction of these remaining rooms, I had to offset them from the ground elevation. If this step is not followed then the rooms would be assumed to be at 0' elevation and directly on the other side of the court. Since the interior partitions are 18' high and the exterior rooms will begin at the concourse level, I assigned these rooms to 18' above grade, Figure 22. Also in this window you can see where the geometry information is entered for each room; Length, Width, Floor to Floor height, and Plenum space. This information was entered for each room according to the dimensions shown in the model above.

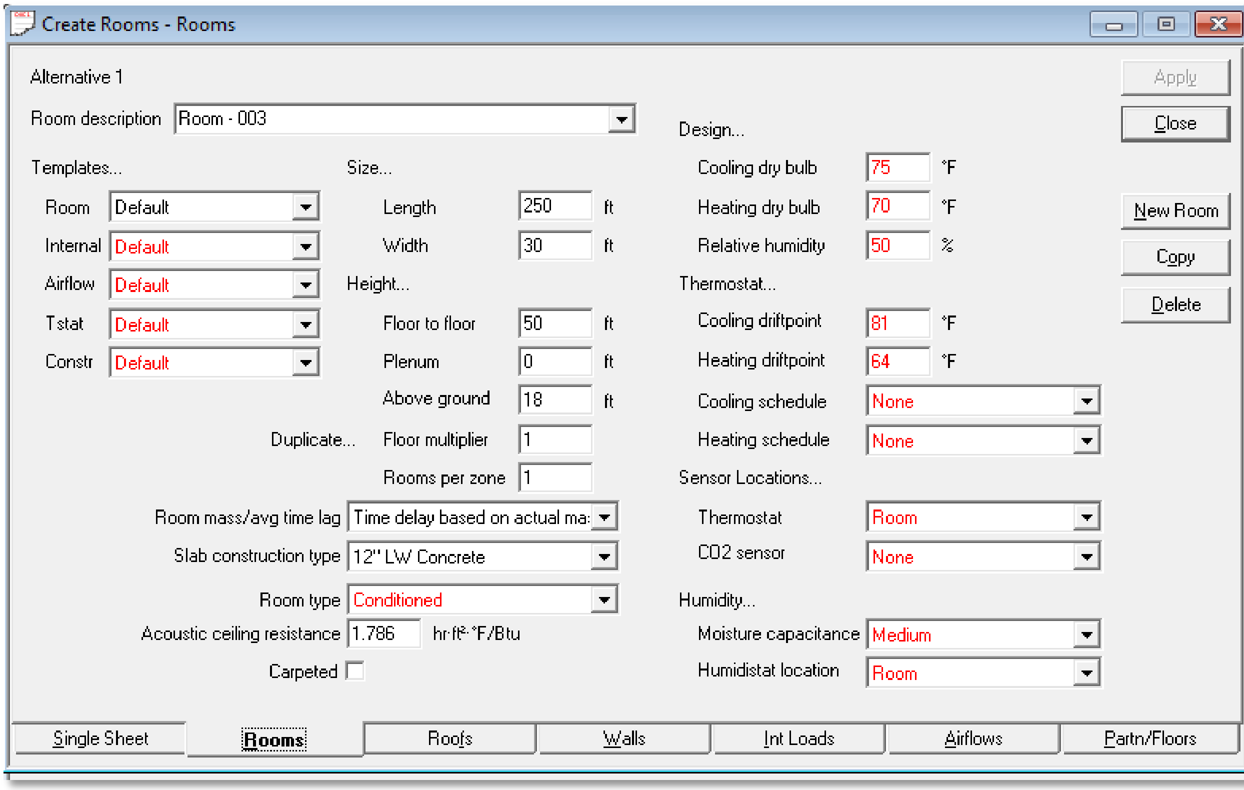


Figure 22 Room Creation Window in TRACE

The last step in creating rooms is assigning internal loads. These loads will be used in the calculation of the peak system loads later and include People, Lighting and Misc. Loads. For the people load I used the building seating plan to calculate the number of people in the space at max occupancy. For Lighting, I had to examine the building lighting systems and shop drawings to determine the total W/SF within the space.

Fixture Schedule:

S1	4-CIRCUIT CFL HIGH-BAY FIXTURE WITH (3) 2-LAMP SWITCHING BALLASTS AND (1) 2-LAMP 1% DIMMING BALLAST, TWIN-FIXTURE CLUSTER MOUNTING BRACKET	6-F42PLT/841 2-F42PLT/830	GUTH	SI2-O5-1N1842TB-ATC	SPORTLITE	277	SUSPENDED	BASKETBALL COURT
S2	CERAMIC METAL HALIDE OPEN-RATED PENDANT-MOUNTED FIXED SEATING CYLINDER DOWNLIGHT	CMH70CU942MED/O	GOTHAM	CH8-70MHC-6AR-LD-277-PM-DWH	PATHWAY 'COVENTRY' SERIES LIGHTOLIER 'CALCULITE' SERIES OMEGA 'REVELATION' SERIES	277	SUSPENDED	OVER SKYBOX & UPPER DECK SEATING
S2E	SAME AS S2, EXCEPT WITH ARC MAINTENANCE DEVICE	CMH70CU942MED/O	GOTHAM	CH8-70MHC-6AR-LD-277-PM-DWH	PATHWAY 'COVENTRY' SERIES LIGHTOLIER 'CALCULITE' SERIES OMEGA 'REVELATION' SERIES	277	SUSPENDED	OVER SKYBOX & UPPER DECK SEATING
S4	BROADCAST SPORTS LIGHTING SYSTEM WITH MOTORIZED SHUTTERS, CATWALK MOUNTING BRACKET, SAFETY CABLE	VENTURE MH1000VBD	WIDE-LITE	AE2M-1000A-MADJ 1000-MPBM-277ESCM-MW-6C-L2320P AMB-S AE2-STY-CBL	STERNER MUSCO	277	CATWALK STANCHION	ARENA SEATING PENDANTS

Figure 23 Fixture Schedule as applied to calculated space, TA Contract Documents

Total Lighting Load = 97.9KVA, thru Panel LP4.

97.9 kVA * 0.9 Power factor = 88.11 kW

88.11 KW / 43340 SF (SF of applied area) = **2.03 W/SF**

The last internal load comes from the building scoreboard. The total load of the scoreboard and ribbon display is 21.2 kVA, thru Panel PB4A.

21.2 kVA * 0.9 Power Factor = 19.08 kW

19.08 kW / 26040 SF (applied to court area only) = **0.73 W/SF**

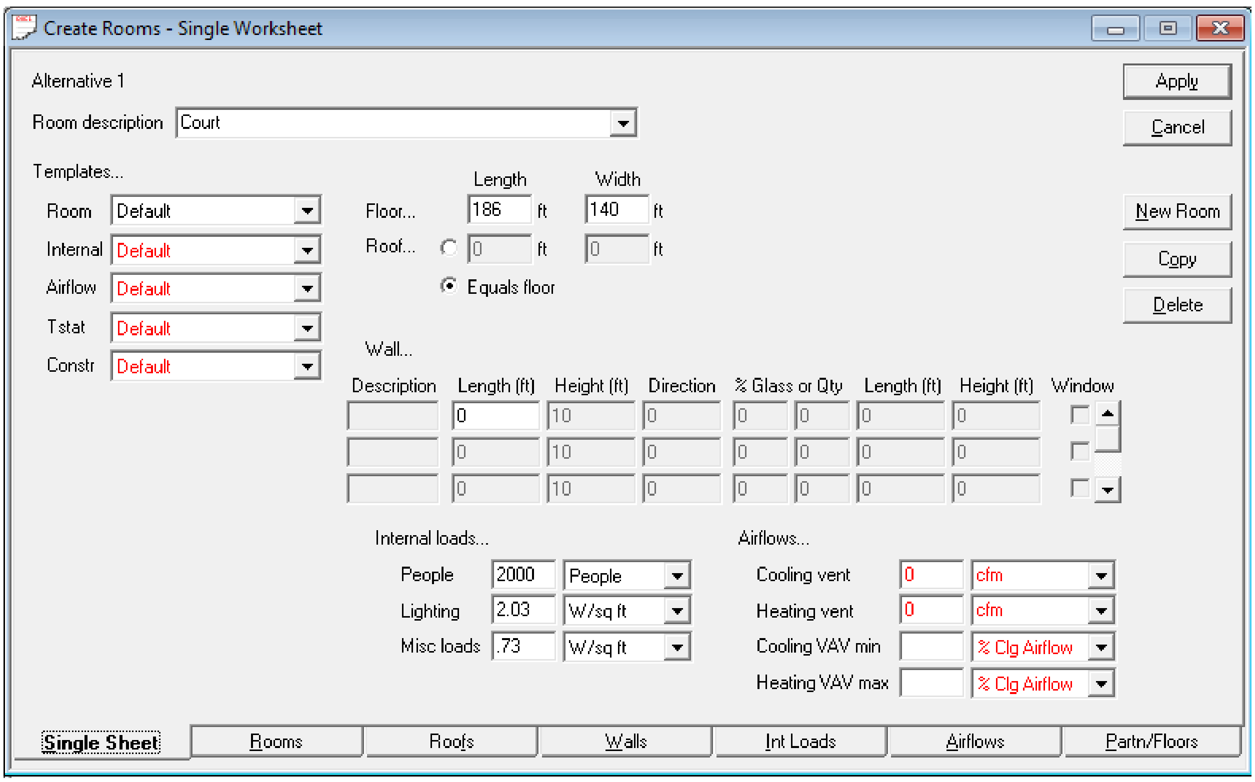


Figure 24 Room Creation Overview Window with Internal Loads

Now that all four rooms have been created I had to create a system within TRACE. Knowing that the existing system is a Single Zone VAV system it was easy to complete. When you select create a system from the TRACE project navigator, Figure 17, you are able to select a system category (Variable Volume) and the system type (Singe Zone VAV), Figure 25. For the purpose

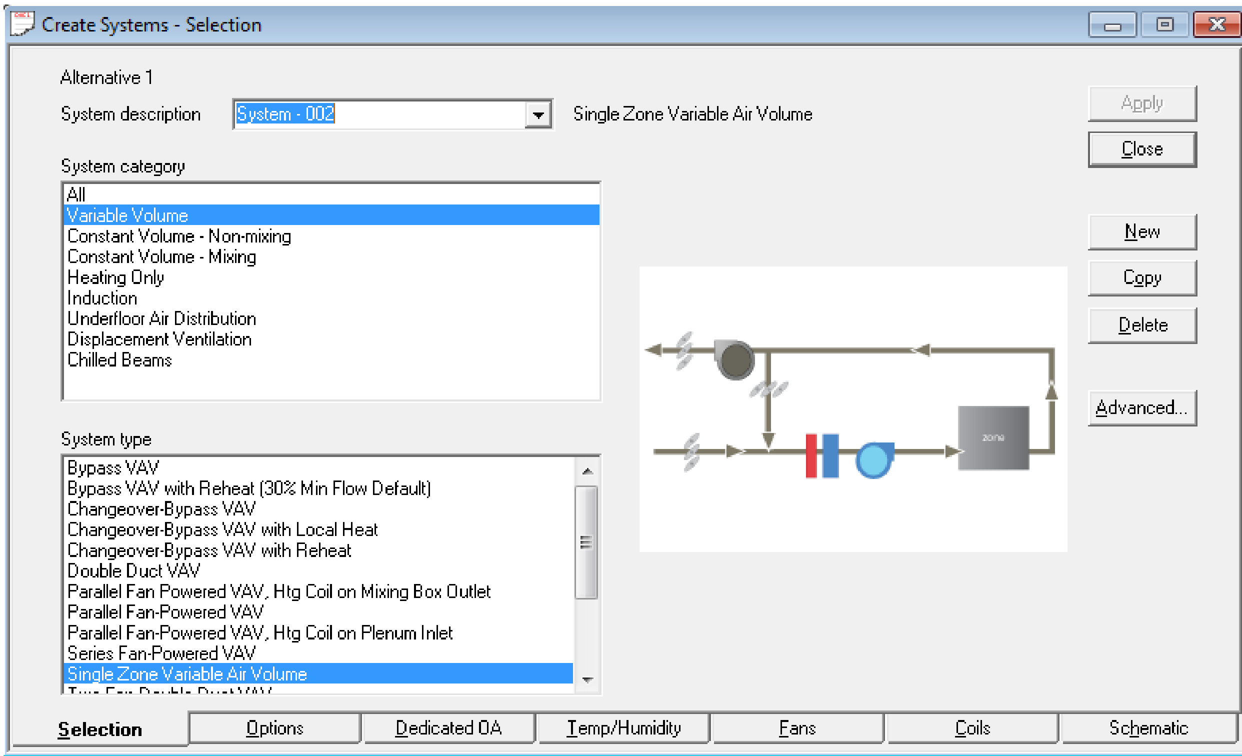


Figure 25 System Creation Window in TRACE

of this calculation, I have left the VAV system as default, as advised, and have not changed any of the other options you seen along the bottom of the system creation window, Figure 25. After the system is created, I assigned all the rooms to the new system via the Assign Rooms to System tab in the project navigator.

Lastly, I ran a report using the Calculate and View Results tab in the project navigator to calculate my peak heating cooling loads. After running the report there are many options for viewing the information such as zone checksums, room checksums, design airflow, engineering checks, and many others. In the design airflow printout, Figure 26, you will see that TRACE has calculated the spaces peak cooling load at 87,041 CFM and peak heating load at 26,830 CFM.

SYSTEM SUMMARY

DESIGN AIRFLOW QUANTITIES

By ACADEMIC

System Description	System Type	MAIN SYSTEM Outside Airflow cfm	Cooling Airflow cfm	Heating Airflow cfm	Return Airflow cfm	Exhaust Airflow cfm	Auxiliary System Supply Airflow cfm	Room Exhaust Airflow cfm
Alternative 1								
System - 002	Single Zone Variable Air Volume	0	87,041	26,830	87,041	0	0	0
Totals		**0**	**87,041**	**26,830**	**87,041**	**0**	**0**	**0**

Note: Airflows on this report are not additive because they are each taken at the time of their respective peaks. To view the balanced system design airflows, see the appropriate Checksums report (Airflows section).

Figure 26 Design Airflow TRACE Calculation, created by Derek Stoecklein

Comparing the TRACE cooling load of 87,041 CFM to the max system output of 94,000 CFM in the current design, this further shows why I believe the system may have been over designed. Like previously stated, I think there is several energy and engineering safety considerations that may play into the over design. Thru further investigation I would be able to examine in more detail how these numbers varied by more than 7,000 CFM, but for the intent of this report I plan to evaluate an alternative system using the calculated load of 87,000 CFM. I addition, with this new load of 87,000 CFM, the existing fans within the rooftop AHUs could be downsize from a Twin City EPFN-490 to an EPFN-445. This new fan will still meet the require fan specs, Figure X, as well as potentially save Towson some money.

E. HVAC equipment shall meet the energy performance requirements of ASHRAE 90.1.

F. Make fan selections to the right of the peak static pressure point and not on any flat portion of the fan curve. Generally, fan selection shall be in the 50 percent to 80 percent range of wide open volume.

1. If it should be necessary to provide fan wheels not described in the manufacturer's standard catalog, factory test the air handling unit to determine the effect on capacities.

Figure 27 Fan Specification item, TA Contract Documents

** All reports can be viewed in full in APPENDIX C*

DuctSox Overview

Different than conventional metal duct, fabric duct products are engineered and manufactured for each project. DuctSox designs can be simple, straight forward systems or very intricate layouts which incorporate fittings such as radius elbows, T's, and transitions. Sections are zippered together to form extended lengths with diameters from 6 to 80 inches. Whether industrial, education, government, commercial, warehousing, food processing, arenas, temporary or permanent, DuctSox offers a proven choice.

DUCTSOX®
Fabric Air Dispersion Products

Figure 28DuctSox Logo, ductsox.com

Fabric Duct vs. Sheet Metal Duct

In a traditional open ceiling building, metal duct systems would discharge air through metal diffusers usually spaced 10 to 15 feet apart. This air is directed to specific zones resulting in less efficient mixing of air in the space and causing drafting and hot or cold spots in most occasions. With a DuctSox system, a more uniform air distribution along the entire length of the fabric system allows for a consistent and uniform air distribution in the occupied space. A more uniform air distribution equals a better air mixing.

Why Fabric Ductwork

DuctSox systems have many advantages and benefits, including:

- Simplified Design/Uniform Air Dispersion
- Cost Savings/Minimal Labor Hours
- Lightweight/Easy to Ship
- Quiet
- Air Porous
- Easy to Maintain/Clean
- Portable
- Flexible
- Colorful/Personalization
- Sustainable Advantages (LEED)

DuctSox Design

DuctSox System Selection

When selecting a DuctSox system, I followed the steps outlined below:

1. *Selecting the Series of DuctSox*

This is the process of defining the cross sectional shape of the duct; I have chosen the standard round duct.

2. *Selecting the Proper Model*

DuctSox has three standard models that define how the air is delivered, Comfort-Flow (CF), High-Throw (HT), and Low-Throw (LW). For the application within the high trusses of Tiger Arena, the High-Throw model has been selected.

3. *Selecting the Proper Fabric*

Choosing from eight fabrics developed to satisfy application requirements in many different space types, I choose TufTex to best fit an Arena application. TufTex is a heavyweight, premium grade non-permeable polyester fabric. Construction features finished seams, a positive inlet anchoring system with cover-up sleeve, zippered end caps, and a zippered inlet collar for a DuctSox Final Filter or Adjustable Flow Device. TufTex offers a 15 year warranty and comes in many color options.

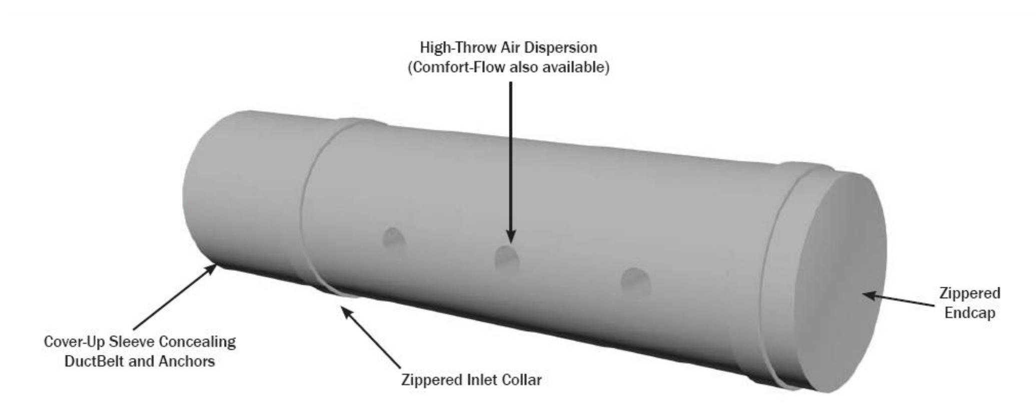


Figure 29 TufTex Duct Details, DuctSox.com

4. Selecting the Proper Suspension System

The suspension system selected for Towson Tiger Arena is a SkeleCore IHS system. This system allows for the duct to assume an inflated appearance even when there is no air flow. The SkeleCore system is a 1/8" cable installed every 5' within the duct fabric and attaches to a cable track that runs the length of the duct and is supported by roof deck mounted cable.

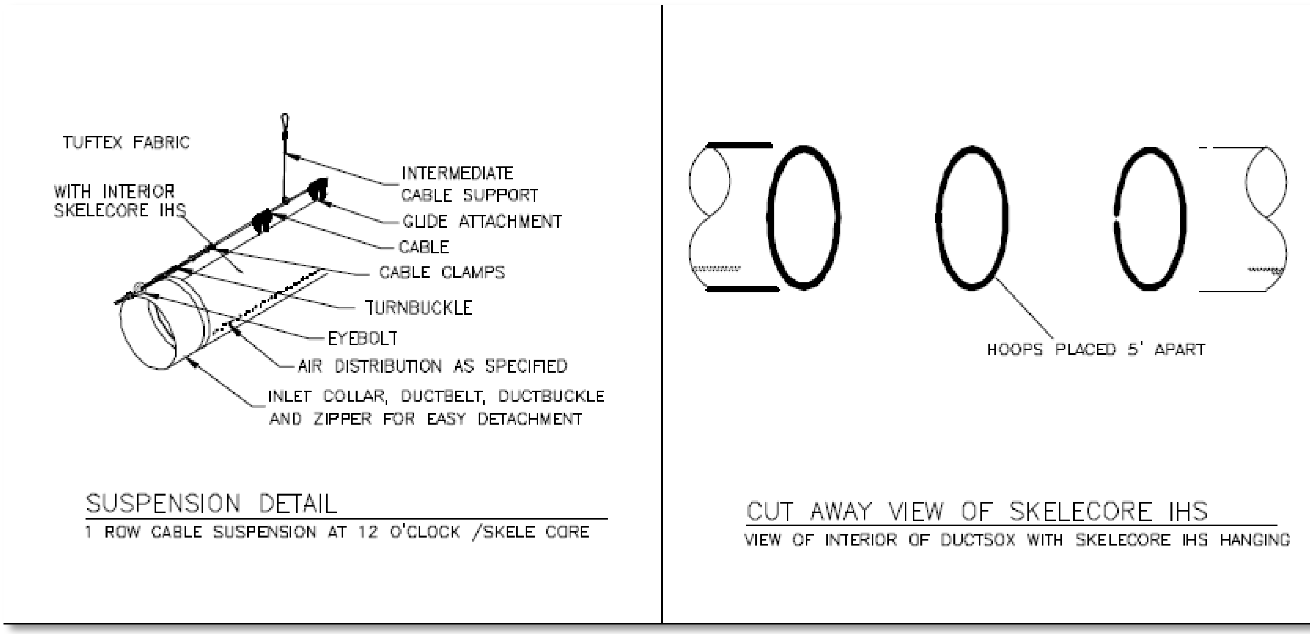


Figure 30 TufTex SkeleCore IHS Details, DuctSox.com

5. Selecting Enhanced/Personalization Options

TufTex has the capabilities to personalized in many ways including color and screen printing. If Towson would like, they could have their logo or school name printed along the sides of the duct during fabrication. Additionally, they can select from a list of color dies that TufTex fabric comes in. For this application, I have chosen the standard white design with no further customization. The existing sheet metal duct system is painted white after installation, so I decided not to chance that architectural selection.

DuctSox System Sizing

Using the DuctSox Engineering and Design Manual I was able to size the fabric and the suspension system. This process also follows a step by step approach, listed below:

1. *DustSox Series/Shape Selection (Standard Shape, previously chosen)*
2. *Design Layout*

Using the CFM calculated for each "room" in TRACE and the existing duct layout, I was able to design the fabric duct diameter, lengths, and sections.

From Engineering and Design Manual:

(2) 46" Dia. x 101' L = (2) Duct Sections Ea.

(4) 32" Dia. x 144' L = (4) Duct Sections Ea.

(2) 32" Dia. x 118' L = (3) Duct Sections Ea.

(2) 32" Dia. x 24' L = (1) Duct Section Ea.

(1) 32" Dia. x 17' L = (1) Duct Section Ea.

= (29) Total Fabric Duct Sections

* *Max Length of 46" Dia. Duct = 35'; Max Length 32" Dia. Duct = 40'*

Qty	DuctSox Description
2	46" Dia x 101' - SkeleCore - Tuf-Tex - Internal Hoop System - Round Standard Color - D1 - Starts with 1 Inlet - Covered - Ends with 1 Zipper - 1 elbow(s) - 0 transition(s) - 1 tee(s) - 0 cross(s) - 0 Filter(s) - 0 AFD(s) - 14355 CFM - .5" Inlet Static - High Throw - - Built for IHS Galv Cable - 5' drops - Glider
4	32" Dia x 144' - SkeleCore - Tuf-Tex - Internal Hoop System - Round Standard Color - D2 - Starts with 1 Zipper - Ends with 1 Endcap - Zipped - 7 zip(s) - 0 elbow(s) - 0 transition(s) - 0 tee(s) - 0 cross(s) - 0 Filter(s) - 2 AFD(s) - 7404 CFM - .5" Inlet Static - High Throw - - Built for IHS Galv Cable - 5' drops - Glider
2	32" Dia x 24' - SkeleCore - Tuf-Tex - Internal Hoop System - Round Standard Color - D3 - Starts with 1 Inlet - Covered - Ends with 1 Zipper - 1 zip(s) - 1 elbow(s) - 0 transition(s) - 0 tee(s) - 0 cross(s) - 0 Filter(s) - 0 AFD(s) - 0 CFM - .5" Inlet Static - High Throw - - Built for IHS Galv Cable - 5' drops - Glider
1	32" Dia x 17' - SkeleCore - Tuf-Tex - Internal Hoop System - Round Standard Color - D4 - Starts with 1 Zipper - Ends with 1 Endcap - Zipped - 0 elbow(s) - 0 transition(s) - 1 tee(s) - 0 cross(s) - 0 Filter(s) - 0 AFD(s) - 0 CFM - .5" Inlet Static - High Throw - - Built for IHS Galv Cable - 5' drops - Glider
2	32" Dia x 118' - SkeleCore - Tuf-Tex - Internal Hoop System - Round Standard Color - D5 - Starts with 1 Zipper - Ends with 1 Endcap - Zipped - 5 zip(s) - 0 elbow(s) - 0 transition(s) - 0 tee(s) - 0 cross(s) - 0 Filter(s) - 2 AFD(s) - 0 CFM - .5" Inlet Static - High Throw - - Built for IHS Galv Cable - 5' drops - Glider

Figure 31 Complete DuctSox Description, Created by DuctSox Representative

3. *Fabric (TufTex, previously selected)*

Premium	Combination of quality fabrics with durable and aesthetic construction. • Inlet Cover Sleeve • Zippered Inlet Connection • Interior Seams/Construction • Zippered Endcap • 10 Year Warranty • Standard AFDs • Launderable	**Sedona-Xm** 6.8 oz/yd² Antimicrobial Treated Woven Polyester, UL Classified, NFPA 90-A, ICC/AC167 Colors: Blue, Natural White, Red, Green, Tan, Gray, Black	Porous; Comfort-Flow; High-Throw (SG Diffuser required); 55% recycled content
		TufTex 8.2 oz/yd² Coated Polyester, UL Classified, NFPA 90A, ICC/AC167 Colors: Red, Green, White, Blue, Taupe, Silver, Black	Non-Porous; Comfort-Flow; High-Throw

Figure 32 Premium Fabric Selections, DuctSox.com

4. *Air Dispersion (Airflow)*

High-Throw Airflow is desirable for the distance the air must be displaced over. In addition to selecting the Airflow Type, I had to design the Airflow Direction. To assume a uniform distribution throughout the arena, I chose 5&7 O'clock for my inlet orientations, Figure 33.

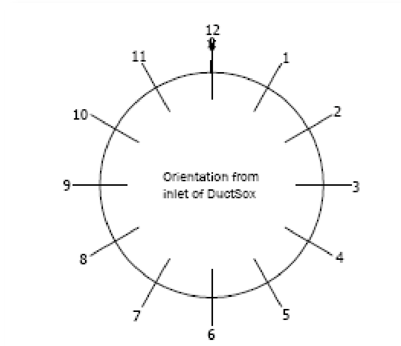


Figure 33 DuctSox Inlet Orientation, DuctSox.com

5. *Suspension (SkeleCORE IHS, Previously Selected)*

Qty	Hardware Description
2	20' - IHS Galv Cable - D1 - Access: 0 Kit I Type - 0 Kit II Type - 0 - 5' Midsupports - 1 Cable Stops
4	164' - IHS Galv Cable - D2 - Access: 1 Kit I Type - 1 Kit II Type - 15 - 5' Midsupports - 4 Cable Stops
2	44' - IHS Galv Cable - D3 - Access: 1 Kit I Type - 0 Kit II Type - 4 - 5' Midsupports - 2 Cable Stops
1	37' - IHS Galv Cable - D4 - Access: 1 Kit I Type - 0 Kit II Type - 3 - 5' Midsupports - 1 Cable Stops
2	138' - IHS Galv Cable - D5 - Access: 1 Kit I Type - 1 Kit II Type - 13 - 5' Midsupports - 2 Cable Stops

Figure 34 Complete Hardware Description, Created by DuctSox Representative

Schedule and Logistic Impacts

Using the Installation Estimator and the newly design DuctSox system; I was able to calculate a complete installation time, Tables 5, 6 and 8. Table 5 breaks down the installation time for the SkeleCORE IHS Galvanized Cable support system. The installation time is calculated using the

Designed DuctSox System				
Hardware (HIS Galv Cable)				
Item	Length (ft)	Unit Hour	Total Hour	Adjusted
32" Dia	821	2 hours for each straight section	34.4	41.6
46" Dia	276	+ .5 hours per 25' of length	9.5	12.6
		Total Hours	**43.9**	**54.2**
		Total Days (rounded up)	**6**	**7**
*Add 10 % for 25" to 40" Dia				
*Add 20 % for 41" to 60" Dia				
*2 man crew				
*Add 10%, > 30' Ceiling Height				

Table 5 DuctSox Hardware Installation Estimate, created by Derek Stoecklein

length of the system as well as the type. I have two types (I and II) of SkeleCORE IHS supports in TA, one for the 32" Dia. and the other for the larger 46" Dia. duct. Using the recommendation in the installation manual of 2 hours per section + .5 hours per 25' length, I came to 44 hours of install time, or 6 days. These durations needed adjusted to accommodate the larger diameter duct as well as the higher ceiling height. The adjusted durations comes out to 7 day duration.

Table 6 is a detailed breakdown of the installation time for each piece of duct fabric. Each unit hour is calculated using the diameter of the duct as well as the lengths of the sections. Assuming a two man crew, and an adjusted value for the increased ceiling height and tight spaces, it takes roughly 7 days to hang the DuctSox itself.

Designed DuctSox System				
		DuctSox		
Item	Qty	Unit Hour	Total Hour	Adjusted
46" Dia x 101' L	2	3.6	7.2	7.9
32" Dia x 144' L	4	5.5	22.0	24.2
32" Dia x 118' L	2	3.58	7.2	7.9
32" Dia x 24' L	1	2.75	2.8	3.0
32" Dia x 17' L	2	4.95	9.9	10.9
		Total Hours	**49.0**	**53.9**
		Total Days (rounded up)	**7**	**7**
**2 man crew*				
**Add 10%, > 30' Ceiling Height*				

Table 6 DuctSox Installation Estimate, created by Derek Stoecklein

Comparing the DuctSox install times to that of the sheet metal, I found a large increase in productivity and weeks of schedule savings. Table 8 outlines the savings found from fabrication, installation, and painting. The standard sheet metal duct took roughly 8 weeks to fabricate and deliver each piece where the DuctSox only takes 4 weeks from approved shop drawing to on-site delivery. This provided a 4 week savings in lead time for the DuctSox.

Lead Time for Fabrication		
Standard	4 weeks	-
Expidited	3 Weeks	+ 10%
Expidited	2 weeks	+ 20%

Table 7 DuctSox Lead Times

The installation of the Sheet metal duct was very time consuming and laborious. The process includes installing all the support struts from throw the roof decking, insulating the interior of each duct section, as well as erecting each piece one by one. With the tight spaces between the trusses, this was challenging to erect the heavy sheet metal pieces from man lifts using the pulley chains and typically 2 man lifts. The Ductsox system comes complete with the SkeleCORE liner. All the installing team needs to do is hang the support hardware and cables, then connect the duct to the cable with a simple clip. The installation of the fabric duct system require a lot less labor and work in the field prior to actually erecting. The duct arrives in its own respective labeled box and is basically ready to erect from the box. As for the durations of these activities, the traditional sheet metal complete install took 70 days. The DuctSox estimated complete installation time is 14 days, a schedule savings of 56 days. That is nearly a 3 month schedule savings just on installation. Also seen in Table 8 is the duration of painting the sheet metal duct. Since the DuctSox comes prefinished in the color of your choice, there is not time needed to paint. The schedule savings for not painting the DuctSox is 30 days.

Schedule Comparision		
Standard Fabrication & Deliver		
DuctSox	4 Weeks	**Savings**
Sheet Metal Duct	8 Weeks	**4 Weeks**
Complete Ductwork Installation		
DuctSox	14 Days	**Savings**
Sheet Metal Duct	70 Days	**56 Days**
Painting		
DuctSox	0 Days	**Savings**
Sheet Metal Duct	30 Days	**30 Days**
**Sheet Metal Complete Installation includes rough-in and insulation*		
**Durations Based on PM Baseline Schedule*		

Table 8 DuctSox vs. Sheet Metal Duration Comparison, created by Derek Stoecklein

Total Time Savings		
Description		**Days**
Fabrication		20
Installation		56
Others		30
TOTAL	**Days**	**106**
	Weeks	**21.2**
	Months	**5.3**
**86 Days on-site labor*		

Table 9 DuctSox Total Schedule Savings, created by Derek Stoecklein

Comprehensive Cost Comparison

Working with a representative from Kogok, the provider/installer of the sheet metal duct at Tiger Arena, I was able to assemble an accurate cost comparison between the two systems. I broke the comparison into material cost and labor cost. When looking into the cost associated with the sheet metal duct, I had to think more global than just the duct itself. In addition to the actual fabrication and delivery of the sheet metal duct, I had looked into the insulation and the final painting of the duct. Each are component that would greatly impact my cost comparison due to that fact the fabric duct will not need either of them. For material cost, I found the sheet metal duct fab and delivery cost to be $375,000, insulation: $50,000, and paint to be $30,000. The total bill of materials is $455,000. As for the DuctSox materials, I found the newly designed system to only cost $37,310. This presents a cost savings of $417,690 just for materials; Table 11.

When looking at the labor cost of the sheet metal duct, I analyzed the same three areas; ductwork= $265,000, insulation= $50,000, and painting= $60,000. The total labor cost for the complete sheet metal duct system is $375,000. This is drastically more expensive then the estimated labor cost of the DuctSox system, at $28,568. A large contributor to these numbers is the fact it takes 86 more days to install the standard sheet metal ductwork and paint then it does hanging the DuctSox system. This savings equals $346,430, nearly 92 percent cheaper to install the DuctSox than sheet metal.

Tiger Arena Mechanical Labor Rates		
Description	**Regular Time**	**Premium Time**
Superintendent	$82.00	$115.00
Foreman	$79.00	$110.00
Sheet Metal Mechanic	$67.00	$97.00
Laborer	$35.00	$50.00

Table 10 TA Labor Rates, created by Derek Stoecklein

Price Comparision		
Material Cost		
DuctSox	$37,310.00	**Savings**
Metal Duct Total	$455,000.00	**$ 417,690.00**
Sheet Metal Duct	$375,000.00	
Sheet Metal Insulation	$50,000.00	
Paint Metal Duct	$30,000.00	
Labor Cost		
DuctSox Total	$ 28,568.00	**Savings**
Metal Duct Total	$ 375,000.00	**$ 346,432.00**
Sheet Metal Duct	$265,000.00	
Sheet Metal Insulation	$50,000.00	
Paint Metal Duct	$60,000.00	
**DuctSox Labor cost includeds (2) Sheet Metal Mechanic, (1) Superintendent, and (1) 80' Manlift w/ Jib (2,188/Week)*		
**8 Hour Work Days*		
**DuctSox price is quoted from Kogok, the same supplier for the existing sheetmetal system*		

Table 11 DuctSox vs. Sheet Metal Price Comparison, created by Derek Stoecklein

New Warranty

DuctSox products designed within their performance criteria are covered by a 1-year Design and Performance Warranty. To ensure the product performs consistently through an entire heating and cooling cycle in the first year of operation. The DuctSox Product Warranty is for replacement or repair credit based on the amount of the warranty period remaining. The warranty covers materials, fabrications, and performance of the fabric portion of the DusctSox system only. Warranty coverage begins at the time of shipment. This is important because most warranty periods begin after substantial completion of the project. Both the Design and Performance Warranty and the Product Warranty exclude damage to the fabric from improper installation, poor maintenance, abuse, abrasion, caustic chemicals, exposure to high temperatures (over 180 deg. F), fabric discoloration and shrinkage, or any unauthorized modifications to the DuctSox system. Warranty does not cover labor, equipment rental, or freight charges incurred as a result of executing the warranty. Figure X shows the Warranty Period for the TufTex, SkeleCore HIS system I used for Towson Tiger Arena.

	Warranty Period (in years)*				
	SkeleCore FTS	SkeleCore IHS	Hangers	1, 2, or 3 Row	Surface Mount
Sedona-Xm, TufTex	20 (pro-rated 11-20)	15 (pro-rated 11-15)	15 (pro-rated 11-15)	10	10

Figure 35 DuctSox Warranty Period, Ductsox.com

Conclusions and Recommendations

Not only does DuctSox have financial and schedule saving benefits, it presents many logistical benefits. The benefits include a cleaner site by eliminating the large sheet metal pieces, safer installation process, and less man power and equipment. With the over welling savings presented in the cost comparison and schedule comparison, I believe a DuctSox solution is a logical and economical choice for any owner, Saving nearly 86 days of on-site labor will generate accelerated schedules of all the surrounding trades as well as lead general conditions savings for Towson.

*"Fabric duct is **24.5%** more efficient than conventional sheet metal duct and diffuser systems" – Iowa State University Mechanical Engineering Dept., Research*

Looking at the system as a whole, we also see that the DuctSox system is more efficient and created a decrease in service load on the main rooftop AHUs. This savings could lead to life cycle savings for Towson. The options presented by the DuctSox system greatly out way those of the standard sheet metal duct and I believe the system should be explored by all owners, in all applications, to evaluate the impacts of this system for their use. DuctSox is a very versatile system and has many applications for almost all situations. The data presented in my analysis proves that the system would have been a great VE solution for Towson Tiger Arena, and should be considered more often in other applications.

Analysis 2: Designing Prefabricating Terra Cotta Wall Panels

Problem Identification

Terra Cotta is a very specialized and somewhat new building material in the United States. With this being said, many logistical problems regarding Terra Cotta have not been realized by construction managers. The largest logistical nightmare of Terra Cotta is material storage and staging. If you are working on a tight site like Gilbane was on Tiger Arena (TA), you run into the problem of where do I put it? If you were working on a job in a downtown location were material storage is not possible then this would be extremely problematic considering the shipment comes from Europe and arrives on large, un-stackable pallets. Lastly, due to the existing site conditions of TA, some safety concerns has arose during the installation of the panels in the East and West façade.

Research Objectives

A clean and safe site is a large driver for productivity on a construction project. With the above problems, I believe Value Engineering a unitized or prefabricated Terra Cotta Wall System could help alleviate many of the problems faced by Gilbane at Tiger Arena and many other contractors using this new building material. In addition, this new system will help improve the time it takes to enclose the arena for interior work to begin earlier.

After researching and designing a prefabricated Terra Cotta wall system for Tiger Arena, I believe there will be many benefits for the Trade Contractor, Gilbane, and Towson U. The installer of the system will have a much easier field install with simple connections and final detailing. Most of the contractors work will be completed in a factory with a controlled environment. Gilbane will see benefits of a decrease in installation time, safer install, less on-site labor to manage, as well as improved site logistics. Towson should expect to receive a cost savings for this new system as well as potential for increased quality of the final product. Although Towson may have to pay more money for an upgraded terra cotta tile to construct the systems, but the overall process may produce a cost savings.

Methodology

The following approach was taken to analyze the supplementation of a prefabricated wall system:

- Research Terra Cotta Rainscreen systems
- Review the current terra cotta system
- Research various prefabricated wall systems and compare the advantages and disadvantages of each type.
- Contact contractors that have used the systems to gather information.
- Design a prefabricated wall panel system for Towson Tiger Arena
- Analyze the current system to the proposed system
- Analyze the cost and schedule saving potential

Terra Cotta Rainscreen Overview

Rainscreen is an exterior make-up consisting of an outer Terra Cotta wall panel, ventilated cavity, and an inner skin. The joints of a rainscreen system are open, allowing pressure equalization in rain conditions to be instantaneous. This condition allows for the pressure inside the cavity wall to be equal to the pressure outside, thus precipitation has no inclination to be driven into cavity. The majority of the precipitation is deflected off the terra cotta face; any penetrating water is disposed of through drainage.

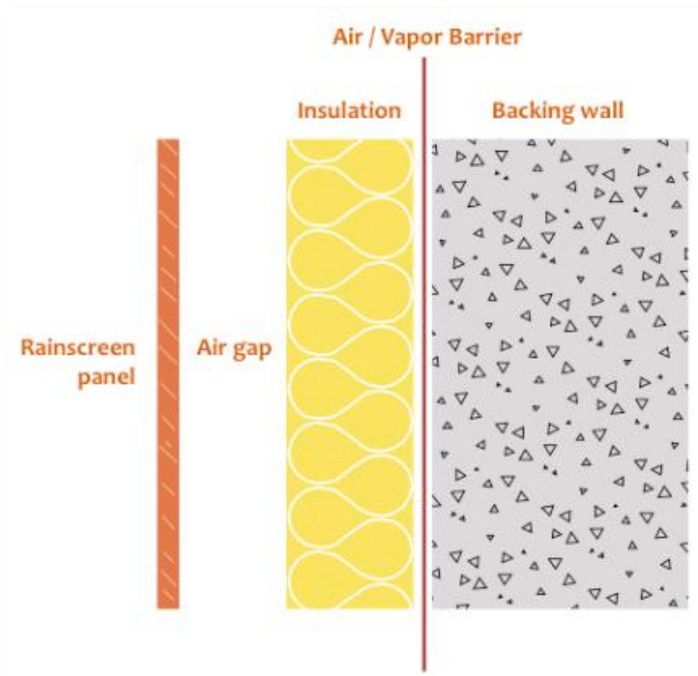


Figure 36 Typical composition of Terra Cotta Rainscreen, terreal.com

The first use of terracotta rainscreen was 20 years ago by a famous Italian Architect – Renzo Piano. Terracotta has many long term benefits

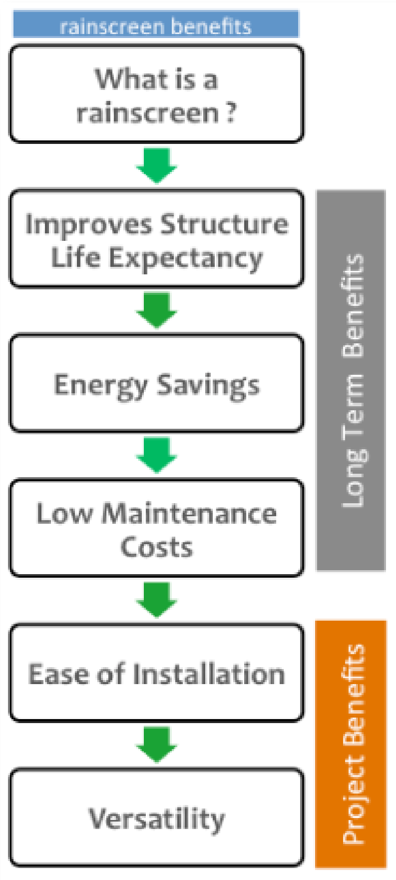


Figure 37 Rainscreen Benefits, Terreal.com

including improved structure life expectancy, energy savings, and low maintenance cost; Figure 37. Some of the ways terracotta improves wall structure life expectancy are through addressing failures in conventional sealed systems, protects the wall from direct weather conditions thank to an additional skin layer, prevents water penetrations with better ventilation, and equalized pressure leads to lower capillary/water absorption. The energy savings properties of rainscreen stems from its thermal compositions, airspace reduces heat transfer and prevents condensation, and decreases "greenhouse gas effect". Surprisingly terracotta panels are very high impact resistant and do not break easily, creating a lower maintenance product from damages. If tiles are broken they can easily be replaced without removing the entire system. Terracotta panels are also unique in the fact that they will not fade over time and no painting is required.

Some of the project benefits of a terracotta system include ease of installation and versatility. The system is very simple and can be installed by many different trades including the exterior framing or glazing trade contractor. Panels can be installed in any weather condition due to no mortar requirements. Lightweight individual panels can be installed from man-lifts preventing the need of scaffolding. Also, the lightweight panels can be installed much quicker than the traditional heavier systems such as brick, stone, granite, and marble.

Terra Cotta panels are made by shaping and firing clay- dirt. The clay consists of water, silica, aluminum, magnesium and other natural elements. The clay is harvested and brought to the plant were it is blended, ground, and screened for impurities. The moisture is removed in dryers, panels are then extruded under pressure, color or surface treatments added, and finally fired at very high temperatures to complete the panel.

Towson Arena Terra Cotta Analysis

Towson Arena was designed with multiple façade materials, ranging from curtain wall, metal panels, c-channel, split-face CMU's, and terra cotta. The majority of the Terra Cotta exists on the East and West elevations, with a small area on the North. The terra cotta located on the east and west is located between each glazing unit and is a typical dimension of 5' L x 1' H. The existing terra cotta panels are by Avenere Cladding, LLC; NeaCera Terra Cotta Rainscreen, Figure 38. This panel is a tongue and grove system that is supported by a vertical support system attached to the exterior sheathing; reference cut sheet in APPENDIX D. The make-up of the existing terra cotta wall system includes 16 Ga. metal framing, glass rock sheathing, z-bar girts, 2' ridged insulation, vertical support rails, air space, and the NeaCera Panel. The system extends 6 ½" from the glass rock surface.

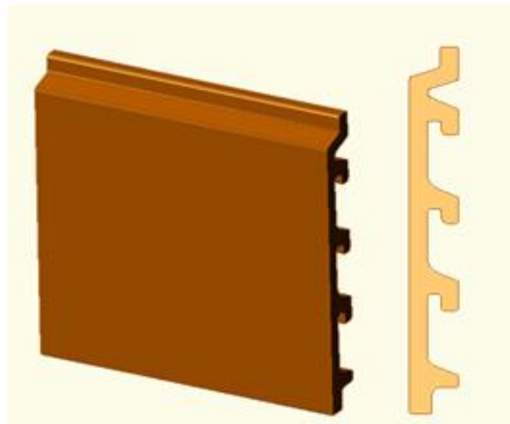


Figure 38 NeaCera Terra Cotta, avenerecladding.com

When examining the terra cotta installation process and the existing site conditions I found several complications. The first and most important is the demand for onsite storage of the terra cotta panels, rails, and insulation. Next is the restrictions of the site on the west and east elevations. The west elevation is adjacent to the only road on and off site; this means there cannot be any blockages of this road at any time. In addition to the road usage issue, this road is steeply sloped and causes issues with man lifts when trying to extend out over the road. The lifts require level ground to extend past defined points, and the road has restricted the lifts from extending to full boom. In order to meet these demands, the trade contractor needed to order ultra-boom lifts for the installation of the west terra cotta. The same issue is realized on the East elevation with traffic congestion and unstable ground for the lifts. The poor weather and muddy conditions along the east elevation caused many issues with lifts becoming immobilized. In addition, the mortar mixing station for the mason is located near the east elevation of TA and this conflict caused issues with congestion and material movement.

Lastly, the issue of safety is compromised through this method of installation. As seen in Figure 39, on the west façade all the lifts had to boom out over the load. This causes an issue with larger vehicles coming onto sight; caution tape had to be hung from the lifts to alert incoming traffic of the overhead obstacle. The congestion cased on the east during this phase of construction was greatly impacted by the amount of labor in one area at one time. The terra cotta was installed while the zinc panels were being installed and the mason was making mortar runs all day long. If a prefabricated system was implemented at these locations, a large risk could be eliminated as well as clearing up the site logistics.

Figure 39 West Elevation, taken by Derek Stoecklein

Prefabricated Terra Cotta Rainscreen Systems

In order to prefabricate panels for Towson Tiger Arena, new panels needed to be selected. The existing panels were not rated for prefabrication do to the support system used. A Piterak XS 18 Rainscreen by Terreal North America, LLC has been selected as the new terra cotta panel. I chose this panel due to its clip support system and its use on other prefabricated terra cotta wall panels.

Figure 40 Piterak XS 18, terreal.com

The new panels will have a similar make-up with the same overall thick of 6 ½" to maintain the same architechtural look. Each panel will be shop finished and contain the metal studs, king span insulation panel system, vertical support system, clips, and the terra cotta panels. The original terra cotta panels were supported by a tongue and grove support rail. With this support system, the weight of the top panel was the only thing holding the panel from moving upwords. This is the reason why the original panel would not work for prefabrication, due to transportation requirments. The new Piterak system is supported by a clip attached to a vertical support rail, Figure 41. The clip will help support the terra cotta panels from moving around more than the tongue and groove support.

Figure 41 Support System for terra cotta panels,Terreal.com

The use of a Kingspan Optimo Smooth insulated metal panel system will allow for a simple backup construction of the prefabricated panels. This system provides high R-value and minimizes the amount of materials needed. . Removing the layer of Glassroc and air vapor barrier typically used will save in fabrication time. The Optimo Smooth panel uses a tongue and groove joint, creating an air tight thermal layer. The panels come in lengths from 6' to 20', widths from 2' to 3 ½' and thicknesses from 2" to 4". The panels are constructed with a foam rigid insulation core and wrapped with galvanized steel. They will be attached to the metal stub framing and have the support profile rails attached to the front face.

Figure 42 Optimo Smooth Insulated Metal Panel joint, kinspanpanels.us

R-Value Comparison ft²·°F·h/Btu			
Description	R-Value	Thickness	Subtotals
Existing System			
FOAMULAR 250 Rigid Foam Insulation	5 per inch	3"	15
GlassRoc Exterior Sheating	.51 per SF	5/8"	0.51
		Total	15.51
Prefabricated System			
Optimo Smooth Insulated Metal Panel	7.5 per inch	3 5/8"	27.19
		Total	27.19

The prefabricated panels will be attached to the structure using a 4" x 10" bent plate, bolted to the top of the slab or a clip and angle supported under the steel beams. The connection will depend on the location. For the West elevation there will be a clip and angle connection at level one and three, as well as a bolted bent plate at the second level. A typical slab connection detail can be seen in Figure 43.

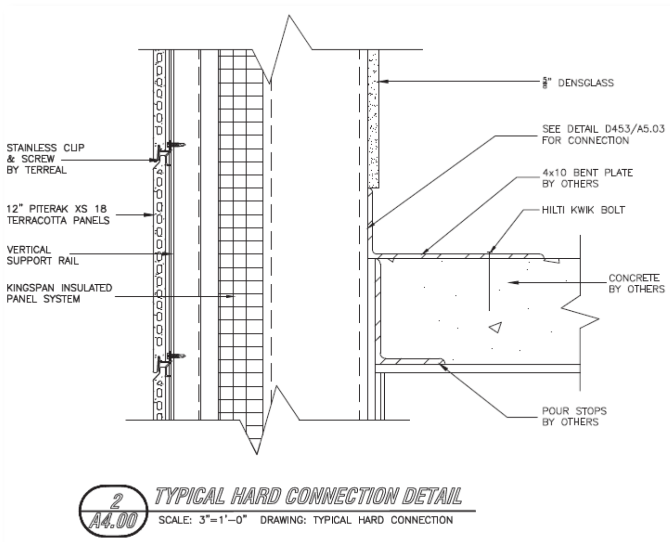


Figure 43 Typical Connection for Prefabricated Terra Cotta Wall Panels, provided by Wyatt Inc.

**Detail provided by Wyatt Inc.*

Lastly, when I examined the existing terra cotta, I identified the sections that could be prefabricated and the ones that would not benefit from prefabrication. I found two wall sections that a prefabricated panel would not be feasible due to the canopy roof. These sections are located along the promenade walk way, at the main entrance, and near the east entry way. Of the roughly 6,000 SF of terra cotta, these two areas only take 720 SF. These sections will have to be field installed as the traditional system is installed.

Design of Panels

** Panel locations and details can be seen in APPENDIX D*

Panal	Width	Height	SF	# of TC Panels
1	11'-0"	37'	413	74
2	5'-8"	37'	210	37
3	5'-8"	37'	210	37
4	5'-8"	37'	210	37
5	5'-8"	37'	210	37
6	5'-8"	37'	210	37
7	5'-8"	37'	210	37
8	5'-8"	37'	210	37
9	5'-8"	37'	210	37
10	5'-8"	37'	210	37
11	11'-0"	37'	413	74
12	11'-0"	37'	413	74
13	5-8"	20'	113	20
14	5-8"	20'	113	20
15	5-8"	20'	113	20
16	5-8"	20'	113	20
17	5-8"	20'	113	20
18	11'	20'	220	40
19	11'	20'	220	40
20	11'	20'	220	40
21	-	-	193	40
22	11'	8'	88	16
23	11'	30'	333	60
24	11'	30'	333	60
		Total	5301	951
** Terra Cotta Dimensions: 5' W x 1' H*				

Table 12 Designed Panel Sizes, created by Derek Stoecklein

Delivery of Panels

The delivery and installation process for the panels will be based on the numbered table above. Starting with panel 1 and finishing with panel 24, all panels will be erected with the on-site crane. These picks will be coordinated with Gilbane and the crane operator to insure availability when the panels arrive on-site. The crane used for Towson Tiger Arena is a Manitowoc 999, rated at 200 TON. The extra-long boom and jib attachment will allow for easy panel erection around each side of the building without moving the crane.

Just in time delivery will be utilized to eliminate extra panels and backed up truckloads. The panels will come complete from the factory with support angles and clips at the pre-determined locations. Once on-site, the crane will pick the panels from the truck to final location on the building. Prior to the detaching the crane, the panel must be supported at the top and bottom location and verified for alignment and placement. Complete installation of a panel is assumed to take one day. Complete installation includes picking, counter clashing top and bottom, verifying install location and levelness, and all support connections.

Schedule and Cost Comparison

Comparing the schedule & cost of the existing system with the prefabricated system was challenging due to the amount of work and different trades required for the standard stick built system. The areas analyzed in the standard system are layout, framing, sheathing, air barrier, and terra cotta. That equates to three different trades all involved in the installation of the complete terra cotta system. After completing a take-off of the given tasks on the 6015 SF of existing terra cotta, I found the cost to be $628,397 with duration from layout to completing the terra cotta of 211 days. That's 10.5 months and roughly $65.60 SF for material and labor.

To compare these numbers to a prefabricated system, I was able to research two case study applications of prefabricated terra cotta. I was able to receive cost data of $65SF to $90SF for material and labor. These numbers are largely different due to the applications of each and the level of difficulty. Since the panels I design for TA are relatively uniform and rectangular shapes, I assumed an average price of 70$ a SF for material and labor. As stated before, there are two sections of the building that will not benefit from the prefabrication process due to the conflicting canopy roof. Considering this, I needed to add a line item in my prefabricated price and schedule for the stick built sections. The estimated cost of a prefabricated terra cotta system for TA is $674,510, with an overall duration of 119 days.

Tiger Arena Terra Cotta Cost		
Task	Duration	Cost
WEST		
Layout	6	$7,500
Framing	20	$45,075
Sheathing	10	$21,200
Air Barrier	16	$59,756
Terra Cotta	20	$33,750
Sub Total	**72**	**$167,281**
EAST		
Layout	6	$7,200
Framing	20	$34,800
Sheathing	7	$20,300
Air Barrier	16	$33,344
Terra Cotta	15	$22,500
Sub Total	**64**	**$118,144**
NORTH		
Layout	5	$8,300
Framing	7	$26,150
Sheathing	7	$11,300
Air Barrier	6	$21,771
Terra Cotta	10	$18,750
Sub Total	**35**	**$86,271**
Misc Cost		
Terra Cotta Fab and Del	40	$250,000
Punchlist / Closeout	-	$6,700.00
Sub Total	**40**	**$256,700**
Complete		
Total	**211**	**$628,397**

Table 13 Tiger Arena Terra Cotta Estimate, created by Derek Stoecklein

Prefabricated Panels		
Task	**Duration**	**Cost**
Terra Cotta Fab and Del	40	$250,000
Prefab and Del Panels	35	$211,800
Installation of Panels	24	$158,850
Punchlist / Closeout	-	$6,700
Stick Built Sections	20	$47,160
Total	**119**	**$674,510**
**Prefab and Del Panels & Installation = 70$ SF, assumed 40$ for material and 30$ for labor*		

Table 14Prefabricated Panel Estimate, created by Derek Stoecklein

The cost of the two systems does not vary drastically. I believe this is due to the cost of delivering the panels to the site, as well as the cost of the upgraded terra cotta panels. I do not find this surprising, considering I never expected a cost savings. When I began my analysis of this system, I was expecting to see the largest savings in on-site construction, as well as increased safety and quality. The schedule comparison in Table 14 displays the on-site construction savings of 92 days. With this schedule savings, Gilbane can concentrate their efforts of completing the remaining façade constructions on the North and South to provide a closed in building earlier.

Schedule Comperision		
Existing System	**211**	**Installation Savings of 92 Days**
Fab and Del Terra Cotta	40 Days	
Complete Installation	171 Days	
Prefabricated System	**119**	
Fab and Del Terra Cotta	40 Days	
Shop Fabrication	35 Days	
Installation	24 Days	
Stick Built Section	20 Days	

Table 15 Schedule Comparison, created by Derek Stoecklein

Conclusions and Recommendations

In Italy, terra cotta means "Baked Earth". Terra Cotta is made the same as brick and clay roof tiles that have performed excellent and lasted 100's of years. Designed with a new modern look but the same "peace of mind" of centuries of successful performance from the most natural building products. Rainscreen systems allow for an equalized pressure, giving any precipitation inclination to drive into the cavity. Terra Cotta is a 100 percent natural and recyclable, giving it valuable points with a LEAN and Green owner. Terra Cotta seems to be becoming a very popular building material, rightly so with the advantages covered in this report. Although Terra Cotta maybe initially more expensive than other materials, it will save the owner through its long life cycle.

"A wall panel made of dirt that will remain color permanent, fully functional, and beautiful for more than 100 years." – Terreal North America, LLC

Through my analysis of supplementing a prefabricated terra cotta panel system on Towson Tiger Arena, I have found several advantages as well as disadvantages. The main advantages of the system are schedule, safety, quality, and logistics. Using a prefabricated system will increase the safety on-site in two major ways; less labor and material on-site at a given time and no longer will the West façade need to be built with Ultra Boom lifts over the main site access road. These items will also improve the logistics of the site. Removing additional labor and the staging required for all the terra cotta panels will eliminate site congestion and confusion. Quality should also see a significant increase. When constructing any façade in the field you always face the elements. These elements will almost always impact the finish quality of the final product. Another quality issue faced is the access to work and materials which was very poor on TA due to current site constrains and conditions. Prefabricating these panels in a controlled factory condition will help eliminate these safety, quality and logistic issues. The major disadvantage I found with this system is the access to some of the façade locations, limiting any logical prefabrication at those locations. Another disadvantage I found for the implementation of a prefabbed system at TA was the panels needed to be upgraded to a more expensive terracotta, leading to in overall increase in the cost of the system..

My recommendations for implementing prefabricated wall panels at Towson Tiger Arena would be to identify a prefabricated system as desirable or logical early in and introduce a design assist approach for the major bid packages. This design assist approach would help provide constructability and design recommendations to the design team. If the system was more standard in dimensions across all the building materials, the entire façade of Towson Tiger Arena could have benefited from prefabrication. The prefabricated system designed in this analysis is feasible and constructible but the global impacts to a stick-built facade around it may over way the advantages listed. In conclusion, I believe the entire façade would need to be prefabricated to see the benefits of all the responsible parties. The terra cotta seemed the most logical to try and prefab due to its simplistic design and configurations. In the end, I think I would need to be a complete prefabbed faced for the real advantages of prefabrication to be realized by the team.

Analysis 3: Production Planning of the Truss MEPF

Problem Identification

The MEPF work within the trusses of Tiger Arena is very intense and involves a large amount of coordination between all the responsible parties. Issues began when the electrician, plumber, and sheet metal crews and the sprinkler contractor were all fighting for space that wasn't there. Tiger Arena is an open concourse arena with very little useable area to access the truss work other than from the bowl floor. With less than 10,000 SF of usable space for staging, hoisting, and equipment, there isn't much room for work to flow. Essentially the contractors were scheduled to complete all their work within the scoped time and no further guidance for sequencing or coordination of space.

Collaborative work planning is a term to describe the process used to improve work flow within a given space or project through advanced planning and problem identification early on. Collaborative work planning uses several tools to identify parameters and propose solutions such as last planner, quality circles, house of quality, space planning, design structure matrix, SIPS, production sequence planning, labor tracking, and a long list of others. For Tiger Arena, a more detailed approach to collaborative work planning would help greatly in improving the work flow and production of all the trade contractors within the trusses.

Methodology

The following approach was taken to analyze collaborative work planning of the truss MEPF:

- Evaluate the baseline schedule and the actual schedule.
- Research collaborative planning tools and how they will improve the production during this phase of construction.
- Implement and analyze the collaborative planning method selected.
- Compare the new sequencing and planning methods to the actual.

Research Objectives

Through the implementation of production planning, the productivity of the MEPF systems will be improved and decrease the congestion of the bowl floor. The work will be re-sequenced into an organized and manageable process that best fits all the needs of the contractors. Increased planning will eliminate the contractors from working over top of each other in the same spaces to try and install there system according to the baseline schedule. Additionally, the coordination between each foreman and weekly look a heads to identify what each trade will be doing will help eliminate safety hazards and confusion between what the contractor is responsible for at a given time. In conclusion, collaborative work planning should help improve the schedule, site congestion, cost savings to Towson, and overall value added by identify and meeting the owners wants.

Towson Arena Schedule Examination

The MEPF phase of Towson Tiger Arena includes the following activities:

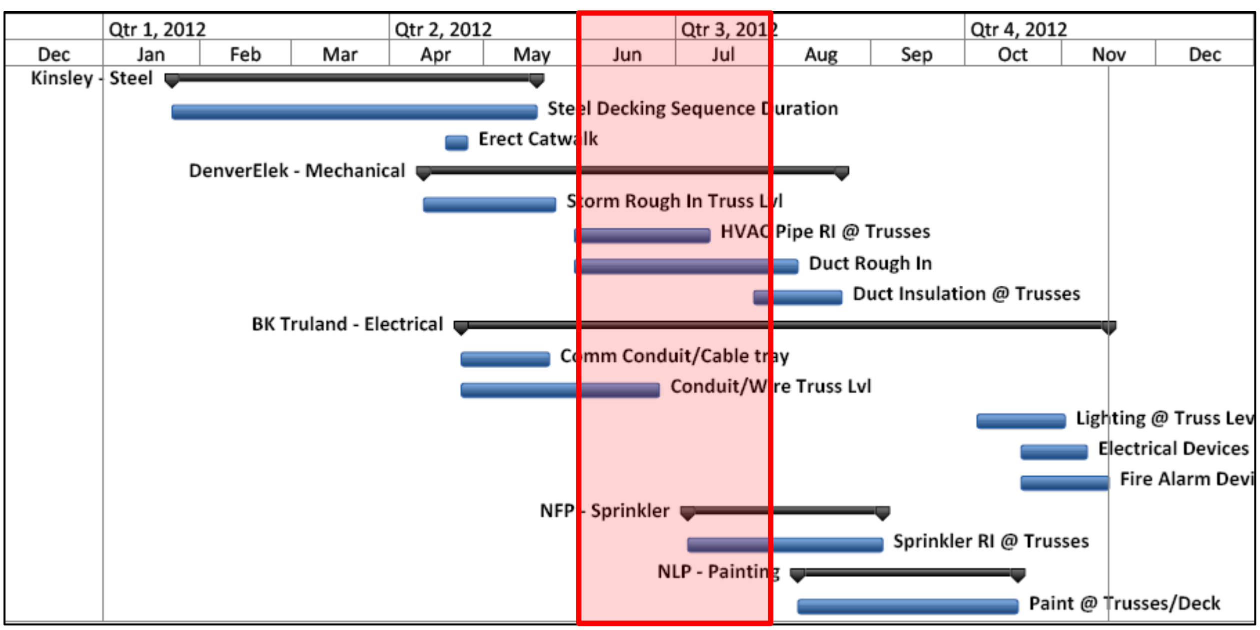
- Sprinkler
- Strom
- Communication Conduit
- HVAC Pipe
- Duct work
- Lighting
- Electrical Conduit
- Painting
- Fire Alarm
- Electrical Devices

Baseline Schedule

This is a large amount of work that needs to be coordinated and scheduled to allow for the work to flow without delays and increased cost. As seen in Table 16, the baseline schedule, this phase is scheduled to begin on April 12, 2012 with storm water rough in (RI). This makes the most since due to the concerns of slope requirements of this system. In order for this phase to begin, the rough decking must be installed for support of the MEPF systems. The steel decking is erected from the NE corner of TA towards the SW corner, following the steel truss erection. Following the storm RI is the comm conduit and elect conduit, duct RI, sprinkler RI, duct insulation, painting, and finish work. According to the baseline schedule, all this work will be completed by November 15, 2012.

Baseline Schedule			
Task	Duration	Baseline Start	Baseline Finish
Sprinkler RI @ Trusses	44	7/5/2012	9/4/2012
Storm Rough In Truss Lvl	30	4/12/2012	5/23/2012
Comm Conduit/Cable tray	20	4/24/2012	5/21/2012
HVAC Pipe RI @ Trusses	30	5/30/2012	7/11/2012
Conduit/wire Truss Lvl	45	4/24/2012	6/25/2012
Duct Rough In	50	5/30/2012	8/8/2012
Duct Insulation @ Trusses	20	7/26/2012	8/22/2012
Paint @ Trusses/Deck	50	8/9/2012	10/17/2012
Lighting @ Truss Level	20	10/5/2012	11/1/2012
Fire Alarm Devices and Test Truss Level	20	10/19/2012	11/15/2012
Electrical Devices @ Truss Level	15	10/19/2012	11/8/2012

Table 16 Baseline Schedule, created by Derek Stoecklein



Schedule 1 Baseline, created by Derek Stoecklein (Seen if full in APPENDIX F)

When looking at this sequence choosing, we most also consider the erection of catwalk. This is important because for the Comm. conduit, electrical conduit and sprinkler system are all supported by the catwalk in designed locations. This erection is schedule for April 25 thru May 23, 2012. As you can see in the attached baseline schedule, Schedule 1, during June and into July four different contracts are fighting to complete work in the same space. With the confined space requirements listed before this will become a problem.

Actual Schedule

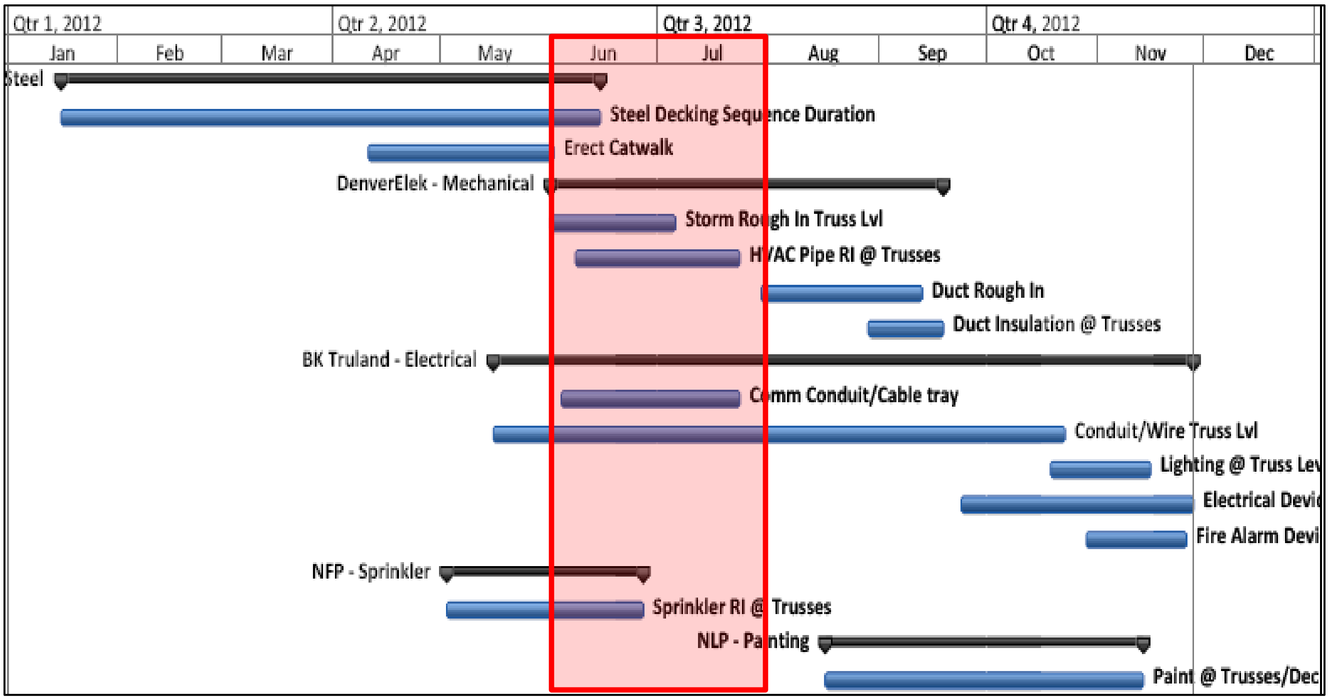
Knowing how the project was scheduled from the beginning I was anxious to compare this to the actual construction duration. Table 17, 18 and 19 help to illustrate the difference between the baseline and actual construction schedules. In Table 17, the red dates identify the activities that are "Late Starts" and the blue dates identify "Actual Starts". As you can see in the Delta column, the majority of the activities did not start on-time. Table 18 shows this comparison with the start and finish dates of the truss MEPF.

	Actual Start Dates				
	Task	Actual Duration	Baseline Start	Actual Start	Delta
Actual Starts vs. Baseline Analysis	Sprinkler RI @ Trusses	39	7/5/2012	5/3/2012	45
	Storm Rough In Truss Lvl	25	4/12/2012	6/1/2012	36
	HVAC Pipe RI @ Trusses	32	5/30/2012	6/8/2012	7
	Comm Conduit/Cable tray	36	4/24/2012	6/4/2012	29
	Conduit/Wire Truss Lvl	114	4/24/2012	5/16/2012	16
	Duct Rough In	33	5/30/2012	7/30/2012	43
	Duct Insulation @ Trusses	15	7/26/2012	8/29/2012	35
	Paint @ Trusses/Deck	63	8/9/2012	8/17/2012	6
	Lighting @ Truss Level	20	10/5/2012	10/19/2012	10
	Fire Alarm Devices and Test Truss Level	21	10/19/2012	10/29/2012	6
	Electrical Devices @ Truss Level	47	10/19/2012	9/24/2012	19

	Actual Finish Dates				
	Task	Actual Duration	Baseline Finish	Early Finish July	Delta
Actual Starts vs. Baseline Analysis	Sprinkler RI @ Trusses	39	9/4/2012	6/26/2012	50
	Storm Rough In Truss Lvl	25	5/23/2012	7/5/2012	31
	HVAC Pipe RI @ Trusses	32	7/11/2012	7/23/2012	8
	Comm Conduit/Cable tray	36	5/21/2012	7/23/2012	45
	Conduit/Wire Truss Lvl	114	6/25/2012	10/22/2012	85
	Duct Rough In	33	8/8/2012	9/12/2012	25
	Duct Insulation @ Trusses	15	8/22/2012	9/18/2012	19
	Paint @ Trusses/Deck	63	10/17/2012	11/13/2012	19
	Lighting @ Truss Level	20	11/1/2012	11/15/2012	10
	Fire Alarm Devices and Test Truss Level	21	11/15/2012	11/25/2012	6
	Electrical Devices @ Truss Level	47	11/8/2012	11/27/2012	13

Table 17 Actual vs. Baseline Comparison

Some of the important activates to note in these tables are Electrical conduit, Comm conduit and Sprinkler RI. As noted before, all of these activates need the catwalk to be erected in order to complete them. The catwalk took 38 days to erect, that's a difference of 33 extra work days.



Schedule 2 Actual Durations, created by Derek Stoecklein

The large reason for this decrease in productivity was the lack of material ordering for the catwalk steel. This had a large impact in the entire productivity of the truss MEPF because is caused the work to be pushed closer together and created more congestion within the small space.

Another thing to note from Schedule 2 is the increase in some of the durations that is directly related to poor production, site congestion and access to material. The Comm conduit saw in increase in duration of 16 days and the electrical conduit increased 69 days. Lastly, I noticed a large move in the start date of the sprinkler system of almost two months. In the comparison schedule that I have attached, you can see the baseline schedule and the actual schedule superimposed over each other to help illustrate the increase indurations and the changes that had to be made.

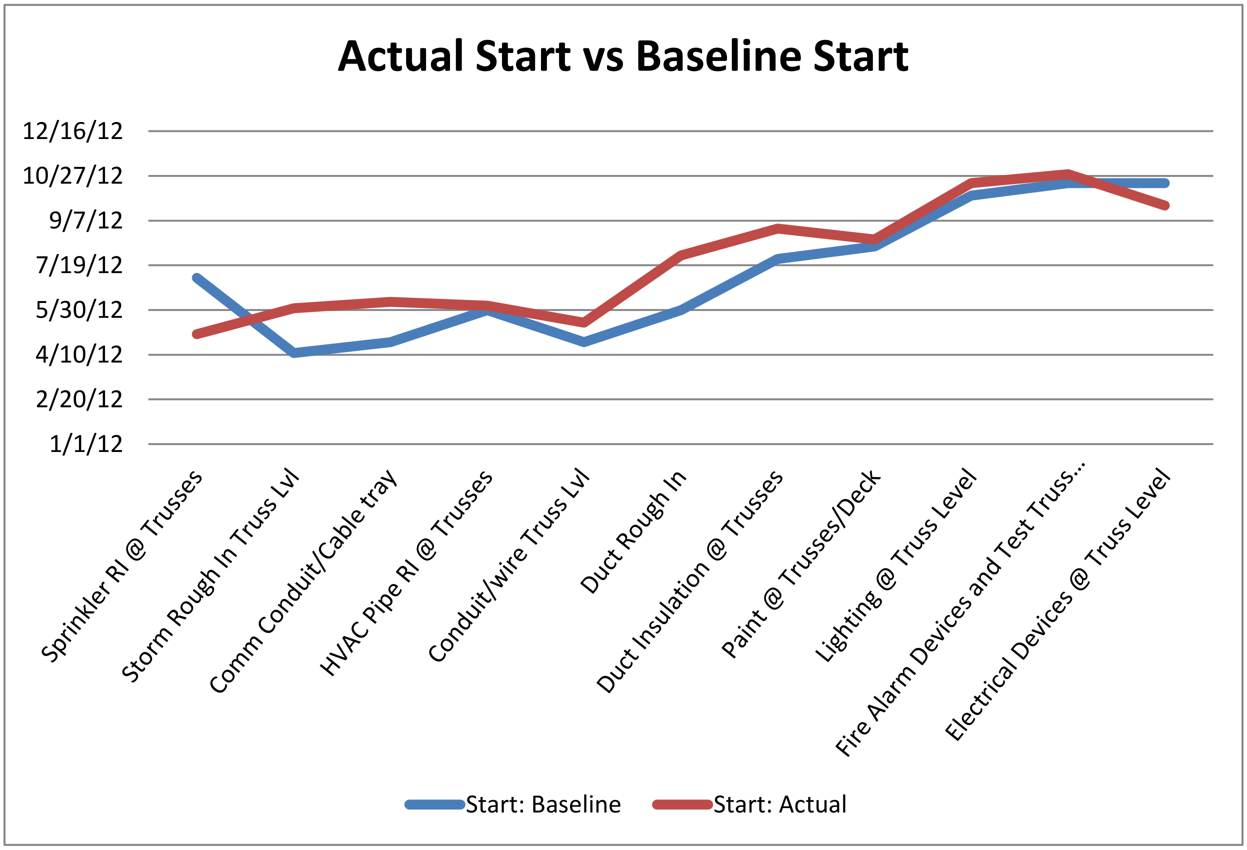


Table 19 Actual vs. Baseline Start Plot, created by Derek Stoecklein

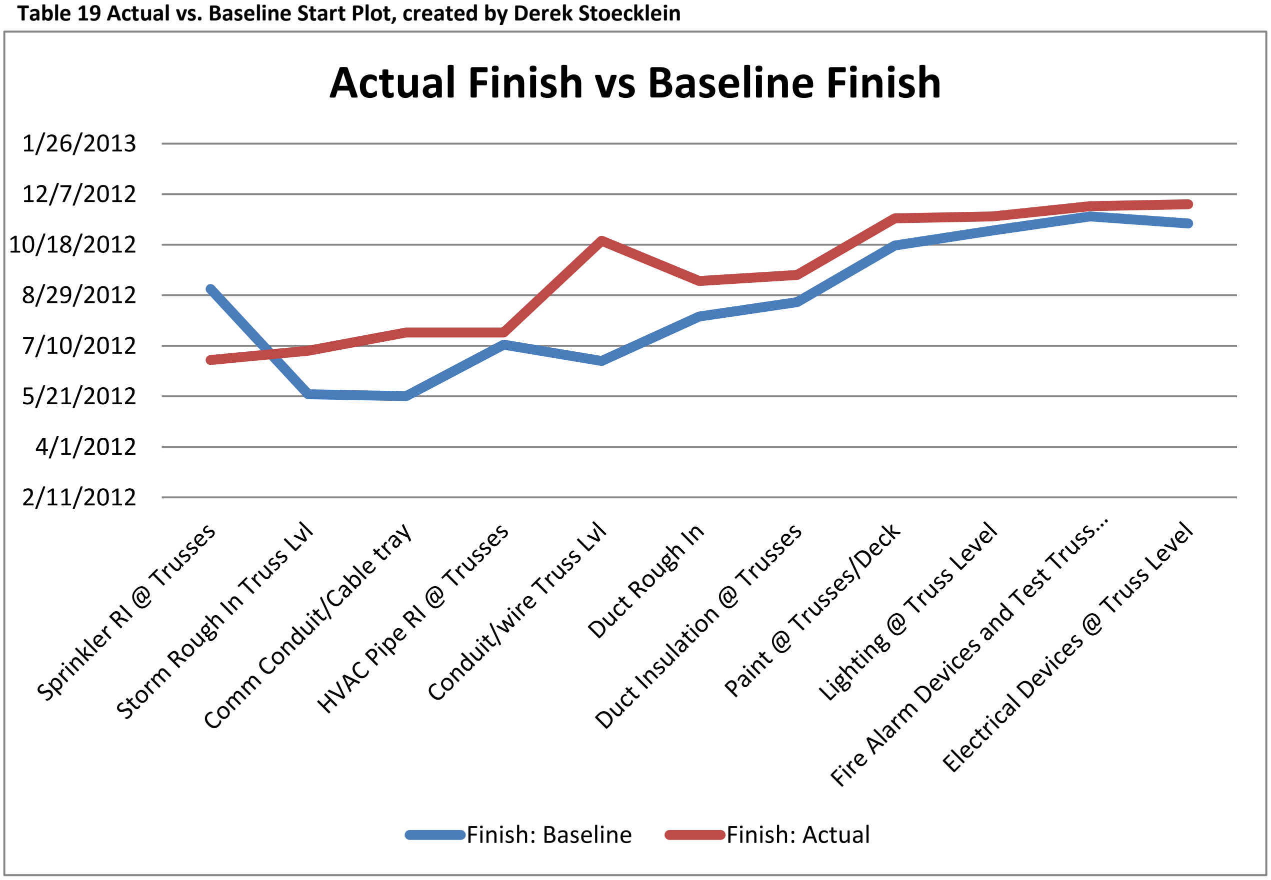
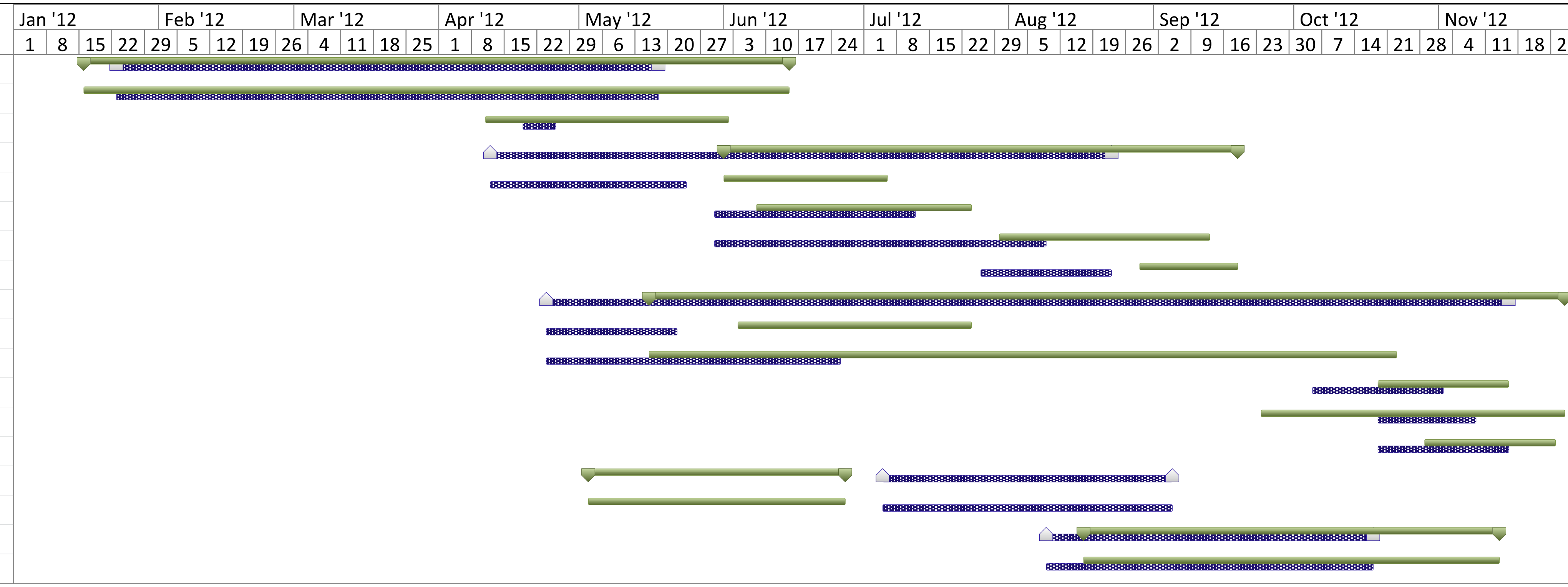


Table 18 Actual vs. Baseline Finish Plot, created by Derek Stoecklein

	Name	Duration: Current	Duration: Previous	Duration: Diff
1	**Kinsley - Steel**	**109 days**	**84 days**	**25d**
2	Steel Decking Sequence Duration	109 days	84 days	25d
3	Erect Catwalk	38 days	5 days	33d
4	**DenverElek - Mechanical**	**78 days**	**95 days**	**-17d**
5	Storm Rough In Truss Lvl	25 days	30 days	-5d
6	HVAC Pipe RI @ Trusses	32 days	31 days	1d
7	Duct Rough In	33 days	51 days	-18d
8	Duct Insulation @ Trusses	15 days	20 days	-5d
9	**BK Truland - Electrical**	**140 days**	**148 days**	**-8d**
10	Comm Conduit/Cable tray	36 days	20 days	16d
11	Conduit/Wire Truss Lvl	114 days	45 days	69d
12	Lighting @ Truss Level	20 days	20 days	0d
13	Electrical Devices @ Truss Level	47 days	15 days	32d
14	Fire Alarm Devices and Test Truss Level	21 days	20 days	1d
15	**NFP - Sprinkler**	**39 days**	**44 days**	**-5d**
16	Sprinkler RI @ Trusses	39 days	44 days	-5d
17	**NLP - Painting**	**63 days**	**50 days**	**13d**
18	Paint @ Trusses/Deck	63 days	50 days	13d



Project: Towson Tiger Arena MEP
Date: Thu 3/21/13

Task: Baseline
Task: Actual
Milestone: Previous
Milestone: Current
Summary: Baseline
Summary: Actual
Placeholder Duration: Previous
Placeholder Duration: Current
Placeholder Start: Previous
Placeholder Start: Current
Placeholder Finish: Previous
Placeholder Finish: Current
Inactive Task: Previous
Inactive Task: Current
Inactive Milestone: Previous
Inactive Milestone: Current
Inactive Summary: Previous
Inactive Summary: Current

Construction Productivity

Time and cost overruns in large scale construction projects are very common. Studies show that between 70 percent and 90 percent of projects exceed the original planned cost and that the overrun commonly varies between 50 percent and 100 percent of budget. The causes of construction overruns have been investigated and the most common causes are listed below:

- Poor or incomplete design and documentation
- Client scope change during construction
- Mistakes during construction
- Delays in decision making or instructions
- Poor communication and information dissemination
- Poor planning and scheduling
- Weather
- Labor skills, availability or disputes
- Incorrect material types or quantity

Introduction of Last Planner

Large scale construction projects suffer from cost and time overruns that are typically a symptom of productivity problems and directly affect overall industry profitability. As a result, methodologies have been developed to reduce the risk of overruns and improve project outcomes. A number of these methods are based upon Lean production principles that focus on identifying value, eliminating waste and creating a smooth flow of materials, information and work. The application of Lean to construction is based upon treating the construction site as a temporary production line and is referred to as Lean Construction.

The Last Planner System (also known as Collaborative Planning, Lean Planning, Pull Planning, and Short-term planning) is a method of controlling and providing certainty around materials, resources and dependencies at the work face by using a collaborative approach for *pull* scheduling.

The key practices of the Last Planner System (LPS) include:

- Minimizing work variability between tasks as a way of improving the labor utilization.
- Creating *look-ahead* plans that are based upon work tasks that can be completed without interruption, rework, or remobilization.
- Planning work on weekly basis through coordination meetings involving planners and supervisors.
- Measuring progress by monitoring the actual completion of work and using weekly learning to improve work practices.

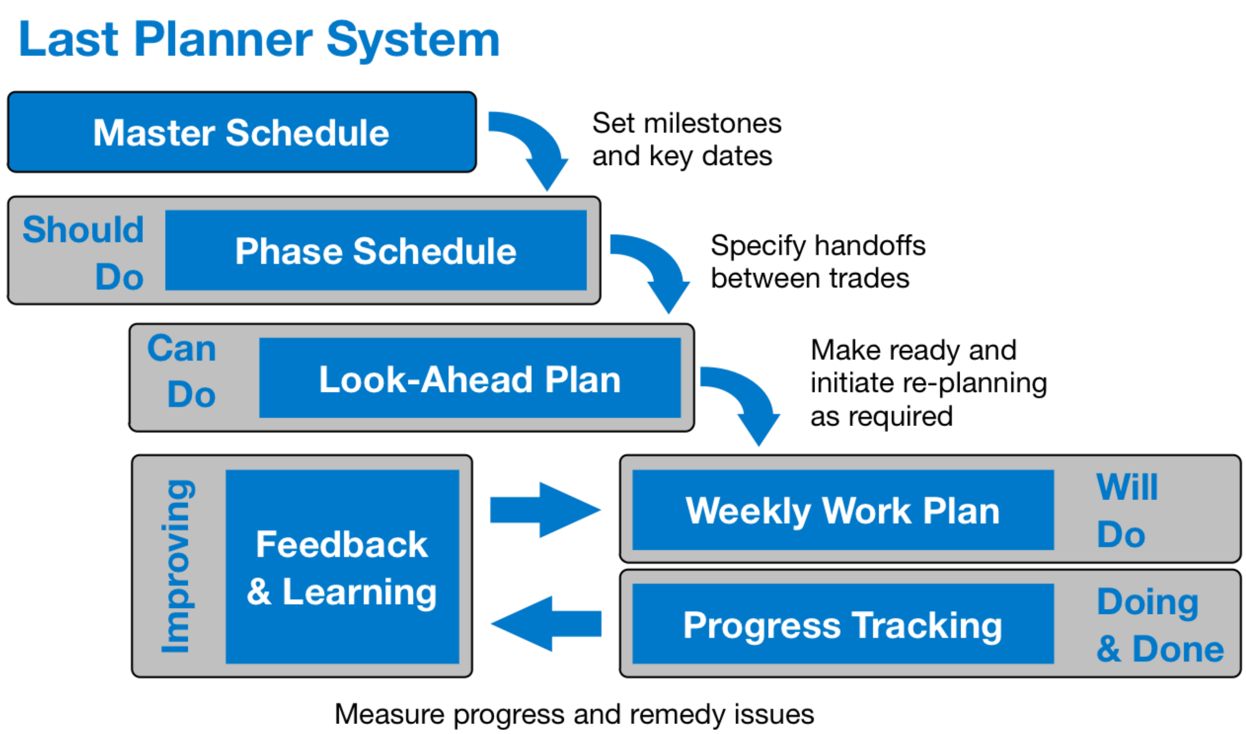


Figure 44 Last Planner Process Map, Agile and Lean Applied to Construction

The Last Planner

The LPS has four levels of planning. The degree of detail in plans is refined and uncertainty is reduced through each level by careful consideration of what SHOULD and CAN be done, Figure 44. Planning this way keeps objectives firmly in front of the project team and helps identify and remove obstacles to their achievement. The resulting predictable flow of work from one crew to the next reduces waste, simplifies further planning and finally is the key to delivering value to the clients.

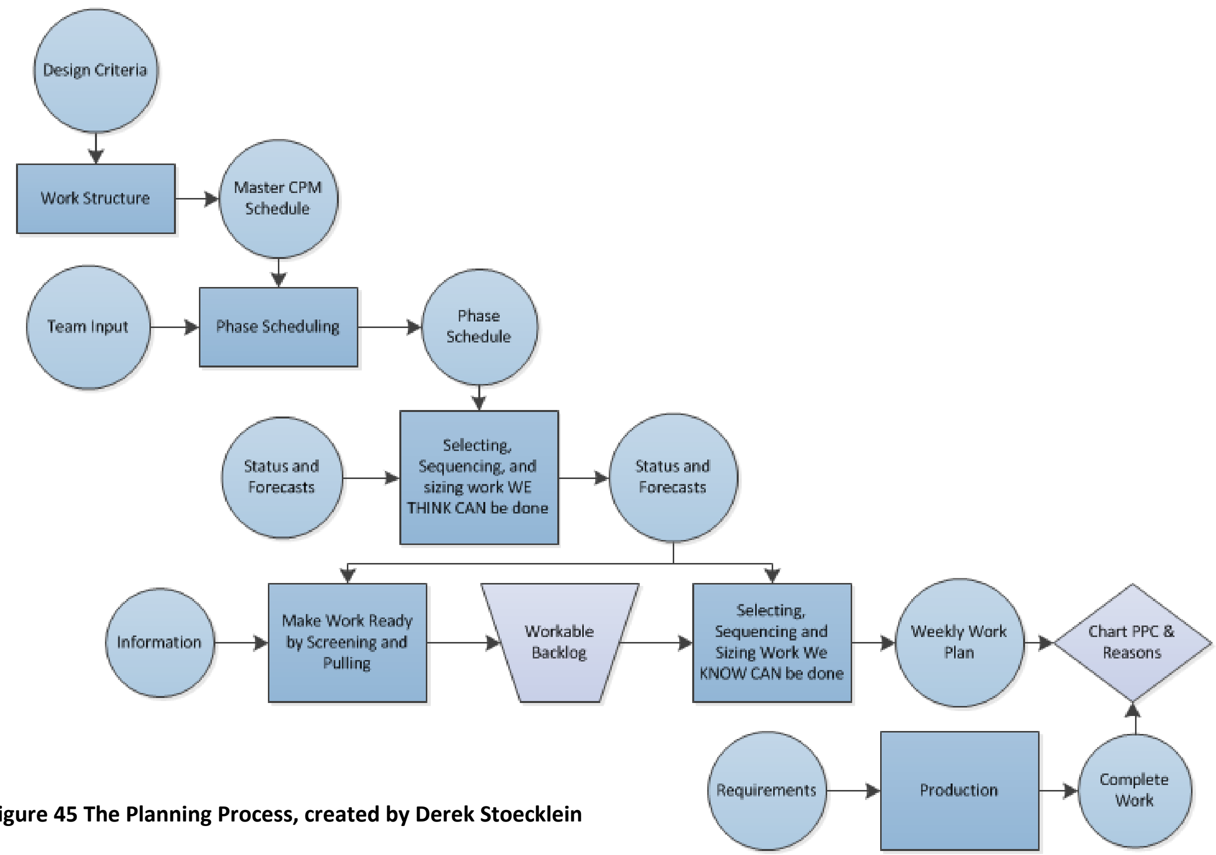
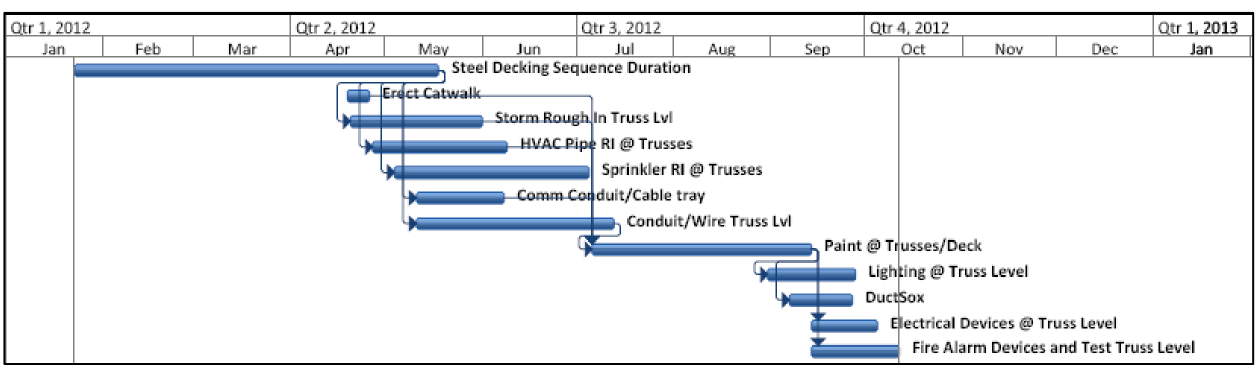


Figure 45 The Planning Process, created by Derek Stoecklein

The planning system in Figure 45 illustrates the process taken for Last Planner on a more detailed level than Figure 44. A master CPM schedule is created to demonstrated the feasibility of completing the work in the available time, develop and display execution strategies, determine when long lead items are needed, and identify milestones important to the client. At the next level, a more detailed phase schedule will be created to support the completion of the master schedule milestones.

Phase schedules developed to achieve the milestones should be prepared closer to action but early enough to make work ready and assure coordination. Phase schedules should be prepared at least six weeks prior to the start of their first activity or even sooner if longer lead times have been identified. The best practice is to gather the work management team, review the master schedule and appropriate milestones and then working back from that milestone to identify the work needed to complete the phase. In the case of TA, this phase is the MEPF in the trusses and will involve the mechanical, electrical, plumbing, sprinkler, steel, and painting contractor. This back-to-front process identifies the conditions required for work to be released from one activity to the next and the coordination necessary to allow multiple activities to proceed concurrently. In conclusion, master schedule activities are magnified in phase scheduling. Each phase includes activates that in turn must be further magnified and screened in the lookahead plan that typically includes work for the next six weeks.

In schedule X, you can see the re-sequencing of the MEPF truss work that I choose based of the parameters of the last planner system. With this collaborative work planning system in place, it allows the work to be sequenced concurrently with small five day lags between start dates. This phase schedule would need to be completed in conjunction with the responsible parties by the middle of March to insure all the materials are available and work is properly coordinated.



Schedule 3 Re-Sequenced Schedule, created by Derek Stoecklein

The next step in the process is lookahead planning. The process is straightforward; activities fall into the lookahead schedule, typically six weeks before the work is supposed to start. As time passes, the level of detail is magnified as specific tasks within the larger activity are identified. Each task is screened to assure requirements are identified and pulled into readiness to maintain a backlog of work available to the last planner.

This lookahead period is used to:

- Shape workflow sequence rate.
- Match workflow to the amount of labor and equipment available.
- Prepare and maintain a backlog of ready work to assure continues work when rates of production vary from planned.
- Develop detailed plans for how work is to be done considering safety, environmental, and quality issues.

Thus lookahead planning assures the flow of work through the production system.

How LPS Works

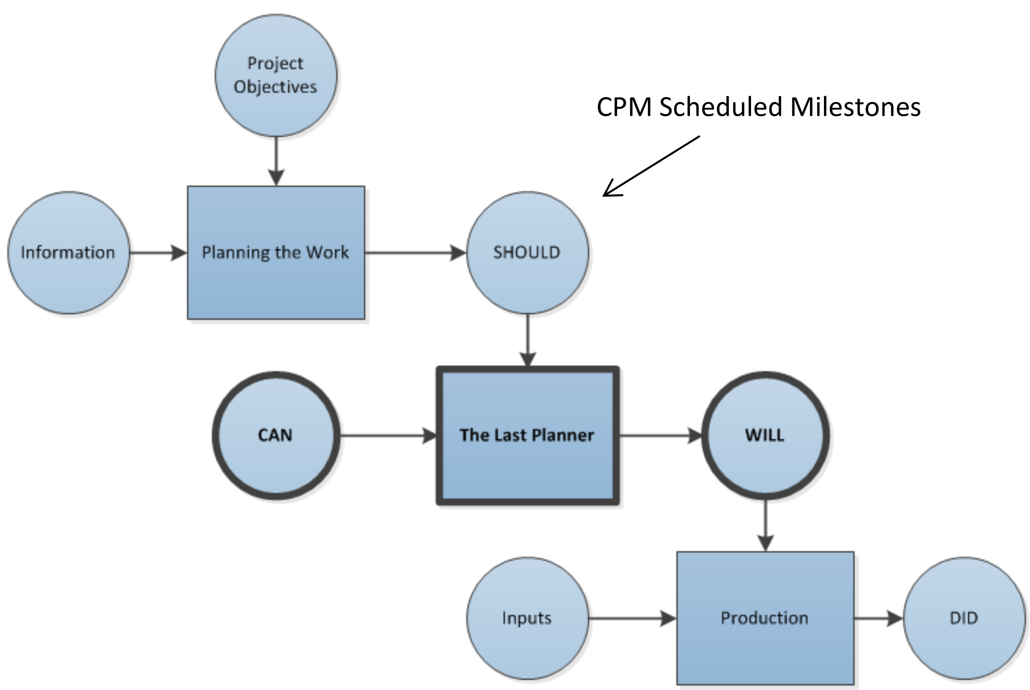


Figure 46 Input of Last Planner, created by Derek Stoecklein

Telling people what should be done is not enough. The planning system must assure they have what it takes to do the job. Discovering what *can* be done only after the crew arrives will not assure reliable workflow between crews.

A reliable assignment, one that gets done at the required time, determines a **"WILL"** be done, after considering both what **"SHOULD"** from the Master CPM Schedule and what **"CAN"** be done based on the situation at hand. The Last Planner's Weekly Work Plan is a committed plan of only work that CAN be done. Increased plan reliability improves performance of the crew and simplifies coordination with others because they will be better able to organize their work and plan the methods to be applied. Thus the certainty of workflow from one crew to the next is a key to improving project performance.

Re-Sequencing of MEPF Work Overview

Task Name	Duration	Start	Finish
Steel Decking Sequence Duration	84 days	Mon 1/23/12	Thu 5/17/12
Erect Catwalk	5 days	Thu 4/19/12	Wed 4/25/12
Storm Rough In Truss Lvl	30 days	Fri 4/20/12	Thu 5/31/12
HVAC Pipe RI @ Trusses	31 days	Fri 4/27/12	Fri 6/8/12
Sprinkler RI @ Trusses	44 days	Fri 5/4/12	Wed 7/4/12
Comm Conduit/Cable tray	20 days	Fri 5/11/12	Thu 6/7/12
Conduit/Wire Truss Lvl	45 days	Fri 5/11/12	Thu 7/12/12
Paint @ Trusses/Deck	50 days	Fri 7/6/12	Thu 9/13/12
Lighting @ Truss Level	20 days	Fri 8/31/12	Thu 9/27/12
DuctSox	14 days	Fri 9/7/12	Wed 9/26/12
Electrical Devices @ Truss Level	15 days	Fri 9/14/12	Thu 10/4/12
Fire Alarm Devices and Test Truss Level	20 days	Fri 9/14/12	Thu 10/11/12

Table 20 Re-Sequenced Schedule Durations, created by Derek Stoecklein

Re-Sequencing Considerations

- Catwalk must be done for sprinkler to finish and Comm conduit on catwalk.
- Storm RI first to meet designed slopes.
- NE to SW corner erection phases to stay out of the way of the steel and catwalk erection.

- Storm, HVAC pipe, Sprinkler, Conduit must be in before painting.
- DuctSox not painted anymore and finish electrical work not painted.
- 5 day lag on start for Storm, HVAC pipe, Sprinkler, Conduit to allow the prior trade to move on.
- Comm conduit and Elect conduit will be installed by the same trade so they will start together.
- Same with electrical and fire devices.

*Re-Sequenced schedule seen in full in APPENDIX F

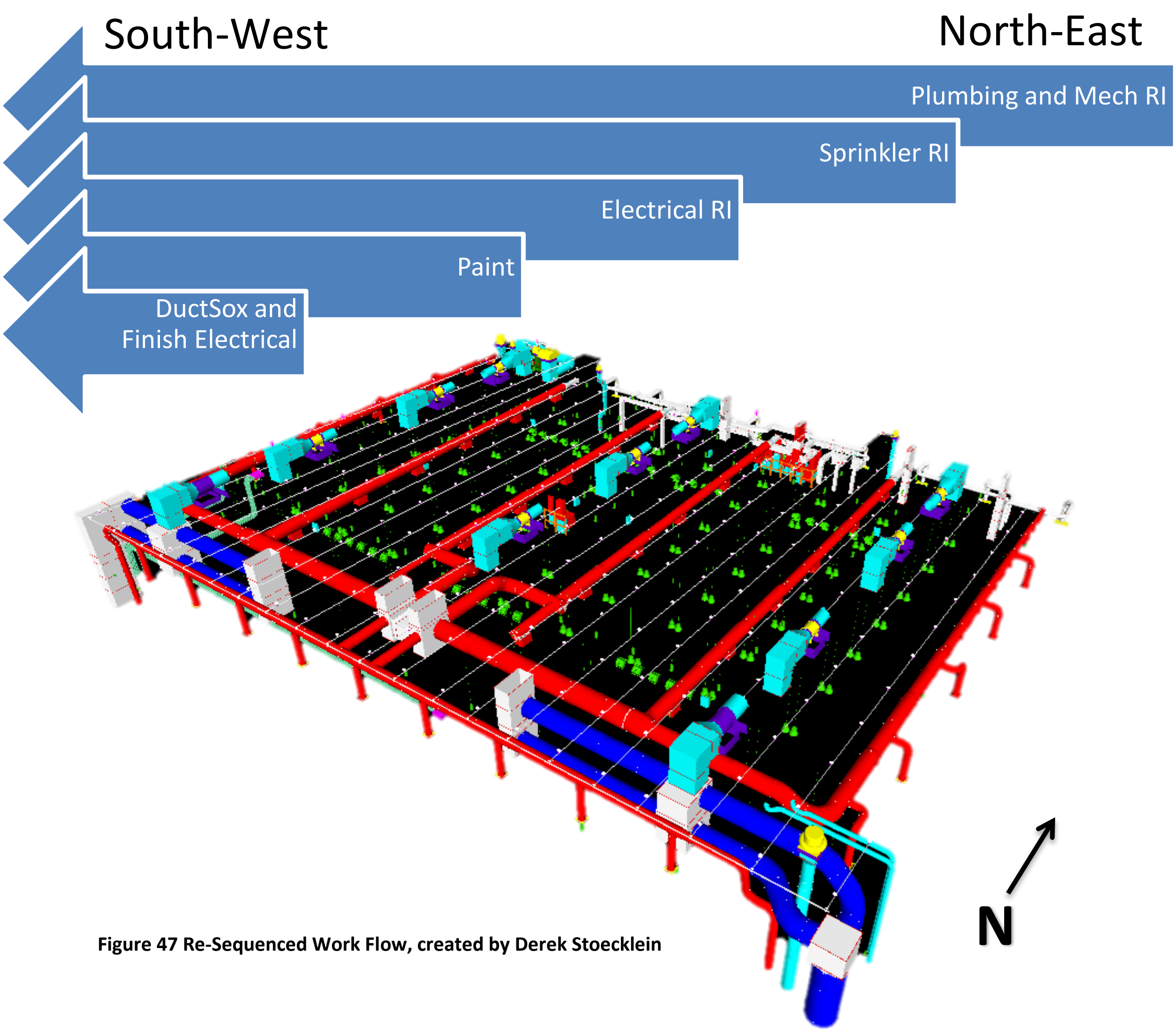
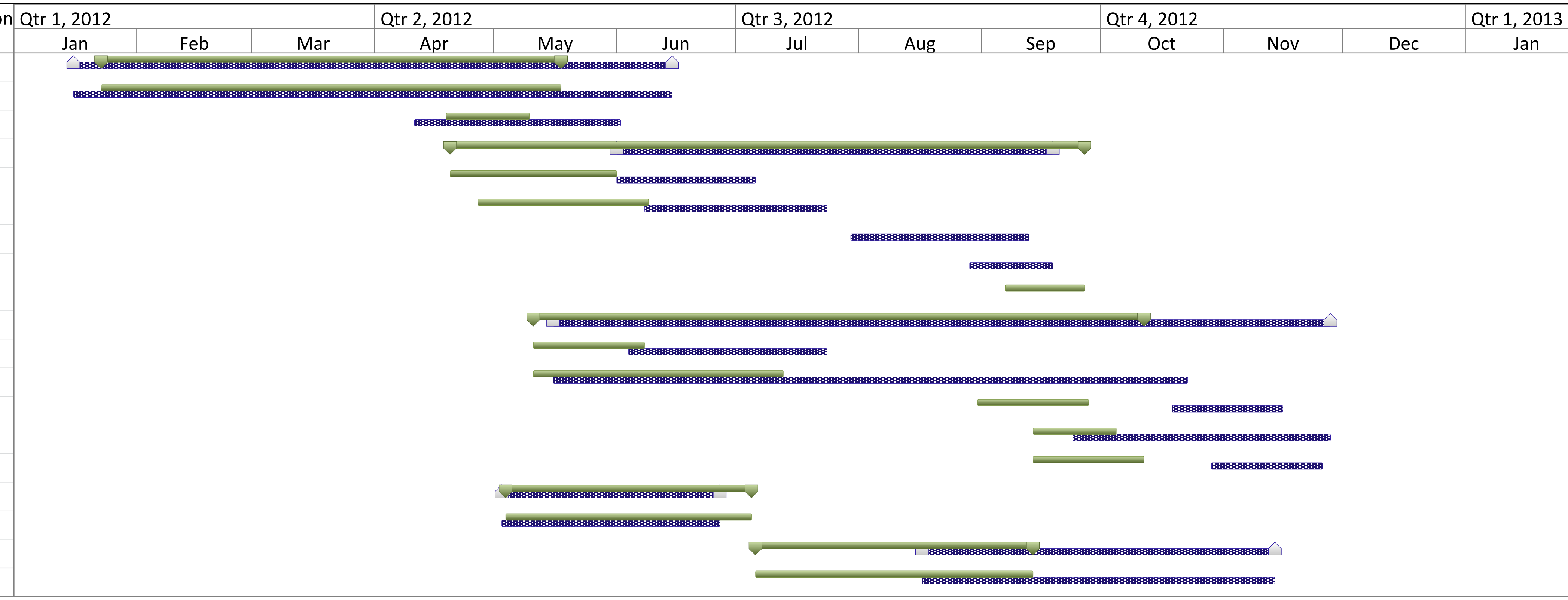


Figure 47 Re-Sequenced Work Flow, created by Derek Stoecklein

	Name	Duration: Current	Duration: Previous	Duration Diff
1	**Kinsley - Steel**	**84 days**	**109 days**	**-25d**
2	Steel Decking Sequence Duration	84 days	109 days	-25d
3	Erect Catwalk	15 days	38 days	-23d
4	**DenverElek - Mechanical**	**114 days**	**78 days**	**36d**
5	Storm Rough In Truss Lvl	30 days	25 days	5d
6	HVAC Pipe RI @ Trusses	31 days	32 days	-1d
7	Duct Rough In		33 days	
8	Duct Insulation @ Trusses		15 days	
9	DuctSox	14 days		
10	**BK Truland - Electrical**	**110 days**	**140 days**	**-30d**
11	Comm Conduit/Cable tray	20 days	36 days	-16d
12	Conduit/Wire Truss Lvl	45 days	114 days	-69d
13	Lighting @ Truss Level	20 days	20 days	0d
14	Electrical Devices @ Truss Level	15 days	47 days	-32d
15	Fire Alarm Devices and Test Truss Level	20 days	21 days	-1d
16	**NFP - Sprinkler**	**44 days**	**39 days**	**5d**
17	Sprinkler RI @ Trusses	44 days	39 days	5d
18	**NLP - Painting**	**50 days**	**63 days**	**-13d**
19	Paint @ Trusses/Deck	50 days	63 days	-13d



Project: Re-Sequenced vs. Actual
Date: Fri 3/22/13

Task: Actual
Task: Re-Seq
Milestone: Previous
Milestone: Current
Summary: Actual
Summary: Re-Seq
Placeholder Duration: Previous
Placeholder Duration: Current
Placeholder Start: Previous
Placeholder Start: Current
Placeholder Finish: Previous
Placeholder Finish: Current
Inactive Task: Previous
Inactive Task: Current
Inactive Milestone: Previous
Inactive Milestone: Current
Inactive Summary: Previous
Inactive Summary: Current

General Conditions Impact

After comparing the Actual schedule to the re-sequenced schedule created using last planner, I found a savings of 33 days at the end of the MEPF phase. Two large components for this schedule decrease is the implementation of a DuctSox system, as well as concurrent activity scheduling. The new finish date for this phase is 10/11/12, instead of the actual finish date of 11/27/12. This means that all the finish work on the court can begin earlier as well as the scoreboard and ribbon display. I believe that the decrease in schedule of 33 days will carry over the remaining phases and allow for early substantial completion. The implementation of last planner will also aid in this success.

From the analysis of the fabric duct, I calculated the general conditions (GC) for TA at $214,927 a month or $10,747 a day. If Gilbane is able to maintain this schedule decrease for the duration of the project through the last planner system and tracking the work that CAN be done, Towson should see a GC savings of roughly **$354,629.**

Conclusions and Recommendations

Gilbane experienced several complications when it came to the MEPF work within the trusses that impacted the overall schedule. Through overtime and Saturday work, they were able to get back on track in the end, but not without costing the owner more money than expected. Planning what should happen and what CAN happen was an issue. When the baseline schedule was created, all the trades agreed on their milestones and durations, but with many of the productivity issues I listed above, they could not meet these dates in all occasions. That is where the Last Planner System comes in. Gilbane made an effort to organize two week lookahead schedules and discuss with trade contractors during daily foreman meeting but the lack of advanced planning was missing. The problem is they were using the baseline schedule to determine what should come up next. By the time the two week schedule were made and discussed with the foremen, it was too late for them to organize and order material and labor. The Last Planner System would solve this issue by planning six weeks ahead of schedule and tracking the progress of organizing and ordering up to the start date. With the baseline schedule durations and milestone pre coordinated with each trade and phase, Gilbane has a great platform to pull the LPS from. If they would have implemented a system like this into their production planning from the beginning, they would have hit the original substantial completion date of 1/31/13. Once the work began to fall behind, it is hard to implement this practice.

In conclusion, the LPS is a Lean construction tool that requires the entire team's cooperation and input. Not only is LPS a production planning tool, it can also be seen to have impacts on the safety and quality of a project. These impacts can be seen due to the advanced planning and coordination of the trades. Giving them greater direction on what they should be doing each day and who will be following them up in a given area. I believe TA could have seen a great benefit from last planner and the industry could also use this tool to improve productivity on almost any job type.

Analysis 4: Cisco StadiumVision

Problem Identification

Towson has created a poor reputation for itself within the basketball community through many losing seasons. To change this reputation, Towson made a bold move to rebuild their program from the ground up, with the plan to clear this reputation and create a winning one. A huge challenge for sports organizations, especially Towson with their previous reputation, is getting fans to come. The options presented to home spectators has greatly increased and become more interactive with HDTV, DVR's and PCs. This forces sports and entertainment venues to place increased focus on upgrading the sporting experience for their fans.

"State of the Art Technology throughout…A Basketball fan's dream"
"The Best Basketball facility in the Mid-Atlantic" – Towson's University

Not only is this possible, it is right in front of them. With amenities including a hospitality room, hall of fame room, multipurpose room, and several high end donor/president suites, innovative technologies would be a perfect fit. The ultimate fan experience is what Towson wants, and through creating a technologically wired building from head to toe they will excel in creating the ultimate experience.

Research Objectives

The solution is simple; create the ultimate experience with Cisco StadiumVision, an innovative, end to end video and digital content distribution solution that transform the look and feel of a venue. Designed to easily and cost effectively deliver live game video and programming, target advertising and promotions, and customized content to any display, on a per event basis, the "total package" for Towson .With near limitless capabilities for promoting themselves and creating an interactive environment within the arena, Cisco StadiumVision can help meet Towson's vision.

The implementation of a technology such as this will create a unique, compelling experience that keeps fans coming back to Tiger Arena again and again. Also, allowing Towson to generate exciting new business opportunities through the many powerful applications of this system. Through this research, I will find the advantages of Cisco StadiumVision to the spectator and the venue owner as well as analysis the system demands of adding all this technology to Tiger Arena. A detailed analysis will be completed on the power support of Cisco's system and insuring that Tiger Arena can handle this additional load.

Methodology

The following approach was taken to analyze Cisco StadiumVision:

- Determine Towson's exact wants/needs out of Tiger Arena
- Explore case studies and how current owner/users feel about the system
- Evaluate the current system within Tiger Arena
- Research Cisco StadiumVision through online examination, *cisco.com*
- Analyze the potential benefits to Towson and the fans
- Design a Cisco StadiumVision solution for Tiger Arena
- Evaluate the electrical demands of an upgraded system
- Determine if Tiger Arena's current system can handle the new electrical demands
- Provide conclusion and recommendations

Figure 48 Cisco SV Content Service Framework, Cisco.com

Preliminary Research

Tiger Arena is currently designed with some unique audio visual and IT capabilities such as event broadcasting and Wi-Fi hotspots. Within TA there are 2 production rooms, one on the first floor and the other located on the third floor, and a large IT room located on the first floor. Housed in the large IT room are three IT server racks that will be moved from Unitas Stadium (Towson's lacrosse and football field) into TA for video broadcasting and connections to the campus cable systems. Towson decided they would like to use TA for all their production of events in TA as well as Unitas stadium. This would involve running the existing systems in Unitas into TA through a sizable ductbank. The connections would be made directly to the three servers in the IT room and from there run to the productions rooms, truck pads, and camera platforms. In addition to them moving the IT equipment to Tiger Arena, new equipment would need to be installed to handle the new systems as well as the original in Unitas.

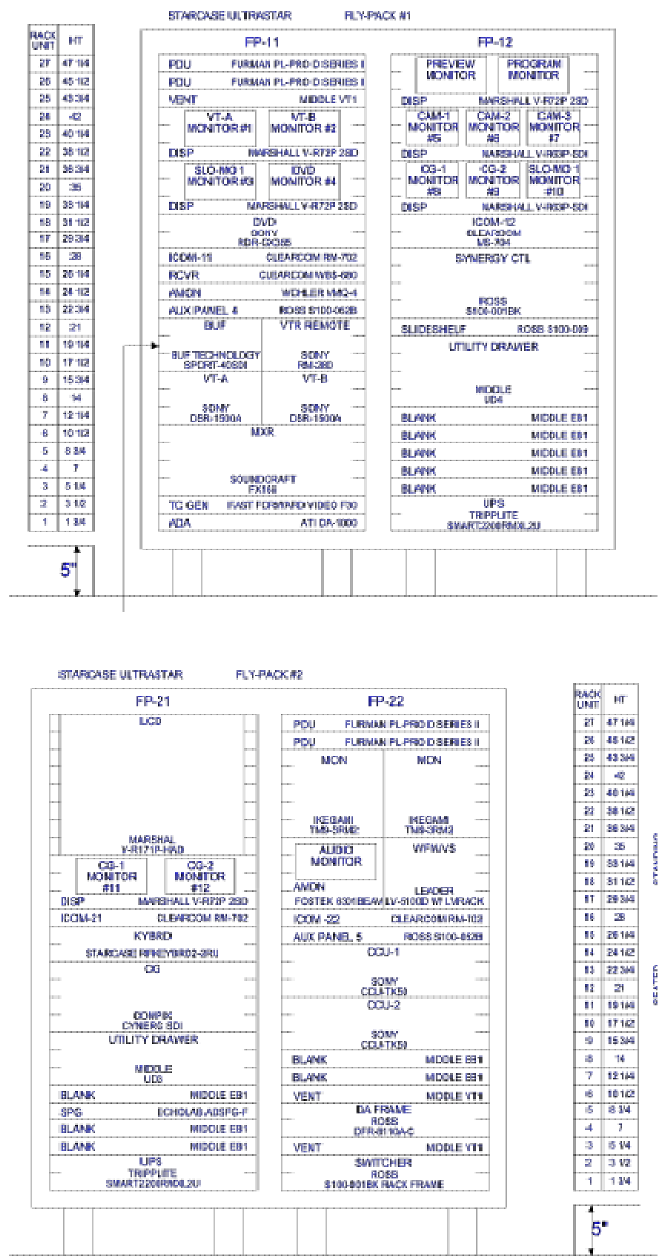


Figure 49 Existing racks from Unitas, TA Contract Documents

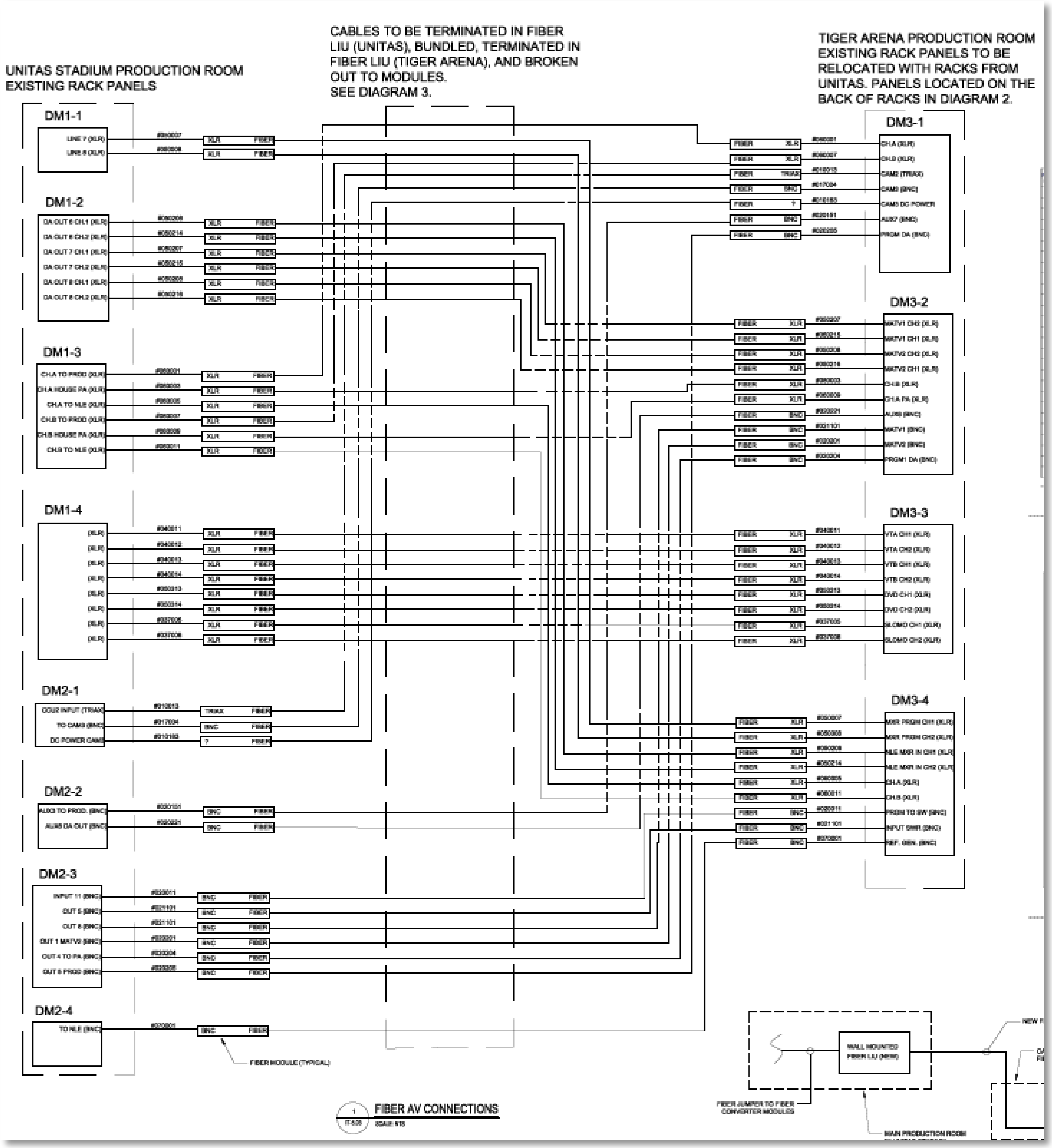


Figure 50 Tiger Arena and Unitas Fiber Connections, TA Contract Documents

The production rooms in Tiger Arena will house the event staff and all the venue controls for the scoreboard, video switching, camera feeds, and others. TA has previsions in place for future expansion of systems and technology, but they unfortunately didn’t explore opportunities to implement these technologies in the current design. The building has Wi-Fi hotspots located throughout for access by fans and personnel, as well as AV support and connections within the private boxes and multipurpose areas. Towson had the idea in mind that there would be a need and want for a connection with the spectators though technology medians, they just weren't sure what this system would be.

When I first researched Cisco Connected Stadium and their StadiumVision solution, I found that it to be a unique application for sports and entertainment venues that was somewhat overseen. When most people think of Cisco, they think of a "network" and a "service or connectivity," not enhancing a fan experience or generating extra revenue for a venue. That is actually exactly what StadiumVision and Cisco are proposing. In Cisco Connected Stadium, it is evident how it links four major operations of a venue together into one end-to-end network, figure 51. Cisco has created an advanced solution for these venues, and I plan to explore deeper into how StadiumVision works with the current systems of Tiger Arena and what it can offer Towson and the fans.

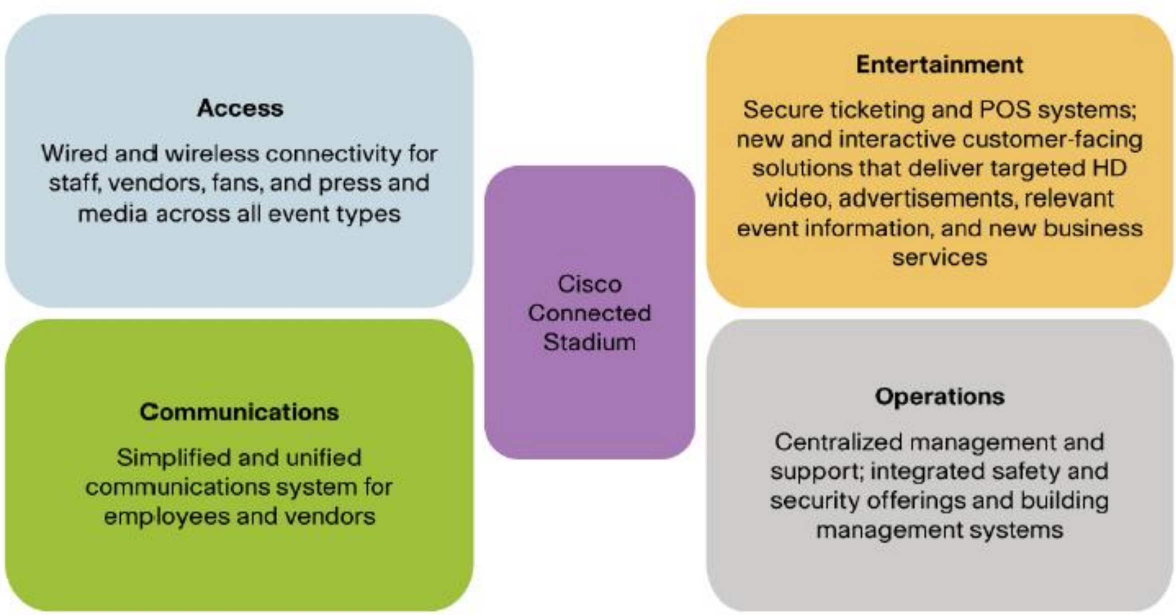


Figure 51 The Cisco Solution, *Cisco.com*

The Ultimate Experience

"Fans go to a live event to be part of a tribal experience: to connect to the action, to connect with their favorite stars, to connect with other fans, and to be part of something bigger than themselves." – Cisco

If you go into a venue today you will see that today's fans refuse to be just spectators. Fans are demanding more engagement with the game and players. The large price to attend many sports and entertainment events today is creating a larger demand of a more immures and interactive environment at a venue.

"With the growth of social media today, 49% of spectators share their events experience via social media, and 73% bring their mobile devices to events." - Cisco

Cisco StadiumVision is the solution to this demand of spectators, creating the "ultimate experience." StadiumVision has a laundry list of features that a spectator would find exiting and becoming more engaged in the event:

- Become Connect with Big Board
- Wi-Fi Connectivity
- Exclusive Features in Private Boxes
- Video feeds on phone
    - Playback Video
    - Different Camera Angles
    - Other Events
- Ordering Concessions
- Ordering Tickets and Promotions
- Directions to Seats and Nearest Amenities
- Player Stats

Some of the exclusive features that will be offered to the private box quests include; HD video in several locations around the suite, touch panels for AV control, and Cisco Unified IP Phones. With all these devices in the suites you will be able to order concessions with the touch of a finger, watch out of town games of your choice, digital TV access, and ticketing and promotional ordering. All of these features can be accessed from the IP Phone or the touch panels located around the suite. Fans will feel immersed in video and a figure tip away from anything they could need.

Figure 52 Luxury Suites Services of Cisco SV, *Cisco.com*

The spectators located around the arena will have many of the same features that can be accessed on their mobile devices. All the content will be feed through a Wi-Fi connection to the quests mobile device. These features include video feeds, trivia and player stat information, ticket and promotion ordering, arena directory and directions to amenities and seat locations, and interactive connection with the big board. Not only will these spectators have mobile interaction, video displays will be strategically placed around the concourse to digitally immerse them in the event and provide them even more interactive digital content.

"Meeting the demands of a new generation of fans"

Revenue Generation for Towson

Cisco has designed StadiumVision with both the end users and the venue owners in mind. SV has the potential to increase earning in many areas for owners including promotions, advertisements, concessions, point of sale, merchandise and others. There SV, the venue can insert Ads into any feed they choose and at any location they choice. This flexibility allows them to spotlight given advertisements and promotions for the particular audience. With the ability to advertise anywhere in the venue unlike the standard still advertisements you traditionally see, they can sell ads to advertisers in a whole new way. Allowing them to choose times and areas they wish to advertise, helping them target their own audience. With a tradition advertisement board, venues have a hard time selling particular areas such as concourse location because of the visibility and attention they may or may not receive. With the technology of ad insertion anywhere in the venue, Towson can sell ads to advertisement companies and digitally rotate them around different locations on demand.

Figure 53 Cisco SV @ CONSOL Energy Center, *Google images*

In addition to outside advertisements, Towson can use this system to digitally advertise their own advertisements and promotions such as campus events, and future venue events. This will allot them to communicate anything they want to their spectators and fine tune the selections of these ads with the current audience. Concessions and merchandise will also see benefit of this system through point of sale advertisement. With digital displays around the venue and at the point of sale, Towson can advertise sales and promotions along with the game feed or other feeds they choose.

The possibilities are near endless with the ways Towson can use Cisco's StadiumVision to generate revenue, and with the application of this system I believe they will see these increases in revenue immediately. Towson will have a platform for Towson to promote their University as well as convey the ads they find most fitting to the audience at the flip of a dime.

StadiumVision Network

Cisco Stadium Vision (SV) is a proven, end-to-end, IP solution, providing advanced video delivery and content management. StadiumVision enables the automated delivery and integration of dynamic and customized content to different areas of the arena through a centrally-managed, distribution and video processing solution. Cisco SV has been built for entertainment and sports venues that have extensive video systems deployed throughout. SV is designed to enhance the viewing of live events and provide in-house advertising. In addition, it uses video systems in clubs, luxury suites, and restaurants to allow fans to view both external network channels and in-house programming.

Cisco StadiumVision comprises four major components, as shown in figure 54:

- Video acquisition (or video headend)
- Converged voice, video, and data high-speed IP network
- Video delivery (and digital signage playback)
- Centralized management and operations

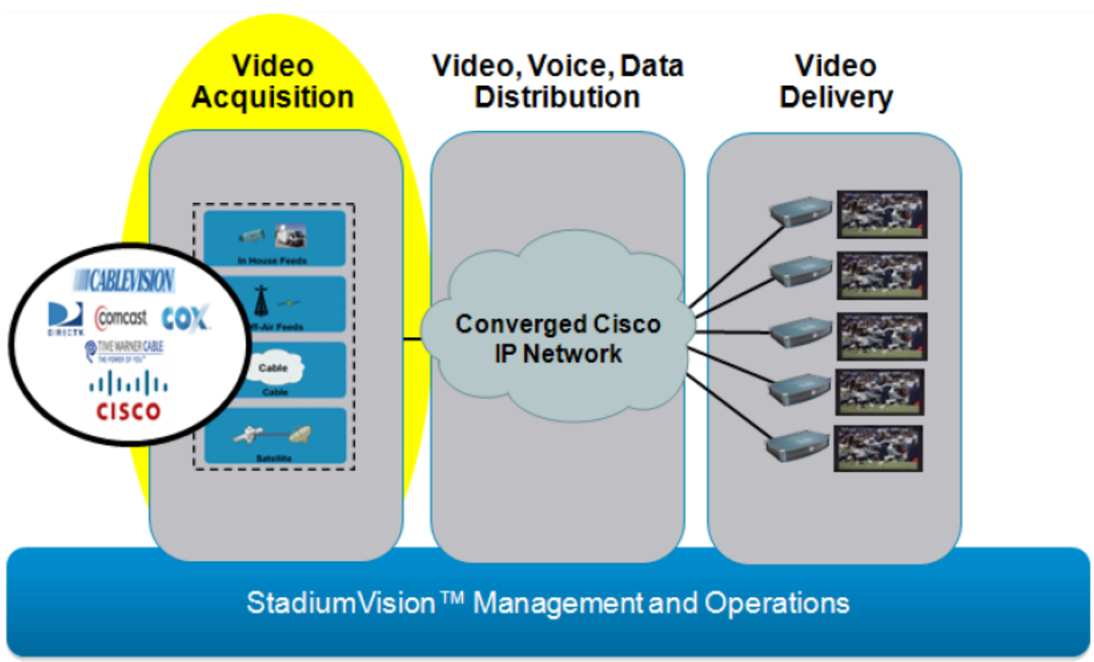


Figure 54 StadiumVision Major Components, from *SV_Headend_DIG_3.0.pdf*

StadiumVision Headend

The Cisco SV headend is the central location of all the systems components and video feeds, designed to acquire, process, and encode the video content. Figure 55 provides a simplified view of the video headend design, incorporating multiple types of video sources and how it is distributed over IP Multicast to the Connected Stadium Network.

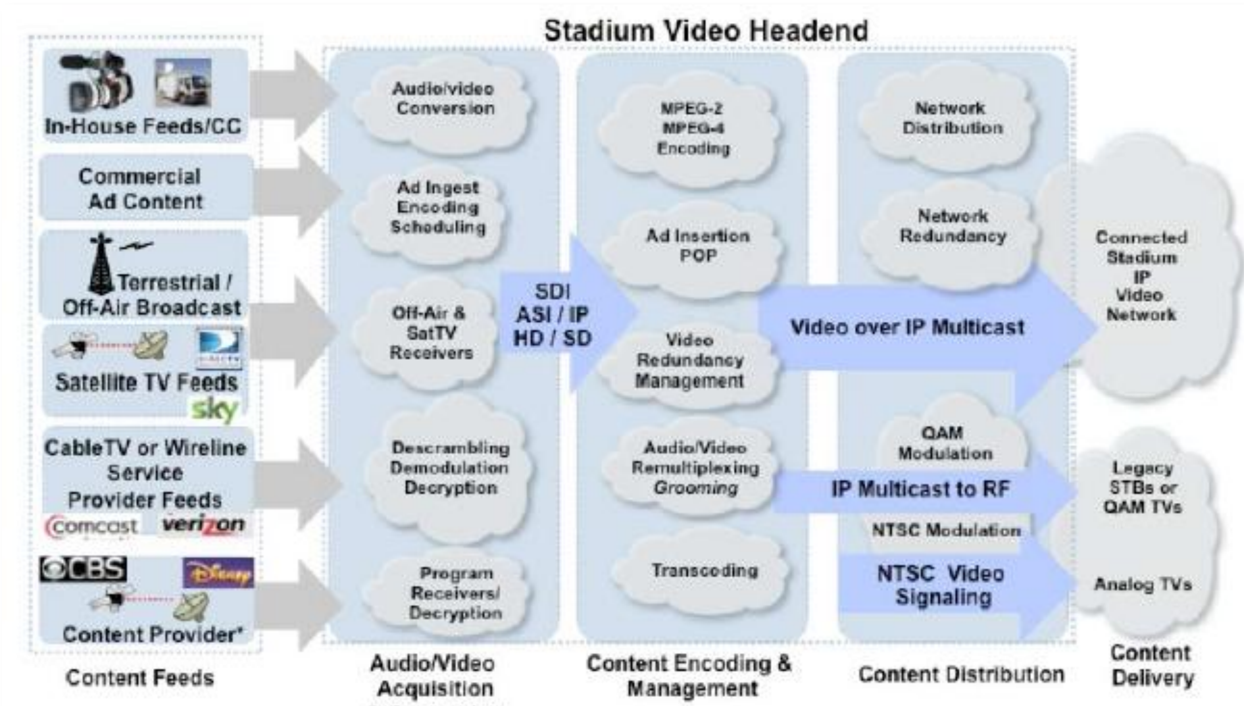


Figure 55 Headend Functional Elements, course *SV_Headend_DIG_3.0.pdf*

In the headend, the video feed is:

- Provided by multiple video sources (In-house, digital, cable, content providers).
- Acquired and processes through the appropriate receivers and decrypters.
- Encoded using the appropriate SD or HD, MPEG-2 or MPEG-4 encoders.
- Groomed and aggregated using the digital content manager, DCM (Video ads are also inserted at this stage where desired).
- Sent via multicast to the IP network.

Once on the network, the video is picked up by a digital media player, DMP, located at all the TV locations. These DMP's are tuned to receive a specific IP multicast address and the video is displayed on the corresponding TV.

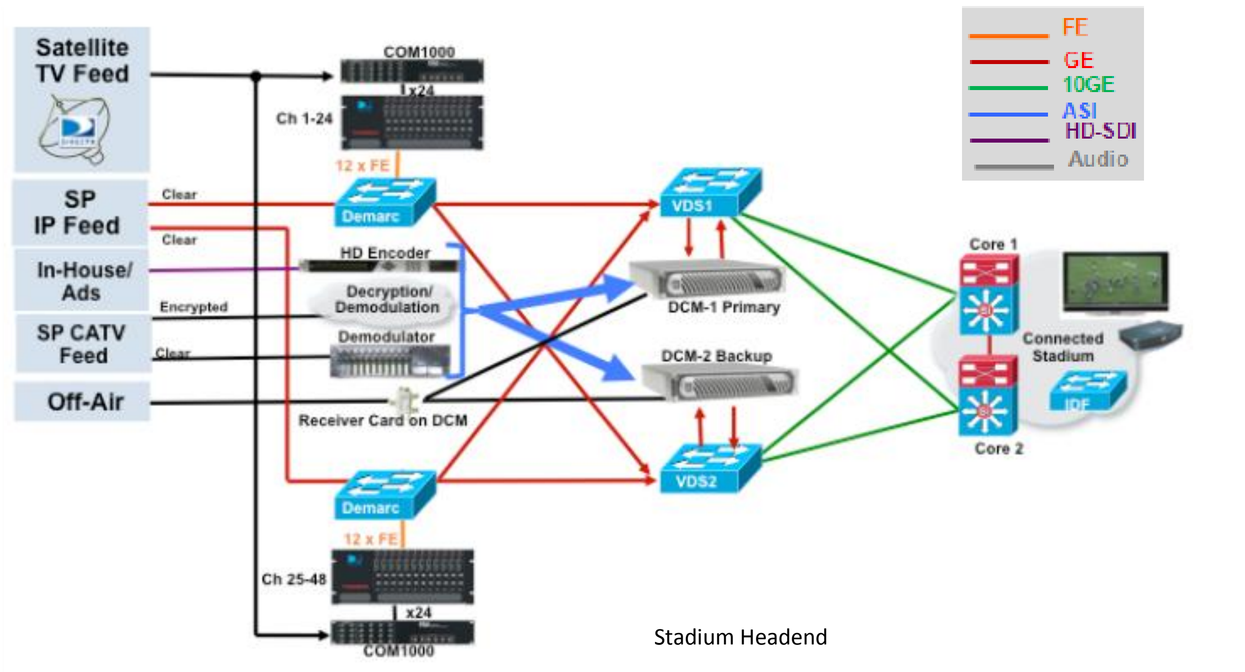


Figure 56 Standard Reference Architecture from the US, source *SV_Headend_DIG_3.0.pdf*

In Figure 56 , you will see the standard architecture that is recommended for Cisco Stadium Vision deployment. The standard architecture goes a step beyond the baseline architecture and incorporates a layer of redundancy to the system for support for additional features and high-availability. At the heart of the headend lie the Core Digital Content Managers (DCMs) and the Video Distribution Switches (VDSs). While some of the other components of the headend may vary depending on the required feeds, these components remain constant. The DCM receives the video feeds from all the different sources and sends them to the VDS. The VDS is the link between the headend and the Converged Cisco IP network in the stadium.

In-House Video Feed

Generally, a venue would have its own in-house channels to broadcast live video to all the video endpoint in the venue. A typical venue may have multiple in-house channels depending on their requirements. These in-house channels are controlled by the staff in the stadium production room, where they pick the channel line-up and provide the feeds to encoders in the Cisco SV headend. These Encoder will then send the content to the DCM, through the VDS and then feed through the Cisco IP network to the DMPs, figure 57.

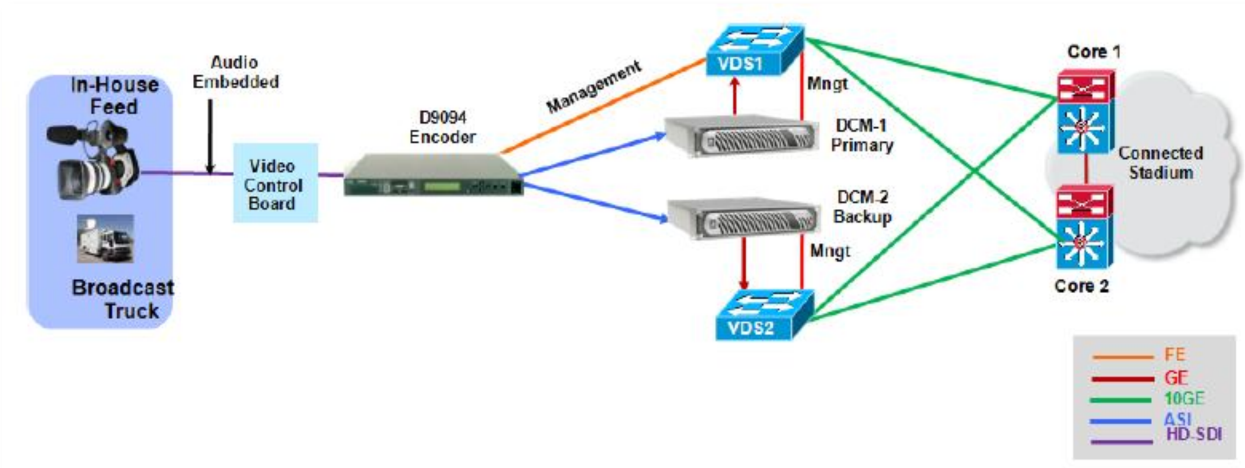


Figure 57 In-House Video Feed, source *SV_Headend_DIG_3.0.pdf*

Satallite TV Feeds

With DirectTV (recommended satellite provider), HD channels can be provided as MPEG-4 over IP Network. Typically, a separate receiver is required for each channel; depending on the number of channels you want this could consume your entire AV rack. To reduce space required and cost, the Thompson/DirectTV COM200 chasses and COM24 receivers will be used. Each COM24 card can hold 2 different channels and each COM200 chasses can hold up to 12 COM24 cards, allowing for 24 channels per COM200 unit. The DirectTV feed connects to the COM receivers via RF and send through individual IP multicast to a demarcation switch (Catalyst 3560).

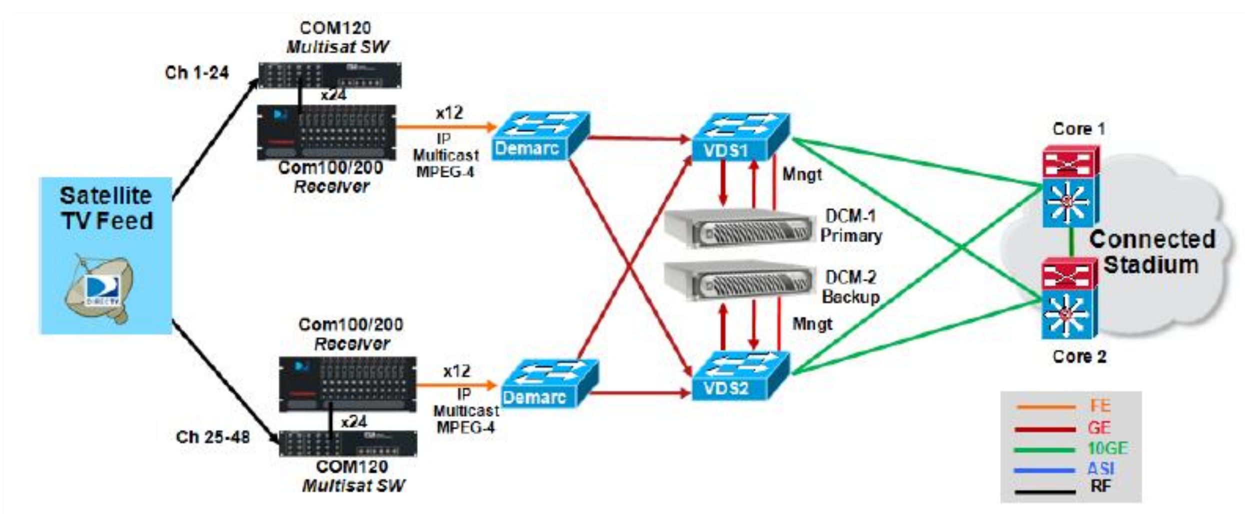


Figure 58 DirectTV Feed, source *SV_Headend_DIG_3.0.pdf*

Ad Insertion

There are two approaches for inserting ads. First would be inserting it into the uncompressed stream and the other would be the compressed MPEG stream. The typical ad insertion would include an SDI router and control panel along with the ad server, highlighted in figure 59. The above architecture will allows for 2-4 unique ad channels over any in-house feed. For more freedom and zone control, more router locations must be added.

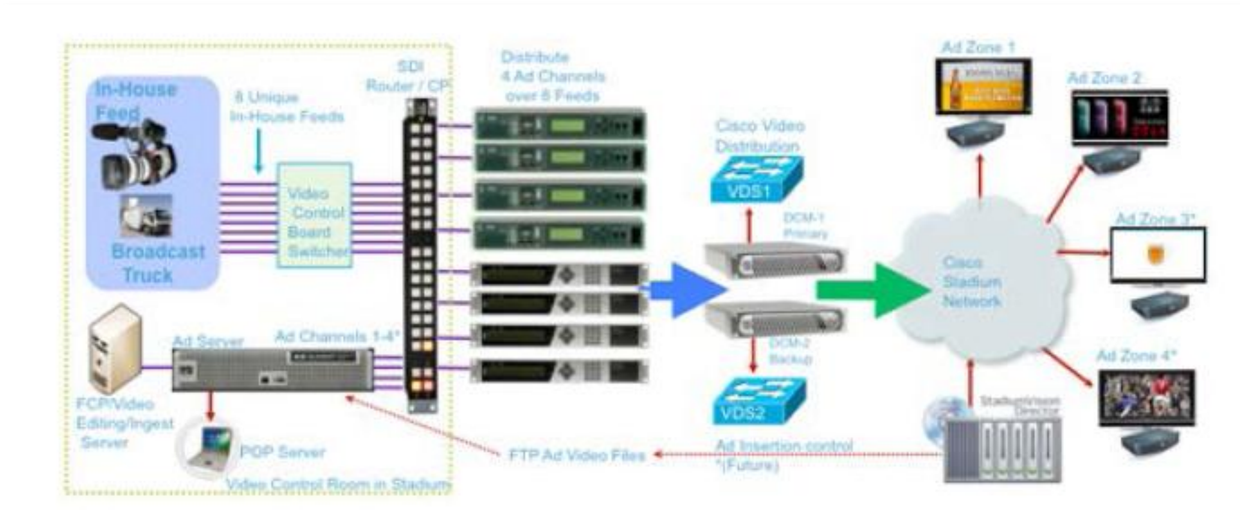


Figure 59 Ad Insertion Architecture with Cisco StadiumVision, source *SV_Headend_DIG_3.0.pdf*

Video Delivery

Each TV location requires a Cisco Digital Media Player (DMP), figure 60, that is individually addressable for targeted ads and content. The DMP is an IP-based hardware endpoint for video decoding and playback of digital media content, including HD broadcasting, on-demand video, text tickers, and other web content. The Cisco DMPs can be attached to virtually any digital TV at any location across the venue such as back office, club, suites, and concourse. These DMPs are controlled centrally by the SV Director or via remotes and touch panels at given locations.

Figure 60 Cisco DMP, Google

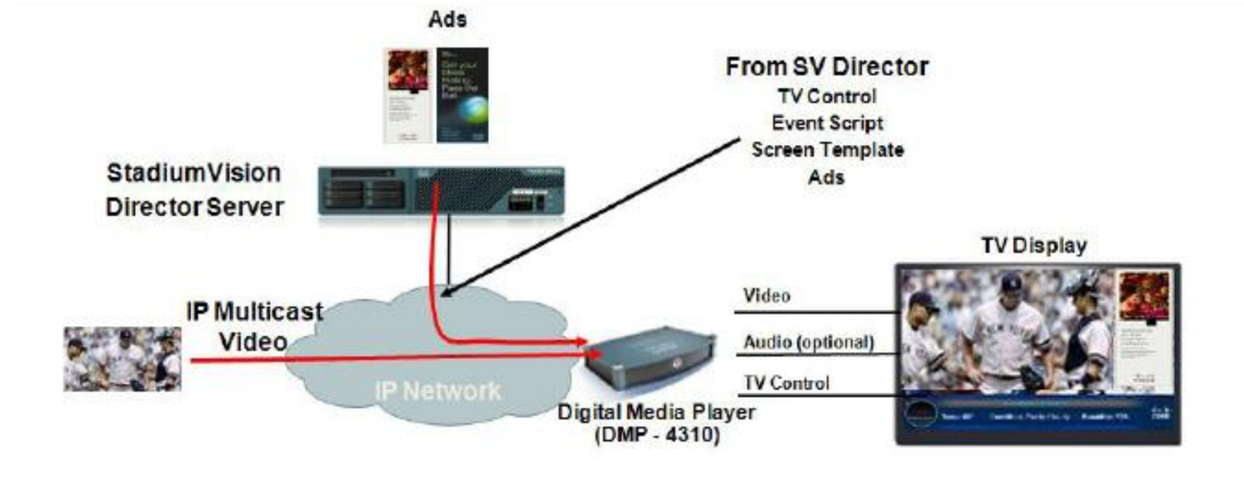


Figure 62 DMP Video Delivery, source *SV_Headend_DIG_3.0.pdf*

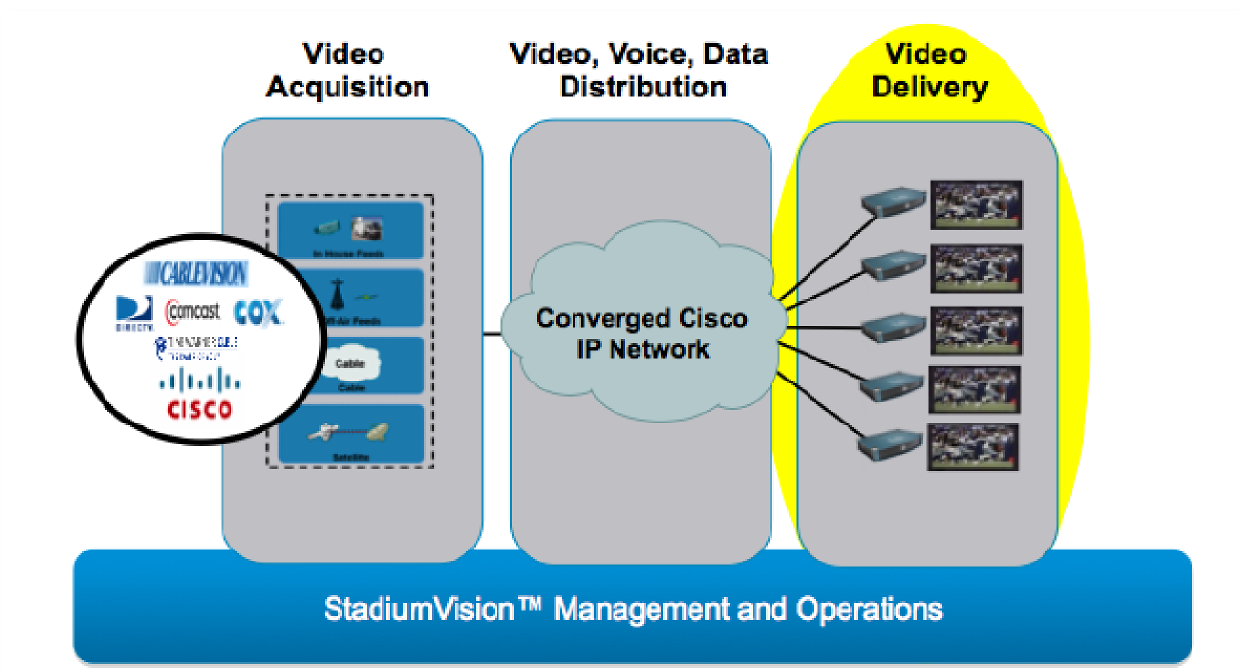


Figure 62 Stadium Vision Major Components, source *SV_Headend_DIG_3.0.pdf*

StadiumVision Mobile Streamer and Reporter

Cisco StadiumVision Mobile (SVM) Streamer is an essential part of the SVM solution, allowing delivery of live and playback video to thousands of mobile devices in a venue. This video content is sent via multicast across the venues Wi-Fi network. Not only does the streamer deliver video content, it can deliver non-video content, such as game statistics, still graphics, text-based promotions, tickers, and much more. The Cisco StadiumVision Reporter is used to measure and report on the quality of the fan experience. This allows the staff to analysis what

Figure 63 StadiumVision Mobile application, source cisco.com

the fans are watching most and are most interested in, and create future business opportunities accordingly. Both the Streamer and the Reporter software are packaged within the Cisco UCS C220 M3 Rack Server.

System Component Analysis

For the design of Towson Tiger Arena's Cisco Stadium Vision, the Basic Architecture was used, no redundancy. SV is a completely customizable system depending on what demands you have for your venue and the required feeds. Figure 64 below shows the rack design for TA that will be placed next to the existing AV racks in the 1st floor production room. From this room, the Cisco Connected Network will run throughout Tiger Arena to all the required locations via IP connections to the DMPs. These locations include suites, concourse level, concessions, Hall of Fame room, multipurpose room, and ticketing.

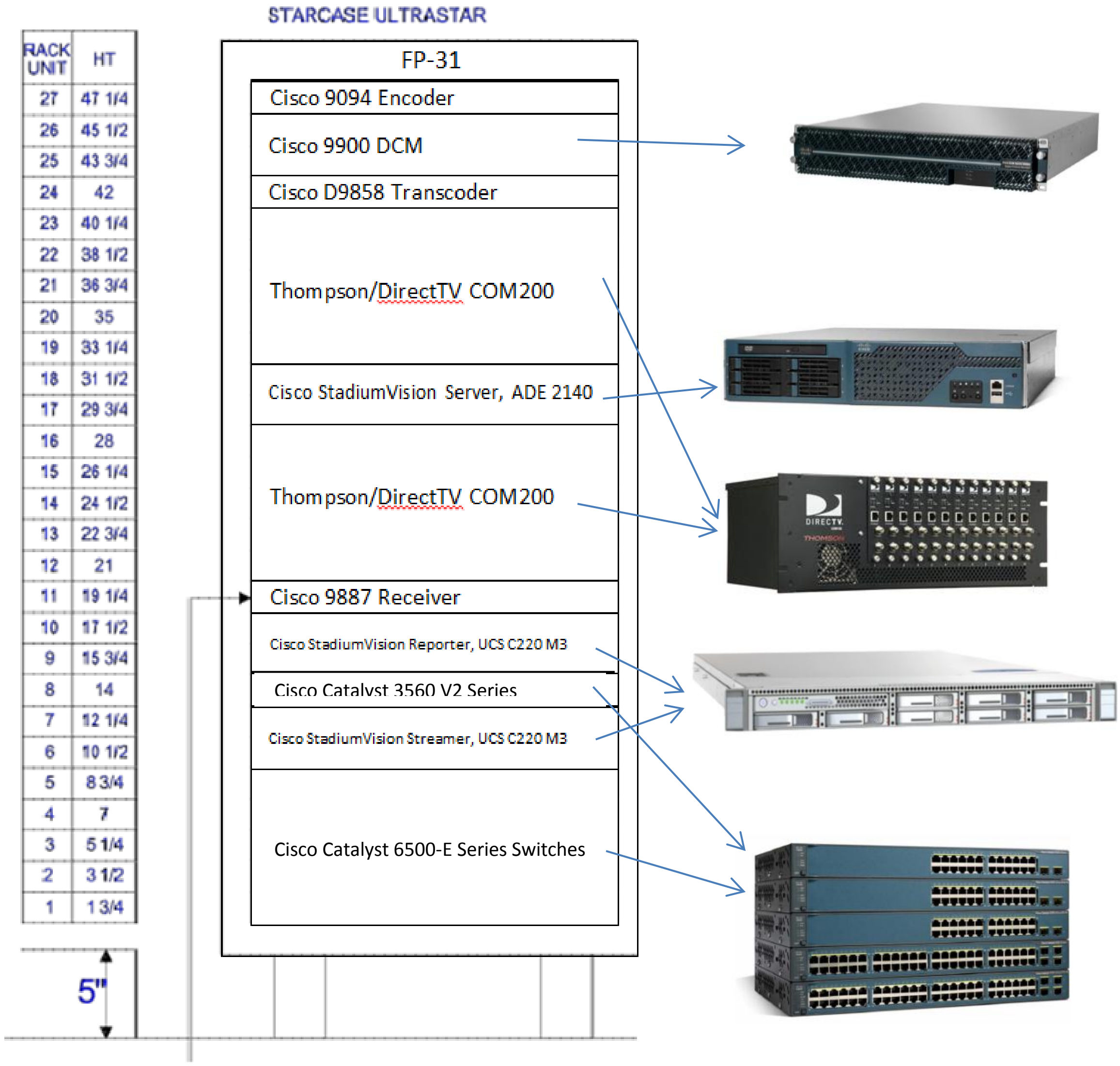


Figure 64 Tiger Arena Designed Cisco StadiumVision Rack, created by Derek Stoecklein; images source cisco.com

Required Rack Equipment v. 3.0	Rack Slot	Amount	Max Power (W)	Power Req. (W)
Cisco 9094 Encoders	1	1	60	60
Cisco D9858 Transcoder	1	1	110	110
Cisco 9887 Receiver	1	1	200	200
Cisco 9900 DCM (Digital Content Manager)	2	1	350	350
Catalyst 3560/3750 Ethernet Switches	1	1	130	130
Catalyst 6504 Switch (Video Distributution System)	5	1	113	113
Thomson/DirecTV COM200	5	2	320	640
Cisco StadiumVision Server, ADE 2140	2	1	600	600
Cisco StadiumVision Reporter	1	1	650	650
Cisco StadiumVision Streamer	1	1	650	650
Rack Total	**20**	**11**	-	**3503**

Table 21 Tiger Arena SV Rack Power Demand, created by Derek Stoecklein

Tiger Arena Cisco StadiumVision Component List

- Cisco 9094 Encoder (1)
  - Encodes in-house feeds to appropriate SD or HD, MPEG-2 or MPEG-4
  - 60 W Max Power
- Cisco D9858 Transcoder (1)
  - Transcodes satellite feeds to appropriate SD or HD, MPEG-2 or MPEG-4
  - 110 W Max Power
- Cisco D9887 Receiver (1)
  - HDTV Receiver
  - 200 W Max Power
- Cisco 9900 Digital Content Manager (1)
  - Creates IP Multicast for distribution
  - 350 W Max Power
- Catalyst 3560 Ethernet Switch (1)
  - DirectTV Distribution Switch
  - 150 W Max Power
- Catalyst 6504 Switch (1)
  - Video Distribution Switch
  - 113 W Max Power
- Thompson/DirectTV COM200 (2)
  - DirectTV Satellite TV Receivers
  - 320 W Max Power
- Cisco ADE 2140 (1)
  - StadiumVision Server
  - 600 W Max Power
- Cisco UCS C220 M3 Rack Server (2)
  - StadiumVision Mobile Reporter and Streamer Unit
  - 650 W Max Power ea.
- Cisco Digital Media Player 4400G (X)
  - Digital receiver at all TV locations that converts the IP Multicast in Video
  - 10" x 8" x 2" @ 4.5lbs
  - Low power consumption

Total Power Required of Rack = **3503 W / 0.95 (Assumed Power Factor) = 3,687 VA @ 120V**

This rack will require a max power output of 3,892 VA. This power demand will come from PB1C located in Security 122. Within the server rack will be a mounted power strip that handles 120V input and output of 208V. This means that the receptacle for this rack will need to be connected to a 2-phase, 20 A breaker. To insure the total power of these components will be handled by one rack power strip, I calculated its max capacity (VA).

120V (Circuit Voltage) x 32A (Circuit Max Capacity) = **3,840 VA**

WIRING SCHEDULE: PANEL RP1C

120 / 208 VOLTS 3 PHASE 4 WIRE 100 AMP MAINS SURFACE MOUNTED

CIR-CUIT	POLE	DESCRIPTION	WIRE/ CONDUIT	BREAKER POLE	BREAKER AMP	KVA / Ø AØ	AØ	BØ	BØ	CØ	CØ	CIR-CUIT	POLE	DESCRIPTION	WIRE/ CONDUIT	BREAKER POLE	BREAKER AMP
1	1	CUH-TA-1 (VESTIBULE 124)	#12-3/4"C	1	20	0,3	1,4					2	2	HAND DRYER MEN'S 131	#8-3/4"C	1	20
3	3	REC FAN ASSIST 134,135,137	#8-3/4"C	1	20			1,0	1,4			4	4	HAND DRYER MEN'S 131	#8-3/4"C	1	20
5	5	REC EVENT MGMT 133, 134	#8-3/4"C	1	20					0,8	0,8	6	6	REC MEN'S 131	#8-3/4"C	1	20
7	7	REC WOMEN'S 132	#8-3/4"C	1	20	0,8	0,8					8	8	REC RECEPTION 125, CORR	#10-3/4"C	1	20
9	9	HAND DRYER WOMEN'S 132	#8-3/4"C	1	20			1,4	0,8			10	10	REC PRESS RM 127	#12-3/4"C	1	20
11	11	HAND DRYER WOMEN'S 132	#8-3/4"C	1	20					1,4	0,8	12	12	REC PRESS RM 127	#12-3/4"C	1	20
13	13	REC PRESS ROOM 127	#12-3/4"C	1	20	0.8	1.0					14	14	REC AVR PRESS RM 127	#12-3/4"C	1	20
15	15	REC PRESS ROOM 127	#12-3/4"C	1	20			0.8	0.5			16	16	REC METAL DETECTOR 125	#12-3/4"C	1	20
17	17	REC EVENT STAFF 121	#12-3/4"C	1	20					0,6	0,5	18	18	REC METAL DETECTOR 125	#12-3/4"C	1	20
19	19	REC EVENT STAFF 121, CORR 114	#12-3/4"C	1	20	0,8	0,5					20	20	REC EWC 125	#12-3/4"C	1	20
21	21	REC SECURITY 122, CORR	#12-3/4"C	1	20			0,8	0,8			22	22	REC AVR SECURITY 122	#12-3/4"C	1	20
23	23	REC PRODUCTION 129	#10-3/4"C	1	20					0,8	0,8	24	24	REC PRODUCTION 129	#10-3/4"C	1	20
25	25	REC PRODUCTION 129	#10-3/4"C	1	20	0.8	0.8					26	26	REC PRODUCTION 129	#10-3/4"C	1	20
27	27	REC PRODUCTION 129	#10-3/4"C	1	20			0.8	1.0			28	28	REC PRODUCTION 129	2#10+#10G-	2	20
29	29	REC PRODUCTION 129	#10-3/4"C	1	20					0.8	1.0	-	30		3/4"C		
31	31	REC PRODUCTION 129	2#10+#10G-	2	20	1.0	1.0					32	32	REC PRODUCTION 129	2#10+#10G-	2	20
-	33		3/4"C					1,0	1,0			-	34		3/4"C		
35	35	REC PRODUCTION 129	2#10+#10G-	2	20					1,0	0,8	36	36	REC PRODUCTION 129	#10-3/4"C	1	20
-	37		3/4"C			1,0	**0,4**					**38**	**38**	**REC TV PRESS ROOM 127**	**#12-3/4"C**	1	20
	39	SPARE		1	20								40	SPARE		1	20
	41	SPARE		1	20								42	SPARE		1	20
						5,5	5,9	5,8	5,5	5,4	4,7						
						11.4		11.3		10.1							

CONNECTED LOAD = 32.8 KVA

DEMAND LOAD = 23,2 KVA

MIN AIC RATING = 10,000 AMPS SYMMETRICAL

MAIN BREAKER 100 AMPS

NOTE: PROVIDE SEPARATE NEUTRAL FOR EACH CIRCUIT

LOCATION SECURITY 122

Figure 65 Panel RP1C, TA Contract Documents

This 3,840 means the rack will have no problem supporting the loads of the SV components. The server power strip will connect to a NEMA L14-20R (2 phase wires, neutral and ground) receptacle, Figure 66 Since this receptacle requires two phases on PB1C, the addition of this circuit will fill the panel near capacity and eliminate the opportunity to expand any electrical system through this panel board. This should not be an issue though due to the fact panel board RP1B is located in Maintenance 118, only two rooms over and has

Figure 66 NEMA L14-20R Diagram, google.com

plenty of spares. Calculations have also been done to insure the panel can hold the additional load and no main breaker upsizing are needed. The demand load current increased from 64.4 Amps to 75.2. With 100 Amp Mains and a 100 Amp breaker, the panel does NOT need altered to provide for this added load.

WIRING SCHEDULE: PANEL RP1C																	
120/208 VOLTS			3PHASE 4 WIRE					100 AMP MAINS					SURFACE MOUNTED				
CIRC-UIT	POLE	DESCRIPTION	WIRE/ CONDUIT	BREAKER POLE	BREAKER AMP	KVA/Ø AØ		BØ		CØ		CIRC-UIT	POLE	DESCRIPTION	WIRE/ CONDUIT	BREAKER POLE	BREAKER AMP
1	1	CUH-TA-1 (VESTIBULE 124)	#12-3/4"C	1	20	0.3	1.4					2	2	HAND DRYER MEN'S 131	#8-3/4"C	1	20
3	3	REC FAN ASSIST 134,135,137	#8-3/4"C	1	20			1.0	1.4			4	4	HAND DRYER MEN'S 131	#8-3/4"C	1	20
5	5	REC EVENT MGMT 133, 134	#8-3/4"C	1	20					0.8	0.8	6	6	REC MEN'S 131	#8-3/4"C	1	20
7	7	REC WOMEN'S 132	#8-3/4"C	1	20	0.8	0.8					8	8	REC RECEPTION 125, CORR	#10-3/4"C	1	20
9	9	HAND DRYER WOMEN'S 132	#8-3/4"C	1	20			1.4	0.8			10	10	REC PRESS RM 127	#12-3/4"C	1	20
11	11	HAND DRYER WOMEN'S 132	#8-3/4"C	1	20					1.4	0.8	12	12	REC PRESS RM 127	#12-3/4"C	1	20
13	13	REC PRESS ROOM 127	#12-3/4"C	1	20	0.8	1.0					14	14	REC AVR PRESS RM 127	#12-3/4"C	1	20
15	15	REC PRESS ROOM 127	#12-3/4"C	1	20			0.8	0.5			16	16	REC METAL DETECTOR 125	#12-3/4"C	1	20
17	17	REC EVENT STAFF 121	#12-3/4"C	1	20					0.6	0.5	18	18	REC METAL DETECTOR 125	#12-3/4"C	1	20
19	19	REC EVENT STAFF 121, CORR 114	#12-3/4"C	1	20	0.8	0.5					20	20	REC EWC 125	#12-3/4"C	1	20
21	21	REC SECURITY 122, CORR	#12-3/4"C	1	20			0.8	0.8			22	22	REC AVR SECURITY 122	#12-3/4"C	1	20
23	23	REC PRODUCTION 129	#10-3/4"C	1	20					0.8	0.8	24	24	REC PRODUCTION 129	#10-3/4"C	1	20
25	25	REC PRODUCTION 129	#10-3/4"C	1	20	0.8	0.8					26	26	REC PRODUCTION 129	#10-3/4"C	1	20
27	27	REC PRODUCTION 129	#10-3/4"C	1	20			0.8	1.0			28	28	REC PRODUCTION 129	2#10+#10	2	20
29	29	REC PRODUCTION 129	#10-3/4"C	1	20					0.8	1.0	-	30		G-3/4"C		
31	31	REC PRODUCTION 129	2#10+10G-	2	20	1.0	1.0					32	32	REC PRODUCTION 129	2#10+#10	2	20
-	33		3/4"C					1.0	1.0			-	34		G-3/4"C		
35	35	REC PRODUCTION 129	2#10+10G-	2	20					1.0	0.8	36	36	REC PRODUCTION 129	#10-3/4"C	1	20
-	37		3/4"C			1.0	0.4					38	38	REC TV PRESS ROOM 127	#12-3/4"C	1	20
39	39	CISCO STADIUM VISION RACK	3#10+10G-	2	20			1.9					40	SPARE		1	20
-	41		3/4"C							1.9			42	SPARE		1	20
						5.5	5.9	7.7	5.5	7.3	4.7						
		CONNECTED LOAD =	36.6	KVA		11.4		13.2		12.0							
														MAIN BREAKER	100	AMPS	
		DEMAND LOAD =	27.1	KVA				NOTE: PROVIDE SEPARATE NEUTRAL FOR EACH CIRCUIT									
		MIN AIC RATING =	10,000	AMPS SYMMETRICAL										LOCATION	SECURITY 122		

Figure 67 Panel RP1C with Cisco SV Breaker, created by Derek Stoecklein

The wire for circuit 39 was sized by calculating the current that will be drawn by this load and using table 350.16 from 2011 NEC, Figure 68. Because the circuit run was less than 100 ft., the voltage drop on the load is nearly negligible. The ground wire was calculated by using table 250.122, Figure 69. Conduit was sized via table Appendix C in NEC 2011 using number of conductors and their respective size Figure 70.

Size	Temperature Rating of Conductor. [See Table 310.104(A).]						Size
	60°C (140°F)	75°C (167°F)	90°C (194°F)	60°C (140°F)	75°C (167°F)	90°C (194°F)	
AWG or kcmil	Types TW, UF	Types RHW, THHW, THW, THWN, XHHW, USE, ZW	Types TBS, SA, SIS, FEP, FEPB, MI, RHH, RHW-2, THHN, THHW, THW-2, THWN-2, USE-2, XHH, XHHW, XHHW-2, ZW-2	Types TW, UF	Types RH, RHW, THHW, THW, THWN, XHHW, USE	Types TBS, SA, SIS, THHN, THHW, THW-2, THWN-2, RHH, RHW-2, USE-2, XHH, XHHW, XHHW-2, ZW-2	AWG or kcmil
	Copper			Aluminum or Copper-Clad Aluminum			
18	—	—	14	—	—	—	—
16	—	—	18	—	—	—	—
14**	15	20	25	—	—	—	—
12**	20	25	30	15	20	25	12**
10**	30	35	40	25	30	35	10**
8	40	50	55	35	40	45	8

Figure 68 Table 350.16, NEC 2011

Table 250.122 Minimum Size Equipment Grounding Conductors for Grounding Raceway and Equipment		
Rating or Setting of Automatic Overcurrent Device in Circuit Ahead of Equipment, Conduit, etc., Not Exceeding (Amperes)	Size (AWG or kcmil)	
	Copper	Aluminum or Copper-Clad Aluminum*
15	14	12
20	12	10
60	10	8
100	8	6

Figure 69 Table 250.122, NEC 2011

Trade Size		Wire Size (THWN, THHN) Conductor Size AWG/kcmil																			
		14	12	10	8	6	4	3	2	1	1/0	2/0	3/0	4/0	250	300	350	400	500	600	700	750
1/2	EMT	12	9	5	3	2	1	1	1	1	1											
	IMC	14	10	6	3	2	1	1	1	1	1	1										
	GRC	13	9	6	3	2	1	1	1	1	1											
3/4	EMT	22	16	10	6	4	2	1	1	1	1	1	1	1								
	IMC	24	17	11	6	4	3	2	1	1	1	1	1	1								
	GRC	22	16	10	6	4	2	1	1	1	1	1	1	1								

Figure 70 Appendix C, NEC 2011

Conclusions and Recommendations

My conclusion of Cisco Stadium Vision is that it is a cost effective, extremely beneficial system for any venue. The simplicity of the system is amazing and the connectivity to an existing system is perfect. StadiumVision can easily be installed in Towson Arena and distributed across and IP network to all the TV locations that already exist as well as new locations around the concourse and other areas. Through many case studies of venues using StadiumVision currently, the management teams have seen great returns on their investments immediately. CONSOL Energy Center (Pittsburgh, PA) saw a 200 percent increase in the number of advertisers, 300 percent increase in concourse advertising and sponsorship revenues, and created a more memorable and impactful brand experience with 80 percent of fans retaining the digital content they viewed.

"The value that we are receiving from Cisco Stadium Vision far outweighs just a financial investment. We can easily justify it financially, but the value to our brand is immeasurable. We can demonstrate to sponsors and fans that they gain a far better experience, and there is not a more effective way to do it." – David Peart, Senior Vice President of Sales and Service, CONSOL Energy Center

In another case study, Staples Center (Los Angeles, CA) saw a 9 percent increase in revenue from concessions in a trial month in March and a 400 percent increase in revenue from select pilot promotions offered. Other applications of Cisco can be found in Dallas Cowboys Stadium, Toronto Blue Jays Ball Park, and Metlife Stadium.

"Cisco solutions are helping us use our new home to deliver the biggest and best experience in the world of sports and entertainment." - Jerry Jones .Owner and General Manager, Dallas Cowboys

It is evident through the above select case studies and comments from owners, general managers, and other users of Cisco that Stadium Vision has been a great financial investment for them, and more importantly, their fans. They look forward to working closely with Cisco in the future to continually advance the technology and its capabilities. Cisco StadiumVision should be a staple in any sports and entertainment venue, and I believe Tiger Arena and Towson would greatly benefit from the addition of this system and all it can offer them.

Resources

General

Towson Tiger Arena Contract Documents (8-14-12)

Analysis 1: DuctSox

ASHRAE standards 62.1. (2010). Retrieved from http://openpub.realread.com/rrserver/browser?title=/ASHRAE_1/ashrae_62_1_2010_1024

"Commercial and Industrial Fabric HVAC Ductwork Leader | DuctSox." *Ductsox.* N.p., n.d. Web. 16 Mar. 2013.

DuctSox Sales and Marketing Associates

Analysis 2: Prefabricated Terra Cotta Panels

"Home - Terreal Terracotta." *Terreal Terracotta.* N.p., n.d. Web. 16 Mar. 2013.

"NeaCera the Next Generation of Terra-Cotta Panels Architectural Back Ventilated Rainscreen Cladding." *NeaCera the Next Generation of Terra-Cotta Panels Architectural Back Ventilated Rainscreen Cladding.* N.p., n.d. Web. 16 Mar. 2013.

"Optimo Smooth." *Kingspanpanels.* N.p., n.d. Web. 16 Mar. 2013.

Wyatt Inc. *(PSUEC Building, Harrisburg, PA)*

Analysis 3: Production Planning and Re-sequencing

Smith , Adrian . "Agile and Lean Applied to Construction." . Ennova, 22 Sept 2011. Web. 23 Mar 2013. <http://ennova.com.au/blog/2011/09/agile-lean-compared-applied-construction>.

Howell, Gregory. "A Guide to the Last Planner for Construction Foremen and Supervisors." *Lean Construction Institute.* n. page. Print. <http://leanconstruction.org/news.htm>.

Analysis 4: Cisco StadiumVision

Cisco StadiumVision. 3.0. San Jose: Cisco Systems, Inc, 2012. Print.

Cisco stadiumvision. (n.d.). Retrieved from http://www.cisco.com/web/strategy/sports/StadiumVision.html

Cisco. (2012). Consol energy center energizes fans and sponsers. *Customer Case Study*

APPENDIX A: Project Overview

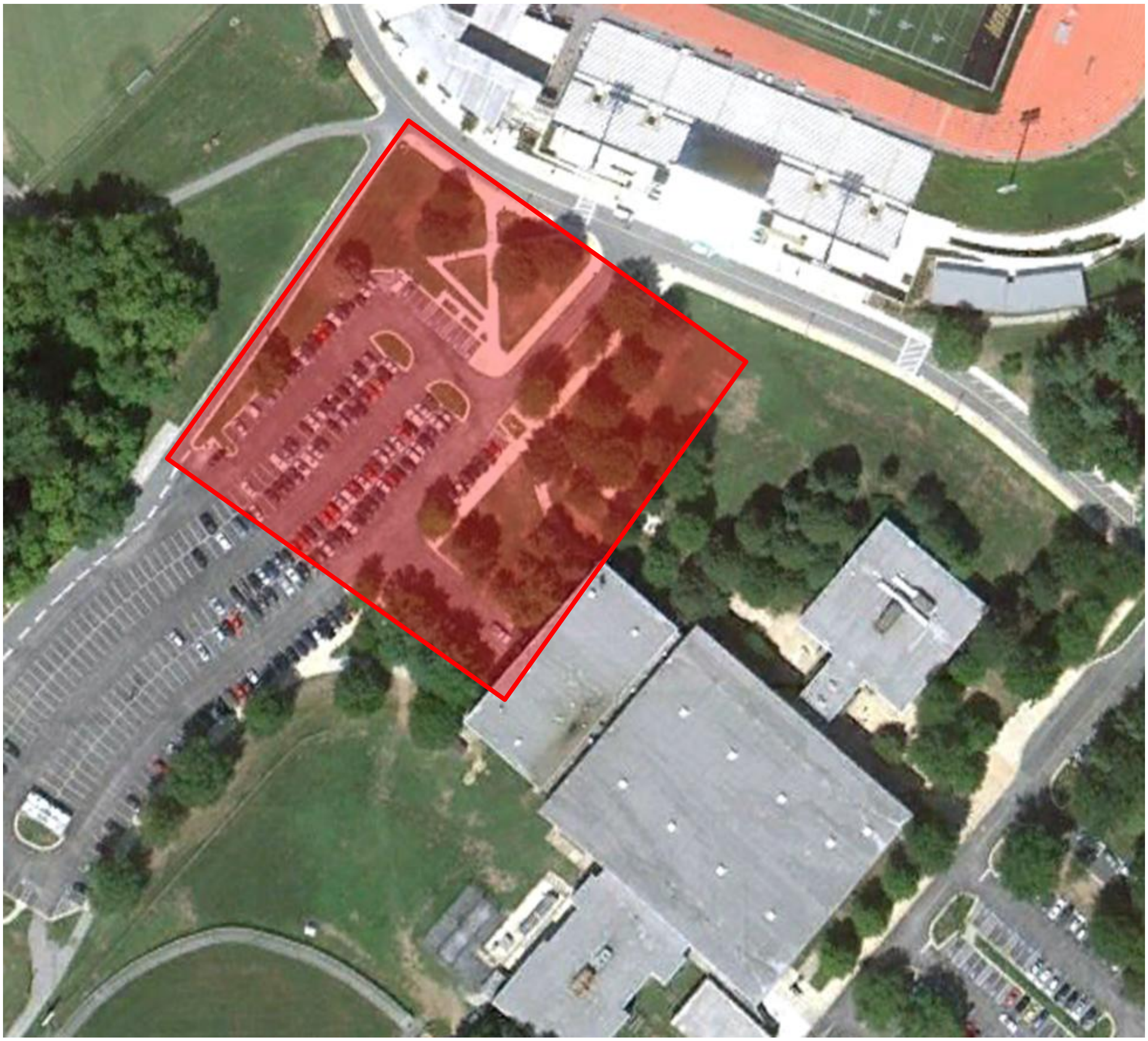


Figure 71 Proposed Site Location, google maps

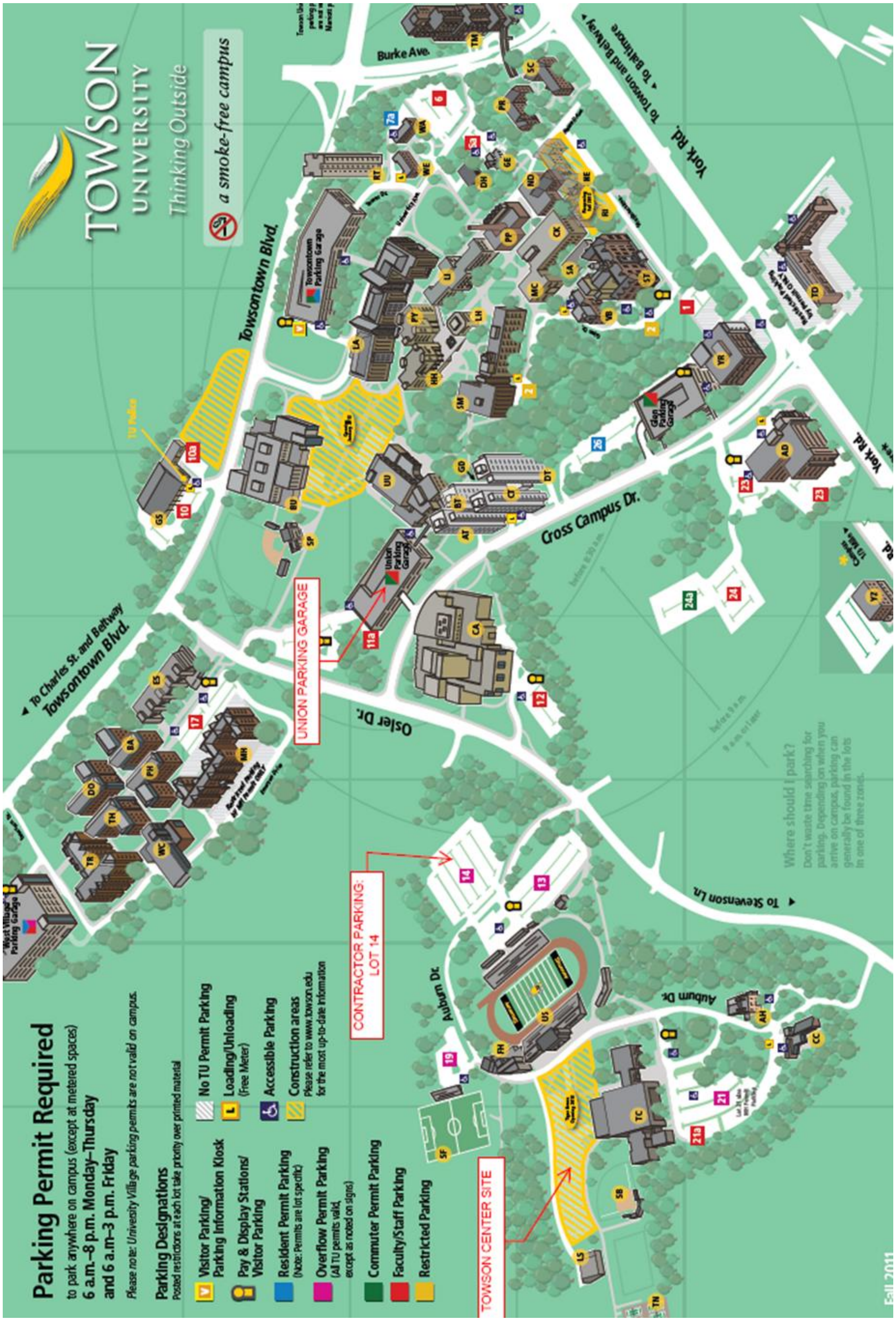


Figure 72 Towson University Campus Map, TU.com

APPENDIX B: Construction Overview

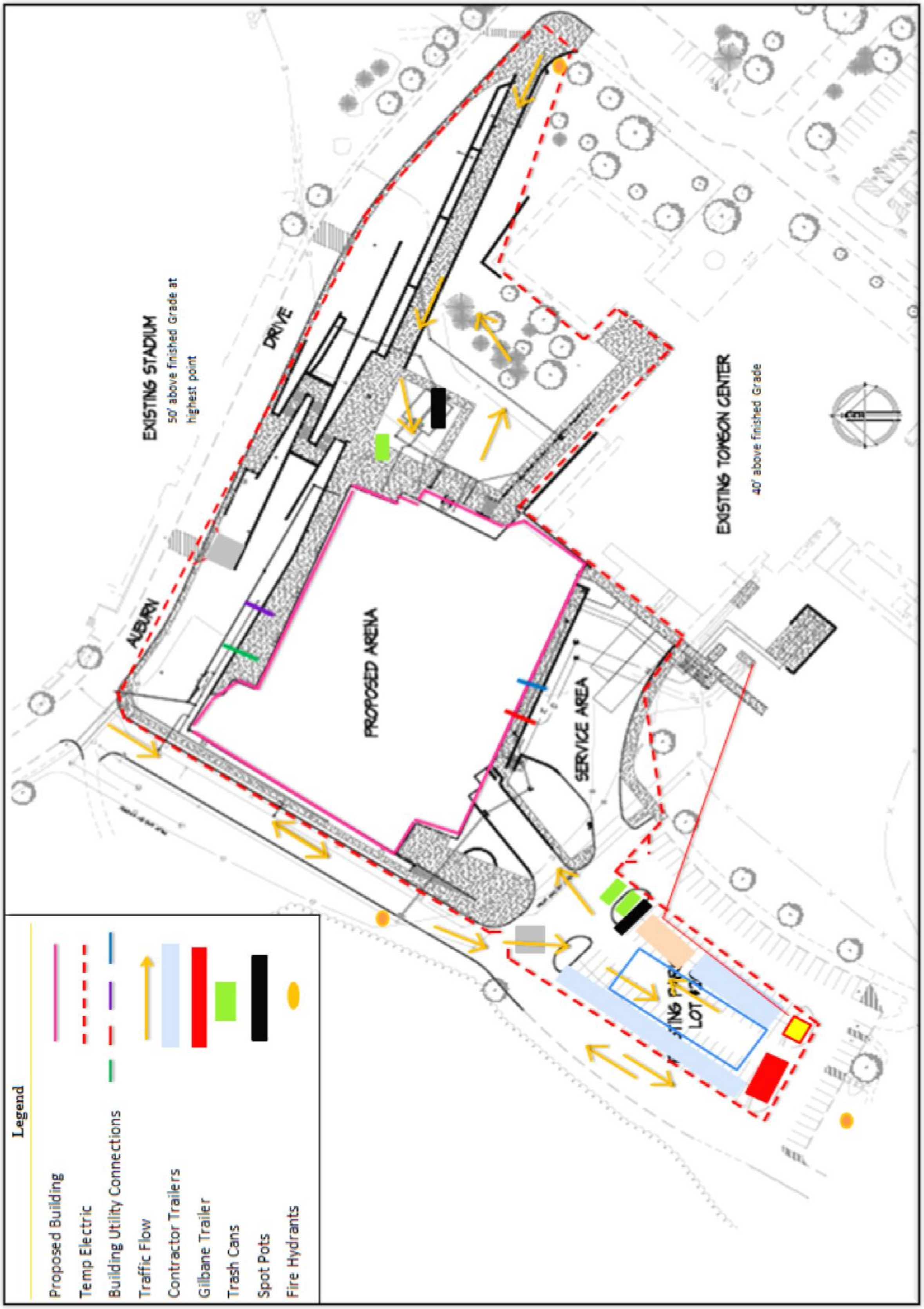


Figure 73 Tiger Arena Site Map, created by Derek Stoecklein

APPENDIX C: Fabric Duct Analysis

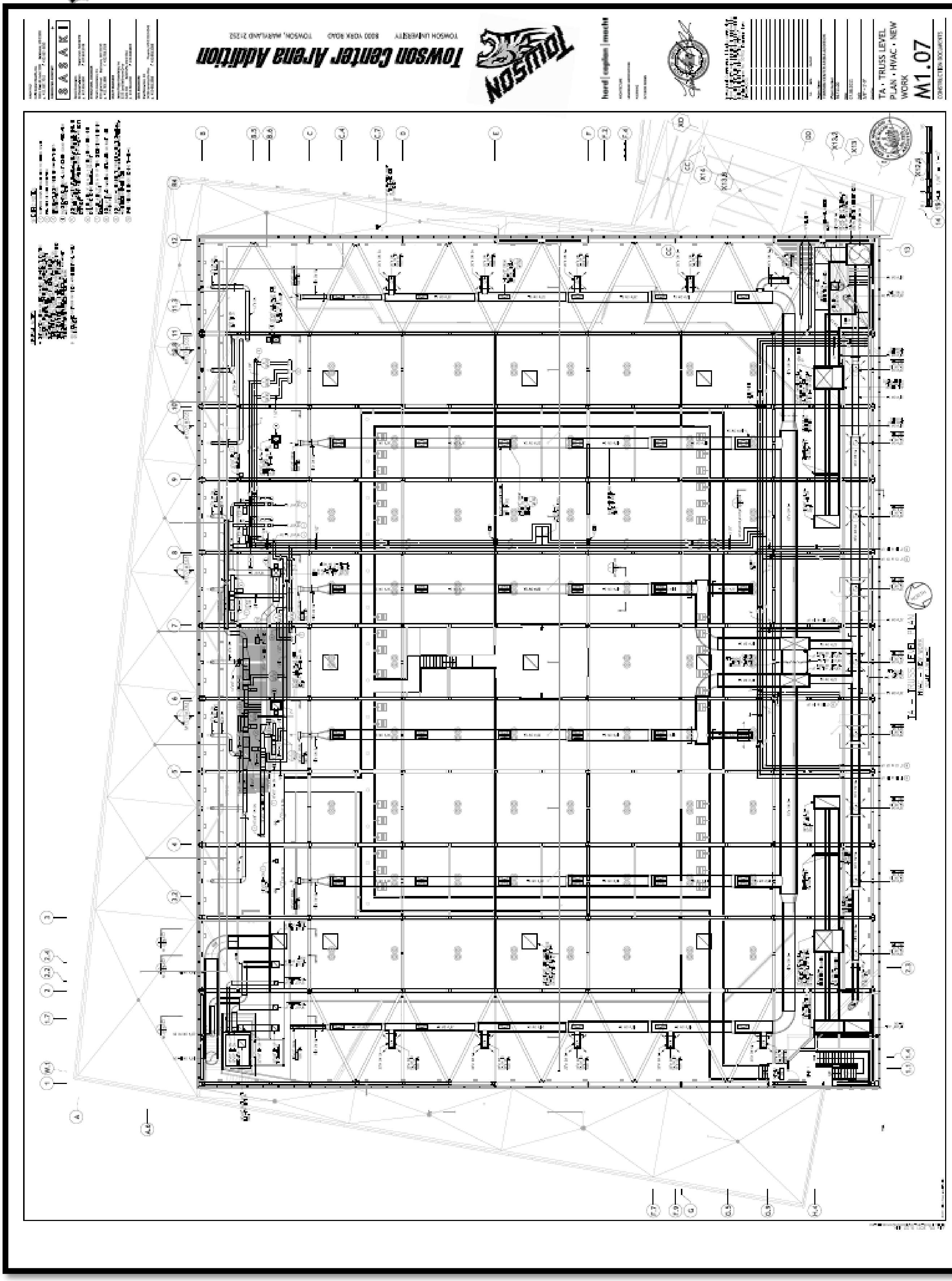


Figure 74Existing Mechanical System in Trusses, TA Contract Documents

Zone Checksums

By ACADEMIC

Court

COOLING COIL PEAK / CLG SPACE PEAK

Cooling Coil Peak — Peaked at Time: Mo/Hr: 7 / 18; Outside Air: OADB/WB/HR: 87 / 74 / 106

CLG Space Peak — Mo/Hr: 7 / 18; OADB: 87

	Space Sens. + Lat. Btu/h	Plenum Sens. + Lat Btu/h	Net Total Btu/h	Percent Of Total (%)	Space Sensible Btu/h	Percent Of Total (%)
Envelope Loads						
Skylite Solar	0	0	0	0	0	0
Skylite Cond	0	0	0	0	0	0
Roof Cond	41,134	0	41,134	4	41,134	5
Glass Solar	0	0	0	0	0	0
Glass/Door Cond	0	0	0	0	0	0
Wall Cond	0	0	0	0	0	0
Partition/Door	8,345		8,345	1	8,345	1
Floor	0		0	0	0	0
Adjacent Floor	0	0	0	0	0	0
Infiltration	0		0	0	0	0
Sub Total ==>	49,479	0	49,479	5	49,479	7
Internal Loads						
Lights	159,974	0	159,974	16	159,974	21
People	660,000	0	660,000	68	450,000	59
Misc	101,317	0	101,317	10	101,317	13
Sub Total ==>	921,291	0	921,291	95	711,291	93
Ceiling Load	0	0	0	0	0	0
Ventilation Load	0	0	0	0	0	0
Adj Air Trans Heat	0		0	0	0	0
Dehumid. Ov Sizing			0	0		
Ov/Undr Sizing	0		0	0	0	0
Exhaust Heat		0	0	0		
Sup. Fan Heat			0	0		
Ret. Fan Heat		0	0	0		
Duct Heat Pkup		0	0	0		
Underflr Sup Ht Pkup			0	0		
Supply Air Leakage		0	0	0		
Grand Total ==>	970,770	0	970,771	100.00	760,770	100.00

HEATING COIL PEAK

Mo/Hr: Heating Design; OADB: 13

	Space Peak Space Sens Btu/h	Coil Peak Tot Sens Btu/h	Percent Of Total (%)
Envelope Loads			
Skylite Solar	0	0	0.00
Skylite Cond	0	0	0.00
Roof Cond	-82,378	-82,378	90.80
Glass Solar	0	0	0.00
Glass/Door Cond	0	0	0.00
Wall Cond	0	0	0.00
Partition/Door	-8,345	-8,345	9.20
Floor	0	0	0.00
Adjacent Floor	0	0	0.00
Infiltration	0	0	0.00
Sub Total ==>	-90,723	-90,723	100.00
Internal Loads			
Lights	0	0	0.00
People	0	0	0.00
Misc	0	0	0.00
Sub Total ==>	0	0	0.00
Ceiling Load	0	0	0.00
Ventilation Load	0	0	0.00
Adj Air Trans Heat	0	0	0
Ov/Undr Sizing	0	0	0.00
Exhaust Heat		0	0.00
OA Preheat Diff.		0	0.00
RA Preheat Diff.		0	0.00
Additional Reheat		0	0.00
System Plenum Heat		0	0.00
Underflr Sup Ht Pkup		0	0.00
Supply Air Leakage		0	0.00
Grand Total ==>	-90,723	-90,723	100.00

TEMPERATURES

	Cooling	Heating
SADB	54.0	78.3
Ra Plenum	75.0	70.0
Return	75.0	70.0
Ret/OA	75.0	70.0
Fn MtrTD	0.0	0.0
Fn BldTD	0.0	0.0
Fn Frict	0.0	0.0

AIRFLOWS

	Cooling	Heating
Diffuser	32,733	9,820
Terminal	32,733	9,820
Main Fan	32,733	9,820
Sec Fan	0	0
Nom Vent	0	0
AHU Vent	0	0
Infil	0	0
MinStop/Rh	9,820	9,820
Return	32,733	9,820
Exhaust	0	0
Rm Exh	0	0
Auxiliary	0	0
Leakage Dwn	0	0
Leakage Ups	0	0

ENGINEERING CKS

	Cooling	Heating
% OA	0.0	0.0
cfm/ft²	1.26	0.38
cfm/ton	404.62	
ft²/ton	321.89	
Btu/hr·ft²	37.28	-3.48
No. People	2,000	

COOLING COIL SELECTION

	Total Capacity ton	Total Capacity MBh	Sens Cap. MBh	Coil Airflow cfm	Enter DB °F	Enter WB °F	Enter HR gr/lb	Leave DB °F	Leave WB °F	Leave HR gr/lb
Main Clg	80.9	970.8	760.8	32,733	75.0	62.6	65.4	54.0	52.4	56.2
Aux Clg	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0
Opt Vent	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0
Total	80.9	970.8								

AREAS

	Gross Total	Glass ft²	Glass (%)
Floor	26,040		
Part	11,736		
Int Door	0		
ExFlr	0		
Roof	26,040	0	0
Wall	0	0	0
Ext Door	0	0	0

HEATING COIL SELECTION

	Capacity MBh	Coil Airflow cfm	Ent °F	Lvg °F
Main Htg	-90.7	9,820	70.0	78.3
Aux Htg	0.0	0	0.0	0.0
Preheat	0.0	0	0.0	0.0
Humidif	0.0	0	0.0	0.0
Opt Vent	0.0	0	0.0	0.0
Total	-90.7			

Project Name: Towson Tiger Arena
Dataset Name: TRACETowson.trc

TRACE® 700 v6.2.9 calculated at 03:34 PM on 01/30/2013
Alternative - 1 System Checksums Report Page 1 of 4

Figure 75 TRACE Court Checksums, created by Derek Stoecklein

Zone Checksums

By ACADEMIC

Room - 003

COOLING COIL PEAK / CLG SPACE PEAK

Cooling Coil Peak — Peaked at Time: Mo/Hr: 9 / 15; Outside Air: OADB/WB/HR: 84 / 68 / 79

Clg Space Peak — Mo/Hr: 9 / 15; OADB: 84

	Space Sens. + Lat. Btu/h	Plenum Sens. + Lat Btu/h	Net Total Btu/h	Percent Of Total (%)	Space Sensible Btu/h	Percent Of Total (%)
Envelope Loads						
Skylite Solar	0	0	0	0	0	0
Skylite Cond	0	0	0	0	0	0
Roof Cond	5,981	0	5,981	1	5,981	1
Glass Solar	191,415	0	191,415	28	191,415	34
Glass/Door Cond	11,672	0	11,672	2	11,672	2
Wall Cond	86,135	0	86,135	13	86,135	15
Partition/Door	2,500		2,500	0	2,500	0
Floor	0		0	0	0	0
Adjacent Floor	0	0	0	0	0	0
Infiltration	0		0	0	0	0
Sub Total ==>	297,703	0	297,703	44	297,703	52
Internal Loads						
Lights	46,076	0	46,076	7	46,076	8
People	330,000	0	330,000	49	225,000	40
Misc	0	0	0	0	0	0
Sub Total ==>	376,076	0	376,076	56	271,076	48
Ceiling Load	0	0	0	0	0	0
Ventilation Load	0	0	0	0	0	0
Adj Air Trans Heat	0		0	0	0	0
Dehumid. Ov Sizing			0	0		
Ov/Undr Sizing	0		0	0	0	0
Exhaust Heat		0	0	0		
Sup. Fan Heat			0	0		
Ret. Fan Heat		0	0	0		
Duct Heat Pkup		0	0	0		
Underflr Sup Ht Pkup			0	0		
Supply Air Leakage		0	0	0		
Grand Total ==>	673,778	0	673,779	100.00	568,778	100.00

HEATING COIL PEAK

Mo/Hr: Heating Design; OADB: 13

	Space Peak Space Sens Btu/h	Coil Peak Tot Sens Btu/h	Percent Of Total (%)
Envelope Loads			
Skylite Solar	0	0	0.00
Skylite Cond	0	0	0.00
Roof Cond	-23,726	-23,726	11.82
Glass Solar	0	0	0.00
Glass/Door Cond	-87,724	-87,724	43.70
Wall Cond	-86,777	-86,777	43.23
Partition/Door	-2,500	-2,500	1.25
Floor	0	0	0.00
Adjacent Floor	0	0	0.00
Infiltration	0	0	0.00
Sub Total ==>	-200,727	-200,727	100.00
Internal Loads			
Lights	0	0	0.00
People	0	0	0.00
Misc	0	0	0.00
Sub Total ==>	0	0	0.00
Ceiling Load	0	0	0.00
Ventilation Load	0	0	0.00
Adj Air Trans Heat	0	0	0
Ov/Undr Sizing	0	0	0.00
Exhaust Heat		0	0.00
OA Preheat Diff.		0	0.00
RA Preheat Diff.		0	0.00
Additional Reheat		0	0.00
System Plenum Heat		0	0.00
Underflr Sup Ht Pkup		0	0.00
Supply Air Leakage		0	0.00
Grand Total ==>	-200,727	-200,727	100.00

TEMPERATURES

	Cooling	Heating
SADB	56.9	91.3
Ra Plenum	75.0	70.0
Return	75.0	70.0
Ret/OA	75.0	70.0
Fn MtrTD	0.0	0.0
Fn BldTD	0.0	0.0
Fn Frict	0.0	0.0

AIRFLOWS

	Cooling	Heating
Diffuser	28,289	8,487
Terminal	28,289	8,487
Main Fan	28,289	8,487
Sec Fan	0	0
Nom Vent	0	0
AHU Vent	0	0
Infil	0	0
MinStop/Rh	8,487	8,487
Return	28,289	8,487
Exhaust	0	0
Rm Exh	0	0
Auxiliary	0	0
Leakage Dwn	0	0
Leakage Ups	0	0

ENGINEERING CKS

	Cooling	Heating
% OA	0.0	0.0
cfm/ft²	3.77	1.13
cfm/ton	503.82	
ft²/ton	133.58	
Btu/hr·ft²	89.84	-26.76
No. People	1,000	

COOLING COIL SELECTION

	Total Capacity ton	Total Capacity MBh	Sens Cap. MBh	Coil Airflow cfm	Enter DB °F	Enter WB °F	Enter HR gr/lb	Leave DB °F	Leave WB °F	Leave HR gr/lb
Main Clg	56.2	673.8	568.8	28,289	75.0	62.5	65.1	56.9	54.5	59.8
Aux Clg	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0
Opt Vent	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0
Total	56.2	673.8								

AREAS

	Gross Total	Glass ft²	Glass (%)
Floor	7,500		
Part	3,348		
Int Door	0		
ExFlr	0		
Roof	7,500	0	0
Wall	15,500	3,800	25
Ext Door	0	0	0

HEATING COIL SELECTION

	Capacity MBh	Coil Airflow cfm	Ent °F	Lvg °F
Main Htg	-200.7	8,487	70.0	91.3
Aux Htg	0.0	0	0.0	0.0
Preheat	0.0	0	0.0	0.0
Humidif	0.0	0	0.0	0.0
Opt Vent	0.0	0	0.0	0.0
Total	-200.7			

Project Name: Towson Tiger Arena
Dataset Name: TRACETowson.trc

TRACE® 700 v6.2.9 calculated at 03:34 PM on 01/30/2013
Alternative - 1 System Checksums Report Page 2 of 4

Figure 76 TRACE Room 003 Checksum, created by Derek Stoecklein

Zone Checksums

By ACADEMIC

Room - 004

COOLING COIL PEAK / CLG SPACE PEAK

Cooling Coil Peak — Peaked at Time: Mo/Hr: 7 / 10; Outside Air: OADB/WB/HR: 81 / 72 / 106

CLG Space Peak — Mo/Hr: 7 / 10; OADB: 81

	Space Sens. + Lat. Btu/h	Plenum Sens. + Lat Btu/h	Net Total Btu/h	Percent Of Total (%)	Space Sensible Btu/h	Percent Of Total (%)
Envelope Loads						
Skylite Solar	0	0	0	0	0	0
Skylite Cond	0	0	0	0	0	0
Roof Cond	3,496	0	3,496	1	3,496	1
Glass Solar	62,401	0	62,401	17	62,401	21
Glass/Door Cond	1,642	0	1,642	0	1,642	1
Wall Cond	45,977	0	45,977	13	45,977	16
Partition/Door	1,881		1,881	1	1,881	1
Floor	0		0	0	0	0
Adjacent Floor	0	0	0	0	0	0
Infiltration	0		0	0	0	0
Sub Total ==>	115,397	0	115,397	32	115,397	39
Internal Loads						
Lights	30,103	0	30,103	8	30,103	10
People	220,110	0	220,110	60	150,075	51
Misc	0	0	0	0	0	0
Sub Total ==>	250,213	0	250,213	68	180,178	61
Ceiling Load	0	0	0	0	0	0
Ventilation Load	0	0	0	0	0	0
Adj Air Trans Heat	0		0	0	0	0
Dehumid. Ov Sizing			0	0		
Ov/Undr Sizing	0		0	0	0	0
Exhaust Heat		0	0	0		
Sup. Fan Heat			0	0		
Ret. Fan Heat		0	0	0		
Duct Heat Pkup		0	0	0		
Underflr Sup Ht Pkup			0	0		
Supply Air Leakage		0	0	0		
Grand Total ==>	365,610	0	365,610	100.00	295,575	100.00

HEATING COIL PEAK

Mo/Hr: Heating Design; OADB: 13

	Space Peak Space Sens Btu/h	Coil Peak Tot Sens Btu/h	Percent Of Total (%)
Envelope Loads			
Skylite Solar	0	0	0.00
Skylite Cond	0	0	0.00
Roof Cond	-15,501	-15,501	17.70
Glass Solar	0	0	0.00
Glass/Door Cond	-26,566	-26,566	30.34
Wall Cond	-43,611	-43,611	49.81
Partition/Door	-1,881	-1,881	2.15
Floor	0	0	0.00
Adjacent Floor	0	0	0.00
Infiltration	0	0	0.00
Sub Total ==>	-87,559	-87,559	100.00
Internal Loads			
Lights	0	0	0.00
People	0	0	0.00
Misc	0	0	0.00
Sub Total ==>	0	0	0.00
Ceiling Load	0	0	0.00
Ventilation Load	0	0	0.00
Adj Air Trans Heat	0	0	0
Ov/Undr Sizing	0	0	0.00
Exhaust Heat		0	0.00
OA Preheat Diff.		0	0.00
RA Preheat Diff.		0	0.00
Additional Reheat		0	0.00
System Plenum Heat		0	0.00
Underflr Sup Ht Pkup		0	0.00
Supply Air Leakage		0	0.00
Grand Total ==>	-87,559	-87,559	100.00

TEMPERATURES

	Cooling	Heating
SADB	55.4	89.4
Ra Plenum	75.0	70.0
Return	75.0	70.0
Ret/OA	75.0	70.0
Fn MtrTD	0.0	0.0
Fn BldTD	0.0	0.0
Fn Frict	0.0	0.0

AIRFLOWS

	Cooling	Heating
Diffuser	13,581	4,074
Terminal	13,581	4,074
Main Fan	13,581	4,074
Sec Fan	0	0
Nom Vent	0	0
AHU Vent	0	0
Infil	0	0
MinStop/Rh	4,074	4,074
Return	13,581	4,074
Exhaust	0	0
Rm Exh	0	0
Auxiliary	0	0
Leakage Dwn	0	0
Leakage Ups	0	0

ENGINEERING CKS

	Cooling	Heating
% OA	0.0	0.0
cfm/ft²	2.77	0.83
cfm/ton	445.75	
ft²/ton	160.83	
Btu/hr·ft²	74.61	-17.87
No. People	667	

COOLING COIL SELECTION

	Total Capacity ton	Total Capacity MBh	Sens Cap. MBh	Coil Airflow cfm	Enter DB °F	Enter WB °F	Enter HR gr/lb	Leave DB °F	Leave WB °F	Leave HR gr/lb
Main Clg	30.5	365.6	295.6	13,581	75.0	62.5	65.3	55.4	53.4	57.9
Aux Clg	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0
Opt Vent	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0
Total	30.5	365.6								

AREAS

	Gross Total	Glass ft²	Glass (%)
Floor	4,900		
Part	2,520		
Int Door	0		
ExFlr	0		
Roof	4,900	0	0
Wall	7,000	1,120	16
Ext Door	0	0	0

HEATING COIL SELECTION

	Capacity MBh	Coil Airflow cfm	Ent °F	Lvg °F
Main Htg	-87.6	4,074	70.0	89.4
Aux Htg	0.0	0	0.0	0.0
Preheat	0.0	0	0.0	0.0
Humidif	0.0	0	0.0	0.0
Opt Vent	0.0	0	0.0	0.0
Total	-87.6			

Project Name: Towson Tiger Arena
Dataset Name: TRACETowson.trc

TRACE® 700 v6.2.9 calculated at 03:34 PM on 01/30/2013
Alternative - 1 System Checksums Report Page 3 of 4

Figure 77 TRACE Room 004 Checksum, created by Derek Stoecklein

Zone Checksums

By ACADEMIC

Room - 005

COOLING COIL PEAK / CLG SPACE PEAK

Cooling Coil Peak — Peaked at Time: Mo/Hr: 7 / 18; Outside Air: OADB/WB/HR: 87 / 74 / 106

CLG Space Peak — Mo/Hr: 7 / 18; OADB: 87

	Space Sens. + Lat. Btu/h	Plenum Sens. + Lat Btu/h	Net Total Btu/h	Percent Of Total (%)	Space Sensible Btu/h	Percent Of Total (%)
Envelope Loads						
Skylite Solar	0	0	0	0	0	0
Skylite Cond	0	0	0	0	0	0
Roof Cond	7,740	0	7,740	2	7,740	2
Glass Solar	62,969	0	62,969	16	62,969	20
Glass/Door Cond	6,150	0	6,150	2	6,150	2
Wall Cond	56,873	0	56,873	15	56,873	18
Partition/Door	1,881		1,881	0	1,881	1
Floor	0		0	0	0	0
Adjacent Floor	0	0	0	0	0	0
Infiltration	0		0	0	0	0
Sub Total ==>	135,613	0	135,613	35	135,613	43
Internal Loads						
Lights	30,103	0	30,103	8	30,103	10
People	220,110	0	220,110	57	150,075	48
Misc	0	0	0	0	0	0
Sub Total ==>	250,213	0	250,213	65	180,178	57
Ceiling Load	0	0	0	0	0	0
Ventilation Load	0	0	0	0	0	0
Adj Air Trans Heat	0		0	0	0	0
Dehumid. Ov Sizing			0	0		
Ov/Undr Sizing	0		0	0	0	0
Exhaust Heat		0	0	0		
Sup. Fan Heat			0	0		
Ret. Fan Heat		0	0	0		
Duct Heat Pkup		0	0	0		
Underflr Sup Ht Pkup			0	0		
Supply Air Leakage		0	0	0		
Grand Total ==>	385,826	0	385,826	100.00	315,791	100.00

HEATING COIL PEAK

Mo/Hr: Heating Design; OADB: 13

	Space Peak Space Sens Btu/h	Coil Peak Tot Sens Btu/h	Percent Of Total (%)
Envelope Loads			
Skylite Solar	0	0	0.00
Skylite Cond	0	0	0.00
Roof Cond	-15,501	-15,501	17.70
Glass Solar	0	0	0.00
Glass/Door Cond	-26,566	-26,566	30.34
Wall Cond	-43,611	-43,611	49.81
Partition/Door	-1,881	-1,881	2.15
Floor	0	0	0.00
Adjacent Floor	0	0	0.00
Infiltration	0	0	0.00
Sub Total ==>	-87,559	-87,559	100.00
Internal Loads			
Lights	0	0	0.00
People	0	0	0.00
Misc	0	0	0.00
Sub Total ==>	0	0	0.00
Ceiling Load	0	0	0.00
Ventilation Load	0	0	0.00
Adj Air Trans Heat	0	0	0
Ov/Undr Sizing	0	0	0.00
Exhaust Heat		0	0.00
OA Preheat Diff.		0	0.00
RA Preheat Diff.		0	0.00
Additional Reheat		0	0.00
System Plenum Heat		0	0.00
Underflr Sup Ht Pkup		0	0.00
Supply Air Leakage		0	0.00
Grand Total ==>	-87,559	-87,559	100.00

TEMPERATURES

	Cooling	Heating
SADB	55.8	87.7
Ra Plenum	75.0	70.0
Return	75.0	70.0
Ret/OA	75.0	70.0
Fn MtrTD	0.0	0.0
Fn BldTD	0.0	0.0
Fn Frict	0.0	0.0

AIRFLOWS

	Cooling	Heating
Diffuser	14,832	4,450
Terminal	14,832	4,450
Main Fan	14,832	4,450
Sec Fan	0	0
Nom Vent	0	0
AHU Vent	0	0
Infil	0	0
MinStop/Rh	4,450	4,450
Return	14,832	4,450
Exhaust	0	0
Rm Exh	0	0
Auxiliary	0	0
Leakage Dwn	0	0
Leakage Ups	0	0

ENGINEERING CKS

	Cooling	Heating
% OA	0.0	0.0
cfm/ft²	3.03	0.91
cfm/ton	461.30	
ft²/ton	152.40	
Btu/hr·ft²	78.74	-17.87
No. People	667	

COOLING COIL SELECTION

	Total Capacity ton	Total Capacity MBh	Sens Cap. MBh	Coil Airflow cfm	Enter DB °F	Enter WB °F	Enter HR gr/lb	Leave DB °F	Leave WB °F	Leave HR gr/lb
Main Clg	32.2	385.8	315.8	14,832	75.0	62.5	65.2	55.8	53.7	58.5
Aux Clg	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0
Opt Vent	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0
Total	32.2	385.8								

AREAS

	Gross Total	Glass ft²	Glass (%)
Floor	4,900		
Part	2,520		
Int Door	0		
ExFlr	0		
Roof	4,900	0	0
Wall	7,000	1,120	16
Ext Door	0	0	0

HEATING COIL SELECTION

	Capacity MBh	Coil Airflow cfm	Ent °F	Lvg °F
Main Htg	-87.6	4,450	70.0	87.7
Aux Htg	0.0	0	0.0	0.0
Preheat	0.0	0	0.0	0.0
Humidif	0.0	0	0.0	0.0
Opt Vent	0.0	0	0.0	0.0
Total	-87.6			

Project Name: Towson Tiger Arena
Dataset Name: TRACETowson.trc

TRACE® 700 v6.2.9 calculated at 03:34 PM on 01/30/2013
Alternative - 1 System Checksums Report Page 4 of 4

Figure 78 TRACE Room 005 Checksum, created by Derek Stoecklein

SYSTEM SUMMARY

DESIGN AIRFLOW QUANTITIES

By ACADEMIC

System Description	System Type	MAIN SYSTEM Outside Airflow cfm	MAIN SYSTEM Cooling Airflow cfm	MAIN SYSTEM Heating Airflow cfm	MAIN SYSTEM Return Airflow cfm	MAIN SYSTEM Exhaust Airflow cfm	Auxiliary System Supply Airflow cfm	Room Exhaust Airflow cfm
Alternative 1								
System - 002	Single Zone Variable Air Volume	0	87,041	26,830	87,041	0	0	0
Totals		**0**	**87,041**	**26,830**	**87,041**	**0**	**0**	**0**

Note: Airflows on this report are not additive because they are each taken at the time of their respective peaks. To view the balanced system design airflows, see the appropriate Checksums report (Airflows section).

Project Name: Towson Tiger Arena
Dataset Name: TRACETowson.trc

TRACE® 700 v6.2.9 calculated at 03:34 PM on 01/30/2013
Design Airflow Quantities Report Page 1 of 1

Figure 79 TRACE System Summary, created by Derek Stoecklein

445 EPFN (9-Blade, Arr. 1 and 4)

Wheel Diameter: 44.50" Fan Efficiency Grade = FEG85

CFM	1" SP		2" SP		3" SP		4" SP		5" SP		6" SP		7" SP		8" SP		9" SP		10" SP		12" SP	
	RPM	BHP	RPM	BHP	RPM	BHP	RPM	BHP	RPM	BHP	RPM	BHP	RPM	BHP	RPM	BHP	RPM	BHP	RPM	BHP	RPM	BHP
12000	403	2.47																				
13800	420	2.84																				
15600	440	3.25	560	6.49																		
17400	461	3.68	574	7.17																		
21000	507	4.69	610	8.70	700	12.97																
24600	558	5.92	652	10.42	735	15.24	812	20.30	886	25.69												
28200	612	7.37	697	12.37	775	17.69	846	23.24	914	29.07	978	34.98										
35400	727	11.20	798	17.20	865	23.49	929	30.06	989	36.88	1046	43.92	1101	51.13	1154	58.44	1205	65.81	1256	73.55		
42600	848	16.57	907	23.31	966	30.73	1022	38.28	1077	46.14	1129	54.12	1179	62.36	1226	70.57	1273	79.18	1318	87.76		
49800	972	23.71	1024	31.37	1074	39.50	1124	48.16	1173	57.06	1220	65.99	1266	75.14	1311	84.56	1354	94.06	1396	103.78		
57000			1144	41.50	1188	50.39	1233	60.00	1276	69.79	1319	79.90	1361	90.09	1402	100.39	1443	111.03	1482	121.61		
64200			1267	54.06	1307	63.90	1346	74.08	1386	84.95	1424	95.87	1463	107.31	1500	118.56	1537	130.03				

MAXIMUM RPM: CLASS I = 944 CLASS II = 1202 CLASS III = 1545 **Outlet Area** = 15.38 ft² **Max. BHP** = 38.36 x (RPM / 1000)³

Class I = First white section
Class II = Blue shaded section
Class III = Bolded section after blue section
Underlined figures indicate Maximum Static Efficiency

Performance certified is for installation Type A; Free inlet, Free outlet.
Power rating (BHP) does not include transmission losses.
Performance ratings do not include the effects of appurtenances (accessories).
Performance based on a shaft height of 31.09" above the base on fan size 445.

Figure 80 Twin City 445 EPFN Fan specs, twincity.com

490 EPFN (9-Blade, Arr. 1 and 4)

Wheel Diameter: 49.00" Fan Efficiency Grade = FEG85

CFM	1" SP		2" SP		3" SP		4" SP		5" SP		6" SP		7" SP		8" SP		9" SP		10" SP		12" SP	
	RPM	BHP	RPM	BHP	RPM	BHP	RPM	BHP	RPM	BHP	RPM	BHP	RPM	BHP	RPM	BHP	RPM	BHP	RPM	BHP	RPM	BHP
16000	376	3.29																				
18000	392	3.74																				
20000	409	4.20	514	8.25																		
24000	446	5.26	542	9.89	627	14.89																
28000	487	6.53	576	11.75	654	17.34	726	23.18														
32000	531	8.02	612	13.77	685	19.91	752	26.34	816	33.08												
36000	577	9.77	651	16.09	720	22.78	783	29.79	843	37.13	899	44.48	955	52.38								
44000	673	14.24	736	21.62	797	29.53	854	37.62	908	46.06	958	54.56	1007	63.42	1055	72.53	1101	81.67	1146	91.03		
52000	774	20.34	828	28.62	881	37.63	932	46.90	981	56.35	1028	66.06	1073	76.03	1116	86.13	1158	96.48	1200	107.26		
60000	878	28.34	925	37.53	971	47.38	1017	57.90	1061	68.50	1104	79.29	1147	90.58	1187	101.71	1226	113.14	1264	124.79		
68000			1025	48.61	1066	59.34	1107	70.79	1147	82.60	1186	94.57	1225	106.87	1263	119.30	1300	131.89	1336	144.66		
76000			1127	62.09	1164	73.77	1201	86.08	1237	98.79	1273	111.99	1309	125.58	1343	138.87	1378	152.77				

MAXIMUM RPM: CLASS I = 857 CLASS II = 1091 CLASS III = 1403 **Outlet Area** = 18.64 ft² **Max. BHP** = 62.10 x (RPM / 1000)³

Class I = First white section
Class II = Blue shaded section
Class III = Bolded section after blue section
Underlined figures indicate Maximum Static Efficiency

Performance certified is for installation Type A; Free inlet, Free outlet.
Power rating (BHP) does not include transmission losses.
Performance ratings do not include the effects of appurtenances (accessories).
Performance based on a shaft height of 34.23" above the base on fan size 490.

Figure 81 Twin City 490 EPFN Fan specs, twincity.com

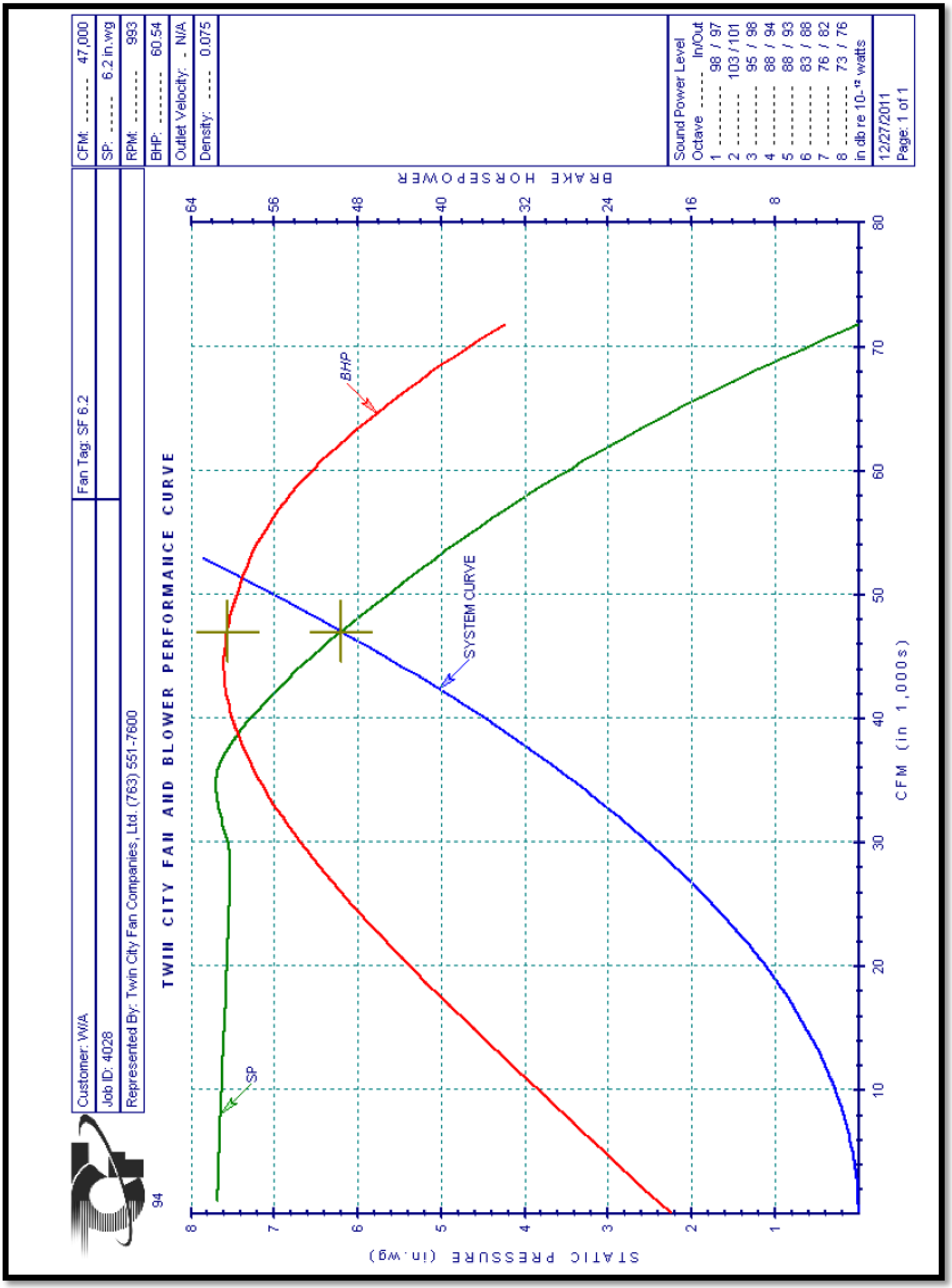


Figure 82 Twin City Fan Performance Chart, Twin City Submittals

Step 1: Estimate the time required to connect the DuctSox System to the inlet.

Inlet Diameter	Man Hours
8" - 24"	.5 Hours
25" - 40"	.75 Hours
41" - 60"	1 Hours

Step 2: Estimate the time required to install the suspension system and to attach the DuctSox System. This includes connecting zippered sections and fittings together. It is important that your estimate is based on straight sections of DuctSox in the same horizontal plane.

Suspension System	Man Hours
SkeleCore FTS	2 Hours for each straight section + 3.5 Hrs. per 42' of length
SkeleCore IHS Cable	2 Hours for each straight section + 0.5 Hr. per 25' of length
SkeleCore IHS Track	2 Hours for each straight section + 0.5 Hr. per 25' of length
Cable	2 Hours for each straight section + 0.5 Hr. per 25' of length
Flush Mount U-Track	2 Hours for each straight section + 1.0 Hr. per 25' of length
Hanging U-Track	2 Hours for each straight section + 1.5 Hrs. per 25' of length
SS Track*	2 Hours for each straight section + 1.5 Hrs. per 25' of length

Times are based on 1-row cable or track. For 2-row systems, multiply time by 2.
Add 10% for diameters that are 25" to 40".
Add 20% for diameters that are 41" to 60".
For D-Shape and Quarter-Round use Flush Mount Track (multiply x 2 for 2-row)
*Food Processing Stainless Steel Track

Special Notes:

- All estimated times are in man hours and achieving estimated times will require minimum two man crews.
- Cable installations based on wall to wall installation and does not include times to manufacture and install knee braces as every job is different in complexity.
- For applications where floor and ceiling elevations change. please consult DuctSox.
- Estimates based on ceiling heights less than 30'. Additional labor required when working at extended heights.
- Estimates based on easy access, without ceiling obstructions.
- Estimated times are conservative for experienced DuctSox installers.

Figure 83 DuctSox Labor Estimate Data, Ductsox.com

APPENDIX D: Terra Cotta Analysis

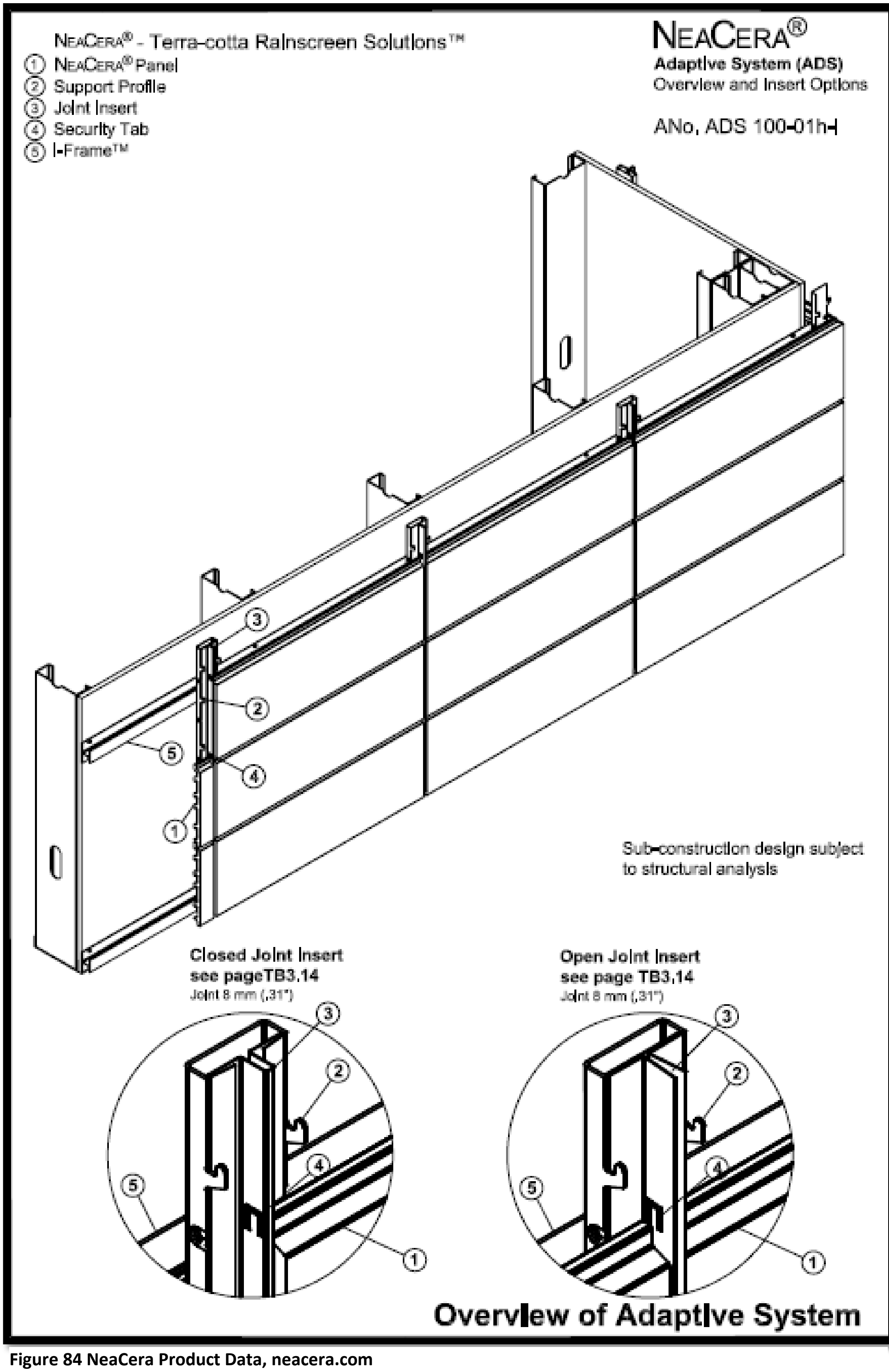


Figure 84 NeaCera Product Data, neacera.com

Getting Started

Created: 08 12 2010
Revised: 09 14 2010

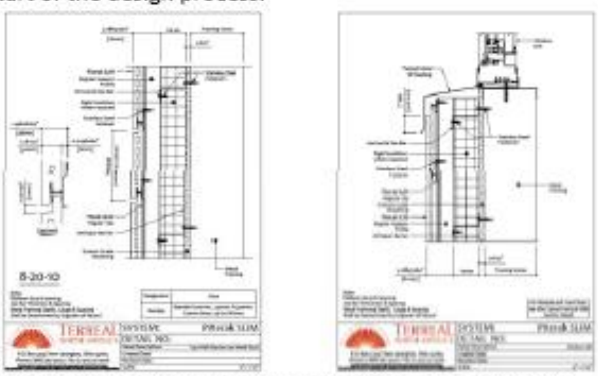
TERREAL NORTH AMERICA

ROOF TILES AND WALL CLADDINGS

Terra Cotta Cladding

Designing A Framing System:

Terreal created the first terra cotta rainscreen system 20 years ago. Terreal's vast terra cotta rainscreen knowledge and experience can help design and detail an efficient system for your project. For technical assistance on the structural framing, wall system design, and project specific details involve Terreal at the start of the design process.



Terreal has the details needed for your wall design – please contact us.

Terra cotta framing systems

Budget Pricing:

Terreal and assistance from our installers can provide accurate budget pricing prior to your project going out to bid. To provide accurate budget numbers, panel size, panel color, panel thickness, and structural framing system design for attachment to the primary structural wall must be provided.

For Single Skin Terra Cotta Panels: Panel System ranges from $9 - $15 / SF (terra cotta panel and support framing)
For Single Skin Terra Cotta Panels: Panel System ranges from $25- $40 / SF (terra cotta and support framing installed)
For Double Skin Terra Cotta Panels: Panel System ranges from $13 - $23 / SF (terra cotta panel and support framing)
For Double Skin Terra Cotta Panels: Panel System ranges from $35 - $60 / SF (terra cotta and support framing installed)
For Factory Panelized Wall Systems (in lieu of field stick built): Panel Systems range from $60 - $90 / SF (installed)

** labor (union vs. non-union), building height, jobsite conditions, jobsite location & panelized vs. "stick build" in field all can influence the budget numbers shown above
** budget numbers above include estimated freight from Europe, excludes all applicable sales tax
** budget numbers above are for standard products, standard colors, and standard textures

Installers:

Terra cotta rainscreen systems can be and have been installed by many different construction trades. Terreal and its family of natural building product manufacturers can help locate qualified installers for your project. Please contact us for assistance on finding the right installation partner for your project.

Field Cutting Terra Cotta Panels

Figure 85 Terreal Cost Data, terreal.com

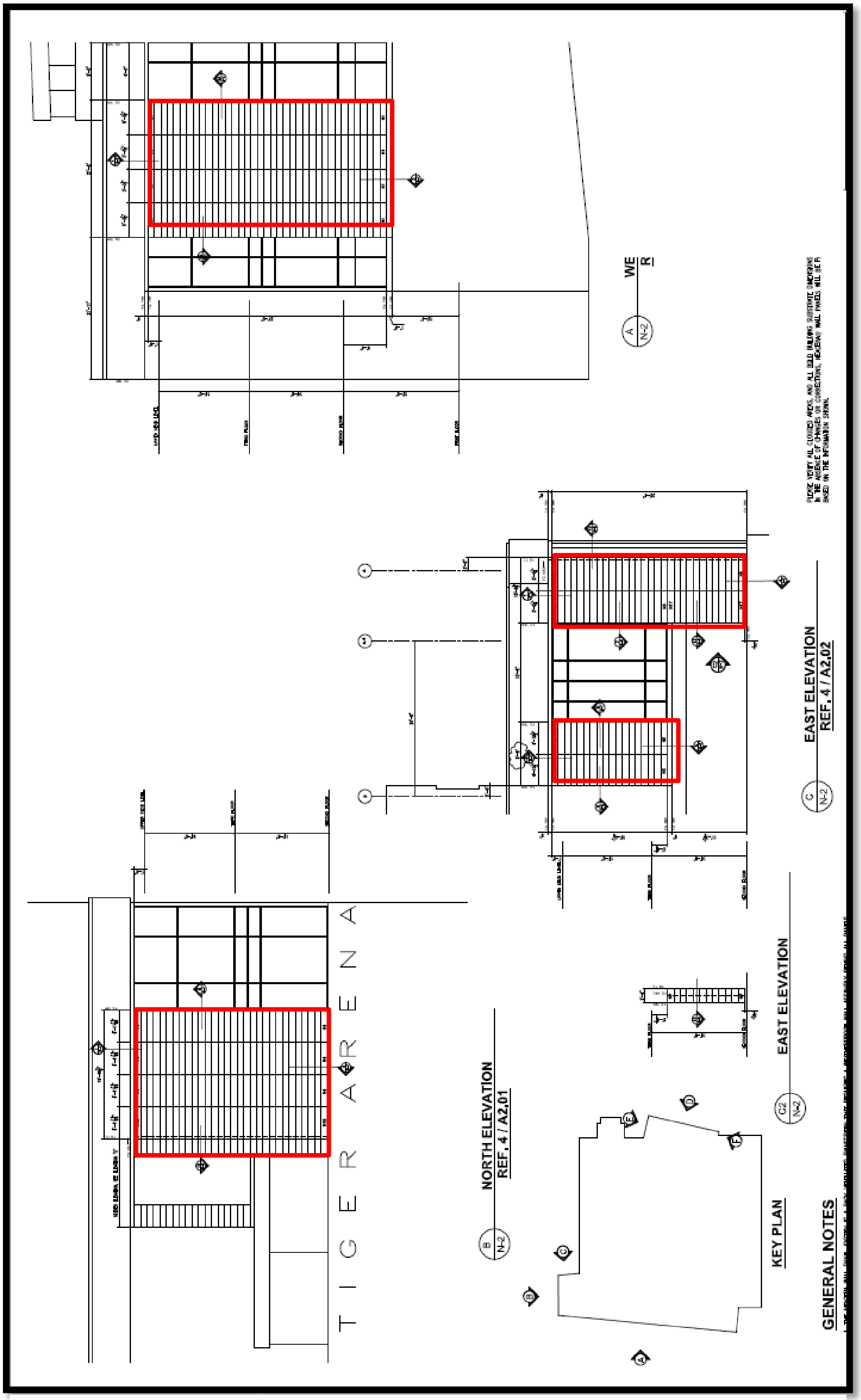


Figure 86 TA Terra Cotta Panel Locations, Ta Contrcat Documents

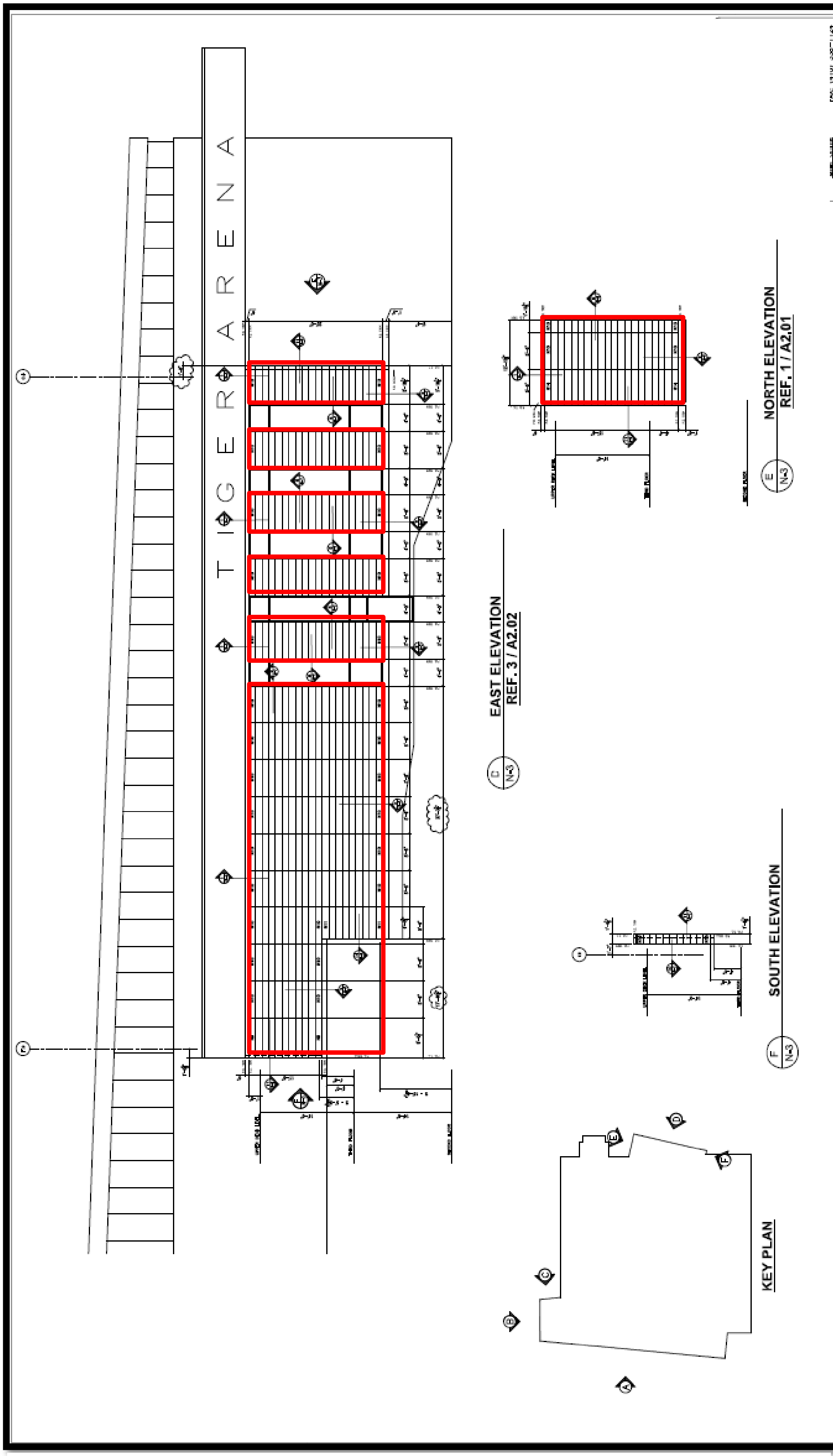


Figure 87 TA Terra Cotta Panel Locations, Ta Contrcat Documents

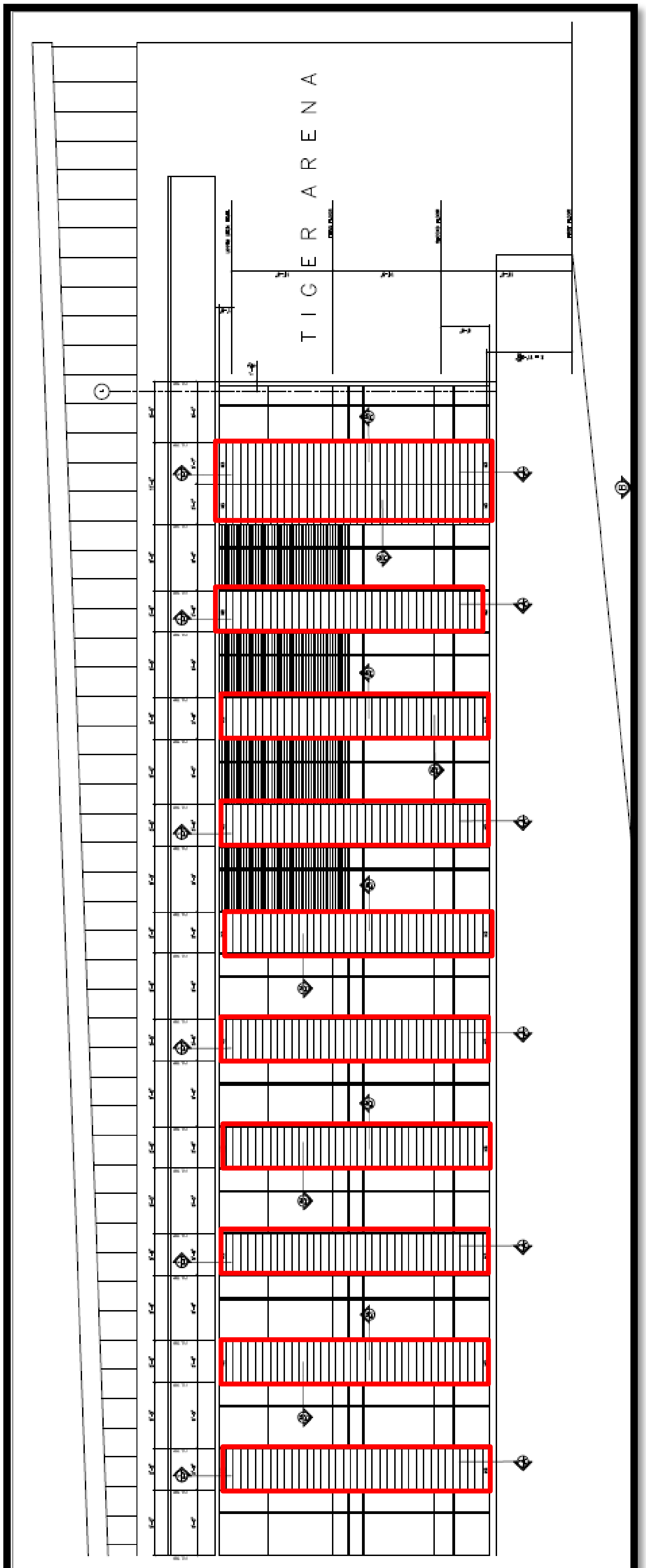
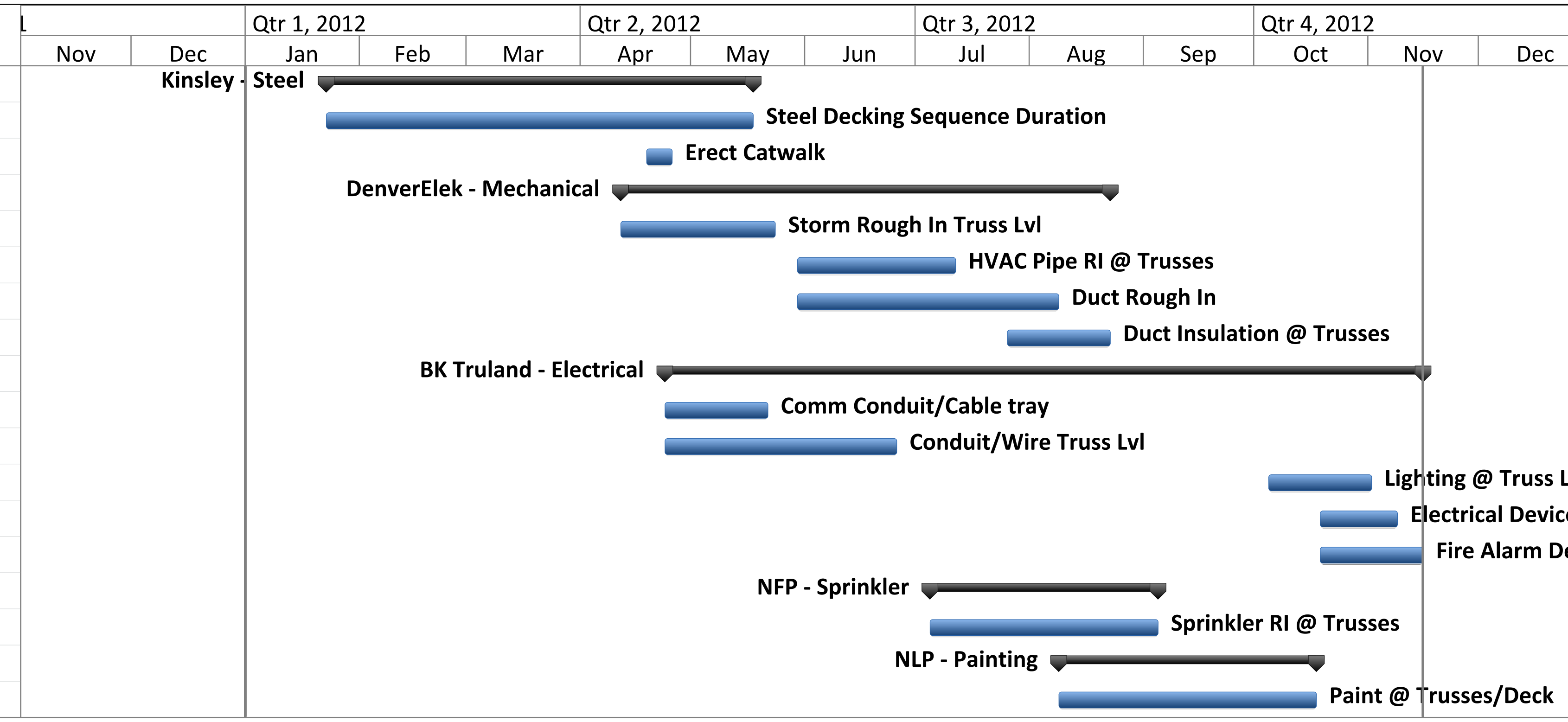


Figure 88 TA Terra Cotta Panel Locations, Ta Contrcat Documents

APPENDIX: E: Collaborative Work Planning of the Truss MEPF

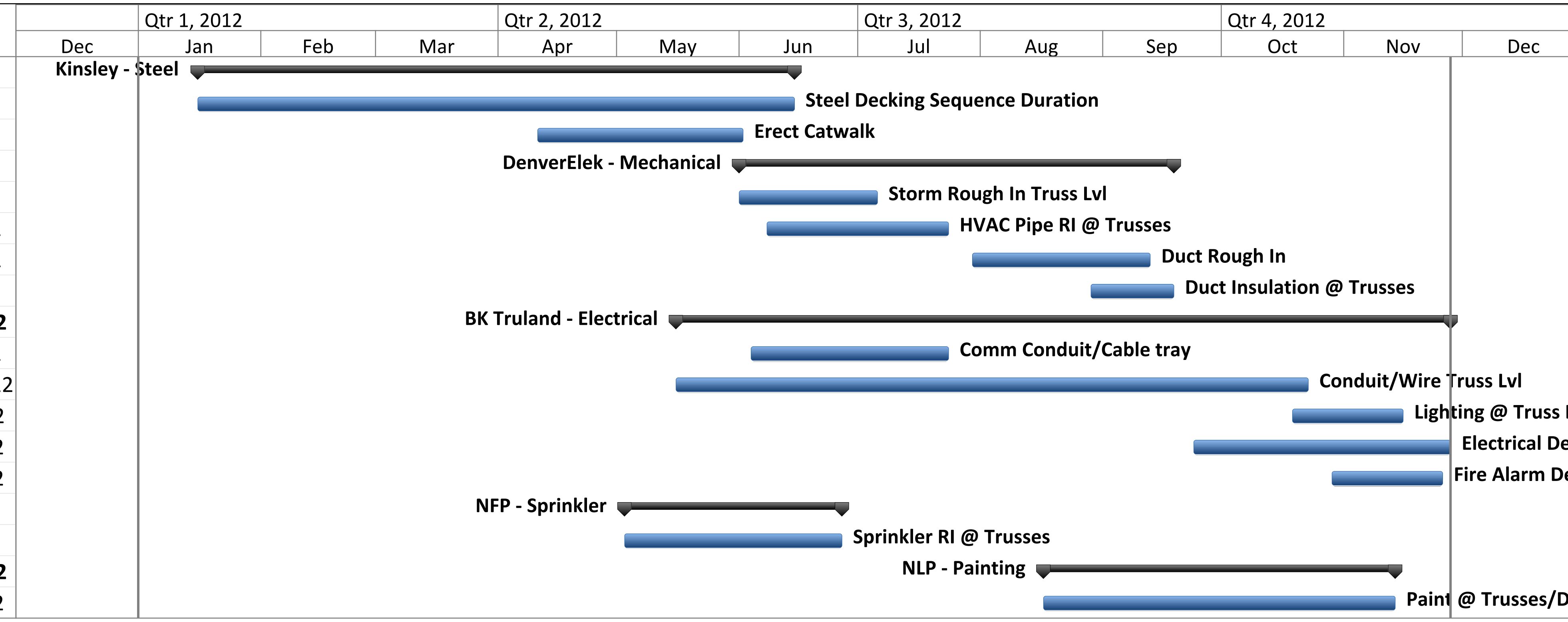
ID	Task Name	Duration	Start	Finish	Predecessors
1	**Kinsley - Steel**	**84 days**	**Mon 1/23/12**	**Thu 5/17/12**	
2	Steel Decking Sequence Duration	84 days	Mon 1/23/12	Thu 5/17/12	
3	Erect Catwalk	5 days	Thu 4/19/12	Wed 4/25/12	
4	**DenverElek - Mechanical**	**95 days**	**Thu 4/12/12**	**Wed 8/22/12**	
5	Storm Rough In Truss Lvl	30 days	Thu 4/12/12	Wed 5/23/12	
6	HVAC Pipe RI @ Trusses	31 days	Wed 5/30/12	Wed 7/11/12	
7	Duct Rough In	51 days	Wed 5/30/12	Wed 8/8/12	
8	Duct Insulation @ Trusses	20 days	Thu 7/26/12	Wed 8/22/12	
9	**BK Truland - Electrical**	**148 days**	**Tue 4/24/12**	**Thu 11/15/12**	
10	Comm Conduit/Cable tray	20 days	Tue 4/24/12	Mon 5/21/12	
11	Conduit/Wire Truss Lvl	45 days	Tue 4/24/12	Mon 6/25/12	
12	Lighting @ Truss Level	20 days	Fri 10/5/12	Thu 11/1/12	
13	Electrical Devices @ Truss Level	15 days	Fri 10/19/12	Thu 11/8/12	
14	Fire Alarm Devices and Test Truss Level	20 days	Fri 10/19/12	Thu 11/15/12	
15	**NFP - Sprinkler**	**44 days**	**Thu 7/5/12**	**Tue 9/4/12**	
16	Sprinkler RI @ Trusses	44 days	Thu 7/5/12	Tue 9/4/12	
17	**NLP - Painting**	**50 days**	**Thu 8/9/12**	**Wed 10/17/12**	
18	Paint @ Trusses/Deck	50 days	Thu 8/9/12	Wed 10/17/12	



Project: Combined Baseline Sched
Date: Fri 3/22/13

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

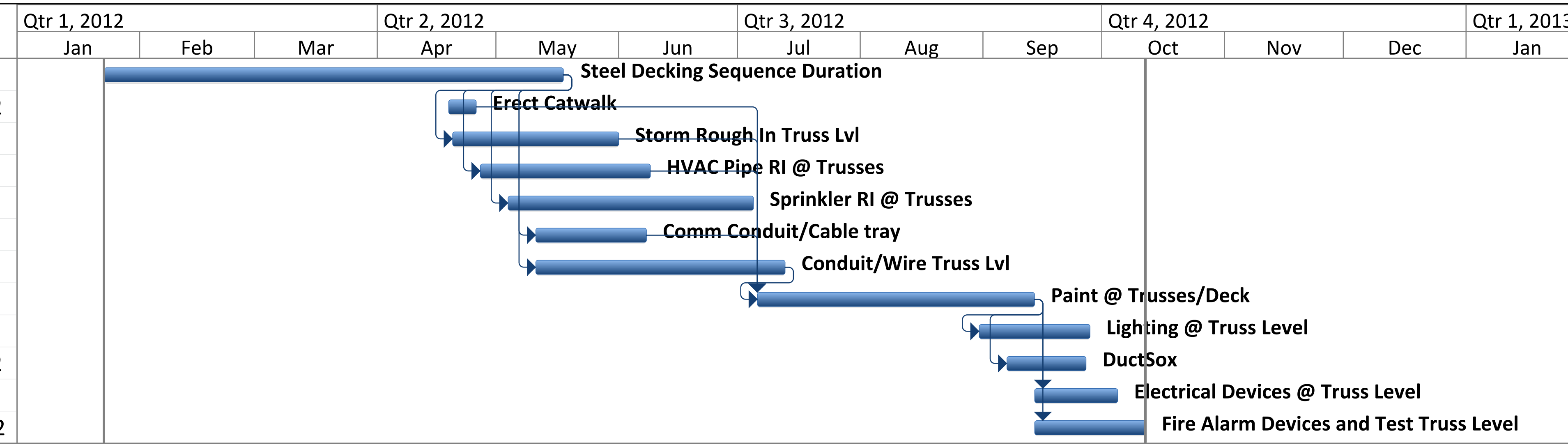
ID	Task Name	Duration	Start	Finish
1	**Kinsley - Steel**	**109 days**	**Mon 1/16/12**	**Thu 6/14/12**
2	Steel Decking Sequence Duration	109 days	Mon 1/16/12	Thu 6/14/12
3	Erect Catwalk	38 days	Wed 4/11/12	Fri 6/1/12
4	**DenverElek - Mechanical**	**78 days**	**Fri 6/1/12**	**Tue 9/18/12**
5	Storm Rough In Truss Lvl	25 days	Fri 6/1/12	Thu 7/5/12
6	HVAC Pipe RI @ Trusses	32 days	Fri 6/8/12	Mon 7/23/12
7	Duct Rough In	33 days	Mon 7/30/12	Wed 9/12/12
8	Duct Insulation @ Trusses	15 days	Wed 8/29/12	Tue 9/18/12
9	**BK Truland - Electrical**	**140 days**	**Wed 5/16/12**	**Tue 11/27/12**
10	Comm Conduit/Cable tray	36 days	Mon 6/4/12	Mon 7/23/12
11	Conduit/Wire Truss Lvl	114 days	Wed 5/16/12	Mon 10/22/12
12	Lighting @ Truss Level	20 days	Fri 10/19/12	Thu 11/15/12
13	Electrical Devices @ Truss Level	47 days	Mon 9/24/12	Tue 11/27/12
14	Fire Alarm Devices and Test Truss Level	21 days	Mon 10/29/12	Sun 11/25/12
15	**NFP - Sprinkler**	**39 days**	**Thu 5/3/12**	**Tue 6/26/12**
16	Sprinkler RI @ Trusses	39 days	Thu 5/3/12	Tue 6/26/12
17	**NLP - Painting**	**63 days**	**Fri 8/17/12**	**Tue 11/13/12**
18	Paint @ Trusses/Deck	63 days	Fri 8/17/12	Tue 11/13/12



Project: Combined Actual Schedu
Date: Fri 3/22/13

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

ID	Task Name	Duration	Start	Finish
1	Steel Decking Sequence Duration	84 days	Mon 1/23/12	Thu 5/17/12
2	Erect Catwalk	5 days	Thu 4/19/12	Wed 4/25/12
3	Storm Rough In Truss Lvl	30 days	Fri 4/20/12	Thu 5/31/12
4	HVAC Pipe RI @ Trusses	31 days	Fri 4/27/12	Fri 6/8/12
10	Sprinkler RI @ Trusses	44 days	Fri 5/4/12	Wed 7/4/12
5	Comm Conduit/Cable tray	20 days	Fri 5/11/12	Thu 6/7/12
6	Conduit/Wire Truss Lvl	45 days	Fri 5/11/12	Thu 7/12/12
11	Paint @ Trusses/Deck	50 days	Fri 7/6/12	Thu 9/13/12
7	Lighting @ Truss Level	20 days	Fri 8/31/12	Thu 9/27/12
12	DuctSox	14 days	Fri 9/7/12	Wed 9/26/12
8	Electrical Devices @ Truss Level	15 days	Fri 9/14/12	Thu 10/4/12
9	Fire Alarm Devices and Test Truss Level	20 days	Fri 9/14/12	Thu 10/11/12



Project: Re-Sequenced MEPF

Date: Fri 3/22/13

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

APPENDIX F: CISCO StadiumVision Analysis

WIRING SCHEDULE: PANEL RP1C																			
120/208 VOLTS			3PHASE 4 WIRE						100 AMP MAINS					SURFACE MOUNTED					
CIRCUIT	POLE	DESCRIPTION	WIRE/CONDUIT	BREAKER		KVA/Ø						CIRCUIT	POLE	DESCRIPTION	WIRE/CONDUIT	BREAKER	
				POLE	AMP	AØ		BØ		CØ						POLE	AMP
1	1	CUH-TA-1 (VESTIBULE 124)	#12-3/4"C	1	20	0.3	1.4					2	2	HAND DRYER MEN'S 131	#8-3/4"C	1	20
3	3	REC FAN ASSIST 134,135,137	#8-3/4"C	1	20			1.0	1.4			4	4	HAND DRYER MEN'S 131	#8-3/4"C	1	20
5	5	REC EVENT MGMT 133, 134	#8-3/4"C	1	20					0.8	0.8	6	6	REC MEN'S 131	#8-3/4"C	1	20
7	7	REC WOMEN'S 132	#8-3/4"C	1	20	0.8	0.8					8	8	REC RECEPTION 125, CORR	#10-3/4"C	1	20
9	9	HAND DRYER WOMEN'S 132	#8-3/4"C	1	20			1.4	0.8			10	10	REC PRESS RM 127	#12-3/4"C	1	20
11	11	HAND DRYER WOMEN'S 132	#8-3/4"C	1	20					1.4	0.8	12	12	REC PRESS RM 127	#12-3/4"C	1	20
13	13	REC PRESS ROOM 127	#12-3/4"C	1	20	0.8	1.0					14	14	REC AVR PRESS RM 127	#12-3/4"C	1	20
15	15	REC PRESS ROOM 127	#12-3/4"C	1	20			0.8	0.5			16	16	REC METAL DETECTOR 125	#12-3/4"C	1	20
17	17	REC EVENT STAFF 121	#12-3/4"C	1	20					0.6	0.5	18	18	REC METAL DETECTOR 125	#12-3/4"C	1	20
19	19	REC EVENT STAFF 121, CORR 114	#12-3/4"C	1	20	0.8	0.5					20	20	REC EWC 125	#12-3/4"C	1	20
21	21	REC SECURITY 122, CORR	#12-3/4"C	1	20			0.8	0.8			22	22	REC AVR SECURITY 122	#12-3/4"C	1	20
23	23	REC PRODUCTION 129	#10-3/4"C	1	20					0.8	0.8	24	24	REC PRODUCTION 129	#10-3/4"C	1	20
25	25	REC PRODUCTION 129	#10-3/4"C	1	20	0.8	0.8					26	26	REC PRODUCTION 129	#10-3/4"C	1	20
27	27	REC PRODUCTION 129	#10-3/4"C	1	20			0.8	1.0			28	28	REC PRODUCTION 129	2#10+#10	2	20
29	29	REC PRODUCTION 129	#10-3/4"C	1	20					0.8	1.0	-	30		G-3/4"C		
31	31	REC PRODUCTION 129	2#10+10G-	2	20	1.0	1.0					32	32	REC PRODUCTION 129	2#10+#10	2	20
-	33		3/4"C					1.0	1.0			-	34		G-3/4"C		
35	35	REC PRODUCTION 129	2#10+10G-	2	20					1.0	0.8	36	36	REC PRODUCTION 129	#10-3/4"C	1	20
-	37		3/4"C			1.0	0.4					38	38	REC TV PRESS ROOM 127	#12-3/4"C	1	20
39	39	CISCO STADIUM VISION RACK	3#10+10G-	2	20			1.9					40	SPARE		1	20
-	41		3/4"C							1.9			42	SPARE		1	20
						5.5	5.9	7.7	5.5	7.3	4.7						
						11.4		13.2		12.0							

CONNECTED LOAD = 36.6 KVA

MAIN BREAKER 100 AMPS

DEMAND LOAD = 27.1 KVA

NOTE: PROVIDE SEPARATE NEUTRAL FOR EACH CIRCUIT

MIN AIC RATING = 10,000 AMPS SYMMETRICAL

LOCATION SECURITY 122

Figure 89 Panel with Cisco SV Breaker, created by Derek Stoecklein

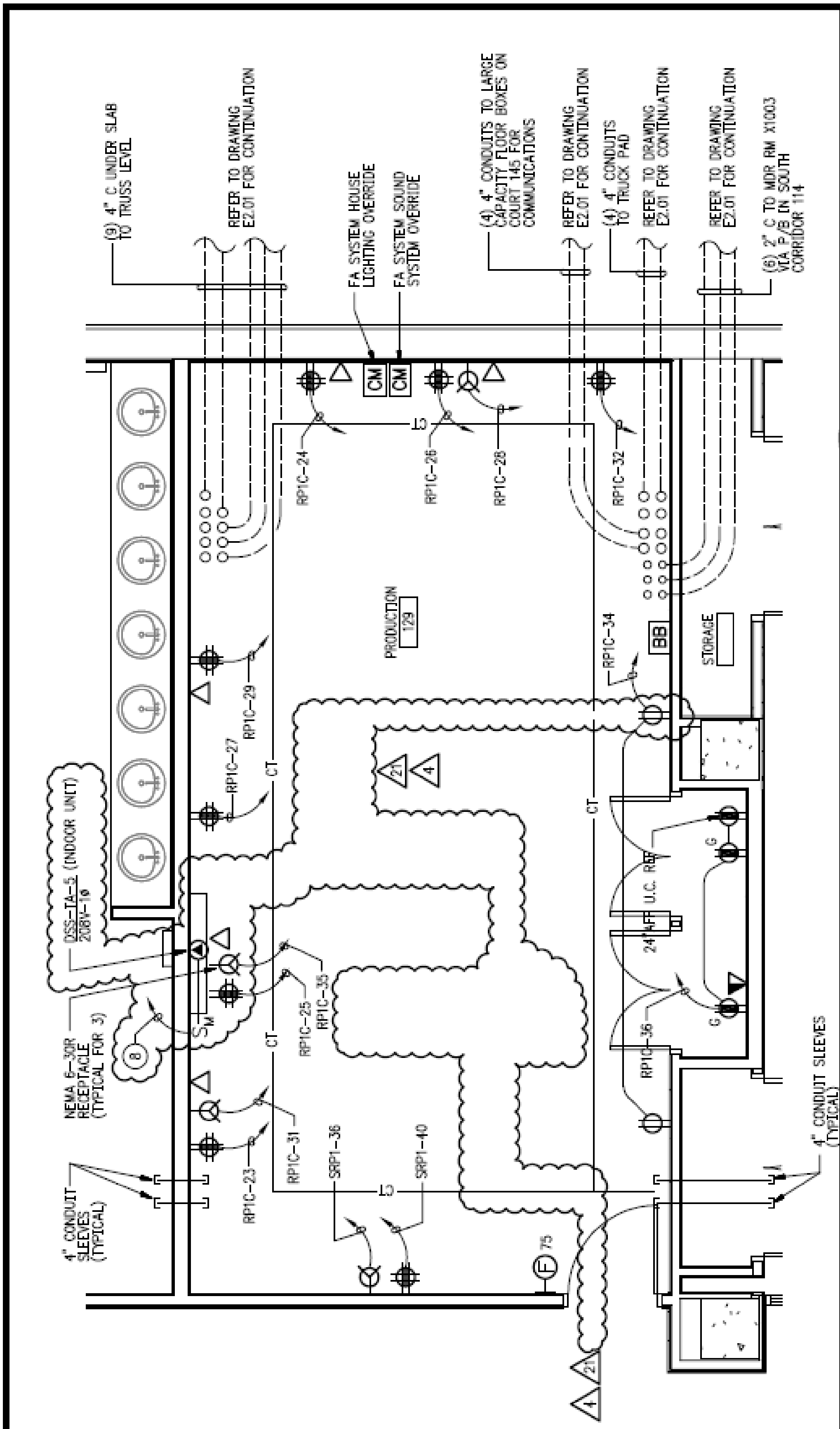


Figure 90 Original TA Production Room 129 Power E4.02, contract documents

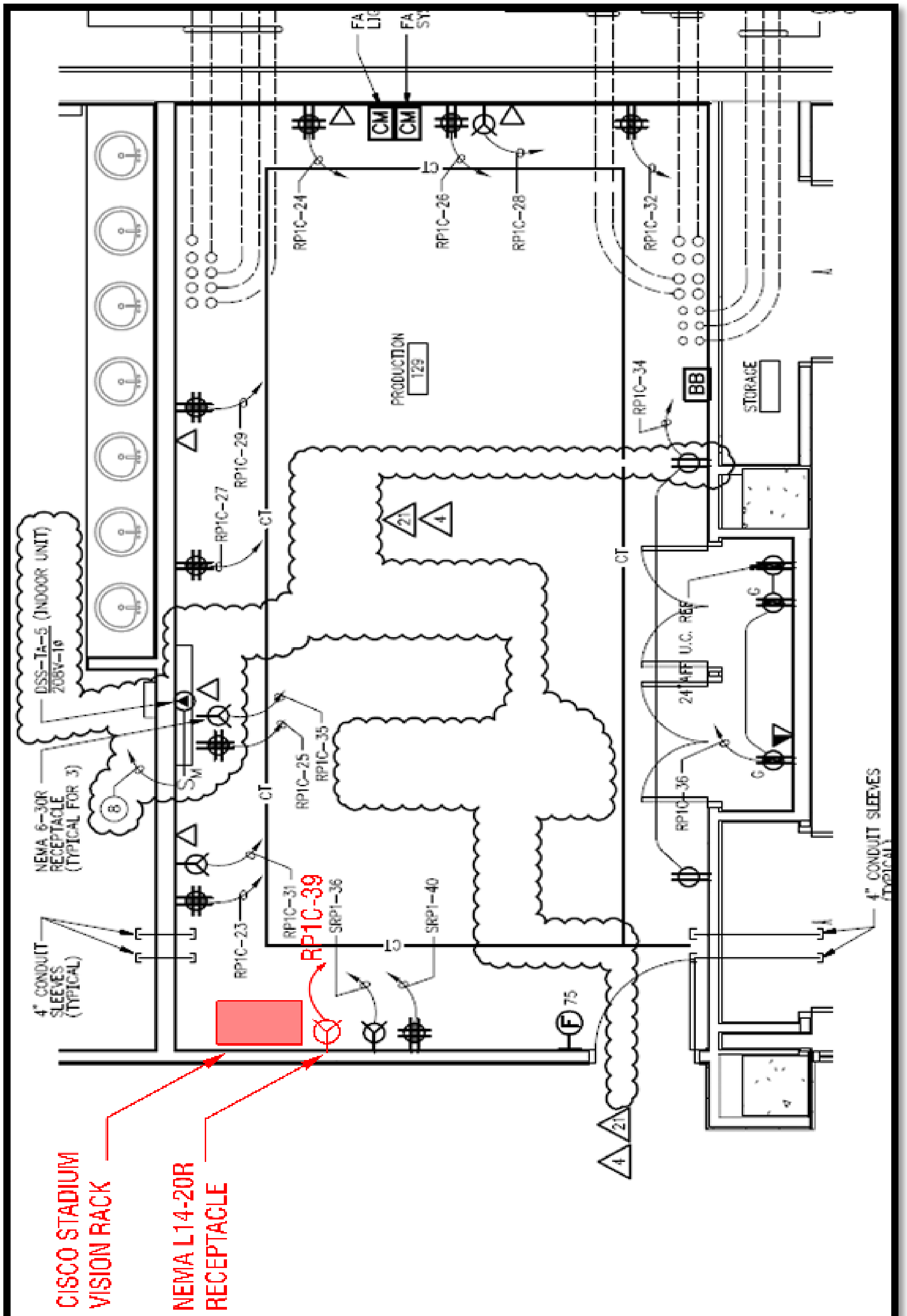


Figure 91 Production Room with Cisco SV Rack Detailed, created by Derek Stoecklein

WIRING SCHEDULE: PANEL RP1C																	
120 / 208 VOLTS			3 PHASE 4 WIRE					100 AMP MAINS						SURFACE MOUNTED			
CIR-CUIT	POLE	DESCRIPTION	WIRE/ CONDUIT	BREAKER POLE	BREAKER AMP	KVA / Ø AØ		BØ		CØ		CIR-CUIT	POLE	DESCRIPTION	WIRE/ CONDUIT	BREAKER POLE	BREAKER AMP
1	1	CUH-TA-1 (VESTIBULE 124)	#12-3/4"C	1	20	0,3	1,4					2	2	HAND DRYER MEN'S 131	#8-3/4"C	1	20
3	3	REC FAN ASSIST 134,135,137	#8-3/4"C	1	20			1,0	1,4			4	4	HAND DRYER MEN'S 131	#8-3/4"C	1	20
5	5	REC EVENT MGMT 133, 134	#8-3/4"C	1	20					0,8	0,8	6	6	REC MEN'S 131	#8-3/4"C	1	20
7	7	REC WOMEN'S 132	#8-3/4"C	1	20	0,8	0,8					8	8	REC RECEPTION 125, CORR	#10-3/4"C	1	20
9	9	HAND DRYER WOMEN'S 132	#8-3/4"C	1	20			1,4	0,8			10	10	REC PRESS RM 127	#12-3/4"C	1	20
11	11	HAND DRYER WOMEN'S 132	#8-3/4"C	1	20					1,4	0,8	12	12	REC PRESS RM 127	#12-3/4"C	1	20
13	13	REC PRESS ROOM 127	#12-3/4"C	1	20	0,8	1.0					14	14	REC AVR PRESS RM 127	#12-3/4"C	1	20
15	15	REC PRESS ROOM 127	#12-3/4"C	1	20			0.8	0.5			16	16	REC METAL DETECTOR 125	#12-3/4"C	1	20
17	17	REC EVENT STAFF 121	#12-3/4"C	1	20					0,6	0,5	18	18	REC METAL DETECTOR 125	#12-3/4"C	1	20
19	19	REC EVENT STAFF 121, CORR 114	#12-3/4"C	1	20	0,8	0,5					20	20	REC EWC 125	#12-3/4"C	1	20
21	21	REC SECURITY 122, CORR	#12-3/4"C	1	20			0,8	0,8			22	22	REC AVR SECURITY 122	#12-3/4"C	1	20
23	23	REC PRODUCTION 129	#10-3/4"C	1	20					0,8	0,8	24	24	REC PRODUCTION 129	#10-3/4"C	1	20
25	25	REC PRODUCTION 129	#10-3/4"C	1	20	0,8	0,8					26	26	REC PRODUCTION 129	#10-3/4"C	1	20
27	27	REC PRODUCTION 129	#10-3/4"C	1	20			0.8	1.0			28	28	REC PRODUCTION 129	2#10+#10G-	2	20
29	29	REC PRODUCTION 129	#10-3/4"C	1	20					0.8	1.0	-	30		3/4"C		
31	31	REC PRODUCTION 129	2#10+#10G-	2	20	1.0	1.0					32	32	REC PRODUCTION 129	2#10+#10G-	2	20
-	33		3/4"C					1,0	1,0			-	34		3/4"C		
35	35	REC PRODUCTION 129	2#10+#10G-	2	20					1,0	0,8	36	36	REC PRODUCTION 129	#10-3/4"C	1	20
-	37		3/4"C			1,0	0,4					38	38	**REC TV PRESS ROOM 127**	**#12-3/4"C**	1	20
	39	SPARE		1	20								40	SPARE		1	20
	41	SPARE		1	20								42	SPARE		1	20
						5,5	5,9	5,8	5,5	5,4	4,7						
		CONNECTED LOAD =	32,8	KVA		11,4		11,3		10,1							
														MAIN BREAKER	100	AMPS	
		DEMAND LOAD =	23,2	KVA		NOTE; PROVIDE SEPARATE NEUTRAL FOR EACH CIRCUIT											
		MIN AIC RATING =	10,000	AMPS SYMMETRICAL										LOCATION	SECURITY 122		

Figure 93 Panel RP1C, TA Contract Documents

WIRING SCHEDULE: PANEL RP1B																	
120 / 208 VOLTS			3 PHASE 4 WIRE					100 AMP MAINS						SURFACE MOUNTED			
CIR-CUIT	POLE	DESCRIPTION	WIRE/ CONDUIT	BREAKER POLE	BREAKER AMP	KVA / Ø AØ		BØ		CØ		CIR-CUIT	POLE	DESCRIPTION	WIRE/ CONDUIT	BREAKER POLE	BREAKER AMP
1	1	REC MAINT SHOP 118	#12-3/4"C	1	20	0.8	0.8					2	2	REC MAINT SHOP 118	#12-3/4"C	1	20
3	3	REC MAINT SHOP 118	#12-3/4"C	1	20			0.8	0.8			4	4	REC MAINT SHOP 118	#12-3/4"C	1	20
5	5	REC MAINT SHOP 118	#12-3/4"C	1	20					0,8	0,8	6	6	REC MAINT SHOP 118	#12-3/4"C	1	20
7	7	REC LOADING	#12-3/4"C	1	20	0,6	0,5					8	8	WINCH CONTROL PANEL	#12-3/4"C	1	20
9	9	REC LOADING	#12-3/4"C	1	20			0,6					10	SPARE		1	20
	11	SPARE		1	20								12	SPARE		1	20
	13	SPARE		1	20								14	SPARE		1	20
	15	SPARE		1	20								16	SPARE		1	20
	17	SPARE		1	20								18	SPARE		1	20
	19	SPARE		1	20								20	SPARE		1	20
	21	SPARE		1	20								22	SPARE		1	20
	23	SPARE		1	20								24	SPARE		1	20
	25	SPARE		1	20								26	SPARE		1	20
	27	SPARE		1	20								28	SPARE		1	20
	29	SPARE		1	20								30	SPARE		1	20
						1.4	1.3	1.4	0.8	0.8	0.8						
		CONNECTED LOAD =	6.5	KVA		2.7		2.2		1.6							
														MAIN BREAKER	100	AMPS	
		DEMAND LOAD =	6,4	KVA		NOTE; PROVIDE SEPARATE NEUTRAL FOR EACH CIRCUIT											
		MIN AIC RATING =	10,000	AMPS SYMMETRICAL										LOCATION	MAINT SHOP 118		

Figure 92 Panel RP1B, TA Contract Documents

Device	Power Requirements
Cisco D9900 DCM	350 W (max); 110 to 240V AC
Cisco D9094 Encoder	60 W (max) ; 100 V AC
Cisco D9887 Receiver	200 W (max); 95 to 135 / 180 to 265 V AC
Cisco D9858 Transcoder	110 W (max); 110 to 240V AC
Cisco Spectra QAM Demod	8 W; 48V AC
3rd Party Set-top Box	Varies – 15-20 W; 110 to 240V AC
DirecTV COM200	320 W (max with redundant PSU); 110 to 240V AC
Catalyst Switches	PoE is not required. Power supplies for switches should be sized accordingly.

Figure 95 Cisco SV Power Requirements, Cisco.com

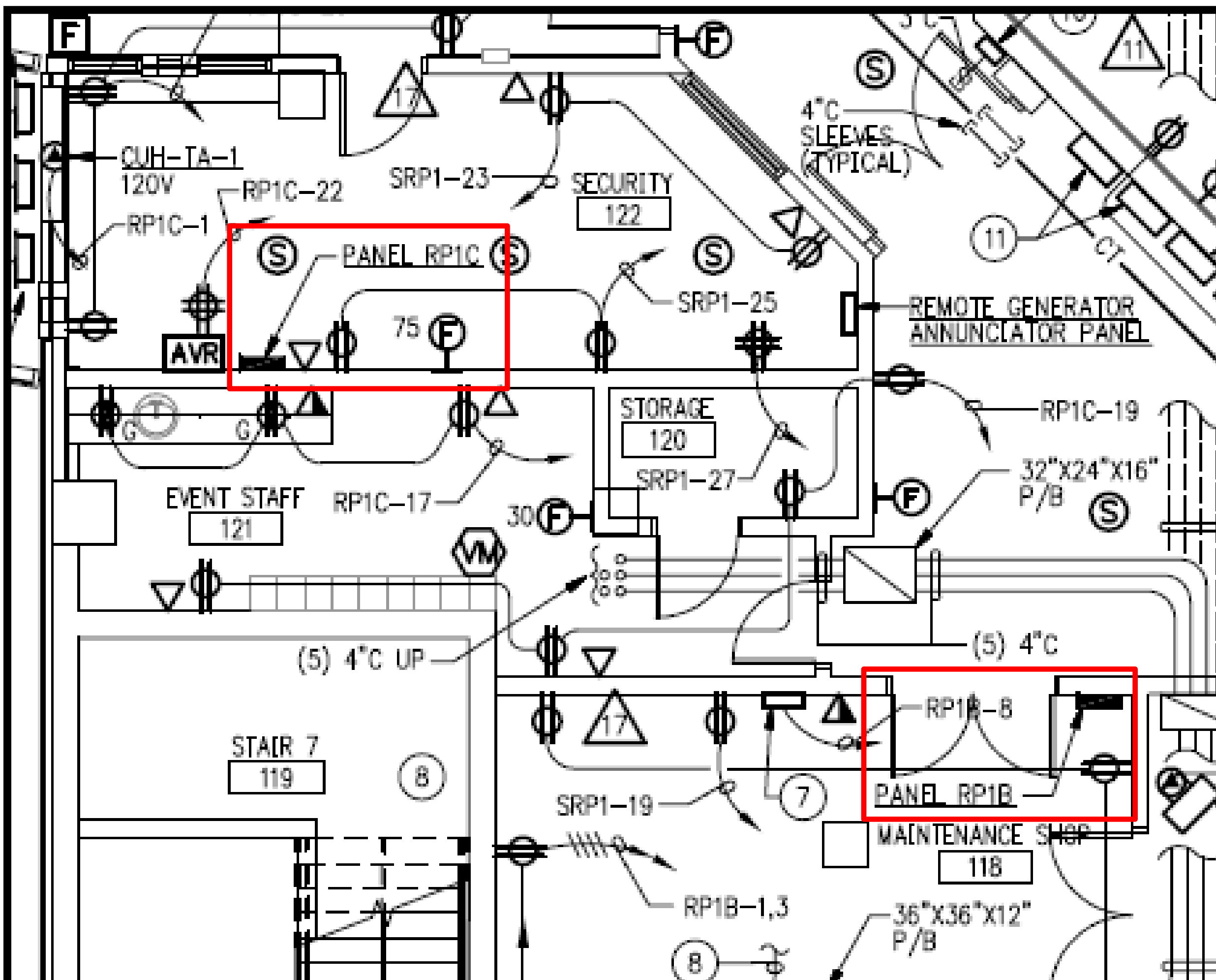


Figure 94 TA Panel RP1C and RP1B Locations, TA Contract Documents

Specifications for 40 Amp Units 208V-120V

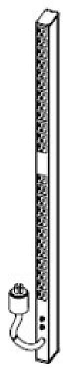
AC Voltage Input:	200 to 230V
AC Voltage Output:	100 to 115V
Frequency:	60 Hz
Load Capacity:	UL Rated 32Amps max – (2) 16 Amp circuits
Circuit Breaker:	(2) 20 Amp UL489 Listed circuit breakers
Output Receptacle:	NEMA 5-20R
Product Warranty:	2 years
Power Cable – AWG Length & Plug Type:	12/4 SJT Type, L14-20P, 12ft. [3.6m]
With Local Ammeter Readout:	0-20 Amp 4-digit display +/- 0.2A LCD with backlighting
With Remote Ammeter Readout:	0-30A 3-digit display +/- 0.2A Remote LCD with backlighting

40A Power Commander Power Distribution Units

Catalog No. 4B44B2-2

Twenty-four (24) 20A simplex outlets in two banks of 12. Black housing.

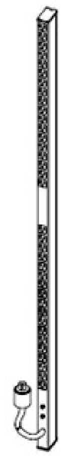
Length: 48" [1.2m]
Width: 1 1/2" [38mm]
Depth: 2 7/8" [73mm]



Catalog No. 4B86B2-2

Thirty-six (36) 20A simplex outlets in two banks of 18. Black housing.

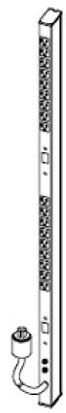
Length: 70" [1.8m]
Width: 1 1/2" [38mm]
Depth: 2 7/8" [73mm]



Catalog No. 4B53B2-2-AM

Eighteen (18) 20A simplex outlets in two banks of 9. Two lighted LCD digital ammeters. Black housing.

Length: 54" [1.4m]
Width: 1 1/2" [38mm]
Depth: 2 7/8" [73mm]



Catalog No. 4B43B2-2-RAM

Eighteen (18) 20A simplex outlets in two banks of 9. Two lighted remote LCD ammeters. Black housing.

Length: 48" [1.2m]
Width: 1 1/2" [38mm]
Depth: 2 7/8" [73mm]

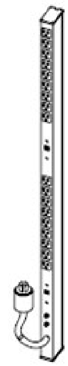


Figure 96 Server power strip, starcase.com