United States

Department of the Interior

# Cafeteria Modernization


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Department of the Interior Cafeteria Modernization

1849 C Street NW,
Washington D.C.

April 7, 2011

Final Report

    

United States

# Department of the Interior

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## Design Team

Owner: General Services Administration

Occupant: The Department of the Interior

General Contractor: Grunley Construction Company

Construction Manager: Jacobs Engineering

Architect: Shalom Baranes Associates

Structural engineer: Thorton Tomasetti

MEP: Allen and Shariff

Lighting: Coventry Lighting

## Project Overview

Location: 1849 "NW" C Street, Washington D.C.

Construction Dates: February 6,2009 - July 29,2010

Contract: The Cafeteria Modernization Project is actually part of the overall whole Modernization Package for the Department of the Interior. The original bid for Wing 6 was won in 2001.Each wing since has been added to the original contract under the term "Option". The cafeteria project is actually part of Option 3/ Wing 3.

Budget: The Cafeteria Project is actually budgeted as a change order for Option 3/Wing 3. The PDL (price determined later) change order is estimated to come in between $9-11 Million

Delivery Method: Design- Bid- Build

## Architecture

Generally the flow of function in this renovation moves from the most public space being the dining room at the West end, to the most private being the back of kitchen and utility spaces at the east end. Another important architectural struggle is to give the space a fresh state of the art appearance without losing the spaces historical value. The historic tiles, murals, base boards, and stone were all tied into the new sky lights, terrazzo floors, and pyrock ceiling effectively to create a uniform and yet independent space.

## Lighting

The renovated sky light system will provide the majority of the lighting in the common area. It will be supplemented with energy efficient artificial lighting systems that serve the multiple lighting scenes necessary for the various functions of the dining room.

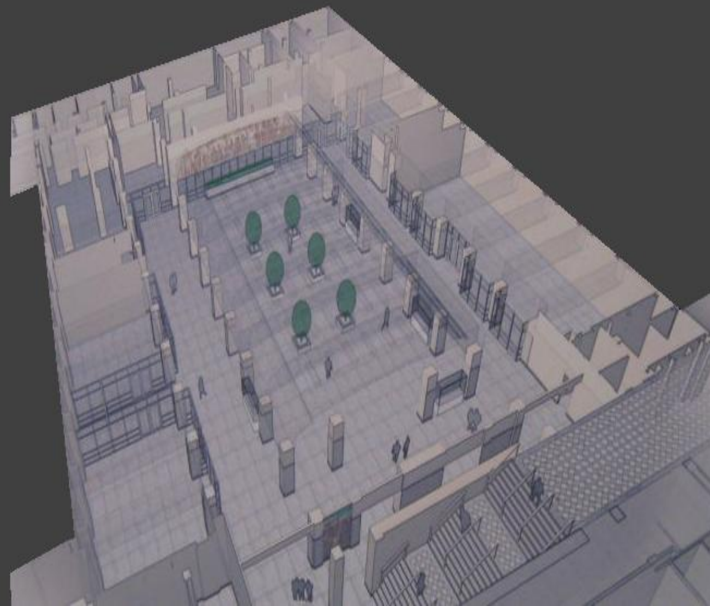
## Mechanical

All existing Mechanical Equipment is to be removed. The space will have six new VAV air handling units. The cooling system uses chilled water from the building cooling towers. The heating system includes electric baseboard heaters underneath each window.

## Construction

**Abatement**- As with most renovations with early 20th century construction, there is Lead and Asbestos in most all construction materials. Abatement must be built into the schedule keeping in mind, that there will be other occupants in the building during construction and that the amount of abatement necessary may increase due to lack of As-Builts.

**LEED:** The Cafeteria Modernization is striving for a Silver Rating under the LEED© Commercial Construction 2.0v. The design review marked 30 "probable" points and 17 "possible" point. By reusing a lot of the original materials in the renovation, the cafeteria maintains historic preservation as well as sustainable construction.



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http://www.engr.psu.edu/ae/thesis/portfolios/2011/msg5056/index.html

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# Executive Summary

This final report documents the research and analyses that were performed on the Department of Interor Cafeteria Modernization Project. The core of this investigation evaluates critical industry issues, value engineering decisions, reviews of constructability, and opportunities to reduce the project schedule. The three analyses are as followed:

### **Technical Analysis I** *Critical Industry Issue: Using Tablet PCs for Quality Control*

Analysis I will research the use of Tablet PCs in the field to specifically aid in the quality control process. By being able to access the BIM Model and other construction documents in the field, many of the errors in the quality control process can be remediated. The cafeteria project is a prime candidate for this technology due to the lack of quality control throughout the project.

### **Technical Analysis II** *Historic Preservation*

This analysis breaks down each of the historic preservation decisions on a cost, schedule, and architectural basis. This section also contains an architectural breadth which will propose an alternative design without the historic preservations. The proposed design is then compared to the original design based on cost, schedule, and aesthetics.

### **Technical Analysis III** *Advanced Lighting System*

This analysis combines the use of advanced lighting controls, a proposed PV system, and a DC power supply to provide and energy and cost savings for the dining room lighting system. This section includes a lighting/electrical breadth to look into the design of these systems.

# 2.0

# Project Background


## 2.1 Introduction

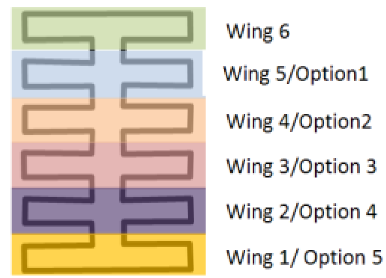



Figure 1: Project Phasing Plan

The Department of the Interior building is located at 1849 "NW" C Street in Washington D. C.. It was constructed in 1936 under the New Deal, and featured some of the most state of the art technologies in the building industry at its time, such as air conditioning and fire protection. In the mid 90's, plans for the modernization of the Department of the Interior building began coming into discussion. In 2001, Grunley Construction Company was awarded the contract to the modernization of Wing 6. The contract for the modernization of each additional wing has been has added as an amendment or "Option" to the original contract. The cafeteria for the Department of the Interior is located on the basement level of Wing 3 and Wing 4. It has been contracted as a change order for the modernization of Wing 3.

The Department of Interior Cafeteria Modernization project began construction on February 6, 2009. The cafeteria project included the renovation of multiple spaces, all for the purpose of providing the Department of Interior and its employees with upgrade facilities for their day-to-day lives. The project renovation scope includes a dining area, post office, Interior Department Recreation Association Office, credit union, two conference rooms, a barber shop, kitchen area, servery area, locker room, three walk in coolers, mechanical room, electrical room and elevator. Renovations to the building's structure (steel frame encased in concrete) would include a new skylight system for the dining area, and slab replacement in the kitchen. The original schedule had called for completion in March of 2010, but did not actually occur until July 29th.

Just as with the schedule, the original estimate did not come in on budget either. The original proposal from the general contractor came to $7,888,275. Although the final cost are still being comprised, the actual cost is predicted to be between $9 Million to $11 Million. The cafeteria modernization was given notice to proceed with a Price to be Determined Later (PDL) agreement. Upon completion, all parties will have a meeting to sort out who is responsible to pay for areas where the project went over budget. Although time and money may have exceeded expected values, all parties were satisfied with the final product .On August 4, 2010, a grand opening was held where cafeteria modernization had received rave reviews by the Department of Interior employees.

## 2.2 Owner Background

The General Service Administration is an independently run government organization. Their purpose is to support all of the government agencies by means of office space, transportation, communication or whatever means necessary. Those in the construction industry know GSA as the owner of all government buildings. In the DC area in particular, GSA is the largest employer of construction services. Working with GSA as an owner provides a unique scenario, in that many of their employee's actually have engineering and construction degrees. The GSA representatives on the Department of the Interior Modernization Project have been acting as an owner on construction projects for 20-30 years.

### Department of the Interior Cafeteria

This project is a GSA owned building that has been leased to the Department of the Interior since the 1920's. The cafeteria serves both DOI and other government employees working in neighboring buildings. The existing DOI cafeteria had been last updated in the 1970's. The outdated architectural appearance, the closed in ceiling, inefficient mechanical system, and dilapidated kitchen area were due for modernization. Before the design phase, a feasibility study was taken to determine the factors that will provide a better cafeteria for DOI employees, neighboring government workers, and day-to-day visitors. This feasibility study was critical in determining a new vendor that would eventually occupy the cafeteria's kitchen.

In addition to the cafeteria's kitchen, there are two conference rooms and four offices spaces. The occupants of the four offices space will also serve to enhance the quality of life for those who occupy the Department of Interior Office Building. A new post office will allow government employees to handle all mailing needs while at work. The Interior Department Recreation Association (IDRA) office will serve as a gift shop for visitors. In addition, a new credit union, and barber shop will allow visitors and employees to run their daily errands during work hours. In conclusion, the mission critical is to provide all those who spend time in the DOI Building with a higher quality, easier, and more efficient experience.

### Logistics

The cafeteria project creates all kinds of logistical concerns in regards to time to cost, quality, schedule, safety, and phasing:

#### Cost

The cafeteria is being built under a Price to be Determined Later (PDL) agreement. This being said, GSA requested an estimate by the architect, CM, and GC before any notice to proceed. It was expected that Grunley would complete this project within range of those estimates. A negotiation meeting will be held at the end of construction, where all parties will come together to sort out cost that have exceeded original estimation. Grunley agreed to a PDL keeping in mind that GSA provides them with a large amount of work, both on this project and others. Jacobs, is responsible for keeping track of Grunley's construction cost and watching out for the owner's best interest.

### Quality

GSA expects quality in both materials and craftsmanship. It is up to Grunley to manage their subcontractors' quality of work. It is Jacobs' responsibility to ensure that all construction is per contract documents. It is Shalom Baranes' responsibility to ensure that all contract documents are per code, and owner's specifications. In the end, the quality of the cafeteria modernization rest in each party's hands.

### Schedule

Grunley began abatement in March of 2009. They were expected to have the cafeteria handed over in February of 2010. Due to unforeseen existing conditions, Grunley was significantly behind schedule. Conveniently, GSA was unable to procure a cafeteria vendor by their desired date, and thus Grunley was allowed to push back completion until August. August was an absolute deadline, because the vendor's contract stated that they could occupy the space by then.

### Safety

Throughout the construction of the cafeteria, neighboring office spaces were occupied. It was critical that DOI employees were not affected at all by any construction processes. Temporary walls were built to separate the construction area from the neighboring corridor. Negative air pressure was maintained to ensure that no construction odors or pollutants could enter occupied space. In addition to the occupants' safety, any party that entered the construction area was forced to abide by the Grunley Construction Safety Plan. Hard hats, protective eye wears, and steel-toed boots were required at a minimum at all times.

### Phasing

The Department of the Interior building consists of six wings, with a large corridor running down between them. The Cafeteria lies under Wing 4 and Wing 3. It was decided that the Cafeteria would be included within the Wing 3 phase, but not begin until halfway through Wing 3 Construction. Originally Wing 3 and the cafeteria were supposed to be completed at the same time, but delays in the cafeteria pushed back the completion date as mentioned above.

## 2.3 Project Delivery Method

### Contracts

As previously stated, the Department of Interior Modernization Project was awarded to Grunley Construction Company for Wing 6 based on a Design-Bid-Build delivery method in 2001. Each addition to the original contract ("Option") has been proceeded upon under a PDL (Price Determined Later) agreement. The cafeteria is actually a Change Order for the Option 3/Wing 3 contract. Also a PDL, the cafeteria is treated as a Cost Plus Fee contract with room for negotiation on the cost for construction. Between Grunley already being on-site, prior knowledge about this building's construction, and an existing relationship with rest of the project team, this is the best delivery method for the cafeteria. A contract with a PDL requires a lot of trust between the CM, GC, and owner. A PDL only works in this system because of the potential for repeat business that comes with working for GSA. Additionally, Grunley holds bonding and the insurance plan on the rest of the building's construction and thus providing a cost savings for the owner.

The original construction management contract was awarded to Tishman Construction. After the Completion of Wing 5, the owner opted to release Tishman Construction and go with Jacobs Engineering as the Construction Management Agency. Jacobs is hired under a Lump Sum contract.

Finally, the architect of the Department of Interior Modernization Project, and particularly the cafeteria is Shalom Baranes Associates. The architect holds all the contracts with the engineering and design subcontractors. Shalom Baranes subcontracts engineering and design services out for whatever they cannot complete in-house.

### Communication

All design communication runs through Shalom Baranes Associates. Any RFI or submittal will come through them, and then passed down to the appropriate engineer or designer. All construction communication runs through Grunley. Grunley must follow government regulations for contractor selection (minority owned contractors, bidding process, bidding invitations, etc.). Any communication between the construction team, the design team, and the owner runs through Jacobs Engineering. Jacobs acts solely for the Owner's Interest and thus only holds a contract with the owner despite lines of communication with every party.

## Project Organization Chart

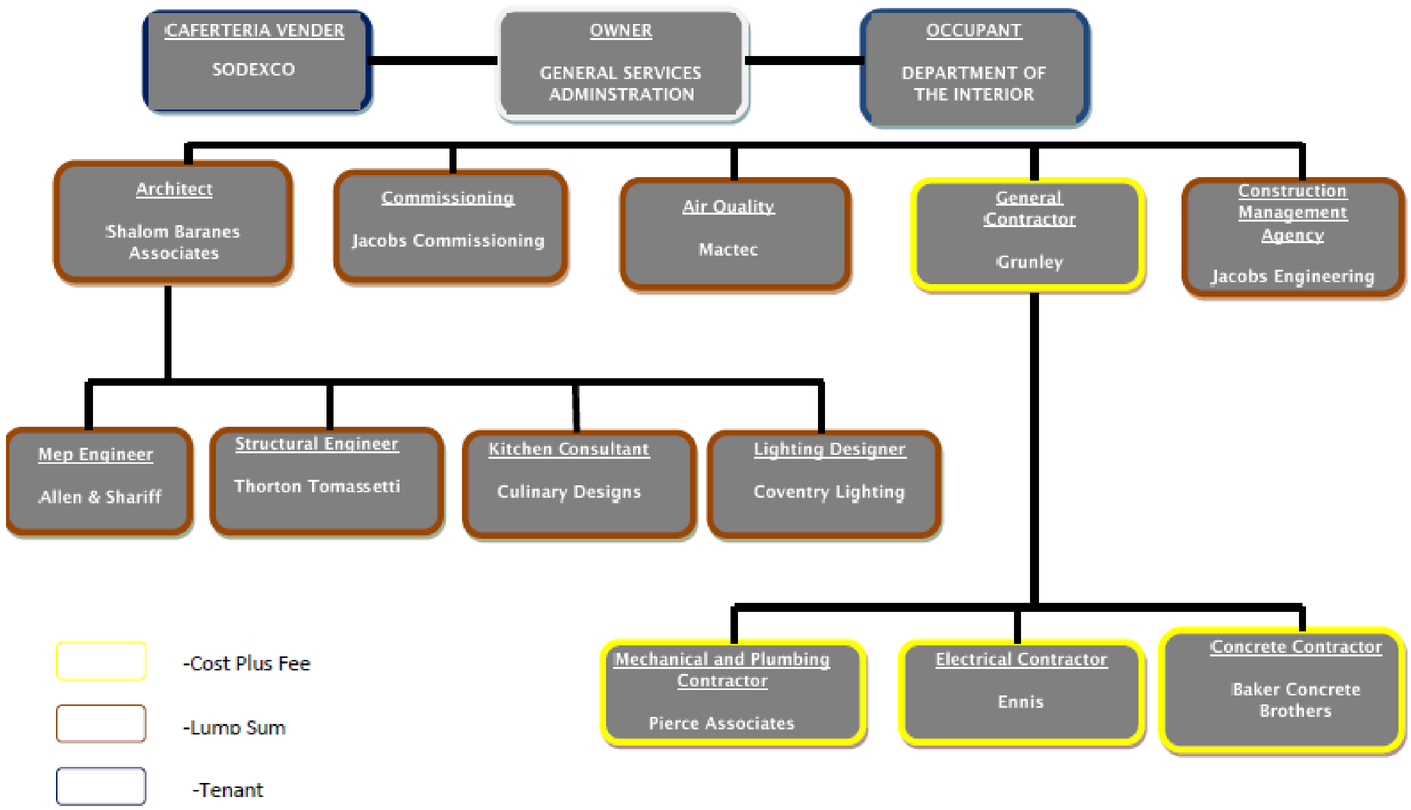



Figure 2: Project Organization Chart

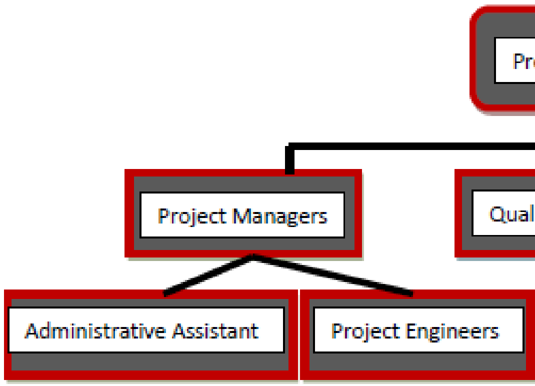
## 2.4 Project Staffing Plan

### Staff Allocation

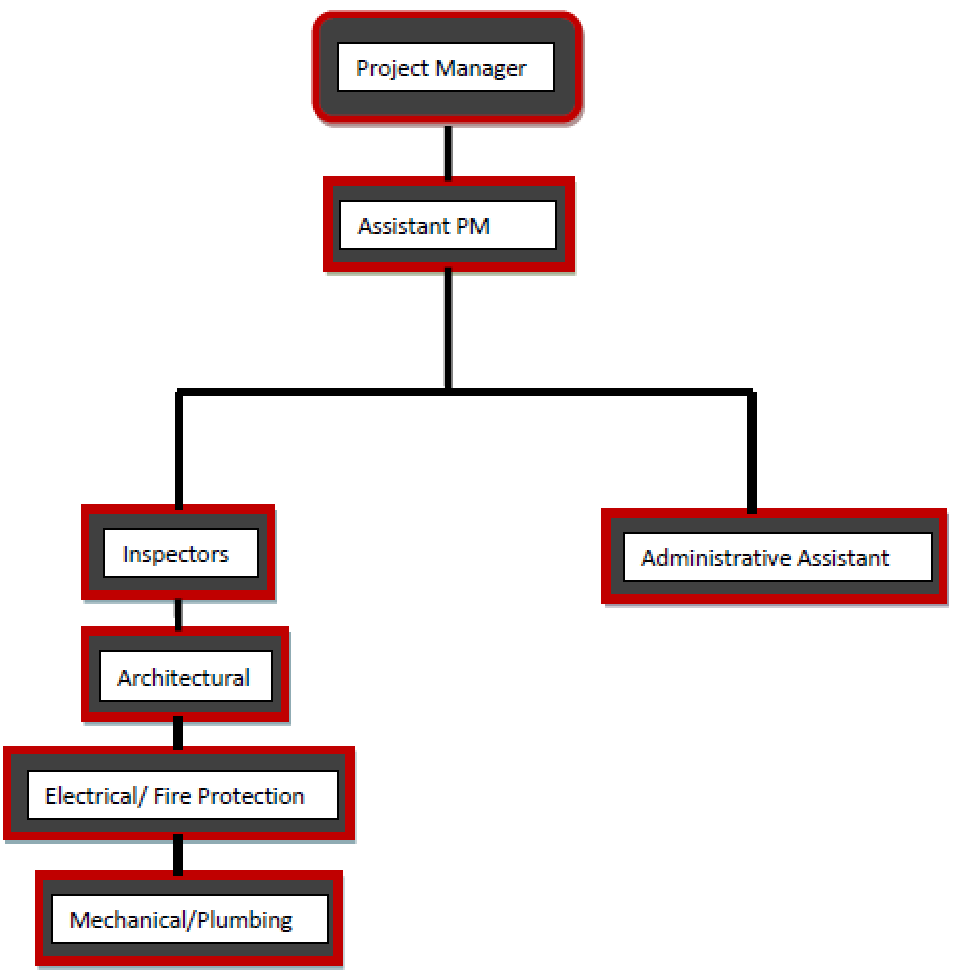
The Cafeteria Modernization presented both the General Contractor and the Construction Manager with a staffing dilemma. The cafeteria project ran simultaneously with the modernization of Wing 2 and Wing 3. While it needed enough staff to handle the $10 Million change order, it was not large enough to allocate personnel solely to the cafeteria. Both Grunley and Jacobs decided to divide management personnel to strictly handle the cafeteria, while using the rest of the team to work on both the cafeteria and wing modernizations.

Grunley assigned one project manager and one superintendant to head up the cafeteria. The quality control manager, project engineers, administration as well as the field laborers and foreman split their time between the cafeteria and wing projects. Jacobs on the other hand, assigned an assistant project manager to lead the construction management, while splitting the rest of the staff's time between projects.

## General Contractor Staffing Chart




## Construction Management Staffing Chart



# 3.0

# Design and Construction

## 3.1 Local Conditions

Washington D.C. is one of the largest markets for construction in the world. Between the building codes, zoning, water table height, population density, and traffic, it is also one of the most challenging places to build. The following were construction issues that were a result of the local conditions.

### Concrete

As most experienced in DC construction are aware, concrete is king. This is true due to the restriction on building height according to the district zoning regulations. DOI was unique in that its structural system consisted of steel beams encapsulated in concrete, as opposed to the usual reinforced concrete structures. The cafeteria modernization did not have to take any of this into account, but there was significant concrete placement on the project. The availability of concrete and the number of skilled concrete contractors drove down the price and drove up the quality of placement on this project.

### Terrazzo

Terrazzo is a popular flooring material used in government office buildings. The popularity of terrazzo in the DC area made finding competent contractors and quality materials an easy task.

Figure 3: Dining Room Corridor

### Stone

Figure 4: Stone Transition

Popular throughout the Department of the Interior Building, black quarry stone is used from flooring transitions, to baseboards, to door trim. This historic stone was pulled from a quarry in DC in the early 1920’s that is no longer in use. Somehow, a piece of historic stone that had been taken out for preservation was lost and needed to be replaced. Unfortunately no such local stone could match the historic one. In the end a close match was shipped in from a Tennessee quarry.

### LEED

A few LEED points were considered easily achievable, such as local material selections and a sustainable site. Washington, D.C.,, being the construction epicenter that it is, made the selection of materials from within a 500 mile radius easily achievable. The location of the DOI Building in regards to public transportation and various shopping facilities also made the sustainable site selection credits feasible.

## Parking

There is no on-site parking due to the location of this project. Local parking garages were available for $15/day. The Metro System is the most popular means of transportation with a bus station on the block over and the Metrorail being 5 blocks away. There is room for a truck or two within the construction fence on 18th and 19th street, but only for quick drop on and offs. Any cranes or delivery trucks can only access the site at night, when more than one lane shut down in possible. All lane closures must be worked out through the District.

## Recycling/ Tipping Fee

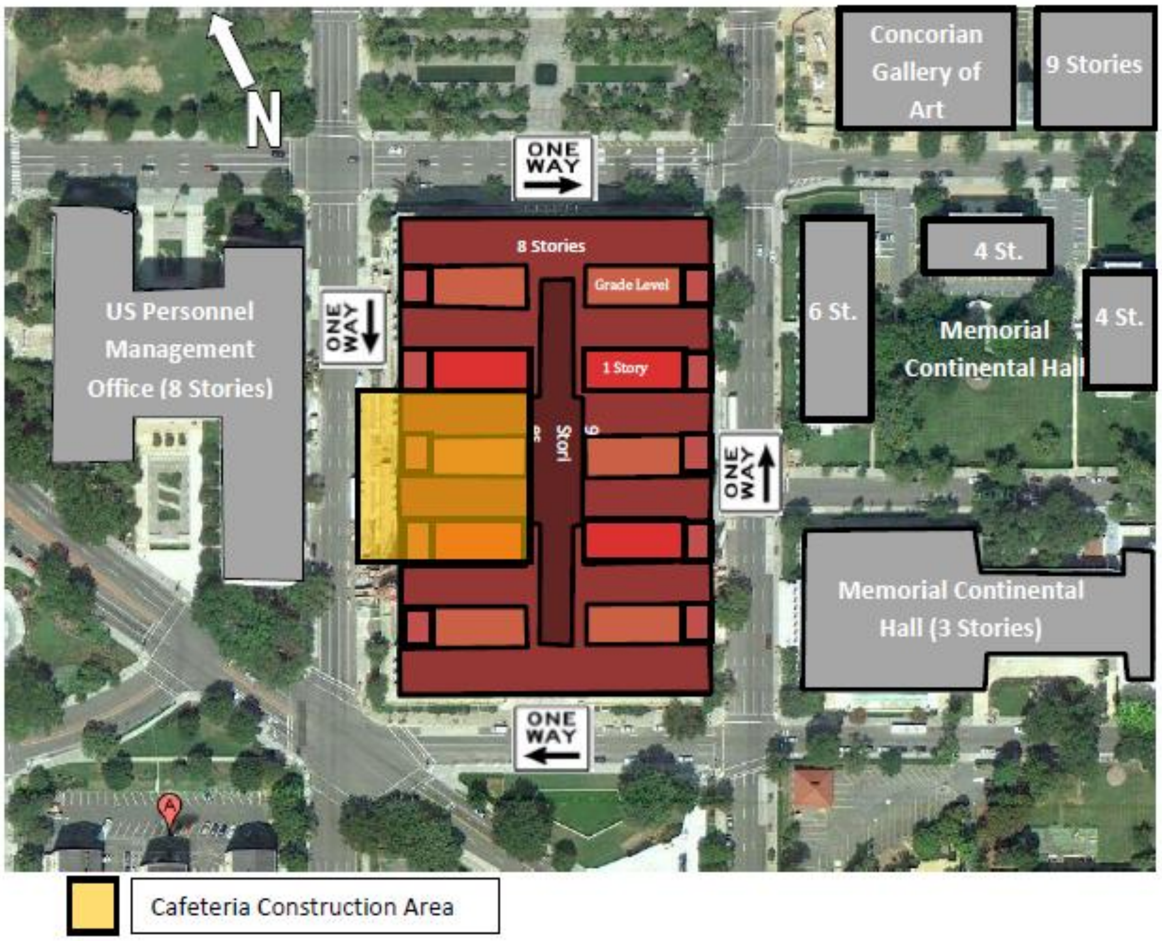
One dumpster is available onsite for garbage. It is sorted for recyclables off site. The typical tipping fee is $500.

Figure 6: Cafeteria Dumpster

## Soil/Subsurface Conditions

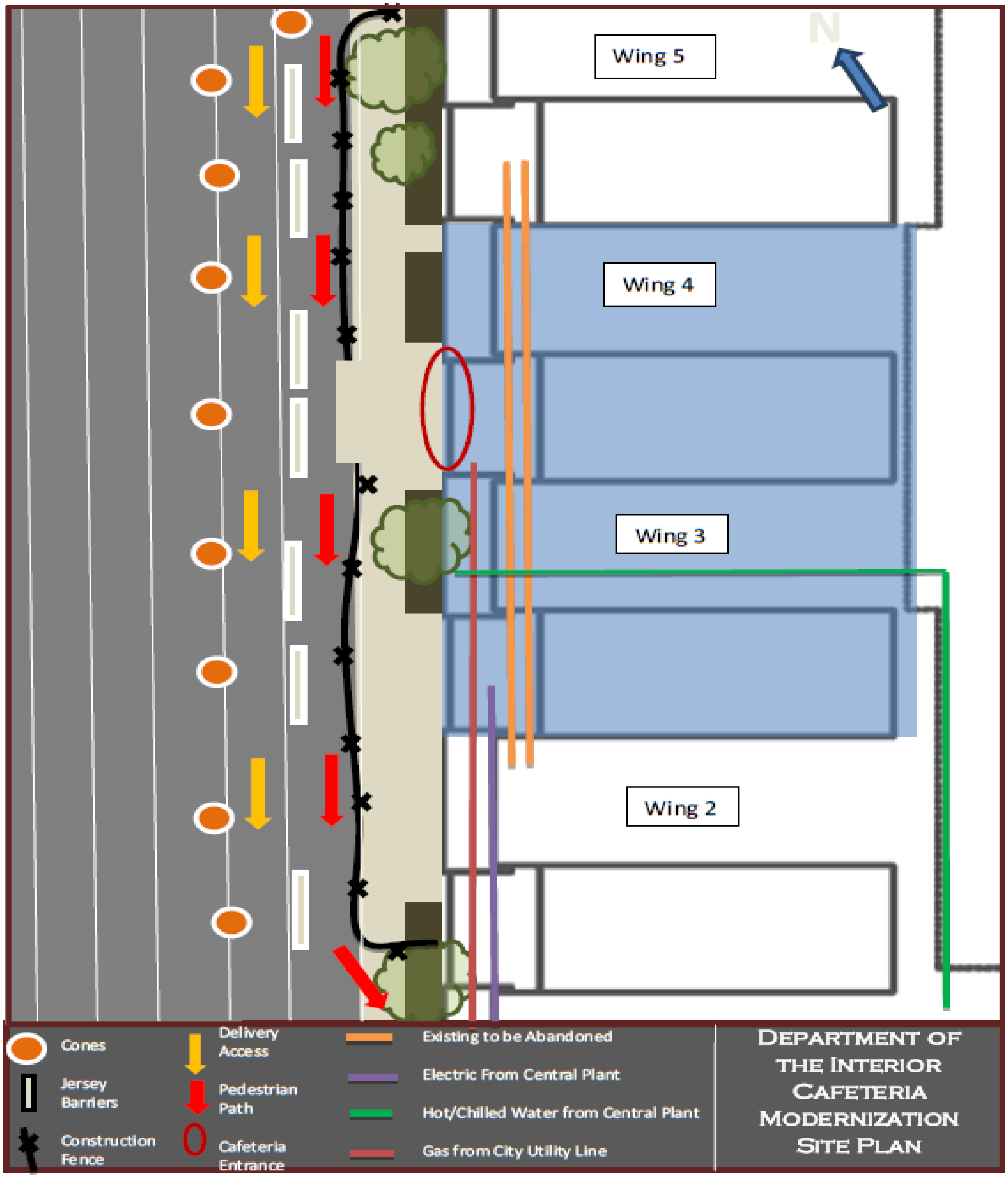
Washington D.C. was built on top of a swamp, and thus has a high water table. One morning, a half hour thunderstorm overflowed the city sewer system, and flooded every neighboring street as well as the mechanical and electrical room in the cafeteria. This being said, waterproofing, rebar coverage, drainage, and structural foundations needed more than normal consideration.

## 3.2 Site Layout




The Department of the Interior building is located in the Foggy Bottom Section of Washington D.C., just east of the Washington Monument and White House. As with building in any city, parking is at a premium. Two hour limited parking is available on most city streets and while some parking is available in the parking garages, most workers commute by the Washington Metro System. 19th Street is the only access road to the cafeteria entrance. It is a five lane road that has been reduced to three lanes due to the cafeteria construction (Refer to Site Plan for pedestrian/traffic/delivery patterns). Need for further lane closure must be schedule during night shifts, and receive District approval. Delivery schedules must take into account daytime and rush hour traffic as well as presidential motorcade roadblocks.

## Site Plan



Wing 5
N
Wing 4
Wing 3
Wing 2
Cones
Jersey Barriers
Construction Fence
Delivery Access
Pedestrian Path
Cafeteria Entrance
Existing to be Abandoned
Electric From Central Plant
Hot/Chilled Water from Central Plant
Gas from City Utility Line
Department of the Interior Cafeteria Modernization Site Plan

## 3.3 Building Systems Summary

| Yes | No | Work Scope |
|---|---|---|
| X | | Demolition |
| X | | Structural Steel Frame |
| | X | Precast Concrete |
| X | | Cast In Place Concrete |
| X | | Mechanical System |
| X | | Electrical System |
| | X | Masonry |
| | X | Curtain Wall |
| | X | Support of Excavation |
| X | | LEED Certification |

### Demolition

Demolition was the first phase of construction in the modernization of the cafeteria. The original cafeteria was laden with dilapidated carpet, flooring, equipment etc.. Fortunately, the cafeteria also had some historic pieces that were to be incorporated with the new design in order to pay homage to its history. Removing original ceramic tiles, stone flooring transitions, and stone bases requires a significant amount of time and care. In addition to removing and refinishing those materials, there were various murals painted in the cafeteria that needed proper protection. In one instance a contractor working on the opposite side of a wall mural accidentally punctured through to the opposite side of the wall disturbing the mural. Fortunately this was the only incident throughout the construction. Before any of the above could take place, the site must first be declared free from hazardous materials.

Abatement of hazardous materials was a concern throughout modernization of the entire Department of the Interior Building. The cafeteria was no exception. Asbestos was found all over the site from the glue on flooring tiles, to the insulation of piping. In addition to asbestos, lead paint needed to be removed from all surfaces as well. This abatement period was scheduled to occur during night time shifts. All abatement work was done by the contractor Aceco, and daily air quality monitoring performed by Mactec.


Figure 7: Dining Room Demolition Comparison

## Structural Steel

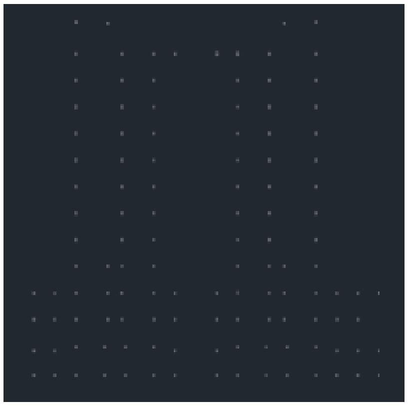


Figure 8: Steel Column Plan

The Department of the Interior Building structure consists of a steel frame encased in cast in concrete. The building was designed in the 1930's to be an example to the rest of the country by having the most advanced mechanical, electrical, communication and fire proofing systems. Encasing steel in concrete was considered the best fire proofing possible at the time. In addition to fireproofing, encasing steel in concrete led to greater spacing for columns and thus making wider corridors and common areas possible. Most of the structure was left untouched in the modernization of the cafeteria.

The largest structural feature on this project lies in the new skylight system for the dining room roof. The dining room roof, lies between Wing 4 and Wing 3, and is one story above grade. The roof is supported by eight main girders that span the entire dining area from north to south. In the original skylight system the roof was completely flat. The new proposed skylights consist of eight pyramid-like skylights that rest on a one foot high cast-in-place concrete curb. The new skylight system adds a significant amount of load to the original roof. After a structural review by Thornton Tomassetti, it was decided that the original steel encased in concrete roof structure could support the load.

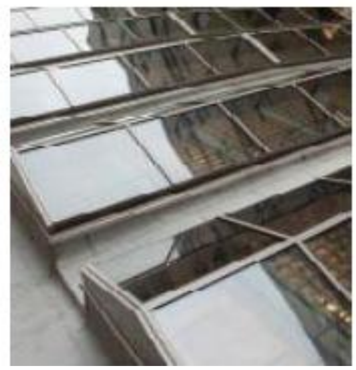


Figure 9: Skylight System

## Mechanical

The mechanical system was designed under the following circumstances:

- Summer outdoor design conditions: 91°F dry bulb, 77°F wet bulb.
- Winter outdoor design conditions: 17°F dry bulb.
- Indoor design conditions: 75°F, 50%RH cooling; 70F heating
- R-19 Walls
- U-0.95 Windows
- R-12.5 Roof
- ASHRAE 62.1 Ventilation Requirements

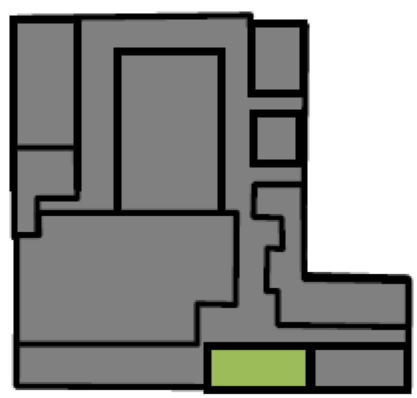


Figure 10: Cafeteria Plan

The system's cooling is provided by chilled water cooling coils in each of the new air handlers. This chilled water comes from the existing base-building cooling plant. The system's heating is provided from multiple sources. Each air handler receives hot-water from the base-building plant. Reheat coils are furnished in each VAV box with exterior exposure. In addition, electric baseboard heaters are located under every tall window. The dining room, kitchen, IDRA, post office, and two conference rooms each have their own air handling unit that is controlled by individual wall mounted thermostats. The kitchen's air handling unit is a Variable Air Volume unit so as to handle the multiple zones in the kitchen. The entire cafeteria is covered with a dry standpipe sprinkler system.

## Electrical

The cafeteria project contains a complex electrical system. Between the lighting controls in the dining room, the electric heating, and the multitude of kitchen equipment the electrical system has many different loads to account for. The system brings in power at both 480Y/277 and 208Y/120 due to the different demands for voltage. All existing panel boards and wiring were removed during demolition and replaced by new ones. The power is supplied from the base building's power system and is also backed up by the main building's generator. The IDRA, post office, credit union, and barbershop all have their own panel.

Figure 10: Electric Room

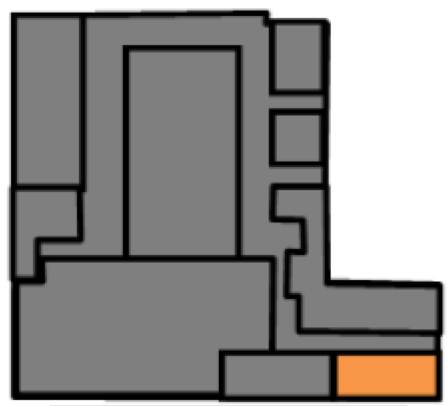


Figure 11: Cafeteria Plan

## LEED Certification

The cafeteria modernization project is working towards achieving a Silver Certification for LEED for Commercial Construction v2.0. The initial design analysis called out 30 "probable" and 17 "possible" points. The construction management process would prove to be vital in this certification due to a significant focus in points through waste recycling, restoration of original materials, material selection from local manufacturers, as well as indoor air quality during construction. A LEED consultant was hired on this project during the design phase and retained throughout the construction period.

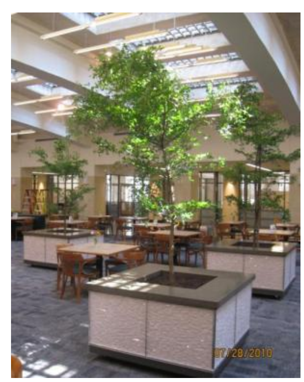


Figure 12: Dining Room Planter

## 3.4 Detailed Schedule Summary

The Department of the Interior Cafeteria Modernization received the Construction Notice to Proceed on February 6, 2009. The first actual construction to take place was the abatement of lead, asbestos, and any other harmful construction material that was present in the site. To avoid endangering any of the building's occupants, all abatement took place during night shifts. After abatement was completed selective demolition began throughout the cafeteria space. Demolition would run slower than usual due to the preservation of many of the original construction materials (ie. Ceramic tiles, murals, stone transitions, stone bases, etc.).

A major scheduling obstacle, laid in the completion of the new skylight system. Due to lack of as-builts, the contractors were unable to approximate the correct scheduling time for the removal of original roofing membrane. This would not be the last major delay to the schedule. Perhaps the largest delay came after the completion of demolition in the kitchen area. The utility trenches under the kitchen were in far worse condition then previously planned for. Replacing dilapidated utility lines, filling the trench with aggregate, and placing a 4" concrete slab over the trenches held up the original schedule by more than a month.

After the skylight system was completed and the utility trench sorted out, the framing of walls and installation of mechanical and electrical systems began. Due to the cafeteria's tie-in to the rest of the building's utilities, coordination was deemed critical to the schedule. BIM modeling was used to design and coordinate all MEP to prevent conflicts from scheduling delays.

In the construction of spaces like a cafeteria, there is a significant focus on finishes. Not only did finishes take longer than scheduled, but also the punch list process dragged out due to the lack of quality control and supervision of finish contractors. The cafeteria punch list compiled more than 1600 items, and even after the occupation of the vendor, over 100 items were still open. The drawn out punch list process pushed back the LEED Flush out to the point where it could not be completed prior to vendor occupation and thus loss of that LEED credit.

See Appendix A for Schedule

# 4.0

# Analysis I: Implementation of Tablet PCs for Quality Control

## 4.1 Proposal

### Problem

Quality Control was a problem throughout the construction of the Department of Interior Cafeteria. Most issues stemmed from lack of communication amongst the project team. Material deliveries were not checked with specifications, finish systems were not installed per the contract documents, and punch list items were unclear and repeatedly failed inspection.

Materials were frequently delivered to the site, marked as being delivered, but often never inspected to make sure that they were the specified materials. A quality control person can physically look at the material, but unless they have the construction drawings or specifications along with them, mistakes can occur. The wrong ceramic wall tile was installed, the wrong colored caulk was placed, and the wrong type of acoustic tile was put in all because they were not inspected properly upon delivery.

Frequently during the project, entire architectural systems were installed improperly. The biggest issue lied in the transitions from one finish to another. In most instances, it was just a lack of communication with the subcontractor as far as what the detail or specification called for.

Finally, all the short comings in the quality control process came to light during the punch list process. The cafeteria punch list consisted of over 1600 items. Most of these items were given vague descriptions with even more vague locations. Due to lack of clarity, most items were deemed complete by the contractor but then deemed incomplete upon the construction manager's review. This lack of communication led to the punch list process lasting for over two months and taking dozens upon dozens of unnecessary man hours.

### Goal

The goal of this analysis is to research how the implementation of Tablet PCs can remediate quality control issues. New developments in software and the growing use of BIM have led to a new great communication tool and it can benefit both the design and construction team. Using Tablet PCs will bring the BIM model out to the field, where it can maximize its potential. Although Tablet PCs can benefit the entire construction process, the majority of this research will dwell on the ability to create better quality control to benefit cost, schedule, and overall quality.

### Methodology

1. Research some Tablet PC's background information
2. Communicate with industry professionals that have implemented Tablet PCs already

3. Determine all short comings in the quality control process on this project
4. Create an implementation plan for using Tablet PCs for this project
5. Select proponents of the project that could have been directly benefitted by using Tablet PCs
6. Do cost and schedule analysis to quantitatively compare using vs. not using Tablet PCs on those proponents
7. Reflect on findings

*Resources*
Jacobs Engineering (Construction Management Agency)
Todd Povell Davis Construction (Industry Professional using Tablet PC's)
AE 473
ENR Magazine
R.S. Means
"Field Software + Tablet PCs+ Construction Field Productivity (Finally)", by Josh Kanner and Adam Omansky

### Expected Outcomes

It is expected that this analysis will prove that using Tablet PCs provides a significant advantage in the construction process and can provide both cost and schedule savings from prevention of construction errors.

## 4.2 Industry on Tablet PCs

As mentioned in an article in ENR titled, "Field Software + Tablet PCs + Construction Field Productivity (Finally)", about the current status of tablet PCs, the original systems were used in the shipping industry to monitor the location and status of packages. The writer touches on the irony that this technology is used for the shipping of a five dollar package but not in a billion dollar industry where it could be even more effective. The first step in answering this quagmire is to consider what is holding the use of tablets back.

The first limiting factor lies in the construction industries fear of technology. Especially in dealing with those who work in the field, anything new always brings about hesitation. Construction may be one of the biggest examples of the "We've always done it this way" mentality. Fortunately, in today's economy there is a need for anything that will decrease cost, shorten schedule, or produce a better end product. Those with that old mentality are falling along the wayside and those who are innovators are in high demand. It is important now more than ever to get contractors and laborers to buy into the use of tablet PCs.

The next limiting factor can be attributed to the lack in development of technology. Early tablets were hard to look at in sunlight, they relied on internet connections, had short battery lives, and were either too big and heavy or too small to view anything on. Often times, one bad experience with a particular technology is enough to turn off some people for good. The good news is that recent developments in technology have solved most of these problems. The chart below reflects the short comings of the previous tablets and the features of the newest technology.

| Past Flaws | Recent Developments |
|---|---|
| Small Unclear Screens | New high definition screens produce life like images and are designed to avoid glare. Tablets are also available large enough to view construction plans with ease. |
| Heavy | New materials have been developed from military research, that are tough enough to handle the day to day work day and yet light enough to carry around. |
| Battery Life | Long lasting Lithium Ion Batteries are now available that can last the entirety of the work day. |
| Hard to write on | Touch screens are now sensitive enough to be written on with an ordinary pen without leaving permanent marks |
| Need Internet | Most Tablets use 3G to stay connected or are developed to automatically synchronize information as soon as it is brought into the trailer's internet connection. |
| Expensive | Prices range from $100 to over a $1,000, but are often a onetime cost that can be paid for by the owner multiple times. |
| Lack of Applications | All kinds of software now exist that can be used from everything from tracking material, to coordinating the BIM model, to streaming video |

## 4.3 Quality Control Cafeteria Modernization Project

Quality Control is something that is continuous throughout a project and every member of the project team is responsible for. It begins with good construction documents such as clear construction details and precise specifications. The primary parties responsible for this are the architects and engineers. If the documents leave out any room for error then there is almost no reason the contractor should do anything different than what the contract documents call for. On this particular project, nearly every issued stemmed from a disagreement in the construction specifications and details. Out of the 1600 punch list items, nearly 75% were a result of unclear specification or contractor not fulfilling a specification. The issues from unclear specifications either resulted in a long strand of RFIs or disputed punch list items. Either way these issues created major schedule delays, conflicts in the project team, ate up enormous amount of time and in the end cost either the owner or GC money.

The next step in quality control lies in the hands of the general contractor. It is their responsibility to decide on how to achieve the required quality. This includes determining the construction methods, equipment and materials to be used, as well as the craftsmen to put the work in place. Each one of these decisions is worked out through the submittal process. This process is often considered inefficient, bureaucratic, and a large waste of time and money. Countless times project submittals went back and forth between the architect and contractor because of discrepancies in the specification. Something as simple as, which buffering method the contractor was to use on the new kitchen equipment, was disputed for an entire week before the contractor ended up eating the cost of getting the surfaces refinished.

The third issue in quality control pertains to getting things constructed properly the first time. The cost and schedule is hit the hardest when a system is completed only to be ripped out because it was done incorrectly the first time. The majority of the time these occurrences were due to a misinformed contractor. This means that the contractor is completely financially response for this fix and thus will have diminished margins. On the modernization project, the contractor caulked over two hundred feet of storefront before the architect saw that it was the wrong type and color caulk. Although the caulk itself was not very expensive, the amount of time it took to install the first caulk, then remove it, and reinstall the right caulk took days.

The final part of quality control lies in the construction management agency's hand and that is to determine and report all deficiencies. If someday down the line the owner's realizes that some part of the project was incorrectly done or that something is not according the contract documents, the contractor will usually not be able to be held liable. Other times, the work was incorrectly put into place, and due to a tight schedule the owner accepted it because the removal and rebuild would impinge to heavily on deadlines. This instance occurred on the cafeteria project during the installation of ceramic wall tile in the kitchen and server. The contractor received a ceramic tile that was the right color and sized but was manufactured in Mexico. Unfortunately, the cafeteria project was striving for a LEED rating and was relying on a point for having materials from within a 500 mile radius. No one on the CM agency side realized that the tile was made in Mexico until the entire system was done. Removing the tile would have been crippling to the schedule and thus the owner signed off on leaving the tile and forfeiting the LEED point. This ended up still costing the GC for having to refund the owner, and left the owner with something they had not agreed upon.

Attention to aforementioned parts of quality control will be the goal of the implementation plan. The use of tablet PCs has potential to remediate problems in each of the aspects of quality control. The implementation plan will outline how tablets can be used to produce a better quality control program.

## 4.4 Implementation Plan

- **Proposal Process**
  The first step to implementing tablet PCs is to get owner buy in. The general contractor or the CM agent must convince the owner that the added cost of using tablets on the project will pay back dividends in quality, budget, and schedule. If an owner can be convinced to buy into this additional cost, the general contractors can afford to buy these systems and keep them for multiple projects and yet charge multiple project owners for the cost. This added monetary benefit could be enough to convince all general contractors to begin using tablet PCs.

- **Field Staff Training**
  If the general contractor is going to convince an owner that using tablet PCs will benefit the project, than they must train their field staff on how to properly use the tool. All superintendents, field engineers, and even foreman should be comfortable with each of the software programs. Often with early BIM models, contractors were forced to create models to satisfy the owner's requirements, but were never actually used during construction. These examples are a total waste of time and money. It is critical that once the owner buys into the use of this technology that the GC is able to deliver.

- **Construction Document Viewing**
  Perhaps the most important step in implementing tablet PCs into the field for quality control is to allow for construction document viewing to be easily done. As stated above, the biggest cause for the downfall of quality control was the inability to have specifications and plans on hand during construction. The field

staff will be able to show labors exactly what needs to be done, leaving no room for error.

- **RFI Process**
  The RFI Process has the potential to be expedited substantially by the use of tablet PCs in the field. RFI's will now be able to be written in the field, and will be able to have pictures and videos taken with the tablet itself attached. In some instances, RFI's will be resolved via webcam. An architect sitting in his office in California, can be live streamed to a construction site in Washington D.C. through the tablet in order to answer a design question by a field engineer. Recordings of the actually streaming video may even be recorded and saved to be kept as legal documents. Although all of this may seem a distant reality, the potential for this efficiency is there.

- **Daily Updates**
  Most contractors are required by contract to submit daily reports to tell the construction manager what activities are being performed that particular day. Implementing tablet PCs will become an additional part of this daily report process. Each day the general contractor will be required to submit either pictures or videos of the activities that are taking place. This will allow to the CM agent or A/E to find mistakes earlier in the process and remove any chance any improper installations of a system or material. In addition to quality control, this daily update system will ensure better safety on site. If a particular activity presents a high safety risk, the safety personnel can monitor the activity remotely. By putting more eyes and ears on laborers, tablets are removing more risk of unsafe practices during construction.

- **Submittals/ Material Handling**
  The ability to view submittals and to monitor material deliveries will be greatly improved by the use of tablet PCs. By having the entire submittal available at all times, the superintendent will be able to ensure that the correct material has been delivered and has been put into place. This particular aspect ties closely into the coordination with the BIM model. By attaching all relevant submittal information to each component of the BIM model, every member of the construction team can see anything that they need by the click of a mouse. Having the PC in the field will allow the field staff to receive a delivery, check the delivered material against the actual submittal, assigned a location to it from the tablet's GPS software, and update the material's status in the BIM model in a matter of minutes.

- **Close Out/ Punch List**
  All of the measures mentioned above will benefit the project close out process. In particular, the punch list process will be greatly simplified. When creating a punch list item the field staff will first use a program that will allow many parties to view and work with at the same time. By the architect, CM agent, and GC having the latest punch list available at all times, a significant amount of confusion will be avoided. The second step will be to attach documents to each item on the punch list to ensure that the item is as clear as possible. Word documents can be attached to each item to fully explain why the item is being written up. Specifications and Plans can be attached to each item to serve as references. Pictures and Videos can be attached to each item to ensure location and current status. Finally, the GPS and the BIM Model can be used to assign locations to each item to further clarify any confusion.

## 4.5 Cost/ Schedule Analysis

For most projects, the cost of quality control goes ignored. In order to further demonstrate the benefits of tablet PCs this analysis will assign a cost to the larger punch list items on the Cafeteria Modernization Project. Punch list items are essentially the result of lapse in quality control. Any aspect of construction that fell through the cracks of the quality control program ends up on the project punch list. R.S. Means will be used to approximate the cost to the budget and schedule for each item.

- #1044:Terrazzo Floor Finish Not to Specification
  During the submittal process for the dining room terrazzo, a sample was agreed upon with a particular glossy finish. During the actual installation of terrazzo, there was a significant amount of dust in the construction zone and thus left the terrazzo with a dull and foggy finish. Every party agreed that the finished product was not acceptable. According to R.S. Means, the cost of a cast-in-place terrazzo floor system with an epoxy finish is 10% higher than a system without a finish. Based on the 8,990 Sq. Ft of terrazzo that needed to be resurfaced, at $12.50/ sq. ft the entire system cost $112,000. This would result in a estimate of **$11,200** to resurface the terrazzo surface to fulfill the specification. The resurfacing started on a Friday afternoon and finished on the Sunday shit, adding **3 days** to the schedule.

- #884: Wrong Color Caulk Between Terrazzo and Storefront
  As stated mentioned earlier, a laborer was provided with the wrong color caulk when caulking the space between the terrazzo and storefront façade. 200 LF of caulk had to be replaced at a price of $1.64/ LF (R.S. Means) resulting in a **$324** mistake which resulted in an entire **1 Day** of extra work.

- #356: Wrong Ceramic Tile
  Also mentioned earlier, the tile contractor improperly installed a brown ceramic wall tile that was made in Mexico throughout the Servery and Kitchen Area. The owner was willing to forfeit the LEED for regional material usage in order to save budget and schedule. 1880 Sq. Ft of ceramic tile would have needed to be replaced at $1.38/ Sq. Ft for demolition of the existing and $6.84/Sq. Ft for the material and installation of the replacement tiles. The cost of this mistake would **$15,500** to the budget and **3 Days** for demolition and **3 Days** for reinstallation. (R.S. Means values for Cost and Schedule)

- #1590: Dining Room Trees Do Not Fit Specification
  This item was a prime example of the general contractor not reviewing the specification and thus results in a major error. The specification called for two olive trees between the height of 8-10 ft, two between 8-9 ft, and two greater than 10 ft. The actual trees put into place ranged everywhere from 6-12 ft in height and did not follow the specifications' quantities. The worst part of this mistake was that the tree had to be picked from a nursery during the growing season and the replacements would not be available for an entire year. Each tree cost $273 resulting in a cost of **$1,683** plus the credit decided upon for the owner having the wrong trees for a year.

| Punch List Item | Cost Impact | Schedule Impact |
|---|---|---|
| **#1044** | $11,200 | 3 Days |
| **#884** | $324 | 1 Day |
| **#356** | $15,500 | 6 Days |
| **#1590** | $1,683 | N/A |
| **Total** | $28,707 | 10 Days |

This analysis only consider four of the sixteen hundred punch list items on the Department of the Interior Cafeteria Project and still resulted in nearly $30,000 in cost and 10 Days in schedule impact. Each of the items could have been caught and resolved if tablet PCs would have been implemented on this project. Using analysis such as this one would be enough to convince any general contractor to use tablets on their projects.

## 4.6 Conclusion

The final conclusion of this analysis is that tablet PC's present a significant opportunity for improvement in quality control. Every project has room for improvement in their quality control program. Although original systems lacked the technology to be useful, current Tablet PC's are now a simple and cheap means for improving quality, cost, and schedule

# 5.0

# Analysis II: Historic Preservations

## 5.1 Proposal

### Problem

The Department of the Interior Building was built in the 1940's under President Roosevelt's New Deal. The original building materials used, are almost as meaningful to the Department of the Interior office, as the murals upon its walls. For this reason, the architect was instructed to preserve some of the cafeteria's original design, to ensure that some of its history could live on. The architect decided to save all the wall murals, the dining room wall and column tiles, the stone wall bases, and the stone floor transitions. Many of these decisions were made purely for design reasons, and did not take constructability or value engineering into mind. Some of the preservations would take countless labor hours and cause a number of constructability issues.

### Goal

The goal of this analysis is to review the architectural preservation decisions and provide as much information for cost and schedule analysis as needed to make value engineering decisions.

### Methodology

1. Break out each historic preservation decision
2. Determine the cost for each preservation
3. Determine the impact to schedule for each preservation
4. Determine the architectural impact of removing that feature
5. Make a value engineering decision for which historic preservations is worth Keeping
6. Proposal Alternative Architectural Finishes
7. Create Revit Model of Space
8. Compare Cost and Schedule impacts of original vs. alternative design

*Resources*
Project Architect
R.S. Means
Revit
Home Depot

### Expected Outcome

It is expected that most of the architectural historic preservations will be more schedule intensive and costly than using new construction materials. With that said, most historic preservations are not kept based on economic decisions. This analysis will give a better understanding of the marriage of those two factors.

## 5.2 History

By the early 1930's the Department of the Interior out grew its small office in the General Services Administration Building and had been split up into 17 various locations. In 1933 Franklin D. Roosevelt took office and appointed Harold Ickes as the Secretary of the Interior. Ickes who was also Administrator of Public Works set forth a proposal for a Department of the Interior Building to be constructed for $12.74 Million dollars. In April of 1935 the construction of the new home for the Department of Interior began. Althought the architect was the prominent Waddy Butlet Wood, no design decision was made without Ickes' input. Ickes watched over every mural that was painted personally. He requested that every mural reflect the spirit of the Department of Interior. Ickes' personal input into the design and construction of the Department of Interior is the reason that many of the materials and design aspects are considered to be worthy of historic preservation.

## 5.3 Preservation Decisions

### Skylights

One of the largest design features on this project lies in the new skylight system for the dining room roof. The cafeteria's original design had flat ceiling skylights that allowed natural light to flood the dining room. During the World Wars it became a government mandate to cover all glass ceiling exposures to protect incase of espionage or bombing. These orginial skylights were abandoned in place and cloved up with layers of roofing material. The new design calls for the return of natural light to the dining room by replacing the previous drop ceiling with a new skylight system that will restore natural light to the space.

Figure 12: New Skylights

The proposed skylight system will require demolition of the present drop ceiling, the original skylights, and the current roofing system. There will also need to be concrete curbs built around the roof openings to support the new skylights. The replacement roofing and removal of present roofing will not be considered in this decision because they were deemed necessary regardless of whether new skylights were installed or not.

### Cost Considerations:

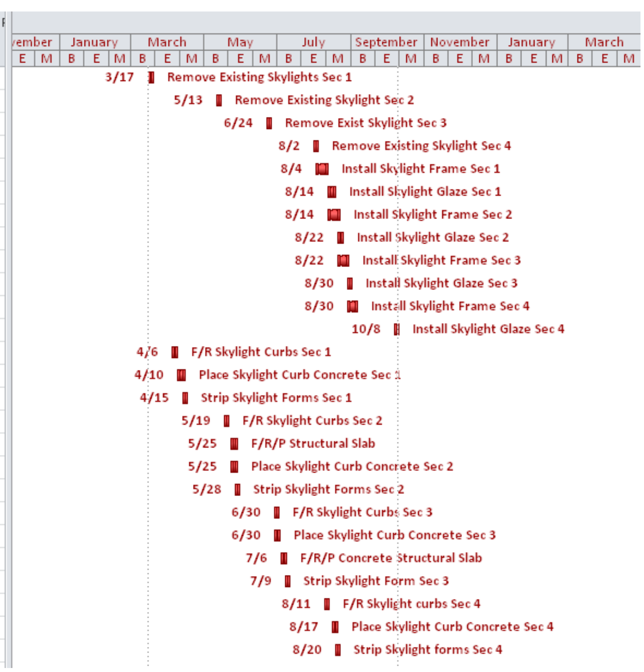
*All cost quantities are derived from 2010 R.S. Means Interior Cost Data

- Demolition of Ceiling Drywall,suspended 5700 S.F. @ $1.13/S.F. in Labor Cost
- Skylight Concrete Curb 18"x9" for 740 L.F. @ $345/C.Y. for Labor, Material, and Equipment. (Includes forms, reinforcing steel, concrete, placement and finishing)
- Skylight cost came from General Contractor Proposal

| Div. | | Quantity | Units | Unit Cost | Total |
|---|---|---|---|---|---|
| | **Demolition** | | | | |
| **0200** | Suspended Drywall | 5700 | S.F. | 1.13 | $6,441 |
| | **Structure** | | | | |
| **3920** | Concrete Curb | 30.83 | C.Y. | 345 | $10,637 |
| | **Skylight System** | | | | |
| | Skylights | 42 | E.A. | 540 | $22,680 |
| | | | | **Subtotal** | **$39,758** |
| | | | **Location Adjustment** | .988 | $39,280 |
| | | | | **Total** | **$39,280** |

### Schedule Considerations:

| Task Name | Duration | Start | Finish |
|---|---|---|---|
| Remove Existing Skylights Sec 1 | 2 days | Tue 3/17/09 | Wed 3/18/09 |
| Remove Existing Skylight Sec 2 | 2 days | Wed 5/13/09 | Thu 5/14/09 |
| Remove Exist Skylight Sec 3 | 2 days | Wed 6/24/09 | Thu 6/25/09 |
| Remove Existing Skylight Sec 4 | 2 days | Sun 8/2/09 | Mon 8/3/09 |
| Install Skylight Frame Sec 1 | 6 days | Tue 8/4/09 | Tue 8/11/09 |
| Install Skylight Glaze Sec 1 | 2 days | Fri 8/14/09 | Mon 8/17/09 |
| Install Skylight Frame Sec 2 | 6 days | Fri 8/14/09 | Fri 8/21/09 |
| Install Skylight Glaze Sec 2 | 2 days | Sat 8/22/09 | Mon 8/24/09 |
| Install Skylight Frame Sec 3 | 6 days | Sat 8/22/09 | Fri 8/28/09 |
| Install Skylight Glaze Sec 3 | 2 days | Sun 8/30/09 | Mon 8/31/09 |
| Install Skylight Frame Sec 4 | 6 days | Sun 8/30/09 | Fri 9/4/09 |
| Install Skylight Glaze Sec 4 | 2 days | Thu 10/8/09 | Fri 10/9/09 |
| F/R Skylight Curbs Sec 1 | 2 days | Mon 4/6/09 | Tue 4/7/09 |
| Place Skylight Curb Concrete Sec 1 | 3 days | Fri 4/10/09 | Tue 4/14/09 |
| Strip Skylight Forms Sec 1 | 2 days | Wed 4/15/09 | Thu 4/16/09 |
| F/R Skylight Curbs Sec 2 | 2 days | Tue 5/19/09 | Wed 5/20/09 |
| F/R/P Structural Slab | 3 days | Mon 5/25/09 | Wed 5/27/09 |
| Place Skylight Curb Concrete Sec 2 | 3 days | Mon 5/25/09 | Wed 5/27/09 |
| Strip Skylight Forms Sec 2 | 2 days | Thu 5/28/09 | Fri 5/29/09 |
| F/R Skylight Curbs Sec 3 | 2 days | Tue 6/30/09 | Wed 7/1/09 |
| Place Skylight Curb Concrete Sec 3 | 3 days | Tue 6/30/09 | Thu 7/2/09 |
| F/R/P Concrete Structural Slab | 2 days | Mon 7/6/09 | Tue 7/7/09 |
| Strip Skylight Form Sec 3 | 2 days | Thu 7/9/09 | Fri 7/10/09 |
| F/R Skylight curbs Sec 4 | 2 days | Tue 8/11/09 | Wed 8/12/09 |
| Place Skylight Curb Concrete Sec 4 | 3 days | Mon 8/17/09 | Wed 8/19/09 |
| Strip Skylight forms Sec 4 | 2 days | Thu 8/20/09 | Fri 8/21/09 |




Total Schedule Days: 71 Days

## Ceramic Wall Tile

Figure 13: Historic Ceramic Wall Tile

During site investigation, a section of drywall had been removed from a dining room column exposing the original ceramic tile. It was deemed to be in relatively good condition, and the idea to uncover all of the dining rooms original ceramic tile and to restore it to its original condition was born. The original ceramic tile was created in the 1930's and would thus be impossible to replicate exactly. Any significantly damaged tile would have to be replaced by relocating tiles from other locations. A standard for deeming which cracked or broken tiles were acceptable and which were not was drafted into the construction documents to facilitate these decisions. In all, the restoration of the ceramic tile would require the demolition of the surfaces covering them, the removal and reinstallation of broken tiles, and finally the refinishing of the ceramic tile and grout.

**Cost Considerations:**

*All cost quantities are derived from 2010 R.S. Means Interior Cost Data

- Demolition of Drywall that is covering up the original ceramic tile, 1100 S.F. @ $0.41/ S.F. of wall
- Demolition of the original ceramic tile in certain areas so that it may be repurposed in locations where the the original tile has been broken or chipped, 200 S.F. @ $1.34/ S.F. of wall
- Plywood Protection for all ceramic tile surfaces to prevent from damage during other demolition or construction 210 L.F. @ $10.10/L.F.
- Replacing and regrouting broken ceramic tile with tile removed from other areas, material and labor cost is $0.475/ S.F. @ 200 S.F. of replaced tile
- Refinishing the ceramic tile with a ceramic coating @ 1.46/ S.F. of tile

| | Item | Quantity | Units | Unit Cost | Total |
|---|---|---|---|---|---|
| **Div.** | **Demolition** | | | | |
| **1000** | Dry Wall | 1100 | S.F. | 0.41 | $451 |
| **3760** | Replacement Tiles | 200 | S.F. | 1.36 | $272 |
| **0305** | Protection | 210 | L.F. | 10.10 | $2,121 |
| | **Restoration** | | | | |
| **900** | Reinstallation | 200 | S.F. | 4.75 | $950 |
| **3600** | Refinishing | 1100 | S.F. | 1.46 | $1606 |
| | | | | **Subtotal** | **$5400** |
| | | | **Location Adjustment** | .988 | $5335 |
| | | | | **Total** | **$5335** |

**Schedule Considerations:**

| Task Name | Duration | Start | Finish |
|---|---|---|---|
| Salvage Tile | 20 days | Sat 5/9/09 | Thu 6/4/09 |
| Reinstall/Repair/Replace Tile | 25 days | Sat 6/6/09 | Thu 7/9/09 |
| Install Ceramic Tile Protection | 5 days | Mon 6/8/09 | Fri 6/12/09 |
| Remove Ceramic Tile Protection | 2 days | Sun 1/10/10 | Mon 1/11/10 |


Total Schedule Days: 52 Days

## Wall Painted Murals

As mentioned early in the history section, the Department of the Interior building is riddled with wall murals dating back to the 1930's. Harold Ickes wanted each one of these elaborate murals to depict the various aspects of life in America that the department watches over. Most of the murals contain images of Native Americans, wildlife, or scenes from National Parks. Although these murals are not protected by the Federal Historic Preservation guidelines, they have high sentimental value to the department. This preservation decision encompasses the complete protection of mural walls during demolition and construction, scaffolding to support the protection, removal of protection, and finally restoration of the originally painting by a restoration contractor.

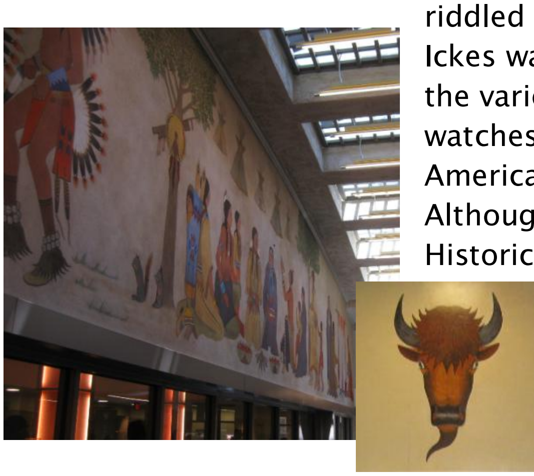


Figure 14:Dining Area Murals

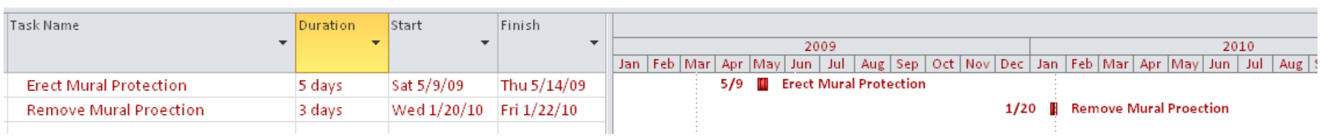
**Cost Considerations:**

* All cost quantities are derived from 2010 R.S. Means Interior Cost Data

- Temporary Mural Protection of 3/4 " Plywood supported by scaffolding, 120 LF @ $10.10/ S.F.
- (20) Sections of Steel Tubular Scaffolding 7'6" high rented for 8 Months at $7.70 per section per month
- Restoration price for the murals was take from General Contractors Bid

| Div. | Item | Quantity | Units | Unit Cost | Total |
|---|---|---|---|---|---|
| | **Demolition** | | | | |
| | Protection | 120 | LF | 10.10 | $1212 |
| **2250** | Scaffolding | 20 | EA | 7.70/month | $1232 |
| | **Restoration** | | | | |
| | Restoration Artist | 1 | | 1150 | $1150 |
| | | | | **Subtotal** | **$3594** |
| | | | **Location Adjustment** | .988 | $3550 |
| | | | | **Total** | **$3550** |

**Schedule Considerations:**




Total Schedule Days: 8 Days

## 5.4 Analysis Summary

| Preservation Item | Cost | Schedule Impact | Architectural Contribution |
|---|---|---|---|
| **Skylights** | • $39,280<br>• Reduces the cost of the roofing materials<br>• Reduces the cost artificial light necessary if controls are used | • 71 Days<br>• Increases complexity of the roof schedule<br>• Pushes back Dry-In Date | • Brings Natural Light in the Space<br>• Decreases Need for Artificial Lighting<br>• Restores Original Design<br>• Brings the Outside environment indoors<br>• Supplements the natural light brought in through the courtyard<br>• Gives a connect with nature that is consistent with the theme of the Department of the Interior |
| **Ceramic Wall Tile** | • $5,335<br>• Any other system would require a material cost as well as its own labor cost<br>• Removing Drywall without destroying tile increases demolition cost | • 55 Days<br>• Alternative system may have less or more schedule impact<br>• Constructing and Removing protection is an addition schedule cost | • Restores original construction materials<br>• Restores original design<br>• Sets the tone for all the color selection of all other finishes<br>• Provides a durable wall material<br>• Does not give the pristine “brand new” quality that a new material would |
| **Historic Murals** | • $3,550<br>• Covering up the murals would have a material and labor cost | • 8 Days<br>• The location of the scaffoldings decrease productivity<br>• The professional restoration must be completed before LEED Flush Out<br>• Any delays in schedule will increase rental cost | • Pays tribute to the original design<br>• Pays tribute to the theme of the Department of the Interior<br>• Creates a color scheme that sets the tone for the rest of the room design<br>• Provides a central focal point in the space |

## 5.5 Architectural Breadth: Proposed Alternate Design

### Skylight Alternate

The dining room without the skylight system is a rather simple redesign. The decision to remove the skylight system is purely economic and so the redesign must be economic to the project cost and schedule. By removing the skylight design, the roofing system will be continuous for the entirety of the dining room space. Erasing the need to phase the roof construction, build concrete curbs, erect the skylights, as well as the added installation time to build the roof around the skylights will dramatically reduce the schedule. In order to determine the addition roofing cost, a square foot estimate will be used to account for the extra square footage of roofing.

The dining room ceiling will also have to be redesigned to account for the absence of skylights. The Pyrock® spray plaster finish will be continuous across the entire dining room ceiling area. Since the construction materials are the same for the most part, no change in acoustics will need to be considered.

**Cost Consideration:**

| Item | Total System Cost | Sq. Ft Cost | Redesign Quantity | Redesign Cost |
|---|---|---|---|---|
| Roofing System | $41,500* | $8.30/ Sq. Ft** | 1152 Sq. Ft | $9,561 |
| Pyrock® | $9,250* | $1.85/ Sq. Ft** | 1152 Sq. Ft | $2,131 |
| | | | Total | **$11,692** |

*Value Determine in General Contractors Original Proposal

**Based off of 5,000 Sq. Ft of Dining Room Roof/Ceiling Area

**Schedule Consideration:**

According to R.S. Means, a built-up asphalt roofing system as called for in the original design takes 0.036 Hours per crew per Square Foot. By these numbers, it will require one crew an extra **5 days** to roof the additional amount of roof area without the skylight system.

### Ceramic Wall Tile Alternate

The proposed redesign calls for mosaic tile to replace the existing restored ceramic tile. The proposed Stone/Glass mosaic tile comes in 12 in x 12in sheets which are easy to install and economic at $13.75/ Sq. Ft.  It has similar acoustical properties, as well as being just a durable as the original tiles.

Figure 15: Merole® Glass/Stone Mosiac Tile

**Cost Consideration:**

| Item | Quantity | Material Cost | Installation Cost | Total |
|---|---|---|---|---|
| **Ceramic Tile** | 1100 Sq. Ft | $13.75/ Sq. Ft* | 6.21/ Sq. Ft* | **$21,956** |

*Home Depot Price for Merola® Tile

** R.S. Means Value for Glass Mosaic Tile

**Schedule Consideration:**

According to R.S. Means, ceramic wall tile in square foot sheets take .028 Hours per Sq. Ft per crew**. The entire system could be installed in **1 day** is there are at least four crews installing tile at a time.

*Home Depot Price for Merola® Tile

** R.S. Means Value for Glass Mosaic Tile

### Historic Mural

Figure 16: Home Legend Hand Scratched Veneer

The location of each of the murals is the focal point of the space. When sitting anywhere in the dining room, the occupants' eyes are automatically drawn to the front of the room. For this reason, the mural walls must contain a bold design feature. Below the murals, are large planters containing various natural vegetation. A common theme throughout the Department of the Interior Building's design is the attention to nature. Since the department itself, is responsible for all of the nation's national parks, it is important to involve nature in the dining room's redesign as well. For those reason, the mural wall redesign consist of a dark hand scraped walnut veneer paneling. The dark color will provide contrast to the light colors throughout the space. The natural wood textures will accent the various plants and trees in the space.

**Cost Consideration:**

| Item | Quantity | Material Cost | Equipment Cost | Installation Cost | Total |
|---|---|---|---|---|---|
| **Hand Scraped Wood Veneer** | 1200 Sq. Ft | $3.98/ Sq. Ft* | - | 1.03/ Sq. Ft** | $6012 |
| **Scizzor Lift** | 1 | - | $295/Week | - | $295 |
| | | | | Total | **$6,305** |

**Schedule Consideration:**

Estimating that it takes 0.028 hours per sq. ft per crew to install this system it would take a crew a little more than **4 Days** to install this system.

*Home Depot Price for Home Legend® Product
** R.S. Means Value for Wood Veneer
***Sunbelt Rentals (Construction Equipment Renting Company) Rate

| Item | Original Schedule Impact | Original Cost Impact | Redesign Schedule Impact | Redesign Cost Impact |
|---|---|---|---|---|
| Skylights | 71 Days | $39,280 | 5 Days | $11,692 |
| Ceramic Tile | 55 Days | $5,335 | 1 Day | $21,956 |
| Murals | 8 Days | $3,550 | 4 Days | $6,305 |
| | | | | |
| Total | 134 Days | $48,165 | 10 Days | $39,953 |

**Redesign Saves: 124 Days AND $8,212**

Refer to Appendix C for Rendering of Proposed Design

## 5.6 Conclusion

Acknowledgement of the Department of the Interior's building is of significant importance to the project's design. Architectural decisions are rarely made on just schedule and budget impacts. This being said, architectural decisions should not be made without considered schedule and budget. In the end, the best solution is lies in the value engineering decision. Although the skylights and murals contribute significantly the spaces appeal, the restore ceramic tiles are both cost to schedule, budget, and overall aesthetic appeal. Based on this analysis, the best design would preserve the murals and skylights, but replace the ceramic tile throughout.

# 6.0

# Analysis III: Advanced Lighting System

## 6.1 Proposal

### Problem

One goal in designing the cafeteria was to take advantage of every potential situation for sustainable design. The cafeteria lighting system uses energy efficient ballast and luminaires. The cafeteria design also uses a new skylight system and roof. Unfortunately, the new lighting system for the dining room does not take advantage of advanced lighting controls to measure the amount ofdaylight available with a Daylight Harvesting System (DHS) and then use a Centralized Dimming and Switching system (CDS) to adjust the amount of artificial light necessary. These systems propose an opportunity for energy savings.Although these systems may decrease the amount of energy necessary, they will not result in a Net-Zero energy lighting system for the dining room.

### Goal

The goal of this analysis is to incorporate photovoltaic panels on the dining room roof to produce enough energy to make a Net-Zero energy lighting system for the dining room. By decreasing the amount of energy necessary with the installation of a DHS and CDS system and actually producing energy with photovoltaic the dining room should be able to be self-sufficient or at least need minimal auxiliary power.

### Methodology

1. Research existing lighting system
2. Select DHS and CDS systems
3. Determine the lighting electrical demand
4. Research PV design
5. Perform solar studies to measure the amount of solar power available
6. Calculate amount of available space of PV panels
7. Research photovoltaic systems that can meet the lighting demand and fit the amount of roof available
8. Perform cost analysis for this system
9. Summarize the economic cost/savings of making this design change

   *Resources*

   AE 311
   EE 212
   www.solar-estimator.org
   www.freesunpower.com
   Lutron Electronics, Inc.
   www.helpusolar.com
   Applicable Literature
   Dr. Riley

## Expected Results

I expect to find a system that will provide sufficient electricity to power the Dining Room lighting demands. The hard part will be finding a system that will fit in the a lot amount of space that is not hampered by shading and yet still reach the necessary demand load. The General Services Administration plans on owning this building for most likely its entire life, and thus they will be more likely to accept a longer payback period than most private building owners.

## 6.2 Existing Lighting

The existing lighting system was chosen with sustainability in mind. Since the owner of this project is the General Service Administration, they have much more experience than a typical owner. GSA owns hundreds of government buildings across the country and even overseas. They pay utility bills for each of these buildings and thus they have design standards for which all their buildings energy systems must be held to. On this project, the design called for very efficient electronic ballast with a single T5 lamp. These luminaires provide good color, allow for dimming, provide high lumen/watt output, and long lifespan. For all those reasons, this system was a good selection by the architect and owner, and thus will not be replaced in this analysis' redesign.

The layout of the lighting system also provided an interesting architectural feature to the dining room. Each luminaire was suspended by string from the ceiling. Each of the 8 bays consisted of 16 suspended luminaires. Each luminaire was suspended at a different height to provide an oscillating wave appearance. This design feature is also important to the overall space and will also be kept in the redesign.

Figure 16: Lighting Array

## 6.3 Advanced Lighting Controls System Selection

The original lighting system was a sound sustainable design in many ways. The system has all the right components for a sustainable design with the exception of one part. Although the lights were capable of being dimmed for the various uses of the space, the dimming function was not used for energy saving purposes. By implementing a daylight harvesting and a controlled dimming system, the dining room lighting design would be able to take full advantage of its sustainable design.

Since most of the original system consisted of Lutron products, a Lutron system was chosen for the advanced lighting controls. The Ecosystem® is comprised of a Bus Supply, Occupancy Sensors, and Ecosystem Ballast, a photo-sensor, and a portal system programming device. These components will work together to ensure that 50 foot-candles are maintained at the surface level in the dining room based on the combination of natural and artificial light. Based on consumer reviews of this system, it is easy to install and even easier to maintain. Both of these features are important to both the cost of installation as well as the feasibility of the building's facilities crew maintenance. Below is a model wiring diagram of the system's components.

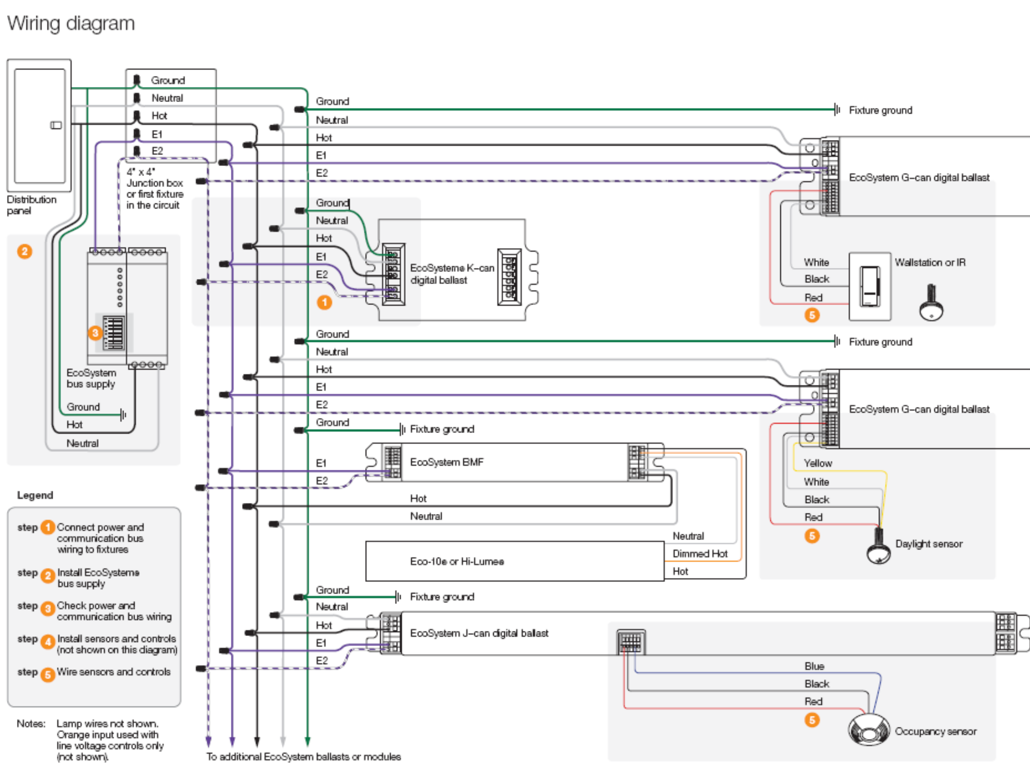



Figure 17: Wiring Diagram

## 6.4 Lighting/ Electrical Breadth

### Solar Study

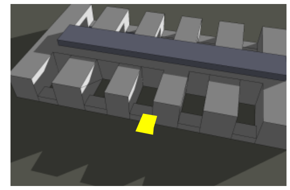


Figure 18: Option 1

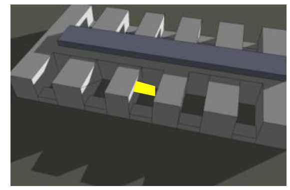
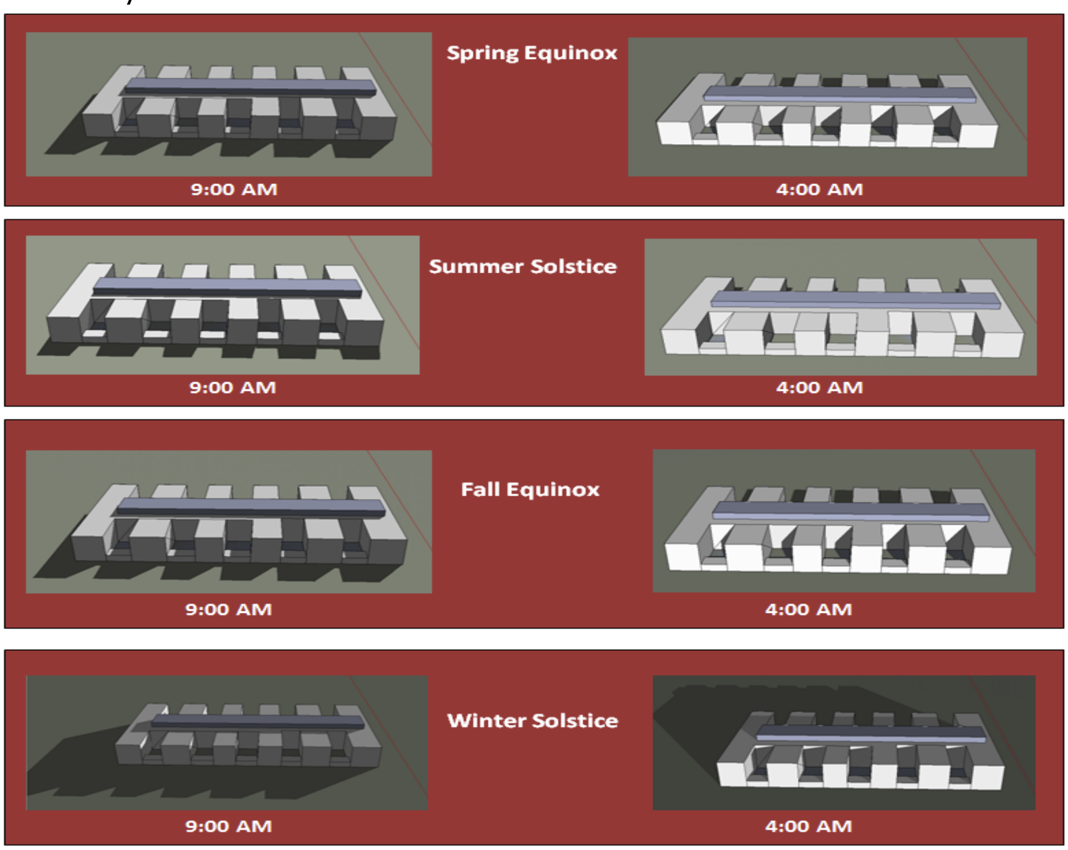


Figure 19: Option 2

Before beginning to design a photovoltaic system, a solar study must be performed to determine the various shadows that occur during the peak solar energy collection time (9:00AM -4:00PM). The ideal panel array is located in a position that receives sun for the entire 9am-4pm collection period. In reality, usable roof area is at a premium on this site and thus this decision becomes very difficult. The first option was to integrate the panels between the rows of skylights on the roof. This system would provide to shortest wire path from the collector, to the battery, to the lighting system. The second option was to locate to collectors on the second story roof on the west end of the cafeteria. This was the only other location that was considerable usable and closes enough to the dining room.

After the solar study, option 2 was clearly the most favorable location. Option 1 was almost always in shadow which would reduce the amount of potential power and could possibly even damage the panels. Option 2 does experience significant shadow in the early hours of the winter but it avoids shadow for the majority of the collection period throughout the year.



## Lighting Demand

Determining the lighting load to size the photovoltaic system is extremely difficult. The first step was to measure the amount of natural light the space experiences throughout the course of the time that the dining room is in use (6am-3pm). Using AGI a daylight study was performed on the spring and fall equinox, as well as the summer and winter solstice. See Appendix B for sample images of the spring equinox study. From this study it should be noted that a significant amount of light ranging from 0-30 foot-candles can be measure at the floor level just from the natural light contribution throughout the day.

As mentioned earlier, one of the keys to this analysis is to use the natural light contribution to decrease the amount of artificial light that needs to be supplied. Since the space requires 50 foot-candles at the floor level, and the natural light supplies 35 foot-candles, the lighting system needs only to supply 25 foot-candles. By dimming the lighting system to produce only 25 foot-candles at floor level, the demand of power will also be decreased. Since the system will constantly be in flux between the amount of light needed from the lighting system, and the amount of power necessary is hard to predict. The lighting demand can either be determined by assuming that every light is being used at full power from 6am to 3pm, or by estimating a percentage of the maximum demand. For this analysis, a photovoltaic system will be designed based on the maximum lighting power demand.

For the maximum demand, each lamp uses 28 Watts and there are a total of 128 lamps used for the Dining Room. At peak load, when all lamps are on, the spaces uses 3584 Watts per Hour. Since on an average day, the Dining Room Lights will be on from 6am until 3pm the average daily lighting demand is thus 32,250 Watt-Hours. This demand yields a 999 kWh monthly demand and an 11770 kWh yearly demand. For the most part, the system will never be at this demand, but an excess power can either be diverted back to the grid and sold to the electric company or used to power another system.

## Photovoltaic Selection

Using helpusolar.com, and plugging in the annual energy demand of 11770 kWh, the average amount of sunshine hours (4.23 for Washing D.C.), and the goal of 100% of energy demand, the DC Solar Array Size was determined to be 10.16 kW. Using the Sharp® 224 Poly Panel for this design, it is determined that 45 panels at 224W each, are necessary to meet the demand. The specification sheet for these panels are located in Appendix C. These particular panels were selected for the 25 year warranty, durability, long-life, and high cell efficiency.

## Array Design

The second story roof location that was selected in the solar study is a 50’ x 30’ foot area. Each Sharp® panel is 3’x5’. By keeping the panels in rows of 11 the array allows room for maintenance. By keep the array to the north most side of the building, some early morning shadowing can be avoided. The panels will be fixed at an angle of 38% based on the buildings latitude.

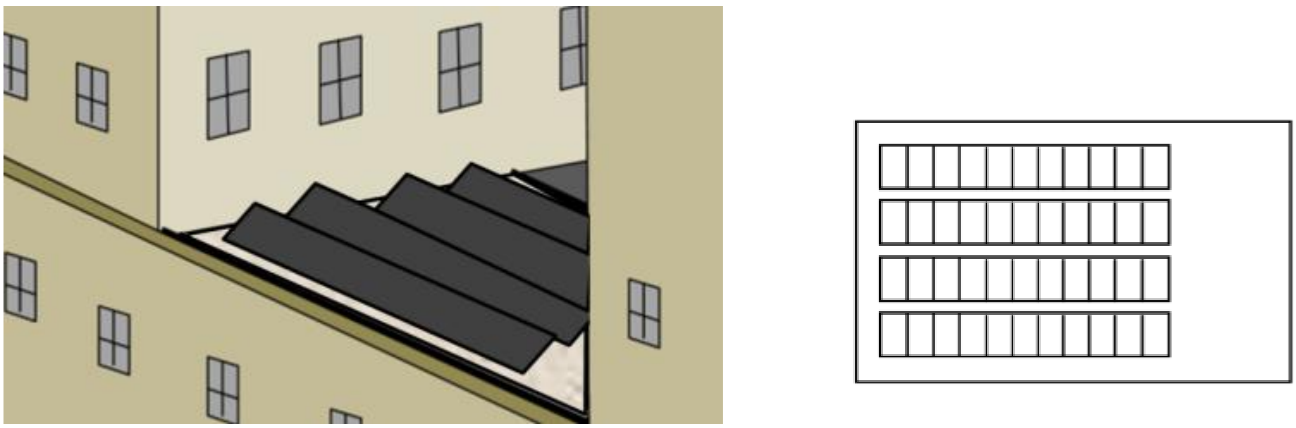


Figure 20: Proposed PV Array

## Charge Controller Selection

A Maximum Power Point Tracking controller will be used to maintain the proper charging voltage on the batteries. This controller increases the amps in order to make up for a lower voltage in the battery.

## Battery Selection

Selecting the proper battery for this system is critical to the sustainability and efficiency of this design. An Absorbed Glass Mat (AGM) battery type will be used in this design for a multitude of reason. They are leak and spill proof which will make maintenance easy. They do not emit any gases which will allow for their storage in the building. Locating the battery storage in the building is important because of the decrease inefficiency when batteries are exposed to extreme temperatures. These types of batteries are also better at maintaining voltage, slowing discharge, and last longer. The particular AGM battery used for this design is made by Sun Xtender®.

### 6.4.7 DC Power Use

An additional part of this system's sustainable design lies in the usage of direct DC power from the Collectors, to the batteries, to the fixtures. Many involved with sustainable construction and design are aware of the benefits of using DC power as oppose to AC power from the grid. Although DC power is not a good solution for systems that have vast expanses of wire, it is a feasible solution for this design. DC power uses low voltage between 12-48V as opposed to AC power which can be between 120-277V presenting a much safer alternative. DC power is also much easier to install and modify. Perhaps the most significant reason for DC usage is due to its efficiency. Traditionally DC power from the solar panels is inverted to AC power at an efficiency of 80%. Directly supplying DC power from the panels to the light fixtures provides a savings of 20%.

Since a tie to the grid is also necessary to serve as a backup during instances of low solar contribution, and also a means of selling back excess power, it is necessary to still have an inverter in the system. The difference in this design will be that the only time power will be converted is when not enough or too much solar energy is available. Reference the diagram below:

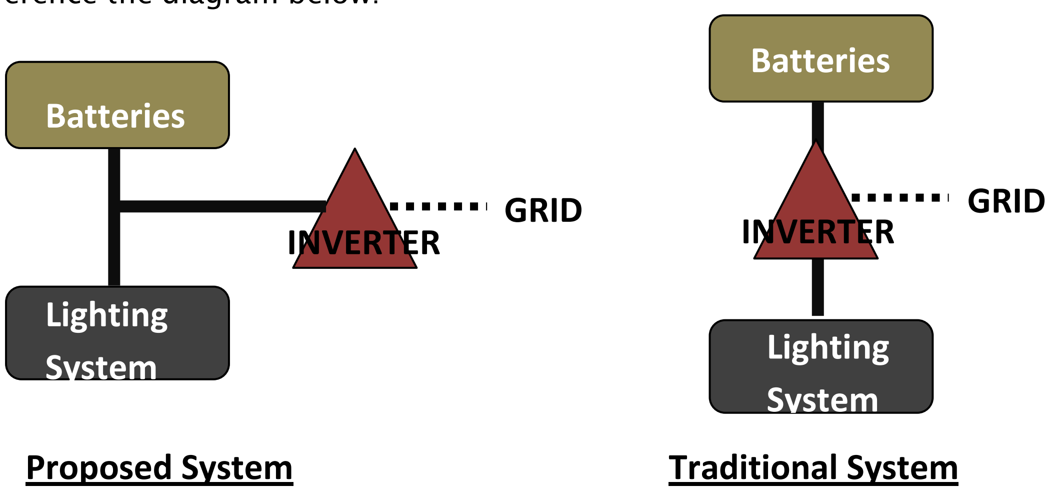



Figure 21: Inverter Set Up

## 6.5 Cost Analysis

A precise cost analysis is very difficult to calculate based on the complexity and variability of this proposed design. This proposal is set up to provide energy savings in three different ways. The first energy savings is due to the advanced lighting controls dimming the amount of energy used by the lighting system based on the amount of natural light present. The second energy savings comes from the implementation of photovoltaic panels to produce free electricity. The final aspect of energy savings comes in the usage of DC power as opposed to traditional AC power.

To give idea of the energy savings, a study of an average day's energy demands will be considered. March 21, the spring equinox was chosen as the most typical day because it is in the middle of both solar extremes. The following lighting demand was calculated is based on the AGI study in Appendix B.

| Hour | % Natural Light | % Artificial Light | Proposed System Demand | Original System Demand |
|---|---|---|---|---|
| **6:00-7:00AM** | 0% | 100% | 3,584 Wh | 3,584 Wh |
| **7:00-8:00AM** | 6% | 94% | 3,369 Wh | 3,584 Wh |
| **8:00-9:00AM** | 12% | 88% | 3,153 Wh | 3,584 Wh |
| **9:00-10:00AM** | 16% | 84% | 3,010 Wh | 3,584 Wh |
| **10:00-11:00AM** | 21% | 79% | 2,831 Wh | 3,584 Wh |
| **11:00-12:00PM** | 24% | 76% | 2,723 Wh | 3,584 Wh |
| **12:00-1:00PM** | 30% | 70% | 2,509 Wh | 3,584 Wh |
| **1:00-2:00PM** | 36% | 64% | 2,294 Wh | 3,584 Wh |
| **2:00-3:00PM** | 44% | 56% | 2,007 Wh | 3,584 Wh |
| | | **Total Demand** | 25480 Wh | 32256 Wh |

Average Daily Savings: (32,256 Wh - 25,480 Wh) = 6.7 kWh

Estimated Yearly Savings: 2473 kWh

Potomac Electric Power Rate: $0.154/kWh

Cost Savings: $380/Year

The next energy savings is determined by the usage of DC power as opposed to AC power. Since 20% of the power is lost from the conversion of DC to AC, the photovoltaic system would have actually needed to produce 120% of the lighting demand load in order to supply enough power.

Average Daily Demand with DC Power: 25.48 kWh

Average Daily Demand with AC Power: (25.48 x 120%) = 30.58 kWh

Average Daily Energy Savings: (30.58 - 25.48) = 5.1 kWh

Estimated Yearly Savings: 1861.5 kWh

Potomac Electric Power Rate: $0.154/kWh

Cost Savings: $286/Year

The final energy savings is determined by the implementation of a photovoltaic system to supply energy to the lighting system. The system was designed supply 32.25 kWh per day. On average daily demand calculated above is 25.48 kWh, 6.7 kWh to be sold back to the grid. Potomac Electric Power Company allows for electricity to be sold back grid at the same price rate that it is supplied.

Daily Solar Energy Supplied: 32.25 kWh

Estimated Yearly Savings: 11,770 kWh

Potomac Energy Power Rate: $0.154/ kWh

Cost Savings: $1812/Year

To determine the cost each of these energy saving solutions was determined from a couple different sources. The cost of a photovoltaic system of this size in Washington D.C. is estimated at $74,160 based on the calculations of solar-estimate.com. Fortunately this system is qualified for a significant amount of financial incentive rebates. The District of Columbia Public Service Commission (PSC) provides a rebate of $44,106 which is broken down into ten $4,413 payments over ten years. The DC Renewable Energy Incentive Program (REIP) provides an incentive of $21,540. The Federal Government ensures a $22,248 rebate. The Federal Government also provides a Modified Accelerated Cost Recovery System (MACRS) which is a $15,146 tax credit for the systems depreciation. The other system cost will come from the new Lutron EcoSystem® advanced lighting controls. Price of similar systems was estimated at $10,000 from 1touchmove.com. The following chart determines the payback period for this proposal:

| Item | Year 1 | Year 2 | Year 3 | Year 4 | Year 5 |
|---|---|---|---|---|---|
| **Advanced Lighting Control Energy Savings** | +$380 | +$380 | +$380 | +$380 | +$380 |
| **DC Power Savings** | +$286 | +$286 | +$286 | +$286 | +$286 |
| **PV System Energy Savings** | +$1812 | +$1812 | +$1812 | +$1812 | +$1812 |
| **PV System Cost** | -$74,160 | | | | |
| **DC PSC Rebate** | $0 | +$4,413 | +$4,413 | +$4,413 | +$4,413 |
| **DC REIP Rebate** | +$21,540 | $0 | $0 | $0 | $0 |
| **Federal Tax Rebate** | +$22,248 | $0 | $0 | $0 | $0 |
| **MACRS Rebate** | $0 | +$15,146 | $0 | $0 | $0 |
| **EcoSystem® Cost** | -$10,000 | $0 | $0 | $0 | $0 |
| | | | | | |
| **Annual Cash Flow** | -$37,894 | $22,037 | $6,891 | $6,891 | $6,891 |
| **Cumulative Cash Flow** | -$37,894 | -$15,857 | -$8,966 | -$2,075 | +$4,816 |

**Break Even Point: 4 Years**

## 6.6 Conclusion

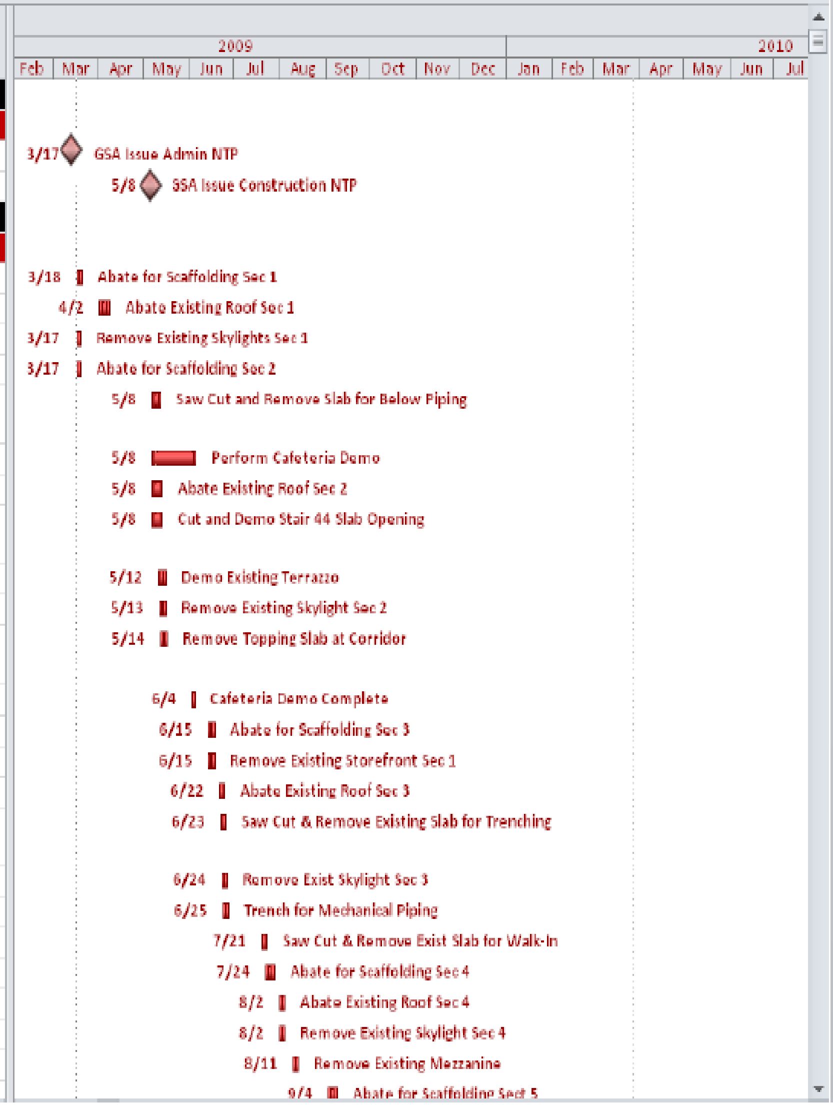
This analysis combined three sustainable design features in order to produce a Net Zero Energy System. In designing these concepts, a significant amount of assumptions needed to be made in order to draw this conclusion. In an ideal design, every aspect from the ballast to the dimmers, to the photo sensors would have been selected together. The photovoltaic system would have been designed to produce exactly the amount of solar energy needed based of the lighting demand taking dimming into account. Similarly, the entire systems wiring would have been designed to provide DC current from the collectors, to the charge controller, to the batteries, and ultimately to the fixtures. Attempting to retrofit an original design with all three of these changes is nearly impossible. Based on the findings of this analysis, designing a system that includes all of these components would prove to be both sustainable and economical.

Timeline

Start Mon 3/16/09 — April, May, June, July, August, September, October, November, December, January, February, March — Finish Fri 3/26/10

Gantt Chart

| | Task Name | Duration | Start | Finish |
|---|---|---|---|---|
| 1 | **Start Up** | | | |
| 2 | **Administration** | | | |
| 3 | GSA Issue Admin NTP | 0 days | Tue 3/17/09 | Tue 3/17/09 |
| 4 | GSA Issue Construction NTP | 0 days | Fri 5/8/09 | Fri 5/8/09 |
| 5 | **Sitework** | | | |
| 6 | **Demolition** | | | |
| 7 | Abate for Scaffolding Sec 1 | 2 days | Wed 3/18/09 | Thu 3/19/09 |
| 8 | Abate Existing Roof Sec 1 | 3 days | Thu 4/2/09 | Mon 4/6/09 |
| 9 | Remove Existing Skylights Sec 1 | 2 days | Tue 3/17/09 | Wed 3/18/09 |
| 10 | Abate for Scaffolding Sec 2 | 2 days | Tue 3/17/09 | Wed 3/18/09 |
| 11 | Saw Cut and Remove Slab for Below Piping | 2 days | Fri 5/8/09 | Mon 5/11/09 |
| 12 | Perform Cafeteria Demo | 20 days | Fri 5/8/09 | Thu 6/4/09 |
| 13 | Abate Existing Roof Sec 2 | 3 days | Fri 5/8/09 | Tue 5/12/09 |
| 14 | Cut and Demo Stair 44 Slab Opening | 3 days | Fri 5/8/09 | Tue 5/12/09 |
| 15 | Demo Existing Terrazzo | 3 days | Tue 5/12/09 | Thu 5/14/09 |
| 16 | Remove Existing Skylight Sec 2 | 2 days | Wed 5/13/09 | Thu 5/14/09 |
| 17 | Remove Topping Slab at Corridor | 2 days | Thu 5/14/09 | Fri 5/15/09 |
| 18 | Cafeteria Demo Complete | 0 days | Thu 6/4/09 | Thu 6/4/09 |
| 19 | Abate for Scaffolding Sec 3 | 2 days | Mon 6/15/09 | Tue 6/16/09 |
| 20 | Remove Existing Storefront Sec 1 | 2 days | Mon 6/15/09 | Tue 6/16/09 |
| 21 | Abate Existing Roof Sec 3 | 2 days | Mon 6/22/09 | Tue 6/23/09 |
| 22 | Saw Cut & Remove Existing Slab for Trenching | 2 days | Tue 6/23/09 | Wed 6/24/09 |
| 23 | Remove Exist Skylight Sec 3 | 2 days | Wed 6/24/09 | Thu 6/25/09 |
| 24 | Trench for Mechanical Piping | 2 days | Thu 6/25/09 | Fri 6/26/09 |
| 25 | Saw Cut & Remove Exist Slab for Wall | 2 days | Tue 7/21/09 | Wed 7/22/09 |
| 26 | Abate for Scaffolding Sec 4 | 2 days | Fri 7/24/09 | Mon 7/27/09 |
| 27 | Abate Existing Roof Sec 4 | 2 days | Sun 8/2/09 | Mon 8/3/09 |
| 28 | Remove Existing Skylight Sec 4 | 2 days | Sun 8/2/09 | Mon 8/3/09 |
| 29 | Remove Existing Mezzanine | 2 days | Tue 8/11/09 | Wed 8/12/09 |
| 30 | Abate for Scaffolding Sect 5 | 2 days | Fri 9/4/09 | Mon 9/7/09 |




◆ MILESTONE

▬ DURATION

| | Task Name | Duration | Start | Finish |
|---|---|---|---|---|
| 31 | Abate for Existing Roof Sec 5 | 2 days | Sat 9/19/09 | Mon 9/21/09 |
| 32 | Saw Cut Corridor Openings | 5 days | Thu 12/24/09 | Wed 12/30/09 |
| 33 | Remove Existing Storefront Sec 2 | 2 days | Fri 1/29/10 | Mon 2/1/10 |
| 34 | **Superstructure and Enclosure** | | | |
| 35 | **Roof** | | | |
| 36 | Install Rubber Roof Membrane Sec 1 | 2 days | Fri 4/24/09 | Mon 4/27/09 |
| 37 | Install Rubber Roof Membrane Sec 2 | 2 days | Sun 5/3/09 | Mon 5/4/09 |
| 38 | Install Rubber Roof Membrane Sec 3 | 2 days | Wed 6/17/09 | Thu 6/18/09 |
| 39 | Install Rubber Roof Membrane Sec 4 | 2 days | Wed 8/26/09 | Thu 8/27/09 |
| 40 | Install Rubber Roof Membrane Sec 5 | 2 days | Sat 8/29/09 | Mon 8/31/09 |
| 41 | Install ISO Insulation Entire Roof | 2 days | Thu 10/1/09 | Fri 10/2/09 |
| 42 | Install Multi-Ply Roofing | 2 days | Mon 10/5/09 | Tue 10/6/09 |
| 43 | Install Cap Sheet and Flashing | 2 days | Wed 10/7/09 | Thu 10/8/09 |
| 44 | Test Roof | 1 day | Fri 10/9/09 | Fri 10/9/09 |
| 45 | **Skylights** | | | |
| 46 | F/S/D Skylights | 10 days | Fri 5/8/09 | Thu 5/21/09 |
| 47 | F/S/D Skylight Glazing | 65 days | Tue 5/5/09 | Mon 8/3/09 |
| 48 | Install Skylight Frame Sec 1 | 6 days | Tue 8/4/09 | Tue 8/11/09 |
| 49 | Install Skylight Glaze Sec 1 | 2 days | Fri 8/14/09 | Mon 8/17/09 |
| 50 | Install Skylight Frame Sec 2 | 6 days | Fri 8/14/09 | Fri 8/21/09 |
| 51 | Install Skylight Glaze Sec 2 | 2 days | Sat 8/22/09 | Mon 8/24/09 |
| 52 | Install Skylight Frame Sec 3 | 6 days | Sat 8/22/09 | Fri 8/28/09 |
| 53 | Install Skylight Glaze Sec 3 | 2 days | Sun 8/30/09 | Mon 8/31/09 |
| 54 | Install Skylight Frame Sec 4 | 6 days | Sun 8/30/09 | Fri 9/4/09 |
| 55 | Install Skylight Glaze Sec 4 | 2 days | Thu 10/8/09 | Fri 10/9/09 |
| 56 | **Concrete** | | | |
| 57 | F/R Skylight Curbs Sec 1 | 2 days | Mon 4/6/09 | Tue 4/7/09 |
| 58 | Place Skylight Curb Concrete Sec 1 | 3 days | Fri 4/10/09 | Tue 4/14/09 |
| 59 | Strip Skylight Forms Sec 1 | 2 days | Wed 4/15/09 | Thu 4/16/09 |

MILESTONE

DURATION

| Ac | Ac | Task Name | Duration | Start | Finish |
|---|---|---|---|---|---|
| 60 | | F/R Skylight Curbs Sec 2 | 2 days | Tue 5/19/09 | Wed 5/20/09 |
| 61 | | F/R/P Structural Slab | 3 days | Mon 5/25/09 | Wed 5/27/09 |
| 62 | | Place Skylight Curb Concrete Sec 2 | 3 days | Mon 5/25/09 | Wed 5/27/09 |
| 63 | | Strip Skylight Forms Sec 2 | 2 days | Thu 5/28/09 | Fri 5/29/09 |
| 64 | | F/R/P AHU-1 Pad | 5 days | Fri 6/5/09 | Thu 6/11/09 |
| 65 | | F/R/P Water Heater Concrete Pad | 3 days | Fri 6/5/09 | Tue 6/9/09 |
| 66 | | F/R/P Gas Pressure Booster Concrete Pad | 3 days | Fri 6/12/09 | Tue 6/16/09 |
| 67 | | F/R Skylight Curbs Sec 3 | 2 days | Tue 6/30/09 | Wed 7/1/09 |
| 68 | | Place Skylight Curb Concrete Sec 3 | 3 days | Tue 6/30/09 | Thu 7/2/09 |
| 69 | | F/R/P Concrete Structural Slab | 2 days | Mon 7/6/09 | Tue 7/7/09 |
| 70 | | Strip Skylight Form Sec 3 | 2 days | Thu 7/9/09 | Fri 7/10/09 |
| 71 | | F/R/P Curb for Lockers | 3 days | Wed 7/22/09 | Fri 7/24/09 |
| 72 | | F/R Kitchen Structural Slab | 3 days | Thu 7/23/09 | Mon 7/27/09 |
| 73 | | F/R/P Walk-in Structural Slab | 3 days | Tue 7/28/09 | Thu 7/30/09 |
| 74 | | Place Concrete for Kitchen Structural | 2 days | Thu 7/30/09 | Fri 7/31/09 |
| 75 | | Place Concrete for Stair 44B | 3 days | Wed 8/5/09 | Fri 8/7/09 |
| 76 | | F/R Skylight curbs Sec 4 | 2 days | Tue 8/11/09 | Wed 8/12/09 |
| 77 | | Place Concrete Stair 44 | 3 days | Fri 8/14/09 | Tue 8/18/09 |
| 78 | | Place Skylight Curb Concrete Sec 4 | 3 days | Mon 8/17/09 | Wed 8/19/09 |
| 79 | | Strip Skylight forms Sec 4 | 2 days | Thu 8/20/09 | Fri 8/21/09 |
| 80 | | F/R/P T-225 Concrete Pad | 3 days | Mon 11/2/09 | Wed 11/4/09 |
| 81 | | F/R Mechanical Pad Sec 5 | 2 days | Wed 9/16/09 | Thu 9/17/09 |
| 82 | | Place Mechanical Pad Concrete Sec 5 | 3 days | Tue 9/22/09 | Thu 9/24/09 |
| 83 | | Strip Mechanical Pad Forms Sec 5 | 2 days | Fri 9/25/09 | Mon 9/28/09 |
| 84 | | Steel | | | |
| 85 | | Install Stair 33 Structural Steel Pans | 5 days | Fri 6/5/09 | Thu 6/11/09 |
| 86 | | F/S/D Corridor Structural Steel | 20 days | Fri 6/19/09 | Thu 7/16/09 |
| 87 | | F/S/D Stair 44B Steel Pan Stairs | 30 days | Fri 6/19/09 | Thu 7/30/09 |
| 88 | | F/S/D Stair 44 Steel Handrail | 30 days | Fri 6/19/09 | Thu 7/30/09 |
| 89 | | F/S/D Stair 44b Steel Guardrail | 30 days | Fri 6/19/09 | Thu 7/30/09 |
| 90 | | F/S/D Stair 44B Handrail | 30 days | Fri 6/19/09 | Thu 7/30/09 |

◆ MILESTONE

DURATION

Start Mon 3/16/09 — Finish Fri 3/26/10

| ID | Task Name | Duration | Start | Finish |
|---|---|---|---|---|
| 91 | F/S/D Stair 44 Steel Guardrail | 30 days | Fri 6/19/09 | Thu 7/30/09 |
| 92 | F/S/D Stair 44 Steel Pan Stairs | 30 days | Wed 7/1/09 | Tue 8/11/09 |
| 93 | Install Corridor Structural Steel Pan St | 5 days | Fri 7/17/09 | Thu 7/23/09 |
| 94 | Install Stair 44b Steel Pan Stairs | 3 days | Fri 7/31/09 | Tue 8/4/09 |
| 95 | Install Stair 44 Steel Handrail | 3 days | Fri 7/31/09 | Tue 8/4/09 |
| 96 | Install Stair 44 Steel Guardrail | 3 days | Fri 7/31/09 | Tue 8/4/09 |
| 97 | Install Stair 44b Handrail | 3 days | Fri 7/31/09 | Tue 8/4/09 |
| 98 | Install Stair 44B Steel Guardrail | 3 days | Fri 7/31/09 | Tue 8/4/09 |
| 99 | Install Stair 44 Steel Pan Stairs | 2 days | Wed 8/12/09 | Thu 8/13/09 |
| 10( | MEP | | | |
| 101 | Mechanical & Plumbing | | | |
| 102 | Excavate for Below Slab Piping | 2 days | Tue 5/12/09 | Wed 5/13/09 |
| 103 | Rough-In Below Slab Piping | 2 days | Thu 5/14/09 | Fri 5/15/09 |
| 104 | Test Below Slab Piping | 1 day | Mon 5/18/09 | Mon 5/18/09 |
| 105 | F/S/D AHU 1 thru 7 | 40 days | Fri 6/5/09 | Thu 7/30/09 |
| 10( | F/S/D SS-1 & SS-2 | 40 days | Fri 6/5/09 | Thu 7/30/09 |
| 107 | F/S/D EF 1 thru 4 | 40 days | Fri 6/5/09 | Thu 7/30/09 |
| 10( | F/S/D Diffusers/Registers/ Grilles | 40 days | Fri 6/5/09 | Thu 7/30/09 |
| 109 | F/S/D VAV 1 thru 15 | 40 days | Fri 6/5/09 | Thu 7/30/09 |
| 11( | Install SS1 & SS2 Outside Units | 2 days | Fri 6/5/09 | Mon 6/8/09 |
| 111 | F/S/D Motorized Dampers | 40 days | Fri 6/19/09 | Thu 8/13/09 |
| 112 | Reconnect Trench Piping | 3 days | Thu 6/25/09 | Mon 6/29/09 |
| 113 | Prepare Mech Coordination Drawings | 15 days | Fri 6/26/09 | Thu 7/16/09 |
| 114 | Install Registers and Grilles | 2 days | Wed 6/3/09 | Thu 6/4/09 |
| 115 | Rough-In Ceiling Piping | 5 days | Wed 7/22/09 | Tue 7/28/09 |
| 11( | Insulate Ceiling Piping | 2 days | Tue 7/28/09 | Wed 7/29/09 |
| 117 | Install AHUs 1 thru 7 | 4 days | Fri 7/31/09 | Wed 8/5/09 |
| 11( | Install EF 1 thru 4 | 2 days | Fri 7/31/09 | Mon 8/3/09 |
| 119 | Install VAV 1 THRU 15 | 8 days | Fri 8/7/09 | Tue 8/18/09 |
| 12( | Rough- In HVAC Controls Conduit | 3 days | Fri 8/14/09 | Tue 8/18/09 |
| 121 | Install AHUs CW&HW S&R | 3 days | Fri 8/14/09 | Tue 8/18/09 |
| 122 | Install Motorized Dampers | 2 days | Fri 8/14/09 | Mon 8/17/09 |
| 123 | Install Branch Gas Piping | 3 days | Wed 8/19/09 | Fri 8/21/09 |

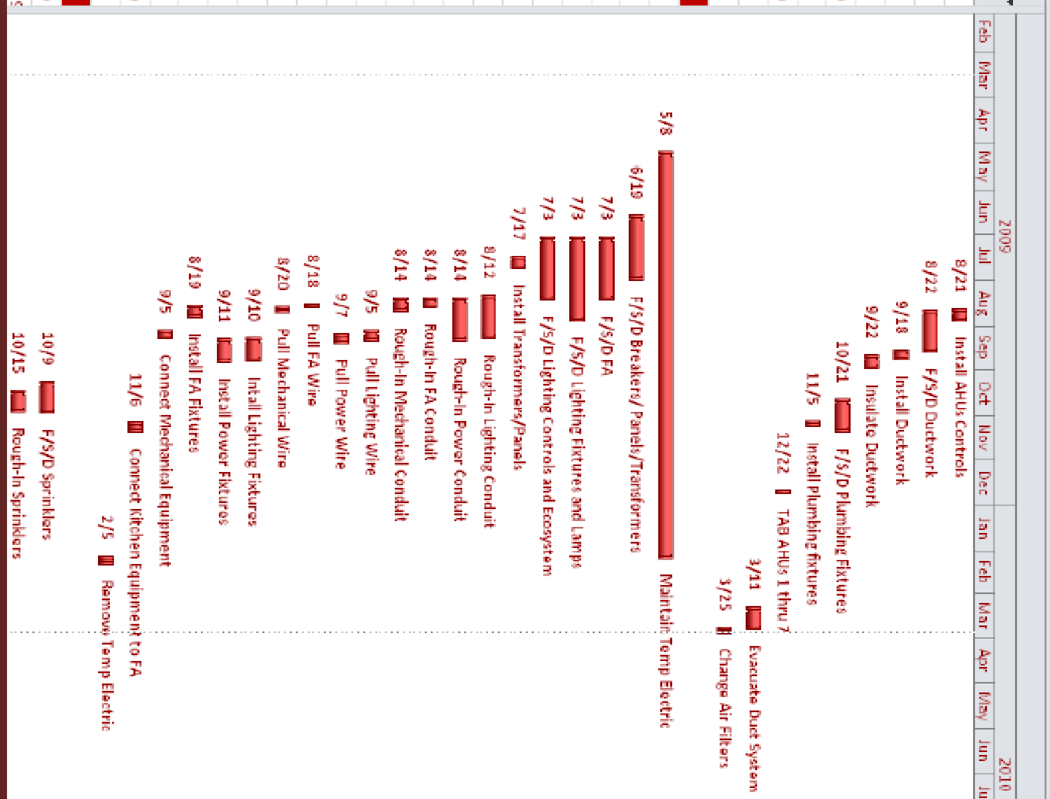


MILESTONE

DURATION

Start Mon 3/16/09 — Finish Fri 3/26/10

| ID | Task Name | Duration | Start | Finish |
|---|---|---|---|---|
| 124 | Install AHUs Controls | 5 days | Fri 8/21/09 | Thu 8/27/09 |
| 125 | F/S/D Ductwork | 20 days | Sat 8/22/09 | Thu 9/17/09 |
| 126 | Install Ductwork | 3 days | Fri 9/18/09 | Tue 9/22/09 |
| 127 | Insulate Ductwork | 5 days | Tue 9/22/09 | Mon 9/28/09 |
| 128 | F/S/D Plumbing Fixtures | 15 days | Wed 10/21/09 | Tue 11/10/09 |
| 129 | Install Plumbing fixtures | 2 days | Thu 11/5/09 | Fri 11/6/09 |
| 130 | TAB AHUs 1 thru 7 | 1 day | Tue 12/22/09 | Tue 12/22/09 |
| 131 | Evacuate Duct System | 10 days | Thu 3/11/10 | Wed 3/24/10 |
| 132 | Change Air Filters | 2 days | Thu 3/25/10 | Fri 3/26/10 |
| 133 | **Electrical and Fire Alarm** | | | |
| 134 | Maintain Temp Electric | 195 days | Fri 5/8/09 | Thu 2/4/10 |
| 135 | F/S/D Breakers/ Panels/Transformers | 30 days | Fri 6/19/09 | Thu 7/30/09 |
| 136 | F/S/D FA | 30 days | Fri 7/3/09 | Thu 8/13/09 |
| 137 | F/S/D Lighting Fixtures and Lamps | 40 days | Fri 7/3/09 | Thu 8/27/09 |
| 138 | F/S/D Lighting Controls and Ecosyster | 30 days | Fri 7/3/09 | Thu 8/13/09 |
| 139 | Install Transformers/Panels | 5 days | Fri 7/17/09 | Thu 7/23/09 |
| 140 | Rough-In Lighting Conduit | 20 days | Wed 8/12/09 | Tue 9/8/09 |
| 141 | Rough-In Power Conduit | 20 days | Fri 8/14/09 | Thu 9/10/09 |
| 142 | Rough-In FA Conduit | 3 days | Fri 8/14/09 | Tue 8/18/09 |
| 143 | Rough-In Mechanical Conduit | 5 days | Fri 8/14/09 | Thu 8/20/09 |
| 144 | Pull Lighting Wire | 5 days | Sat 9/5/09 | Thu 9/10/09 |
| 145 | Pull Power Wire | 5 days | Mon 9/7/09 | Fri 9/11/09 |
| 146 | Pull FA Wire | 1 day | Tue 8/18/09 | Tue 8/18/09 |
| 147 | Pull Mechanical Wire | 2 days | Thu 8/20/09 | Fri 8/21/09 |
| 148 | Intall Lighting Fixtures | 10 days | Thu 9/10/09 | Wed 9/23/09 |
| 149 | Install Power Fixtures | 10 days | Fri 9/11/09 | Thu 9/24/09 |
| 150 | Install FA Fixtures | 5 days | Wed 8/19/09 | Tue 8/25/09 |
| 151 | Connect Mechanical Equipment | 3 days | Sat 9/5/09 | Tue 9/8/09 |
| 152 | Connect Kitchen Equipment to FA | 3 days | Fri 11/6/09 | Tue 11/10/09 |
| 153 | Remove Temp Electric | 2 days | Fri 2/5/10 | Mon 2/8/10 |
| 154 | **Sprinkler** | | | |
| 155 | F/S/D Sprinklers | 15 days | Fri 10/9/09 | Thu 10/29/09 |
| 156 | Rough-In Sprinklers | 10 days | Thu 10/15/09 | Wed 10/28/09 |



MILESTONE

DURATION

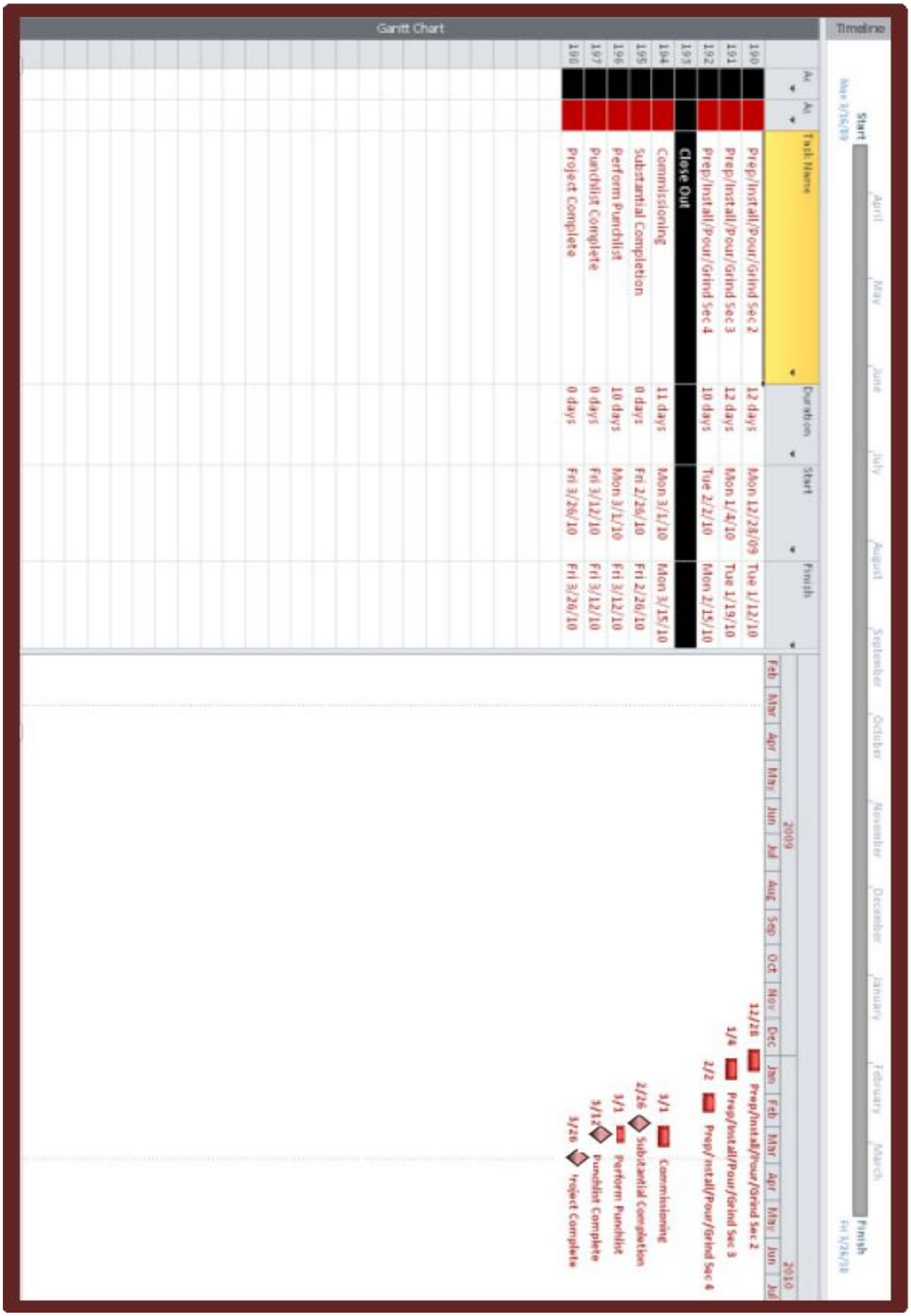
Timeline: Start Mon 3/16/09 — Finish Fri 3/26/10

Gantt Chart

| | Task Name | Duration | Start | Finish |
|---|---|---|---|---|
| 157 | Install Tamper and Flow Switches | 5 days | Sat 10/24/09 | Thu 10/29/09 |
| 158 | Trim Sprinklers | 5 days | Wed 10/28/09 | Tue 11/3/09 |
| 159 | Test Sprinkler | 1 day | Thu 11/5/09 | Thu 11/5/09 |
| 160 | **Finishes** | | | |
| 161 | **Tile and Carpet** | | | |
| 162 | Salvage Tile | 20 days | Sat 5/9/09 | Thu 6/4/09 |
| 163 | Reinstall/Repair/Replace Tile | 25 days | Sat 6/6/09 | Thu 7/9/09 |
| 164 | F/S/D Kitchen Ceramic Tile | 30 days | Thu 9/10/09 | Wed 10/21/09 |
| 165 | Install Resilent Base | 2 days | Thu 9/10/09 | Fri 9/11/09 |
| 166 | Install Kitchen Ceramic Tile | 5 days | Mon 10/5/09 | Fri 10/9/09 |
| 167 | F/S/D Quarry Tile Floor | 30 days | Wed 10/28/09 | Tue 12/8/09 |
| 168 | Install Quarry Tile Floor | 12 days | Mon 11/9/09 | Tue 11/24/09 |
| 169 | F/S/D Carpet | 20 days | Tue 11/10/09 | Mon 12/7/09 |
| 170 | Install Carpet | 5 days | Sun 1/3/10 | Thu 1/7/10 |
| 171 | **GWB and ACT** | | | |
| 172 | Patch/Plaster/GWB Exterior Walls | 6 days | Tue 6/2/09 | Tue 6/9/09 |
| 173 | Frame/GWB/Finish Offices | 10 days | Fri 6/12/09 | Thu 6/25/09 |
| 174 | Frame/GWB/Finish Corridors | 15 days | Tue 7/14/09 | Mon 8/3/09 |
| 175 | Frame/GWB/Finish Kitchen | 15 days | Mon 8/3/09 | Fri 8/21/09 |
| 176 | Frame/GWB/Finish Dining Room | 12 days | Fri 8/28/09 | Mon 9/14/09 |
| 177 | Frame/GWB/Finish Conference Spac | 8 days | Tue 9/15/09 | Thu 9/24/09 |
| 178 | Frame/GWB/Finish Utility Spaces | 10 days | Sat 10/3/09 | Thu 10/15/09 |
| 179 | Frame/GWB/Finish Ceilings | 30 days | Thu 11/5/09 | Wed 12/16/09 |
| 180 | Install ACT Grid | 12 days | Fri 11/20/09 | Mon 12/7/09 |
| 181 | Install ACT Tile | 8 days | Thu 12/10/09 | Mon 12/21/09 |
| 182 | **Paint** | | | |
| 183 | Paint Existing Cielings | 3 days | Wed 8/19/09 | Fri 8/21/09 |
| 184 | Apply Concrete Sealer | 1 day | Mon 9/7/09 | Mon 9/7/09 |
| 185 | Paint GWB Cielings | 20 days | Thu 12/10/09 | Wed 1/6/10 |
| 186 | Paint GWB Partitions | 20 days | Thu 12/10/09 | Wed 1/6/10 |
| 187 | Paint Sprinklers | 2 days | Tue 11/3/09 | Wed 11/4/09 |
| 188 | **Terrazzo** | | | |
| 189 | Prep/Install/Pour/Grind Sec 1 | 10 days | Thu 8/6/09 | Wed 8/19/09 |

◆ MILESTONE

▬ DURATION



| | Task Name | Duration | Start | Finish |
|---|---|---|---|---|
| 190 | Prep/Install/Pour/Grind Sec 2 | 12 days | Mon 12/28/09 | Tue 1/12/10 |
| 191 | Prep/Install/Pour/Grind Sec 3 | 12 days | Mon 1/4/10 | Tue 1/19/10 |
| 192 | Prep/Install/Pour/Grind Sec 4 | 10 days | Tue 2/2/10 | Mon 2/15/10 |
| 193 | Close Out | | | |
| 194 | Commissioning | 11 days | Mon 3/1/10 | Mon 3/15/10 |
| 195 | Substantial Completion | 0 days | Fri 2/26/10 | Fri 2/26/10 |
| 196 | Perform Punchlist | 10 days | Mon 3/1/10 | Fri 3/12/10 |
| 197 | Punchlist Complete | 0 days | Fri 3/12/10 | Fri 3/12/10 |
| 198 | Project Complete | 0 days | Fri 3/26/10 | Fri 3/26/10 |

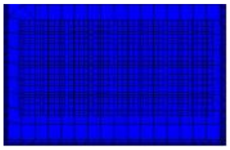


MILESTONE
DURATION

# Lighting Demand Study

## Spring Equinox

### March 21



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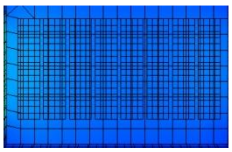

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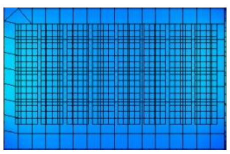

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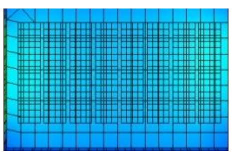

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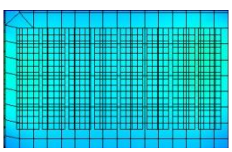

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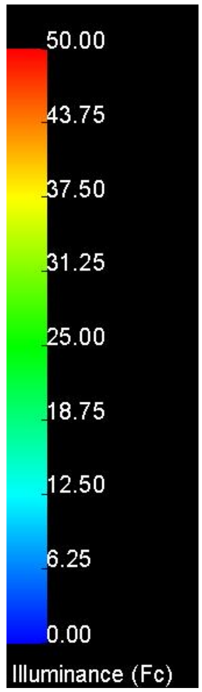


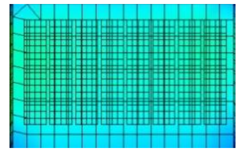

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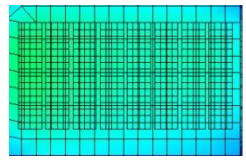

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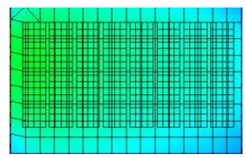

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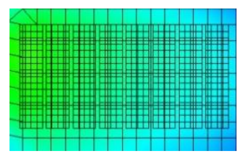

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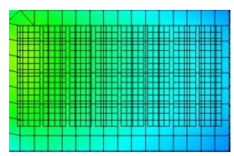
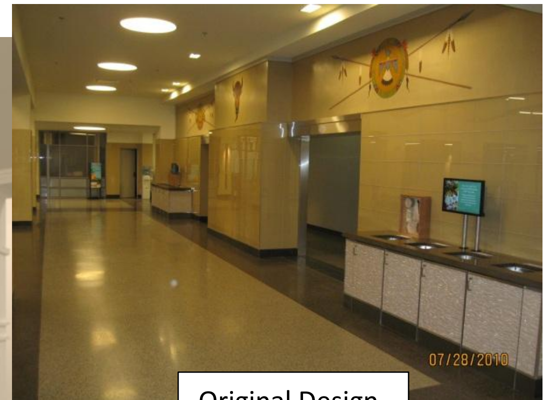


3:00PM

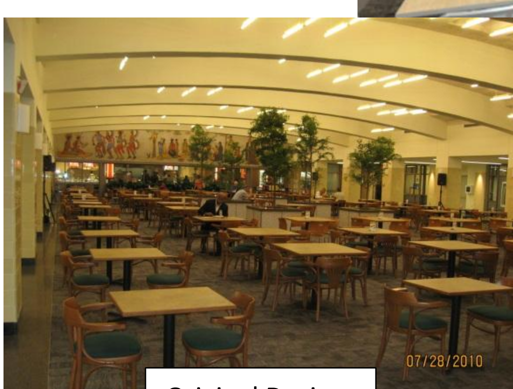
## Proposed Redesign Renderings

Proposed Design




Original Design

Proposed Design




Original Design